



ECTP

**INNOVATIVE BUILT
ENVIRONMENT**

**Strategic Research & Innovation Agenda
2024-2030**

October 2023



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Glossary

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

Built environment: it refers to human-made structures and networks. It can be defined as the human-made space in which people live, work, and recreate on a day-to-day basis, and ranges in scale from buildings and parks or green space to districts and cities, including supporting infrastructure, such as water supply or energy networks.

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.

Co-botics: neologism formed from the concept of “Cooperative Robotics” and the words “cooperation” and “robotics”. Co-botics refers to a robotic device designed, manufactured, and used to interact and cooperate with a human, unlike a conventional robot which operates completely autonomously.

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

Extended Reality: it refers to immersive technologies that expand our real world and combine it with virtual elements. It takes three forms: Augmented Reality (AR) that provides an extension of the real world; Virtual Reality (VR) to experience virtual worlds; and Mixed Reality (MR) that combines AR and VR, i.e., that combines our real world with virtual environments.

Frugal buildings: frugal innovation is a process of reducing the complexity and cost of a good and its production, rather than innovating with a sense of limitless resources. Frugal buildings demonstrate frugality in their use of energy, materials and water for construction and operation, promote circularity, and strive to produce more well-being with less resources.

Generative design: design exploration method of using AI algorithms to generate and evaluate multiple design alternatives based on input from the user (such as design goals, parameters like performance or spatial requirements, materials, manufacturing methods, cost constraints...).

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 culture¹.

Industry 5.0: according to the European Union, industry 5.0 “provides a vision of industry that aims beyond efficiency and productivity as the sole goals and reinforces the role and the contribution of industry to society.” “It places the wellbeing of the worker at the centre of the production process and uses new technologies to provide prosperity beyond jobs and growth while respecting the production

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



limits of the planet.” It complements the Industry 4.0 approach by “specifically putting research and innovation at the service of the transition to a sustainable, human-centric and resilient European industry”.

Infrastructure: it provides the backbone of modern, well-functioning economies by providing connectivity through enabling the flow of goods, people, and information, and by supplying the necessary inputs in the form of energy and water that constitute the foundation for most commercial and industrial activity. Infrastructure is also critical for delivering numerous services - such as electricity, water and sanitation, broadband connectivity, public transport, health care, education, and flood protection - that are essential for health and quality of life, and for providing protection against natural elements (OECD definition).

Mid-door environment: Mid-door spaces have some elements fully controlled, while others are uncontrolled or partially controlled like in train station. They offer protection from the elements but allow in more sunlight and allow more temperature fluctuation than an indoor space.

Nature-based Solutions: the European Commission defines Nature-based Solutions (NBS) as: "Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes, and seascapes, through locally adapted, resource-efficient, and systemic interventions". Nature-based solutions must therefore benefit biodiversity and support the delivery of a range of ecosystem services.

New European Bauhaus (NEB): initiative launched in 2021 by the European Commission and inspired by the multidisciplinary, collaborative, and holistic approach from Bauhaus school legacy. It is conceived as a movement to re-think the built environment, embracing art, culture, science and technology in a collaborative and life centric perspective inspired and learning from nature.

Regenerative design: regenerative buildings (sometimes referred also as restorative buildings) are designed and operated to reverse ecological damage and have a net-positive impact on the natural surrounding environment. They are integrated into a larger system, helping to produce and share resources like clean water, energy, and food. Regeneration also seeks to improve the resilience of the environment.

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).

Urban areas: they are characterized by a continuous human settlement and infrastructures that support various activities of our urban daily lives, including public and private services. These areas typically exhibit high population density, a mix of land uses (residential, commercial, industrial, recreational, etc.), and a developed network of buildings, roads, utilities, and amenities.

Urban mining: it 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
AR	Augmented Reality
B.E.	Built Environment
BIM	Building Information Modelling
CDW	Construction and Demolition Waste
EED	Energy Efficient Directive
EPBD	Energy Performance of Buildings Directive
eV	Electric Vehicle
IA	Innovation Action
IFC	Industry Foundation Classes
IoT	Internet of Things
LBD	Linked Building Data
LCA	Life Cycle Approach
mCHP	micro Combined Heat and Power
MR	Mixed Reality
NBS	Nature-based solutions
NEB	New European Bauhaus
nZEB	Nearly Zero Emission Building
PEB	Positive Energy Building
PED	Positive Energy Districts
RES	Renewable Energy Sources
RIA	Research and Innovation Action
R&I	Research & Innovation
V2G	Vehicle to Grid
XR	Extended Reality



Foreword

ECTP as the key player in driving research, innovation, and competitiveness across the construction sector, for the benefit of the built environment and its citizens

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 representatives from buildings, districts, as well as transport and utility network infrastructures domains). It gathers more than 150 Member organisations and individual members from construction and other sectors across the whole supply chain of the built environment. The main mission of ECTP is **to identify, develop and support implementing new Research and Innovation strategies (R&I)** to improve the competitiveness of the construction industry, meet the societal needs of a 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 European Technology and Innovation Platforms, industry-led stakeholders' fora that are recognised by the European Commission as key actors in driving innovation. As such, ECTP is co-signatory and in charge of the **Build4People co-programmed partnership** established with the European Commission in 2021, which aims to catalyse the transition to a people-centric, climate-neutral, sustainable, and smart built environment.

ECTP Strategic Research and Innovation Agenda 2030

The built environment and construction industry has an essential role to play in the socio-economic transition towards a sustainable and climate-neutral economy and society. The way we design and build our buildings and infrastructures impacts the way we live, as individuals and communities. It also impacts the climate, resources, and biodiversity on the planet. On both dimensions, **industry must undergo some deep transformation to deliver a more sustainable, resilient, inclusive, and enriching built environment.** Research and innovation are key drivers in this transformation.

A major mission of ECTP is to develop a sectoral *Strategic Research and Innovation Agenda (SRIA)* to identify the challenges that the built environment and construction industry has to take up and propose R&I pathways to achieve them. This SRIA identifies and describes the future R&I priorities for developing and rolling-out the solutions that will help taking up the **societal, environmental, 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 will provide secure, safe, and smart living places for all citizens in Europe.



1. The context in 2023

We are living in a fast-changing environment, where climate, society and technology are evolving at an ever-accelerating pace. We could simply state that, since 2019 and the previous version of the SRIA, *a lot has changed*.

The Positions Papers² released in 2022 by the six committees³ of ECTP analyse in detail the main societal, technological and policy trends that the built environment and its industrial sector are facing in the coming years. A brief synthesis is provided below.

Environmental context

We witness in our everyday lives how **human activities are impacting the earth's climate**: temperature peaks break new records every year, and extreme weather events like floods or mega fire are getting more intense and frequent. **Human activities also impact the earth's resources and inhabitants**: pollution triggers numerous negative impacts on human health; together with the overexploitation of natural resources, it leads to biodiversity losses and modified ecosystems.

The built environment consequently faces critical challenges: **improve its resilience** to climate hazards; **decarbonise**; and **re-think its relationship to nature**.

Geopolitical context

The war in Ukraine triggered some drastic increases in energy prices and raised new concerns in Europe about the **security of energy supply**, and the level of energy consumption. More largely, the geopolitical situation worldwide leads to **more disruptions in supply chains**, and the world competition on raw materials becomes fiercer and fiercer. The resulting high energy prices and inflation rates lead to increasing energy poverty. More recently, the war in Israel has led to increasing concerns in terms of terrorism.

In consequence:

- The built environment must be designed and operated in a manner that enables **the physical and digital security of all citizens**, and that increases **autonomy in energy supply (at building, district, city level)**, at controlled cost,
- The construction industry must evolve to improve the **security and resilience of supply chains**, using the **full potential of locally available resources** (circularity).

² The Position Papers can be downloaded [from this page](#)

³ The six Committees are: Built Environment Decarbonisation; Built for Life; Digital Built Environment; Heritage and Regeneration; Infrastructure and Mobility; Materials and Sustainability.



Societal trends

The Covid19 pandemic led to deep changes in our living patterns, especially regarding working and mobility habits. Our conception of safety and health in the built environment was also modified.

With the war in Ukraine and the high inflation rates, **energy poverty** is progressing in Europe, and the question of affordability of housing becomes critical. Other societal challenges already identified in 2019 also remain actual, such as the **ageing of population**, and the lack of accessibility and inclusiveness of buildings and infrastructures.

The built environment therefore needs to:

- Be **healthy, accessible and affordable** to all, by providing safety and well-being (comfort, health) to its inhabitants,
- **Contribute to social cohesion**, i.e. be designed, governed, and operated in a manner that positively impacts individuals and communities, building upon our cultural built heritage
- **Adapt** to the evolving needs and behaviours of populations.

Technological trends

The continuous advances in **digitalisation** and in particular in **Artificial Intelligence** pave the way for new applications in the construction industry. Together with automation and robotics, they represent a tremendous opportunity of **significant performance gains** (environmental, economic, human safety gains) for the construction industry, from design to manufacturing and onsite construction - but this **potential is still to be captured** and realised.

Permanent innovation in **materials** also paves the way to more safety, comfort, and sustainability in the built environment, but with significant challenges in terms of scale up and **industrialisation**.

The construction sector needs to:

- Better **integrate these technologies** in all industrial, decision-making and training processes, for more **competitiveness** and **sustainability** of Europe's industry and **workforce**
- Ensure their **safety in use**, in terms of **health, ethics, and privacy**.

Policy framework and regulatory evolutions

Today's European regulatory landscape is very rich and evolving at a fast pace, spanning from energy and raw materials to Artificial Intelligence, also covering new topics such as nature restoration. This brings additional constraints and opportunities to drive forward the energy and environmental transition in the construction sector. Beyond regulation, policies and strategies initiated by the European Commission also give an unprecedented impulse to innovation for a decarbonised, sustainable built environment.

The main changes (i.e., regulations, directives as well as policies and strategies) introduced since the latest version of the SRIA (2019) are listed below. As of July 2023, most of these regulatory evolutions are still in discussion, with ongoing dialogues between the European Commission, the Parliament and the Council.



	Regulatory framework	Policies & Strategies
Energy	EU Green Deal and Fit for 55 Package: revision of Energy Efficiency Directive (EED) and Renewable Energy Directive (RED), ... Recast of Regulation for internal market for electricity (EMD)	REPowerEU EU Solar Energy Strategy
Buildings	Recast of the Energy Performance of Buildings Directive (EPBD)	Renovation wave strategy and action plan New European Bauhaus Transition pathway for Construction Level(s) framework
Transport & Infra	Alternative Fuels Infrastructure Regulation (AFIR) Revision of Combined Transport Directive and Intelligent Transport Systems (ITS) TEN-T revision	Sustainable and Smart Mobility Strategy Green Infrastructure Strategy Guidance for drone services
Materials	Revised Construction Products Regulation Proposal for a European Critical Raw Materials Act and Net-Zero Industry Act	Circular economy action plan
Water	Water Reuse Regulation (WRR) Revision of Urban Waste Water Treatment Directive (UWWTD)	
Biodiversity & Nature	Nature Restoration Law (NRL)	EU Biodiversity Strategy for 2030 EU Pollinators Initiative Zero Pollution Action Plan
Data & AI	Data Governance Act (DGA), Cybersecurity Act, Network and Information Security (NIS2) Directive Artificial Intelligence Act, AI Liability Directive	Common European Data Spaces (cultural heritage, health, energy) Digital Europe Strategy
Air quality	Revision of Ambient Air Quality Directives (AAQD)	
Health	New Pact on Migration and Asylum	European Health Union European Care Strategy
Financing	EU Taxonomy, for sustainable investments Emissions Trading System 2 for fuel combustion in buildings	GPP Criteria

The different targets and opportunities laid out in these regulatory texts (but some of them likely to change depending on the outcomes of dialogues) are synthesised in Figure 1 for buildings, in Figure 2 for infrastructures, with a focus on materials in Figure 3.

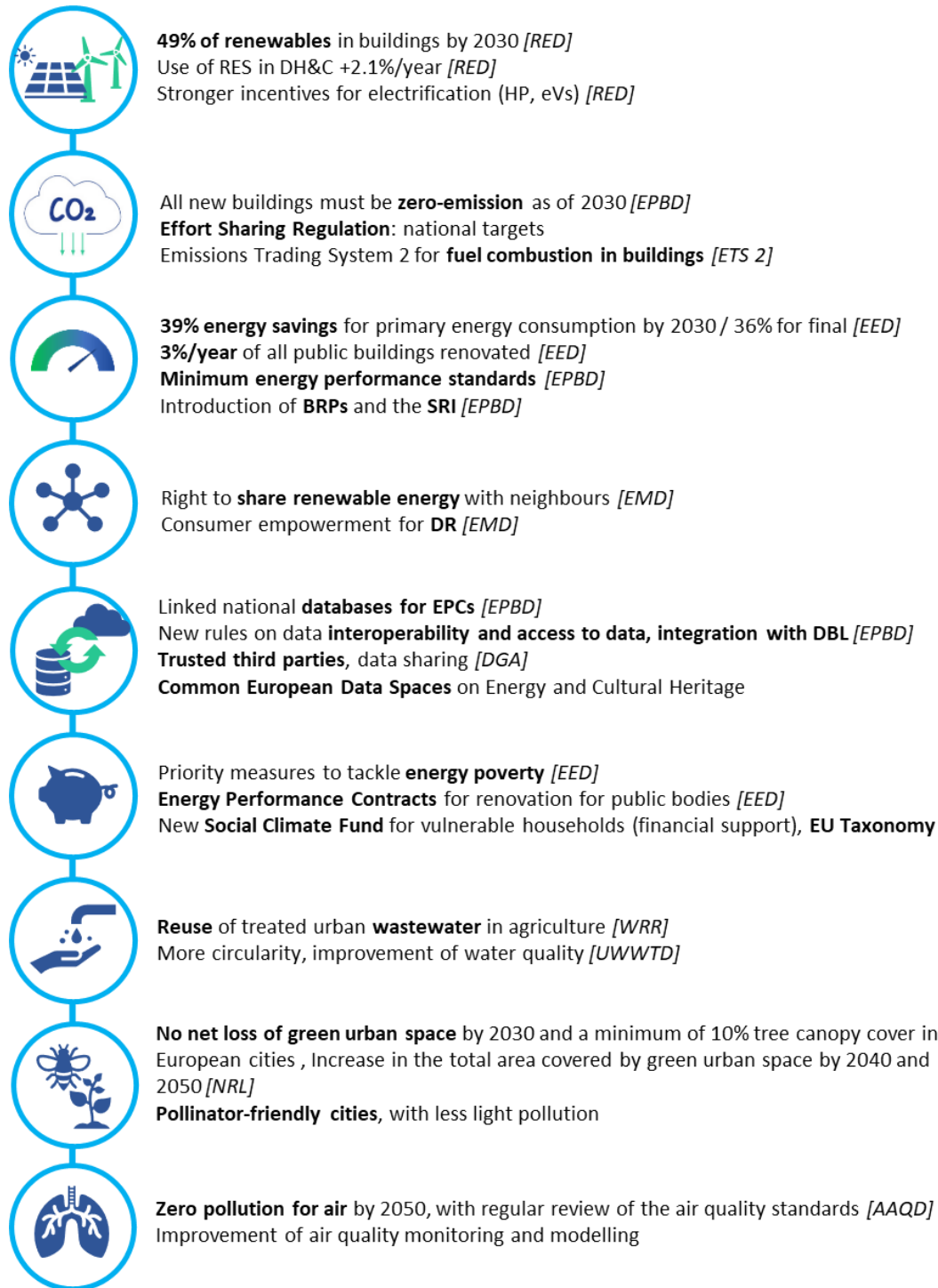


Figure 1: Targets set in the EU regulatory framework and in ongoing recasts, applicable to buildings

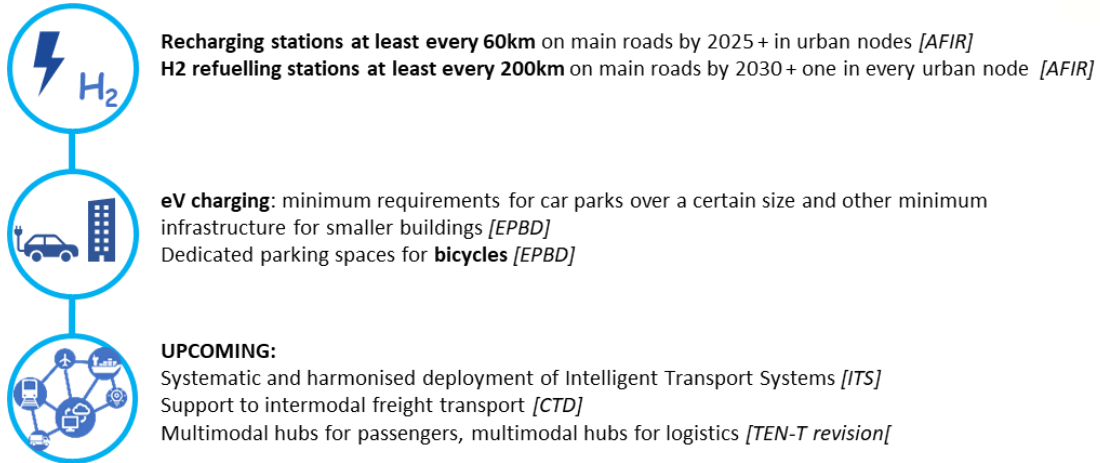


Figure 2: Targets set in the EU regulatory framework and in ongoing recasts, applicable to infrastructures

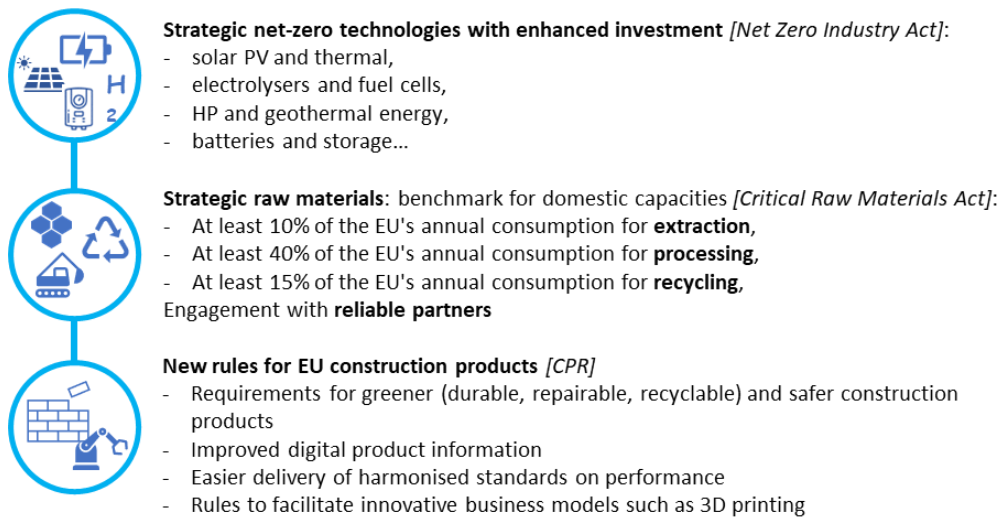


Figure 3: Targets set in the EU regulatory framework and in ongoing recasts, focusing on materials



2. ECTP vision 2030 and associated structure of the SRIA

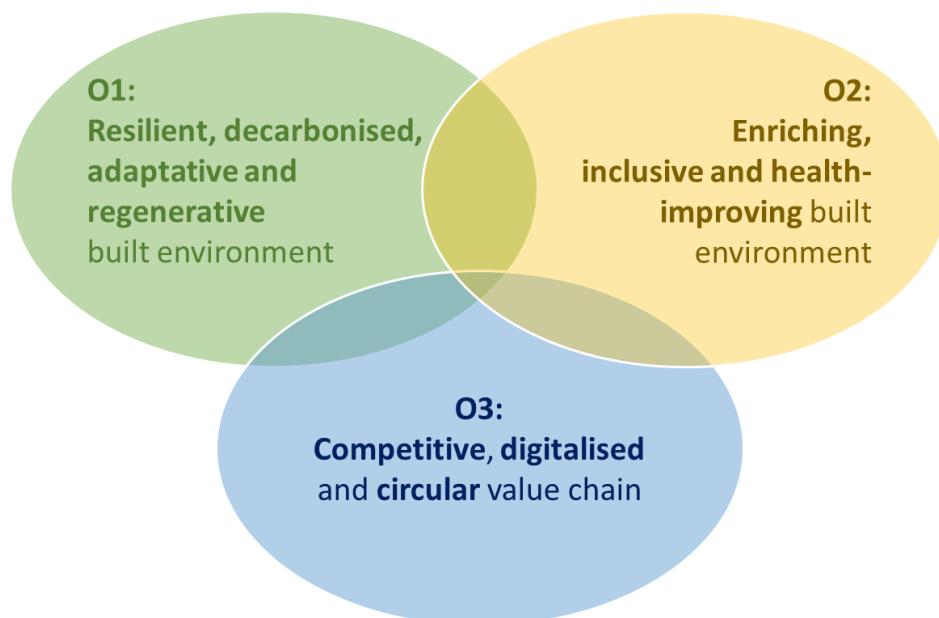
ECTP vision and objectives 2030

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

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

To achieve such a vision, three objectives are set by 2030:

- Objective 1: A resilient, decarbonised, adaptative and regenerative built environment,
- Objective 2: An enriching, inclusive and health-improving built environment,
- Objective 3: A competitive, digitalised, and circular value chain.



*The highest quality of life, for the largest number of citizens,
with the lowest environmental impact*

Figure 4: The three Objectives 2030 of ECTP SRIA



Methodology to identify and qualify the R&I activities by 2030

The methodology deployed to elaborate this SRIA relies on the principle of ‘collective knowledge’, building upon a collaborative approach involving a maximum number of knowledgeable people within and outside the ECTP:

- During a first phase conducted during April 2023, a review of the environmental, technical, and societal challenges faced by the built environment was performed, together with an analysis of the key technological trends. It also included a detailed review of the political and regulatory context. This first phase enabled to define the three high-level Objectives 2030 with the representatives of ECTP Committees⁴ in May 2023.
- This review was completed by an analysis of the position papers, roadmaps and research agendas recently published by the main initiatives from the sector (in particular industrial associations, European technology platforms and European Partnerships)⁵, as well as a screening of the latest calls from the programmes Horizon Europe, LIFE, and Digital Europe.
- In a second phase, three working groups were set up with ECTP members (one group per Objective 2030). Each of them conducted two online workshops during June 2023 in order to discuss and prioritise the various R&I topics required to reach the Objective 2030.
- All the material collected was consolidated into a first version of the SRIA published in July 2023 for consultation. This consultation inside and outside ECTP ran until October 2023. It was completed by a series of interviews with experts in order to address some specific dimensions of the SRIA and check their alignment and complementarity with other roadmaps⁶.
- The final version of the SRIA integrating all collected feedback was released in October 2023.



Figure 5: Timelines of elaboration of the SRIA

⁴ The six Committees are: Built Environment Decarbonisation; Built for Life; Digital Built Environment; Heritage and Regeneration; Infrastructure and Mobility; Materials and Sustainability.

⁵ A non-exhaustive list includes: the SRIAs and roadmaps of the European partnerships Made In Europe, Processes4Planet, Driving Urban Transition, AI Data Robotics, 2Zero, Smart Networks and Services, Circular Biobased Europe, Europe's Rail, Innovative health, Connected Cooperative Automated Mobility, ERTRAC; and the roadmaps and positions papers of the associations FIEC, EMIRI, IDIH, EuRIC, EMI.

⁶ Interviews were conducted with members of EMIRI, BDITA, DUT Partnership, ERTRAC, Housing Europe and the Advance Material Initiative (see concluding section for details).



How to read this SRIA

For each of the three Objectives 2030 listed above, the associated R&I activities are described and organised as presented below.

1. A hierarchical approach is followed:

- The objective is described, thus providing the scope of the associated R&I activities,
- The R&I Priorities are defined,
- For each R&I Priority, the R&I topics are defined,
- Each R&I topic is then described with a list of subtopics.

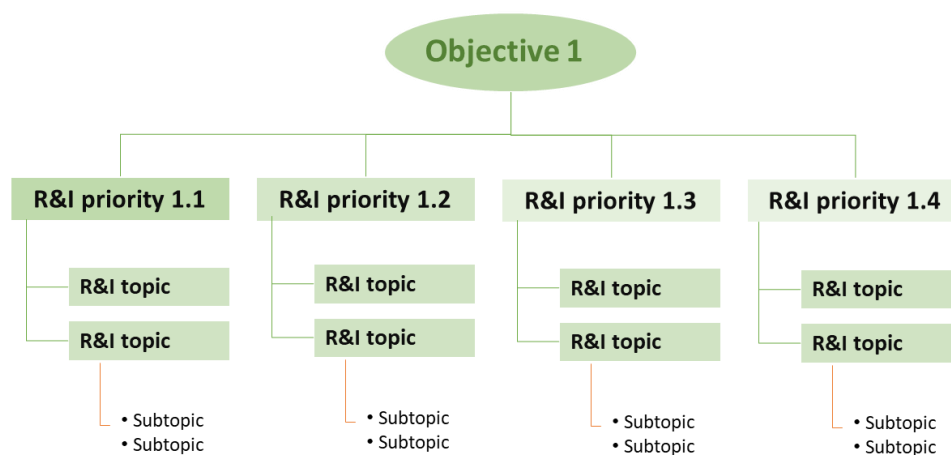


Figure 6: Representation of the hierarchical structure of the SRIA

2. Timelines are defined for each R&I Priority and topics

For each priority, a synthetic diagram provides an overview of the timing of projects and expected maturity of results. To that end, three categories are considered that are linked to EC-funding programmes and instruments:

- **RIA: Research and Innovation Action** (Horizon Europe programme), considered to cover TRL 2-3 to TRL 5 (Applied research, proof of concept...)
- **IA: Innovation Action** (Horizon Europe programme), considered to cover TRL 5 to TRL 7 (prototype, demonstration)
- **Implementation and scale up**: considered to cover TRL 7 to TRL 9, that can be funded by a wide range of European public funding instruments such as Coordination and Support Actions in Horizon Europe, LIFE, Innovation Fund, EIC Accelerator, or Digital Europe.

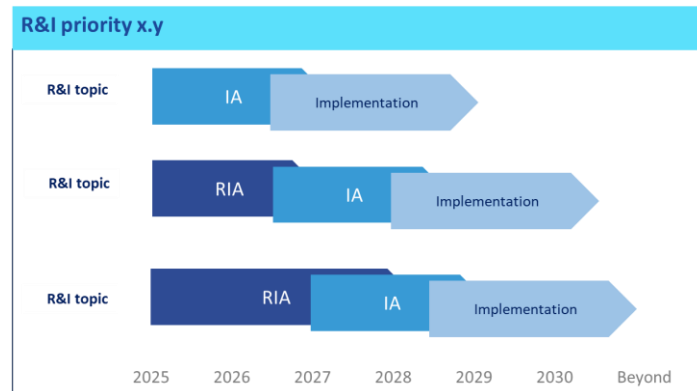


Figure 7 : Representation of the timeline of topics for each R&I priority

The arrows in Figure 7 are to be read as follows:

- The starting point represents the estimated current maturity of concepts/innovations (considering ongoing Horizon Europe calls 2023-2024),
- The arrows "RIA" and "IA" and "Implementation" correspond to the period of implementation of new projects (the related calls for proposals are supposed to be released during the previous year(s)),
- Each R&I topic includes several subtopics supporting projects with different maturity levels, which explains the overlap between arrows.

Note that the maturity is systematically expressed using the **Technology Readiness Levels** (TRL) as it is the reference scale used by the European Commission in its calls for proposals.

However, as some R&I topics feature a strong dimension of **social acceptance and adoption by society**, those topics are also qualified using the **Societal Readiness Levels** (SRL) scale proposed by the [Innovation Fund Denmark](#), recalled in annex of this document.

3. R&I subtopics are listed and qualified in terms of maturity

For each topic, the associated sub-topics are listed in a table, and qualified with:

- the estimated current maturity level expressed according to the TRL scale,
- the estimated date (year) when project results should reach TRL 8/9 approaching market take-up.

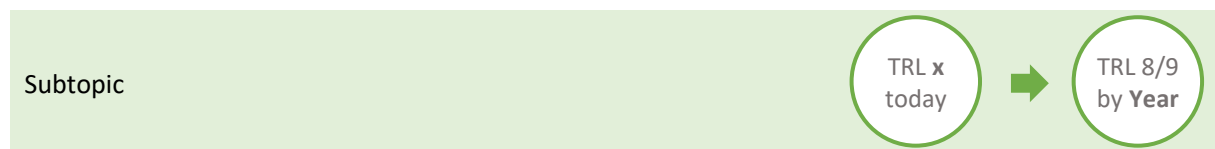


Figure 8: Template of table used to list and qualify the different subtopics



3. Objective 1: Resilient, adaptive, decarbonised and regenerative built environment

This first objective focusses on the resiliency, adaptability, and decarbonisation of the built environment, and sets priorities for moving towards generating positive impacts on the environment.

Resilient: Buildings and infrastructure need to be safe and resilient, in a context of growing uncertainty. Protection of people and infrastructures has become an increasing concern in the past years. This relates to natural and man-made hazards but also to the ageing of built structures. The built environment should be designed, built, and operated in a way that anticipates, prepares for, and adapts to changing climate conditions (such as increasing temperatures, shifting patterns of precipitation, increased intensity or recurrence of extreme weather events and rising sea levels) and better resist to disruptive events (e.g., earthquakes or man-made threats).



In the short term, the most vulnerable buildings and infrastructures should be adapted to be able to maintain their habitability, functionalities and values in unprecedented heat waves or during summer and winter-time power outages.

In the longer term, being climate-resilient also means being able to cope with uncertainty and variability, as the extent of the local physical impacts of climate change are complex to quantify accurately. Strategic approaches to infrastructure planning and urban planning are required: according to OECD⁷, considering climate impacts for individual assets, such as a bridge, is necessary but not sufficient to ensure that the system functions reliably despite a changing climate. Buildings and infrastructures should therefore be seamlessly integrated in cities to improve climate-resilience.

Adaptive: Beyond the adaptation to climate change, the built environment should adapt to changing behaviours and conditions (at different timescales, from near real-time to several decades) and to new technologies and new usages, so as to reduce its carbon footprint over its whole life cycle. Design and construction processes should therefore be thought ahead for multiple life cycles, including reuse and recycling.

The daily operation and actual performance of buildings and infrastructures should be optimised (either in an active way with smart technologies, or with passive measures) to reduce the CO₂ emissions related to energy use, while maintaining a high level of comfort and indoor environment quality. This optimisation requires a better integration with the electricity grid (where buildings can become active nodes providing flexibility services and locally generated energy supported by the current policy framework e.g., Energy Communities) and with other networks such as transport, data and district heating and cooling.

Across their life cycle, buildings should also be able to evolve and adapt to new types of use (e.g., from tertiary to residential, from parking lots to housing⁸) through enhanced modularity and flexibility. Transport infrastructures, in particular transport hubs should adapt to changing mobility patterns, multi-modality, and new transport technologies (e.g., micro-mobility, autonomous cars, e-cargo bikes...). This adaptiveness will enable to increase the lifetime of assets and buildings, which will in turn decrease the “grey” CO₂ related to the use of materials.

Decarbonised: to reach the EU targets, the EU building stock has to become decarbonised by 2050. This implies:

- Renovating in-depth the existing building stock to increase its energy efficiency and increase the share of local renewable energy, along with storage and network flexibility, and where relevant preparedness for low-temperature heating,
- Designing and constructing new buildings that are at least nearly zero emission (nZEBs), and when possible positive energy buildings (PEBs).

A large range of active and passive solutions already exist, and innovative ones have been developed and demonstrated in EU funded projects. Market uptake is however still challenging, and renovation is not happening at the required pace. Solutions for renovation (and for nZEBs and PEBs) need to become more affordable and better integrated in the practices of the construction value chain.

Regenerative: The efficiency of the built environment should also go beyond energy and encompass water and waste: buildings and infrastructures should aim for holistic ‘frugality’. In the longer term,

⁷ OECD (2018) ENVIRONMENT POLICY PAPER NO. 1: Climate-resilient Infrastructure

⁸ See for instance the ‘reversible’ student housing [Rosalin Franklin](#) in France



they could even become regenerative, i.e., generate positive impacts on the climate and environment as a whole. The built environment could for instance act as a carbon sink, either thanks to innovative materials (e.g. embodied carbon in building materials), or through the integration of Nature-based Solutions. The increasing use of recycled content will also contribute to reduced extraction, carbon footprint and raw material imports.

To enable the construction value chain to reach this first objective, four R&I priorities, which should be completed by 2030, have been identified:

- **Priority 1:** Implement methods and technical solutions for resilience, protection, and adaptation,
- **Priority 2:** Make solutions for building renovation and decarbonisation more affordable and easier to implement,
- **Priority 3:** Demonstrate solutions for better building/ infrastructure integration into energy and mobility networks,
- **Priority 4:** Demonstrate regenerative and frugal designs, integrating NBS and considering adaptability and reuse.

Each of these priorities has then been broken down into three R&I topics, as presented in Figure 9.

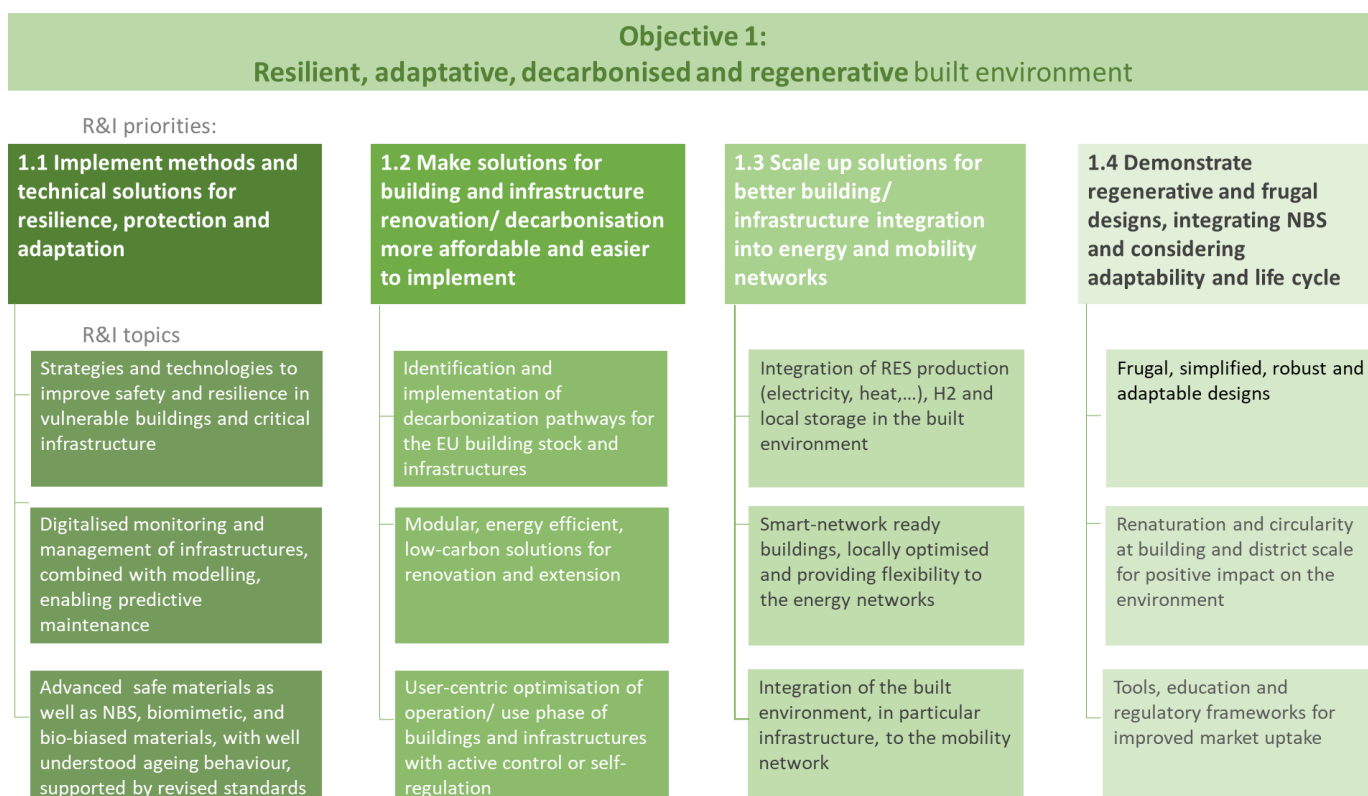


Figure 9 : Overview of R&I priorities for Objective 1



R&I priority 1.1: Implement methods and technical solutions for resilience, protection and adaptation

The first R&I priority focusses on the resilience of the built environment, and in particular the protection, adaptation and predictive maintenance of the existing buildings and assets.

Several barriers or challenges indeed remain to be overcome to increase the resilience of our built environment. The first barrier relates to the lack of a common and coordinated approach to identify and protect/adapt vulnerable buildings and critical infrastructures in the very short-term. Secondly, usual management practices of assets and infrastructures do not sufficiently consider changing patterns, for instance due to climate or usage; as a consequence, maintenance schedules, methods and tools have to be upgraded. Finally, the full potential of advanced materials to increase the resilience of the built environment is yet to be unlocked.

This R&I priority is broken down into three topics:

- Strategies and technologies to improve safety and resilience of vulnerable buildings and critical infrastructures,
- Digitalised monitoring and management of infrastructures combined with modelling, enabling predictive maintenance,
- Advanced safe (non-harmful) materials as well as recycled, biomimetic, nature-based and bio-biased (or bio-fabricated) materials, with well understood ageing behaviour, supported by revised standards.

Figure 10 shows the estimated timeline to develop solutions at TRL9 within projects which are launched to address the challenges behind these three topics. Details on the scope of each topic are given in the next paragraphs.

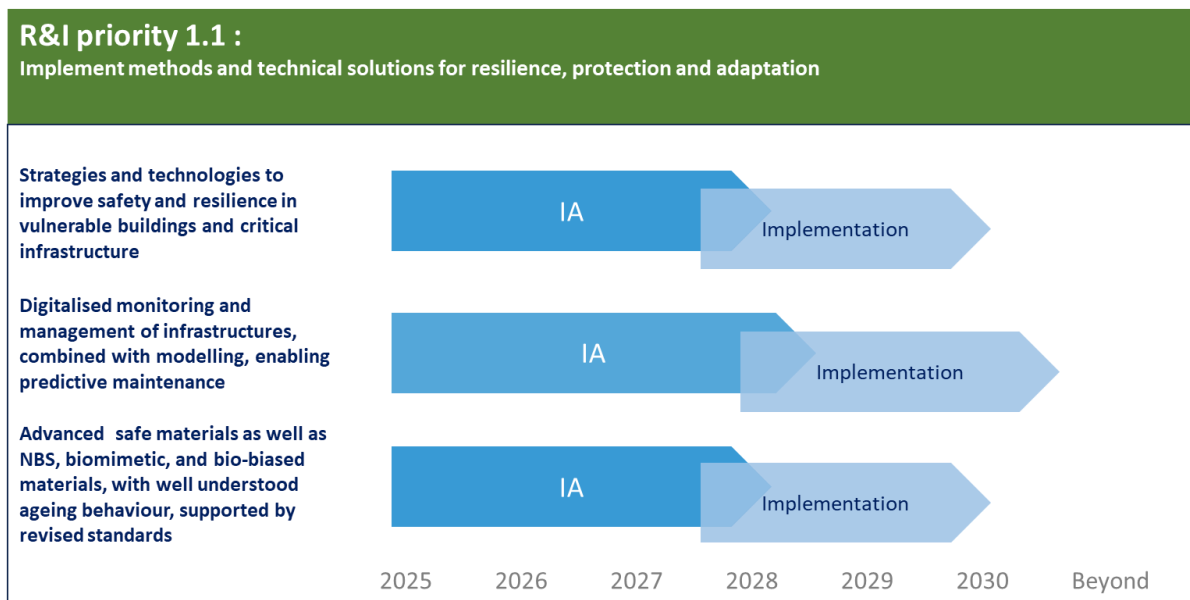


Figure 10 : Timeline of topics within priority 1.1



► *Strategies and technologies to improve safety and resilience in vulnerable buildings and critical infrastructures*

The aim of this topic is to urgently improve safety and resilience in vulnerable buildings and infrastructures.

Its scope includes:

Develop harmonised, holistic vulnerability assessment tools and KPIs with multi-hazards and dynamic risk analysis and models to assess buildings & infrastructures resilience (existing and newly built), mixing various data sources and considering uncertainty and cascading effects, to define short, mid and long-term scenarios and mitigation measures from a governance, social, technical standpoint.	TRL 4/5 today	→	TRL 8/9 by 2030
To develop a comprehensive methodology for resilience-guided transport infrastructure risk management , supporting the design and implementation of measures that reduce vulnerability, enable rapid recovery after disruptions, improve adaptivity and enable transformation of the road infrastructure through civil engineering measures and NBS	TRL 4 today	→	TRL 8/9 by 2030
Develop and implement adaptation solutions (flexible and multi-domain: climate-energy-water) to prepare vulnerable buildings and critical infrastructures to climate change and its consequences (e.g., keep habitable in unprecedented heat-waves and during power outage in summer & winter, retrofitting to adapt to increased occurrence of extreme events), while retaining high building values. This could include international cooperation.	TRL 4 today	→	TRL 8/9 by 2030
Develop and implement awareness campaign, training, stakeholder engagement tools and policy development to increase community-based resilience , and monitor the impact of the actions.	TRL 4/5 today	→	TRL 8/9 by 2030

► *Digitalised monitoring and management of infrastructures, combined with modelling, enabling predictive maintenance*

The topic aims at developing technologies and methods for the roll out of predictive maintenance in infrastructures to extend lifetime, reduce failures or ruptures, and increase resilience to hazards.

Its scope includes:

Develop new methods and advanced sensors for infrastructure monitoring and maintenance through non-destructive approaches (e.g., quantum sensors, spectral imaging, IoT, drones, fiber optics, remote sensing) as well as low cost, plug&play, connected monitoring systems and virtual sensors reusing existing data.	TRL 4 today	→	TRL 8/9 by 2030
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Develop Digital Twins combined with VR/AR, AI analysis, for predictive risk assessment, event planning and management, training, post event evaluation and recovery	TRL 4 today	→	TRL 8/9 by 2032
Develop risk-based standards and multi-hazards models and tools for predictive and proactive maintenance of buildings and infrastructures (including transport) and incremental renovation plans, determining remaining useful life	TRL 4 today	→	TRL 8/9 by 2030
Develop and implement intervention strategies and tools for rapid recovery after disruptive events (including for instance support from autonomous platforms and unmanned autonomous vehicles)	TRL 4 today	→	TRL 8/9 by 2030

► *Advanced safe materials as well as NBS, biomimetic, recycled and bio-biased materials, with well understood ageing behaviour, supported by revised standards*

The aim of this topic is to prepare the integration of materials that can improve resilience to climate change and natural hazards.

Its scope includes:

Demonstrate durable and safe (non-harmful, flame-resistant) bio-based materials and smart materials (e.g., smart and bio-based composites, shape memory and superelastic materials, reinforcement thermoplastics, phase change materials, biomimetic materials, ...) that can increase the resiliency of the build environment and its occupants	TRL 4/5 today SRL 3	→	TRL 8/9 by 2030 SRL 7
Develop and implement new accelerated ageing protocols (testing, modelling, monitoring) for innovative /recycled materials and components to better understand their long-term behaviour and support circularity	TRL 5 today	→	TRL 8/9 by 2027
Adapt standards to account for new findings on the use of materials, incl. recycled, circular, bio-based and NBS, but also changing conditions (climate, extreme events...) and news uses (e.g. materials used in garages where eVs are parked)	TRL 4 today	→	TRL 8/9 by 2030



R&I priority 1.2: Make solutions for building and infrastructure renovation and decarbonisation more affordable and easier to implement

The second R&I priority addresses the scalability potential of solutions for energy efficient renovation and operation, towards the decarbonisation of the existing building stock by 2050.

The Renovation Wave launched by the European Commission in 2020 still faces multiple obstacles. The first barrier relates to the lack of support for building/ assets owners to identify and select the optimal solution (from a life cycle perspective) for renovation including heating equipment and integration of renewable energy and promising energy carriers, along with the business models to finance the transition at building and district scale. The affordability (and acceptability), scalability and potential for industrialisation of renovation packages constitutes a second barrier. Finally, the optimisation of the use phase of a building and infrastructure is still challenging; smart, automated regulation can be poorly accepted by users (who will tamper with the controls or feel uncomfortable) and it is not suitable for all buildings. For those buildings (in particular small residential), simplification and focus on passive solutions is an option. The optimisation of the use phase – either in an active or passive way – is however critical to achieve the performance that has been targeted by design. The barriers related to skills availability and industrialisation being covered in Objective 3, Priority 1.2 aims at tackling barriers associated to decision-making mechanisms, affordability, and easiness of implementation.

This R&I priority is broken down into three topics:

- Identification and implementation of decarbonization pathways for the EU building stock,
- Modular, energy efficient, low-carbon solutions for renovation and extension,
- User-centric optimisation of operation/ use phase of buildings and infrastructures with active control or self-regulation.

Figure 11 shows the estimated timeline to develop solutions at TRL9 within projects which are launched to address the challenges behind these three topics, all three topics being consistent in terms of TRL. Details on the scope of each topic are given in the next paragraphs.

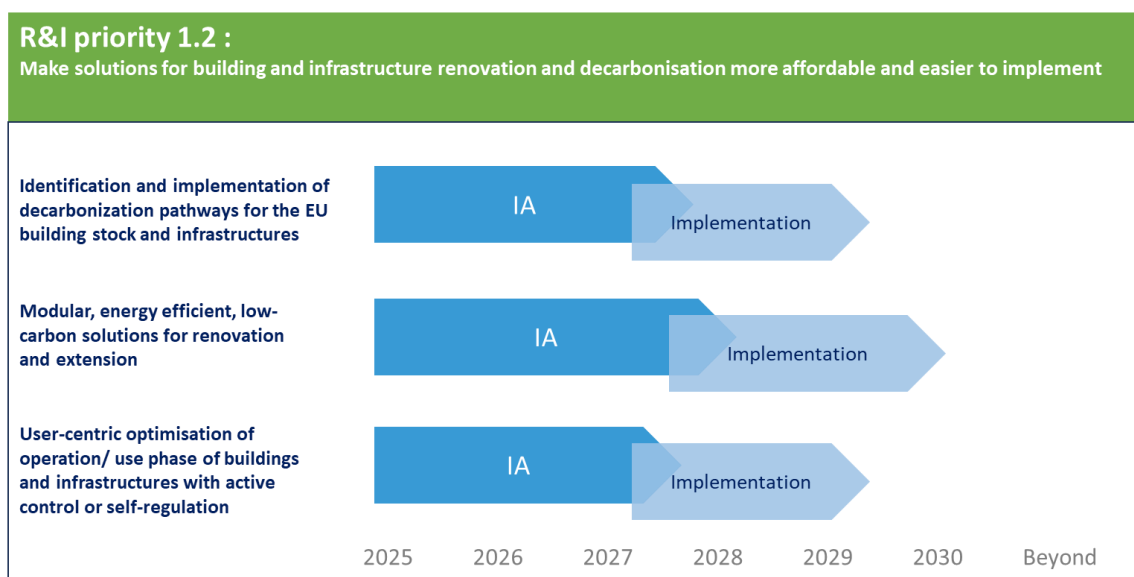


Figure 11 : Timeline of topics within priority 1.2



► *Identification and implementation of decarbonization pathways for the EU building stock and infrastructures*

The aim of this topic is to streamline the ‘renovation pipeline’ and support building owners in the decision-making process.

Its scope includes:

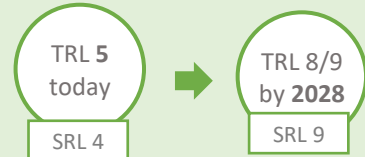
Develop a **comprehensive tool dedicated to the building environment decarbonisation** (including also assets in the public domain such as roads, railways, energy infrastructures, etc.). This requires the pooling of different European **databases** to support building owners in the understanding of the life cycle footprint of their stock, development of **decarbonisation scenarios**, informed decision-making which involves occupants and users, and **follow-up of action plans**, duly taking into account the **Digital Building Logbook** and **renovation passports** as foreseen in the EPBD forecast.



Develop **Digital Twins / advanced BIM approaches and tools integrating user data, BMS and LCA & LCC** to support the selection of decarbonisation pathways with simulation and optimization, considering the construction/ renovation process, in particular logistics. This requires the use of **adequate ontologies, open datasets, open inventories and libraries**, and uncertainty intervals.



Deploy **new financing and business models** as well as **novel governance approach for deep energy-efficient renovation** of the existing building stock (e.g., carbon crediting, ESCOs, crowd funding, etc.) which are user centric and involve and incentivise key stakeholders (incl. occupants) along the value chain.



► *Modular, energy efficient, low-carbon user-centric solutions for renovation and extension*

The topic aims at accelerating and industrialising the renovation, while making it less intrusive.

Its scope includes:

Develop and demonstrate **affordable lightweight / prefabricated construction solutions for renovation and upgrade of existing buildings and infrastructure**, which integrates **energy efficient heating and cooling (e.g. heat pumps)** as well as **renewable energy sources**, being smart, plug-and-play and interoperable with building management solutions, considering the efficiency-first principle as set out by the recast EED.



Develop and demonstrate **fast and prefabricated construction solutions for rebuilding existing infrastructures under operation** making use of latest innovations in materials and automation and





robotics, including unmanned vehicles for cost-efficient and safe operations.

Develop and demonstrate **modular affordable, flexible and scalable renovation packages** (incl. insulation, glazing, lighting), which can also be used in staged deep renovation, exploiting local natural sources for heating, cooling, ventilation, lighting as well as for energy production, reducing energy losses through the building envelope but also improving summer comfort, adaptable to different building uses and users' needs and considering indoor environmental quality and impact at system level.



Develop and demonstrate **portable additive manufacturing solutions along with advanced sensing, AR tools and 3D modelling solutions** for quick assessment and fast repair in situ and facilitate the reuse of damaged constructions.



► *User-centric optimisation of operation/use phase of buildings and infrastructures with active control or self-regulation*

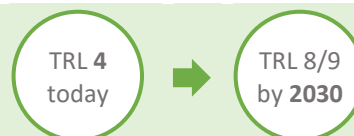
The aim of this third topic is to reduce the energy consumption during the use phase of the built environment, through a combination of active and passive approaches, with occupants at the centre, so that real performance is in line with performance by design.

Its scope includes:

Demonstrate **(cloud or edge) platforms to monitor and optimise the use phase of buildings and infrastructures**, thanks to sensors (incl. for IEQ), IoT, actuators, control systems and BMS, and that fully integrate the users.



Develop approaches to **safely integrate Artificial Intelligence to technologies, BMS and optimisation platform** so that they match occupants' behaviours in the most energy efficient way.



Share and implement best practices for the **self-regulation of buildings to decrease need for active control**, thanks to advanced and smart materials (e.g., phase-change materials) or low-tech adaptable envelope systems (e.g., simplified design, controlled natural ventilation, passive cooling and lighting, insulation⁹).



Adapt and integrate **highly efficient (80-90%) mCHP solutions** based on Fuel Cells in buildings to reduce primary energy consumption for the generation of electricity and heat (building upon lessons learnt from the mobility sector).



⁹ KPIs related to glazing, insulation and lighting technologies can be found in EMIRI Technology Roadmap, Sept. 2019



R&I priority 1.3: Scale up solutions for better buildings/infrastructures integration into energy and mobility networks

Buildings and infrastructures taken in isolation (off the grid) cannot be fully decarbonised unless they are turned into autonomous assets at considerable cost. To reach (overall) zero-carbon levels, buildings should rely on strong and flexible interactions with networks. The third R&I priority therefore focusses on demonstrating solutions for better integration of the built environment into energy and mobility networks.

Several barriers remain to be addressed for this integration at broader scale. The first barrier concerns the building scale, with the improvement of the integration of local generation, storage as well as hydrogen to enable buildings to become “smart-network ready”. The second barrier is related to integrating these “smart-network ready” buildings into energy networks and finding the right balance between local optimisation and the provision of flexibility. Finally, the intricate connections between the built environment, transport and mobility should be addressed from a holistic, multi-modal perspective.

This R&I priority is broken down into three topics:

- Integration of RES production (electricity, heat, etc.), H2 and local storage in the built environment, fully exploiting the potential of EV storage capacity,
- Smart-network ready buildings, locally optimised and providing flexibility to the energy networks, leveraging opportunities offered by energy sharing and energy communities,
- Integration of the built environment, in particular infrastructure, to the mobility network.

Figure 12 shows the estimated timeline to develop solutions at TRL9 within projects which are launched to address the challenges behind these three topics. Details on the scope of each topic are given in the next paragraphs.

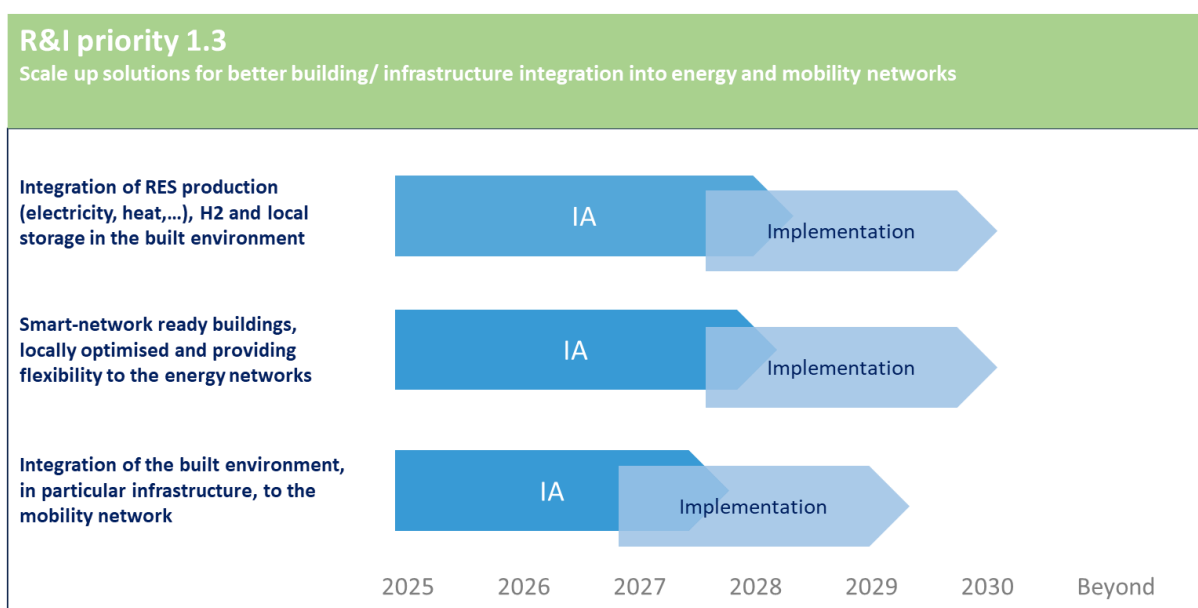


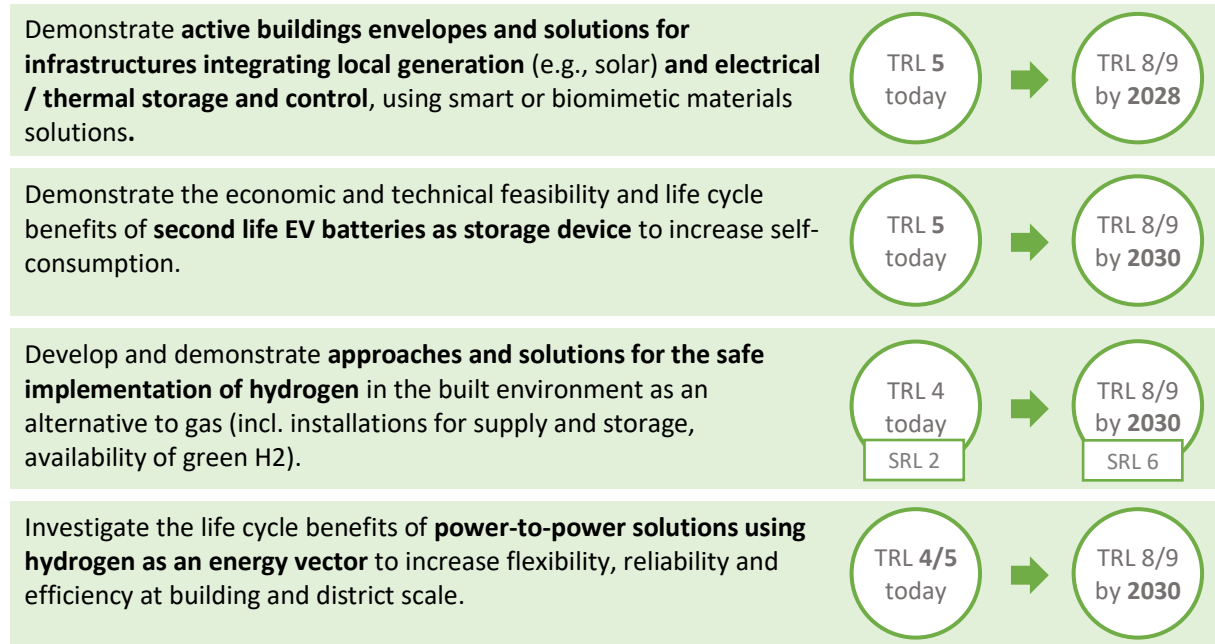
Figure 12 : Timeline of topics within priority 1.3



► *Integration of RES production (e.g., electricity, heat, etc.), H2 and local storage in the built environment*

The aim of this topic is to increase the production and use of renewable energy at building scale.

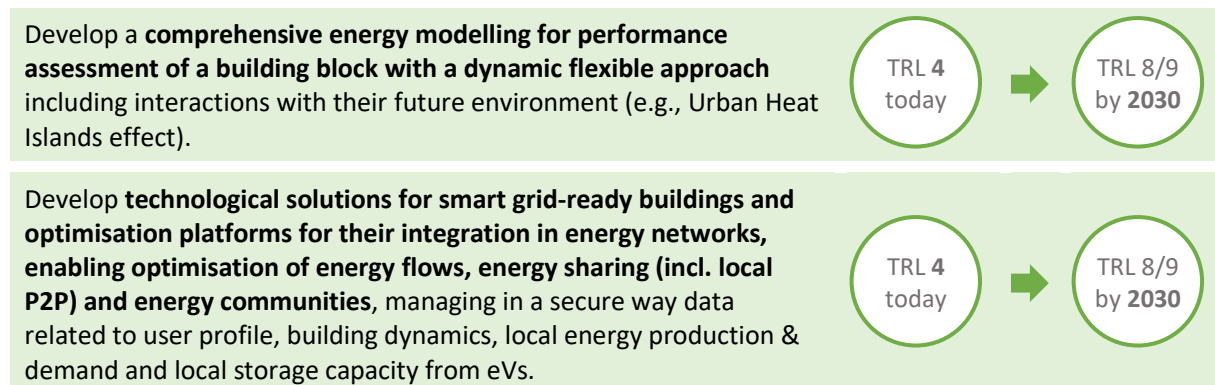
Its scope includes:



► *Smart-network ready buildings, locally optimised and providing flexibility to the energy networks*

The topic aims at fully integrating the buildings to the energy networks so that they become an active node. The last topic on Positive Energy Districts (PED) is highly connected to the Positive Energy Districts transition pathway of the DUT partnership.

Its scope includes:





Consolidate, scale up and replicate approaches and solutions for **Positive Energy Districts (PEDs)**, including technologies & platforms described above, and develop enabling governance and business models.



► *Integration of the built environment, in particular infrastructure, to the mobility network*

The aim of this third topic is to make sure that transport infrastructures adapt to stakeholders' needs and constraints (e.g., mobility, freight) and are ready to integrate at fast pace and high-volume charging stations, parking spaces and multi-modal transport hubs in line with new or upcoming EU regulation. This topic has strong connections with the mobility roadmap of European Road Transport Research Advisory Council (ERTRAC).

Its scope includes:

Demonstrate and implement **approaches to better promote sustainable mobility through the built environment** (e.g., green spaces and safer infrastructures for cycling and walking) and include co-benefits (e.g., renaturation, well-being, and health) into energy & environmental balance at city scale, closely linked to the emerging Health City Managers responsibilities and overall governance.



Develop and implement **approaches for the fast, large-scale roll-out of eV charging stations** and of **dedicated parking spaces for bicycles** in buildings (in particular condominiums), taking into account social aspects (acceptance, accessibility, safety), planning/ financing and decision-making mechanisms as well as technical constraints (e.g. grid constraints, mixed uses)



Deploy modular, scalable solutions to integrate **new mobility and logistics practices** (e.g. micro-mobility, teleworking, e-commerce deliveries, urban air mobility, unmanned autonomous vehicles) and user requirements to existing infrastructures, paying attention to the interface with buildings (impact on access and space), along with suitable agent-based modelling tools to simulate scenarios, monitoring and impact assessment to assess benefits for the citizens.



Develop, implement, and scale up designs for **integrated, multi-modal, and multi-stakeholders transport hubs**





R&I priority 1.4: Demonstrate regenerative and frugal designs, integrating NBS and considering adaptability and life cycle

The fourth priority goes beyond mitigating negative impacts on climate through the decarbonisation of the built environment; it covers other environmental aspects such as biodiversity, water, use of raw materials, and sets out R&I activities to exceed neutrality and generate positive impacts.

This forward-looking priority is however facing multiple barriers. Firstly, given the state of climate emergency, efforts have been concentrated so far on reducing the energy consumption during the use phase. Other critical topics such as water scarcity, raw material depletion and biodiversity loss therefore need to be better accounted for. Secondly, life cycle approaches are still poorly implemented except in large or exemplary projects (and even in those projects, they are not systematically associated to decision-making mechanisms, and usually do not consider concepts such as design for adaptability). Finally, approaches such as frugal designs or regenerative designs, renaturation at district scale, circularity, may collide with interests and norms prevailing today and be hindered by the lack of skills, standards, and adequate building codes.

This R&I priority is broken down into three topics:

- Frugal, simplified, robust and adaptable designs,
- Renaturation and circularity at building and district scale for positive impact on the environment,
- Tools, demo spaces, training, and regulatory frameworks for accelerated market uptake.

Figure 13 shows the estimated timeline to develop solutions at TRL9 within projects which are launched to address the challenges behind these three topics. Details on the scope of each topic are given in the next paragraphs.

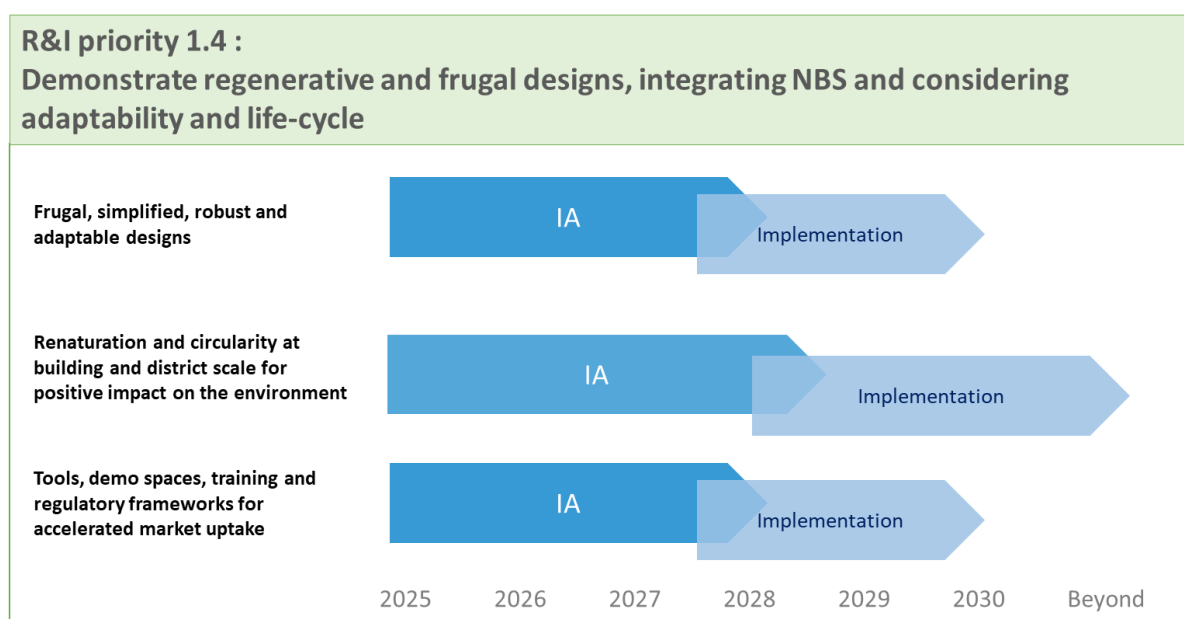


Figure 13 : Timeline of topics within priority 1.4



► *Frugal, simplified, robust and adaptable designs*

The aim of this topic is to make the built environment more frugal (beyond energy) and adaptable to new uses, to extend its lifetime and reduce its overall environmental footprint.

Its scope includes:

Develop and demonstrate designs that can balance energy efficiency and adaptability (change/optimisation of use) during the building life cycle, taking into account context dynamics such as social trends, hazards predictions, urban transformation.	TRL 4 today	→	TRL 8/9 by 2030
Develop and demonstrate effective and affordable solutions at local scale for water treatment/re-use and resource upcycling which properly consider the civil and industrial domains creating sustainable and circular approaches at district or city scale.	TRL 5 today	→	TRL 8/9 by 2028
Develop and demonstrate best practices for frugal designs for different typologies of buildings and considering frugality in energy, in materials, in technology.	TRL 4 today	→	TRL 8/9 by 2030
Develop and demonstrate advanced, data-driven maintenance, management and upgrade concepts for large infrastructures to extend service life and save grey energy.	TRL 4 today	→	TRL 8/9 by 2030

► *Renaturation and circularity at building and district scale for positive impact on the environment*

The topic aims at going beyond sustainability and make a positive impact on the environment (i.e., regenerative built environment).

Its scope includes:

Develop a harmonised definition of “regenerative building” with metrics and KPIs, as well as a structured design framework and enabling technologies. This should include Post Occupancy Evaluation approach coupling measure and qualitative data collection.	TRL 3/4 today	→	TRL 8/9 by 2032
Develop affordable, durable and safe NBS for green integration to the building envelope to contribute to solar gain control, water management, protection of biodiversity, etc., as well as decision-making and maintenance guidelines.	TRL 4 today	→	TRL 8/9 by 2032
Explore solutions for CO2 storage in the built environment (carbonisation of materials, use of NBSs as green facades and roofs, food production, micro-algae wastewater systems, etc.).	TRL 4 today	→	TRL 8/9 by 2032



Develop **innovative urban symbiosis approaches** based on strategies, technologies and materials that improve the renaturation and circularity of the built environment (e.g. reuse of grey water, biodiesel, biogas, etc.), building on the **synergies between building typologies and uses at district scale**.



► *Tools, demo spaces, training and regulatory frameworks for accelerated market uptake*

The aim of this third topic is to develop the enabling conditions for the uptake of innovative designs, materials, and solutions.

Its scope includes:

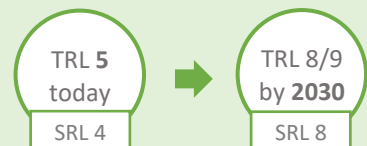
Develop **holistic decision-making support tools for the planning and design** of large projects, taking into account life cycle approaches, local conditions, social and climate vulnerability.



Implement **Digital Twins to assess the behaviour of new materials or designs in real conditions** starting from their characterisation at reduced scale.



Co-create '**demo spaces**' (e.g., **proof of concepts, living labs**), **guidelines, standards and paths to fast-track certification** for the implementation of innovative/circular technologies, providing quantitative information (inc. user feedback) to market stakeholders.



Develop and implement **training modules for architects, upskilling of workers and co-creation approaches** to support market uptake of low-carbon, biobased or circular materials and integration of NBS.



Provide **policy recommendations to adjust regulation & building codes** (e.g., to permit/support the use of recycled material and NBS, or to re-purpose buildings).





4. Objective 2: Enriching, inclusive and health-improving built environment

The second objective focuses on built environments that are enriching, inclusive and that have a positive impact on health, and sets priorities for moving towards the creation of a societal added value for all European citizens by 2030.

Enriching: To make the built environment truly sustainable, spaces that not only meet functional needs but also contribute positively to people's lives are needed. Enriching built environment refers to designing and creating physical spaces, infrastructures and surroundings in a manner that enhances the quality of life, contributes positively to the experiences of the people who interact with those spaces, enables climate mitigation, and finally generates societal value.

To be enriching, the built environment should fully harness cultural heritage and the creative industries as a resource to encourage sustainable behavioural change towards societal and climate resilience.



Furthermore, advanced, and cost-effective technologies are needed to safeguard cultural heritage against deterioration, climate change and disruptive events.¹⁰

To get a social return on investment in the built environment, new design and development strategies for both urban and rural renewal should prioritise several elements. These encompass establishing connections with biodiversity and natural elements (urban and rural greening), ensuring a seamless continuation of services between public and private spaces, and facilitating harmonious urban-rural development to solve the urban and rural divide.

Finally, new and sustainable business models are required so that tomorrow's improved built environment is not only conceptual, but a practical reality within the reach of all European citizens.

Inclusive: The built environment has to be built *for* and *with* the people, leaving no one behind¹¹. An inclusive built environment recognises and accommodates differences in the way people use the built environment and along their whole life. It prioritises accessibility, affordability, diversity, and equal participation for all individuals, regardless of their abilities, age, gender, ethnicity, culture, socio-economic status, or any other characteristic.

To avoid exclusionary mechanisms, the sector needs to pursue its effort, moving beyond place making and human design, towards inter-generational design and a true citizen and user-led process over all the buildings and assets life cycle phases.

Research should focus on social, psychological, and cultural differences in user requirements, expectations, and utilisation patterns of the built environment as well as on massive migration and associated effects. New designs and more diverse housing typologies should serve the purpose of an increased flexibility, adaptability and evolvability of the built environment to new needs or uses of a fast-evolving society and account for future threats.

Citizen empowerment, education and cross-disciplinary approaches involving all the stakeholders (researchers, designers, architects, planners, construction workers, social services and the general public) also play a crucial role in advocating for inclusive practices.

Health-improving: The design of our built environment and the areas where people live, work, travel and play are directly related to the amount of time people spend outdoors, meaning that our health and wellbeing strongly depends on how and with which materials our buildings and infrastructures are built, maintained, and renovated. The built environment has then a huge role to play in improving health, well-being, and human performance¹².

To improve the positive impacts of buildings and infrastructures on the citizen's health and wellbeing and to allow active and healthy ageing¹³, predictive and preventive built environment models, spaces for social interaction, new construction materials and adapted design as well as smart technologies needs to be integrated into standard practices. The safety of indoor and outdoor environment, but also of the city and rural areas as well as the access to care services remain key research & innovation actions for the sector.

¹⁰ [Cultural Heritage and Climate Change: New Challenges and Perspectives for Research](#), White Paper by JPI Cultural Heritage & JPI Climate, March 2022

¹¹ In line with the [New European Bauhaus](#)

¹² [IWI Global Research Agenda](#), January 2021

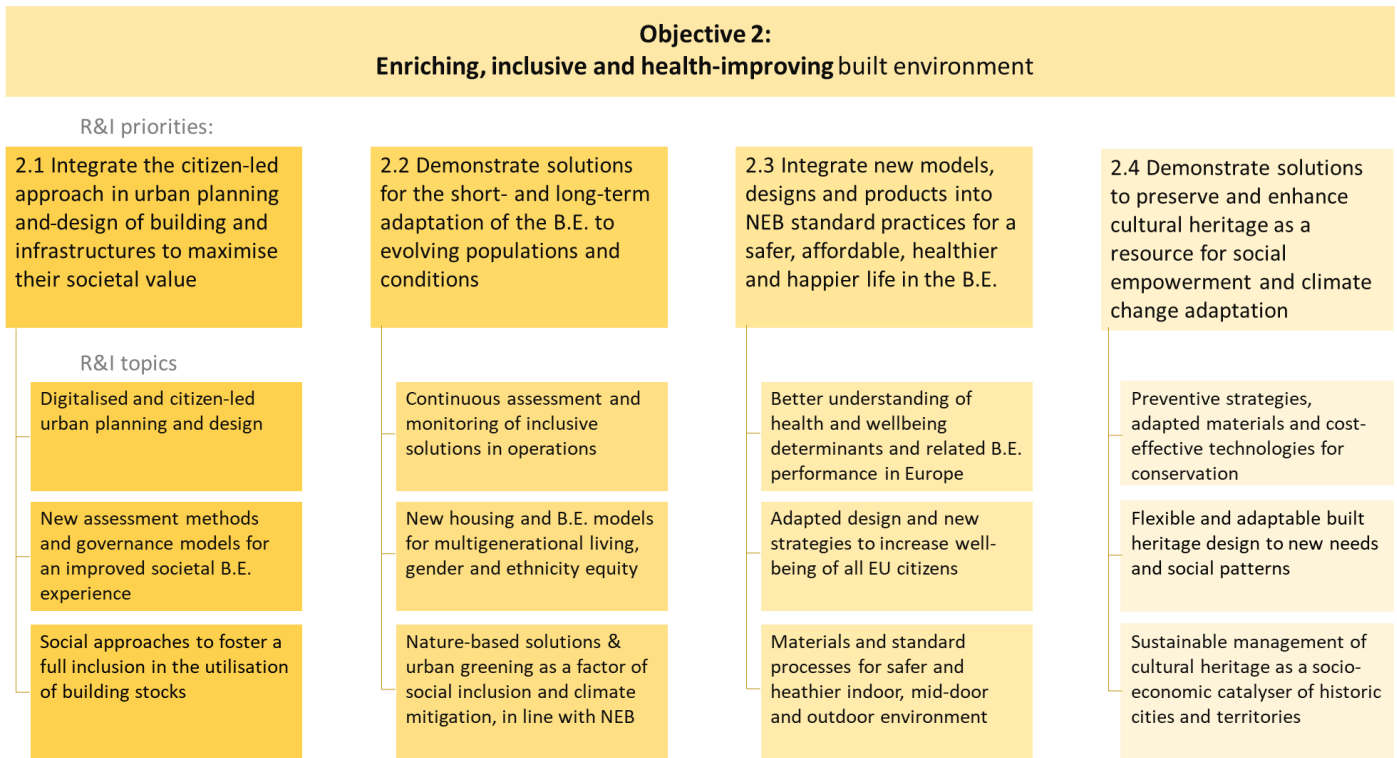
¹³ European Commission. (2021). Green Paper on Ageing: Fostering solidarity and responsibility between generations.



To enable the construction value chain to reach this second objective, four R&I priorities, which should be completed by 2030, have been identified:

- **Priority 1:** Integrate the citizen-led approach in urban planning and design of building and infrastructures to maximise their societal value,
- **Priority 2:** Demonstrate solutions for the short- and long-term adaptation of the built environment (B.E.) to evolving populations and conditions,
- **Priority 3:** Integrate new models, designs, tools and products into standard NEB practices for a safer, affordable, healthier, and happier life in the built environment,
- **Priority 4:** Demonstrate solutions to preserve and enhance cultural heritage as a resource for social empowerment and climate change adaptation.

Each of these priorities has then been broken down into three R&I topics, as presented in Figure 14.



ECTP draft Strategic Research and Innovation Agenda 2023

Figure 14 : Overview of R&I priorities for Objective 2



R&I priority 2.1: Integrate the citizen-led approach in urban planning and design of building and infrastructures to maximise their societal value

The first R&I priority focusses on the integration of the citizen-led approach in urban planning and design phases of building and infrastructures to maximise their societal value.

Although human-centred approaches and universal design have already been successfully deployed in built environment and urban planning research and practice, they are far from “business as usual”. 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 to roll out participative processes for urban planning, and building & infrastructure design. Furthermore, once in operation, user-centric methodologies often fall short of citizen engagement even when user’s views are incorporated into design specifications. The first barrier therefore relates to engagement methodologies. Secondly, usual governance processes do not sufficiently consider the human experiences with the built environment and lack of evidence-based strategies for decision-making. Finally, social sciences studies must be integrated in education programs to increase the user and inhabitants’ ownership and create more equitable built environment. This R&I priority is broken down into three topics:

- Digitalised and citizen-led urban planning and design,
- New assessment methods and governance models for an improved societal built environment experience,
- Social approaches to foster a full inclusion in the utilisation of the building stocks.

Figure 15 shows the estimated timeline to develop solutions at TRL9 within projects which are launched to address the challenges behind these three topics. Details on the scope of each topic are given in the next paragraphs.

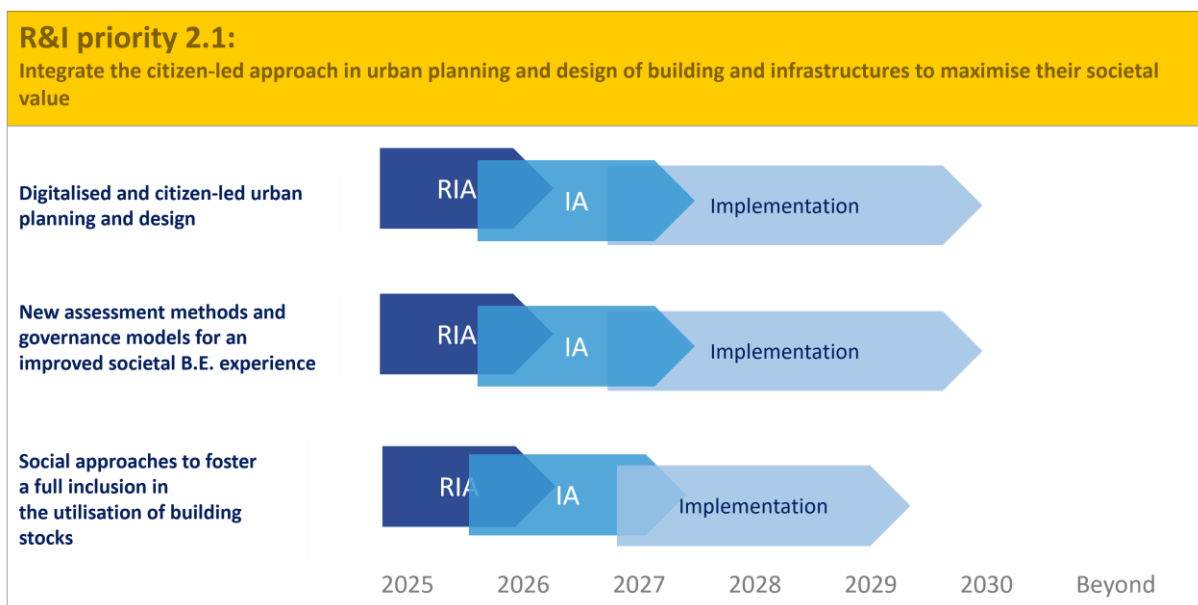


Figure 15 : Timeline of topics within priority 2.1



► *Digitalised and citizen-led urban planning and design*

The aim of this topic is to enable a citizen-led participatory design, ensuring a more user-centred built environment.

The scope includes:

Integrate AI within interactive tools to promote new co-design and co-creation methodologies involving all citizens, enabling equality and including the non-human dimension (flora and fauna) .	TRL 6 today	➔	TRL 8/9 by 2028
Develop and use digital tools and XR to first simulate and then show/edit in real time construction and urban development projects , in order to raise city planners/future users' awareness and participations.	TRL 6 today	➔	TRL 8/9 by 2028
Develop tools and methods for multi-party and multi-parameter design, addressing inclusion and social cohesion . This includes ownership and public/private governance models, best practices, etc.	TRL 4 today SRL 3	➔	TRL 8/9 by 2030 SRL 7
Propose a set of strategies and methodologies to extend the application of lived experience methodologies to project governance , collaborative research development, and workforce training based on real-life experiences.	TRL 6 today	➔	TRL 8/9 by 2030

► *New assessment methods and governance models for an improved societal built environment experience*

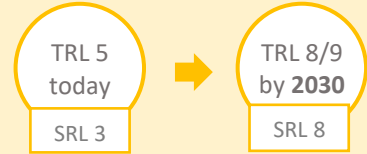
The aim of this topic is to foster the adoption of new participative approaches to go beyond human design and steer for generation of societal value.

The scope includes:

Develop and integrate digitalized citizen-led participatory processes with benchmark and evidence-based method to support decision-making and provide optimal solution to a more people-centric and nature inclusive built environment. This includes bottom-up organised local communities approach, involvement of social housing inhabitants, etc.	TRL 4 today SRL 3	➔	TRL 8/9 by 2030 SRL 7
Develop and demonstrate mixed methods approaches to understand built environment experiences and increase awareness (e.g., SoftGIS methods, use of TRL/SRL scale to evaluate the citizen experiences, etc.).	TRL 5 today	➔	TRL 8/9 by 2028
Propose a new set of indicators on social impact and standardise the use of S-LCA approaches to support decision-making and raise awareness.	TRL 5 today	➔	TRL 8/9 by 2030



Establish a practical framework **to evaluate user/citizen acceptance of reused/circular materials** in new built and/or renovated houses, which is enabled by development and effective use of material processes and characterization.

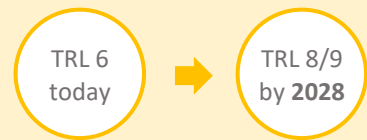


► *Social approaches to foster a full inclusion in the utilisation of building stocks*

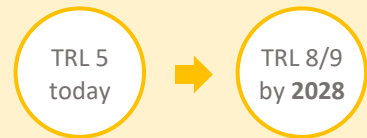
The aim of this topic is to ensure a more inclusive design and avoid exclusionary mechanisms.

The scope includes:

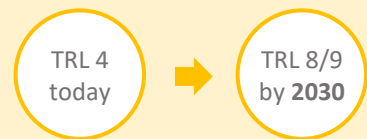
Define **social, psychological, and cultural differences in citizen's requirements, expectations, and utilisation patterns of the built environment to integrate subjective dimension** and increase cohabitation and the inhabitants' sense of ownership.



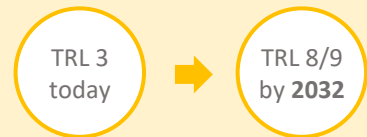
Propose **continuous training, life-long learning, and education programme** to citizens as well as to the workforce, considering social cohesion and **gender dimension**. This includes the documentation of progress about gender equality.



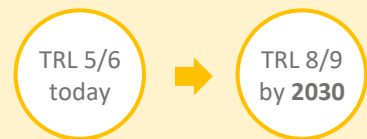
Set up a practical framework to **co-design common spaces in residential buildings and areas with diverse groups of citizens to create spaces that are intergenerational, open to all social groups**, and ingrained in the idea of 15-minute city (e.g., community-based infrastructure). This implies **cross-sectoral collaboration** with social housing associations, social services, psychologists, etc.



Investigate the impacts of massive migration triggered by extreme events on urban futures, and incorporate these investigations across all research and innovation domains to provide fast and liveable solutions.



Develop cross-sectoral and interdisciplinary partnerships with e.g. municipalities to form large-scale field trial in a real-life environment in the municipalities where solutions are tested, implemented and evaluated (e.g. risk vs benefit sharing). **Integrate citizens science and crowdfunding** in such partnerships to address gender and ethnicity gaps.





R&I priority 2.2: Demonstrate solutions for the short- and long-term adaptation of the built environment to evolving populations and conditions

The second R&I priority focusses on continuous monitoring, demonstration and adaptation of newly developed/available solutions and uses of spaces to provide adequate solution to climate change and emerging threats, to evolving behaviours and building's usage, improving affordability, energy poverty and accessibility of the built environment. Although a lot of work has been initiated, some key barriers remain to be addressed.

Digital tools and AI-based solutions are key enablers to make the built environment responsive to users' needs and to new uses of a fast-evolving society. However, 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.

As the society evolves and urban demographics change, the sector must look for and demonstrate creative building solutions to create more equitable and nature-inclusive spaces, conceive new models of ownership, re-design homes to house multiple families or individuals and create new forms of community that truly reflect the current population.

Finally, to adapt to evolving conditions and have a positive effect on health, wellbeing, social cohesion, crime reduction, climate adaptation and mitigation, and provide economic gains, urban and rural greening is yet to be unlocked. In particular, Nature-based Solutions must be balanced with social and aesthetic perception and uses for a wider adoption.

This R&I priority is broken down into three topics:

- Continuous assessment and monitoring of inclusive solutions in operations,
- New housing and built environment models for multigenerational living, gender, and ethnicity equity,
- Nature-based Solutions & urban greening as a factor of social inclusion and climate mitigation, in line with the New European Bauhaus.

Figure 16 shows the estimated timeline to develop solutions at TRL9 within projects which are launched to address the challenges behind these three topics. Details on the scope of each topic are given in the next paragraphs.

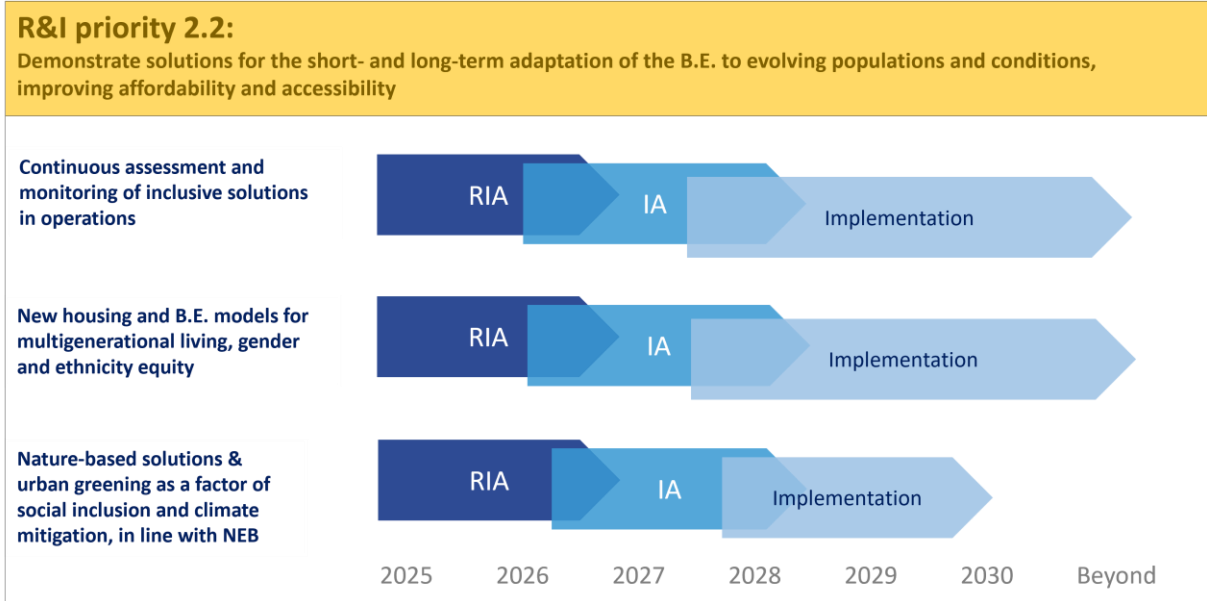


Figure 16 : Timeline of topics within priority 2.2

► *Continuous assessment and monitoring of inclusive solutions in operations*

The aim of this topic is to apply participative process to the operation and maintenance of buildings, with the development and demonstration of solutions using users’ feedback to continuously adapt the solutions, improve the efficiency of use, comfort, governance, and preservation of the assets.

The scope includes:

<p>Integrate digital tools (e.g., XR, aerial and ground robots) and platforms into a continuous assessment and monitoring framework for data-driven design decisions, enabling knowledge-sharing and collaboration among relevant actors, as well as active community engagement to foster replication of inclusive solutions.</p>	<p>TRL 5 today SRL 3</p> <p>→</p> <p>TRL 8/9 by 2028 SRL 7</p>
<p>Develop digital/ AI and simulation-based solutions and information library to better assess the accessibility of buildings, cultural assets and public spaces and improve accessibility of urban and rural spaces.</p>	<p>TRL 3 today</p> <p>→</p> <p>TRL 8/9 by 2030</p>
<p>Deploy automated compliance checking of building design (BIM, IFC, LBD) with predefined requirements.</p>	<p>TRL 3 today</p> <p>→</p> <p>TRL 8/9 by 2031</p>

► *New housing and built environment. models for multigenerational living, gender, and ethnicity equity*

The aim of this topic is to ensure a more user centric built environment considering evolving populations.



The scope includes:

<p>Develop affordable, inclusive and replicable housing models that provide more liveable solutions for diverse groups of people spanning different generations, cultures, ethnicities, and genders and addressing isolation in cities. This includes for instance enhancement of community-based grass root movements.</p>	<p>TRL 4 today</p>	<p>➔</p>	<p>TRL 8/9 by 2030</p>
<p>Demonstrate the performance of built environment infrastructure, emergency responses and disaster risk management, in reducing inequities for disadvantaged/ marginalised- population, along with models to support refugee migration and foster citizen-acceptance.</p>	<p>TRL 4 today</p>	<p>➔</p>	<p>TRL 8/9 by 2030</p>
<p>Develop more diverse housing typologies with appropriate policies and financing schemes to tackle energy poverty, reduce energy demand and guarantee affordable housing (e.g. subsidizing, rent control, zoning, etc). This also includes renovation and adaptation strategies.</p>	<p>TRL 3 today</p>	<p>➔</p>	<p>TRL 8/9 by 2035</p>

► *Nature-based Solutions and urban greening as a factor of social inclusion and climate mitigation, in line with the New European Bauhaus*

The aim of this topic is to recognise the use of Nature-based Solutions and urban greening as an asset delivering well-being and socio-environmental benefits.

The scope includes:

<p>Test and promote approaches to enhance biodiversity in cities for health and inclusion (e.g. construction packages that welcome biodiversity).</p>	<p>TRL 3-4 today</p>	<p>➔</p>	<p>TRL 8/9 by 2030</p>
<p>Demonstrate solutions enabling public and local authorities to interact with citizens and implement Nature-based Solutions, including funding mechanisms and sustainability and scalability plans.</p>	<p>TRL 5/6 today</p>	<p>➔</p>	<p>TRL 8/9 by 2028</p>
<p>Analyse and understand the distribution of urban ecosystem services to ensure an equitable distribution of services and avoid environmental and climate justice issues.</p>	<p>TRL 4 today</p>	<p>➔</p>	<p>TRL 8/9 by 2030</p>
<p>Valorise bio-resources and bio-based materials for construction to achieve lightweight and sustainable solutions for design and construction that adhere to NEB principles, reducing CO2 emissions for both new and existing buildings.</p>	<p>TRL 5/6 today</p>	<p>➔</p>	<p>TRL 8/9 by 2028</p>
<p>Demonstrate Nature-based Solutions for social inclusion to support and engage culturally diverse groups, different age groups, tackling relevant societal challenges as disabilities and neurodiversities.</p>	<p>TRL 5 today</p>	<p>➔</p>	<p>TRL 8/9 by 2030</p>



R&I priority 2.3: Integrate new models, designs, and products into standard NEB practices for a safer, affordable, healthier, and happier life in the built environment

The third R&I priority aims to foster the uptake of solutions improving the impact of urban and rural areas and their related infrastructure on the citizens' health and wellbeing.

The Real Estate sector's shift in focus from energy to occupants, initiated by the Paris climate agreements, has been accelerated by the impact of the pandemic on working and living conditions. The ongoing transition requires a change in the way buildings are assessed. This involves considering not only their material but also their societal implications (such as health determinants and populations victims of violence). To achieve this, new assessment frameworks must be proposed, new business models are needed and the performance of new designs and materials in enhancing physical and mental health, facilitating access to care services, ensuring wellbeing, comfort, ageing well and human performance, must be demonstrated.

This R&I priority is broken down into three topics:

- Better understanding of health and well-being determinants and related built environment's performance in Europe,
- Adapted design and new strategies to increase well-being of all EU citizens,
- Materials and standard processes for safer and healthier indoor, mid-door and outdoor environment.

Figure 17 shows the estimated timeline to develop solutions at TRL9 within projects which are launched to address the challenges behind these three topics. Details on the scope of each topic are given in the next paragraphs.

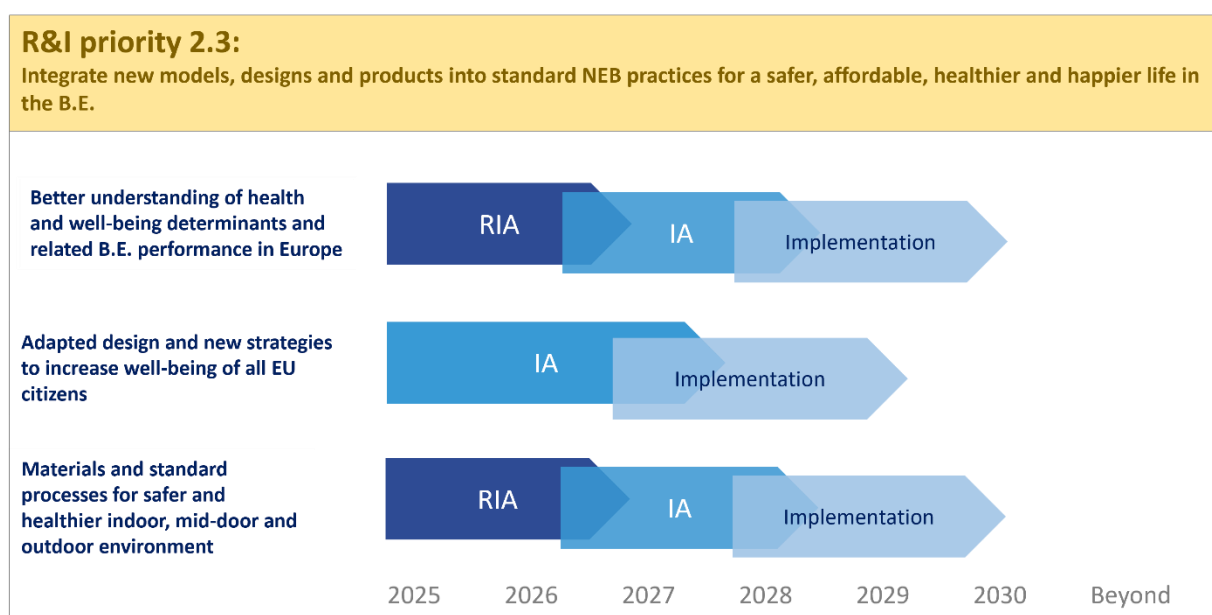


Figure 17 : Timeline of topics within priority 2.3



► *Better understanding of health and well-being determinants and related built environment's performance in Europe*

The aim of this topic is to mobilise the potential of the built environment and limit the need for institutionalised healthcare.

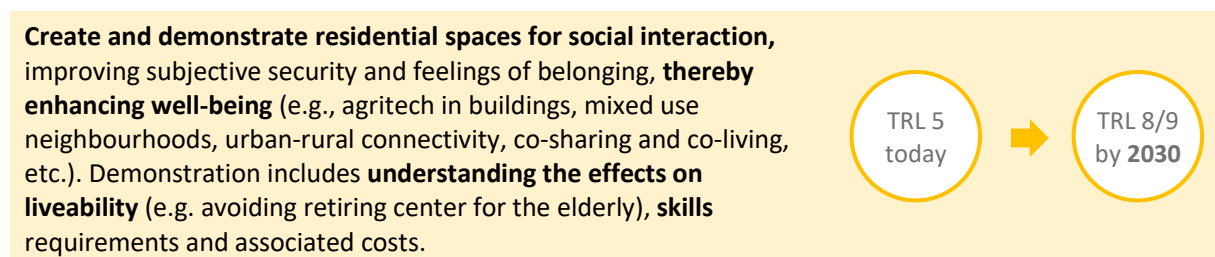
The scope includes:



► *Adapted design and new strategies to increase well-being of all EU citizens*

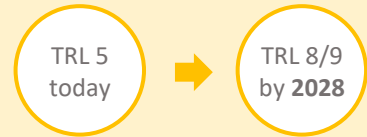
The aim of this topic is to support well-being and healthy and active ageing.

The scope includes:

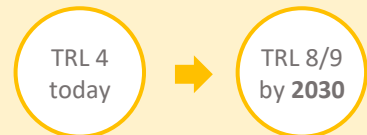




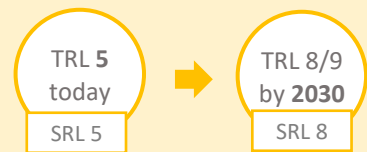
Set up a framework to increase the percentage of buildings and neighbourhoods that cater for the changing (ageing) demographics of the populations, bringing ethnographic and co-design techniques to ageing well and considering the role of smart tech and “datafication”.



Develop **novel approaches and technologies** (e.g., autonomous vehicles, smart sensors, smart monitoring) **for care services in rural areas** to enable healthy ageing in place while ensuring sustainability for public health agencies and citizens. This should include costs-benefits analysis to support decision making by asset managers and real estate developers.



Establish educational programs in Architecture and Civil Engineering to increase awareness of healthy buildings and well-being.



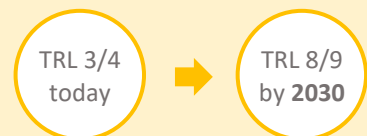
► *Materials and standard processes for safer and healthier indoor, mid-door, and outdoor environment*

The aim of this topic is to increase the safety of city areas and intelligent use of construction materials and HVAC for a healthier environment and an optimal comfort of living. The scope includes:

Develop fall prevention strategies at EU level. This includes demonstration of slip resistant floors with nanomaterials for low maintenance costs, standardization of sustainability assessment of slip resistance of floors at the EU level (including performance durability over time).



Develop user centric designed HVAC systems to fully use the potential of these systems for the health of the occupants, including the non-native digital population (e.g. elderly). This includes AI adaptive control of HVAC and natural interaction language.



Introduce novel HVAC approaches based on smart materials (e.g., photonics for air sanitation, elastocaloric cooling, etc.) **and demonstrate performance of HVAC** in terms of exposure to harmful aerosol particles as well as resilience to crisis such as pandemic threats.

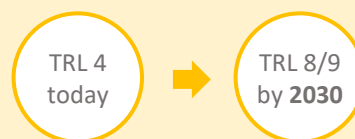


Evaluate potential situational effects on the performance of HVAC systems and establish guidelines to standardise new HVAC systems, thereby facilitating their adoption across the European Union.





Demonstrate and deploy new designs, technologies and materials for improved IEQ/OEQ (passive climatisation, air-tight building envelope, active surfaces, advanced filters, hydroscopic control etc.), **health, comfort of living and aesthetics**. This includes cross-sector collaboration and developing new metrics to assess their well-being performance (e.g., physical and mental health as well as citizen acceptance).



R&I priority 2.4: Demonstrate solutions to preserve and enhance cultural heritage as a resource for social empowerment and climate change adaptation

The fourth R&I priority focusses on preventive conservation and valorisation of cultural heritage to regenerate depopulated areas, create jobs, develop tourism, and establish links between social communities.

European cultural heritage is endangered, as climate change and scarce maintenance are hindering its proper conservation and promotion. In order to make the most of cultural heritage as a resource for social empowerment, it is therefore essential to develop effective preventive conservation strategies and to rely, in particular, on digital technologies to improve the preservation, maintenance, inclusiveness, access, and promotion of cultural heritage.

Secondly, built cultural heritage has a significant potential to reduce its carbon footprint through improving energy efficiency and overall, in some cases reducing the need to construct new buildings and providing more compact cities. Furthermore, as cultural heritage is often perceived as a collective property, therefore intervening on this asset constitute an important opportunity for showcasing innovation and promoting the integration of energy transition principles and climate change adaptation to the entire society.

Finally, a holistic approach is lacking in strategic planning and regeneration strategies for depopulated areas: historic assets are too often considered at the scale of the building unit only, and new uses are rarely considered.

This R&I priority is broken down into three topics:

- Preventive strategies, adapted materials and cost-effective technologies for conservation,
- Flexible and adaptable built heritage design to new needs and social patterns,
- Sustainable management of cultural heritage as a socio-economic catalyser of historic cities and territories.

Figure 18 shows the estimated timeline to develop solutions at TRL9 within projects which are launched to address the challenges behind these three topics. Details on the scope of each topic are given in the next paragraphs.

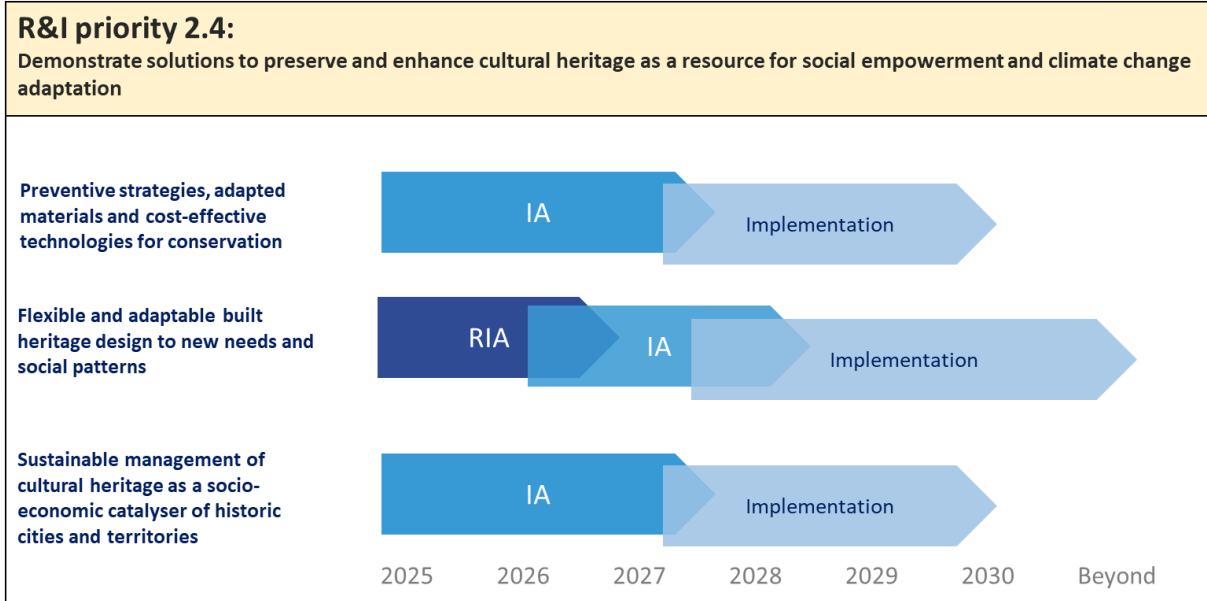


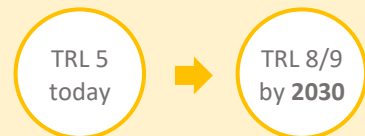
Figure 18 : Timeline of topics within priority 2.4

► *Preventive strategies, adapted materials and cost-effective technologies for conservation*

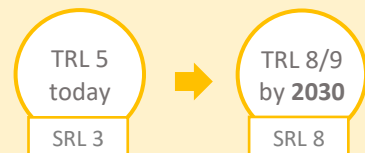
The aim of this topic is to Safeguard Culture Heritage against deterioration, climate change and disruptive events.

The scope includes:

Develop a sustainable conservation value chain. This includes the understanding of **multi-scale deterioration process, development of new and well adapted conservation materials, advanced assessment methods to control the efficiency and a new framework enabling a cost-effective production of conservation materials** on small to medium scale.



Explore past building techniques and skills to extract and apply climate change and disaster resilience methods to contemporary construction practices, leveraging ancestral knowledge to foster a circular economy approach in cultural heritage preservation.



► *Flexible and adaptable built heritage design to new needs and social patterns*

The aim of this topic is to forge sustainable cities and territories and empower citizens.

The scope includes:



Apply AI and immersive solutions to support integrated design and planning approaches **for beautiful, inclusive, and net zero heritage solutions in line with the New European Bauhaus**. This includes involving the local residents in the co-design process.

TRL 3
today



TRL 8/9
by 2032

Develop and test digital/ AI based solutions to use and reuse the historical building stock as a priority over demolition and new construction.

TRL 5
today



TRL 8/9
by 2030

Assess the role of cultural interventions in cities to drive inclusion and avoid isolation, fostering innovative **approaches which fully value cultural heritage and creative industry** while empowering sustainable business models and public private partnerships.

TRL 5
today



TRL 8/9
by 2030

► *Sustainable management of cultural heritage as a socio-economic catalyser of historic cities and territories*

The aim of this topic is to bring economic and social dynamism in urban and rural areas.

The scope includes:

Develop sustainable and circular tourism strategies to support cultural heritage maintenance while keeping cities authenticity and avoid gentrification.

TRL 5
today



TRL 8/9
by 2030

Promote cultural heritage as a valuable well-being asset for citizens and tourists, for example by **enhancing the sensorial experience** during the visit of historical buildings, museums, etc., and generating customised visit itineraries which are taking into account the health status, physical impairments, etc.

TRL 4
today



TRL 8/9
by 2030

Propose continuous training and education programmes to young generation for a better understanding of EU cultural heritage values.

TRL 5/6
today



TRL 8/9
by 2028



5. Objective 3: Competitive, digitalised, and circular value chain

This third objective focusses on the construction value chain, and its transition towards more competitiveness, full digitalisation, and circularity, in view of minimising its environmental impact while maximising its social and economic benefits¹⁴.

Competitive: in a context of geopolitical uncertainty, skills shortage and supply chain disruptions, the European construction industry must reinforce its attractiveness, building upon its capacity to produce in a more sustainable manner.

New technologies such as AI, IoT, and automation in on-site and off-site production need to be integrated faster to existing industrial processes to enable performance gains, at various levels, such as workers' safety on construction sites, resources efficiency and their long-term use/reuse, user experience and comfort, asset management.

¹⁴ Note that the dimension of construction logistics is considered to be already addressed by the roadmaps developed by ERTRAC (see <https://www.ertrac.org/documents/>)



The efforts made to implement more sustainable industrial processes must be recognised and turned into a competitive advantage; a proper, comprehensive assessment framework is required to benchmark the impact and potential of competitive solutions, from materials to buildings, from new to recycled.

The disruptions experienced in various supply chains must lead towards improving our knowledge of the resources locally available and how to use/reuse them at best. Alternative and substitute solutions (e.g., materials, disassembly, etc) must be explored to fill the gaps, at affordable costs.

Further integration is required between stakeholders of the value chain to propose products and services that are suited to the changing needs of users and to fast-evolving regulations, identifying industrial synergies to reduce costs.

Finally, education and training must integrate all the above changes to attract and retain a large workforce; the latest technologies and learning methods should be applied to new curricula integrating the most recent knowledge about digitalisation, sustainability, quality, and soft skills.

Digitalised: the sector needs to pursue its efforts towards digitalisation as a driver for knowledge sharing, high quality, and sustainability. A seamless data integration will enable to better share information between industrial stakeholders, optimise interactions within the value chain, and improve final services to end users.

The further integration of AI and automation in industrial processes will create new possibilities in terms of modularity and customisation. AI will also support the rationalisation of design and asset management in terms of resource efficiency and availability.

However, a number of challenges remain, for example interoperability and openness at first, but also the questions of data availability, quality, validity, and maintenance on the long term. A comprehensive life cycle data management approach is required at industry level, and in connection with the ongoing developments at EU level (e.g., Common European Data Spaces). Open data architectures, frameworks and tools are necessary to support the uptake of data-driven businesses.

Demonstrating the social and economic value of digitalisation is also a pending challenge: what are and how to measure the benefits of sharing data for building/infrastructure owners? For citizens?

Circular: increasing the circularity of the construction industry will enable to reduce its environmental impact, support local employment and skills, and will contribute to strengthen the supply chains by making the best of local primary and secondary resources.

However, this implies a deep transformation of most industrial processes. For example, design needs to consider the local availability of materials and components -including waste from building stock-, and the future reuse and recycling of products; manufacturing shall evolve towards remanufacturing; deconstruction shall be replaced by disassembly in view of reuse and recycling.

The reuse, upcycling and recycling processes must take up a triple challenge to ensure their market uptake; to demonstrate the safety, user acceptance, and economic attractiveness of the resulting products. Solutions lie both in the deployment of a harmonised framework to guarantee the quality and safety of items, and in the identification of the successful (local) market opportunities and regulatory conditions.

To enable the construction value chain to reach this third objective, four R&I priorities, which should be completed by 2030, have been identified:

- **Priority 1:** Ensure seamless and high-quality data streams with clear governance and demonstrated value, for life cycle and value chain optimisation,
- **Priority 2:** Demonstrate solutions enabling increased industrial and human performances,



- **Priority 3:** Demonstrate solutions and local workflows to enable re-use, recycling, and upcycling in both onsite and offsite processes
- **Priority 4:** Develop a framework to assess/ validate the impacts and potential of buildings, infrastructures, components, and materials.

Each of these priorities has then been broken down into three R&I topics, as presented in Figure 19.

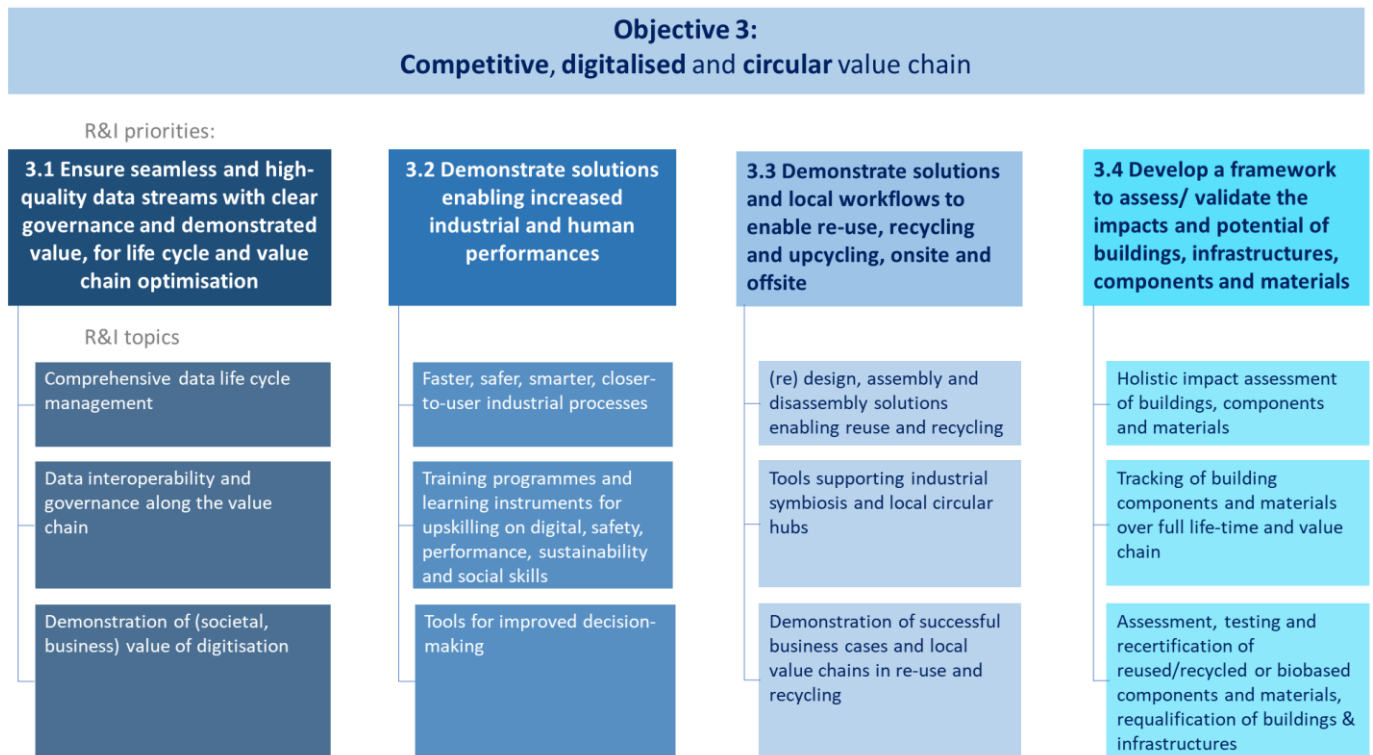


Figure 19 : Overview of R&I priorities for Objective 3

R&I priority 3.1: Ensure seamless and high-quality data streams with clear governance and demonstrated value, for life cycle and value chain optimisation

The first R&I priority focusses on data. In this new era where “data is the new gold”, a set of barriers remain to transform this statement into a reality for the construction industry.

The first barrier is related to the data management over its full life cycle: how to ensure the data quality, validity, privacy-preserving access, and its availability on the long term?



The second barrier is the lack of harmonised framework to ensure interoperability, and the lack of open data platforms, which both limit data sharing along the value chain and impede the development of higher-quality or more integrated services.

The third barrier relates to the value of digitalisation in the industry, that needs to be clearly demonstrated for all stakeholders: in which cases is it beneficial, and for whom? How to share this value along the full life cycle of a building?

This R&I priority is therefore broken down in three topics:

- Comprehensive data life cycle management
- Data interoperability and governance along the value chain
- Demonstration of (societal, business) value of digitisation

Figure 20 shows the estimated timeline to develop solutions at TRL9 within projects which are launched to address the challenges behind these three topics. Details on the scope of each topic are given in the next paragraphs.

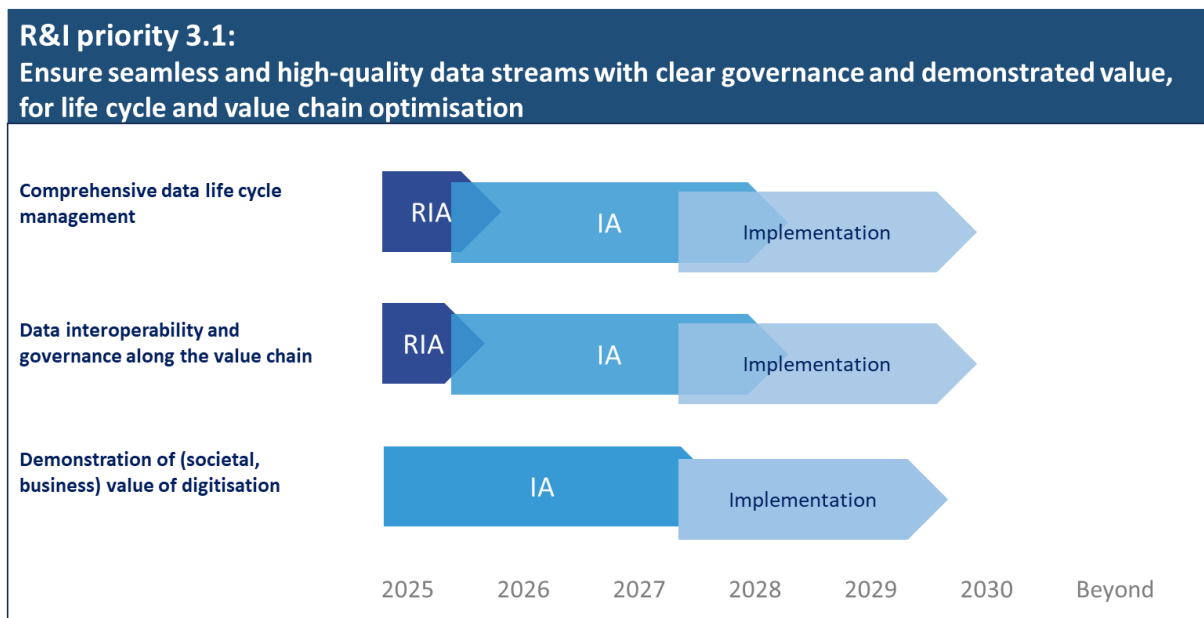


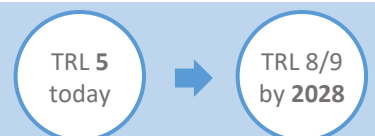
Figure 20 : Timeline of topics within priority 3.1

► Comprehensive data life cycle management

The aim of this topic is to ensure data availability, validity, sovereignty, use, sharing and storage, from short to long-term.

Its scope includes:

Develop multipurpose Life cycle data management strategies and tools for the built environment with circular perspective, including the management of **data quality, data validity and availability on the long term, and level of data aggregation.**





Develop **EU data lake(s) dedicated to construction**, including private and public data sets, pushing for more open data, and aligned with the EC strategy on **Common European Data Spaces**.

Processes and procedures should also be defined for **effective data validation, anonymization**, integration into such databases.

TRL 4
today



TRL 8/9
by 2030

Develop a European common referential for Technical Data and Life Cycle Assessment (LCA) data to foster the use of these data.

TRL 5
today



TRL 8/9
by 2030

Set up a harmonized measurement framework with indicators to assess privacy and ethics for users, and which could be linked to other assessment schemes such as the smart readiness indicator and/ or the logbook.

TRL 4-5
today



TRL 8/9
by 2030

► *Data interoperability and governance along the value chain*

The aim of this topic is to enable increased data integration between tools and throughout the value chain.

Its scope includes:

Set up a **standardised framework to ensure data interoperability in BIM and all related components**. This includes common construction ontology and models, integration of machine-readable certification, and homogenised framework for material information and tracking of materials / components flows. The ethics and data privacy dimensions should be fully included in such framework.

TRL 5
today



TRL 8/9
by 2028

Explore a practical framework and solutions for the **decentralized production and consumption of data**, including a possible decentralised digital identity for all construction entities (e.g., components, operations, resources), based on the model of Uniform Resource Identifier (URIs) or Globally Unique Identifier (GUIDs), and being persistent, secure, verifiable, retrievable, decentralised, and versionable.

TRL 5
today



TRL 8/9
by 2030

Install national and European coordinated **open data architectures** based on international standards for open data access and scalable digital business models.

TRL 5
today



TRL 8/9
by 2030

► *Demonstration of (societal, business) value of digitisation*

The aim of this topic is to make sure to implement digitalisation when it is useful and beneficial.

Its scope includes:



Demonstrate, at the End of Life, the benefits of the data collected during the whole life cycle for building/infrastructure owners.

TRL 5
today



TRL 8/9
by 2028

Demonstrate in a transparent manner the benefits for customers and citizens from using digital twins and related tools.

TRL 5
today



TRL 8/9
by 2028

Develop and demonstrate data driven methodology on Total Value of Ownership (in analogy to Total Cost of Ownership), including possible public-private approaches to ensure residual value of buildings, building elements and materials.

TRL 4
today



TRL 8/9
by 2030

R&I priority 3.2: Demonstrate solutions enabling increased industrial and human performances

This priority is largely about integrating the latest digital developments into the industrial processes, but also into the decision-making and learning processes in view of improving the competitiveness of the overall industry.

BIM, AI, and automation provide new opportunities to improve industrial processes, from generative design to off-site and on-site construction. However, some of these applications (e.g., prefabrication) still need to demonstrate their economic viability, by identifying the profitable use cases.

Digital tools such as extended reality (XR) can also foster new ways of learning and training. More generally, to face its shortage of skilled workforce and its lack of attractiveness to talents, the sector needs to re-think its approach to education and life-long-learning, from engineers to construction workers. Programmes shall integrate the latest concepts and solutions in relation to design, safety, materials, sustainability performances, maintenance quality, and include soft skills. Appealing learning tools are required, as well as a homogenised framework for skills recognition.

Finally, digital tools shall also demonstrate their benefits in various decision-making processes such as investment and asset management, and help in the complex assessments processes related Environmental, social, and governance (ESG) investing, or the EU Taxonomy.

On this basis, this R&I priority counts three topics:

- Faster, safer, smarter, closer-to-user industrial processes,
- Training programmes and learning tools for upskilling on digital, safety, performance, sustainability, and soft skills,
- Tools for improved decision-making.



Figure 21 shows the estimated timeline to develop solutions at TRL9 within projects which are launched to address the challenges behind these three topics. Details on the scope of each topic are given in the next paragraphs.

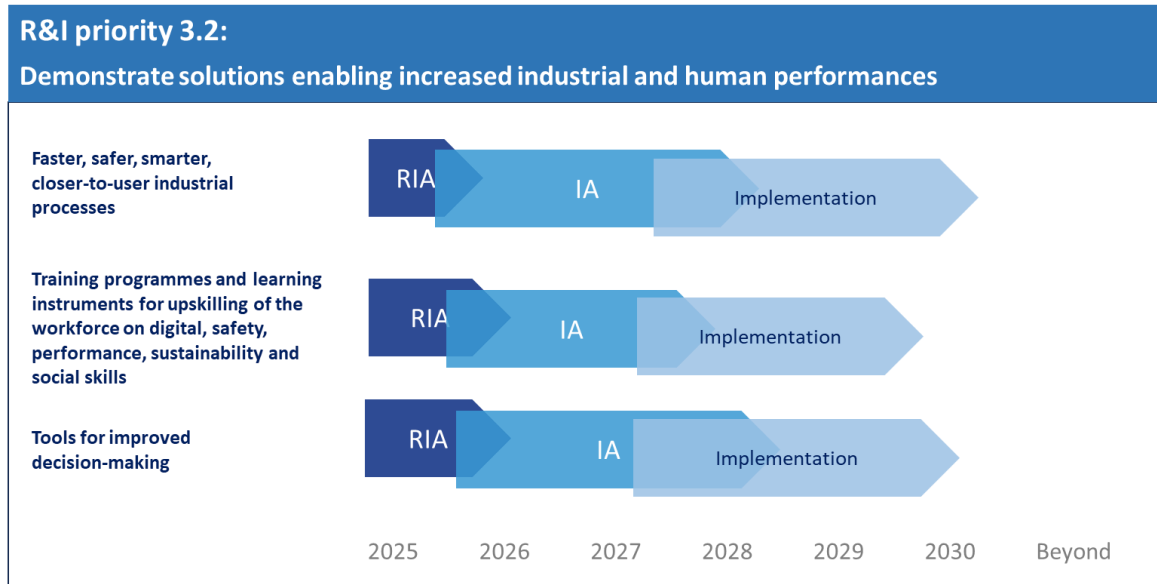


Figure 21 : Timeline of topics within priority 3.2

► *Faster, safer, smarter, closer-to-user industrial processes*

The aim of this topic is to increase the competitiveness of industrial processes.

Its scope includes:

Develop and demonstrate robotic platforms (aerial and ground) with increased autonomous capabilities, and cobotic solutions to support manually intensive tasks on construction sites , to increase workers' safety, reduce accidents, and contribute to reduce the shortage of blue collar.	TRL 4 today SRL 3	→	TRL 8/9 by 2030 SRL 7
Develop AI-driven construction processes enabling optimised planning and real-time adaptation to emerging challenges (e.g., generation of multiple planning and construction alternatives, exploration of 'what if' scenarios).	TRL 4 today	→	TRL 8/9 by 2030
Identify/demonstrate successful business cases for off-site manufacturing and prefab solutions , especially for renovations, to enable the scale up of investments.	TRL 5 today	→	TRL 8/9 by 2028
Automate the integration of tools such as scanners and sensors into BIM (BIM to Machines).	TRL 4 today	→	TRL 8/9 by 2030



► *Training programmes and learning instruments for upskilling on digital, safety, performance, sustainability and soft skills*

The aim of this topic is to increase the competitiveness of European workforce.

Its scope includes:

Develop new training & life-long learning methods and tools (integrating extended reality, Digital Twins and AI technologies) to maximize the quality and safety of maintenance and construction/deconstruction processes, and integrating the latest knowledge on new materials, technologies, and designs, as well as soft/social skills.	TRL 5 today	→	TRL 8/9 by 2028
Develop 'agile curricula' on innovative digital methods and solutions, with continuous updating of the learning content.	TRL 5 today	→	TRL 8/9 by 2029
Develop EU wide recognized skills-based curricula, through the harmonization of the different levels of education (academic, LLL, vocational training...).	TRL 5 today	→	TRL 8/9 by 2028

► *Tools for improved decision-making*

The aim of this topic is to increase the efficiency of industrial investments.

Its scope includes:

Develop, demonstrate, and validate new economic tools enabling value transfer between stakeholders , in order to encourage primary investors to enhance the quality of their buildings, considering that they will have a payback from future owners, users, stakeholders.	TRL 5/6 today	→	TRL 8/9 by 2028
Apply generative AI for the evaluation of upgrading solutions of the asset (e.g., accessibility, energy efficiency, etc.) based on digital models (BIM and Digital Twin).	TRL 4 today	→	TRL 8/9 by 2030
Demonstrate and deploy BIM and Digital Twin-based assessment tools for risk management, Environmental, social and governance assessment (ESG) & EU taxonomy for supporting investments decision-making.	TRL 4 today	→	TRL 8/9 by 2030
Design a EU-wide framework for the harmonisation and automation of the digital building permit , for more transparency towards citizens and users, and efficiency in the work flows.	TRL 5 today	→	TRL 8/9 by 2030



R&I priority 3.3: Demonstrate solutions and local workflows to enable re-use, recycling, and upcycling in both onsite and offsite processes

This priority is focused on how to implement the challenging ambitions of reuse and recycling in the construction sector. While there are no quantified regulatory targets yet, the trend is however clearly set. Making re-use and re-cycling to become the new standard requires to transform the design, manufacturing, construction, and deconstruction processes, so they consider, anticipate, and implement the second life of items. The local availability of resources must become a primary criterion in these processes, which implies that knowledge and information about such resources be shared. The local value chains also need to be re-thought and possibly re-organised in this new perspective, and within favourable regulatory and market conditions, considering the paradigm of circular hubs fostering industrial and cross-sectoral symbiosis, as described in the Process4planet SRIA¹⁵.

To support user acceptance and awareness raising on the benefits of reused and recycled products, showcase examples are needed to convince and inspire stakeholders, from building owners to manufacturers and end users. This R&I priority is therefore broken down in three topics:

- Design, remanufacturing, and (dis-, re-) assembly solutions for reuse and recycling,
- Tools to support industrial symbiosis and circular hubs,
- Demonstration of successful business cases and local value chains in re-use and recycling.

Figure 22 shows the estimated timeline to develop solutions at TRL9 within projects which are launched to address the challenges behind these three topics. Details on the scope of each topic are given in the next paragraphs.

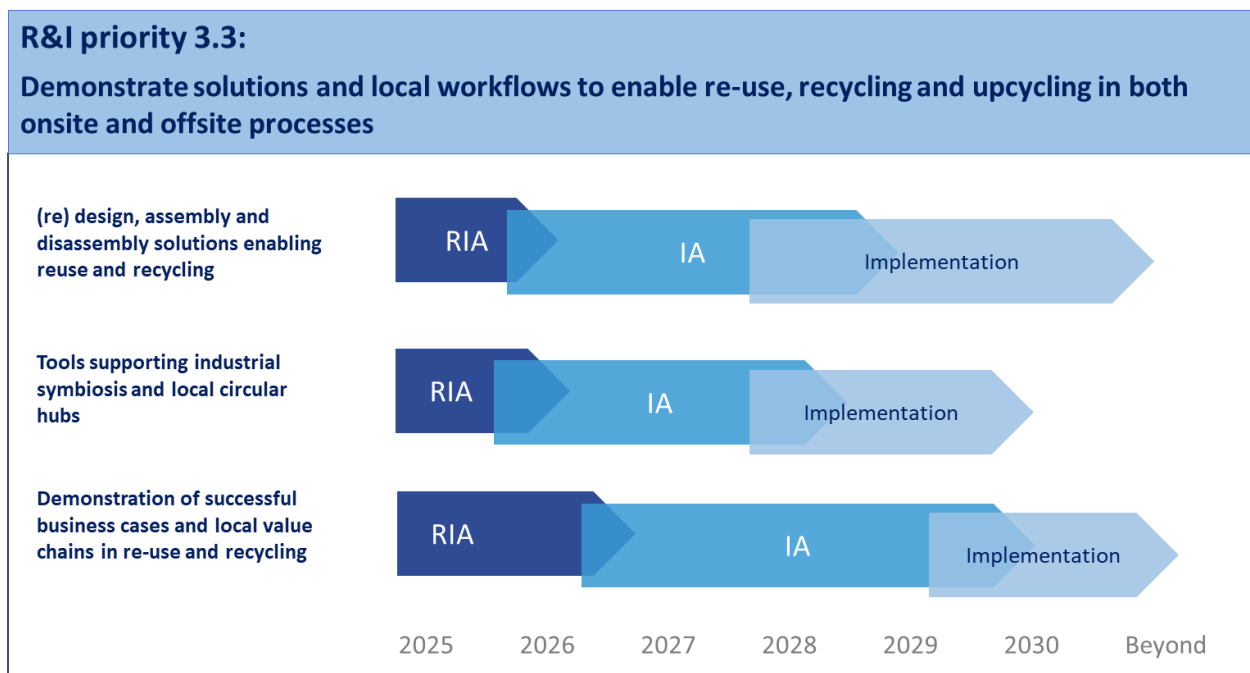


Figure 22 : Timeline of topics within priority 3.3

¹⁵ See <https://www.aspire2050.eu/p4planet/about-p4planet>



► *Design, remanufacturing, and (dis-, re-) assembly solutions for reuse and recycling*

The aim of this topic is to provide the tools to implement reuse and recycling.

Its scope includes:

Develop solutions, including co-botics, for onsite assembly, disassembly and re-assembly of modular and circular building & infrastructure components.	TRL 4 today	→	TRL 8/9 by 2030
Develop generative, multi-parametric design methods and tools , considering locally harvestable building/ infrastructure elements, and the future reusability/recyclability of components, and including cost-benefit analysis.	TRL 3/4 today	→	TRL 8/9 by 2032
Demonstrate the adaption/enlargement of the ' Safe and Sustainable by design ' ¹⁶ to construction products' design, with related indicators to be considered at design phase.	TRL 5 today	→	TRL 8/9 by 2028
Demonstrate remanufacturing solutions, building upon experience from other sectors (e.g. knowledge on the remanufacturing of batteries from the automotive to the grid service sector could be transferred for building applications) .	TRL 5-6 today	→	TRL 8/9 by 2030
Develop DT-based solutions to organise and share the information for recycling and demolition (e.g., scan to BIM, property sets, and methods for cost-effective modelling).	TRL 5 today	→	TRL 8/9 by 2028
Develop pre-qualified and standardized plug and play and reversible connections as alternatives to the linear ones (e.g., welding, adhesives, deformable connectors, etc.).	TRL 4 today	→	TRL 8/9 by 2030

► *Tools to support industrial symbiosis and circular hubs*

The aim of this topic is to support the development of local value chains and markets.

Its scope includes:

Develop platforms for industrial and cross-sectoral symbiosis , to enable that the waste of one factory, farm or construction site becomes a resource for another, and considering the	TRL 5 today	→	TRL 8/9 by 2030
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¹⁶ European assessment framework under testing, to assess the safety and sustainability of chemicals and materials including for the construction sector: see https://research-and-innovation.ec.europa.eu/news/all-research-and-innovation-news/recommendation-safe-and-sustainable-chemicals-published-2022-12-08_en



occupancy/underuse of the building stock. Landfills and rural areas should also be included in the scope.

Develop all in one digital solutions (from pre-auditing to the final new products) for **building/ infrastructure material upcycling**, exploiting latest developments in sensors and measuring techniques (e.g., spectral imaging).

TRL 5
today



TRL 8/9
by 2030

Investigate the **regulatory conditions** (including certification) necessary for the emergence of re-use/ recycling **marketplaces**.

TRL 5
today



TRL 8/9
by 2030

► *Demonstration of successful business cases and local value chains in re-use and recycling*

The aim of this topic is to support the market uptake of the recycling and reuse processes developed.

Its scope includes:

Demonstrate ‘showcase’ buildings and infrastructures designed and built with reused components to stimulate broad interest from the public/owners, test end-user acceptability, and increase attractiveness of such practices.

TRL 3/4
today



TRL 8/9
by 2032

Demonstrate practices for re-use, re-cycling, repair work and upgrade of existing buildings and infrastructures, and the related value chains for specific high-impact materials and components.

TRL 4
today



TRL 8/9
by 2030

Identify and assess the market opportunities for a variety of reused/recycled products, including end-user acceptance, process industrialisation potential, and data needs and gaps.

TRL 3/4
today



TRL 8/9
> 2030

Develop provisions for performance-based design, execution and maintenance, in line with the structural Eurocodes and other relevant harmonised European standards that enable use of broad range of concepts based on reuse and recycling (incl. reuse of reclaimed elements and recycling of material) and low-carbon material solutions

TRL 4
today



TRL 8/9
by 2030



R&I priority 3.4: Develop a framework to assess and validate the impacts and potential of buildings, infrastructures, components, and materials

This priority is about setting a common framework to evaluate the overall impact of products, from techno-economic to social-environmental considerations, and to guarantee the safety, quality, sustainability and performance of these products when re-used or recycled.

Today, we are still missing a common and standardised approach to evaluate the impact of buildings, components, and materials, in a manner that considers at once the technical, environmental, and social dimensions. Both the assessment methods and the related tools are required to evaluate and validate such performances.

Also, generalising the re-use and recycling process raises a new issue: how to keep track of building components and materials over full their life cycle, and across the value chain? The concept of passport or logbook, as already initiated for buildings, should be extended to construction products, components, and materials, to enable their 'cradle-to-cradle' follow up. A standardised framework is required, with easy-to-implement procedures, easy-to-integrate digital tools, and data sharing platforms.

Going one step further, the aspect of recertification and requalification of products remains to be addressed. Methodologies, assessment tools, testing methods and schemes are needed to evaluate and validate the reusability of components, buildings and infrastructures, and the recyclability of materials: safety, sustainability and performances are to be checked and validated. The availability of such local resources needs to be assessed and widely shared.

This R&I priority is broken down in three topics:

- Holistic impact assessment of buildings, components, and materials,
- Tracking of building components and materials over full lifetime and value chain,
- Assessment, testing and recertification of reused/recycled or biobased components and materials, requalification of buildings & infrastructures.

Figure 23 shows the estimated timeline to develop solutions at TRL9 within projects which are launched to address the challenges behind these three topics. Details on the scope of each topic are given in the next paragraphs.

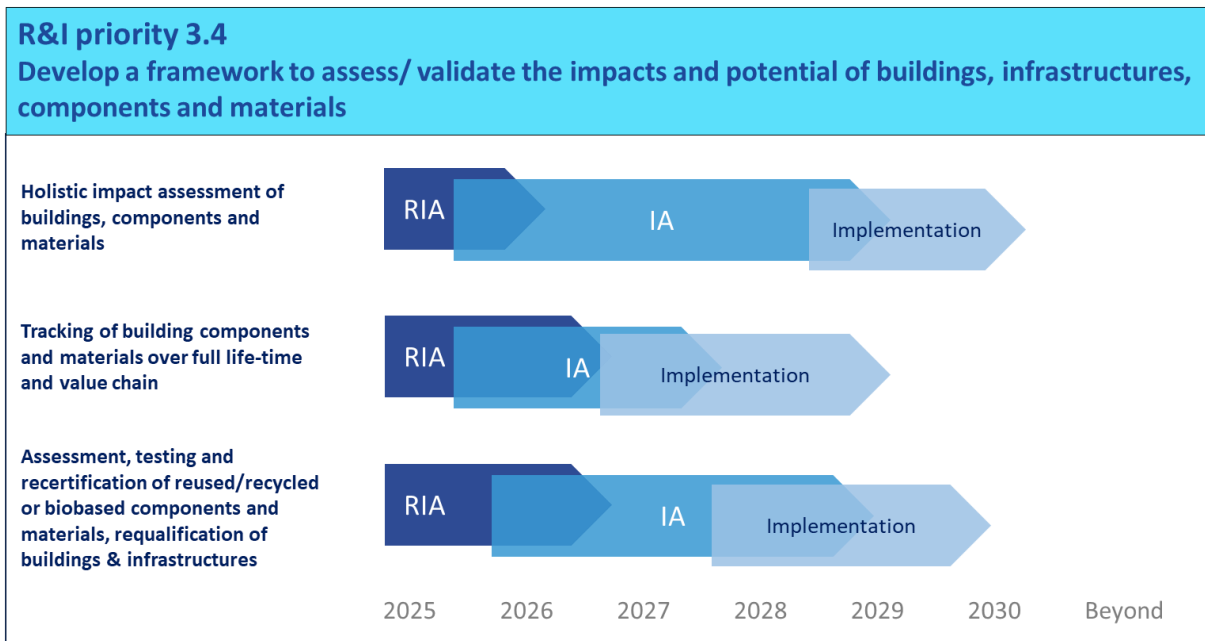


Figure 23 : Timeline of topics within priority 3.4

► *Holistic impact assessment of buildings, components, and materials*

The aim of this topic is to enable to design and compare products considering all their impacts, over their whole life cycle.

Its scope includes:

Develop a holistic assessment framework encompassing life cycle costs, environmental impacts (including life cycle global warming potential (GWP) and carbon storage) and social impacts.	TRL 4 today	→	TRL 8/9 by 2030
Develop innovative tools which rely on BIM and Digital Twins data to validate and evaluate buildings' sustainability performance, through the use of the Level(s) framework.	TRL 4 today	→	TRL 8/9 by 2030
Develop design and assessment tools to model and monitor material flows within buildings, like it is done for energy performance.	TRL 4 today	→	TRL 8/9 by 2030

► *Tracking of building components and materials over full lifetime and value chain*

The aim of this topic is to the transparency in usage/operation of material/components and buildings.

Its scope includes:



Setup the framework and tools (e.g., data models, software, integration into BIM, use of Digital Twins) for Digital Material/product passport ¹⁷ with ability to track them from production to end of life.	TRL 5 today	→	TRL 8/9 by 2028
Demonstrate a harmonised framework for the roll out of the EU digital building logbook , including clear data ownership and privacy rules, and building upon the existing initiatives and data sharing platforms	TRL 6 today	→	TRL 8/9 by 2030
Design and test easier processes and tools for environmental product declarations , and set up a related EU data platform.	TRL 5 today	→	TRL 8/9 by 2028
Develop an EU platform for sharing data about fossil-free and emission-free construction machinery and equipment (e.g., availability, autonomy, power, cost, etc.).	TRL 5 today	→	TRL 8/9 by 2028

- ▶ *Assessment, testing and recertification of reused/recycled or biobased components and materials, requalification of buildings & infrastructures.*

The aim of this topic is to ensure the safety, sustainability, and performances in re-use of material/components and buildings.

Its scope includes:

Develop EU wide methodologies for the requalification/recertification of building elements , with transparent evaluation model and criteria for recycling quality (safety, sustainability, performances). Such methodologies should also include non-destructive testing methods to (quickly) requalify reused materials, products and components and how to link this information with digital product passports.	TRL 4 today	→	TRL 8/9 by 2030
Develop EU wide methodologies for fast-track qualification and model-based verification of bio-based materials and building elements .	TRL 4 today	→	TRL 8/9 by 2030

¹⁷ Building upon the pilot experience led with the battery passport (the new EU Battery Regulation making compulsory for electric vehicle batteries with a storage capacity above 2 kWh to have a passport from 2026).



Develop easy and accessible (possibly AI-supported) methods and tools to assess and validate the reusability and availability of building parts and materials, from building to city scale.

TRL 4
today



TRL 8/9
by 2030

Elaborate some common definition and metrics for building vacancy and underuse.

TRL 5
today



TRL 8/9
by 2029



6. Conclusions

The present Strategic Research and Innovation Agenda (SRIA) reflects a collective vision of the future R&I in the construction industry and the built environment, based on the expertise of key sector players within and outside the ECTP association.

This SRIA defined three overarching goals to be achieved by 2030 through European R&I activities in order to support the emergence of a sustainable, resilient, and inclusive built environment, delivered by a circular and competitive industry:

- **Objective 1** targets a resilient, decarbonised, adaptative and regenerative built environment,
- **Objective 2** deals with deploying an enriching, inclusive and health-improving built environment,
- **Objective 3** focusses on the competitiveness, digitalisation, and circularity of the construction value chain.

For each objective, a detailed R&I program is proposed, structured along 4 R&I priorities, as synthesised in the diagram below.

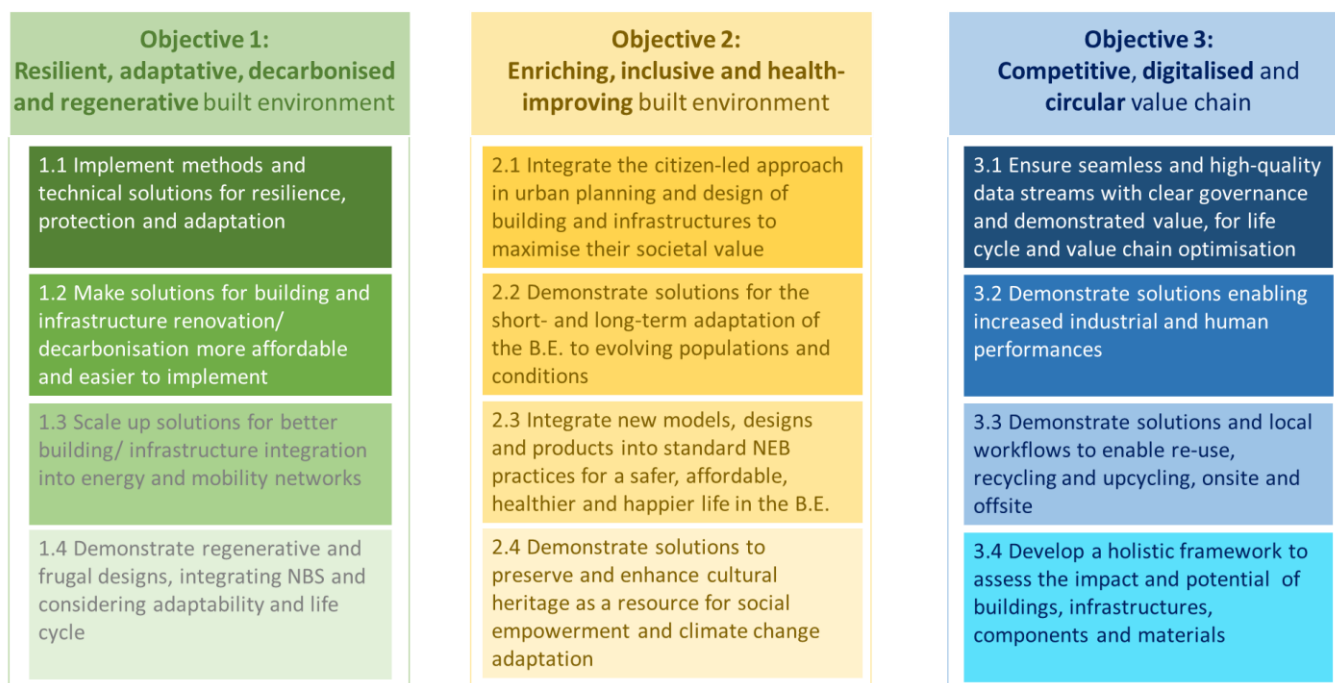


Figure 24 : Synthesis of R&I priorities per Objective 2030

As a result, 36 R&I topics overall are listed and described to foster innovative solutions from TRL4 to higher maturity levels, most of them aiming at reaching the market by 2030. For some topics that are strongly related to societal acceptance and adoption, the Societal Readiness Levels scale is used as well to complete the description.

A consultation phase was organised towards key associations of the sector in order to align and interface at best this SRIA with other industrial roadmaps and strategic research agendas at EU level.



We would like to thank the respondents from the following organisations, who contributed to improve the coverage of this SRIA and its interfacing with other R&I agendas:

- Interactions with representatives of **EMIRI** (*Energy Materials Industrial Research Initiative*) allowed for the alignment and complementarity with **the 2030 Agenda of the Advance Material Initiative** and the related upcoming European partnership,
- Interactions with **Housing Europe** enabled a cross-checking all R&I topics related to Objective 2 in terms of social housing considerations,
- Interactions with **ERTRAC** (*European Road Transport Research Advisory Council*), more specifically with representatives of their Urban Mobility Working Group, also belonging to **POLIS** (*network of cities and regions for transport innovation*) contributed to the alignment and complementarity with the **ERTRAC roadmap**, the agenda of the **2ZERO** (*Towards zero emission road transport*) **partnership** in which ERTRAC is involved, and the agenda of the **CCAM** (*connected cooperative and automated mobility*) **partnership** in which POLIS is involved,
- Interactions with representative of the **DUT** (*Driving Urban Transition Partnership*) ensured the complementary in topics between this SRIA and the '**Circular Urban Economies Transition Pathway**' of the DUT roadmap,
- Interactions with representatives of **BDTA** (*Building Digital Twin Association*) allowed for a thorough review of all R&I topics related to data and part of Objective 3,
- The feedback from **A.SPIRE** (*Association for Sustainable Process Industry through Resource and Energy Efficiency*) allowed to review and adjust the alignment and complementarity of this SRIA with the **Processes4Planet Partnership agenda**, in particular on the questions safety and performance of recycling processes, and efficiency of industrial symbiosis,
- The feedback from **FIEC** (*European Construction Industry Federation*) highlighted the criticality and emergency of addressing the objectives of resilience, sustainability and decarbonation.

We also thank all ECTP members who actively contributed to elaborating and reviewing this document.



Annex: maturity scales used

► *Technology Readiness Levels*

The table below recalls the TRL scale as formulated by the European Commission for the Horizon Europe programme.

Level	Definition
TRL1	Basic principles observed
TRL2	Technology concept formulated
TRL3	Experimental proof of concept
TRL4	Technology validated in lab
TRL5	Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL6	Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL7	system prototype demonstration in operational environment
TRL8	System complete and qualified
TRL9	Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)



► *Societal Readiness Levels*

The table below recalls the SRL scale as formulated by the [Denmark Innovation Fund](#).

Level	Definition
SRL1	identifying problem and identifying societal readiness
SRL2	Formulation of problem, proposed solution(s) and potential impact, expected societal readiness; identifying relevant stakeholders for the project.
SRL3	Initial testing of proposed solution(s) together with relevant stakeholders
SRL4	Problem validated through pilot testing in relevant environment to substantiate proposed impact and societal readiness
SRL5	Proposed solution(s) validated, now by relevant stakeholders in the area
SRL6	Solution(s) demonstrated in relevant environment and in co-operation with relevant stakeholders to gain initial feedback on potential impact
SRL7	Refinement of project and/or solution and, if needed, retesting in relevant environment with relevant stakeholders
SRL8	Proposed solution(s) as well as a plan for societal adaptation complete and qualified
SRL9	Actual project solution(s) proven in relevant environment

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