MATERIALS & SUSTAINABILITY
AN ECTP COMMITTEE FOR INNOVATIVE BUILT ENVIRONMENT

ECTP Materials and Sustainability Committee

Horizon Europe 2022-2027 POSITION PAPER

ECTP
INNOVATIVE BUILT ENVIRONMENT

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

Published in June 2022.

Table of content

List of acronyms

AI Artificial Intelligence

API Application Programming Interface

BIM Building Information Modelling

CDW Construction and Demolition Waste

ECTP European Construction, built environment and energy efficient building Technology Platform

EED Energy Efficiency Directive

EPBD Energy Performance of Buildings Directive

ETA European technical assessment

EU European Union

IAQ Indoor Air Quality

IEQ Indoor Environment Quality

IoT Internet of Things

LCA Life Cycle Analysis

LCC Life Cycle Cost

M&S Material and Sustainability

NOx Nitrogen Oxide

OECD Organisation for Economic Co-operation and Development

OITB Open Innovation Test Beds

R&I Research and Innovation

VOC Volatile Organic Compounds

1. Introduction

1.1. Overall context and challenges

According to the European Commission, buildings are responsible for approximately 40% of EU energy consumption and 36% of the energy-related greenhouse gas emissions. At present, about 35% of the EU's buildings are over 50 years old and more than 75% of the building stock is energy inefficient. With the current rate of renovation of around 1% of buildings each year, it would take a century to upgrade the building stock to modern and zero energy levels.

The energy inefficiency of the building stock is due to a number of shortcomings, including lack of maintenance and insufficient investment, defective construction, either through an inappropriate choice of materials or due to a lack of professional expertise, change of use, outdatedness of the building.

Research and innovation in the construction materials sector must tackle the following societal challenges to improve the situation and deploy energy-efficient and low-carbon solutions in the built environment:

- **Energy efficiency and decarbonisation**: The climate emergency calls for a deep change in the way materials are produced and assets are built. Enhanced traditional materials as well as new and bio-sourced materials can increase the resilience and sustainability of the built environment and minimise climate change impacts. This applies to a broad range of construction materials used in different applications such as buildings, cities, infrastructures, energy applications and possibly others.
- **Resource preservation and circular economy**: The OECD [1] estimates that the global consumption of resources will grow by up to 40% by 2040 and close to 90% by 2060[2]. Since most of the key raw materials needed by European industry are produced outside Europe, European industry experiences a rapidly increasing global competition when securing access. This context has been worsened by the COVID-19 pandemics and the Ukrainian war, which have caused disruptions in the global supply chain and led to shortages of certain critical products in Europe. Enhanced circularity and enhanced materials and practices will contribute to the reduction of the carbon footprint and the environmental impact generated by materials, but also will boost economic growth and reduce local dependencies on imported raw materials.
- **Industry transformation and digitalisation** (including Competitiveness & Health & Safety on construction site): European technology leadership should be preserved and leveraged by reinforcing and focusing R&I efforts through new approaches to get access to more performant, cost-competitive and sustainable advanced materials. The digitalisation of the construction sector at large is a deep trend, that offers many opportunities for operational improvements, safety of workers at the building site and sustainability. However, the

[1] https://www.oecd-ilibrary.org/environment/global-material-resources-outlook-to-2060_9789264307452-en

[2] (compared to 2017 values)

integration of the related technologies and related changes in work practices is not fully achieved. Furthermore, it is necessary to make up for the lack of skilled workforce to drive a true organizational transformation and digitalization.

- **Human health, user comfort and well-being**: Innovative and improved materials functionalities open new possibilities in the interaction of building materials with people and nature.
- **Demography**: Multi-functional/smart construction materials can support strategies for ageing at home by reducing the associated efforts and risks.
- **Evolving policy/ regulatory framework** providing constraints & opportunities (Construction Product Regulation, EED, EPBD, new Circular Economy Action Plan…)

The permanent advances in material sciences and engineering therefore offer new opportunities to support the performance and resilience of building and infrastructures (resource efficiency, CO_2 neutrality), the integration of renewable energy sources in the new and existing (including historic) built environment, as well as its comfort, health, safety and sustainability.

1.2. Scope and Approach

This Position Paper aims to give an overview of the research and innovation paths that the ECTP Committee on Materials and Sustainability (M&S) recommends by 2027 in order to tackle the above-mentioned challenges.

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

This position paper looks to:

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

1.3. High-level objectives formalised by the Materials and Sustainability committee

Considering the outlined challenges, the M&S Committee has identified five high-level objectives that are critical to overcome societal challenges and to ensure that the construction material sector will, in the long-term, secure its competitiveness and sustainability, namely:

- **Objective 1: Carbon footprint reduction and contribution to the energy transition**

- **Objective 2: Circular economy & sustainable resource management**
- **Objective 3: Safer and more efficient built environment and construction processes**
- **Objective 4: Well-being in the built environment**
- **Objective 5 (cross-cutting): Robust and fast innovation in construction industry**

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

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

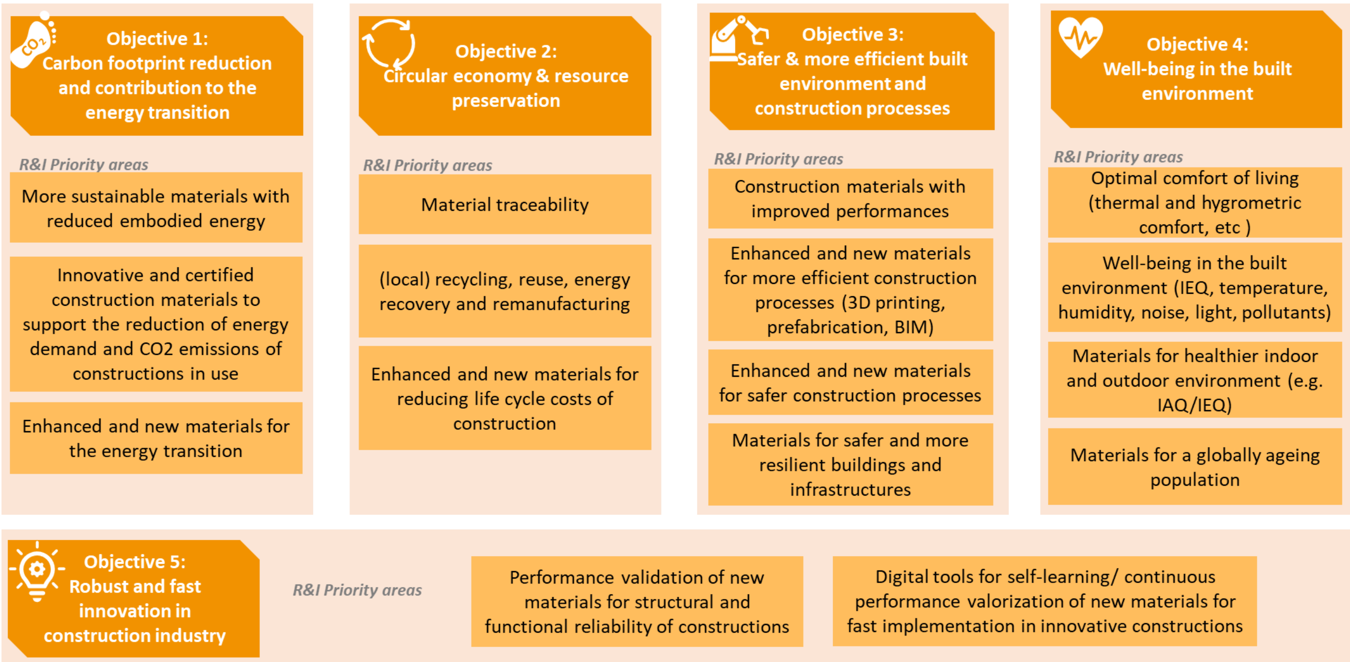

FIGURE 1: High-level objectives formalised by the Materials & Sustainability committee, and related priority areas for research and innovation.

2. Objective 1: Carbon footprint reduction and contribution to the energy transition

To support the construction sector in the carbon footprint reduction and to contribute to the energy transition, Research and Innovation in the construction material sector should focus on the following priority areas:

- Develop more sustainable materials with reduced embodied energy,
- Develop innovative and certified construction materials to support the reduction of energy demand and CO_2 emissions of constructions in use,
- Enhance and develop new materials to support and accelerate the energy transition, i.e. reducing operational energy use or increasing the share of renewables.

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

2.1. More sustainable materials with reduced embodied energy

Embodied energy is the sum of all the energy required to produce any goods, considered as if that energy was incorporated or 'embodied' in the product itself. The production of current construction materials requires high amounts of energy and, together with that, gives rise to significant CO_2 emissions. In fact, the total amount of embodied energy may account for 20% of the building's energy use and significantly more for new buildings with high energy performances. As an example, the production of cement is responsible for about 5% of global greenhouse gas emissions: about 1/3 from the energy used to power the production process and the rest from the CO_2 released during the chemical conversion process.[3]

Reducing embodied energy may therefore significantly reduce the overall environmental impact of the building. Consequently, the reduction of energy demand and emissions in the production of construction materials is of primary importance. This provides opportunities for innovative approaches such as:

- Reduction of CO_2 emissions of traditional construction materials by new routes of production and/or low energy demanding production technologies;
- Development of new materials with reduced CO_2 emissions compared with current materials for the same application (example bio or secondary based raw materials);
- Improvement of traditional materials and development of new materials to reduce material needs in buildings and infrastructures.

[3] https://www.breakthroughenergy.org/eu-policy-overview/buildings/low-carbon-building-materials

Such materials should also consider the current or forthcoming shortage of raw materials (e.g. sand, European wood) and secondary materials (e.g. fly ashes because of shut down of coal power stations), which will require using substitutes.

Research topics in this area include:

- Develop and test large 3D-printing solutions allowing for enhanced durability and low-embodied energy of the building material
- Develop smart coatings to reduce building energy consumption (e.g. for windows: automatic shading, noise and thermal insulation).
- Develop low-CO_2 construction materials (e.g. enhanced traditional materials or materials based on bio-mineralisation) with enhanced durability enabling construction lifetimes of 100+ years. Large-scale structure must be considered for the application of such materials
- Develop cost-efficient solutions for the calcination of clays
- Develop fluids for energy efficient concentrated solar thermal and heat exchanger for water heating
- Develop sustainable materials that can be reused many times without the need of reprocessing it to reduce embodied carbon
- Develop products with higher content of waste materials
- Develop and demonstrate predictable and energy efficient materials production processes (including additive manufacturing): prediction of the availability of the materials and of the quality and constancy of the final output
- Develop design processes with lighter materials solutions, characterised by improved insulation properties, and which avoid the use of heavy machinery during assembly
- Develop new design approaches with alternative locally sourced raw materials to reduce CO_2 emission
- Develop and demonstrate new design approach reducing quantities of materials for the same functional unit

2.2. Innovative and certified construction materials to support the reduction of energy demand and CO_2 emissions of constructions in use

Innovative materials are an important lever to reduce energy demand and CO_2 emissions of buildings in use, in particular to decrease the need for heating and cooling and for repair and maintenance.

Research topics in this area include:

- Develop and demonstrate innovative products maximizing energy efficiency in use and comfort
- Develop and optimise new materials and products with lower carbon footprint and with enhanced thermal resistance
- Develop low CO_2 construction materials with high insulation properties and enhanced circularity by allowing monolithic construction and full recycling at the end of life

- Develop lightweight, highly efficient insulation materials based on new aerogels production ways with less energy consumption and reduced grey energy
- Implement material passports for the building use phase to optimise maintenance and avoid unnecessary interventions
- Combine material databases with simulation tools to assess efficiency

2.3. Enhanced and new materials for the energy transition

Remaining within the goal of limiting global warming to 1.5°C maximum., as set forth in the Paris Agreement requires to significantly increase the share of renewable energies, such as of solar, wind- and geothermal power. The 2030 climate and energy framework targets at least 40% share for renewable energy by 2030. Research into construction materials can contribute and accelerate this transition.

Research topics in this area include:

- Analyse gaps in materials to meet the requirements for the energy transition and design, develop and deploy corresponding materials-related solutions, for instance:
    - new materials/solutions for energy production, storage and transport, adapting them if possible to the local context,
    - materials to overcome the current accumulation limits in hydrogen production electrolysers,
    - material solutions to increase the life-time of solar collectors and their performance
    -
- Develop advanced energy capture and harvesting solutions (e.g. thermoelectricity) integrable into construction materials and components

3. Objective 2: Circular economy & sustainable resource management

The European Commission adopted a new Circular Economy Action Plan in March 2020 to help European businesses and consumers making the transition to a stronger and more circular economy where pressure on natural resources is reduced. The new action plan announces initiatives along the entire life cycle of products. It targets how products are designed, promotes circular economy processes, encourages sustainable consumption, and aims to ensure that waste is prevented, and the resources used are kept in the EU economy for as long as possible. The ECTP aims to support the transition towards a more circular economy, in particular within the context of an increasing shortage of available resources for some primary raw materials used in construction.

Construction materials are produced in huge amounts (e.g. cement ~4 billion tons[4] and steel ~1.9 billion tons annually[5]) and mostly from non-renewable resources. Applications include buildings, transport- and energy infrastructures. Given the huge amounts of natural resources involved it is very important that an increasing effort is made to align construction material design, production, and end of life with circular economy principles. At construction level, innovation in resource efficiency needs to start at the design phase to reduce resource needs during the construction phase (optimization of material needs, use of recycled materials), maximize material durability during use phase, and to allow for optimum material recovery and use at the end of the construction's life.

To meet this objective of circular economy and sustainable resource management, it is proposed to organise the required M&S activities along three priority areas:

- Material traceability
- (local) recycling, reuse, and remanufacturing
- Enhanced and new materials for reducing life cycle costs of construction

They are detailed in the next sections.

3.1. Material traceability

Material traceability is critical to unlock the potential for enhanced recycling and reuse, and may be tackled via implementing digital technologies enabling to tag materials and/or construction parts and to store the data in (open-sourced) databanks.

Research topics in this area include:

[4] IEA (2021), Cement, IEA, Paris

[5] World Steel Association, December 2021 crude steel production

- Design innovative approaches integrating smart functionalities in the materials which can be easily identified through robust and cost-effective traceability solutions (sensors/imaging/marking) to enhance material circularity
- Develop material and product passports combined with open format data/BIM and labelling (QR, RFID) especially in the grave-to-cradle phase to close the loop. The labelling should be integrated on the material itself or in the different step of the production, with information about material composition, processing and properties in order to facilitate reuse & recycling.
- Develop fast tools to assess the stock of materials in buildings
- Develop a digital platform based on BIM and integrating blockchain and IoT solutions for enhanced traceability of the building materials and their reuse, ensuring data security
- Develop space scanning technologies for high-level assessment of material flows in the construction and disassembly phases

3.2. (local) recycling, reuse, and remanufacturing

Construction and demolition waste (CDW) accounts for more than a third of all waste generated in the EU (according to the European Commission). It contains a wide variety of materials such as concrete, bricks, wood, glass, metals and plastic, some with a high resource value, others which could be easily reprocessed into new products or materials. Technology for the separation and the recovery of construction and demolition waste is well established and readily accessible however the level of recycling and material recovery of construction and demolition waste varies greatly across the EU, ranging from less than 10% to over 90%.

Finding solutions to increase the circularity of materials would have a high impact on the sustainability of the construction value chain. Innovation is needed to:

- increase the use of secondary materials from recycling and enhance the refurbishing of the materials/products to reduce the dependency on raw materials, especially critical ones,
- create regional, resource-efficient material cycles in the construction sector without loss of quality in the building material to be used.

Research topics in this area include:

- Develop roadmaps to increase the use and quality of secondary raw materials and/ or local raw materials in the development of construction products to increase their sustainability
- Develop good metrics that combine environmental footprint and handprint[6] (impacts beyond the system boundary) in order to assess the level of circularity.
- Harmonize product standards across all materials to enable efficient and local reuse of products and materials
- Improve recycling for prefabricated products, including multi-layer components (deconstruction and separation at end of life).

[6] As footprint refers to the negative impacts, the term handprint is used to refer to positive impacts, i.e. positive changes to environmental and social impacts that we cause outside of our footprints.

- Establish local value chains for recycling and re-use of building materials to reduce transport and regionally structure the circular economy
- Develop platforms and open API to boost the market of recycled and secondary materials. In particular, develop and test national logistics platforms for recycled materials for certification needs, to verify local availability and guarantee the traceability.
- Develop and demonstrate advanced solutions for high-volume sorting of construction and demolition waste. In particular, the following solutions should be considered:
    - portable and modular solutions for on-site sorting of demolition materials and components, using advanced sensing and robotics
    - technologies to assess the quality of waste materials, before and after the separation process, at best in real time at the re-cycling process (XRF, spectroscopy (IR, Raman, Vis), hyperspectral, etc.)
    - robotics to enhance the tracing of material during the recycling phase
- Develop and implement recycling solutions that enable 100% recycling or reuse of construction and demolition waste
- Develop solutions for the enhancement of properties of finer fractions and of fine recycled concrete aggregates for a better use of recycled construction materials

3.3. Enhanced and new materials for reducing life cycle costs of construction

A key factor for maintaining and improving competitiveness of the European construction materials industry is to reduce life cycle costs. In particular, the development of enhanced and new materials contributing to increasing material efficiency and speed of construction, reducing operational and maintenance costs as well as harvesting energy is of major importance.

Research topics in this area include:

- Develop materials (e.g. lightweight materials) to support innovative circularity concepts in the built environment and the flexibility of spaces and uses, e.g. multi-use of spaces over the course of a day.
- Develop and prioritise low-maintenance durable materials to reduce lifecycle costs
- Develop 3D construction material solutions (processes, equipment, materials) to increase material efficiency and speed of construction
- Deploy and industrialise the manufacturing of composite and multi-material building blocks which combines active and passive functionalities for transparent and opaque components, addressing the whole life cycle (e.g. assembly, operation and decommissioning). Standardisation & certification processes shall be addressed.
- Develop LCC methodologies adapted for different build elements, and assess life cycle costs gains generated by using secondary materials
- Develop methods to predict the lifetime of materials and products at laboratory scale, reproducing failure mechanism, in order to propose solutions to increase the material lifetime
- Develop digital and scanning tools for reliable and accurate material audits before renovation or demolition, to enable selective demolition

4. Objective 3: Safer and more efficient built environment and construction processes

Upgraded and innovative industrialised construction processes will enable to reach the 2030 objective of 20% productivity increase, as stated in ECTP 2019 Strategic Research and Innovation Agenda. This gain will result from the integration and rationalisation of new materials, technologies, new designs and techniques in the manufacturing and construction processes that will trigger drastic cost reductions. To increase the efficiency of the construction processes but also the renovation of buildings and the demolition/deconstruction processes, the following four R&I priority areas are proposed:

- Construction materials with improved performances
- Enhanced and new materials for more efficient construction processes (3D printing, prefabrication, BIM)
- Enhanced and new materials for safer construction processes
- Materials for safer and more resilient buildings and infrastructures

They are detailed in the next sections.

4.1. Construction materials with improved performances

The European Commission estimates that 70% of product innovation across all industries is derived from new or improved materials. With approximately one-third of construction cost attributed to construction materials, the scope for applying advanced building materials is considerable.

Research topics in this area include:

- Develop additive manufacturing as a resource-efficient way to produce lighter construction materials with a higher strength/weight ratio
- Develop new material combination for multi-functional characteristics (structural foam concrete, fast curing, crack control...)
- Develop mineral-based materials for highly efficient insulation with improved fire resistance, load bearing and durability
- Develop lightweight bio-based materials which are durable and have improved strength
- Develop new materials for easier maintenance and repair actions
- Develop innovative materials with high compatibility with bricks, air and hydraulic lime for retrofitting purpose
- Demonstrate the durability of innovative materials and /or composites such as those with self-cleaning properties, hygienic properties, cool-roof properties

4.2. Enhanced and new materials for more efficient construction processes (3D printing, prefabrication, BIM)

Despite increasing relevance of new trends such as 3D printing and off-site construction, currently, less than 50% of new builds are designed and built modular first mainly due to lack of standardization[7]. Productivity in construction could receive a substantial boost from standardization, modularization, additive manufacturing (3D-printing) and prefabrication.

Research topics in this area include:

- Develop 3D printing construction material solutions (processes, equipment, materials) to increase material, material efficiency and speed of construction. For instance, develop multi-material and multi-function 3D-Printing solutions for integration into the structure, for thermal and acoustic insulation, for electrical and piping works, etc.
- Develop lighter structural systems, compatible with existing elements
- Develop and demonstrate low-cost and reliable quality control procedures for prefabricated and 3D printed materials and products (to be used both off and on-site), including certification procedures
- Develop embedded sensors and IoT solutions for lifelong monitoring of prefabricated solutions
- Scale-up the logistic chain of prefabricated element and on-site 3D printer
- Develop the next-generation digital construction machines and construction robots for off-site and prefabricated construction processes, as well as new equipment adapted to handling large, prefabricated components in space-constrained construction site

4.3. Enhanced and new materials for safer construction processes

The number of health implications and accidents in the building industry is high due to a harsh working environment: heavy weights, repetitive movements, noise, dust, vibrations, work in altitude etc. It will be more and more difficult in the future to attract well-trained employees, and the shortage of blue-collar construction workers is imminent and should be tackled in the near future. Therefore, there is an urgent need to improve the working conditions related to the production and construction of buildings and structures.

Research topics in this area include:

- Develop lightweight materials coupled with advanced digital models, design approaches, sensing and robotic technologies for efficient and safe on-site operations

[7] Construction Disruption Radar – November 2021

- Develop materials to enable the automatization of construction, maintenance and deconstruction works thanks to technologies such as robotics (e.g. modular elements for easy robotic installation, adhesives for easy machine separation of composite layers,)
- Develop solutions to replace conventional materials containing hazardous constituents with safe/ hazardous-free materials
- Define strategies to increase prefabrication and reduce the needs for on-site processes and improve safety.

4.4. Materials for safer and more resilient buildings and infrastructures

Enhanced and innovative material shall also strive to minimise danger or risk of harm related to natural hazards, fire, structural ageing, radiation, etc., to improve structural functionality and durability, in particular for application and renovation interventions. This includes designs, materials and solutions that contribute to better respond to man-made and natural threats such as floods, soil drying out, other climate-driven events and earthquakes; as well as those allowing more efficient and cost-effective surveillance, restoration and conservation of buildings and infrastructures.

Research topics in this area include:

- Develop and improve material models for numerical simulation of internal processes (such as hygro-thermal). Such models combined with real environmental data (e.g. weather, traffic, vibrations) can replace costly sensors used for monitoring of the material state.
- Develop and demonstrate new materials and structural elements with improved properties (vibration damping, heat and moisture resistance, resilience to flood, etc.)
- Develop self-sensing materials (e.g. cement, wood, ceramic tiles, bricks, etc.) with low-costs and high integrability in real applications
- Develop and demonstrate the benefits and use of self-healing materials and products (e.g. self-healing concrete)
- Use monitoring and adaptive systems such as lightweight materials to increase strength and durability of buildings (i.e. react autonomously to external disturbances)
- Develop sensors for real-time monitoring of material degradation phenomena, corrosion and ageing of construction infrastructures

5. Objective 4: Well-being in the built environment

In developed societies, people spend on average over 90% of their time indoors and most of the remaining time in urban built environments. Therefore, indoor and urban outdoor environment quality is a major impact factor for the health and comfort of people, which influence productivity and wellbeing.

Materials functionalities can be developed to open new possibilities in the interaction of building materials with citizens and nature. Developments in new technologies (e.g. nano-technology, self-functional additives) offer new opportunities for traditional and new building materials. The further development and industrial uptake of new functionalities, such as surface active materials (e.g. photocatalytic, antibacterial, antiviral surfaces), self-healing capacities, sensor technologies, thermal, sealing etc. can play a key role for well-being in the built environment.

On the other hand, some of the chemicals used in building materials may carry potential health risks (sick building syndrome and associated respiratory, neurotoxic and dermatologic symptoms). The European Chemicals Strategy for Sustainability[8] aims to better protect citizens and the environment, and boost innovation for safe and sustainable chemicals, including in construction. To minimize the impact of hazardous building material components on indoor air quality and protect the health of manufacturing and maintenance workers, the sector shall develop safe materials for substituting potentially dangerous ones when possible.

To address these challenges, research and innovation actions can be broken-down into three priority areas:

- Well-being in the built environment and optimal comfort of living
- Materials for healthier indoor and outdoor environment (e.g. IAQ/IEQ)
- Materials for a globally ageing population

They are detailed in the next sections.

5.1. Well-being in the built environment and optimal comfort of living

Well-being in the built environment relies on well-balanced comfort parameters, which need to be actively or passively controlled. Smart materials could enhance the controllability if they ensure tuneable properties (adsorption, transport) and lower emissions, and are able to provide healthier and more comfortable indoor environment; with adaptable behaviour like storage (moisture/ thermal/ energy) or cleaning abilities and enabling passive control.

[8] Chemicals Strategy for Sustainability, Towards a Toxic-Free Environment, European Commission, October 2020.

The built environment must integrate all knowledge and innovations that can contribute to improve the indoor and outdoor environment quality, and the responsiveness of buildings and infrastructures in view of increased comfort and customised services. The solutions should account for the thermal and hygrometric comfort levels in the indoor environment, crucial key-factors for comfort and health, as well as for the consequences of climate change (warming in particular) and address summer comfort and heat islands issues. The intelligent use of construction materials in combination with adapted design will help to mitigate this risk and ensure an optimal comfort of living in an energy efficient way.

Research topics in this area include:

- Develop and enhance the use of materials (e.g. biomaterials) with thermal and moisture buffering and develop rules for their application
- Develop and demonstrate materials and surface treatments with antimicrobial, antifouling, anti-slipping properties and self-cleaning capabilities.
- Develop materials with entirely new functionality (rain-absorbing, noise absorbing, temperature management, UV ageing)
- Develop advanced solution materials for glazed facades providing optimal multi-domain comfort, including coatings for energy efficient windows with capacity to filter UV light and possibility to change colour in function of the light
- Develop and demonstrate phase-change materials for improved comfort of living: control temperature and reduce energy consumption
- Develop smart materials that react to environmental conditions and improve user comfort (eg. sensors to be integrated in the textiles or windows to monitor the indoor comfort)
- Develop solutions and materials to minimize urban sprawl and occupied space (e.g. vertical densification)
- Develop and demonstrate biomimetic material for buildings that are better integrated in their environment (applications such as surface texturing)
- Develop and demonstrate large-scale application of cool covering materials and durable solutions to reduce heat islands
- Demonstrate and scale-up solutions to include vegetalisation
- Develop assessment methods to evaluate the comfort (eg. when walking) and predict the durability of anti-slippery solutions
- Promote the creation of standards and legislation regarding the data control parameters to be considered for the well-being such as relative humidity, temperature, energy and water consumption, energy balance, air quality, noise, brightness, humidity, bacteria and viruses present in the air, polluting substances, radiation, etc. …
- Promote digitalisation and sensorization (IoT and installation of sensors) of habitable environments (indoor and outdoor, including façade components) for data acquisition with the aim of monitoring, controlling and managing the comfort, health, safety and quality of space.

5.2. Materials for healthier indoor and outdoor environment

The provision of healthy and hygienic structures to live and work is a crucially important issue for the construction sector in the coming years. The quality of indoor and outdoor environments has a significant bearing on human health and performance in any setting (residential, industrial, commercial, public or healthcare). Much of this relates to the quality of air and ventilation particularly in offices and residential buildings (Indoor Air Quality).

Research topics in this area include:

- Develop and demonstrate low costs smart materials (sensing materials, adaptable materials, etc.) for better IEQ. Develop metrics to assess the well-being performance of the materials and products.
- Develop membranes and filters with antimicrobial, antifungal properties for water and air filtration
- Develop and demonstrate materials and active surfaces to capture pollutants, e.g. with new technologies able to degrade and capture air contaminants (VOC, NOx…), photocatalytic functionalization
- Develop solutions to replace conventional materials containing hazardous constituents (e.g. additives, VOC, plasticiser, biocides, fire retardants, microplastics, etc.), with safe/ hazardous substance-free materials to reduce health issues

5.3. Materials for a globally ageing population

Multi-functional/smart construction materials can be a support for the globally ageing population, seeking a feeling of safety & security, comfort and self-esteem especially when ageing in place.

European projects have well documented the building requirements for a globally ageing population and have shown promising results by e.g. developing materials for sight-impaired, internal or external anti-slip paving and easy to clean surfaces. However, efficiency, durability and costs still need to be improved.

Research topics in this area include:

- Develop and utilise materials with safe surfaces easy to clean and maintain (e.g. Antimicrobial and self/cleaning surfaces and floorings, durable in the time for indoor applications)
- Develop intelligent, adaptable material-based solutions for independent and safe living of fragile people
- Promote the development and use of building materials intended to prevent and mitigate the consequences of accidents of elderly people and/or people with reduced mobility. For instance, coatings and anti-slip floorings for ageing population to avoid falling especially under humid conditions

6. Objective 5: Robust and fast innovation in construction industry

While the socio-economic drivers related to energy transition and climate change, circular economy, competitiveness, and well-being, led to the four former objectives for sustainability in construction materials, this fifth objective is transversal to the previous ones and focusses on generic approaches enabling to evaluate, ensure and valorise performance of the (new) material related innovations developed for sustainable constructions.

Indeed, a performance gap of CO_2 emissions between design and actual performance is observed. To close this gap, regulatory and certification processes have a role to play. While the current Construction Products Regulation aims to ensure that all products arriving in the European Union (EU) are safe to use and install, regulations and building codes often limit the introduction of new technologies that could support the reduction of energy demand and embodied carbon reductions. The European technical assessment (ETA) is an alternative for construction products not covered by a harmonised standard. The procedure is established in the construction products regulation and offers a way for manufacturers to draw up the declaration of performance and affix the CE marking. In this procedure it is however not allowed to include continuous performance valorisation.

By focusing on performance rather than prescription, regulation, certification and standardisation processes could ensure that all construction projects contribute to a decarbonised and sustainable built environment with innovative materials and products.

This objective is therefore broken down into two priority areas:

- Performance validation of new materials for structural and functional reliability of constructions
- Digital tools for self-learning/ continuous performance valorisation of new materials for fast implementation in innovative constructions

They are detailed in the next sections.

6.1 Performance validation of new materials for structural and functional reliability of constructions

New construction materials for improved sustainability often include secondary raw materials, new combinations of materials, new processing techniques, etc., which lead to an initially unknown performance. Immediate performance and mechanical properties can be tested with regular testing methods, but the performance in time is less easy to predict in advance. Often standard accelerated ageing test methods, monitoring tools and modelling are valid for well-known materials and have been validated over the years through experience in practice. In other words, validated and modelled relations are established between the actual performance test, monitoring and model parameters (performance indicators). For new materials, this knowledge cannot just be transposed without understanding the underlying mechanisms (chemistry, physics…) leading to the performance (evolution) with time. To reduce cost, investment risk and accelerate the time to market, the European

Commission has invested more than €250 million to support the development of innovative and smart industries through open innovation test beds which facilitate common access to physical facilities, capabilities and services for organisations working across a range of technologies. Actions in this direction should continue.

Research topics in this area include:

- Develop a procedure for rapid deployment of new products by "design by virtual/numerical testing" as alternative to existing Eurocode 0 method. This can be implemented in the new generation of Eurocodes.
- Develop machine-readable certifications (CE, EPD, ...), legislation and building codes. As a starting point, AI (natural language processing) can be used to convert existing data to machine-readable format.
- Provide recommendations at regulatory and contractual levels to make the tendering process more flexible and allow new products to reach the market.
- Provide recommendations to streamline the actual certification and standardisation processes of innovative products to facilitate their market uptake. Comprehensive guidance is needed to support both technical and standardisation experts to provide harmonised technical specifications on the one hand and to translate the standardisation requests in a way that meets both EU and national policy objectives on the other hand.
- Investigate how to test performance of already built in materials with minimal invasive methods and relate the results for new material with modelling and artificial testing, and provide recommendations on how to improve the ETA procedure
- Develop Open Innovation Test Beds (OITB) for construction materials to promote certified quality and performances
- Combine advanced materials modelling and artificial ageing to improve the lifetime and durability prognosis for materials. This approach should produce more robust assessment in comparison with real scale natural ageing.
- Create a database on durability of traditional and innovative materials with protocols and guidelines to be shared and used everywhere in Europe

6.2. Digital tools for self-learning/ continuous performance valorisation of new materials for fast implementation in innovative constructions

Achieving actual uptake by the construction industry of innovative and sustainable construction materials and concepts asks for recognition of current building practices. The acceptance and successful uptake in practice of innovations in constructions often requires adaption of existing design, built, maintenance, use and end-of-life practices and as such these should be an integral part of innovation. In addition, there is a strong need to renew the full educational and professional pathway within the construction sector, trying to up-skill the existing work force.

Research topics in this area include:

- Develop digital methods for fast assessment and efficient use of recycled materials
- Develop new sensors and sensing technologies (e.g. quantum sensors) for performance monitoring. For instance, quantum sensors have an outstanding performance and accuracy near to the limits of detectability.
- Provide learning programme/guidance for material auditors
- PhD and Training Networks to support and promote innovative competences in the field of materials and sustainability in construction

7. Conclusion

7.1. Timing of the different R&I priorities

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

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

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

Objective 1: Carbon footprint reduction and contribution to the energy transition	**2023-2025**	**2025-2027**	**Beyond 2027**
More sustainable materials with reduced embodied energy	between 50 and 75% of votes	<25% of votes	<25% of votes
Innovative and certified construction materials to support the reduction of energy demand and CO2 emissions of constructions in use	between 50 and 75% of votes	between 25 and 50% of votes	<25% of votes
Enhanced and new materials for the energy transition	between 50 and 75% of votes	<25% of votes	<25% of votes

Objective 2: Circular economy & sustainable resource management	**2023-2025**	**2025-2027**	**Beyond 2027**
Material traceability	<25% of votes	between 50 and 75% of votes	<25% of votes
(local) recycling, reuse, energy recovery and remanufacturing	between 50 and 75% of votes	between 25 and 50% of votes	<25% of votes
Enhanced and new materials for reducing life cycle costs of construction	between 50 and 75% of votes	<25% of votes	<25% of votes

Objective 3: Safer and more efficient built environment and construction processes	**2023-2025**	**2025-2027**	**Beyond 2027**
Construction materials with improved performances	between 50 and 75% of votes	between 25 and 50% of votes	<25% of votes
Enhanced and new materials for more efficient construction processes (3D printing, prefabrication, BIM)	between 50 and 75% of votes	between 25 and 50% of votes	<25% of votes
Enhanced and new materials for safer construction processes	<25% of votes	between 50 and 75% of votes	<25% of votes
Materials for safer and more resilient buildings and infrastructures	between 50 and 75% of votes	between 25 and 50% of votes	<25% of votes

Objective 4: Well-being in the built environment	**2023-2025**	**2025-2027**	**Beyond 2027**
Well-being in the built environment and optimal comfort of living	between 50 and 75% of votes	<25% of votes	<25% of votes
Materials for healthier indoor and outdoor environment	between 25 and 50% of votes	between 25 and 50% of votes	<25% of votes
Materials for a globally ageing population	<25% of votes	<25% of votes	between 50 and 75% of votes

Objective 5: Robust and fast innovation in construction industry	**2023-2025**	**2025-2027**	**Beyond 2027**
Performance validation of new materials for structural and functional reliability of constructions	between 50 and 75% of votes	between 25 and 50% of votes	<25% of votes
Digital tools for self-learning/ continuous performance valorisation of new materials for fast implementation in innovative constructions	<25% of votes	between 50 and 75% of votes	between 25 and 50% of votes

7.2. Synergies between the Materials & Sustainability position papers and other ECTP committees

The next diagram synthesises the main topics that are addressed by several ECTP Committees and their respective Position Papers. For the Materials and Sustainability Committee, the overlapping topics are:

- The resilience and climate mitigation with the Infrastructure & Mobility, the Heritage and Regeneration and the Built for Life committees: M&S focuses on innovative materials with reduced embodied energy and supporting the reduction of energy demand and CO_2 emissions in use.
- The questions of inclusiveness and adaptation and the indoor environment quality with the Built for Life committee. For M&S the focus is on smart materials able to provide healthier, safer and more comfortable indoor environment, with adaptable behaviour like storage (moisture/ thermal/ energy) or self-cleaning functionalities and enabling passive control.
- The circularity of the processes and resources with the Infrastructure & Mobility, the Heritage and Regeneration, the Energy Efficient Buildings and the Digital Built Environment committees, with a specific focus on material traceability and the use of secondary and local materials to reduce the dependency of critical raw materials.
- More efficient construction, renovation, and deconstruction processes: M&S focuses on advanced construction materials with improved performances (resistance, strength, energy efficiency, carbon capture etc.) and on materials for an increased productivity and safer construction, renovation, and deconstruction processes (e.g. lightweight materials, materials enabling more automatization and support from robotics).

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

FIGURE 2 SYNERGIES BETWEEN ECTP COMMITTEES

7.3. Link with other initiatives

This Position Paper is aligned with the other key roadmaps related to EU construction materials sector:

- Materials Manifesto Roadmap
- EUMAT Strategic Research Agenda