MATERIALS SUSTAINABILITY
AN ECTP COMMITTEE

ECTP Materials & Sustainability

HORIZON EUROPE (2021-2027) POSITION PAPER

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1. INTRODUCTION

The current EU RTD Framework Program, Horizon 2020, will run until the end of 2020. Discussions and preparations for Horizon Europe, the next Framework Program, covering the period 2021 – 2027 are on-going.

As part of the European Construction, built environment and energy efficient building Technology Platform ECTP, it is the Material and Sustainability (M&S) Committee's goal to develop a common Vision and Strategic Research Agenda for all construction material stakeholders. This common view will serve as a starting point for future networking and R&D cooperation that will develop solutions helping to overcome societal challenges and to ensure that the construction material sector will, in the long-term, secure its competitiveness and sustainability.

A first version of this Position Paper was developed and published in September 2017 with the purpose to provide insight into current and upcoming construction material related key-challenges that we strongly believe deserve to be addressed within Horizon Europe.

Purpose of this update is to make a link between the construction material related key-challenges as identified in the previous version of this Position Paper and the Sustainable Development Goals (UN SDGs) published by the United Nations as part of their 2030 Ambitions.

2. SCOPE AND APPROACH

A dedicated working group was set up for the development and update of this paper. The group was formed from experts coming from industry and academia to ensure that a broad range of competences and experiences was covered.

The first step of the working group towards developing this roadmap was to identify key societal challenges which clearly need to be addressed over the next decade and where innovations in construction materials will make a difference. Climate change, circular economy and resource preservation, competitiveness and economic viability, health and safety, and user comfort are the five key missions that were identified as the main drivers for action.

Chapter 3 of this position paper is on priority topics for Horizon Europe and is consequently centred on these 5 areas identified. It also addresses an additional mission dedicated to evaluate, to ensure and to valorise the performance of the new material related innovations for sustainable constructions. An implementation calendar for the identified priority topics is suggested in chapter 4 on “Implementation”.

The scope of ECTP is continuously evolving, and this is reflected by the scope of this position paper which is no longer limited to buildings: material-related missions for districts and cities are also addressed, as well as for infrastructures and solutions for the energy transitions and other applications.

3. PRIORITY TOPICS FOR HORIZON EUROPE (2021-2027)

3.1 Climate change

A holistic view along the whole life cycle of construction materials and along the whole value chain needs to be adopted to minimize climate change related impacts. This applies to a broad range of construction materials used in different applications such as buildings, cities, infrastructures, energy applications and possibly others.

3.1.1 Reducing embodied energy in construction materials

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. 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 (glass, steel, bituminous binders, cement, composite materials, ceramics and others) 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.

3.1.2 Contribution of construction materials to the reduction of energy demand and CO_2 emissions of constructions in use

Energy demand and CO_2 emissions of buildings in use

Decreasing the need for heating and cooling and for repair and maintenance are important levers to reduce energy demand and CO_2 emissions of buildings in use. This can be achieved by engaging into R&D on:

- New high thermal insulation materials with enhanced durability to be considered in the design phase to ensure superior operational performance along an extended period of life. These materials should be applicable in new buildings and in retrofitting.
- Energy capture and storage materials and systems with superior energy storage capacity, and an excellent performance maintain over a large number of charging-discharging cycles (for day-night or seasonal applications). Charging-discharging kinetics including the ability to dispatch should comply with the needs (cooling/heating) of the building to support the implementation of nearly zero-energy houses and plus energy houses.
- New durability enhanced materials for passive cooling applications such as cool envelope solutions suitable for new and existing, even historical, buildings, and able to mitigate global warming through CO_2-eq emission offset.
- New materials and products (coatings) for the external surface of the building envelope with low solar reflection index ("cool materials") and for heating, including water.

Fig. 3.1: Lightweight concrete used as high-insulation material with enhanced durability to reduce energy demand and CO_2 emissions of buildings in use.
Source: HeidelbergCement AG / Steffen Fuchs

Performance gap of CO_2 emissions between (building) design and actual performance

In a recent detailed study of 50 non-residential projects and 76 homes, Innovate UK illustrated the huge gap between building design and actual building performance. For non-residential buildings, the carbon emissions were on average 3.8 times higher than designed reaching up to 4.6 times in some cases[1]. As buildings account for 40% of the total energy consumption and are responsible for 36% of greenhouse gas emissions in Europe it is of highest importance to close this gap. Approaches for achieving this include:

- Certifying materials performance in-use, including increasing demands for environmental products declaration;
- New characterization tools able to simulate, and to better predict, building operation behaviour in dynamic boundary conditions, (e.g. with varying temperature, humidity content, solar radiation, etc.);
- Implementing supervision and predictive maintenance - using telemetry and analytics of the energy consumption and the buildings' use to optimize maintenance and performance through the product's and asset's lifecycle;
- Improving current or developing new construction processes to reduce quality default risks or material degradation.

Transport related energy demand and CO_2 emissions

Innovative materials are also an important lever to enable transport related solutions with reduced energy demand and CO_2 emissions. Such solutions are enabled by materials:

- Permitting improved energy storage;
- Decreasing of energy consumption by reducing the interaction between pavement and vehicles while keeping safety;
- Achieving the required performances with less volume and/or weight than state-of-the-art materials.

Innovative processes from fabrication (e.g. prefabrication) to delivery on site can contribute to reduce transportation needs and associated impacts.

3.1.3 Materials for the energy transition

Remaining within the goal of limiting global warming to less than 2°C as set forth in the Paris Agreement requires to significantly increase the share of renewable energies, such as of solar, wind- and geothermal power. Research into construction materials can contribute and accelerate this transition by:

- Enabling the construction of new power plants for harvesting renewable energy in harsh environments (e.g. marine/off-shore environment);
- Increasing the efficiency of new power and industrial plants;
- Improving local energy storage;

[1] *The Future for Construction Product Manufacturing*, Construction Products Association, October 2016, p.14

- Improving and/or enabling energy transport and distribution on different scale;
- Developing advanced energy capture and harvesting solutions integrable into construction materials and components;
- Increasing the life-time of solar collectors and their performance.

Fig. 3.2:Powercrete®, a high performance heat conducting concrete used for HV and UHV underground cabling to improve energy transport and distribution
Source: HeidelbergCement AG / Steffen Fuchs

The proposed RDI topics on climate change will contribute to the following SDGs and targets:

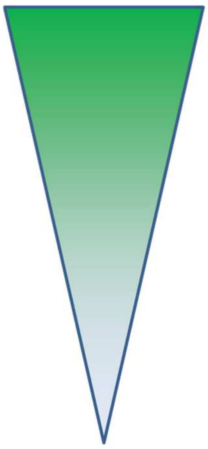
7.2	Increased share of renewable energy
9.1	Reliable, sustainable and resilient infrastructure
12.2	Efficient use of natural resources
13.a	Climate protection

3.2 Circular economy and resource preservation

The European Commission adopted an ambitious new Circular Economy Package in December 2015 to help European businesses and consumers making the transition to a stronger and more circular economy where resources are used in a more sustainable way. The European Construction Technology Platform aims to support the transition towards a more circular economy including resource preservation.

3.2.1 Waste hierarchy and circular economy

J. Cramer[1] recently proposed a useful classification encompassing all possible strategies to favour circular economy. Her 10-R levels shown below suggest a hierarchy from the most 'circular' (= refusing) to the least 'circular' (= energy recovering) strategy.



highly circular practice

- Refuse
- Reduce
- Renew
- Re-use
- Repair
- Refurbish
- Remanufacture
- Re-purpose
- Recycle
- Recovery (energy)

less circular practice

Fig. 3.3: Circularity levels according to J. Cramer[2]

3.2.2 Material research for enhancing circularity and resource preservation

Construction materials are produced in huge amounts (e.g. cement ~4 billion tons and steel ~1.5 billion tons annually) 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. **Material traceability** is an important challenge 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.

However, R&D continues to remain important at all levels of the waste hierarchy to ensure making our economy more circular. This includes – depending on the material - R&D addressing circular economy principles, e.g.:

- Expanding the scope of recycling from mostly structural materials to other functional categories including insulating-, finishing materials, electrical and plumbing elements;
- Making use of abundant sources of residues, side products, waste and possibly pollutants originating from other industries (e.g. processing wastes, extraction and

[2] J. Cramer: MRA Congres 2016 – De Grenzelose Stad

mining wastes, ashes, sewages, municipal solid wastes and others) as secondary raw materials;

- Making use of carbon sink materials (e.g. vegetal fibres)
- Materials involving the use of industrial CO_2 through carbonation or other chemical processes;
- Materials and construction processes for an easy repair and maintenance of the buildings, extending its durability;
- Recycling building materials into a new generation of the same material without loss of functionality (as opposed to traditional processes);
- Handling concrete and demolition waste with mobile, simple and affordable equipment that allow performing local recycling (short circuit);
- Solutions enabling to re-use pieces/products obtained through partial demolition of end-of-life constructions;
- Design of modular systems to enhance the re-use, remanufacture or re-purpose of specific components and pieces.

3.2.3 Materials for reducing life cycle costs of constructions

A key factor for maintaining and improving competitiveness of the European construction materials industry is to reduce life cycle costs. This can be achieved via engaging R&D on:

- Understanding property-performance correlations;
- Developing new materials and components with a “recyclable-by-design” perspective;
- Extending the concept of smart building to all construction types for efficiency operation and management and improved safety and convenience;
- Developing non-destructive sensors to monitor the health status of the protective layers;
- Modelling service life behaviour and improving materials’ durability without compromising costs and environmental impact;
- Simulation tools to support reducing life cycle costs.

The development of materials contributing to reducing operational and maintenance costs as well as energy harvesting is a major topic for all the construction industry.

The proposed RDI topics on circular economy and resource preservation will contribute to the following SDGs and targets:

7.2	Increased share of renewable energy
8.4	Improved resource efficiency
9.2	Sustainable industrialization
12.2	Efficient use of natural resources
12.4	Environmentally sound management of wastes
12.5	Reduced waste generation
13.a	Climate protection
15.1	Sustainable use of ecosystems
15.5	Reduced degradation of ecosystems

3.3 Competitiveness and economic viability

Contrary to many other sectors, the construction industry has not undergone any major disruptive changes during the past 30 years. However, innovation in construction is a powerful lever to secure the sector's competitiveness of tomorrow, and this can be achieved by:

3.3.1 Improving the efficiency of construction materials

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. Key R&D topics include the development of:

- Advances on traditional materials and existing characteristics (optimization, recyclability, extended lifetime…);
- New material combinations and multi-functional characteristics (structural foamcrete, fast curing time, crack control…);
- Innovative materials with entirely new functionality (rain-absorbing, noise absorbing, temperature management, self-monitoring…);
- Innovative and smart materials adapted for new construction processes (e.g. additive manufacturing / 3D printing);
- Simulation tools to support material developments (e.g. Building Information Modelling BIM).

3.3.2 Maximizing the efficiency of the construction process

Productivity in construction could receive a substantial boost from standardization, modularization and prefabrication, in areas such as:

- Improving image of standardization and potential for individualization;
- Handling large prefabricated components in space-constrained construction sites;

- (Semi-) automated construction equipment;
- Developing new construction technologies (like additive printing / 3D-printing) enabled also by advanced materials;
- Developing materials and concepts for reversible buildings;
- Managing digital technologies and big data along the value chain (including BIM) including as build modelling and maintenance and materials traceability.

Reducing the costs of developing and applying building materials is another important lever to improve the efficiency of the construction process.

Fig. 3.4: Materials for additive manufacturing in construction
Source: TECNALIA-IAAC

The proposed RDI topics on competitiveness and economic viability will contribute to the following SDGs and targets:

8.1	Sustainable economic growth
8.2	Higher levels of productivity
8.4	Improved resource efficiency
9.2	Sustainable industrialization
12.4	Environmentally sound management of wastes
12.5	Reduced waste generation through prevention, reduction, recycling and reuse

3.4 Health & safety

Innovative and improved 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, shelf-functional additives) offer new opportunities for traditional and new building materials. The development and industrial uptake of new functionalities, such as surface active materials, self-healing capacities, sensor technologies, thermal, sealing etc. are still in their infancy. Their further development can play a key role in the issues of health and safety but also improved sustainability and environmental aspects (outdoor and indoor environment).

3.4.1 Healthy and hygienic structures

The provision of **healthy and hygienic structures** to live and work is a crucially important issue for the construction sector in the coming years. Much of this relates to the quality of the breathing air and ventilation particularly in offices and residential buildings. Key R&D topics include:

- The development of functionalized coatings incorporating shelf-properties, e.g. self-cleaning or anti-microbiological action with low emission of harmful substances, using for instance new, natural or recycled materials;
- Research on the information structure of chemical and environmental properties of building materials;
- Tools enabling the traceability of standardized identities of building products, using for instance BIM-technologies for low cost and safe digital information transfer;
- Predictive simulation tools of the indoor air quality building upon VOC emissions databases obtained in real environments;
- Pollutant specific sensing systems including new monitoring approaches and sensing standardisation;
- Assessment of health and aquatic toxicological impacts of pollutants: single, mixtures and secondary generated;
- Improved adaptable HVAC systems in respect of health and comfort aspects and with reduced maintenance need

3.4.2 Construction material needs for an ageing population

Multi-functional/smart construction materials can be a support for the **globally aging population**, which more and more desires to live in their houses. Examples can be materials for sight-impaired, internal or external anti-slip paving and easy to clean surfaces. Specific projects in this area are showing promising results. Extensive research and development has been done on photo catalytic self-cleaning but with varying and usually low success rates in terms of efficiency, durability and cost. Further research is needed on:

- Efficient, effective and durable multi-functional material based solutions that improve safety, reduce costs, do not release dangerous substances, and with properties that do not degrade over time;
- Development of tests at laboratory, component and field scale, also involving test persons, to predict functional stability including appropriate measurement technologies - id est. sensors/sensor arrays;
- The holistic approach combining the new solutions and the measurement technologies.

3.4.3 Safety in building and infrastructures

Minimal danger or risk of harm related to natural hazards, seismic events, fire, structural ageing, radiation, etc. should be considered as an important task of future materials, in particular for application and refurbishment interventions in seismic areas as in the central part of Italy and to mitigate the effect of natural hazards. In order to improve structural functionality and durability, new trends include:

- Self-healing materials to heal damage and corrosion;
- Self-sensing materials to sense moisture ingress, mechanical damage and strain;
- Materials with active response to environmental inputs;
- Multifunctional materials (e.g. multifunctional textile with embedded miniaturized sensor) for structural reinforcement and structural and environmental monitoring purposes;
- The development of systems and materials for efficient protection, e.g. coatings, from fire for all types of structures and infrastructures;
- Protection against radiations from multiple sources (X-ray examinations or cellular phone networks) in sensible facilities such as hospitals.

3.4.4 Safety of workers at the building site

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. Furthermore, it will be more and more difficult in the future to attract well- trained employees. Therefore, there is an urgent need to improve the working conditions related to the production and construction of buildings and structures. The research needed includes:

- Material design and optimization, industrialization and developments in repair and maintenance methods;
- Advanced materials with high strength/stiffness to weight ratio compared with conventional materials, enabling reduction in the risk of accidents, injury or death during on-site installation;
- Improved prefabrication techniques, modular design and materials for higher performance of joining technologies.

Practical guidelines for installers will be helpful to reduce their risk at the workplace and to enable them to correctly install construction materials. This will contribute to improve building performances.

The proposed RDI topics on health & safety will contribute to the following SDGs and targets:

3.9	Reduced illness from hazardous chemicals and contamination
8.5	Decent work conditions
9.2	Sustainable industrialization
10.2	Inclusion of all, irrespectively of age and disability
11.3	Inclusive and sustainable urbanization

3.5 User comfort

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 situation of people, which influences productivity and wellbeing. The following missions were identified:

Fig. 3.5: Passive house part of the Richard-von-Weizsäcker-School in Öhringen with occurrence of discomfort. The school was monitored as case study in the EU project CETIEB(www.cetieb.eu)
Source: V. Stegmaier, Landratsamt Hohenlohekreis

3.5.1 Optimal comfort of living

Due to climate change, there is an increasing risk of overheating in summer periods in indoor and urban outdoor environments. 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. Thermal and hygric comfort levels in the indoor environment are crucial key-factors for comfort and health (e.g. mould).

Fig. 3.6: Full mineral high efficient thermal insulation plaster
Source: quick-mix Gruppe GmbH & Co. KG

There is a need to develop new thermal storage and moisture buffering materials in conjunction with innovative ambient conditioning systems based on new technologies able to stabilize the desired comfort parameters. These material-based solutions have the possibility to control inherently the indoor environment (e.g. thermal comfort, relative humidity, energy storage and provision, and self-cleaning capacity) with reduced costs due to less HVAC installation needs. Special environments and needs like in museums and cultural heritage should be taken into account. In addition to end users comfort, also "well-being" of objects, collections and surfaces is of interest, including reconciliation of "comfort" between human beings and such objects. Smart designed envelop materials in combination with adapted nature based solutions could mitigate heat island effects and discomfort due to air pollution in urban areas.

3.5.2 Well-being in the built environment

Well-being in the built environment bases on well-balanced comfort parameters. These need to be actively or passively controlled. Smart materials could enhance the controllability if they ensure tuneable properties (adsorption, transport), 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. While some manufacturers have introduced dynamically changing properties of material (for example glass changing their light transfer spectrum) the domain of controllable properties is quite unexplored, or quite hidden in the research labs of big material or panel manufacturers. The question of measuring flux of any kind (thermal, humidity, air, chemicals), controlling the transfer properties, adsorption properties of smart materials is an open question which may be driven in the near future by M2M revolution. Also, active noise control has been explored and combination with tuned noise adsorption can be envisioned (tuned damping material).

Fig. 3.7: Tartu Mart Reinik Gymnasium's football stadium building intended to improve sporting conditions at the gymnasium
Source: OSIRYS demo building (https://osirysproject.eu/) / Tartu municipality

3.5.3 User experience

Human behaviour and perception has an important influence on indoor environment quality (IEQ) and comfort. Therefore, the user and his experience should be in focus of this mission. A special regard should be dedicated to the subjective human IEQ perception comparing with the real IEQ measured. There is a need of reliable and diffuse sensing systems to assess comfort factors (thermo-hygrometric comfort, illumination and noise) as well as performance of smart materials and generate parameters to be used in intelligent control systems. This includes new monitoring approaches, according to different perspectives and standardisation of sensor technologies in conjunction with improved adaptable HVAC systems in respect of health and comfort aspects and with reduced maintenance needs. Development in the Smart Home sector should be taken into account. In a more disruptive line, advanced materials and construction processes increasing the flexibility for buildings reconfiguration is also a trend. Innovative solutions will have the potential to penetrate competitive markets such as Europe, Asia and the US.

Fig. 3.8: Demonstrator based on a modifiable envelope construction system to generate multiple and non-predetermined self-supporting shapes; developed in the EC funded project HyperMembraneDEMO.

Source: Eurecat

The proposed RDI topics on user comfort will contribute to the following SDGs and targets:

3.9 Reduced illness from hazardous chemicals and contamination

9.1 Reliable, sustainable and resilient infrastructure

9.2 Sustainable industrialization

11.3 Inclusive and sustainable urbanization

3.6 Enabling robust and fast innovation in construction

While the socio-economic drivers related to climate change, circular economy, health and safety, competitiveness and user comfort form five missions to channel the (sub)roadmaps for sustainability in construction materials, this sixth mission is focusing on generic approaches enabling to evaluate, ensure and valorise performance of the (new) material related innovations developed for sustainable constructions.

3.6.1 Robust innovation in constructions

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 aging 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 [e.g., Provis & van Deventer, 2014[3]]. Key R&D topics in this area are:

- Standardisation of methodology developments resulting in uniformly applicable characterization approaches for new materials to enable comparison;
- New accelerated test methods, monitoring tools and models for performance and service life prediction;
- Digital twins: Coupled experimental and numerical verification of material behaviour (including environmental interactions) to supplement traditional experiments with

[3] Provis, J., van Deventer, J (eds). 2014. Alkali Activated Materials. State-of-the-Art Report. RILEM TC 224-AAM. Springer, Netherlands, 388 p.

numerical simulation to achieve higher reliability of interpolated and extrapolated results and faster and cheaper implementation of new materials.

Accelerated ageing

Information achieved by standard accelerated aging tests is strongly material dependent and not easy to compare with real aging processes due to the mostly global evaluation methods. There is a need to develop fast and easy to use evaluation methods on a multi scale level with new microscopic techniques. This would speed up the understanding of material related processes and the possibility to predict real aging and performance processes.

Field exposure sites, living labs and mock-ups

Despite the fact that exposure sites and mock-ups are more long-time assessment methods are on the other hand the only evaluation methods reflecting the real environment in which new materials are to be used. There is need to determine procedures how to set the field exposure sites and mock-ups in order to reflect real environment, to compare rival solutions with the same real conditions, and to characterize different parameters based on which a fast laboratory evaluation method can be developed. The second challenge is to develop a suitable scale up factor for demonstration of new materials' functionality in real buildings.

Monitoring pilots

Ubiquitous sensing is developing very fast. Therefore, new monitoring techniques with a variety of different cost-effective sensors are available and could be used to evaluate in depth material behaviour in real environments.

Fig. 3.9: Experimental platform located at the French National Institute of Solar Energy (INES) near Chambery / France. The experimental platform is used for testing novel materials and systems, e.g. by the EU funded HOMESKIN project (https://homeskin.net/) in their development of thinner insulation systems and by other EU-funded projects
Source: INES Platform

Performance and service life modelling

Advanced testing and analysis methods in conjunction with advanced monitoring will give the possibility to generate multi scale models and perform simulation of new and established materials to understand in depth performance and behaviour.

3.6.2 Fast innovation in constructions

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.

This includes taking into account demands and boundary conditions (e.g. economic) of all parties involved including end-users. A systematic approach, including integration of design, material and environmental and social life cycle assessment (LCA, SLCA) via extensions of BIM models, is necessary to ensure successful valorisation of innovations in the built environment. Dedicated developments in system engineering applied to specific innovations, demonstrators and pilots are needed to set successful examples for each new development in Materials and Sustainability.

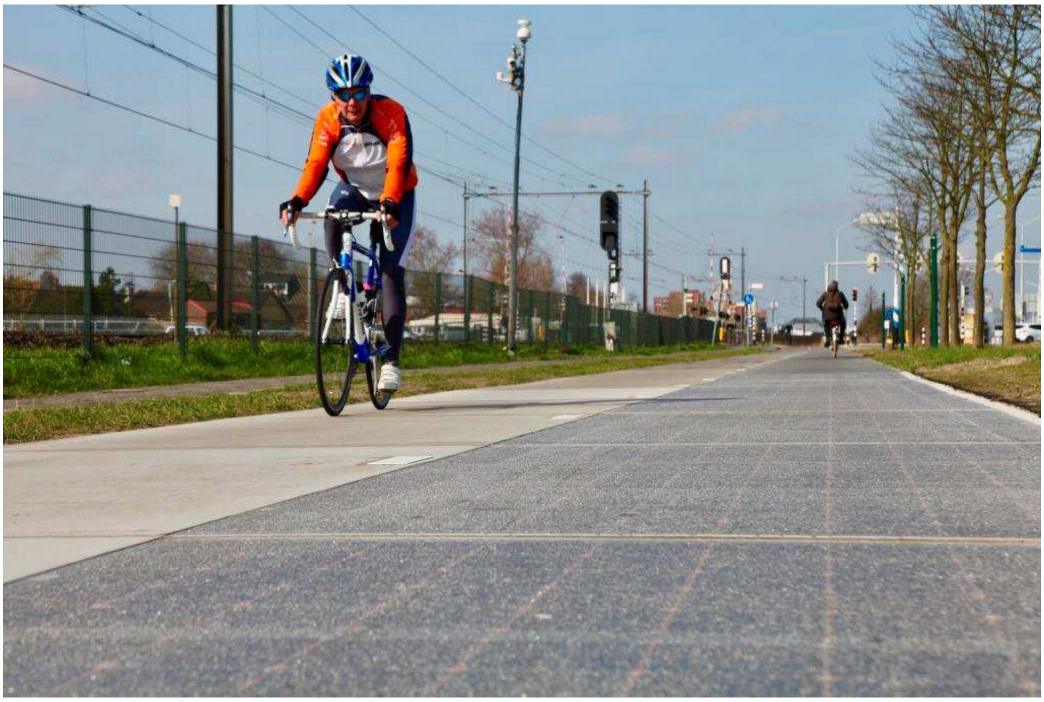


Fig. 3.10: Solar Road converting sunlight into electricity at Krommenie / The Netherlands
Source: Solaroad www.solaroad.nl

4. IMPLEMENTATION

The proposed implementation calendar shown in Table 4.1 targets – in a very efficient way – to provide material related answers to the key societal challenges identified and discussed in this position paper. The related timeline is the result of intense discussions amongst the working group members bringing in a broad range of competences and experiences and also considers the current TRL levels of the related technologies. It goes without saying that the timeline builds on previous roadmaps, in particular on the multi-annual roadmap for the contractual PPP under Horizon 2020 "Energy-Efficient Buildings" and that it clearly reflects the Commissions' previous and on-going efforts in funding a significant number of successful projects under the current EU RTD Framework Program Horizon 2020.

Table 4.1: Proposed implementation calender

Section	**Topics**	**Horizon Europe Topic**		
		early	**mid-term**	**later stage**
		2021 - 2022	2023 - 2025	2026 - 2027
3.1 Climate Change				
	Embodied energy in construction materials			**x**
	Contribution of construction materials to the reduction of energy demand and CO_2 emissions of constructions in use			
	- Energy demand and CO_2 emissions of buildings in use		**x**	
	- Performance gap of CO_2 emissions between (building) design and actual performance		**x**	
	- Transport related energy demand and CO_2 emissions			**x**
	Materials for the energy transition	**x**		
3.2 Circular economy and resource preservation				
	Material traceability	**x**		
	Recycling, re-use, remanufacture and other		**x**	
	Materials for reducing life cycle costs of constructions			**x**
3.3 Competitiveness and economic viability				
	Improving the performance of construction materials		**x**	
	Maximizing the efficiency of the construction process	**x**		
3.4 Health & Safety				
	Healthy and hygienic structures	**x**		
	Construction materials for an ageing population			**x**
	Safety in building and infrastructures		**x**	

	Safety of workers at the building site	**x**		
3.5 User comfort				
	Optimal comfort of living	**x**		
	Well-being in the built environment			**x**
	User experience		**x**	
3.6 Enabling robust and fast innovation in construction industry				
	Performance validation of new materials for structural and functional reliability of constructions			
	- Accelerated ageing	**x**		
	- Field exposure sites, living labs and mock-ups	**x**		
	- Monitoring pilots		**x**	
	- Performance and service life modelling		**x**	
	Performance valorization of new materials for fast implementation in innovative constructions			**x**

5. ANNEX

Mapping relevant H2020 calls and related projects was an important step when developing the implementation timeline for construction material related projects that will help addressing societal key challenges within Horizon Europe. The mapping is shown in Table 5.1.

Table 5.1: Mapping of previous H2020 calls and projects relating to construction / construction materials

Section	Topics	Call Reference	EeB PPP Project	Website
3.1 Climate Change				
	Embodied energy in construction materials	**H2020-MSCA-RISE-2014**	1) SUPERCONCRETE	http://www.superconcrete-h2020.unisa.it/
		H2020-MSCA-ITN-2015	1) TERRE	http://www.terre-etn.com/
	Contribution of construction materials to the reduction of energy demand and CO_2 emissions of constructions in use	**NMPB-17-2016**	1) NewSOL	http://cordis.europa.eu/project/rcn/207604_en.html
	- Energy demand and CO_2 emissions of buildings in use - Performance gap of CO_2 emissions between (building)	**EeB-01-2016**	1) GELCLAD	https://www.gelclad.eu/
			2) INNOVIP	http://innovip-h2020.eu/
			3) WALL-ACE	https://www.wall-ace.eu/

	design and actual performance		4) EENSULATE	http://www.eensulate.eu/
		EE-02-2015	1) ZERO-PLUS	http://www.zeroplus.org/
			2) InDeWaG	http://indewag.eu/
			3) CHESS-SETUP	https://www.chess-setup.net/
		EeB-05-2017	1) RenoZEB	https://renozeb.eu/
			2) HEART	https://heartproject.eu/
			3) REZBUILD	https://rezbuildproject.eu/
			4) ReCO2ST	https://reco2st.eu/
		EeB-07-2015	1) HIT2GAP	http://www.hit2gap.eu/
			2) MOEEBIUS	http://www.moeebius.eu/
			3) QUANTUM	https://www.quantum-project.eu/news/
			4) TOPAs	https://www.topas-eeb.eu/
	- Transport related energy demand and CO_2 emissions			
	Materials for the energy transition	**LCE-17-2017**	1) GEOFIT	https://geofit-project.eu/
3.2 Circular economy and resource preservation				
	Solutions favouring resource preservation	**EeB-04-2016**	1) GREEN Instruct	http://www.greeninstruct.eu/
			2) InnoWEE	http://innowee.eu/
			3) RE4	http://www.re4.eu/
			4) VEEP	http://www.veep-project.eu/
		H2020-WASTE-2014	5) FISSAC	http://fissacproject.eu/es/
			6) HISER	http://www.hiserproject.eu/
			7) BAMB	https://www.bamb2020.eu
		H2020-SPIRE-2016	8) Rehap	http://www.rehap.eu/
3.3 Competitiveness and economic viability				
	Improving the performance of construction materials	**NMBP-06-17**	1) ReSHEALience	
		NMP-19-2015	1) LORCENIS	https://www.sintef.no/projectweb/lorcenis

		NMBP-35-2017	1) INNOVACONCRETE	
	Maximizing the efficiency of the construction process	**EeB-03-2014**	1) Built2SPEC	http://built2spec-project.eu/
			2) INSITER	
		H2020-ICT-2016-1	3) HEPHAESTUS	http://www.hephaestus-project.eu/
3.4 Health & Safety				
	Healthy and hygienic structures			
	Construction materials for an ageing population	**FP7-SME**	1) SLIPSAFE	http://slipsafe.org/
	Safety in building and infrastructures			
	Safety of workers at the building site	**EE-14-2016-2017**	1) Construye2020_Plus	http://construye2020plus.eu/en/home/
			2) BIMEET	https://www.vtt.fi/sites/bimeet
			3) BIMcert	https://energybimcert.eu/
			4) CEN-CE	https://www.cen-ce.eu/
			5) Fit-to-nZEB	http://www.fit-to-nzeb.com/
			6) Net-UBIEP	http://www.net-ubiep.eu/
			7) NEWCOM	https://www.newcomtraining.com/index.php?id=30
			8) PRO-Heritage	https://www.pro-heritage.eu/
			9) CraftEdu	https://www.craftedu.eu/
			10) TRAINEE	http://www.trainee-mk.eu/en/
3.5 User comfort				
	Optimal comfort of living	**H2020-SCC-2016-2017**	1) Nature4cities	https://www.nature4cities.eu/
		EE-04-2016-2017	1) LowUP	http://lowup-h2020.eu/
	Well-being in the built environment			
	User experience	**EE-07-2016-2017**	1) enCOMPASS	http://www.encompass-project.eu/
			2) eTEACHER	http://www.eteacher-project.eu/
			3) BENEFFICE	http://www.beneffice.eu/
			4) FEEdBACk	https://feedback-project.eu/

			5) InBetween	http://www.inbetween-project.eu/
			6) MOBISTYLE	https://www.mobistyle-project.eu/en/mobistyle/Pages/default.aspx
			7) Eco-Bot	http://eco-bot.eu/
			8) UtilitEE	https://www.utilitee.eu/
		EE-06-2016-2017	1) ASSIST	https://www.assist2gether.eu/
			2) CLEAR 2.0	https://www.clear2-project.eu/
			3) ECO2	http://eco2project.eu/
			4) SAVES2	https://saves.unioncloud.org/
			5) SCORE	https://www.score-h2020.eu/
			6) STEP-IN	https://www.step-in-project.eu/
3.6 Enabling robust and fast innovation in construction industry				
	Performance validation of new materials for structural and functional reliability of constructions	**NMBP-06-2017**	1) DACOMAT	https://www.sintef.no/projectweb/dacomat/
			2) EnDurCrete	http://www.endurcrete.eu/
			3) ReSHEALience	https://uhdc.eu/
	- Accelerated ageing			
	- Field exposure sites, living labs and mock-ups			
	- Monitoring pilots			
	- Performance and service life modelling			
	Performance valorisation of new materials for fast implementation in innovative constructions	**EeB-01-2014**	1) BERTIM	http://www.bertim.eu/index.php?lang=en
			2) ECO-BINDER	http://www.ecobinder-project.eu/en/
			3) HOMESKIN	https://homeskin.net/
			4) ISOBIO	http://isobioproject.com/
		EeB-02-2014	1) BRESAER	http://www.bresaer.eu/
			2) E2VENT	http://www.e2vent.eu/