The high-tech building industry in support of the EU energy, climate and sustainability objectives

Towards a generalised European Low-Carbon & Resilient Built Environment

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ECTP FP9 POSITION PAPER

[Version Draft #2 – 18 May 2018]

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This document has been developed by ECTP (European Construction, built environment and energy efficient buildings Technology Platform), in particular with the support of Christian Artelt (HeidelbergCement), Antoine Aslanides (EDF), Javier Bonilla (Acciona), Paul Cartuyvels (Bouygues), Emmanuel Forest (Bouygues), Isabel Rodriguez-Maribona (Tecnalia), Juan Perez (Tecnalia), Miguel Segarra (Dragados) and Alain Zarli (CSTB).

This development has also been supported by Olaf Adan (TNO), Ilari Aho (Uponor), Ignacio Calvo (Acciona), Juan Elizaga (Ferrovial), Henk Miedema (TNO), Rita Moura (PTPC), Laura Tordera (Ferrovial), Johan Vyncke (ECCREDI) and Donato Zangani (RINA Consulting).

Published in May 2018

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1. INTRODUCTION

We shape our buildings and, afterwards, our buildings shape us.

WINSTON CHURCHILL

Always design a thing by considering it in its next larger context: a chair in a room, a room in a house, a house in its environment, an environment in a city plan.

ELIEL SAARINEN

The ECTP (*European Construction, built environment and energy efficient building Technology Platform*), along with one of its main developed instruments in the field of energy efficiency, the EeB cPPP (*Energy-efficient Building contractual Public-Private Partnership*) has as main mission the development and implementation of new research, development and innovation strategies (RDI) to improve the competitiveness of the EU Construction industry, meet societal needs and take up environmental challenges through an Innovative Built Environment. As the leading European membership organization promoting and influencing the future of the Built Environment in Europe and beyond, the ECTP has nurtured and grown over the last 13 years a European common vision and Strategic Research Agenda for the Construction and Built Environment stakeholders, in the fields of energy-efficient buildings, transport infrastructures, cultural heritage, materials and components, as well as active aging in the Built environment and design for all, with a RDI developed in numerous and various European projects over FP7 and H2020.

At a time of brainstorming what is to be the future RDI over the next 10 years, the common views and objectives developed in the scope of ECTP have to 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 industrial sector will, in the long-term, secure its competitiveness and sustainability, whilst the built environment (both buildings and infrastructures) will provide secure, safe and smart living places for all citizens in Europe. As such, the renewed ECTP moto is:

"Making Europe the most comfortable place in the world"

Thanks to user-oriented innovations in the built environment, to the use of digital applications, citizens will be able to participate in the design and day-to-day management of their housing and work environment, and easily commute thanks to high-level service infrastructures. Big data based infrastructure management and smart networks will make life easier and safer for each citizen. In Europe, everyone, from the young to the elderly, can move every day from a comfortable housing to a comfortable working place or entertainment facility, benefiting from a comfortable and healthy well managed urban or rural area, which includes most modern construction technologies and materials as well as preserved cultural heritage.

This Position Paper is consequently developed with the purpose to provide insight into those current and upcoming construction related key-challenges that we strongly believe deserve to be addressed within the upcoming Framework Programme #9 (FP9). The Construction and Built Environment sector includes all man-made surroundings that provide the setting for any human activity: buildings, man-made landscapes, infrastructures and networks supporting various services (transport, energy, pipelines…). The ECTP vision is focused on:

- "**Building for Well-Being**", i.e. creating and managing a user-centric, safe, healthy, adaptable and resilient Built Environment (buildings and infrastructures) based on a social responsible circular economy, fully respecting Europe's values and cultural heritage; and
- "**Transforming our Built Environment related Business**", i.e. transforming the challenges for erecting and operating an energy and resource efficient built environment into business and wealth opportunities that create new and high skilled employment through new value propositions along the entire life cycle stages (designing, producing, operating, renovating…).

The ECTP and associated EeB cPPP are already currently delivering a new impetus in what should be the future European research and innovation policy agendas for the Construction and Built environment sector - based on research and innovation actions, with ambitious greenhouse gas reduction and renewable energy targets by 2050. Leveraging on more than 10 years of research and delivery, the intention is clearly to generate a snow-ball effect leading to innovations with broader outreach and impact, both towards construction actors and stakeholders (including consideration of innovation integration in processes and organising the future professional training of white and blue collars), as well as hitting the end-users (citizens) in terms of increased awareness, co-creation and user experience. The ECTP in particular intends to foster the creation of strategic and long-term public-private partnership(s) supporting European, national, regional and local policies related to energy, environment, mobility, active ageing, the digital agenda, the industry 4.0, smart cities and other urban issues (specifically districts) – aiming at targeting key societal challenges such as ageing population or environmental degradation and climate change, leading to a widening of the concept.

Note: this ECTP FP9 Position paper ships along with dedicated FP9 position papers in relationships with the ECTP Committees (namely *Energy-Efficient Buildings*, *Infrastructures and Mobility*, *Heritage and Regeneration* and *Materials and Sustainability*).

2. The ECTP manifesto

2.1 Vision

By 2040, the construction sector will be a service-oriented business. The User-centric approach will offer flexible and connected spaces, inclusive cities with a high quality of life for all citizens. The 100% BIM approach will guarantee low intrusive work sites lasting 50% less than in 2020 while turning buildings into banks of materials that are 100% reusable or recyclable. Infrastructure will interact with citizens and feature embed self-healing capabilities. Most of urban areas will be carbon neutral and produce on site at least 25% up to 50% of their energy needs from renewable sources. The construction sector will continue providing 10% of total EU-local jobs, supporting EU-identities[1] thanks to its 99% share of SME companies, while representing by far the most integrative industrial sector regarding society.

2.2 Solutions

Innovative business-models delivering value over long life time will be developed to crowd-in private investors, without whom EU's huge infrastructure regeneration and building refurbishment needs in Europe can't be addressed. Technologies will reduce investors' risk while providing construction companies with innovative solutions: (i) Digitalization for mass-customization and industrial efficiency, from design to end-of-life (ex. resource-efficient recyclable pre-fabricated modules, 3D printed construction products) (ii) Real-time assistance & monitoring, improving quality of work (ex. augmented reality to assist workers, better execution in a safer environment) and reducing environmental impacts (ex. advanced operation and maintenance, life-time operation being by far the most impactful phase) (iii) New materials & processes for sustainability, circular economy and nature-based solutions (e.g. Multi-functional materials encapsulating active compounds for improved ageing properties, resource-efficient cement using mineral waste materials like sediments, bio-based high performance insulation material).

2.3 Key assets

The European Union has by far the most sustainable and energy efficient building stock worldwide, with a much lower average energy consumption than in other part of the world (e.g. 32% and 57% less in residential and commercial buildings compared to the US). Because of long-lasting buildings & monuments, EU construction stakeholders are used to innovate while preserving cultural heritage. EU regulation is stimulating innovation further, as is done through the EPBD Directive. The construction sector is representing 8,6% of EU's total GDP in 2016[2], with 40% of EU contractors in the worldwide top-30 ranking[3]. Even if close to 90% of Chinese companies' business is still taking place within China, these companies are now looking to expand globally, starting with making tremendous investments in R&D. Embracing the diversity of actors and challenges while integrating innovations quickly enough to face a fierce global competition requires an EU-level coordination. Since 2013, the contractual Public-Private Partnership instrument has proven to be powerful in coordinating Research & Innovation efforts for the construction sector. Building up on this success and considering the importance of the construction sector for the EU economy, the European Construction Technology Platform (ECTP) is strongly supporting its post-2020 reinforcement.

[1] The EU-identities characterise what makes Europe unique – in the sense that Europe has a long history, is managing diversity in regions and cultures, is integrating people from all over the world, and is proud of its historical and cultural heritage…

[2] FIEC. Key Figures Activity 2016. Construction in Europe

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

2.4 Added-value for Europe

Around 5% of European workers are employed in the construction sector, representing close to 18 million jobs. 1% growth in the construction turn-over immediately creates 200,000 new local jobs in Europe. A large part of the new jobs will relate to future-oriented competencies and skills, namely environment, digitalization or performance monitoring. History shows that construction has been the primary engine for social integration of vulnerable population in Europe. Reducing construction footprint contributes to better quality of life especially in urban areas, lowering the overall cost related to health issues arising from air quality issues. Since 1990, the construction sector has positively contributed to CO_2 reduction in Europe, achieving 34% emissions reduction, well above the overall 2020 energy-climate target. In addition, it is estimated that digitalization will drive an overall 240% efficiency gain in the sector.

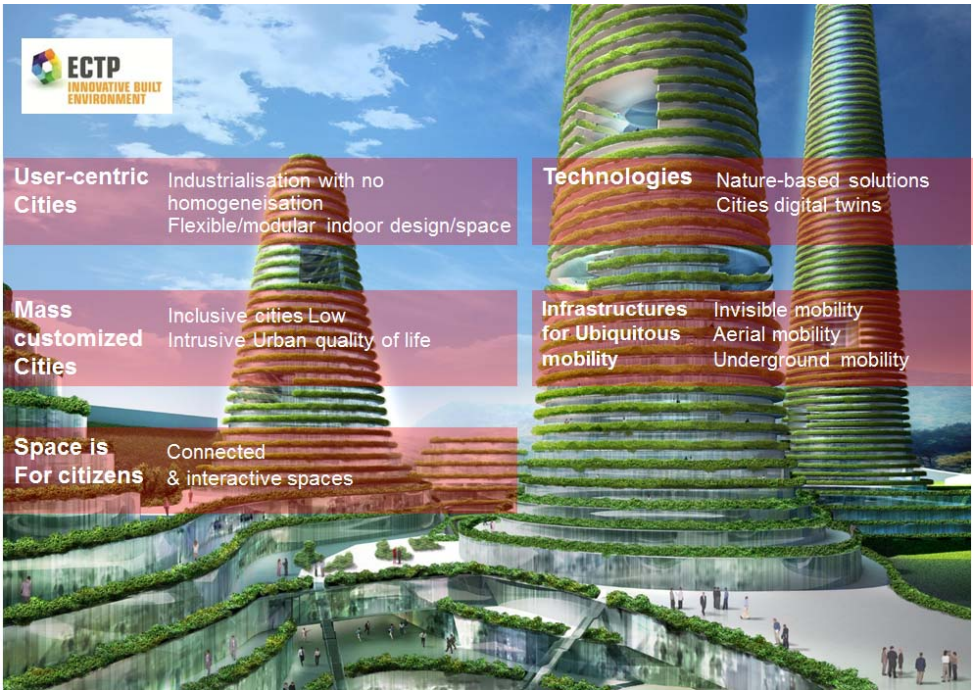


Figure 2: the ECTP vision towards 100 carbon-neutral cities in Europe - 2020-2030.

3. CONTEXT AND AMBITION

The ECTP is taking care of the Built environment as a whole: this encompasses any type of buildings (including office buildings and housing), and infrastructures (again, this could be transport infrastructures as well as types of networks for energy, water, etc.). It also considers the complete life-cycle of buildings and infrastructures, as exhibited in the figure below, including data- and information-empowered design, manufacturing (in relationships with the increasing development of industrialised process in the Construction sector), integration of innovative materials (including nanomaterials) both at manufacturing process and at construction sites, 3D manufacturing and robots/cobots on construction sites, ICT-enhanced operations and management of the built environment (including historic buildings, infrastructures components and districts), and up to decommissioning and recycling.

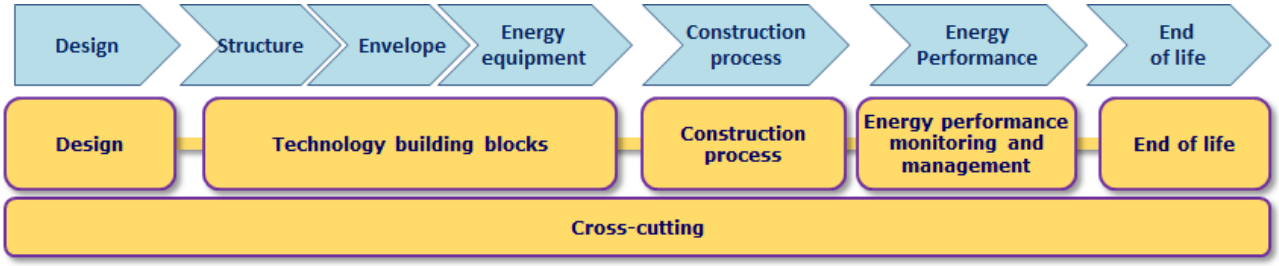


Figure 3.1: segmentation of the Construction value chain as defined in the E2B SRA 2014-2020 Source: EeB PPP Roadmap

In this complex value chain, the overarching challenge is to find a holistic approach for the sector that today and even more tomorrow links the energy, water, resources and all environmental sustainability aspects of the built environment (buildings and infrastructures, as well as their integration and interactions in districts and cities) with:

- An enhanced capability towards mass customisation as a production of personalized custom-tailored buildings/infrastructures and associated services to meet consumers' diverse and changing needs: such mass customisation indeed characterises the Construction sector for decades, but should now be more and more compliant with near mass production prices and quality – and this is to be enabled by technologies such as computerization and ICT, leading to the so-called concept of ***Construction 4.0***;
- a citizen quality of life and satisfaction with respect to his/her expectations, which may vary from one country to the other, from one region to the other, and indeed from one community to another: such an approach means associating to the Industrial Perspective a Societal perspective, leading to a ***Citizen-centric Construction 4.0***.

Construction 4.0 is to be made possible by the "multiplying" of innovative and proven materials, technologies (the so-called KETs - *Key Enabling Technologies*), and components, and their integration supported by enhanced data/knowledge management and ICT. It is also made possible by a deep integration of data management and ICT platforms and tools in all phases of the Construction process. In such consideration, the ECTP today advocates that the value-chain as pictured in Figure 1 as a *linear operational and economic model* (mainly based up to now on the "*source →manufacture →use →throw away*" logical approach) is to drastically evolve - leading to a transformation of the Construction value chain, as depicted in Figure 2 below:

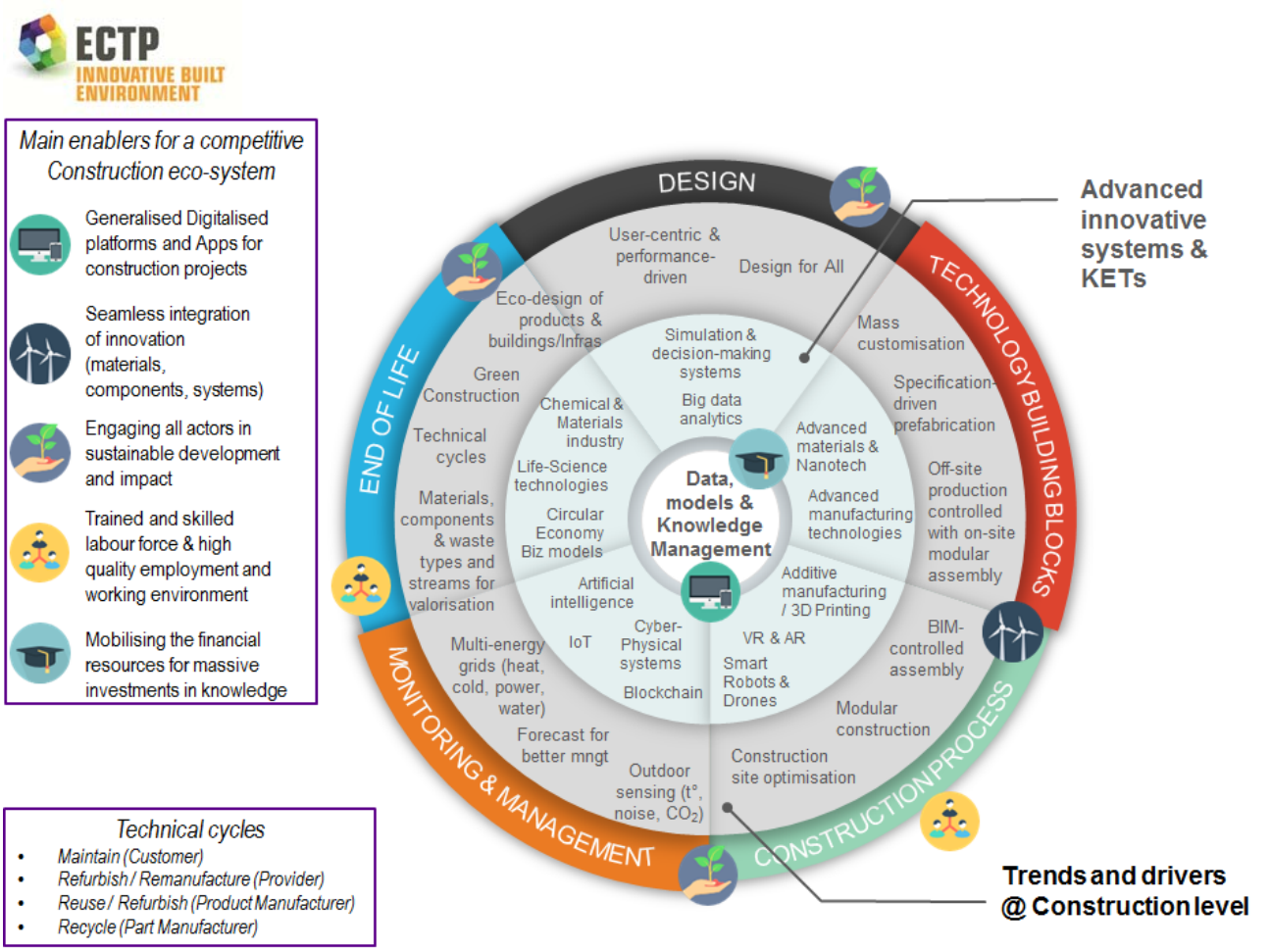


Figure 3.2: the transformed Construction value chain (as considered in ECTP 2020-2030)

It is indeed important to raise that in Figure 2, there is no more linearity as it has been most the case in the past – but indeed at any time streams from any concentric level (*see below*) to the other, as well as the capacity of each stage of the value-chain to interact with elements characterising another stage. The figure above exhibits 3 key characteristics (at 3 levels) of the transformed value chain:

- At the core, the integration of **data, information and models**, that form the digital resources which will in the future feed and empower all activities related to the built environment processes (design, construction, operation & maintenance, etc.), relying on basic digital technologies such as BIM, IoT, Big Data, etc.;
- At a 2nd level, the **KETs and advanced innovative systems** are to provide with the key tools and components sustaining the necessary transformation of process in the whole construction industry value chain and built environment life-cycle – they all rely on the core data/information and their management in the 1st level;
- At a 3rd level, the large **transformation of the various processes in the construction Industry** and sector are fundamentally relying on those 2 previous levels, which provide the bricks to enhanced design, planning, and optimised coordination/execution and operation of construction sites, as well as prefabrication and mass-customisation, while optimising the 3-uple *time-quality-costs* to the benefit of clients and users and in a context of sustainable construction more and more linked in the future to circular economy. This value chain transformation is to be the grounding for achieving the main upcoming targets as exhibited in the next figure.

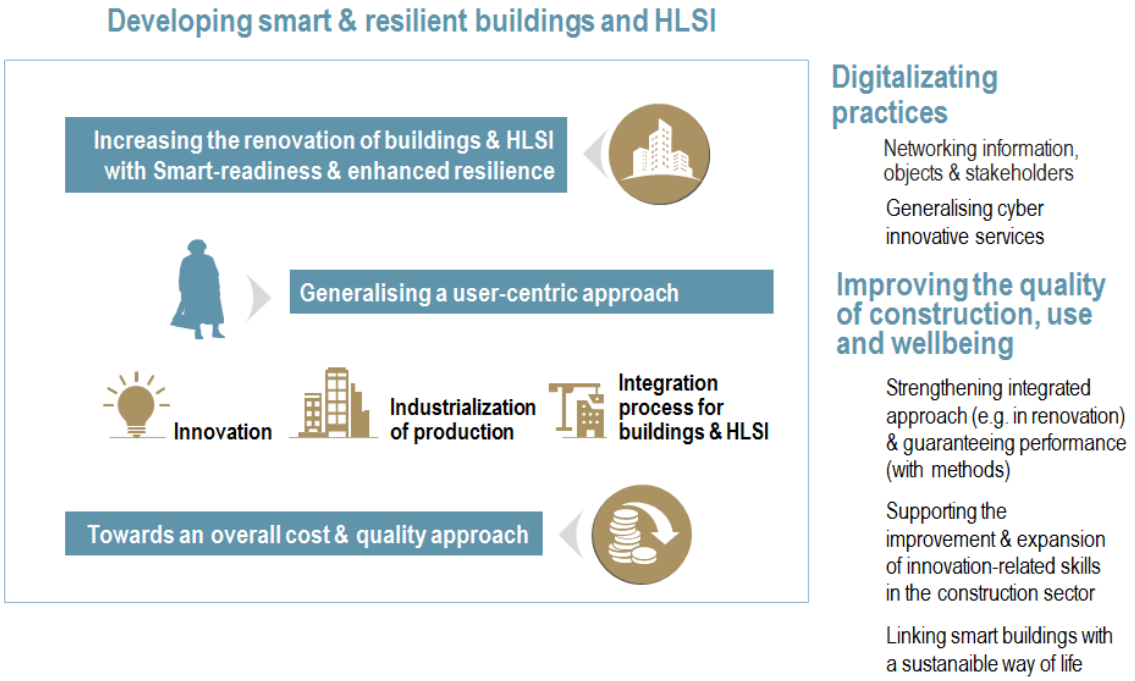


Figure 3.3: towards smart and resilient buildings and HLSI (High-Level Service Infrastructures)

Such a revolution is expected to generate new and amplified impacts in the Construction sector and the Built environment as a whole. For instance, in the specific field of Energy savings and efficiency (which has been since 2010 the key targets of the *Energy-efficient Buildings EeB cPPP*), such an approach is to generate further interest for energy savings or new forms of sustainable energy generation (i.e. renewable energy), but also at combatting energy poverty, improving building performance, safety and affordability for all users. Such targets can only be achieved going further than the building scale, using the Buildings block / neighbourhood / district as the most crucial focus points from now on – sustaining as such the European cities ambitious targets that they have defined since the start of H2020 in their agendas aiming at becoming smarter, more sustainable, resilient, liveable and affordable – but with all this requiring a full flexibility in the Construction value chain and overall process.

The construction sector consequently has a key role when addressing the above-mentioned challenges and must develop all means for allowing to design and construct buildings, neighbourhoods and cities, providing healthy spaces for living, new spaces for working, and new support to enhanced ways of commuting and travelling. It is worth noticing that in its '*Clean Energy for All Europeans*' proposal and the 2nd State of the Energy Union, the European Commission has announced its willingness to demonstrate the benefits of EU industry alliances in strengthening the industrial basis and taking advantage of opportunities arising in the clean energy transition, with three industry led initiatives in focus: renewable energies, batteries/energy storage and construction – also considering that construction is an exemplary industry to integrate innovative developments from the 2 other industry sectors: cooperation with the other industry led initiatives, renewables and batteries, and cooperation with authorities on local level may lead not only large energy savings in buildings and districts, but also new jobs and growth creation.

The ECTP advocates that a holistic approach is mandatory and should include all broader construction related aspects, including designs, developments and integration of innovative components for optimised life-cycle use of materials and resources, digital management and control systems based on BIM and IoT, and involve also urban planning, standard-setting, financing and governance issues, as well as the development of skills and competences for white and blue collars. The figure below introduces to the various types of mega-trends that influence the proposal done by ECTP in this FP9 position paper.

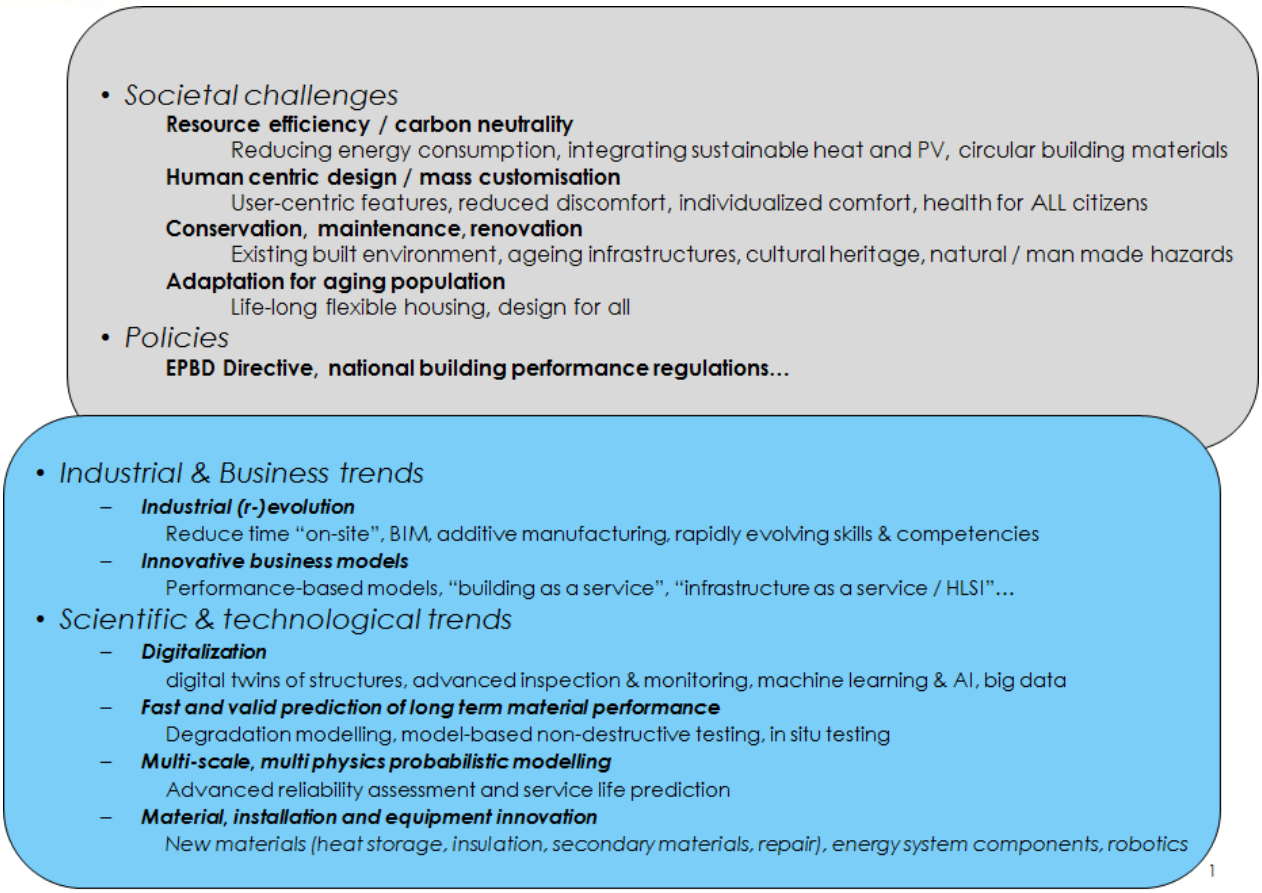


Figure 3.1: Macro-trends challenging the Construction industry

4. A COMPREHENSIVE OBJECTIVE-BASED APPROACH

4.1 Background

Since FP7 and at an accelerated pace under H2020, a consequent number of innovative materials, products and systems have been developed, integrated and assessed in a set of field trials and large-scale pilots, should it be for buildings, infrastructures or at level of districts. For instance, the EeB cPPP periodic monitoring report provides on a yearly basis a detailed analysis of the state of the art and current practices, for each of the 7 technology clusters identified: this includes an in-depth assessment of the technologies developed by the EeB projects which resulted in the identification of a selection of most promising innovations[4]. A similar approach has been followed by the ECTP infrastructure & Mobility Committee (through the REFINET CSA project[5]) through the identification of Best practices in design, construction and maintenance of transport infrastructures, as well as a catalogue of innovative technologies for MMTI (*Multi-modal Transport Infrastructures*).

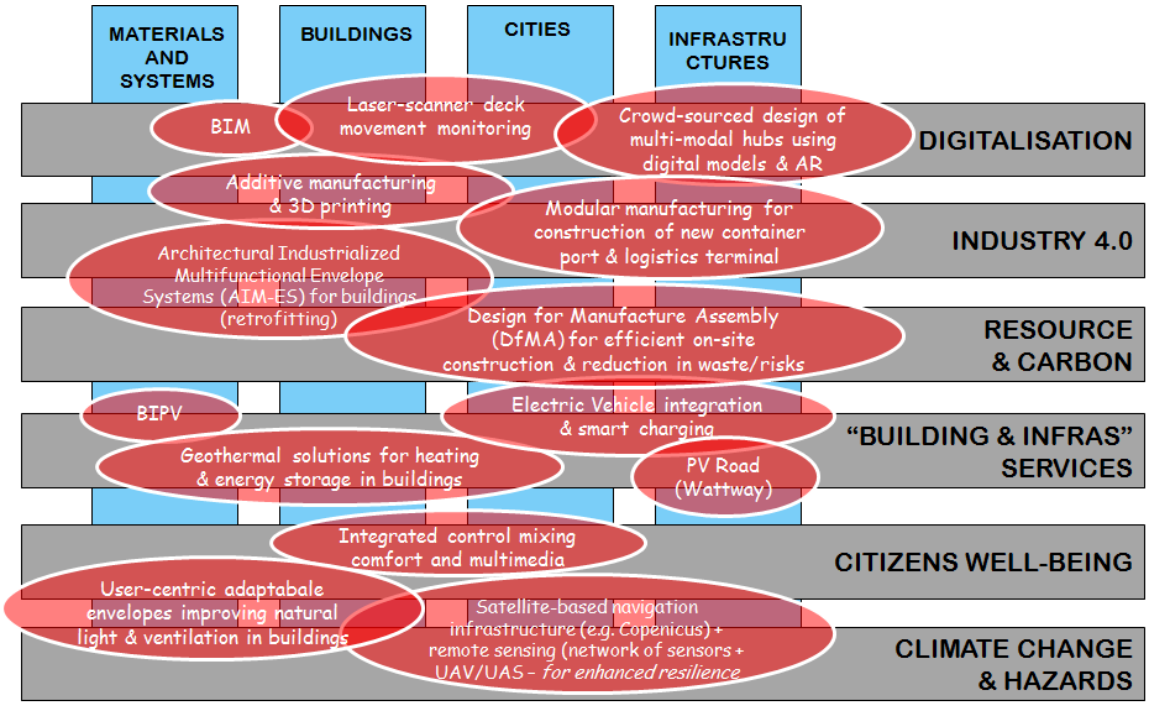


Figure 4.1: (non exhaustive) sample of innovations as developed in ECTP and the EeB

It is worth noticing that the Construction sector fundamentally integrates innovations from many other sectors (materials, energy equipment and systems, manufacturing, robotics, technologies from ICT, etc.) and as such generates a leverage effect towards these other industries: some of those strong relationships are described in more details in the '*Relationships and collaboration with other industries*' section.

[4] EeB PPP Promising Technology Brochures (2016): http://www.ectp.org/fileadmin/user_upload/documents/E2B/0_EeB_PPP_Promising_Techno_Brochures/EeB_PPP_Promising_Technology_Brochures.zip

[5] REFINET / Infrastructure & Mobility Committee resources: http://refinet.eu/resources/publications/

4.2 A 3-pillar approach

The post-H2020 vision from ECTP derives from the need to advance from Energy-efficient to **Ressources-Efficient Buildings** on one side, and from buildings towards **Energy-efficient districts and ultimately Carbon Neutral Cities** in Europe, with **a)** a citizen-centric perspective, **b)** the need to consider buildings and infrastructures in a coherent and comprehensive approach at level of districts and cities, and **c)** the construction and built environment sector as pivotal to achieve the ultimate vision of Carbon Neutral Cities. To do so, the Construction and Built Environment value proposal is constructed over the 4 fundamental areas of interest (challenges) that must be tackled to meet the goal: (1) meeting the Energy / Decarbonisation transition; (2) meeting the digital transition; (3) a circular-economy based built environment; (4) and materials for a sustainable, low-carbon built environment.

The vision from ECTP is synthesised below, based on 3 key pillars: ono so as to meet the Energy / Decarbonisation transition, another one is about meeting the Digital transition (the so-called *Construction 4.0 – with a stakeholder-centric approach*), and a last one related to revolutionise the Construction industry by allowing to systemise the uptake the sustainable innovation in the built environment thanks to the generalisation of lean production and integration – and with a systematic view on a citizen-centric built environment.

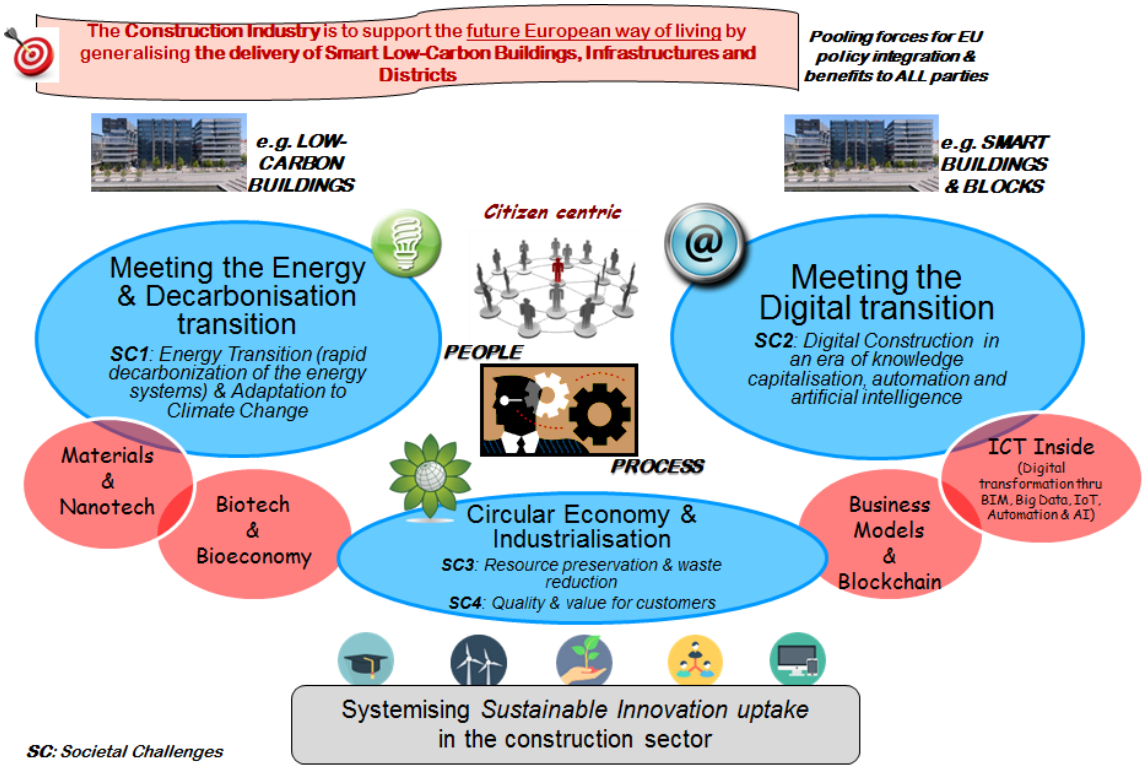


Figure 4.2: a global approach for R&D and Innovation in the Built environment by 2030

4.2.1 Digitalisation

Digitalisation of the construction and transport sectors will also bring new opportunities for research and innovation in construction delivery, operation and maintenance. Adoption of new digital technologies have an enormous potential for increasing the competitiveness of European companies, including SMEs. Technologies, such as Internet of Things & monitoring technologies, Robotics, Virtual and augmented reality, Big Data, Building / Infrastructure Information Modelling and many others will allow a smart management of the Built environment as well as transport infrastructure to ensure safety / security, predict events, failure and cascade

effects while increasing performance and user satisfaction. As mentioned by the BCG[6], one can expect that by 2025 "***full-scale digitalisation […] will lead to annual global costs savings of 13% to 21% in the design, engineering and construction phases, and 10% to 17% in the operations phase***".

For buildings, it is about the development and change of status of our European buildings towards smart buildings, as well as well as their smart readiness, which must characterise their capacity to smoothly integrate more intelligent components and deal with more and more IT-based systems and services. This encompasses the following elements (the *list being not exhaustive!*), with some examples related to energy efficiency, but with potential for adaptation/generalisation to other fields (water, waste, etc.):

- Active/Communicating components (transition towards "connected objects / systems" / IoT) → besides their innovative functions (i.e insulation, generating energy, storage, etc.), components need to exhibit an API – so as to be part in some "agnostic" way to any agent-based / event-based networks. This is a prerequisite to transform buildings in "smart-grid ready" / "smart-network ready" buildings or HLSI. This may refer to improve the quality of the installation works too – through inbuilt data/information;
- Integration of the components in the buildings and HLSI, both physically, but also "logically", i.e. scaling/parameterizing according building/HLSI typologies, constraints, etc., providing compliant input data used to further issue, for instance regarding a building or a multi-modal transport hub, an Energy Performance Certificate (the building is an assembly of various "smart" components serving the overall EE) → this requires a high level of "interoperability" among components, between components and their 'container' (building or HLSI).
- Integration of the building components in **services**, according to users demands/expectations and constraints, and according to demands/requirements from outside the buildings/HLSI, e.g. mobility systems (V2H), grids infrastructures, etc. (i.e. all the "external" networks). This should allow to tangibly transform the buildings with communication interfaces between their own equipments and the surrounding infrastructures → this is linked with the "empowerment" objective of the Commission: "Put customer at the centre of the energy system".
- Systems that allow to optimize the structuring and sizing/dimensioning of the systems and the grids, electric & heating/cooling (energy, but power management too), with scaling-up considerations. Indeed, these systems are not part per se of the built environment, but may be supportive to decision-making systems and may play an important role wrt investments (in renovation, maintenance, etc.) → 2 notions behind this: **(i)** make sure people have enough energy, which will be CO2 free etc. – this deals with energy and prices **(ii)** make sure the maximum demand can be satisfied (winter time, 07.00 PM…) and this is related to power. / a kind of overall vs dynamic differentiation.
- More funding support towards any development related to the "interfacing" of the various energy components to improve the achievement and the flexibility of the "energy mix" in the sense of favouring the complementarities of the various energies;
- More funding is required around the buildings & districts energy profiles / audits, and the awareness of (all types of) users (*there are some bunch of ongoing developments around this topic, still a lack of some structured approach according to me – and the integration with the various systems*!);
- Huge amount of data to be further generated and managed, with issues related to security & privacy (adding quite some additional complexity at level of ICT tools).

For infrastructures, digitalisation means the true development of a Digital Era for Transport. Many tend to think that, when applied to transport, the word "Digital" refers mainly to the rolling stock (e.g. all smart vehicles, trains, ships or aircrafts) whereas it is obvious that we can demonstrate see more profound changes, as advocated by ECTP: first, in the way infrastructures for the different transport modes will be built by the use of digital technologies, and the sector is still undergoing the digitalisation of its productive processes in an environment that is more complex than the one of manufacturing. Secondly, in the level of services to be provided by the infrastructures (referred as *High Level Transport Infrastructure* or *HLSI* – see ECTP I&M FP9 Position paper) to vehicles: for instance, the generation of infrastructure management data to provide

[6] BCG – The Boston Consulting Group: "Digital in Engineering and Construction: the Transformation Power of Building Information Modeling" report, 2016.

positioning services in areas without GPS coverage, to furnish structural data about the road condition, to pinpoint fallen objects on the road or areas of damaged pavements, to make available information related to traffic restrictions or detours, to provide a better user experience in concessions or in public infrastructure, etc.. Thirdly, in the way infrastructures are going to be managed and maintained in the future: technologies as IoT together with Artificial Intelligence can deliver more efficient management of the infrastructure and its maintenance. It should also serve to implement innovative maintenance methods based on actual infrastructure condition, less invasive and less traffic disrupting so automated traffic flow would not be disturbed.

4.2.2 Industrialisation

As it is the case for the built environment, the construction process also has potential to become more effective in terms of environmental, economic and social sustainability, including with the increase of its productivity. This productivity has largely increased in other sectors like manufacturing or services over the last 25 years, when Construction has not yet taken full advantages of digitalization, design-controlled prefabricated manufacturing and new lean production process. As such, there is a tremendous opportunity over the decade to come for the construction sector to increase its performance from design to decommissioning: the role of the sector has to more and more perceived as an integrating one, bringing together technological solutions and innovation with the needs and wishes of the customers (inhabitants, building owners, social housing, local authorities and municipalities, etc.) – along a complete value chain (as described in the next figure) that brings together new forms of client-centric or client-driven design, parametric concrete solutions brought by innovators, integration fully controlled along the off-site manufacturing line, the logistics process and the construction on site, and with new technologies and services for management, maintenance, improvement and demolition – all under a "ground" of digital interoperable model-based software and service:

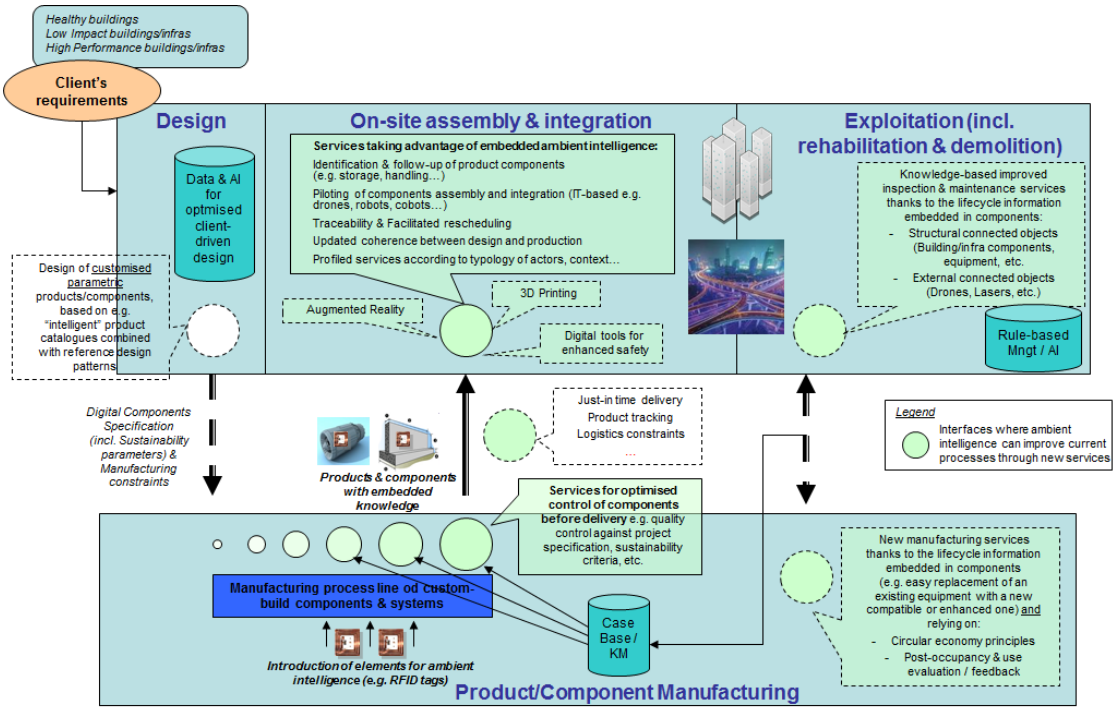


Figure 4.3: Construction 4.0 - Ambient services along the whole value chain and the complete Construction lifecycle

To do so, however, channels of dialogue need to be opened between the construction sector and the various other stakeholders, as well as knowledge gaps regarding innovative processes, products and services, technical solutions etc. need to be found and addressed. On the same time, ways to unlock private financing need to be found, that should facilitate the formation of progressive coalitions across the value chains, which would result in concrete pledges, actions and projects, ambitious innovation targets creating growth and competitiveness – supported by the EU industrial representatives and companies, innovative SMEs, cities, and regions.

As examplifying of such potential industrialisation for the Construction sector, one can consider 2 examples (among many others!):

- Additive manufacturing (also referred as 3D printing), fabricates components in a layer fashion directly from a digital file. A large number of the today applications of additive manufacturing technologies are in the aerospace, automotive, and healthcare industries, but already several experimental applications of additive manufacturing in the construction sector have been achieved. Additive manufacturing for construction has the potential to decrease labor costs, reduce material waste, help in the quality control (thanks to a large increase of digitalisation) and eventually support customized complex geometries that are difficult to achieve using conventional construction techniques. There is a large range of potential applications for construction to exploit the rapidly maturing additive manufacturing technologies for a variety of material types, with still a required need for R&D regarding related methods of implementing additive manufacturing and potential advancements in applications of this technology. Examples of potential advancements include use of multi-materials (e.g., use of high-performance materials only in areas where they are needed), in-situ repair in locations that are difficult or dangerous for humans to access, disaster relief construction in areas with limited construction workforce and material resources, structural and non-structural elements with optimized topologies, and customized parts of high value. The future of additive manufacturing seems promising to the construction industry, but interdisciplinary research is still needed to provide new materials, new processes, faster printing, quality assurance, and data on mechanical properties before additive manufacturing can realize its full potential in building and infrastructure construction.

- IoT- and BIM-enabled platform for on-site assembly services in prefabricated construction: BIM can be a useful support tool in facilitating the on-site assembly services of prefabricated construction, thanks to the use of digital twins (functional digital presentations) it allows. But the use of BIM in the on-site assembly services of prefabricated construction requires a complete, accurate, and timely data exchange along with real-time visibility and traceability – which can be achieved through an appropriate mix of IoT and BIM technologies. Based on stakeholders' requirements and construction site constraints, a full process can be put in place, relying on IT objects and gateways collecting real-time data throughout the working processes of on-site assembly of prefabricated construction using e.g. RFID technology, capturing data being uploaded to some cloud platform in real-time to process and analyse for decision support purposes to the benefits of the involved site managers and workers. BIM associated to AR/VR technologies can deliver visibility/traceability functions, allowing managers to supervise the construction progress and approximate cost information in a real-time manner. Such IoT and BIM-coupled platforms can provide various decision support tools and services to different stakeholders, for improving the efficiency and effectiveness of daily operations, decision making, collaboration, and supervision throughout on-site assembly processes of prefabricated construction.

4.2.3 Circular economy

The Buildings and infrastructure sector is indeed characterised, should it be at European or various national levels, by being a strong consumer of resources (mineral resources, natural and industrial materials, energy resources – with many of them being fossil-fuel based, Biomass, etc.), and at the same time being one of the most important sectors in terms of generating waste with an important potential of valorisation: it is obvious that the sector must face and deal with these challenges, and at the same time a fantastic field of experimentation and development for circular economy, and it is worth noticing that regulators in various countries tend to encourage developing such circular economy in the construction sector – should it be in the context of the energy/decarbonisation transition, or with clear objectives to reuse/refurbish/recycle more than 80% of the waste by 2025. This of course has an impact both in terms of technological transformation of materials and components, devise a full industrialisation of waste management through innovative processes, and requiring putting in place an evolution of the construction stakeholders' channels. More precisely, this implies to:

- Erect a new construction economy based on an increased prevalence of abstemious and smart use of resources, and in particular natural resources and nature-based solutions;
- Develop various strategies and mechanisms to reduce the production of waste on one side, to increase the revalorisation of waste in terms of re-employment or recycling;
- Favour the eco-design of products and components, taking into account their life-cycle, durability, and capacities of being repaired, dismantled and recycled.

4.3 A user-centric perspective – for the European citizens and the Construction stakeholders

The quality of buildings and their environment strongly influences the well-being of their occupants, and indeed **EU citizens** are waiting for improvement of their health, comfort and well-being in their homes, their offices, their schools, where they spend up to 90% of our time, while simultaneously creating quality jobs for local SMEs, improving social inclusion through urban regeneration and skills development, and boosting European competitiveness through innovation and digitalisation. It is more and more acknowledged that implying and integrating the consumer in decision-making, including in the urban forms of the future districts and cities, is required: one has to start from their expectations and views, integrate the appropriate technologies and in the right way, and demonstrate the outcomes match the original expectations. This ca be achieved by new methodologies like User eXperience (UX - defined by "*a person's perceptions and responses that result from the use or anticipated use of a product, system or service*"), Living Labs (in the broad sense of ENoLL[7]) and City Labs (as participatory platforms for open innovation that support experimentation with real users in real-life contexts).

For instance, understanding owners' motivations to support renovation, for the energy retrofitting of buildings, is a major challenge for municipalities, as it aims to better understand owners' barriers to taking action in their buildings thanks to feedback and suggest appropriate decisions and actions. Current Research shows that energy efficiency usually ranks low for citizens in housing priorities, and the main motivations for households behind energy saving measures are financial savings, the energy efficiency pays off being a key argument for the energy retrofitting. But they are other advantages: better labelled homes get better price, sell faster and have higher rents, and banks and insurances already take energy efficiency into account and offer lower rates for better energy performance certificates.

Another aspect to more develop is the need to finely understand users' behaviour so as to change it or adapt the built environment design for it (*design for all*). Behaviour change and adaptation needs a systematic approach based both on social theory (logic model of change) as well as experimentation evidence: what do users need to do to change? What needs to be done in the users' environment so that this change can occur? What do users need to learn to achieve the performance objectives? Knowledge on this complex process behind

[7] http://www.openlivinglabs.eu/

behaviour change can help designers and local authorities design to share insight into the difficult decision-making processes, where a very large diversity of users may have their say and provide some inspiration to tackle the complexity of decision-making processes – with different measures to reduce energy consumption at home with different "customer profiles". This may be considered including policymakers as well, who create many laws and regulations designed to protect consumers, while some policymakers are working to make housing more affordable, such as through targeted tax credits and lending programs.

On another side, attention must be paid to the variety of **actors' skills** offered in the building sector, from white collar to blue collars, with incentives to training courses for renovation energy and water efficiency, digitalisation of the sector, integration of innovative materials and components, etc., would help boost employment (including youth employment by changing the image of the Construction sector to an innovative and technological sector, and including in some of the EU's poorest regions, thereby improving economic, social and territorial cohesion, a key objective of the MFF. Such an approach is guaranteed to create employment in Europe, improving local economies and addressing inequalities. Considering the example of energy, the challenges the construction sector is facing spans from integrating renewables and storage solutions, energy-efficient components at level of the envelope and inside the buildings, to promoting the uptake of technologies when deep-renovating houses and, at the same time, improving the quality of life of entire neighbourhoods, thereby serving socio-economic objectives.

4.4 Relationships and collaboration with other industries

The Construction business plays an important role in the development of Industry 4.0 in Europe and is a major player of the digital, low carbon and circular economy: there is a major work to do and impact to achieve in generalising Energy-efficient and decarbonised buildings and districts as well as optimizing resilient transport infrastructures, in delivering the best materials, products and systems - for new buildings as well for cultural heritage efficient renovation - and in designing a sustainable built environment to the benefit of all citizens, including the elderly. In this context, enlarging European support to R&D in construction business seems a major priority to transform the construction sector in a more and more service-oriented business, while remaining one of the most powerful drivers of growth, jobs and investments, and representing by far the most integrative industrial sector regarding society. The next figure[8] gives an overview of the impact of the Construction sector (onsite construction & Real Estate) in relationships with other sectors and industries:

[8] **Estimated consumption of output from other sectors by Onsite construction and Real estate services in EU27, 2007** - FWC Sector Competitiveness Studies N° B1/ENTR/06/054 – Sustainable Competitiveness of the Construction Sector - ECORYS

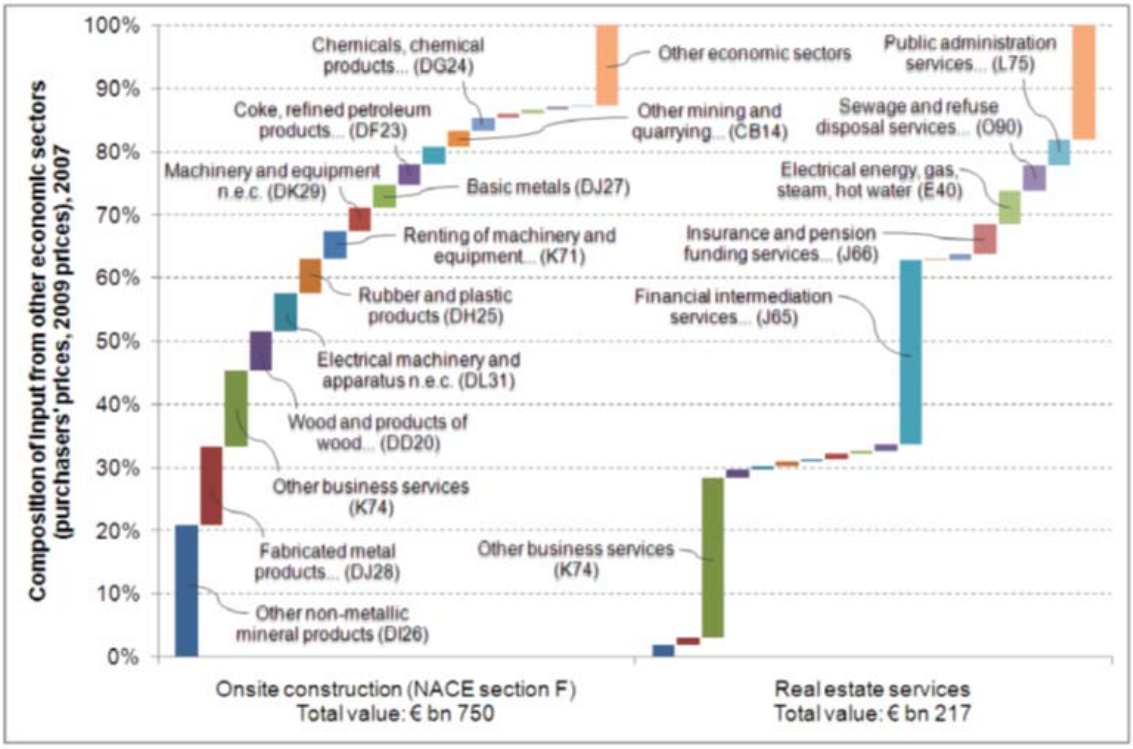


Figure 4.4: the Construction sector 'snowball effect'

In such a context of developed integration and interactions with other domains and stakeholders, the next table is an initial start in identifying the potential relationships that the Construction sector (through the ECTP) could bridge with other initiatives, platforms and programs in terms of connected or joined research, development and innovation:

Domain	Initiative	R&I items leading to collaboration with the identified initiative(s)
Energy Efficiency in Buildings & Districts	Platforms: EUMAT Renawable Heating & Cooling (RHC-ETIP) ETIP PV	Technology needs identification Technology roadmap endorsement
	PPPs/JTIs: SPIRE FoF FC&H JU	Transformation of the building sector (construction 4.0), industrialization and mass customization, integration of the waste streams of different industrial sectors and the development of circular economy models, new RES energy generation.
	Initiatives: EIP SCC EUROACE	Dissemination and promotion of energy efficiency in buildings. Institutional support, codes, standards. Promotion of the energy-related market uptake.
Materials	Emiri	Contribution to building-related part of the EMIRI Roadmap
	AMANAC	Knowledge exchange on life cycle assessment (LCA) and life cycle cost assessment (LCCA) related to construction materials

	VERAM	Input to VERAM's vision and roadmap for European Raw Materials in 2050
	Think Nature project	Knowledge exchange on "Nature-based solutions in building, infrastructure, district and city level"
	SPIRE	Connection with the Association and SPIRE projects through the key Committee members
Cultural heritage	International institutions: UNESCO ICCROM ICOMOS	Institutional support, codes, standards, charts for the conservation of cultural heritage.
	JPIs: Cultural Heritage Urban Europe	CH preservation and promotion from institutional perspective. Management of historic cities.
	Initiatives: Europa Nostra ViMM	Dissemination and promotion of cultural heritage. Virtual heritage.
Transport Infrastructure and Mobility	Platforms: ACARE, ALICE, CEDR, ERRAC, ERTRAC, ETRA, Waterborne. PPPs: EeB	Organization of the Transport Research Arena Conference Infrastructure including Transport in the Built Environment of Cities
	Associations: CEDR (Conference of European Directors of Roads) ENCORD (European Network of Construction Companies for Research and Development) FEHRL (Forum of European National Highway Research Laboratories)	 Open Data Exchange between the industry and the National Road Authorities. Alignment of and collaboration in research topics between ENCORD and the ECTP. Joint FORx4 Initiative between FEHRL and ECTP.
	NTPs: National Construction Technology Platforms	 Collaboration with the Platforms to identify relevant topics in transport infrastructure research.

5. AMBITION AND OBJECTIVES

5.1 The case of Efficient Buildings and Districts

Buildings account for 40% of total energy consumption and around 75% of them are energy inefficient. Low energy efficiency in buildings is due to a number of shortcomings, including lack of maintenance and insufficient investment, defective construction (either for inappropriate choice of materials or lack of professional expertise), change of use, outdatedness of the building, and others. Europe's energy inefficient building stock is huge and, with the current rate of renovation of around 1% of buildings each year, it would take a century to upgrade the building stock to modern, near-zero energy levels.

There is a crucial need of innovation to improve the situation and deploy energy-efficient and low-carbon solutions in the built environment, to avoid an ever-increasing inefficient buildings stock in the next decades. According to a new report by the EU-funded iBRoad project – *The Concept of the Individual Building Renovation Roadmap* –,97% of the EU's building stock, amounting to over 30 billion m2, is not considered energy efficient, and 75 to 85 % of it will still be in use in 2050. The ambition of ECTP is to reach at mid-term a 4-5% renovation rate in Europe by 2027 (with +0.5% each year), in order to cope with the evident need to achieve rapid growth in replacing particularly inefficient and carbon-intensive buildings through developing appropriate innovation partnerships and business models.

Clean energy buildings are about much more than saving energy: they are built with enhanced materials with increased durability and reusability, increase occupant comfort, quality of life and productivity, have the potential to integrate renewables, storage and digital technologies and to link buildings with their surroundings, especially the transport system. Investment in a clean energy building stock can drive the transition to a low-carbon economy. With all the know-how gathered in technology innovation in buildings in the framework of the EeB PPP in H2020, the E2B Committee sees the need to extend from Energy-efficient to **Resource-Efficient Buildings** on one side, and from buildings towards **Energy-efficient districts and ultimately Carbon Neutral Cities** on the other side, enabling the technology developments that are needed to face Europe's challenges and ambition by 2030 and 2050.

EU's *Accelerating clean energy in buildings* report also recognizes the need for expanding our scope by stating that "the EU is already a global leader in innovation systems for buildings. Integrating energy efficiency, renewables, storage and connecting to digital and transport systems through buildings allows further expanding on this leadership and making the most of the favorable regulatory framework".

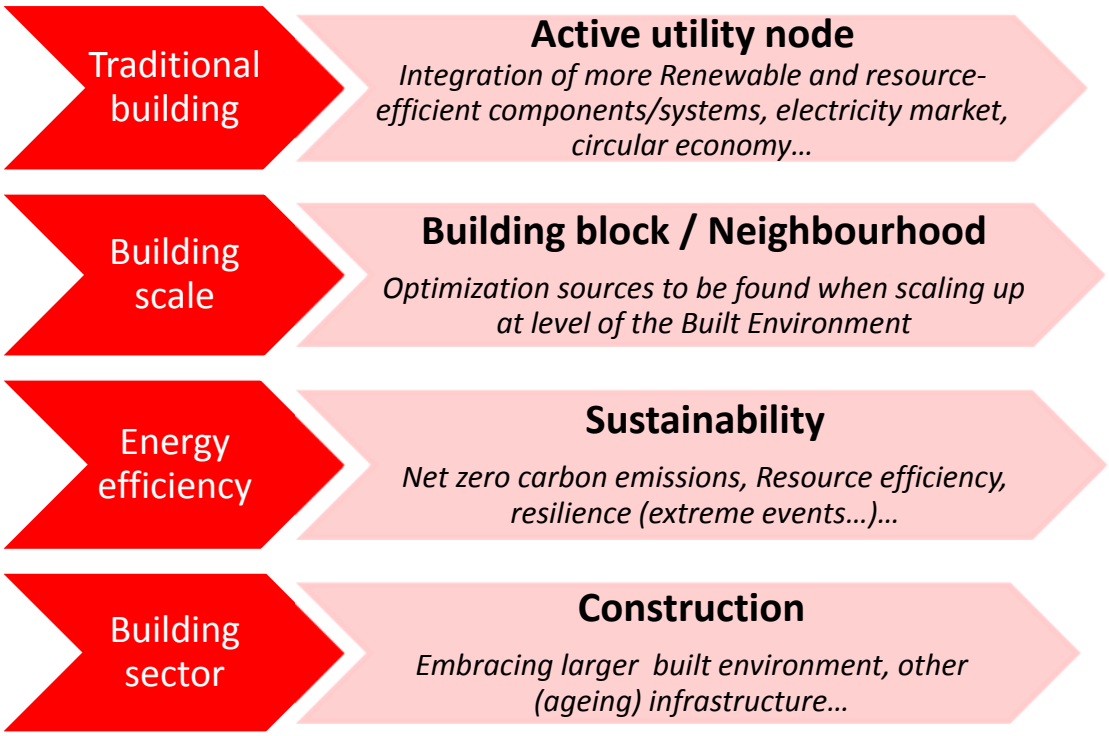
This will also support the technological developments that are needed, as defined in the Clean Energy for All Europeans Package. In particular, the value proposal of the E2B Committee targets several of the gears that need to be empowered to achieve a modernization of the European Economy: Innovation, the Energy Union and Climate Change, the Circular Economy and the Digital Single Market.

Innovation, by defining the technologies that need to be developed, from research to market uptake, aiming for a modernization of the construction sector and its contribution to the European economy and welfare, and creating synergies between the energy, transport, circular economy and digital market.
The Energy Union and Climate Change, with a focus in the technology requirements to reach a renovation rate of 4-5% by 2030while generalizing the concept of low-carbon (near zero) energy buildings.
The Circular Economy, with the built environment and construction sector having a pivotal role to reach the targets set in the Circular Economy Package, by fostering the generation of new circular economy models based on the valorisation of waste streams from industrial sectors for construction purposes, through the establishment of industrial symbiosis relationships at regional level.
The Digital Single Market, by the development and integration of digital technologies to increase the efficiency of the construction processes and infrastructure operation, as well as facilitating the adoption of a digital public procurement process.

While the need for innovation at building scale and investing in buildings remain, ECTP has revisited its strategy: reaching the sectorial goals, as well as the energy goals, requires to step-up and focus the effort beyond the building scale.

Hence, ECTP's proposal for the next FP9 is to enlarge the scope of RDI activities and to move **from (passive) Energy Efficient Buildings to (active) Low-Carbon Built Environments**, i.e. extending the considered dimension from buildings to blocks of buildings and districts, and embracing the larger Built environment as an enabler for innovation integration (e.g. recyclable, bio-based materials, intelligent and digital technologies, smart grids for optimized interaction with the environment, circular economy models…) for enhanced sustainability in districts and cities.

The ECTP post-H2020 evolution can be synthesized as shown in the following figure:



The following research priorities summarize the key technology challenges arising from the extended scope described above. The E2B Committee is proposing to tackle and broke down these challenges into specific research priorities in the frame of HORIZON Europe:

- Buildings and block of buildings, including retrofitting uptake: to increase the retrofitting market uptake.
- Active Utility Nodes: to integrate renewables and storage.
- Digital transformation: to collect data from new and existing buildings on web based platforms to which stakeholders of the value chain have access facilitating design processes, renovation and operation & maintenance issues;
- Performance optimization through monitoring and intelligent management platforms: to effectively measure the impact achieved and to trigger the replication potential of innovations developed;
- Interfacing with the built environment: to link buildings with the surrounding transport system, including multi-modal transport hubs and transport infrastructures, as well as to fully integrate the circular economy principles in the built environment and the construction sector;
- Integration and cross-cutting issues: to ensure stakeholders' engagement, users' awareness on energy efficiency, new business models and financial schemes, systemizing integration and market uptake.

These challenges also contribute to the UN Sustainable Development Goals[9], directly or indirectly tackling several of those:

- Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all
- Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
- Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable
- Goal 12: Ensure sustainable consumption and production patterns
- Goal 13: Take urgent action to combat climate change and its impacts

7 AFFORDABLE AND CLEAN ENERGY	• Increase the share of RES • Double the rate of energy efficiency • Enhance international cooperation	• Integration of RES in the built environment • Better energy performance of buildings • International presence of the sector
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	• Quality, sustainable and resilient infrastructure • Upgrade infrastructure and retrofit • Enhance technological capabilities	• Construction and maintenance of resilient and reliable transport infrastructures • Smart maintenance and operation of infrastructures
11 SUSTAINABLE CITIES AND COMMUNITIES	• Adequate, safe and affordable housing • Accessible and sustainable transport • Inclusive sustainable urbanization • Safeguard of cultural and natural heritage • Reduce people affected by disasters • Universal access to green public spaces • Sustainable and resilient buildings utilizing local materials • Resilient buildings, cities and infrastructures	• Cost effective retrofitting and new construction • Multimodal accessible transport networks • Citizen's oriented urban planning • Technologies for long term maintenance of cultural heritage • Nature based solutions for the built environment • Recovering vernacular architecture
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	• Efficient use of natural resources • Waste minimization through prevention, reduction, recycling and reuse • Sustainable public procurement practices	• Extension of life and reuse of existing buildings • Integration of construction and industrial waste into building materials • Green procurement in construction
13 CLIMATE ACTION	• Strengthen resilience and adaptive capacity to climate-related hazards	• Resilient built environment

[9] https://www.un.org/sustainabledevelopment/sustainable-development-goals/

The **Energy-efficient Buildings (EeB) Public Private Partnership (PPP)** is a joint initiative of the European Commission (EC) and the Energy Efficient Buildings (E2B) Committee of the European Construction Technology Platform (ECTP). This initiative aims at promoting research on new methods and technologies to reduce the energy footprint and CO_2 emissions related to new and retrofitted buildings across Europe. In the framework of Horizon 2020, a contractual PPP was agreed between the E2B Committee of the ECTP and the EC, in order to continue investing in research and innovation in this field.

The European Commission already recognizes in its document *Accelerating clean energy in buildings* that a low carbon economy can be only reached through a combination of social, financial, technical and administrative measure that can overcome the challenges faced in these areas. The EeB PPP has been one of the main instruments to overcome the technical challenges through the development of innovative technological solutions.

Important KPIs are derived from the analysis of the projects portfolio already implemented. In average, nearly 3 new technological systems are being developed per project, in addition to 1.5 non-technological innovation. The reduction of CO2 emissions amounts 37.3% and more than 35% reduction of energy use, benchmarked against the best commercially available solution in the market and applied to the same type of building. Energy savings can reach up to 80% when compared to the actual baseline, based on the current existing building consumption. Moreover, an average of 3 demo sites per project will ensure replicability across Europe and maximize the technology visibility and related impact.

Projects have also produced technical breakthroughs which enabled new business models which leverage on performance guarantee and enhanced comfort for the user to be launched. In addition, up to 10 spin-offs and start-up companies have been created as a direct consequence of these R&D projects, with an average of 1.4 patent applications per project.

These indicators are proving that the ECTP, as private part of the EeB PPP, has delivered outstanding results and achieved the goals that were set together with the European Commission, as public part: accelerate the innovation process, maximize the leverage from industry commitment and develop the innovation needs that will drive decarbonization of the building sector in Europe.

The EeB Multi-Annual roadmap is setting our vision and outlines our route towards a high-tech building industry, which turns energy efficiency into a sustainable business covering the entire value chain. According to our roadmap, the current phase of technological development shall focus on the building scale, as implemented in HORIZON 2020, preparing the ground and individual technologies for the next phase which will tackle district-level challenges.

ENERGY EFFICIENT BUILDINGS
AN ECTP COMMITTEE FOR INNOVATIVE BUILT ENVIRONMENT

5.2 Infrastructures and Mobility

The Transport sector is one of the major drivers for economic growth and its reach into every aspect of society cannot be overstated. An efficient and effective transport system not only supports the economy with the movement of people and goods, but its influence is much deeper. Yet, it has a major impact on the environment and on the communities. Most activities in scientific disciplines such as chemistry, physics, computing, economics, psychology, logistics, as well as engineering, such as mechanical, civil, electrical, electronic, are directly or indirectly associated with applications in transport.

The European transport infrastructure network is a shared heritage of great economic value, enabling wealth to be generated across the continent. The magnitude of Europe's transport infrastructure is indeed quite high – in terms of (1) Roads, with a total road network of approximately 5 million km in the 28 EU Member States (60,000 km are motorways), (2) Railways, with a total length of lines around 215,000 km (107,500 km are electrified), and (3) Waterways, with 41,000 km of navigable inland waterways.

5.2.1 An existing infrastructure to be strengthened and transformed

European Transport Infrastructure (TI) needs modernising. As stated in the Transport European First Semester 2016 Thematic Fiche prepared by the Commission, "European transport network infrastructures, and in particular the trans-European transport network (TEN-T), require a proper level of investment (to support) new infrastructure, refurbishment and modernisation of the existing network, as well as an increased coordination between Member States affected by cross-border infrastructure projects".

Many European infrastructures were constructed in the period 1960-1970 and were designed for a working life of 50 years. Now these **infrastructure networks are often strained far beyond their intended capacities** in terms of traffic flows and traffic loads. Large sections already require significant refurbishing. Furthermore, climate change may also have altered the climatic conditions considered at the design stage. Consequently, many of the existing infrastructures no longer fulfil the current functional requirements and today's safety and quality standards.

5.2.2 A new infrastructure to be developed

As result of the different socioeconomic development in the European regions during the second half of the last century, **transport infrastructure still needs to be deployed** in some of them. This is high priority for many European regions, as "building a new regional transport infrastructure, extension and enhancing existing networks and removing transport bottlenecks therefore contributes directly to the fulfilment of the EU Cohesion policy goals". The TEN-T initiative reflects this European need, **promoting and strengthening seamless transport chains for passenger and freight**, while keeping up with future technological trends.

Without R&D and innovation supporting infrastructure construction and renovation, the only option is to keep on building infrastructure the 20th century way – high carbon, low innovation and at high cost – with no way or hard ways to support innovative transport modes. There is an urgent need to modernise construction delivery but the risks, the structure of the industry and the implementation of EU procurement generally align against innovation. A common European-wide approach to the development and delivery of innovative design, construction, maintenance and upgrading concepts and solutions to improve and extend in a user-centric way the capacity and performance of the existing network is also needed.

5.2.3 Why is it important to invest in transport infrastructure research and innovation?

Deteriorating infrastructure, long known to be a public safety issue, **has a cascading impact on the economy**, negatively affecting business productivity, gross domestic product, employment, personal income and international competitiveness. The economic consequences of continued underinvestment in infrastructure and the economic gains that could be made if we choose to invest in infrastructure are astronomical.

There is an **increasing demand for better asset management of transport infrastructure** in order to meet the grand challenges defined by the EU in a cost-efficient way. Infrastructure networks must be designed, built, operated and maintained in a sustainable way, reducing resource and material consumption, with a reduced environmental impact and with increased level of safety. Considerations about climate resilience, availability and cost of energy, new uses of infrastructure, new products and new regulations need to be taken into account as well.

An **ageing society poses a new concern on the variety of users' needs that will necessitate a new approach to the design of infrastructure**. Elderly people will use transportation networks more frequently, particularly in urban areas and for long distance journeys. Younger people are expected to change in favor of multimodal travel patterns with fewer car owners.

Digitalisation of the construction and transport sector will also bring new opportunities for research and innovation in construction delivery, operation and maintenance. Adoption of new digital technologies has an enormous potential for increasing the competitiveness of European companies, including SMEs.

5.2.4 Future of Transport and Mobility

Future of Transport is oriented to develop systems more focused on the citizens ensuring accessibility and inclusiveness while reducing the environmental impact and pollution, in particular improving quality of life of European cities. The **integration between transport infrastructure and digital technologies** will provide personalized seamless journeys across different transport modes. Autonomous vehicles will create more available free space in cities that can be used for other **purposes opening additional possibilities for upgrading the transport infrastructure in the built environment of cities**. Trends like teleworking may cut transport externalities (emissions, disturbances, jams, etc.) by 90%. This is another opportunity for upgrading and **improving the built environment and decarbonizing transport**.

Walking and cycling will continue having bigger presence in cities and urban planning. This means reshaping the urban landscape, **reclaiming in many cases for these types of transport infrastructure that was previously used by motorised vehicles**.

For all this to happen, Transport Infrastructure needs to be physically and technologically upgraded and adapted:

- **Intelligent Infrastructure**, allowing to collect and analyse data in real time will provide increased operational efficiency for infrastructure as well as for mobility.
- **Reduced operation and maintenance costs** for the assets can be achieved by making better informed decisions.
- New **non-disruptive techniques for upgrade and maintenance** of infrastructure will help to achieve steady traffic flows.
- **New materials** to provide cost-effective strengthening capabilities to old infrastructures
- **Infrastructure needs to be resilient** to the effects of climate change and man-made hazards.

In addition, and as an overarching feature, **an efficient Asset Management process is needed** to ensure cost-effectiveness in planning, design, delivery, operation and maintenance of large infrastructures or infrastructure networks. Indeed, infrastructure asset management generally focuses on the later stages of a facility's life cycle, specifically maintenance, rehabilitation and replacement; risk-based approaches are not always integrated, and network resilience perspective is not implemented throughout the lifecycle, etc. and once such services are provided, there is not is not a harmonised approach for infrastructure asset management. A coherent and multi-modes framework is needed in combination with lean procurement methodologies, financial, economic and risk assessment modules: technological solutions and tools for smart governance, and risk-based delivery and management of TI.

In this sense, **Innovative Infrastructure Financing methods** are needed for the transport infrastructure of the future. Public and private collaboration within innovative funding schemes are needed to construct **High Level Services Infrastructure** able to serve tomorrow's mobility and to upgrade the existing one to the new service standards.

5.2.5 ECTP's REFINET Multi-Modal Transport Infrastructure Model

REFINET's main output, the **RMMTI Model**, is a high-level non-transport-mode specific model that serves as a living reference for objectives and sustained criteria for defining the design & operation specification of infrastructure projects in Europe, based on ECTP's High Level Service Infrastructure concept, for each transport mode. The model itself can be exploited in two main ways, as an infrastructure performance index and as guiding principle and strategy for the European multimodal transport infrastructure network for defining a long-term research and innovation programme for the European transport infrastructure. The RMMTI model is a 3-tier model with the layered levels as shown in the figure.

Figure 5.2: ECTP's RMMTI model structure

5.3 Materials

As part of the European Construction, built environment and energy efficient building Technology Platform ECTP, the Material and Sustainability (M&S) Committee developed a common Vision and Strategic Research Agenda for all construction material stakeholders as summarized in this Position Paper to provide insight into current and upcoming construction material related key-challenges that we strongly believe deserve to be addressed within FP9.

The Position Paper builds on 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. The paper also addresses an additional mission dedicated to evaluate, to ensure and to valorise the performance of the new material related innovations for sustainable constructions.

5.3.1 Priority topics FP9 2021-2027

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, using Life Cycle Analysis (LCA), applies to a broad range of construction materials used in different applications such as in buildings, cities, infrastructures, energy applications and possibly others. The focus must be directed toward both the reduction of embodied energy and of the energy in use, reducing the gap of CO2 emissions between (building) design and actual performance. Furthermore, materials to facilitate the energy transition to renewables must be pushed. This includes materials e.g. for new power plants and for energy transport and distribution.

Fig. 4.3 : 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)

Circular economy 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 production with circular economy principles. Innovation in resource efficiency needs to start at the design phase of a construction 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 on recycling, reuse, energy recovery and remanufacturing.

Competitiveness and economic viability

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 costs attributed to construction materials, the scope for applying advanced and more-efficient building materials is considerable, not only in use, but also at the level of production processes. A key factor for maintaining and improving competitiveness of the European construction materials industry is to analyse and reduce Life Cycle Costs (LCC). The development of materials contributing to reducing operational and maintenance costs as well as energy harvesting is an important topic for the construction industry.

Fig. 4.4 : Materials for additive manufacturing in construction (Source: TECNALIA-IAAC)

Health & safety

The provision of healthy and hygienic structures to live and work is a crucially important issue for the construction sector in the coming years. Considering the impact of materials on environment and health, much of this relates to the quality of the breathing air and ventilation particularly in offices and residential buildings. The development and application of functionalized covers or envelopes, such as nano-coatings, incorporating shelf-properties, is now a reality and significant further innovations in this area are expected over the coming decades. The development and industrial uptake of new functionalities, such as surface active materials, self-healing capacities, sensor technologies, thermal, sealing etc. are indeed still in their infancy. 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.

In addition, 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 and to mitigate the effect of natural hazards. Innovation in materials can also significantly improve safety of workers at the building site, by reducing the operational effects of heavy weights, repetitive movements, noise, vibrations etc. (e.g. light materials, improved prefabrication and joining technologies).

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 comfort of people, which influences productivity and wellbeing. Improved and smart materials can improve comfort of living (e.g. by automatically regulate thermal and moisture levels), well-being and user experiences considering all relevant dimensions of the Indoor Environmental Quality (IEQ), including air quality, visual performances, noise, subjective perception, etc.

Enabling robust and fast innovation in construction

This sixth "horizontal" mission is focusing on approaches enabling to evaluate, ensure and valorise performance of the (new) materials. Performance validation for structural and functional reliability of constructions is of paramount importance, including standardised accelerated aging tests, field exposure sites, living labs, mock-ups and monitoring pilots. The ultimate goal is to improve understanding and accurately model performances and service life. A systematic approach, including integration of design, material and LCA/LCCA via extensions of BIM models, is necessary to ensure successful valorisation of innovations in the built environment.

Fig.4.5: 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)

5.4 The specific European case of Cultural Heritage

A living cultural heritage for an attractive Europe

European cultural heritage is the testimony of our shared past and the root of our identity. It is a non-renewable & no-relocatable resource that enriches the collective memory, enabling Europe's future to be more humane for its population, so it should be conserved with care.

Cultural heritage not only provides people with a sense of identity and belonging, it also brings a large impact to many economic sectors such as tourism, cultural industries, urban planning, regional planning, arts and design. It enhances European competitiveness through technical innovation and traditional skills preservation and can also contribute to improving the EU's relations with other regions. The importance of cultural wealth can be measured in socioeconomic and environmental terms, such as growth in quality employment, increasing of well-being in unified communities, and reduction of CO2 footprint.

Spending on conservation of cultural heritage in Europe is worth an estimated €5 billion a year, driven by SME's. 40% of worldwide tourism has a cultural dimension[10], and therefore it represents an important part of the cultural and creative industries, which provide jobs for 8.5 million people in the EU (producing approximately 26.7 indirect jobs for each direct job[11]) and contribute up to 4.5% to Europe's GDP[12].

Through the Declaration of 2018 as European Year of Cultural Heritage[13,] the European Union has recognized that the ideals, principles and values embedded in Europe's cultural heritage constitute a shared source of remembrance, understanding, identity, dialogue, cohesion and creativity for Europe.

Cultural heritage in the context of the European city

The city is a strong determinant of where and how almost everyone lives, works and enjoys, and urban environment makes up citizen's way of life. It can be said that all business and social activities rely on the city, so its conservation condition and indoor environment is highly relevant for the quality of life. The ancient European city is the actual basis of the European identity and singularity, and the history of Europe can be read through the archaeological sites and old cities from the early European cultures until now.

The importance of the city to stop poverty, protect the planet, and ensure prosperity for all has been recognised by United Nations, in Goal Nr. 11: Sustainable cities and Communities: Make cities inclusive, safe, resilient and sustainable 14. Some key figures supporting this fact are:

- Half of humanity – 3.5 billion people – lives in cities today
- By 2030, almost 60 % of the world's population will live in urban areas
- The world's cities occupy just 3 % of the Earth's land, but account for 60-80 % of energy consumption and 75 % of carbon emissions

European cities are characterised by their historic building stock, with more than 40% of it built before 1960, and around 12% with historical value, 73% of these included in urban areas[15.] This means that our present cities should be adapted to the new socioeconomic, environmental and cultural trends, while preserving integrity and authenticity. This enormous challenge, even higher when addressing to cultural heritage buildings, can be only tackled by research & innovation.

[10] http://www.oecd.org/cfe/tourism/theimpactofcultureontourism.htm
[11] T. M. Nypan (2005), Directorate for Cultural Heritage, Norway; http:// www.nba.fi/tiedostot/b425fd75.doc
[12] Europa Nostra (2013): Europa Nostra support creative Europe. Position paper prepared by the Europa Nostra Board
[13] https://ec.europa.eu/culture/european-year-cultural-heritage-2018_en
[14] http://www.un.org/sustainabledevelopment/cities/. United Nations, NY (USA), (2015)
[15] World Urbanization Prospect-The 2009 Revision. United Nations. http://esa.un.org/unpd/wup/index.htm

Figure 4.6: Skyline of Santiago de Compostela (Source: EFFESUS project)

Research needs and goals

The importance of cultural heritage research has been recognised over the years in the EU framework programs by the European Commission, and a high number of methodologies, systems, technologies and materials frequently used at present to protect cultural heritage arise from previous EC research activities.

But protection of cultural heritage is in continuous evolution in terms of concepts, scope, approaches, methodologies and technologies. Cultural Heritage is no longer about restoration of symbolic heritage or the importance of a single asset, but it should be enlarged to include historic buildings and cities, cultural landscapes, modern architecture and other elements responsible of our European identity and history, where cultural heritage should be adapted to reach the citizen's requirements, in continuous evolution, while preserving its authenticity and integrity.

Considering cultural heritage as an essential part of our life, new approaches and definitions are needed: definition of cultural heritage in contemporary global environment, with special attention to its integration into the natural and urban environment through space planning, re-evaluation of current values of cultural heritage, implementation of heritage understanding into practice, and holistic approach to heritage protection , considering the interaction of immovable, movable and intangible heritage.

Preventive conservation is especially relevant with regards to deep restoration processes, following the same evolution as human health, that prioritize prevention and prediction to intervention. To implement this strategy, predictive decay models, monitoring technologies, non-destructive techniques, intensive 3D digitizing & modelling, and integral management systems should be developed.

A more holistic understanding of cultural heritage must be incorporated in the physical, political, public and professional society. Indeed, it is necessary to develop appropriate strategies to understand culture as a new economic sector of Europe that should be developed at local level.

Moreover, the contribution of cultural heritage for better environment should be considered, as it brings environmental benefits and the environmental protection through a reduction in raw materials consumption, pollution and waste, and increased energy saving. However, it should be also considered that climate change may significantly hinder cultural heritage.

Considering the above-mentioned needs, the main topics to be addressed by the Heritage & Regeneration Committee of the ECTP, have been blocked in 4 axes:

Figure 4.7: Priority areas in cultural heritage research. (Source: Own ellaboration)

LOW CARBON BUILDINGS: Historic buildings will only survive if maintained as living space, but this implies modern energy efficiency and comfort levels. Heritage research could provide best practice examples, sustainable traditional and new materials and restoration methods to re-use and improve existing buildings and their specific elements. The use of such solutions would generate an enormous saving of grey energy and an adaptive renovation to a better energy standard to protect the visibility and use of our cities and build heritage.

RESILIENCY AND CLIMATE CHANGE: Built cultural heritage need a strong enhancement of its resilience, due to its specific character and related preservation demand. In the past, decay was, except for acts of war, mainly due to natural weathering. During the 19th and 20th C, the scale of human direct damage to heritage objects (e.g. vandalism, illicit trade) also increased. Now, in the 21st C, climate change is expected to even more increase environmental load on cultural heritage. This asks for preventive conservation and effective maintenance including the mitigation of effects of foreseen climate change and man-made and natural hazards.

SMART CITIES: Achieving the whole power of cultural heritage as an enabler of sustainable development of cities requires a holistic technical and methodological framework of the whole urban area management, building bridges of understanding and compatibility between the existing building stock with cultural value and the current requirements of safety, habitability, environmental sustainability, support for the elderly, identity and well-being. The concepts of authenticity and new generation cities should be combined in the historic city by using research and innovation as key drivers of the enhancement of the historic city attractiveness for investment, living and leisure.

DIGITALISATION: Digitization of cultural heritage contributes to the preservation of movable and immovable assets since their virtual reproduction can make them accessible for future generations, could facilitate the diagnosis and management, and could improve efficiency of the restoration process. In order to make cultural heritage more handily, usable, transferable and sustainable, a huge applied research is opened on affordable and accurate digitization methods, modeling, interoperability and usability of content, terminologies, long term preservation, and long-term accessibility. A key objective is using the potential of cultural heritage for developing new digital services for professionals and citizens, allowing more interactivity and collaboration by implementing new digital management systems and openness of software tools.

SOCIOECONOMIC CHALLENGES: Socioeconomic issues are evolving every day, and therefore, the role of culture and cultural heritage in a changing society needs to be continuously shaped. On top of that, today, we are witnessing a marked shift in the development paradigm. New models of partnership and governance are being shaped. And this also affects cultural heritage management. The adaptation of these new paradigms requires a continuous innovation in technical and socioeconomic issues linked to cultural heritage, thus needing to develop new research priorities in terms of management, economic values, identity and multiculturality, involvement of citizens and new generations, and moving from theory to practical application.

Proposal for FP9

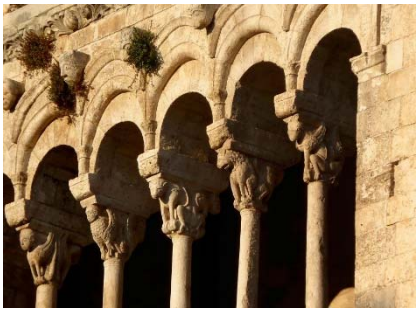


Figure 4.8: Detail of capitals. Puglia. (Source: ISAC-CNR)

The development of the research topics mentioned above and their implementation into practice requires an ambitious research program aiming at tackling cultural heritage needs. We therefore strongly promote cultural heritage research and development in the coming FP9 with all the interdisciplinary fields of research defined above. The cross-cutting approach of cultural heritage and its consideration as the fourth pillar of sustainability will contribute to a much broader scope: more prosperity for the citizens and better cohesion within the European society as well as a sustainable future for European cities.