Strategic Research & Innovation Agenda 2021-2027

APPENDIX DOCUMENT

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ANNEX 1: Detailed content of R&I topics

OBJECTIVE 1: CLEAN BUILT ENVIRONMENT AND CITIES

R&I 1.1 Energy renovation of buildings and upgrading of infrastructures

R&I topic	State of the art	Topic scope	Nature of activities required
Cost-effective multi-functional and/or prefabricated retrofitting technological packages, integrating RES	Prototypes for different types of prefabricated façade systems and adaptable packages (including RES) have been developed and demonstrated in real environment, thereby reaching an average TRL 6. **Projects:** *BRESAER, BERTIM, E2VENT, 4RinEU, HEART, HEATCOOL, HOMESKIN, REZBUILD, RECO2ST, RenoZEB, BuildHEAT, P2ENDURE, StepUP, IMPRESS, Be-SMART, Sunhorizon, tech4win, PVsites, EXCESS, PV-ADAPT, DREEAM,*	↘ **Certified, industrialised and market-ready multifunctional** (passive & active) **prefabricated turnkey packages** for retrofitting**, including RES** and, for instance: ○ Energy positive glazing for curtain walls and skylight ○ Solutions for energy demand reduction in summer (with e.g. natural and mechanised ventilation, nature-based solutions, etc.) ○ Passive solutions exploiting natural ventilation and/or solar energy ○ Compact, low cost solutions for energy storage at building and district level ○ cost-efficient non-intrusive BIPV elements for both new and renovated buildings ○ Functional, low cost Building Energy Management Systems for existing buildings, including historical ones, in particular for small and medium size buildings ↘ **Lean construction tools, protocols** and methodologies for deep energy renovation, including prefabrication or 3D printing allowing both mass production and customization, with a focus on **suitability for SMEs** ↘ Deep renovation solutions must include **an analysis of resilience** of the renovated building/infrastructure against major disruptive events, such as flooding and/or other climate-driven events and/or earthquakes	Integration & demo (scaling up and industrialisation) Framework (socio economic studies, standardization)
Certified sustainable and durable construction materials, including re-used and recycled materials	RDI projects have so far focussed on developing advanced insulation materials and nanotechnology-based materials, as well as reducing the embodied energy of more traditional materials (e.g. concrete) thanks to the integration of by-products. The missing	↘ Development of a **common EU procedure to fast-track the process of technical quality control, standardization and certification** of new materials and components ↘ **Material labelling according to lifecycle performance**, including CO_2 footprint (with cradle to cradle approach) and preventing "hidden" ecological impacts ↘ **Novel and multifunctional materials with improved life cycle**, long service life, designed for (in situ) enhancement, re-use and/or easily recyclable	Integration & demo (scaling up, industrialisation) Framework (labels, standards, certification)

	standards and lack of market acceptance of new materials is often a bottleneck in the innovation process. **Projects:** *PROGRESS, InnoWEE, Holisder, Plug N Harvest, EFFESUS, ISOBIO, ECO-BINDER*	↘ Protocol (and the related label) for the **non-destructive evaluation of reusable components** ↘ **Low carbon and durable solutions and materials for retrofitting**, including cultural heritage (low tech, bio-based, locally sourced, or innovative materials compatible with traditional materials) *Points related to the integration of waste are listed in 1.3.*	
Optimal solutions to adapt existing infrastructures to new transport patterns	New mobility patterns and clean transport are being tested by Smart Cities projects, including e-mobility, traffic fluidisation. **Projects:** *MySmartLife, STARDUST and other SCC01 projects, RESIN, TRIANGULUM*	↘ **New technologies for the adaptation of existing transport infrastructures**, including the integration of charging infrastructure for e-mobility ↘ **Decision support tools** supporting the development of robust adaptation strategies for infrastructure (including the supporting geostructures) to adapt them to multimodal, low carbon mobility needs	Integration & demo (scaling up, industrialisation) Framework (standards, certification)
Green procurements and new business models for renovation supported by decision-making tools	Holistic and integrated business models (in particular One Stop Shop, Energy Performance Contracting) and smart financing initiatives (e.g. green mortgages, third party financing) have been successfully demonstrated but their uptake and replication are slow and the perception of investment risk remains high. **Projects:** *MODER, GREEN INSTRUCT, CITYnvest, iBROAD, EeMAP, EuroPACE, Step UP, QualitEE, I.MODI, TRIANGULUM*	↘ **New green procurements** to accelerate deep renovation of buildings and the renovation/ adaptation of infrastructures to new transport solutions, with e.g. tax incentives, labels. Applications for **low cost social housing regeneration** ↘ **Scale-up of integrated user-centred renovation services** involving all relevant stakeholders in the value chain (design, financing, suppliers, contractors, utilities, etc.) ↘ Tools based on digital twins to **secure renovation investments by reducing the performance gap** and lowering the investment risk ↘ **Socio-economic studies** to better understand and quantify the **non-financial co-benefits** of renovation for buildings and infrastructure (social e.g. health, comfort, well-being, productivity, and environmental) and develop multi-vectoral Cost Benefit Analysis ↘ **New contractual models** for commissioning and to extend the developer/ contractor responsibility for long-term efficiency ↘ **District decision-making tool** for assessing the energy performance and **planning renovation at district scale**, using for instance cadastral data	Integration & demo (scaling up) Framework (socio economic studies, business models)

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

R&I topic	State of the art	Topic scope	Nature of activities required
Smart-grid ready and smart-network ready buildings, acting as active utility nodes	Solutions have been piloted for smart-grid ready buildings (with e.g. demand response, on-site RES optimisation) **Projects:** *THERMOSS, BIM4EEB, DRBOB, FC-DISTRICT, HOLISDER, E-HUB, EPIC-HUB, RESILIENT, ODYSSEUS, TRIANGULUM*	↘ **Solutions** enabling a **seamless and flexible integration of buildings to the energy grid as prosumers**, taking into account the building users and occupants ↘ Solutions enabling a **better integration of buildings to the city networks**, in particular **water and wastewater**, to encourage the local re-use of water, as well as an optimised management of wastewater and rainwater (solve sanitary issues, economic competitiveness of solutions, standardisation) ↘ **Integration of BIM with energy modelling** and simulation at building level and district level	Integration & demo (scaling up, industrialisation) Framework (business models, standards)
Interoperable components for positive energy blocks and districts, including a better integration of local renewables	- Pilots for dynamic exchange of energy (heat, electricity) between buildings - Pilots of Energy Hub, Virtual Power Plants, microgrids **Projects:** *E-HUB, EPIC-HUB, RESILIENT, DREEAM, Be-SMART, FC District, Bricker, RESPOND, RENNOVATES, Plug-N-Harvest, +CitiesXChange, BEAMS, SEEMPUBS, Cityfied, CITYOPT, ZERO-PLUS, TRIANGULUM*	↘ **Energy sharing platforms and services**, connected to local energy markets, including demand response, EV integration, RES integration at building to district scale ↘ **Modular, versatile, flexible and standardised solutions**, well integrated to the local environment, buildings and cultural heritage, for **energy generation at district level, including BIPV** ↘ **Market and regulatory ready solutions for micro-grid** to share self-produced energy within blocks buildings ↘ **Smart financing and new business models for the integration of RES** (e.g. shared ownership, energy communities), including **raising awareness** and **building up skills** in the construction value chain	R&D Integration & demo (scaling up, industrialisation) Framework (business models, training)
Multi-modal transport hubs and urban mobility infrastructures	**Projects:** *HighLite, +CitiesXChange, SEAM4US*	↘ **Integrated design and operation** of future ground and underground transportation infrastructures that take into account environmental impacts (air quality, noise, vibrations, etc.) ↘ **Industrialised construction processes** for the development of new multimodal transport hubs, minimizing the disruptions and impacts to the urban activity and environment ↘ **ICT tools for mobility optimization (with lifecycle approach)**, with smart control between the electricity grid and transport grid ↘ **Business models for EV charging points** in all office, commercial and multitenant residential buildings	R&D Integration & demo (scaling up, industrialisation) Framework (business models)

Uptake of performance contracts	- Projects to make EPCs models more accessible to SMEs, and more attractive for the residential sector **Projects:** *Step UP, NOVICE, EPC+, Cityfied*	↘ Measures to **accelerate and scale up the adoption of energy performance contracts** (incl. commissioning) ↘ Development of **enhanced EPCs with longer commissioning and condition-based maintenance** to replace maintenance contracts ↘ Development of **EPCs for the residential sector**, valorising both energy efficiency and flexibility (through demand response)	Framework (business models)

R&I 1.3 Life Cycle Approach and Circular Economy

R&I topic	State of the art	Topic scope	Nature of activities required
Integration of construction and demolition waste in new constructions and industrial symbiosis	- Prototypes of materials with reduced embodied energy thanks to the integration of waste and other secondary materials **Projects:** *HISER, RE4, VEEP, FISSAC, PAPERCHAIN, BAMB, MAESTRI, SO-WHAT, STREAM-0D, SUS-CON, VEEP, InnoWEE*	↘ Demonstration of multiple **CDW (Construction & Demolition Waste) reuse technical and economic viability** at regional level (CDW streams, protocols and guidelines), with e.g. exchange platforms and services ↘ **New instruments** (financing, green procurement, labelling, standards, BREFs & guidelines) **to stimulate the integration of CDW** (and other waste) **business in the construction ecosystem**, with better valuation of the externalities of waste management and better understanding of local resource streams ↘ Improved **reuse of CDW fines** ↘ **Modelling of performance and ageing** of materials that incorporate waste ↘ **CDW quality control** (esp. with regard to unwanted contamination) ↘ **Innovative routes to recycle/upcycle waste and residue streams from one industry into raw material for the others**, e.g. use of other sectors' by-products (e.g. steel slag) for the production of new construction materials (e.g. cement or other eco-materials (e.g. geopolymers) ↘ **Validation at real scale of industrial symbiosis strategies** to be applied in the construction sector	Integration & demo (scaling up & industrialisation) Framework (business models)

More sustainable materials with reduced embodied energy and high performance to reduce the life cycle cost	- Prototypes of materials integrating waste and residues - Prototypes of enhanced materials (e.g. concrete) with reduced embodied energy and/or life cycle cost **Projects:** *INNOWEE, RE4, VEEP, RE4, SESBE, BRESAER, LORCENIS, ENDURCRETE, ECO-BINDER, MASTRO, HEALCON, REINVENT, SUSCON*	↘ **Locally sourced bio-based materials** with low carbon impact and capturing/ storing CO2. **Modelling** of their insulating, acoustic and hygrometric performance and ageing. **Mechanisation** of their application. ↘ New design and construction techniques using **less materials** (in weight) ↘ **New design** and manufacturing techniques for **innovative prefabs and multifunctional materials** (including recycled materials such as CDW), with large-scale demonstration of performance (energy, durability, protection against fire) ↘ **Advanced multifunctional materials and components with optimal recycling and re-using potential** (e.g. through new designs enabling the re-use) ↘ **New routes for the low energy production of traditional materials** (e.g. glass, steel, cement, ceramics), with energy auditing of production processes as part of the overall energy performance assessment (i.e. to account for the embodied energy in the final carbon footprint)	R&D Integration & demo (scaling up & industrialisation) Framework (business models)
Tools to facilitate the life cycle-based approach	- Prototypes of materials developed with a life cycle approach with demonstration on single buildings - Recommendations for a harmonised LCA methodology **Projects:** *Re4, Open heritage, DESIGN4ENERGY, EEBGUIDE, InnoWEE*	↘ **New standards/models for building design with life cycle & circular approach**, which also account for **summer comfort** (with e.g. more performant natural and mechanised ventilation) and integrates data on future climate conditions and risks (**adaptation to climate change**) ↘ Improvement of the **integration of holistic building assessments in Green Public Procurements**, with e.g. building certification (e.g. LEED, BREEAM, DGNB, HQE), to stimulate circular economy) that takes into account LCA ↘ **Rich and open datasets for LCA** in the construction sector, with clear methodologies and multicriteria techniques (including reference service life of buildings and their components, end of life scenarios) ↘ **Digital representation** including 3D geometry, performance and all material properties required for LCA modelling ↘ **Multicriteria decision-making tools for investments** including full environmental impact (LCA/ LCC), with CO_2 reduction as a leading principle ↘ Improvement of the **understanding of user-interactions with the built environment and public spaces** (design choice, behaviour, long-term well-being)	Framework (standards, economic studies)
New approaches to circular economy and nature-based solutions	- Prototypes of bio-based materials and NBS with demonstration on single buildings	**Holistic approaches for the integration of circular economy and nature-based solutions (NBS) at the scale of building blocks and districts**:	Integration & demo (scaling up & industrialisation)

	Projects: *ISOBIO, Osirys, Ribuild, NATURE4CITIES, URBANGREENUP, UNLAB.*	↘ NBS in cities (**green spaces, water systems, innovative heating and cooling networks allowing to cope with heat rejection into outdoor air)** to **reduce the heat island issue** and improve heat control ↘ NBS and **green corridors** to reintroduce **more biodiversity in cities** ↘ Validated and replicable approaches and **decision-making tools for the implementation of NBS** (valuation of overall impacts, including on biodiversity) at building and district scale ↘ **Policy recommendations** (for instance on mandatory share of recycled materials or nature-based solutions in new buildings) ↘ Solutions for the **integration of food production** within the built environment	Framework (policy recommendations, business models)

OBJECTIVE 2: BUILD FOR AND WITH THE PEOPLE

R&I 2.1: Participative and dynamic built environment

R&I topic	State of the art	Topic scope	Nature of activities required
Solutions to foster dynamic and participative urban planning, down to building level	- Applicable findings from social sciences and REX from urban planning projects to involve citizen and manage co-creation processes, - IT tools developed to manage participative processes - IT tools available for awareness and education purposes (virtual, augmented reality) **Projects:** *RIBuild, ROCK, nature4cities, Heritage and Threat - HeAT, ARCHES, CHIME, COURAGE, EHRI, EMOTIVE, Imareculture, meSch, TRACES; APRILab; b-part; CAPA.CITY; CIVIC, UNALAB*	↘ **Scale up the use of digital systems** and social sciences findings to involve stakeholders and citizens in participative urban planning & design ↘ Scale up the **use of tools fostering awareness and education of citizens** as members of the city community (including the accessibility to Cultural Heritage via virtual reality, etc.) ↘ Scale up of initiatives such as one-stop-shop increasing awareness raising and actions towards renovation ↘ *see also priority 2.2 on co-creative processes within the overall ecosystem*	Integration & demonstration / framework
Interactive operation and management of city assets	**Projects:** *Select4cities, HERACLES, HERITAMUS, PLUGGY; C3PLACES; CIVIC; DESENT; GUST; IP-SUNTAN*	Use of **digital tools and apps** to: ↘ support **new services for the citizen and the city** (transport, health, car parks, waste management) ↘ **involve stakeholders and citizens in monitoring and maintenance of buildings**	Integration & demonstration / framework
Solutions for the regeneration of urban and rural areas	Numerous ongoing research and tests regarding regeneration strategies **Projects:** *CLIC, HERCULES, SHELTER, TRACES, ROCK, EFFESUS, 3S RECIPE, BRIGHT FUTURE, UNALAB*	↘ New urban development and **'smart growth' models** ↘ New approaches to provide a **better connectivity and a new dynamism to rural and peri-urban areas** (“smart villages”) ↘ Novel strategies to **increase well-being and economic prosperity** of citizens living in cities and in the rural areas ↘ *For participative urban planning see R&I 2.1* ↘ *For points specific to Cultural Heritage see R&I 2.4*	Framework (business models, socio-economic studies)

R&I 2.2: Inclusive and affordable built environment

R&I topic	State of the art	Topic scope	Nature of activities required
New designs of buildings, infrastructures, multimodal hubs and public spaces for accessibility and inclusiveness	***Projects**: C3PLACES; CONCOORD;*	↘ **optimal locations** for transport assets for accessibility and inclusiveness (for passenger and freight activities) ↘ design of infrastructures to **improve the access to different types of facilities and amenities**, and reduce the commuting time (environmental insertion approach) ↘ **holistic platforms for sharing services** including transport services *see participative urban planning and design in R&I 3.1*	R&D
Solutions for the ageing population, including new services from home	- Ongoing development of a certification framework related to ageing at home - Numerous development projects on robotics-based and sensor/IT based solutions to prolong autonomy at home ***Projects**: FARSEEING; PROGRESSIVE; HOME4LIFE; City4Age; CODALoop; HEART; I-SUPPORT; GrowMeUp; RADIO; SILVER; ACTIVAGE; eWALL…*	↘ Development of **new services from home**, based on the integration of functionalities within the built environment (surveillance and monitoring of elderly, provision of health treatments, interactions, logistical support….) ↘ **Better accessibility of the built environment and public spaces** with **seamless living and mobility patterns** (i.e. continuum of uses) ↘ Scaling up of **KPIs and certification framework for age-friendliness** of built environment, taking into account its potential to evolve ↘ Integration of **ICT-based functions** in the built environment to better involve the elderly ↘ Tools to assess and monitor the progressive implementation of age-friendliness criteria in local/national regulatory environments	Framework, Integration & demo
Financing schemes and business models for holistic renovation services (energy, accessibility, comfort)	Diverse innovative financing mechanisms have already been developed and are implemented across Europe. **Projects**: *STUNNING, iBRoad, EuroPACE, Energiesprong / Transition Zero, Oktave…*	↘ Enhancement and replication of the different financing and incentive mechanisms created and tested on local scales, to **make renovation affordable** ↘ Socio economic studies to **understand barriers at end user level** ↘ Targeted **marketing and awareness raising campaigns**	Framework

R&I 2.3: Healthy and comfortable built environment

R&I topic	State of the art	Topic scope	Nature of activities required
Solutions for healthier indoor and outdoor environment (air quality, safety, comfort) from building to city scale	Numerous ongoing technology developments, at diverse maturity stages **Projects***: EnDurCrete; BREATHE; CASUAL; CITYFOOD; DeSCIPHER; Financing Clean Air; Vertical Green 2.0, UNALAB*	↘ **solutions improving acoustical, thermal and hygrometric comfort**, natural and artificial **light**, minimizing vibrations and electro-magnetic fields, providing **pollutants monitoring and filtration** (e.g. filtering of smokes from biomass heating) ↘ Use of **nature-based solutions** ↘ **Self-cleaning**, self-healing, anti-slip and anti-fouling materials ↘ New materials and solutions that **diminish urban heat island effect**, including revegetation, and related **certification systems,** as well as innovative heating and cooling networks allowing to cope with heat rejection into outdoor air ↘ **Revegetation** as a support to biodiversity (technical solutions and new governance) and resilience (e.g. heavy rains) (“renaturing cities” concepts) ↘ See also R&I 1.3	Integration & demo
Solutions for smart and responsive buildings exploiting an improved knowledge of user experience (Building as a service)	- Numerous ongoing technology developments, at diverse maturity stages. Integration mainly at demo level so far. - Ongoing EU work on Smart Readiness Indicator for Buildings **Projects***: HEART; BESMART, SUSTAGE; HEAT4COOL; MOBISTYLE*	↘ **Data analytics and self-learning algorithms on users preferences** ↘ **Active and adaptative skins** ↘ **Sensors and actuators embedded** in the built environment; Smart and responsive thermostats ↘ **Real time comfort measurements**	Integration & demo
Low-disruptive construction and retrofitting processes	**Projects**: *CIVIC*	↘ Use of **4D BIM** with what-if scenarios and analysis of alternative solutions considering costs, energy performance and disruption to users ↘ Low disruptive and cost-effective construction processes using **pre-fabrication** ↘ *See also R&I 3.1*	

R&I 2.4: Living cultural and historical built environment

R&I topic	State of the art	Topic scope	Nature of activities required
Solutions for a more open, accessible and inclusive cultural heritage	- Market available ICT technologies - numerous ongoing projects related to Cultural Heritage apps **Projects**: *CLIC; RURITAGE; OpenHeritage EFFESUS, PLUGGY, EMOTIVE*	↘ Use of **ICT technologies** to allow **increase accessibility and inclusiveness** of cultural sites (3D modeling, virtual reality, augmented reality), ↘ **New cultural contents, services and 3D digital reconstruction** of cultural assets for public access ↘ **"Open sites"** to citizens/tourists enabling a better understanding of interventions for the preservation of monuments ↘ Approaches to foster a better understanding by citizens of cultural heritage and its **sociocultural value**	Integration & demo
Solutions for a low carbon, resource efficient and resilient cultural heritage, from prevention and monitoring to maintenance and retrofit	Ongoing R&D projects investigating solutions dedicated to cultural heritage restoration and preservation **Projects**: REBUILT, STORM, Iresist, HERACLES, PROTHEGO, *RURITAGE; OpenHeritage*	↘ Strategies and tools for the **adaptation of cultural heritage to new uses** when no longer serving the original functions, while maintaining its cultural value ↘ Open source data base of **heritage relevant materials** ↘ **Cost-efficient retrofitting solutions** for historic buildings to reduce the risk of cultural heritage loss ↘ **New ecodesign standards/requirements for heritage maintenance** and retrofitting (including LCA and BIM) ↘ Tools for **predictive maintenanc**e tailored to Cultural Heritage specificities; ↘ Sustainable solutions for **improved resilience, durability and safety** of historical buildings ↘ Recovering and adaptation of **ancient construction techniques and materials** for sustainable restoration ↘ More extensive **protection, preservation and valorization strategies** of cultural heritage (e.g. as a mitigator of social pressures in multicultural environments)	R&D, integration & demo
Sustainable tourism strategies compatible with conservation of cultural assets	Ongoing R&D projects about sustainable tourism and people's perception on and relationship to Cultural Heritage **Project**s: *CLIC, HERCULES,*	↘ **Sustainable tourism strategies** at local, regional, national and transnational level, increasing local economic development, while respecting and improving citizen's way of life ↘ Development of **monitoring campaigns** to measure the influence of the massive tourism in the interior climate of built heritage	Socio-economic studies

OBJECTIVE 3: PROSPEROUS ECOSYSTEM

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

R&I topic	State of the art	Topic scope	Nature of activities required
Standardization framework and progressive regulation	Complex standardization frameworks in the overall construction processes, but framework missing on data exchange. Regarding data: Open standards are so far poorly adopted, and proprietary data formats and languages still dominate the market.	↘ Develop and generalise a **standardization framework for data, models, exchange protocols**, for testing methods for innovative materials and products ↘ Tackle certification barriers in Europe (**transferability, interoperability, mutual recognition of certificates**). ↘ Scale up approaches for the **progressive implementation of regulation** with prior local tests with early adopters	Framework
Automation and mass-customisation of design and manufacturing processes	- Technologies available on market: sensors, IoT, process data analytics tools, - Ongoing R&D on construction-specific applications, like automated design and construction assistants; **Projects***: SWECO; Bots2ReC; DFAB HOUSE; BUILT2SPEC*	↘ Develop, test and scale up **new smart manufacturing processes** such as modular off-site construction or prefabrication, pop-up factories, 3D printing, generative design, integrating Artificial Intelligence and automated lean measurement ↘ Design manufacturing processes for highly automated environments (swarm robotics; "design from manufacturing") and the related governance and regulation principles ↘ Novel designs incorporating multifunctional material elements produced by Macro 3D printing techniques. This topic includes the construction of elements with the following properties: Self-healing, heat storage, etc... ↘ Ethic assessment and impact assessment of the transition steps to construction 4.0	R&D; Integration & demo
New services for on-site/off site surveillance and monitoring of buildings and infrastructures in construction and in use	*Id* **Projects***:* BUILT2SPEC; ACCEPT; HEPHAESTUS; RIMAROCC, ROADAPT, INTACT	↘ Integrate the use of **drones, sensors, IoT** to develop new on-site processes and services, including **safety, surveillance and quality control** ↘ Risk and observational based design and maintenance, for a better understanding of the behaviour of resilient infrastructure (including the supporting geostructures) ↘ New approaches, tools and sensors to **speed up the quality controls for the reception of the building works** and minimise downtime	Integration & demo

Tools for better-informed decision making and risk management	*Id* **Projects**: *SUSTAGE; Intelligent Communities Lifecycle; SPHERE*	↘ Coupling of **sensors, data collection and data analytics tools** to provide new **optimization and decision-making support** on logistics, production processes, tracking, building operation, etc ↘ **Transparent, decentralised ledger e-market place** for the broking of materials and/or services, allowing full traceability of transaction, materials and interactions ↘ Modern technologies for soil investigations, permanent monitoring and new methods for soil parameter interpretation (e.g. advanced numerical design methods, machine learning, etc.).	Integration & demo

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

R&I topic	State of the art	Topic scope	Nature of activities required
Designs, materials and solutions to improve resilience, preparedness & responsiveness of the built environment to disruptive events	Numerous ongoing projects addressing resilient cities **Projects**: *INTACT, INFRARISK, RAIN RIBS; SMART MATURE RESILIENCE; RESIN; RESCUE, …*	↘ **Metrics** to quantify resilience ↘ **Advanced, enhanceable materials and technologies** for increased durability, resilience and adaptability of buildings and infrastructures, including their foundations. ↘ **Monitoring and early warning systems**; mitigation strategies; ↘ **Real Time monitoring** and control systems for transport networks (standardization and technologies e.g. instrumented vehicles): digital resilience (cybersecurity; mitigation for uninterrupted service) ↘ Integration of **contingency planning** within urban planning ↘ **BIM and interoperable tools for monitoring, detection of critical situations**, support to reaction processes, evacuation of people and first responders ↘ **Self-sensing materials**, materials with **embedded sensors**, durability and calibration of these sensors ↘ integrated solutions for the design and/or renovation of buildings, infrastructures and urban spaces aimed at improving their climate resilience (to natural disruptive events such as earthquakes and/or floods and/or extreme climatic events). This should also include the design of ecosystem services to be provided by buildings and infrastructures.	R&D Framework, Integration & demo

Designs for increased flexibility, adaptability and scalability of the built environment	Emerging approaches on resilient by design"; "flexible by design"; Reversible Building Design **Project:** *BAMB; SUSTAGE*	↘ **Design criteria** for building flexibility, adaptative buildings (including to climate change) ↘ **Methods for risk assessment** of the impacts of natural hazards on the built environment (floods, drying out of soils)	R&D
Predictive and integrated maintenance solutions and processes	- prediction models with limited reliability - on the shelf technology for real time monitoring - several ongoing EU R&D projects for predictive maintenance tools, not specific to construction or built environment **Projects:** *SUPREME; PROPHESY; PreCoM*	↘ **Modelling** of the **impact of ageing, natural hazards, man-made threats** on the built environment; prediction of performances over whole life cycle ↘ Integration of **IoT, sensors, automation systems for smart monitoring** and automated maintenance in manufacturing processes and in the built environment ↘ Non-destructive diagnosis: development and validation of an integrated, robust and non-destructive evaluation system (e.g. integration of different type of non-destructive techniques – *ultrasounds, infrared cameras, etc.*) to be calibrated and correlated to destructive test	R&D, Integration & demo
Lifecycle-based asset management and holistic approach of infrastructures	Ongoing initiatives for common framework for LCA-based Asset Management, focused on transport infrastructures **Projects***: AM4INFRA; RAGTIME*	↘ New **risk management tools and approaches**, including new governance systems and **collaboration with the insurance industry**. ↘ **Asset management and life cycle approaches** to optimise costs of resilience of (transport) infrastructure networks ↘ Develop holistic approach of infrastructures by **linking with other networks** (district heating, water supply and sanitation, flood defence, transport and energy infrastructures)) ↘ Develop "Circular by design" approach and tools	R&D

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

R&I topic	State of the art	Topic scope	Nature of activities required
New public and private procurement approaches supporting the implementation of	-Guidelines and tools on Procurement of Innovation (EC; SCI on sustainable construction (ICLEI; EAFIP) and performance-based contracts	↘ Improvement of the **performance of public procurement process** (speed of handling the process for instance with AI evaluation, increase quality, timing, efficiency). ↘ Approaches to **open up the market** for innovative technical, financial solutions and business models.	framework

innovations and the performance-based contractual approach	**Projects:** *SCI network, eafip, STOPandGO; guarantEE*		
New processes, business models and financing mechanisms supporting integration within the construction value chain and with other sectors	**Projects:** *STUNNING; CLIC; ROCK*	↘ New **business models, financial schemes and incentives to support investments** in infrastructures ↘ New **business models for private/ end-user investment** in cultural heritage for a better management of assets (preservation and restoration) ↘ **Supply chain integration tools** (platforms) ↘ Full demonstration on real building processes and sites of the benefits related to the **implementation of integrated and participatory design and delivery processe**s, against business as usual baselines. ↘ **Smart home services** combining IT actors and traditional construction players ↘ **Packaged services on renovation**, from financing to performance monitoring and services ↘ **One-stop shops concepts** on B2B and B2C (renovation, materials…)	Framework, integration & demo
Tools for better-informed decision making on investments and improved risk management	- Worldbank and OECD frameworks on Infrastructure Prioritization and governance - available data analytics and AI tools for analysis and predictions, not specific applications to construction **Projects:** *SUSTAGE*	↘ **Data collection and analytics tools** (big data, AI, Machine Learning) to support decision making and prioritization on investments (risk assessment, long term prediction)	R&D, integration & demo

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

R&I topic	State of the art	Topic scope	Nature of activities required
New digital capabilities training for the sector, both at basic background and highly specialised levels	**Projects**: *buildup skills, EIT Digital; BIMzeED; BIMplement;*	↘ Reinforce **training and education networks & platforms** about digital tools for construction.	Framework

Renewed academic curricula to adjust to industry needs, sustainability targets and a new culture of performance-based commitments, which exploit the full attractivity potential of ICT tools	Training and education networks & platforms on innovation in construction, energy efficiency, sustainability performance targets. **Projects**: *buildup skills; ICARO; CONNECTARCH, ICARO*	↘ **Upgrade academic curricula in content** (performance-based approach, new technologies for energy, health, resilience, LCA approach, asset management, BIM, smart construction, smart built environment, integrated approach to problem solving) ↘ **Upgrade academic curricula in format**, by integrating ICT tools (e.g. virtual reality for to simulate situations and work on problem solving)	Framework
Co-creative processes with all workers in the ecosystem.	- Health and safety worker engagement toolkits - ongoing research on benefits of participative processes in construction	↘ Integrate value **co-creation processes** through more participatory practices: integrated design & delivery solutions, integrated project delivery, participative design ↘ Scale up solution and techniques for **workers engagement in health and safety management** (job Safety Analyses, Site Inspections, reporting of incidents, Problem-Solving …) ↘ *see also priority 2.1*	Integration & demo

OBJECTIVE 4: DIGITALISATION

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

R&I topic	State of the art	Topic scope	Nature of activities required
EU-wide open databases and Data Management Platforms on the performance of the built environment	- Access to data is today complex and fragmented - Variety of platforms/ data repository and format used (providing aggregated data) - Proposition of common data frameworks **Projects:** *SPHERE, MODER, BESOS, CAMPUS21, EXCEED, NRG4CAST, PERFORMER, swimming, BIM-SPEED, BIM4EEB, READY4SMARTCITIES*	↘ **EU-wide open observatory on the existing building stock**, database on buildings and districts energy profiles ↘ **EU-wide open database on the vulnerability** of infrastructures and buildings ↘ **Data management platforms**, with robust models and data management procedures	R&D Integration & demo (scaling up & industrialisation) Framework (business models)
Big data-based building and infrastructure real-time management, monitoring and maintenance, including cultural heritage	- Prototypes of Digital Twins - BIM used in the planning and construction phase but not in operation/maintenance - No full interoperability between software, sensors, etc. (e.g. IFC standard not fully functional) **Projects:** *SPHERE, STARDUST, HIT2GAP, HOLISDER, RESPOND, HEAT4COOL, TABEDE, ODYSSEUS, TRANSFORMER, TRIBUTE, RETROKIT, RESILIENT, READY4SMARTCITIES*	↘ **Real-time Digital Twins** to reduce the performance gap, **BIM platforms** ↘ **Artificial Intelligence** for optimised building control, Smart Grid integration (Demand Response), risk-based (subsoil) condition assessment and predictive maintenance, fault detection ↘ **High-resolution calibration of physics-based models with big-data** (to better describe flexibility, energy performance and comfort) ↘ **Interoperable, plug& play and robust ICT systems**	R&D Integration & demo (scaling up & industrialisation) Framework (business models)
Digital decision-making tools on investment options	- Prototypes of decision-making tools, but running on partial datasets **Projects:** *ENCORE, NEWBEE, URB-GRADE, HIT2GAP, RenoZEB, EEPOS, OptEEmAI*	↘ **ICT and AI algorithms for decision-making** on investment in transportation infrastructure ↘ **BIM-based digital tools for renovation optimisation** and investment de-risking	R&D / Integration & demo (scaling up industrialisation) Framework (business models)

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

R&I topic	State of the art	Topic scope	Nature of activities required
Holistic data-based approach, from tendering to the end of life	- Prototypes of decision-making tool for planning - BIM-Based quality check - Marketplaces bringing together building owners and SMEs **Projects:** *BUILT2SPEC, BIM4REN, BIM-SPEED, NewBEE, ECODISTR-ICT, URB-GRADE, NRG4CAST, PERFORMER, MOEEBIUS, HIT2GAP, SPHERE, TOPAS, Accept*	↘ **Interoperable tools** (with BIM, IoT, data analytics, AI) and systems along the value chain ↘ **BIM-based marketplace** bringing together all the stakeholders ↘ **BIM adaptation for life cycle management and circular economy**, including the tracking of building materials ↘ **BIM adaptation** and roll-out for **cultural heritage** ↘ **Supporting activities for the widespread adoption of BIM** (guidelines for BIM implementation at scale, contribution to standards, sharing of knowledge and experience) ↘ **Data collection, storage and processing on materials and compounds** to predict durability, facilitate reuse and recycling	R&D Integration & demo (scaling up & industrialisation) Framework (business models)
Digital innovation in procurements	- Pilot initiatives at EU and regional scale to validate new schemes for procurement of innovations - Smart contracts and blockchain approaches at prototype scale	↘ **Micro-payments**, automated payments with **smart contracts** ↘ **Blockchain based platform/ marketplace**	R&D Integration & demo

R&I 4.3 Data privacy and security

R&I topic	State of the art	Topic scope	Nature of activities required
Data-based value-added services preserving privacy and security	**Projects:** *SPHERE*	↘ Methodologies and algorithms to **differentiate between community and private data** and **guarantee the privacy** of sensible data with full **transparency** for users ↘ **Standardisation aspect for energy data sharing**, guaranteeing security and anonymization of data (incl. open protocols for equipment control and data exchange) ↘ **Secure data repositories** enabling the access to anonymised data as a basis for new value-added services	R&D Integration & demo (scaling up & industrialisation) Framework (socio-economic studies)

		↘ Social sciences to facilitate the **uptake of data-based services**	
Vulnerability and cybersecurity of digital assets		↘ Digital tools **resistant to cyberattacks** to guarantee the security of digital assets and data (redundancy, resilience)	R&D / Integration & demo (scaling up & industrialisation)

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

R&I topic	State of the art	Topic scope	Nature of activities required
Integrated Information Modelling at district and city level	- CityGML: open data model and XML-based format for the storage and exchange of virtual 3D city models **Projects:** *BIM4REN, OPTEEMAL*	↘ **Integrated district level modelling** (e.g. base on cityGML), including buildings, infrastructures and other networks and covering flows of energy, people, water, waste, data, **to maximise synergies and improve resilience** ↘ Development and deployment of **Transport Infrastructure Information Modelling interoperable with BIM**	R&D Integration & demo (scaling up & industrialisation)
Development of integrated, multi-modal and multi-stakeholders travel information models		↘ Distributed and interoperable sensors and AI for **real-time multi-modal travel information** ↘ New value propositions and enabling tools for **seamless travel experience** and effective mobility of people and goods ↘ Tools using travel information to **assess the impact of e-mobility on the local electricity network**	R&D Integration & demo (scaling up & industrialisation) Framework (business models)

ANNEX 2: SRIA Elaboration process

The development of the SRIA followed a process adapted to the complexity of the topic, including the steps listed below and illustrated Figure 1:

- Definition of an integrated and shared **long-term vision**, taking into account the "mega-trends" challenging the construction sector and the built environment,
- Definition of **goals** underlying this vision,
- Definition of **mid-term objectives** and associated quantified **targets** to meet these goals,
- Identification of **barriers** to be overcome to achieve these targets, and of the **drivers** that can act as points of leverage,
- Identification of R&I needs to overcome the barriers, and clustering in R&I priority areas,
- Proposition of **R&I topics** and their deployment agenda (i.e. detailed technology roadmap).

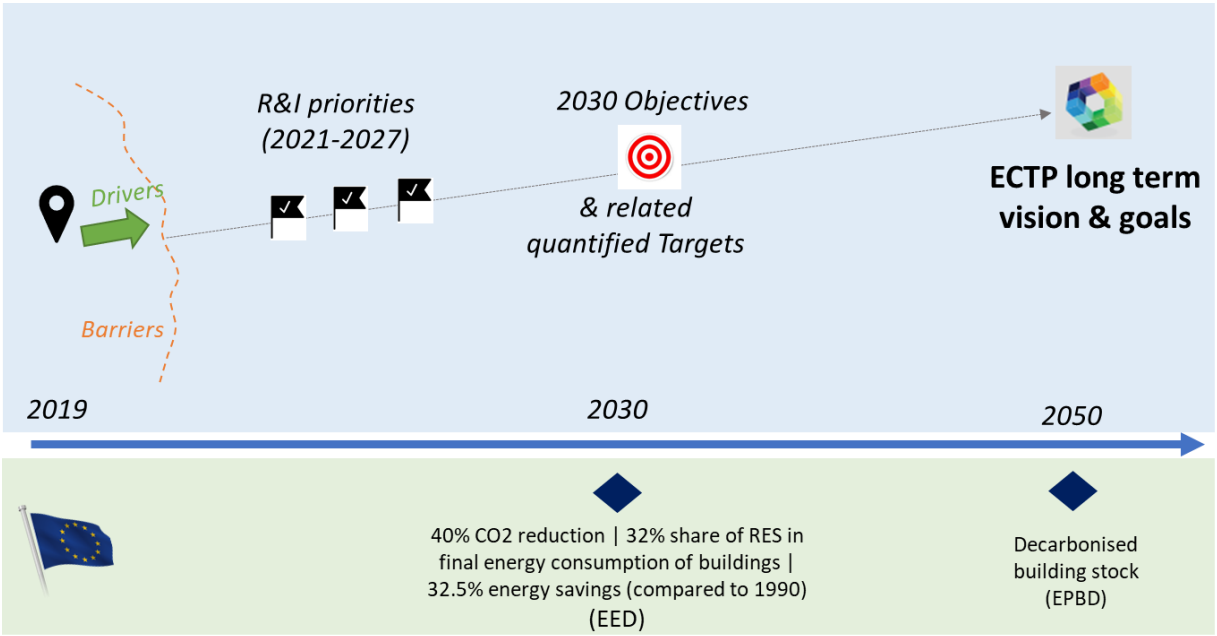

Figure 1 : Structure of the SRIA and phasing with main EC regulatory targets

To ensure that the SRIA adequately reflects the ambitions of the construction sector and all involved parties, these iterative steps have leveraged on a **co-creation process** with the stakeholders from within and outside ECTP, with a **holistic and iterative approach**.

The elaboration process consisted in a set of interviews with ECTP members and other associations, combined with two workshops in May and June 2019 that allowed to build a first full draft of the SRIA, delivered early July 2019.

This full draft was release for an open consultation to the ECTP members and associations during the summer. A final review process was then organised in September 2019 for finalisation of the SRIA by the very end of October 2019.

The next diagram synthesises the overall co-construction and validation process to elaborate the SRIA.

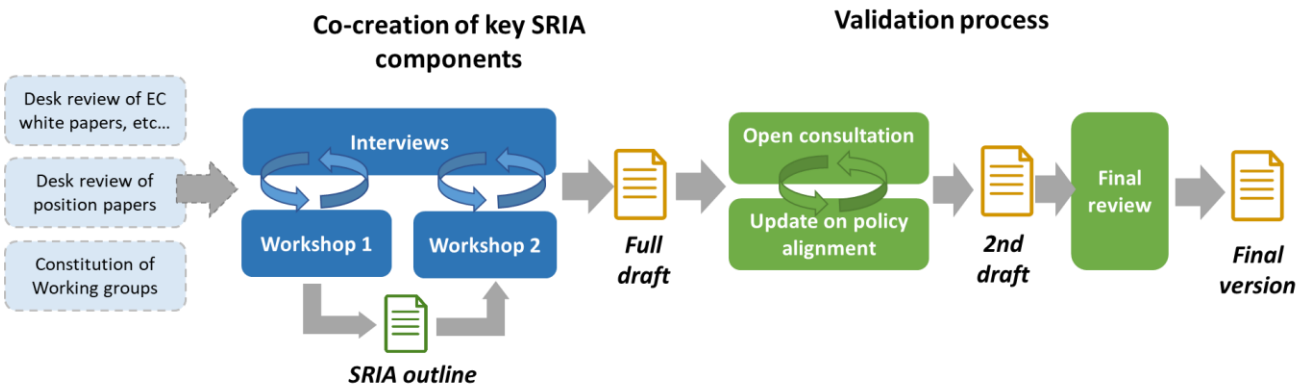

Figure 2 : SRIA elaboration process

ANNEX 3: Elaboration of EC funding budget estimates

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

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

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

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

This budget assessment can be supported by the following reasoning based on the draft budget inputs of Horizon Europe: within the overall 100 b€ budget proposal by the European Commission[1], Pillar 2 of Horizon Europe, entitled *Global Challenges & Industrial Competitiveness*, focuses on "boosting key technologies and solutions underpinning EU policies & Sustainable Development Goals". Within this pillar, the following budget breakdowns is considered:

Clusters	Budget (€ billion)
Health	*€ 7.7*
Inclusive and Secure Society	*€ 2.8*
Digital and Industry	*€ 15*
Climate, Energy and Mobility	*€ 15*
Food and Natural Resources	*€ 10*
Joint Research Centre	€ 2.2

Source: EC, 25 June 2018 presentation

Based on the brief description of these different clusters provided by the EC, is it considered that the three clusters "*Inclusive and Secure Society*", "*Digital and Industry*" and "*Climate, Energy and Mobility*" will cover the vast majority of R&I topics described in the next sections of this document. These three clusters account for 32.8 b€ EC budget.

A conservative estimate is to dedicate 5 to 6% of this budget to R&I related to the Built Environment. This conservative figure, to be compared to the 9% contribution of the construction industry to the European GDP, is estimated taking into account the relatively low R&D intensity in the construction sector compared to other industries. Such estimate corresponds to a budget range of 1640 to 1970 M€.

[1] Source : *European Commission, Horizon Europe presentation given on 25 June 2018*

ANNEX 4: Reference documents

	Date	Source
High level papers		
Ecofys study EU pathways to a decarbonised building sector	2015	ECOFYS
ECSO (European Construction Sector Observatory) Trend Paper Circular Economy	2019	European Construction Sector Observatory
Orientation towards HE Strategic Planning 2021 2024	2019	EC
Towards an EU Research and Innovation policy agenda for Nature-Based Solutions & Re-Naturing Cities	2015	EC
ECTP position papers and related papers		
REFINE Roadmap building up infrastructure networks	2013	ECTP
ECTP AA&D Committee Position Paper on Silver Economy	2015	ECTP
ECTP M S Committee Position Paper	2017	ECTP
ECTP I&M Committee Position Paper	2018	ECTP
ECTP FP9 Position Paper and executive summary	2018	ECTP
ECTP E2B Committee Position Paper	2018	ECTP
ECTP Heritage and Regeneration Position Paper	2018	ECTP
Infrastructure & mobility		
REFINE Strategic Targets and Expected Impacts	2012	ECTP
REFINE Vision in brief	2012	ECTP
REFINE Roadmap building up infrastructure networks	2013	ECTP
Roadmap for Cross-Modal Transport Infrastructure Innovation	2013	multi EU platforms incl. ECTP
REFINET Strategic Implementation Plan (D3.4)	2016	REFINET Project
FORx4 Programme Strategy Paper	2017	ECTP - FEHRL
ECTP I M Committee Position Paper	2018	ECTP
Ageing & design		
ECTP AABE Silver Economy Position Paper	2015	ECTP
Recommendations for the European Reference Framework for Age-friendly Housing	2016	EU Project Neighbourhood of the future
Smart Healthy Age-Friendly Environments	2018	AFE Demy, Caritas Coimbra
Other associations		
ENBRI Building for Society R&I needs		ENBRI
EBC manifesto SMEs	2014	EBC
ECCREDI Key Strategic Themes	2018	ECCREDI
CIB Research Roadmap Intelligent Responsive Buildings	2018	CIB
EuroACE Position Paper post 2020	2018	EuroACE
EMIRI Position paper FP9	2018	EMIRI

EMIRI Mission FP9	2018	EMIRI
Materials Manifesto presented to the EU Parliament	2018	EUMAT
EMIRI Roadmap 2019	2019	EMIRI
Construction 2050 Building tomorrow's Europe today	2019	Multiple associations
ACE Report architects in Europe	2019	ACE
FIEC Manifesto	2019	FIEC
Alliance for Materials Position Paper	2019	EUMAT
Alliance for Materials Memorandum	2019	EUMAT
Other EU Platforms		
ETP SMR SRA	2013	ETP SMR
EUMAT SRA update 2017	2017	EUMAT
ESTEP SRA update 2017	2017	ESTEP
ERTRAC Urban Mobility Roadmap	2017	ERTRAC
ERTRAC Electrification Roadmap	2017	ERTRAC
Manufuture Vision 2030	2018	Manufuture
ETIPSNET VISION 2050	2018	ETIP SNET
ETP SMR (Sustainable Mineral Resources), VERAM Roadmap 2050	2018	ETP SMR
EEB		
E2B roadmap	2010	EeB PPP, EC
Eeb cPPP Multi annual Roadmap	2013	EeB PPP, EC
EeB SoT and Priorities	2017	ECTP
ECTP E2B Committee Position Paper	2018	ECTP
Digitalisation		
CABA cloud technology white paper	2013	CABA Intelligent & Integrated Building Council
ECTP-E2B Committee paper on CLOUD technology use	2016	ECTP
ppt Supporting digitalisation of the construction sector and SMEs	2018	TNO
Confidential EASME Supporting digitalisation of the construction sector and SMEs	2018	EC
European Construction Industry Manifesto For Digitalisation	2018	multiple associations
EURACTIV Manifesto Report Digitising EU construction industry	2019	EURACTIV
Artificial Intelligence Research and Innovation Needs for industries	2019	ECTP
ECTP EeB Artificial Intelligence in Industrial Technologies	2019	ECTP, EeB PPP
FIEC BIM-Manifesto	2019	FIEC
Circular economy		
Declaration Construction in the circular economy	2019	Multiple associations