

ROADMAP MATERIALS FOR BUILDING AND CONSTRUCTION

Materials innovation for a low-carbon, circular and climate-resilient built environment

vito MATERINEX

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EXECUTIVE SUMMARY

A shared strategic framework for materials innovation for a low-carbon, circular and climate-resilient built environment

Buildings and infrastructure support essential societal and economic functions, but their material value chains face two key challenges: circularity and resilience. Circularity requires reduced use of primary raw materials, longer retention of the value of materials and components, and safe, high-quality material loops. Resilience requires buildings, infrastructure, materials and systems to continue functioning reliably under changing climatic conditions, scarcity, disruptions and increasingly demanding performance requirements. Materials innovation translates these societal and market challenges into sustainable economic, societal and strategic value by purposefully connecting applications, materials, products and processes, adoption pathways and ecosystems.

This roadmap provides a common strategic framework for the Flemish building and construction ecosystem. Its core comprises two strategic innovation domains. The first domain, low-carbon and life-cycle-oriented, focuses on reducing environmental impact throughout the entire service life through low-carbon mineral and industrial materials, renewable and bio-based materials, products and systems with a low environmental impact, and low-carbon production and manufacturing. The second domain, resource-efficient, industrialised and climate-adaptive, focuses on safe secondary raw materials and reclaimed components, industrialised, modular and demountable systems, climate-adaptive and resilient materials, and renovation and retrofitting.

Both domains follow the same shared innovation pathway: application need → material, system or process innovation → integration into a product, construction system or practice → performance and life-cycle evidence → scalability and adoption → impact. An initiative can align with one or more innovation lines and draw on the relevant horizontal enablers without having to cover the entire pathway itself.

Five horizontal enablers support the innovation lines within both domains: assessment and validation; digitalisation, product data and traceability; standards and certification; safe and sustainable circularity; and market adoption and value chain collaboration. They do not constitute a separate list of priorities, but represent shared capabilities and enabling conditions needed to make materials innovation reliable, scalable and applicable in practice.

The roadmap helps companies, knowledge institutions, sector organisations and public-sector actors use a common language, formulate relevant research questions, develop coherent project ideas, and identify gaps and complementarities in the innovation portfolio. Better materials only create value when their performance can be demonstrated, their integration into products, systems and processes is feasible, their use is trusted, and the actors involved collaborate across the value chain.

Materials innovation strengthens future resilience by connecting innovative materials with reliable performance, scalable and circular applications, and a strongly collaborative ecosystem. In doing so, it supports the transition to a sustainable built environment.

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1 Why this roadmap?

The societal and industrial challenge, application needs and relevance to Flanders

The transition to a sustainable built environment requires buildings and infrastructure to have a lower environmental impact, use resources more efficiently and withstand changing climatic conditions. At the same time, new solutions must meet the requirements of production, construction, renovation and management. Material choices play a connecting role: they help determine which performance levels are achievable and how long materials and structures retain their function and value. This roadmap illustrates these interconnections and provides the Flemish building and construction ecosystem with a shared direction for connecting materials research with societal and industrial challenges and concrete application needs.

1.1 Transforming buildings and infrastructure

The building and construction value chain extends from raw material extraction and production through the manufacture of construction products, design, engineering, infrastructure works, construction and renovation to use, maintenance, repair, dismantling, reuse and recycling. The value chain is fragmented and includes many SMEs and micro-enterprises. Strategic materials research must therefore be connected with applied research, representative validation, knowledge transfer and practical implementation.

Innovation is needed not only in individual materials, but also in the technologies and processes used to turn materials into components, systems, buildings and infrastructure. The transition simultaneously requires a lower life-cycle impact, greater renovation and repair capacity, more efficient resource use, higher construction productivity, reliable performance and solutions that can withstand changing climatic conditions.

1.2 Why material choices matter

Material choices influence embodied environmental impact, operational performance, durability, maintenance, indoor environmental quality, fire safety, adaptability and end-of-life options. As the operational energy performance of buildings improves, the relative contribution of materials, products, replacement cycles and end-of-life scenarios becomes more important. **Materials innovations must therefore be assessed within their intended application and over their entire service life, taking into account technical performance, environmental impact, safety, ageing, maintenance, repair and end of life**.

Resource efficiency goes beyond recycled content. It also encompasses material reduction, responsible sourcing, longer service life, maintenance and repair, industrialised and demountable construction, high-value reuse and remanufacturing, cascading use (successive use in different applications), recycling and adaptable solutions for the existing building and infrastructure stock.

1.3 Relevance to Flanders

The roadmap supports Flemish companies and knowledge partners involved in materials research and innovation for building and construction. It brings together application expertise, materials science, production, construction practice, infrastructure management, validation and adoption, and aligns innovation opportunities with European research agendas, Flemish policy priorities and industry needs.

For Flemish material and construction product manufacturers, the roadmap provides a framework for positioning innovations, refining research and scale-up questions, and finding complementary partners. Knowledge partners can connect their expertise with needs arising from construction, infrastructure and renovation practice and develop joint research and validation programmes. For sector organisations, clusters, policy actors and infrastructure managers, it helps identify knowledge gaps, evidence needs and opportunities for collaboration. In this way, the roadmap can help reduce fragmentation and strengthen the connection between Flemish materials expertise, industrial development and application in buildings and infrastructure.

2 How to use this roadmap?

A strategic reference framework, not a project selection guide or implementation schedule.

The roadmap supports stakeholders in:

1. positioning research and innovation activities;
2. identifying opportunities within value chains and ecosystems;
3. developing partnerships;
4. aligning investments and innovation initiatives.

The roadmap thus serves as a **strategic reference framework**. It helps stakeholders position activities, establish connections and identify shared innovation questions. It does not prescribe material, product or system choices and does not replace technical, economic, legal or investment assessments.

2.1 Providing strategic direction

The roadmap helps stakeholders position research and innovation activities by considering the interconnections between application needs, materials innovation, translation into products, systems or processes, performance and life-cycle evidence, scalability and adoption, and impact. The two strategic innovation domains and eight innovation lines structure the thematic direction; the horizontal enablers support the pathway from research question to application.

The application need clarifies which problem in buildings or infrastructure is being addressed and which functional, safety, environmental and life-cycle requirements apply. The material, system or process innovation describes the innovation needed in materials, construction systems or associated processes. Integration into a product, construction system or practice clarifies how that innovation fits into the intended application.

Knowledge institutions can thus connect materials research with concrete application questions and evidence needs. Companies can see the interconnections between materials development, manufacturability, performance and application value. Ecosystem actors can identify needs relating to knowledge, infrastructure, validation, standards, partnerships and market adoption.

This strategic direction does not prescribe a technological pathway. It does, however, enable different pathways to be assessed using a common logic, with attention to circularity, resilience and value throughout the entire life cycle.

2.2 Creating a common language and ecosystem alignment

Materials innovation for building and construction brings together diverse perspectives. Material and product developers focus on composition, properties, processing and quality. Designers, engineers, contractors and installers consider system performance, constructability, interfaces and execution. Owners and managers emphasise reliability, service life, maintenance and repair. Demolition, reuse and recycling actors focus on dismantling, traceability, value retention and safe material loops.

The roadmap provides a common language for these perspectives. The strategic innovation domains set the overall direction. The innovation lines show where materials-focused innovation takes place. The shared innovation pathway clarifies how an application need is connected with materials innovation,

translation into products, systems or processes, evidence, scalability, adoption and impact. The horizontal enablers bring together shared capabilities and enabling conditions for assessment and validation; digitalisation and traceability; standards and certification; safe and sustainable circularity; and market adoption and value chain collaboration.

This structure makes opportunities, dependencies and missing links in value chains and ecosystems more readily visible. An innovation question may concern not only a new or improved material, but also its connection with production, design, system integration, validation, data, regulation, procurement, reuse or recycling.

In this way, the roadmap supports strategic alignment and collaboration across the entire value chain, without predetermining roles, partners or technical solutions.

2.3 Assessing the fit of new project ideas

The roadmap positions project ideas through six interconnected elements:

> Application need → material, system or process innovation → integration into a product, construction system or practice → performance and life-cycle evidence → scalability and adoption → impact

The application need clarifies the concrete problem, the user, the context of use and the intended value for buildings, infrastructure, production, renovation or repair. It determines which functional, safety, environmental and life-cycle requirements guide the innovation.

The material, system or process innovation describes the central research question and the intended innovation in materials, construction systems or associated production, processing and assembly processes. This may involve new compositions, structures or functionalities, but also innovative combinations of existing materials and components, reversible connections, modular concepts or new production routes. A new material is therefore not a prerequisite: the interconnections between materials, components and processes may also form the core of the research.

Integration into a product, construction system or practice clarifies how the innovation is developed and incorporated into a component, assembly, product, construction system, production process, construction process, renovation or repair solution. The interactions between materials and components, connections, process conditions and practical execution are explicitly taken into account.

Performance and life-cycle evidence identifies which technical performance, safety, quality, durability, ageing behaviour, environmental impact and circularity aspects need to be demonstrated, against which reference and under which representative conditions. Assessment takes place at the relevant material, component, system or process level and makes trade-offs and potential shifts between life-cycle stages visible.

Scalability and adoption describe how preparations are made for reproducible quality, production and construction capacity, standards, certification, skills, trust and value chain collaboration. They clarify the conditions under which the innovation can be reliably produced, implemented and applied at a larger scale and in diverse application contexts.

Impact connects the project with the intended economic, societal and strategic value and clarifies the demonstrable steps and conditions through which that value can arise. Better technical performance or successful scale-up does not automatically lead to market adoption or broader impact.

The innovation pathway is not a strictly linear sequence of steps. Insights from integration, validation, production or use may refine the research question and innovation choices. The relevant horizontal enablers are additionally selected according to the application, technology maturity and risk profile.

A strong project fit connects application value, a clear research question concerning materials, construction systems or associated production, processing and assembly processes, credible evidence and a feasible pathway towards scalability and adoption. Alignment with the roadmap is an initial thematic and strategic assessment. Scientific quality, feasibility, consortium capacity, risks and suitability for a specific research or innovation instrument still require a separate assessment.

2.4 Maintaining portfolio coherence

The roadmap shows how projects collectively strengthen the two strategic innovation domains, the eight innovation lines, the shared innovation pathway and the horizontal enablers. This makes complementarities, concentrations and gaps in the innovation portfolio visible.

Projects can strengthen the same innovation line through different applications, or complement materials development with translation into products and systems, validation, digitalisation, standards, circularity or market adoption. Connections between innovation lines may also be relevant, for example when a materials innovation simultaneously contributes to lower life-cycle impact, resource efficiency, climate resilience or renovation.

Portfolio coherence does not require an equal distribution of projects across all domains and innovation lines. Flemish industrial strengths, societal needs, market opportunities, knowledge positions and available capacities may justify differences. Diversity can be valuable, but too many isolated initiatives can hinder critical mass and progression towards application.

The roadmap therefore supports dialogue on coherence, complementarity, knowledge gaps and ecosystem development. It does not rank projects, allocate budgets or replace investment or funding decisions.

3 How is this roadmap structured?

From societal and industrial challenges and application needs to material, system or process innovation, adoption and impact

The roadmap connects societal and industrial challenges with materials innovation for buildings and infrastructure. Its central architecture consists of **two strategic innovation domains** comprising eight innovation lines in total. **Circularity and resilience set the direction; a shared innovation pathway and five horizontal enablers connect materials research with application and impact.** The diagram below shows how these elements are interconnected.



Figure 1: Central roadmap architecture for Materials for Building and Construction.

3.1 Circularity and resilience as overarching challenges

Circularity and resilience provide the overarching direction for both innovation domains. Circularity requires reduced use of primary raw materials and longer retention of value through service life extension, repair, reuse and high-quality recycling. Resilience requires materials, buildings, infrastructure and value chains to continue functioning reliably under changing climatic conditions, scarcity and disruptions. These challenges are translated into concrete application needs and requirements for performance, safety and life-cycle impact.

3.2 Two strategic innovation domains and eight innovation lines

The two innovation domains form the thematic core. ‘Low-carbon and life-cycle-oriented’ focuses on reducing environmental impact through raw materials, materials, products, systems and production processes. ‘Resource-efficient, industrialised and climate-adaptive’ focuses on value retention, construction productivity, climate resilience and the adaptation of existing buildings and infrastructure. Each domain comprises four innovation lines that structure the materials-focused research questions. Chapter 4 elaborates on this thematic direction.

3.3 A shared innovation pathway from need to impact

Within both domains, the same innovation pathway connects the application need with materials innovation, translation into a product, system or process, performance and life-cycle evidence, scalability and adoption, and ultimately impact. This connects materials research from the outset with the intended application and the conditions for reliable use. Chapter 6 further explains the connection with value creation and impact.

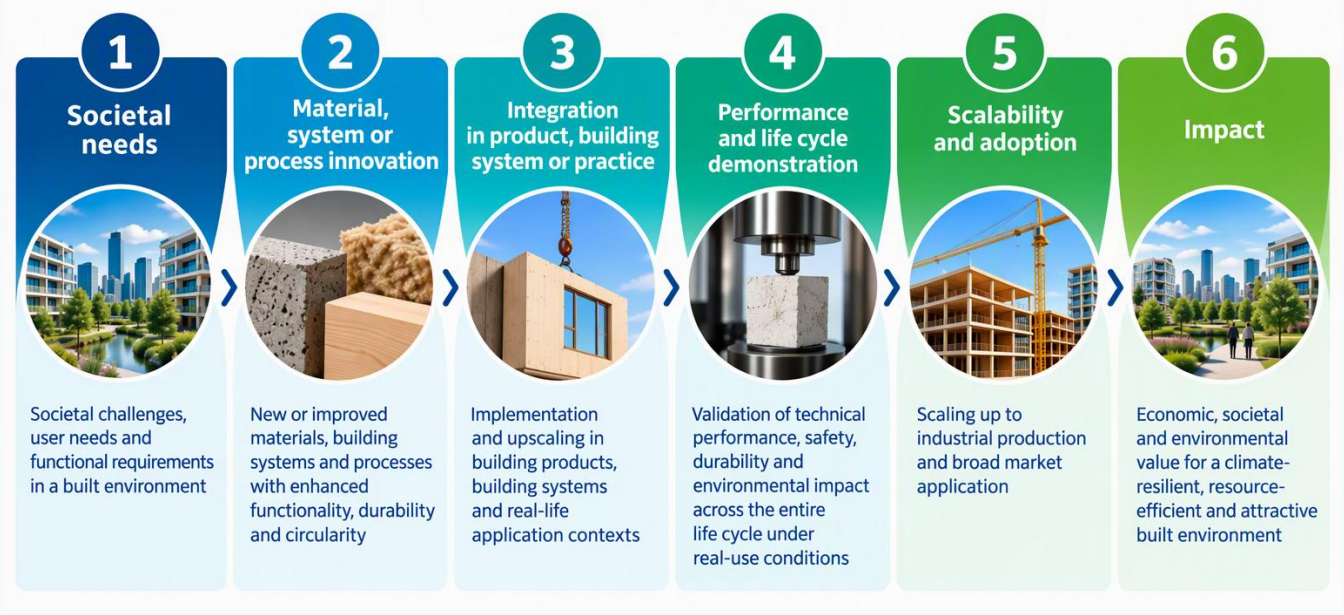


Figure 2: Shared innovation pathway within each strategic innovation domain.

3.4 Horizontal enablers as shared support

Five horizontal enablers support the innovation lines and their pathway to application: assessment and validation; digitalisation, product data and traceability; standards and certification; safe and sustainable circularity; and market adoption and value chain collaboration. They are not separate thematic priorities, but shared capabilities and enabling conditions. The choice and scope of the enablers depend on the application, technology maturity and risks. Chapter 5 explains them in more detail.

4 Strategic innovation domains

The thematic core of the roadmap

The roadmap brings together the priorities for materials innovation in building and construction in two strategic innovation domains: '**Low-carbon and life-cycle-oriented**' and '**Resource-efficient, industrialised and climate-adaptive**'. The first focuses on lower environmental impact throughout the entire life cycle; the second on value retention, construction productivity and adaptation to changing needs and climatic conditions. The two domains complement each other and each comprises four innovation lines connecting application needs with material, product, system and process innovation, evidence and intended value. Circularity and resilience are the overarching principles.

4.1 Low-carbon and life-cycle-oriented

DOMAIN OBJECTIVE **Reduce environmental impact from raw material to scalable system, with demonstrable technical performance, safety, durability and value throughout the entire life cycle.**

This domain comprises four interconnected innovation lines: **low-carbon mineral and industrial materials; renewable and carbon-storing materials; products and systems with a low environmental impact; and low-carbon production and manufacturing**. Together, they connect the selection and development of raw materials and materials with their processing and application in products and systems. The central focus is a demonstrable reduction in environmental impact throughout the entire life cycle, while maintaining the required performance, safety and durability.

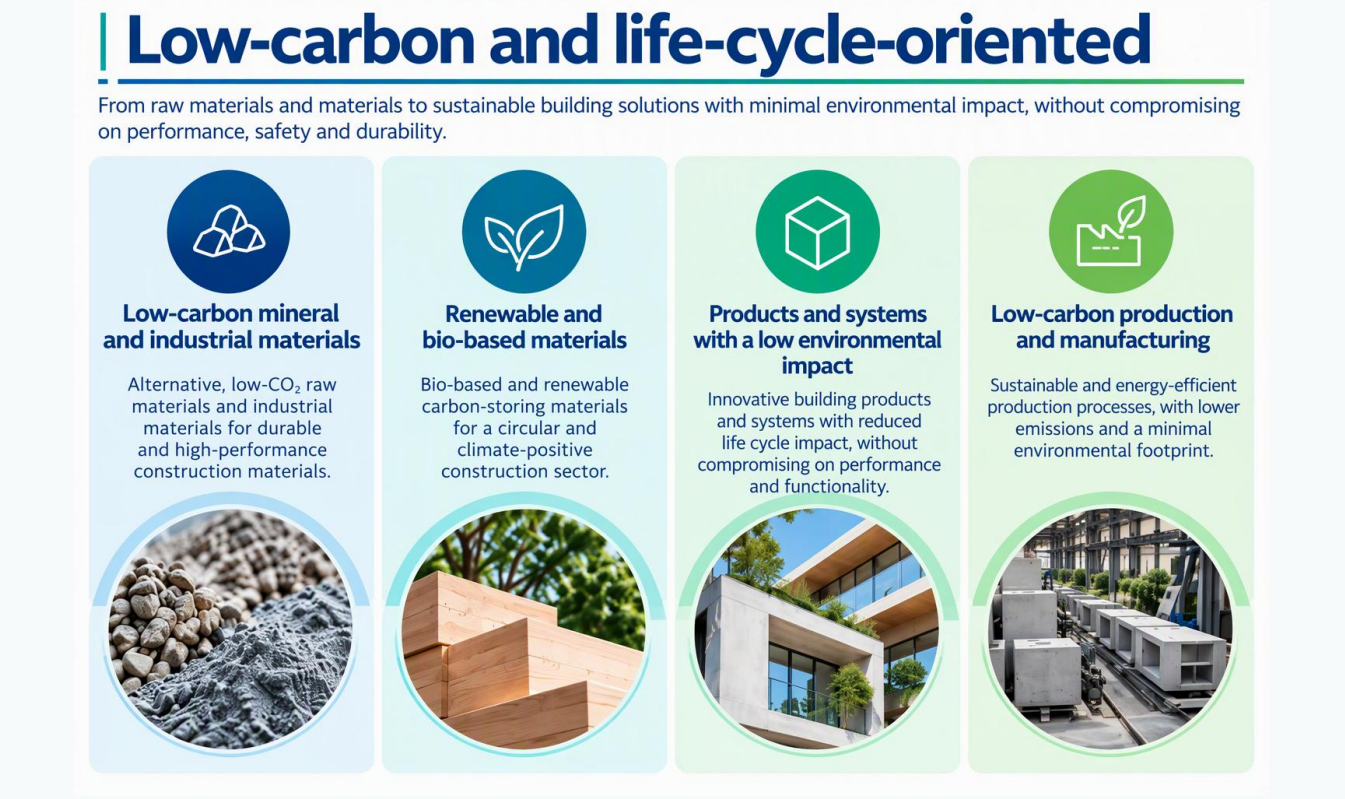


Figure 3: Four innovation lines for low-carbon and life-cycle-oriented materials innovation.

4.1.1 Low-carbon mineral and industrial materials

Challenge and application need. Buildings and infrastructure use large volumes of mineral and industrial materials. Lower embodied impact requires raw materials and formulations with a smaller climate and environmental footprint that also meet functional, safety and quality requirements in representative applications.

Materials innovation. Relevant pathways include low-carbon cement and binders, calcined clay, alkali-activated materials, supplementary cementitious materials, mineral carbonation, concrete and infrastructure components with lower impact, and decarbonisation pathways for steel, asphalt, bitumen, bricks, ceramics, glass and gypsum.

Products, systems, processes and evidence. Material changes are linked to production feasibility, formulation optimisation, reproducible quality, workability, constructability, corrosion and fatigue behaviour where relevant, durability, repairability and compliance. Comparisons are made against a well-justified reference and demonstrate equivalent or better performance and safety for buildings, roads, pavements, bridges or other intended applications.

Intended value. Lower embodied and life-cycle impact without shifting burdens to maintenance, service life, safety, repair or end of life.

4.1.2 Renewable and bio-based materials

Challenge and application need. Renewable raw materials can reduce the use of fossil and mineral resources and temporarily store biogenic carbon. Their value depends on responsible sourcing, appropriate application and credible evidence throughout the entire service life.

Materials innovation. Relevant pathways include structural and engineered timber, materials based on hemp, flax, straw, cellulose and wood fibre, mycelium-based materials and natural fibre composites. The development of bio-based additives, resins and adhesives also offers opportunities for renewable formulations and material bonding. Depending on their properties, these materials and formulations can be used in a wide range of construction products, including insulation materials and coatings. Residual and side streams can be used when quality, safety and continuity of supply are sufficiently assured.

Products, systems, processes and evidence. Research addresses moisture behaviour, fire and smoke, durability, indoor air quality, dimensional stability, processing, connections, maintenance, repair, biogenic carbon storage and end of life. Solutions are validated in their intended context and are not considered a direct replacement without assessment at system level.

Intended value. Responsible use of renewable materials with demonstrable functional performance and life-cycle benefits.

4.1.3 Products and systems with a low environmental impact

Challenge and application need. Low-impact materials only create value when translated into products and building or infrastructure systems that offer demonstrable benefits throughout their entire life cycle and meet functional, safety and quality requirements.

Materials innovation. Relevant pathways include low-carbon components, material- and resource-efficient products, highly efficient and fire-safe insulation, lightweight products, multifunctional materials, materials for thermal energy storage and heat exchangers, and building envelopes, infrastructure elements and renovation systems with a low environmental impact. Material reduction can be achieved through, among other approaches, high and ultra-high strength, optimised structural performance and more efficient use of materials without compromising the required safety, durability or repairability. Multifunctional materials and products can combine a primary function with relevant additional

performance, such as acoustic or sound-absorbing, vibration-damping, surface-protective, hygienic or antimicrobial, antifouling, slip-resistant, and UV- or weather-resistant functionalities. Functional or switchable glazing can also contribute to light, solar and thermal management. These examples are not exhaustive; the additional function must offer demonstrable system value without compromising the primary function, service life, environmental impact or circularity.

Products, systems, processes and evidence. Research connects material choices with product design, system performance and application context. Initiatives demonstrate life-cycle benefits against a well-justified reference and validate functionality, safety, ageing, constructability, maintenance, repair, compatibility and end of life at component and system level. For multifunctional solutions, evidence also demonstrates that additional functions remain robust under relevant exposure, use, cleaning and maintenance.

Intended value. Products and systems with demonstrably lower environmental impact, reliable and purposeful multifunctional performance, and feasible application throughout the entire life cycle.

4.1.4 Low-carbon production and manufacturing

Challenge and application need. The production and manufacture of construction materials and products are often energy- and resource-intensive. Lower climate impact requires process innovations that reduce energy use, emissions and material losses without compromising product quality, safety or production capacity.

Materials innovation. Relevant pathways include process optimisation, electrification and renewable energy where relevant, lower process temperatures, more efficient use of raw materials, reduction and valorisation of production residues, alternative process materials and processing aids, automation and data-driven process control.

Products, systems, processes and evidence. Research links process modifications to reproducible product quality, raw material variation, process stability, energy and emissions performance, scalability and compatibility with existing or new production lines. Evidence makes the impact reduction at process and product level visible and prevents burdens from shifting to other life-cycle stages.

Intended value. Low-carbon and resource-efficient production with lower energy and emissions intensity, reproducible quality and a feasible pathway to industrial scale-up.

4.2 Resource-efficient, industrialised and climate-adaptive

DOMAIN OBJECTIVE **Retain the value of raw materials and components, increase construction productivity and ensure that buildings and infrastructure function reliably under changing climatic conditions.**

This domain likewise comprises four interconnected innovation lines: **secondary raw materials and reclaimed components; industrialised, modular and demountable systems; climate-adaptive and resilient materials; and renovation and retrofitting**. Together, they connect high-value use of materials and components with efficient construction systems and the adaptation of new and existing buildings and infrastructure. The central focus is value retention, construction productivity and reliable performance under changing use and climatic conditions.



Figure 4: Four innovation lines for resource-efficient, industrialised and climate-adaptive building and construction.

4.2.1 Secondary raw materials and reclaimed components

Challenge and application need. Scarcity of primary raw materials and large construction and demolition streams call for safe, traceable and high-quality secondary raw materials and components with defined and reproducible performance.

Materials innovation. Research includes the characterisation, sorting, cleaning and upgrading of recycled aggregates, mineral residues, industrial by-products, reclaimed structural and non-structural components and biomass fractions suitable for cascading use. Urban mining, high-value recirculation, composition transparency, contaminant control, traceability, end-of-waste criteria and quality assurance are integral to this innovation line.

Products, systems, processes and evidence. Secondary raw materials and components are matched with suitable applications and processing routes. Variability, remaining service life, compatibility, logistics, performance after repair or reuse, and repeated use or recycling cycles are also investigated; recycled content alone is not a sufficient measure of circularity.

Intended value. Safe and traceable secondary raw materials and components that meet defined quality requirements and retain their value in high-value applications.

4.2.2 Industrialised, modular and demountable systems

Challenge and application need. Fragmented production and on-site variability increase construction time, waste, failure costs and uncertainty. Industrialisation can improve productivity and quality while supporting circularity.

Innovation pathways. Priorities include prefabrication, modularity, standardisation, automated and quality-controlled production, additive manufacturing (such as 3D printing) for material- and production-efficient components and systems, reversible connections, design for disassembly and efficient dismantling.

Performance and life-cycle evidence. Repeatability, tolerances, material and production efficiency, connection design, logistics, repair, reuse, remanufacturing and future adaptability are considered together. Longer service life, self-healing, corrosion resistance, multifunctionality and predictive maintenance can contribute, provided that future options for value retention are not restricted.

Intended value. Repeatable circular systems that reduce waste and failure costs, increase productivity and retain the value of components.

4.2.3 Climate-adaptive and resilient materials

Challenge and application need. Buildings and infrastructure must remain functional under heat, moisture, drought, flooding and extreme weather conditions. The behaviour of materials, connections and assemblies is therefore essential to resilience.

Innovation pathways. Relevant solutions include heat- and moisture-buffering materials, reflective and cooling surfaces, systems that limit overheating, water-buffering and permeable materials, drought-resistant materials, flood-resistant solutions, moisture-robust junctions, fast-drying systems, UV- and weather-resistant building envelopes, and material interfaces with nature-based solutions. Where relevant, multifunctional surfaces and components can combine additional protective, slip-resistant, antifouling, acoustic or vibration-damping performance with climate-adaptive functions.

Performance and life-cycle evidence. Validation reflects realistic exposure, accelerated and natural ageing, interfaces, corrosion, maintenance, monitoring, repair and post-event performance. Solutions are compatible with building physics, indoor environmental quality, and repair and renovation practice, and are tested where relevant for roads, pavements, bridges, civil engineering structures and water-resilient infrastructure. For combined functions, evidence demonstrates that both the primary climate-adaptive function and the additional performance are maintained over the intended service life.

Intended value. Reliable performance under changing climatic conditions, with less damage, disruption and replacement.

4.2.4 Renovation and retrofitting

Challenge and application need. Renovating, repairing and adapting the existing building and infrastructure stock require low-disruption solutions that are safe and adaptable, improve performance and limit waste and replacement.

Innovation pathways. Priorities include prefabricated façade and roof systems, lightweight panels, moisture-safe insulation, reversible assembly, adaptable interfaces, reusable components, repair materials for concrete, masonry, steel and infrastructure, and repairable and low-maintenance solutions.

Performance and life-cycle evidence. Solutions take into account variation in existing buildings and structures, diagnosis and non-destructive evaluation, remaining service life, accessibility, disruption to users, installation skills, compatibility with existing materials, warranties, monitoring, predictive maintenance and post-repair performance.

Intended value. Longer service life and improved performance through lower-impact renovation and repair, with less disruption, waste and replacement.

5 Horizontal enablers

Supporting capabilities and enabling conditions that connect different innovation domains

The five horizontal enablers provide a shared supporting foundation for the two strategic innovation domains, rather than separate thematic priorities. They help substantiate material choices, strengthen collaboration across the value chain and prepare innovations for production, scale-up and use.

An initiative's choice and use of enablers depend on the application, technology maturity, risk profile and intended pathway to adoption.



Figure 5: Five horizontal enablers supporting innovation lines from research to application.

5.1 Assessment and validation

New materials and circular construction solutions require assessment tools that better explain and predict their behaviour. The development, refinement and validation of quantitative assessment methods, test methods, measurement instruments, and simulation and prediction models must therefore improve understanding of technical performance, quality, safety, service life, environmental impact and circularity. This supports earlier, better-informed material choices, better targeting of extensive empirical testing campaigns, and faster development cycles and knowledge generation. Quantitative methods make properties and performance measurable and comparable and support assessment against performance requirements, including when innovative compositions fall outside existing prescriptive specifications. They thus provide a basis for performance-based regulations, standards and technical specifications and help remove barriers to application. Relevant research pathways include non-destructive characterisation, accelerated ageing methods with a well-established link to in-service behaviour, sensors for non-invasive fault detection, and models for degradation and remaining service life. These developments also support predictive maintenance and better-informed decisions on repair

and reuse. Further development of methodologies for life-cycle assessment (LCA), life-cycle costing (LCC) and circularity assessment makes trade-offs between environmental impact, costs and value retention transparent, including over repeated use and recycling cycles. The reliability, predictive capability and limits of applicability of the tools are substantiated by experimental and real-world data. The innovation lies in the assessment and validation tools themselves, not merely in applying existing tests to a new material.

INTENDED CONTRIBUTION **Validated assessment and prediction tools that accelerate materials development, help target extensive empirical testing campaigns and support performance-based assessment.**

5.2 Digitalisation, product data and traceability

Digitalisation must connect fragmented information and processes in the construction value chain so that materials are produced, applied and reused more efficiently. This enabler supports the development, improvement and validation of digital solutions that make reliable product and material data available and exchangeable, from production and design to use, maintenance and dismantling. BIM-linked information (Building Information Management), product and material passports, and agreements on data governance and interoperability help limit information loss between value chain partners and make origin, composition, performance and use history traceable. Sensors, the Internet of Things (IoT) and digital twins connect this information with the actual behaviour of materials and systems and support process control, predictive maintenance, remaining service life assessment, and decisions on repair and reuse. AI-assisted characterisation and sorting, robotics and additive manufacturing can enable more targeted use of material streams, improve the precision of production and execution, and reduce material losses and failure costs. The added value lies not in digitalisation itself, but in better-informed decisions, higher productivity and demonstrable value retention throughout the entire life cycle.

INTENDED CONTRIBUTION **Improved traceability, process control, maintenance, value retention decisions and readiness for compliance.**

5.3 Standards and certification

New and sustainable construction materials do not automatically achieve large-scale application, even when their technical and environmental benefits have been demonstrated. Existing regulations, standards and technical specifications do not always accommodate innovative compositions, secondary raw materials, reclaimed components or new construction systems. Prescriptive requirements can constrain innovation, while the absence of suitable assessment and certification pathways creates uncertainty for manufacturers, designers, contractors and clients. This enabler therefore focuses not only on compliance with existing frameworks, but also on developing and substantiating performance-based regulations, standards, technical specifications and tender specifications that assess innovative solutions on their demonstrable performance. Research must identify knowledge gaps, relevant risks and limitations of existing assessment frameworks and provide scientifically sound criteria, reference data and assessment protocols at material, product and system level. Technical performance, safety, service life, environmental impact and circularity are considered together. Early alignment with standardisation and certification bodies, public authorities and technical specifiers helps translate research findings into workable compliance and certification pathways, environmental declarations, and criteria for end-of-waste status and secondary raw materials. Clear and evidence-based assessment

frameworks thus strengthen confidence in innovative solutions and support their wider application while maintaining safety and quality.

INTENDED CONTRIBUTION **A clear pathway to compliance and certification for specification, procurement and application.**

5.4 Safe and sustainable circularity

Circular material use only creates sustainable value when materials and components remain safe and functional during extended use and in subsequent application cycles. Recycled content or reusability alone is therefore not sufficient: substances of concern, unknown compositions, ageing and variations in quality can pose risks or restrict future material loops. This enabler focuses on developing materials, formulations, connections and material loops that integrate health, safety, environmental considerations and future value retention from the design stage, in line with safe-and-sustainable-by-design principles. Research addresses contaminants, leaching and emissions, volatile organic compounds and indoor air quality, fire and smoke, composition transparency, variability and ageing, among other aspects. It examines how composition, processing and use history affect safety and performance during production, application, maintenance, repair, reuse, remanufacturing and recycling. The consequences of material choices for future material loops also require attention: additives, coatings or connections that improve performance or service life must not unnecessarily hinder subsequent separation, processing or safe application. Research into safer alternatives, the removal or control of substances of concern, and appropriate quality assurance must clarify which material loops are responsible and under which conditions. This enabler thus helps identify risks early, prevent substances of concern from being passed on through material loops, and retain the technical and economic value of materials over successive use cycles, without shifting health or environmental burdens to future users or other life-cycle stages.

INTENDED CONTRIBUTION **Circular solutions without technical, health or environmental legacy burdens.**

5.5 Market adoption and value chain collaboration

Technically successful materials innovations do not automatically achieve widespread application. Manufacturers, designers, contractors and clients must be able to assess how a solution fits into their practice, what added value it offers and who bears the associated costs, responsibilities and risks. This enabler therefore focuses on the conditions for market adoption and repeatable application, in close collaboration with the value chain partners involved. Demonstrators and reference cases make feasibility and value in use visible and help identify practical barriers early. Research into business and value chain models clarifies how investments, costs and benefits are distributed and how scalable production, supply and service provision can be organised. Warranties, insurability, procurement conditions and risk allocation also require attention. Technical guidelines support correct implementation and help ensure that knowledge gained from initial applications can be transferred more widely. By involving manufacturers, specifiers, contractors and users early, innovation choices can better reflect their needs, and confidence can grow on the basis of demonstrable practical experience. Public and private clients can support early application through performance-based requirements, innovation-oriented procurement and appropriate risk allocation. This establishes a well-founded pathway from initial application to repeatable use across a wide range of projects.

INTENDED CONTRIBUTION **A credible pathway to repeatable application and market adoption.**

6 From materials innovation to value creation and impact

Making the pathway from research findings to practical value explicit

Materials innovation only creates broader value when improved properties translate into reliable construction products and systems, can be produced and applied at scale, and contribute to economic, societal and strategic goals. This chapter distinguishes four interconnected levels: material performance, product and system value, industrial applicability, and impact. Each transition requires additional evidence, enabling conditions and collaboration. This is not a strict linear chain: insights from production, construction, use, renovation and reuse can inform material choices. Success at one level therefore does not automatically guarantee value at the next

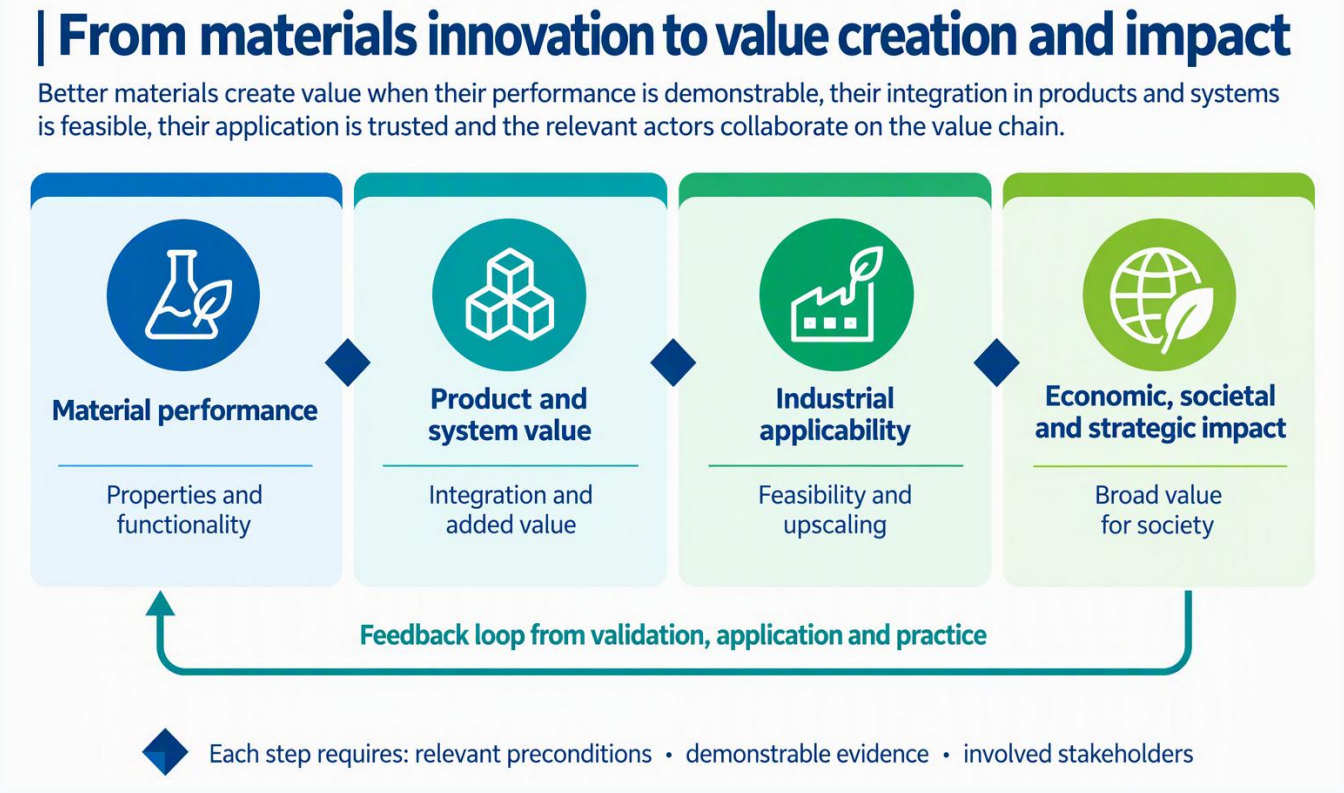


Figure 6: From material performance to reliable construction solutions and broader impact.

6.1 Material performance

Material performance encompasses measurable properties that contribute to the intended application, such as strength, thermal and moisture behaviour, fire safety, workability and resistance to ageing. The desired combination varies with the context of use: the best result for a single property does not necessarily provide the greatest added value. Research must therefore demonstrate which properties improve, against which reference and under which conditions. A distinction is made between theoretical potential, laboratory results and reproducible performance under representative loading and exposure. Environmental impact, resource use and options for repair, reuse and recycling are also considered at

an early stage. This provides a sound basis for further product and system development, without drawing conclusions about the overall application from individual material properties alone.

6.2 Product and system value

A material creates value in its intended application through its integration into a construction product, component or system and its interaction with other materials, connections and structural elements. Material performance therefore cannot simply be translated into the performance of a building or infrastructure asset. A modified composition may, for example, affect junctions, moisture transport, fire behaviour, maintenance or demountability. Validation must demonstrate that the intended benefits are retained at the relevant product and system level, under representative construction and use conditions. Functionality, safety, service life and environmental impact are assessed together, against an appropriate reference and for the same delivered function. For renovation and repair, compatibility with existing materials, remaining service life and disruption are also important. This clarifies the added value the innovation can offer in practice and the associated trade-offs or limitations.

6.3 Industrial applicability

Industrial applicability requires the desired performance to be achieved reproducibly during production, processing and construction at a relevant scale. Reliable raw material specifications, manageable variation, process compatibility, tolerances and quality control are essential. Scale-up also requires attention to energy and material use, production capacity, logistics and compatibility with existing or new production routes and construction processes. A faster process or higher production volume only creates value if quality and performance are maintained. Representative tests must therefore identify the necessary adaptations and process limits. Standards, technical specifications, certification pathways and traceable performance data subsequently support qualification and build confidence among manufacturers, specifiers and contractors. Industrial applicability is not, however, the same as market success: warranties, insurability, risk allocation and value chain collaboration remain decisive for repeatable application.

6.4 Economic, societal and strategic impact

Materials innovation can create economic value through competitive construction products, more efficient production and construction, lower failure costs and new opportunities for repair, reuse and service provision. Societal value can arise through lower life-cycle impact, safe and healthy buildings, climate-resilient infrastructure and a longer useful service life. Strategic value lies, among other things, in strong knowledge positions, reliable material streams, reduced vulnerability to raw material dependencies and access to complementary partners and infrastructure. This impact does not follow automatically from better material performance or successful scale-up. To achieve it, the innovation must actually be applied, and its benefits for companies, users and society must be demonstrated. Costs and risks throughout the entire life cycle are also assessed: a benefit during production must not, for example, be offset by additional maintenance or a shorter service life. This clarifies who benefits from the innovation and what is needed to realise the expected benefits in practice.

7 Ecosystem development and strategic positioning

Connecting complementary capabilities across the Flemish building and construction value chain

Materials innovation for building and construction requires more than individual research findings. It relies on connections between materials knowledge, production capacity, design and construction practice, validation, and opportunities for repair, reuse and recycling. Ecosystem development brings these complementary capabilities together around concrete innovation questions. This involves both collaboration within Flanders and access to complementary European expertise, infrastructure and value chains. This chapter describes how these connections can strengthen the progression from research to reliable application and support the Flemish position.

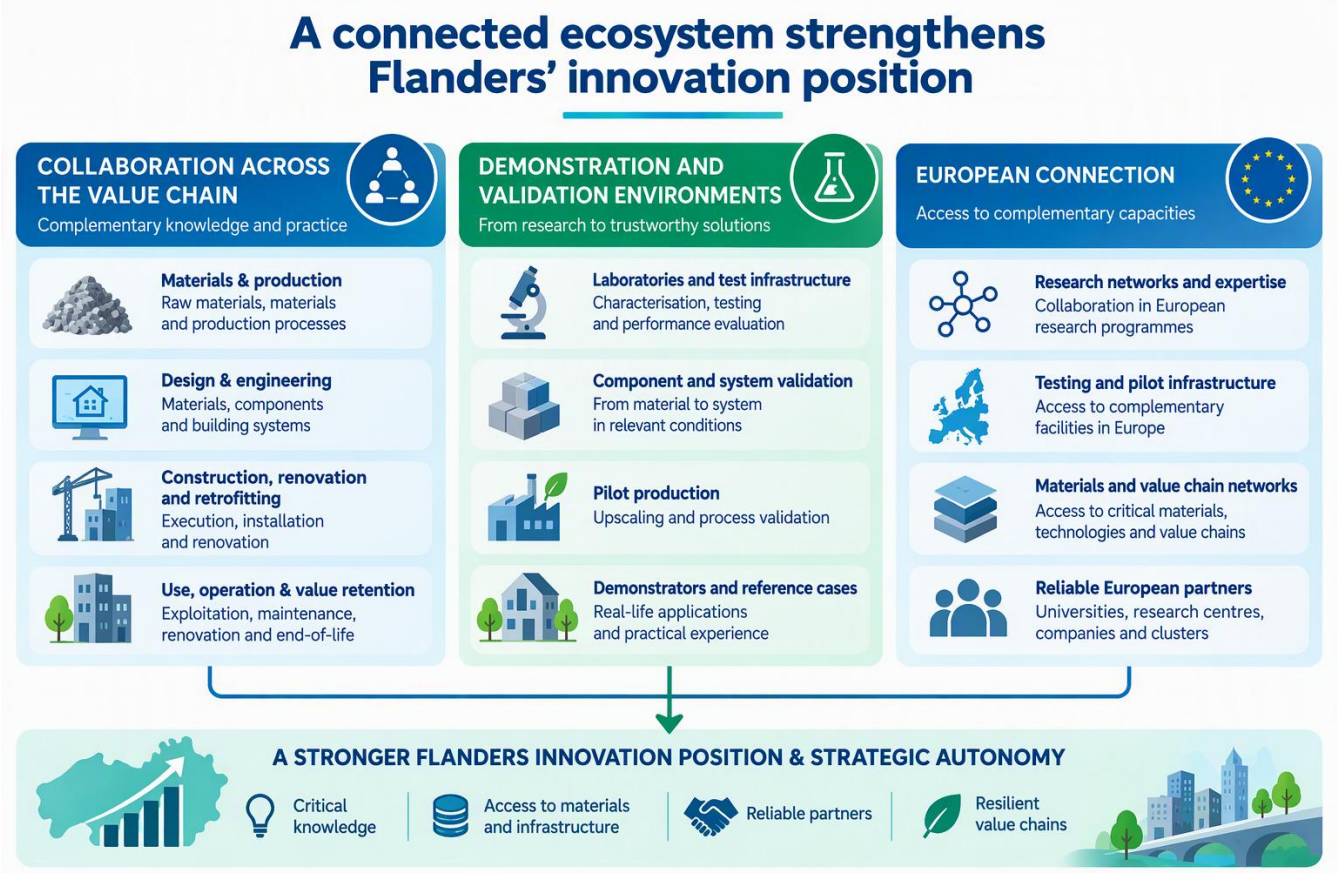


Figure 7: Collaboration, shared infrastructure and European connections as a foundation for materials innovation in building and construction.

7.1 Collaboration across the value chain

Collaboration must connect the knowledge and practical experience needed to develop, produce, apply and subsequently recover value from an innovation. Relevant actors include raw material and material producers, construction product manufacturers, designers, engineering consultancies, contractors, installers, and renovation and repair companies, as well as building and infrastructure owners,

managers, demolition and recycling companies, and reuse actors. Knowledge institutions and collective research centres provide additional research and testing capacity. Sector organisations and clusters support connections with companies and applications, while certification bodies, insurers and public authorities help clarify important conditions for application. Not every initiative needs all these parties: the research question, intended application and dependencies determine which expertise is involved and when.

Added value arises primarily where these perspectives influence one another. Producers contribute requirements for raw material quality, processing and scale-up; designers and contractors highlight interfaces, tolerances and site conditions. Owners and managers provide insights into use, maintenance and repair, while reuse and recycling actors indicate which material combinations and connections enable future value retention. By feeding these insights back into research at an early stage, unsuitable choices and gaps in evidence can be identified sooner. Collaboration is therefore not an end in itself, but a way to address concrete knowledge gaps, dependencies and barriers to application.

7.2 Demonstration and validation environments

Research, testing and pilot infrastructure connects materials development with production and construction practice. Laboratory research explains material behaviour; component- and system-level testing shows how materials, connections and assemblies work together. Pilot production and representative demonstration environments then reveal what changes at larger volumes, under realistic construction conditions and during long-term exposure. Maintenance, repair, dismantling and reuse also require attention. Shared access to equipment, expertise and practical environments helps organisations conduct research that they cannot organise individually. An overview of available capabilities, access conditions and missing testing facilities supports targeted collaboration and avoids unnecessary duplication. Demonstrators and reference cases are particularly valuable when their measurement data, boundary conditions and limitations are made usable for subsequent developments and applications.

7.3 European connections and strategic autonomy

Flemish knowledge and industrial capabilities become more effective when strategically connected with European research networks, testing and pilot infrastructure, and material value chains. This collaboration provides access to complementary expertise, partners, raw material streams and application environments that do not all need to be available within Flanders. The thematic priorities of this roadmap provide a basis for establishing connections with European research and innovation initiatives.

Strategic autonomy does not mean that every link in the value chain must be present locally, but that access to critical knowledge, materials, production capacity and reliable partners is sufficiently assured. Alternative material pathways, secondary raw materials and supplier diversification can help reduce vulnerable dependencies. European connections thus support the Flemish innovation position without automatically adopting European agendas as Flemish priorities.

8 MateriNex: role, research framework and project support

MateriNex provides direction for materials research and supports project development.

8.1 Role of MateriNex

MateriNex supports the Flemish materials research ecosystem and brings companies, knowledge institutions and innovation partners together around shared strategic challenges. For Materials for Building and Construction, this roadmap provides a thematic reference framework for dialogue, project development, ecosystem alignment and portfolio coherence. MateriNex guides stakeholders in forming partnerships and positioning the research content of project ideas.

8.2 Research positioning and technology maturity

MateriNex's mandate focuses on knowledge-intensive materials research at low levels of technology readiness, with high technical or scientific risk and a longer development horizon. From the outset, this research takes account of the application context, representative validation, knowledge transfer, standards and future adoption. The roadmap is neutral with respect to funding instruments and covers the thematic pathway from fundamental knowledge development to application and impact.

8.3 Alignment with research and innovation instruments

Positioning the research content of a project idea precedes the selection of a research or innovation instrument. Only then is it assessed which instrument fits the research question, technology maturity, partners, risks and objectives. Eligibility conditions, submission procedures and assessment criteria are not defined in this roadmap and must always be consulted in the current call and instrument documentation.

8.4 Dynamic use and updating

The roadmap is a dynamic strategic reference framework. Periodic consultation with companies, knowledge institutions and other stakeholders through the Common Interest Group helps assess whether the strategic innovation domains, innovation lines and enablers remain relevant and where new gaps or opportunities are emerging. Updating keeps the thematic direction aligned with evolving technology, regulation and market needs, without turning the roadmap into a timetable or funding guide.

Appendix A. Sources and development process

This appendix explains how the roadmap was developed and which external strategic sources underpin its thematic direction. The roadmap is based on European and international strategies, regulations and research agendas for sustainable construction and advanced materials, supplemented by MateriNex's knowledge base and input from companies, knowledge institutions and other actors in the Flemish building and construction ecosystem.

A.1 Development and updating

The original MateriNex roadmaps were developed in December 2023 and January 2024 with Flemish experts and aligned with relevant European roadmaps. For the 2026 update, this foundation was supplemented with input from the Common Interest Group Materials for Building and Construction, stakeholder surveys and contacts, and consultation with the CIG chair and co-chair.

A.2 Current European frameworks and research agendas

- **Regulation (EU) 2024/3110 – Construction Products Regulation**. Current European regulatory framework for construction products, addressing performance and conformity information, environmental characteristics and digital product information. Regulation - EU - 2024/3110 - EN - EUR-Lex
- **Directive (EU) 2024/1275 – Energy Performance of Buildings Directive (recast)**. Framework for improving the energy performance of buildings and further developing life-cycle-oriented building performance. Directive - EU - 2024/1275 - EN - EUR-Lex
- **Level(s) – European framework for sustainable buildings**. A common European language for the sustainability performance of buildings throughout their life cycle. https://data.europa.eu/doi/10.2779/0393062
- **European Environment Agency, EEA Report 09/2024 – Addressing the environmental and climate footprint of buildings**. An up-to-date synthesis on life-cycle impact, renovation, circularity, climate resilience and nature-positive buildings. Addressing the environmental and climate footprint of buildings | Publications | European Environment Agency (EEA)
- **EN 15804:2012+A2:2019/AC:2021**. Core standard for environmental product declarations for construction products, including relevant rules for life-cycle information and biogenic carbon. BS EN 15804:2012+A2:2019 Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products
- **Materials 2030 Roadmap – Advanced Materials 2030 Initiative**. Strategic research and innovation directions for advanced materials and the connection between materials development and application. 2022-12-09_Materials_2030_RoadMap_VF41.pdf
- **Built4People Partnership – Strategic Research and Innovation Agenda 2021–2027**. Research and innovation agenda for a sustainable, circular and people-centred built environment. Built4People-Partnership-SRIA-March-2022.pdf
- **ERA Industrial Technology Roadmap for Circular Technologies and Business Models**. European research and technology direction for circularity in sectors including construction and energy-intensive industries. ERA industrial technology roadmaps - Research and innovation

- **European Commission (2012) – Strategy for the Sustainable Competitiveness of the Construction Sector and its Enterprises – COM(2012) 433 final**. Strategic policy basis for a sustainable and competitive construction sector, addressing investment, skills, resource efficiency and collaboration across the value chain. COM(2012) 433 final – EUR-Lex
- **European Commission (2014) – Resource Efficiency Opportunities in the Building Sector – COM(2014) 445 final**. Policy basis for more efficient resource use and a lower environmental impact of buildings throughout their entire life cycle, addressing material choices, reuse, recycling and measurable environmental performance. COM(2014) 445 final – EUR-Lex
- **GlobalABC Roadmap for Buildings and Construction**. International direction for the transition to a low-carbon and climate-resilient built environment. Global Roadmap for Buildings and Construction 2020-2050

Appendix B. Complete visual overview of the roadmap




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