CEBE Research Roadmap

June 2026

CEBE

Preface

This roadmap sets out the strategic direction for research within the CEBE programme, outlining the activities required to achieve the vision of a science-based circular, low-carbon and resilient built environment within planetary boundaries.

It provides an overview of the programme's objectives, research activities and intended results, outcomes and impact - as well as its collaboration strategies with academia and industry. It also defines key targets to support the monitoring and evaluation of progress.

The roadmap serves as a reference for understanding the structure, priorities and organisation of the programme and its individual research fields, supporting both internal coordination and external collaboration.

Developed in 2026 by the CEBE Research Field Leads and Co-leads, in collaboration with the Scientific Coordination Group and the Coordination Unit, the roadmap will be updated in connection with the programme's midterm evaluation in 2030.

AALBORG UNIVERSITY
VILLUM FONDEN
SDU
AARHUS UNIVERSITY
DTU

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1. Introduction

CEBE (Civil Engineering and the Green Transition in the Built Environment) is a 10-year research program, supported with 1 billion DKK by the Villum Foundation, to develop new knowledge and new solutions for a sustainable construction sector within planetary boundaries. The program brings together leading construction researchers from four universities (AAU - Aalborg University, AU - Aarhus University, SDU – The University of Southern Denmark and DTU – Technical University of Denmark) in a partnership around common goals.

In addition to delivering groundbreaking research, CEBE will be a common platform for knowledge, new solutions and collaboration between research and the players in the construction sector.

The purpose of the roadmap is to strategically plan what research needs to happen in CEBE, in what order and over what timeframe to achieve the defined goals of the research programme.

The research roadmap includes an overview of the programme's objectives, vision, and strategic importance (Chapter 2) and summarizes the three core challenges CEBE addresses and how the relation is between these and the selected seven research fields (Chapter 3).

The roadmap also describes the sectorial approach applied in CEBE and how collaboration between partners and research fields are facilitated (Chapter 4) as well as how CEBE is structured around four interrelated and partially overlapping phases during its 10 years of operation and its approach to realizing impact.

The ambitions for each of the seven research fields and the relations and interfaces between them are presented (Chapter 5) by answering the questions: 1) What is the challenge being addressed?; 2) What is vision and mission of the research field?; 3) What are research activities and output? and 4) How do the research field facilitate going from research output to realizing the vision? A much more detailed description of each research field is included in separate appendices. These include the research fields 1) ambitions and goals, 2) a mapping of excellent international research environments, 3) a thorough review of the state-of-the art in the field, 4) a presentation of the planned research activities, milestones and timelines for intended output and outcomes as well as a 5) description of the research field approach to facilitate transfer of research results to successfully achieve the intended outcomes and impact.

CEBE is a research program, and its success largely depends on innovation and the construction industry adopting the research results and developing them into solutions that are practically feasible, functional and economically viable. Therefore, the programme will be applying a partnership model to ensure an early involvement and a strong collaboration with building sector actors to facilitate transformation of CEBE research results and to increase the likelihood that this innovation can happen and ultimately succeed (Chapter 6).

An important objective of CEBE is also education of the next generation of engineers and researchers, and the roadmap describes the approach to building knowledge and research capacity for both academia and industry to drive the green transition in construction (Chapter 7).

CEBE programme progress as well as research achievements and impact will be monitored, reviewed and reported during the programme period, both quantitatively and qualitatively. The roadmap presents the CEBE monitoring and review process and a set of key performance indicators to evaluate programme progress (Chapter 8). It also includes an overview of research field specific targets for the first four years to be used for evaluation of the research achievements.

In the CEBE programme we want researchers to take risks, be bold and ambitious in research and in establishing new partnerships for the green transition of the built environment. This entails an increased risk of failure and the emergence of challenges. Risk management is therefore a central element in the CEBE programme and an important aspect in achieving its ambitions. Therefore, the roadmap also describes CEBE's approach to risk management (chapter 9).

2. Programme Vision, Mission and Objectives

Humanity's resource consumption considerably exceeds the Earth's capacity to regenerate and challenges the global balances on which the stability of the planetary boundaries relies. The resource consumption in the built environment is one of the main factors, leading to considerable impacts on planetary boundaries like climate change, biosphere integrity, and land-system change. Barring a step change in the building sector, the products, processes, and practices currently in use will continue to pose increasing threats to human and natural habitats undermining the very foundations of welfare and democracy in our societies.

A world under pressure calls for a radical transformation of how we build. Civil engineers across Denmark unite to rethink the built environment within planetary boundaries. They envision a built environment made from reused, renewable, low carbon materials that last longer and harm less - shaping a resilient, circular future for society.

The CEBE vision is:

A science-based circular, low-carbon and resilient built environment within planetary boundaries.

The CEBE mission is:

To lead change in Civil Engineering by fostering new knowledge, accelerating innovation, advancing education, building research capacity and strengthen international collaboration.

CEBE will address the research challenges through a bold and ambitious investment in research capacity with a focus on excellence in research, encompassing research-based knowledge and education, talent development, research infrastructure, industry engagement and international collaboration. CEBE will deliver new knowledge, breakthrough technologies and long-term socio-economic impact through targeted education, industry partnerships, and strategic projects.

The CEBE programme main objectives:

- **Excellent research:** Perform excellent research, research-based education and make Denmark a leading nation within green transition of the built environment,
- **Research and Innovation Capacity:** Building research and innovation capacity through education of the next generation of engineers and researchers and through

coordinated cooperation between the four universities exploiting their existing individual strengths and developing new strengths in collaboration,

- **Building Sector Innovation:** Facilitate building sector innovation through strategic partnerships, involvement and collaboration with building sector representatives,
- **Impact for Green Transition:** Provide maximum impact for green transition within the built environment within a 5-10-year horizon,
- **International Collaboration:** Have a significant international dimension, both in research collaboration and student exchange and a global perspective on research objectives and output.

3. Core Challenges and relations to CEBE research fields

To encompass the CEBE vision, civil engineering must undergo a transformation across **three core challenges**:

Table 1. CEBE core challenges.

	Core Challenge	Description
A	Sustainable Construction Materials	Decoupling construction from environmental harm by shifting to sustainable materials – circular by design, low-carbon, and from renewable or reused sources
B	Climate Resilient Infrastructure	Redesigning infrastructure and coastal defences for resilience to climate extremes – integrating nature-based solutions, enhanced monitoring, predicted climate risks and optimised response strategies
C	Circular Practices	Breaking systemic inertia in the built environment by driving circular, resource-efficient building design and construction practices – enabled by digital tools, enhanced monitoring for safe life extension and optimised renovation strategies.

CEBE has defined seven strategically aligned Research Fields (RFs) that represent key leverage points to fundamentally address these transformation needs. Three of these constitute the primary levers for change:

- **Low-carbon and robust construction materials** (RF3):
  Delivers scientific foundation for Challenge a) by providing new understandings to enable a science-based approach to the engineering of new renewable, reused and recycled construction materials for the building industry.
- **Climate resilient and adaptive infrastructure** (RF5):
  Advances Challenge b) by assessing and mitigating the risk of climate hazards on building, facilities and infrastructure and by the development of new mitigation strategies based on the concept of abandon-adapt-protect.
- **Extending life of the built environment** (RF7):
  Supports Challenge c) through research on active risk-informed and safe life extension of structures and development of innovative sustainable retrofitting strategies.

To ensure a systems-level transformation, these three research fields are supported by four cross-cutting enablers that reinforce and operationalise the core transitions:

- **Assessing and measuring sustainability** (RF1):
  Provides an analytical backbone through new Life Cycle Assessment (LCA) methods that enable assessment of climate change mitigation and environmental sustainability aligned with absolute targets and tailored to the needs of the built environment, buildings and infrastructure. Enables assessment of sustainable solutions for all three challenges.
- **Design for regeneration, circularity, and longevity** (RF2):
  Contributes to Challenge a) and b) by research on engineering design and construction methods for buildings with environmental loads that enables the regenerative properties of the planetary ecosystems to reestablish the safe operating space below the planetary boundaries and on development of novel methods and tools to engineer long-lasting building systems based on biogenic materials, reuse and upcycling of existing products.
- **Digitalisation and automation** (RF4):
  Supports all challenges by research on the integration of advanced digital tools and automation technologies in construction and deconstruction workflows to enable scalable solutions for resource efficiency and material circularity.
- **Sufficiency, wellbeing and energy efficiency** (RF6):
  Anchors Challenge b) and c) providing new understandings on sufficiency principles for management, use and transformation of the existing building stock.

Combined, the research fields cover the life cycle stages of the built environment from design, construction, operation, life extension to demolition, and guiding actions of change in engineering practices.

4. Programme Architecture

4.1. The Sectorial Approach

The programme has adopted a sectorial approach to address the research challenges. It ensures a long-term strategic development by leveraging universities' strengths and aligning them under a unified national agenda. This research architecture ensures that each field not only stands strong on its own but also contributes integrally to the overall vision.

Each RF is managed by a lead, assisted by co-lead(s) from the other universities. The university partners within each RF have developed a joint plan enabling alignment of their expertise, collaboration, and prioritisation within the designated areas.

Table 2. The role and participation of each partner university in the seven research fields

Research Field	1	2	3	4	5	6	7
	Assessing and measuring sustainability	**Design for regeneration, circularity and longevity**	**Low carbon and robust construction materials**	**Digitalisation and automation**	**Climate resilient and adaptive infrastructure**	**Sufficiency, well-being and energy efficiency**	**Extending the life of the built environment**
AAU	Lead		Co-Lead		Co-Lead	Lead	
DTU	Co-Lead		Lead	Co-Lead	Lead	Co-Lead	Co-Lead
AU		Lead			Co-Lead	Co-Lead	Lead
SDU	Co-Lead	Co-Lead		Lead		Co-Lead	Co-Lead

The sectoral approach exploits both university-specific sectorial expertise and cross-university collaboration to create the critical mass necessary to significantly strengthen research capabilities and establish internationally recognised spearhead positions within each of the seven research fields. The chosen approach will create enduring academic and industrial networks that will continue to empower Danish research and education in sustainable civil engineering beyond the life of the programme, ensuring that innovations are continuously refined and scaled through follow-on funding opportunities.

4.2. Programme Management and Collaboration

To ensure that the research fields collectively support the overall ambition of the programme and facilitate interdisciplinary collaboration, it is essential for CEBE to continuously align efforts, share insights, maintain the momentum of each research field, and foster collaborative activities, all aimed at fulfilling the programme's green transition objectives.

CEBE management will facilitate and assist leads and co-leads in developing a strong collaboration culture within research fields and work packages and in leveraging research team synergies to ensure that knowledge and innovation are not developed in isolation, but across research groups and department barriers.

This will include the following:

- Organisation of regular meetings with research groups to discuss progress including knowledge exchange, collaboration and co-publication within and between research fields,
- Organisation of separate research field workshops focusing on knowledge exchange and cross research group collaboration opportunities,
- Encourage co-supervision of PhD's from different research groups and universities.

In addition, CEBE will have a strong focus on fostering a cohesive sectorial approach and on facilitating interdisciplinary collaboration across research fields, leveraging research field synergies and ensuring that early-career researchers are fully integrated into the initiative. This will enable universities to align their expertise, collaborate, and prioritise their efforts in educating the next generation of engineers and researchers and in attracting international talent. It will include the following:

- Organisation of a 2-day annual meeting on knowledge exchange and dialogue between research fields and partner universities, on stimulating an inspiring research culture, and on fostering a cohesive sectorial approach,
- Promote networking for identification of cross-field research needs and opportunities, for sharing of data and insights, and for initiating cross-field follow-up project funding,
- Initiation of an Interdisciplinary Fellowship Programme supporting interdisciplinary and cross field research projects at the partner universities,
- Establishment of a national research data and analysis platform for sharing of research data and methods and a CEBE Infrastructure Gateway to ensure easy access to state-of-the-art and unique experimental facilities between the partner universities,
- Initiation of programme flagship case studies fostering multidisciplinary approaches and cross-field collaboration,
- Organisation of online meetings and physical PhD seminars by the CEBE Research School with focus on cross-field research challenges and opportunities.

4.3. Programme Phases

The CEBE programme is structured around four interrelated and partially overlapping phases with progress in impact level over time – from research results to long-term transformation (see figure 1).

In the **mobilization phase**, focus is on recruiting, on establishing appropriate teams, workplans, projects and research infrastructure and on structuring of the collaboration/involvement with the building sector and others.

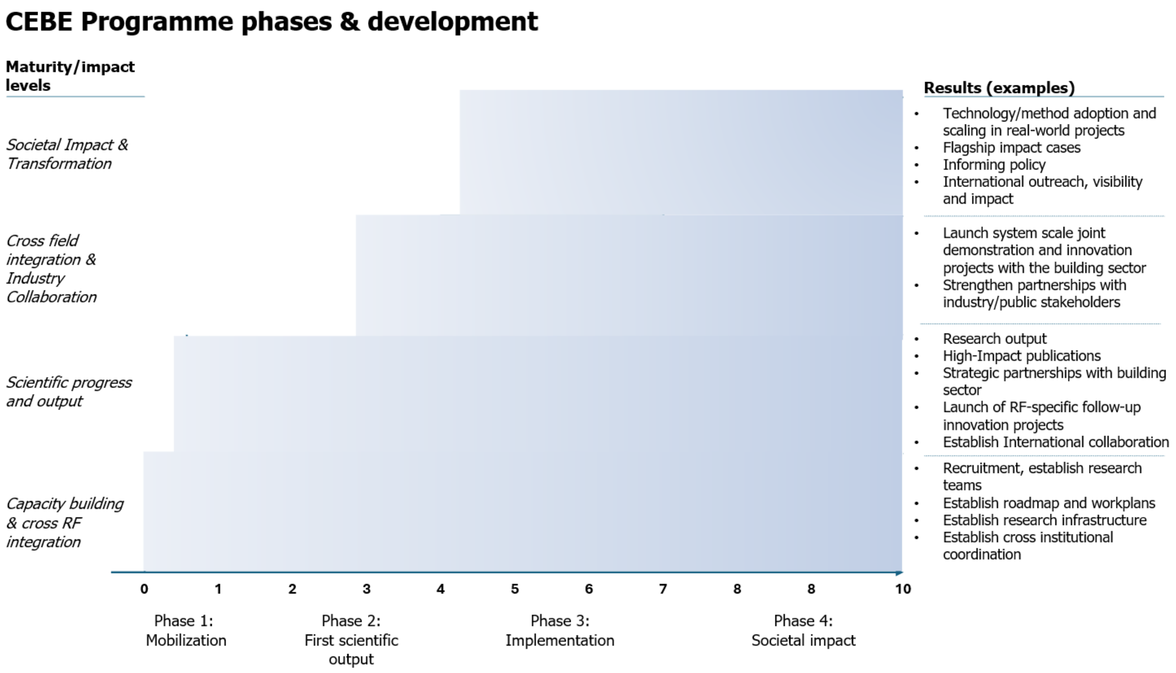
In the phase of **First Scientific Output**, we expect to see the first scientific outputs, high impact publications and the first results of the strategic collaboration with the building sector.

In the phase of **Implementation**, we expect to see follow-up innovation projects with the industry, pilot projects and demonstration of the new technologies.

In the fourth phase of **societal impact**, we expect to see impact on society and climate, with among others the adoption of new materials, LCA methods incorporating planetary boundaries and a practice where buildings are designed for circularity.

The phases and the progression of impact level is also reflected in the program KPIs and the output and impact targets of the individual research field.

Figure 1. CEBE programme phases.



4.4. CEBE approach to realizing impact

CEBE is a research program that primarily works to establish new fundamental knowledge for the transition of the built environment and to educate a new generation of engineers and young researchers, PhDs and post docs – to take part in driving the transformation of the built environment as well as to establish structured collaboration with the industry.

However, to accelerate the transfer of knowledge and to facilitate transformation of research output into real world adoption, CEBE needs a strong collaboration with society, building sector, industry players and governmental authorities. Strong and close collaboration with industry is necessary for them to take ownership in transforming CEBE research results via innovation, test and demonstration into new technologies, methods and solutions that are practically applicable, scalable and economically profitable. CEBE cannot create the intended change in practice but can assist industry players and other stakeholders in creating such change through collaboration and by ensuring the necessary knowledge base and education of the people, who can drive the change.

The realization of actual impact, as represented in the research field specific chapters, will rely on that the CEBE program manages to co-develop and attract funding to innovation and demonstration projects in collaboration with building sector actors. To track this throughout the programme, it also exists as an KPI in chapter 8.

4.5. Global Perspectives

The CEBE research programme has been defined to address challenges in the built environment in developed countries. Several of the research fields (RF 4, 5, 6 and 7) are mainly focusing on challenges in the existing building stock during operation, life extension and deconstruction, while (RF1, 2 and 3) are dealing with the challenges of both existing and new construction.

However, it is expected that the strongest construction-sector development over the next 10–14 years will be in South Asia and Southeast Asia and in other emerging regions in the world driven by rapid urbanization, massive infrastructure needs, and sustained economic growth.

Although the main focus in CEBE is on developed countries, research objectives and outputs should be considered in a global perspective. Each RF has reflected on their role and the possibility of global applicability and scalability of the products/solutions developed, see respective chapters in the appendix.

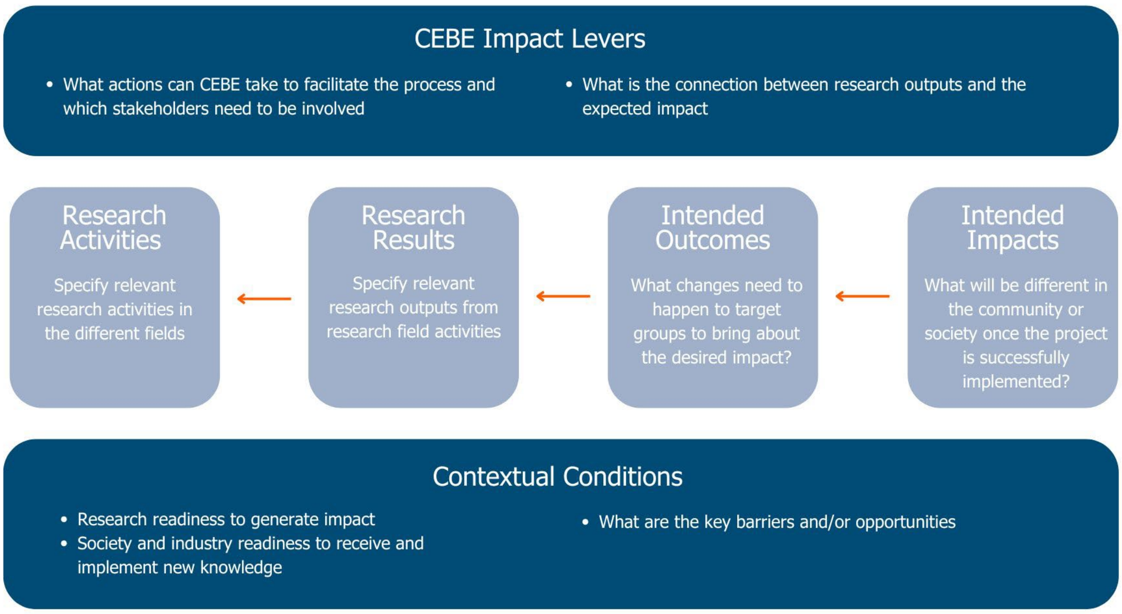
The global perspectives of research objectives and outputs in CEBE will first be addressed and pursued by exploiting already established collaboration with academic institutions in emerging and developing countries. Further applicability of the most relevant and promising developments will rely on that the CEBE program manages to co-develop and attract funding to innovation and demonstration projects in collaboration with relevant actors in these countries. This will develop over time as the CEBE programme continuously will be pursuing opportunities for global collaborations and CEBE will be reporting this effort in the annual report.

5. Research Field Roadmaps

This chapter covers a summary description of each research field based on more thorough roadmaps in CEBE Roadmap Appendix. These roadmaps include descriptions on ambitions, vision and mission, state of the art in the field, how the research field will address the core challenges and their impact framework.

The impact framework describes intended impact, outcome and the associated research activities and outputs. Moreover, there are specific sections on the contextual conditions (opportunities and barriers, research readiness of society and industry etc.), on the so-called CEBE impact levers (what do we do to translate our research output into outcome and impact) and on the main stakeholders/beneficiaries of the specific research field. Finally, each research field has defined specific output, outcome and impact targets including evaluation method and time horizon for each of them. The CEBE impact framework is represented in the figure below.

Figure 2. CEBE Impact Framework



In the following sections, the research field specific chapters in appendix are summarized, answering the following questions:

1) What is the challenge being addressed?
2) What is vision and mission of the research field?
3) What are research activities and output?
4) How do the research field facilitate going from research output to realizing the vision?

Although the programme has adopted a sectorial approach to address the research challenges it is very important that each field not only stands strong on its own but also contributes integrally to the overall vision. Chapter 5.8 presents the relations and interfaces between the research fields and the coordination needed to ensure that the programme as a whole will fulfil its objectives.

5.1. Research field 1 - Assessing and measuring sustainability

The research challenge of the field is how the climate and environmental impact of the entire built environment can be accurately measured – both what is build new and what already exists?

The RF vision is to enable society to evaluate the environmental performance of the built environment and relate it to absolute environmental sustainability limits through scientifically robust, dynamic, and absolute-target sustainability assessment methods driving decisions aligned with planetary boundaries.

This RF will develop scientifically robust, dynamic, and absolute-target-based environmental sustainability assessment methods by advancing the science behind system scoping, temporal modelling, absolute target setting and impact characterization. Deliver tailored decision support tools for buildings, infrastructure, and the wider built environment, enabling researchers, industry, and policymakers to meet emerging environmental targets.

The research activities are structured around three interconnected research areas: absolute sustainability assessments, dynamic and temporally dependent assessments, and system boundary dependent assessments. They include:

- Development of new methodological frameworks for assessing the built environment within absolute targets such as planetary boundaries,
- Advancing LCA methods that integrate the latest developments in quantitative sustainability assessment, thereby strengthening both scientific validity and practical applicability,
- Creation of the methodological foundation that other RF's can use in evaluating their impact towards transition of the built environment within planetary boundaries.

The research output include:

- Novel methods for measuring the built environment (new and existing buildings and infrastructure) within planetary boundaries,
- Definition and methods to assess climate neutral, circular and regenerative solutions,
- Novel methods for assessing the absolute sustainability impacts of buildings and testing techniques and materials to design building projects within planetary boundaries.

The RF will contribute to transfer research output to realize the vision by:

- Making scientifically documented methods available through data sets and tools
- Facilitating uptake and integration of planetary based LCA measurement methods in consultancy and construction practices; in policy frameworks, standards, and regulatory discussions,
- Sharing definitions of circular and regenerative solutions and updating the younger generations with the most advanced and up to date knowledge on sustainability of buildings,

- Collaboration across CEBE research fields (RF2–RF7), early industry involvement, and continuing education to accelerate adoption.

5.2. Research field 2 - Design for regeneration, circularity and longevity

The research challenge of the field is how civil engineering can support the green transition of the built environment through design for regeneration, circularity, and longevity?

The RF vision is to establish a new scientific and practical paradigm for designing buildings with environmental impact that enables the regenerative properties of the planetary ecosystems to reestablish the safe operating space below the planetary boundaries. The field aims to enable the building industry to design and construct buildings and building systems for repeated circularity, enhance biodiversity, and remain resilient over time and under future climate conditions.

This RF will develop research-based methods, processes, and solutions for building design, long-lasting and circular building systems, and construction management with a low environmental impact. Through interdisciplinary research, experimental testing, digital design methods, and co-creation with industry and international partners, the field will generate knowledge that can be implemented in practice. In this way, the research field will accelerate the transition toward long-lasting and circular buildings and urban environments with a regenerative environmental impact.

The research activities include:

- Development of building design methods, including the development of climate-responsive and climate-change-ready building design strategies integrating biodiversity-, water- and ecosystem-related parameters into digital design workflows,
- Development and evaluation of circular building system concepts through lifecycle modelling, material flow analysis and BIM-supported design studies,
- Analysis of reversible connections, adaptability strategies and reuse scenarios for building systems such as façades, roof systems and floor structures,
- Studies of digital material tracking, reuse documentation and lifecycle-oriented construction sequencing, as well as investigations into how computational fabrication, automation and robotics can support handling of reclaimed and non-standard materials.

The research output include:

- Computational design methods, environmental assessment workflows and design principles that enable regenerative environmental performance to inform early-stage architectural and engineering decisions,
- Design methods and digitally supported workflows for circular and adaptable building systems, including façades, roof assemblies, floor systems and interior layers designed for disassembly, reuse and long-term adaptability,

- Methods and process frameworks for integrating regenerative solutions and circular principles into construction planning, logistics and production workflows and approaches for coordination and integration across building processes.

The RF will contribute to transfer research output to realize the vision by:

- Facilitating a widespread adoption of knowledge-based design and construction practices that enable the building industry to develop built environments supporting the regeneration of local and planetary ecosystems.

5.3. Research field 3 - Low carbon and robust construction materials

The research challenge of the field is that the most widely used construction materials have vast environmental impacts, highlighting the need for sustainable alternatives.

The RF vision is to accelerate the adoption of alternative, sustainable, and robust construction materials and components as a new normal through research, i.e., from science-based development to implementation, to meet the urgency of documenting alternative structural materials for the building industry.

The RF will generate the fundamental knowledge required to understand, predict, and engineer the performance of sustainable construction materials through rigorous scientific enquiry at the intersection of experimental investigation and physics-based computational modelling. The RF will equip the building industry with the science-based evidence needed to replace carbon-intensive materials with durable, safe, and resource-efficient alternatives that operate within planetary boundaries.

The research activities include:

- New theoretical framework linking key characteristics and properties across scales, establishing correlations using statistical models and AI,
- Non-destructive testing of materials and components for reuse for documenting properties to establish reliable assessments and criteria for material acceptance to maximize reuse potential,
- Material characterization, structural modelling, and experimental validation to establish design methods that allow alternative materials to be safely used in load-bearing applications,
- Develop and document new low-carbon, resource-efficient, and robust construction materials based on the new theoretical framework,
- Development of a new decision-making framework to support absolute sustainable pathways for construction materials value chains.

The research output include:

- A theoretical, multiscale framework (from nano to component level) as base for the development of alternative materials,

- Methods and guideline tools for testing and documentation as direct input to regulation,
- Predictive models and accelerated tests for durability assessment to support long-term safety in use,
- PoC to documentation of alternative materials and options for upscaling by developers and producers,
- Decision-making framework to support absolute sustainable pathways for the construction material´s value chains.

The RF will contribute to transfer research output to realize the vision by:

- Convincing the industry that alternative materials can be used with the same level of safety as traditional materials, based on scientific evidence at all levels,
- Facilitating stakeholder and user engagement related to the general acceptance of alternative materials,
- Testing of guidelines, and providing inputs to standards, deliver evidence for informed decisions and feasible business cases, and changing legislation to support the production and adaptation of alternative materials,
- Seeking strong collaboration through applied projects to foster change in the selection and use of alternative materials,
- Engaging in continuous outreach to the sector.

5.4. Research field 4 - Digitalisation and automation

The research challenge of the field is how robotics, computation, sensing, digital twins, and interoperable data infrastructures can support circular construction, reduce carbon emissions, improve resource efficiency, and enable lifecycle-informed decision-making.

The RF vision is a built environment that operates within planetary boundaries, where more data leads to less waste, and material use; where construction processes, and building transformation are continuously informed and controlled through reliable lifecycle data; where buildings are conceived as low-carbon, reversible and resource-aware systems, designed for material efficiency, reuse, and long-term adaptability and where construction is organised around traceable material flows, reduced carbon emissions, and automated processes supported by open and interoperable data ecosystems.

This RF will establish the technological foundations for scalable circular construction and low-carbon building systems by integrating computational design and engineering, robotic fabrication, reality capture of the built environment, digital twins of construction operations, and interoperable data infrastructures. The research field will deliver automated prefabrication systems, including 3D concrete printing and robotic timber assembly, as well as robotic deconstruction processes for material recovery, implemented within traceable material flows and lifecycle-informed decision-making across phases.

The research activities include:

- Development of robotic fabrication and deconstruction processes that enable material-efficient construction, reversible building systems, and high-value material recovery,
- Development of data infrastructures, sensing systems, and digital models that enable traceability, coordination, and lifecycle-informed decision-making across construction processes.

The research output include:

- Robotic fabrication and construction technologies for low-carbon building systems,
- Robotic assembly and disassembly systems for timber construction and material reuse,
- Robotic deconstruction systems for material recovery,
- Interoperable data infrastructures enabling structured information exchange and lifecycle coordination,
- Digital twins and monitoring platforms for lifecycle building management,
- Reality capture algorithms and methodologies for extracting geometric, semantic, and material information from the built environment.

The RF will contribute to transfer research output to realize the vision by:

- Pilot implementation in large-scale construction and building transformation contexts providing a basis for validating research outputs under real conditions,
- Deployment of digital tools, robotic systems, and data infrastructures within demonstrator environments, where their performance, scalability, and applicability can be evaluated,
- Open digital platforms supporting data sharing and interoperability, enabling coordination across stakeholders and lifecycle stages.

5.5. Research field 5 - Climate resilient and adaptive infrastructure

The research challenge of the field is to connect theories and procedures for climate change projections at global and regional scales to assess and mitigate the risk of the present and future civil infrastructure at local scales.

The RF vision is to embrace technology and innovative practices to address climate challenges within planetary boundaries and to create a meaningful impact by encouraging municipalities, agencies, and consulting engineers to adopt resilient and comprehensive solutions for urban and coastal management that prioritize biodiversity.

This RF will develop climate resilient and adaptive infrastructure, redesign urban infrastructure and coastal defences for resilience to climate extremes – integrate nature-based solutions, enhance monitoring, predict climate risks and optimise response strategies based on the concept of abandon-adapt-protect.

The research activities include:

- Development of data acquisition, management and models of climate and infrastructure,
- Multiphysics modelling of infrastructure in a changing climate,
- Development of solutions to adapt the coastal and urban zone to rising sea levels and more extreme weather,
- Development of solutions to adapt civil infrastructure to changing weather patterns,
- Projecting climate change scenarios into risk and reliability analysis of civil infrastructure.

The research output include:

- Remote sensing methodologies and data-driven models for understanding of coastal dynamics,
- Nature-inspired solutions explored for shoreline protection, integrating vegetation and marsh land as buffer zones,
- Downscaling of climate change scenarios to local coastal impact and urban infrastructure assessment,
- Improved data management for real time control of urban stormwater management,
- Improved model concepts for reliable forecasting of corrosion, odour, and greenhouse gas related problems as well as system failure risk assessment,
- Multi-Physics computational framework for climate-driven geohazards,
- Systematic analysis of coastal and urban water hazards to facilitate informed decision-making processes.

The RF will contribute to transfer research output to realize the vision by:

- Dissemination through university education and through life-long education courses focused on climate-resilient and livable solutions to equip professionals with essential skills for the future,
- Development of guidelines for implementing resilient methods that enhance biodiversity in urban and coastal areas,
- Dissemination through traditional academic channels such as journal publications and conference contributions,
- Organisation of seminars and workshops with industry leaders and municipal representatives to explore new technologies and methodologies,
- Launch pilot projects that challenge conventional practices to gain acceptance for solutions among a broader range of stakeholders.

5.6. Research field 6 - Sufficiency, well-being and energy efficiency

The research challenge of the field is to integrate sufficiency principles across the full building lifecycle, from design and construction to operation and grid integration.

The RF vision is to bring the concept of sufficiency into the engineering disciplines of indoor environment, building design and technology as well as smart control of buildings. In all of this it is paramount to include humans and their interaction with the buildings as well as the buildings' interaction with smart energy grids for optimised management, and utilising buildings as energy storage and for demand response capabilities.

This RF will generate new interdisciplinary knowledge about sufficiency required to understand and engineer sufficiency solutions within the build environment, including developing the technological foundations of management and smart control of buildings for sufficiency. Through basic research, experimental testing, and digital design methods we will accelerate the transition toward sufficiency in retrofitting and newbuild of buildings and urban environments.

The research activities include:

- Development of building related sufficiency principles along with guidelines for implementation in practice,
- Development of sufficiency-oriented and occupant-centric comfort models,
- Development of sufficiency-based design optimization and evaluation methods,
- Development of a smart building and demand response management platform that integrates sufficiency-based control algorithms balancing energy use and comfort.

The research output include:

- New sufficiency-based building control strategies balancing energy performance, comfort, cost, and environmental impact,
- A proof-of-concept for occupant-driven control systems, including evaluation of potential energy savings,
- A concept methodology for optimizing building designs and technologies using sufficiency criteria and data-driven approaches,
- A digital twin platform capable of integrating sufficiency measures, optimizing building performance, and enabling real-time demand response through sufficiency-based control algorithms.

The RF will contribute to transfer research output to realize the vision by:

- Communication, information and education to spread the knowledge about sufficiency strategies,
- Publishing a policy brief on definition of building related sufficiency to be used by the sector and in CEBE,

- Suggest sufficiency-based comfort norms to relevant standardisation bodies,
- Publish a roadmap to future-proof the building stock application for future weather scenarios, including a decision-making strategy (refurbishment and new build),
- Publish practical guidelines for sufficiency-oriented building operation, including training and workshops for facility managers and grid operators,
- Demonstrating and documenting research solutions in selected buildings.

5.7. Research field 7 - Extending the life of the built environment

The research challenge of the field is to enable safe, reliable, and resource-conscious performance, well beyond original design life span through science-based, risk-informed, and sustainability-driven approaches

The RF vision is a built environment in which extending the service life of existing buildings and infrastructure becomes the preferred pathway.

This RF will develop an interdisciplinary framework for lifetime extension by quantifying deterioration and capacity, forecasting climate-driven demands, creating adaptive retrofit solutions, and delivering transparent risk-and-reliability-based sustainability-informed decision support that integrates structural health monitoring information.

The research activities include:

- Assessing the capacity and residual life of existing structures through combinations of advanced analytical, numerical, and monitoring methods; including modelling of deterioration mechanisms and fatigue damage prediction,
- Prediction of future loading and use scenarios for buildings and infrastructure based on developed sensing approaches combined with analyses of how climate change may influence environmental loading processes and how these changes affect structural safety and long-term durability,
- Investigation of strengthening and repair strategies that increase the capacity and remaining service life of buildings and civil infrastructures as well as adaptive solutions such as active aerodynamic control of slender or line-like structures to reduce loading effects and improve structural resilience,
- Development of decision support frameworks for risk-informed lifetime extension of the built environment including determination of suitable reliability levels for existing structures and practical guidance for risk informed decisions on repair, retrofitting, and transformation.

The research output include:

- Sensing and monitoring technologies that support data driven assessment and adaptive operation of infrastructure including systems for automated inspections, algorithms for virtual sensing of wind loading from structural response measurements, and artificial intelligence methods,

- Efficient methods for assessing the load bearing capacity of reinforced concrete bridges and buildings supported by experimental data for validation,
- Improved modelling tools and experimental techniques for characterizing rebar corrosion and alkali silica reaction and for understanding how these deterioration mechanisms influence structural behavior,
- A framework for diagnosing fatigue induced cracking and estimating the remaining fatigue life of steel structures, supported by multi fidelity structural models, virtual sensing tools and advanced fracture mechanics-based fatigue models for simulating crack initiation and growth,
- Machine learning models for probabilistic prediction of wind conditions affecting structural performance, and a multi physics modelling framework that links large scale climate developments with the local environmental conditions acting on structures,
- Practical improvements to current risk- and reliability-based assessment frameworks.

The RF will contribute to transfer research output to realize the vision by:

- Developing practical guidelines, demonstration projects, and open datasets to translate validated models and monitoring methods into engineering workflows used by consultants and infrastructure owners,
- Collaborate with consulting firms, infrastructure owners, and public authorities to test tools in real projects and build confidence in lifetime extension approaches,
- Engage regulators, standardization bodies, and professional organizations to promote and integrate new reliability frameworks and assessment methods into design standards and approval procedures,
- Provide training programs, workshops, and digital tools to help engineers adopt new modelling, monitoring, and data driven decision support methods,
- Establish shared monitoring platforms and data partnerships among universities, industry, and authorities to address data gaps and support coordinated infrastructure management.

5.8. Research field relations and interfaces

Although each of the research fields focuses on individual knowledge gaps, the ability to meet the vision of the programme and the expected outcomes and impact, ultimately depends on collaborative efforts and extensive exchange and exploitation of research outputs. The seven CEBE Research Fields (RF1–RF7) form an interconnected research ecosystem in which each field contributes specialised knowledge, methods, and data to support a shared mission: enabling circular, low-carbon and resilient built-environment solutions. Their interfaces span methodological alignment, data exchange, co-development of technologies, and coordinated contributions to design, construction, operation, and lifecycle assessment.

- **RF1** provides the methodological backbone of the programme. It develops sustainability assessment methods, LCA frameworks, and planetary-boundary metrics that apply across all RFs. All methods developed in RF1 will be made operational for application across the other research fields. RF1 receives material, performance, and environmental data from RF3, RF4, RF5, and RF6 to refine its models.
- **RF2** focuses on circular design and construction integrating RF1's sustainability metrics, RF3's material performance data, RF4's robotic fabrication workflows, and RF6's sufficiency and comfort models. RF2 acts as a design integrator, translating scientific insights into low-carbon and circular construction strategies.
- **RF3** contributes with material characterisation, reuse strategies, durability insights, and risk methodologies to RF2. It interfaces strongly with RF7 on reliability and lifetime extension, with RF4 on robotic fabrication and deconstruction, with RF1 on LCA data exchange, and with RF5 on low-carbon materials and soil-structure interactions.
- **RF4** is the digital and automation hub, providing robotics, sensing, digital twins, and semantic information models. It collaborates with RF2 on circular construction systems, with RF3 on fabrication constraints and reuse workflows and with RF6 and RF7 on digital twins and monitoring.
- **RF5** anchors the programme in environmental and geotechnical realities. It provides climate-adaptation insights, soil-structure interaction data, and local-material strategies. RF5 provides knowledge and technical solutions essential for the life cycle assessments in RF1. RF5 interfaces with RF3 on low-carbon materials, with RF7 on environmental boundary conditions.
- **RF6** contributes sufficiency concepts, comfort models, building-performance simulation, and smart-operation workflows. It collaborates with RF1 on absolute sustainability, with RF2 on design context, with RF4 on digitalisation, and provides background knowledge to all RFs.
- **RF7** focuses on structural condition assessment, deterioration modelling, and lifetime extension. It interfaces with RF3 on reuse and risk, with RF4 on sensing and digital twins, with RF5 on environmental boundary conditions, and with RF1 on reliability data for sustainability assessments.

The interfaces and interdependencies of the research fields is elaborated and illustrated in more detail in the research field chapters in the appendix. Together, the RFs form a coherent system: RF1 provides evaluation methods; RF2 shapes regenerative design; RF3 supplies material and reuse science; RF4 enables digital and robotic implementation; RF5 grounds the work in environmental conditions; RF6 ensures human-centred and operational relevance; and RF7 secures structural reliability and lifetime extension.

6. Stakeholder Engagement and Collaboration

The vision of CEBE considerably widens the sustainability scope by implying and staging a fundamental transformation of civil engineering practices, methods and technologies thereby clearly differentiating the CEBE initiative from ongoing research programmes and initiatives.

The research output of CEBE will lay the scientific foundation for formulation of a new generation of long-term political sustainability goals for the building sector and will potentially provide the sector with new directions and examples of strategies, methods and technologies to realise a future civil engineering and building sector complying with planetary boundaries.

However, as mentioned in section 4.4 CEBE needs a strong collaboration with society, building sector, industry players and governmental authorities to transform CEBE research results via innovation, test and demonstration into new technologies, methods and solutions that are practically applicable, scalable and economically profitable.

In the following sections, the plans for engagement of and collaboration with these stakeholders are described.

6.1. Building Sector Engagement and Collaboration Strategy

A targeted effort by CEBE management will be to develop CEBE to be a platform for industry collaboration. CEBE will establish a partnership model within the first six months of the programme where building sector and industry representatives will be invited into the "research engine room" of the programme and in close collaboration with CEBE influence and develop the programme, the research output and the impact on industry and society.

These partnerships will offer the following to influence development of research topics and output as well as guide education and training:

- Building sector dialogues at a yearly CEBE Partner summit on long-term development needs and innovation challenges to create a common platform for alignment of research, development and innovation efforts,
- CEBE research field advisory boards providing feedback and recommendations on research field focus, directions and output of specific research projects at biannual research field status meetings (first round of RF meetings in October 2026),
- Co-supervision of CEBE programme PhD's and postdocs and access to CEBE Research School activities including both courses and seminars,
- Industry partners in the Industrial and/or Interdisciplinary Fellowship Programmes,
- Development and implementation of national challenges that unites student teams from the four universities in addressing ambitious sector development challenges,
- Collaboration on master level student projects to test potential implementation and application of research outputs,

- Leveraging opportunities offered by the new Industry Master's programme enabling students to complete the second year of their two-year master's degree while working part-time in a relevant company.

Based on the developed partnership model the individual Research Fields will involve industry as early as possible in their research and further develop their own strategies and initiatives for industry involvement and collaboration. The partners in CEBE already work closely together with industrial partners in several R&D projects and CEBE will provide an opportunity for further strengthening these collaborations to develop and maintain a more strategic long-term involvement of industry partners. The CEBE partnership will offer co-development of follow-up funding to strengthen the programme's innovation and implementation capability and to facilitate transferring of research output into practical solutions. This will include:

- Organisation of workshops to facilitate discussions and development on follow-up funding of development and innovation projects with potential partners,
- Co-development of flagship case studies in collaboration between CEBE, industry, public or private stakeholders, and private foundations to transform research outcomes to practical test and demonstration of new methods and solutions and to ensure a strong systemic approach to transferring research output to both immediate and more long-term societal and industrial impacts.

6.2. Academic Collaboration Strategy

The programme's ambition is to reach world-class research capacity and quality by exploiting the synergies of an integrated sectorial approach. To maximise the synergies the programme will throughout its lifetime promote networking and facilitate and co-fund collaborative research projects by establishing an Interdisciplinary Fellowship Programme supporting interdisciplinary and cross field research projects

CEBE will also facilitate close collaboration with outstanding international academic partners. The collaboration will enable knowledge exchange, open discussions on research achievements and a mutual dialogue on research challenges and development needs providing an excellent basis for establishing important international university partnerships. The international engagement will also facilitate and activate cross-field coordination and collaboration. It will include the following activities:

- Organisation of biennial international conferences gathering leading international academics and industry managers enabling a mutual dialogue on research challenges and needs, taking stock of new international research agendas and pushing new sustainability and green transition paradigms,
- Access for international researchers to the national research data and analysis platform established for sharing of data and method and to the CEBE Infrastructure Gateway established for sharing of state-of-the-art and unique experimental facilities,
- Engagement of international partners in the International Partner Fellowships programme and in international follow-up funding applications,

- Invitations of international academics to act as peer-reviewers, keynote speakers, workshop/conference co-leads, lecturers at the research school, international host for PhD/postdocs and as hosts for the International Mobility Programme,
- Strengthening and coordinating present involvement of Danish researchers in international organisations and standardisation,
- Attracting existing large international conferences to Denmark to secure extra international visibility and recognition.

6.3. Informing policy, regulatory authorities and community

Policy makers and regulatory authorities are key stakeholders in the transformation of the built environment towards operating within planetary boundaries and much of the future change in the construction sector will be driven by regulatory developments.

The partners in CEBE already have relatively close dialogue with public authorities on the development of new policies for a sustainable build environment and have also key representation in relevant advisory boards.

We expect CEBE to strengthen both the amount and quality of evidence informing the public authorities driven by a significant strengthening of the foundation for science-based policy recommendations and of the synergies coming from the structured and aligned collaboration across the partners and the civil engineering research.

Throughout the programme, CEBE will engage with and inform public authorities (DK, EU and abroad). Among other things, we will arrange targeted seminars at the Danish parliament, contribute to future revisions of the "Climate Act" and the "National Strategy for a Sustainable Built Environment" and organise seminars together with our European partners (ENBRI, ECTP, B4P) to inform EU policy officers and the Commission.

Transforming the built environment also requires involvement of communities and the public. We will work strategically with communicating research objectives, challenges and results publicly (website, Linkedin etc.) and engage the public in the CEBE vision. Moreover, we imagine CEBE participation in public exhibitions on new construction and community involvement in pilot projects and demonstrations.

7. Education and Capacity Building

The CEBE programme has a strong focus on education of the next generation of engineers and researchers and on building knowledge and research capacity for both academia and industry to drive the green transition in construction. Therefore, an important objective of the programme is to position Denmark as frontrunner in taking the next steps in the green transition in the built environment through scholarly renewal and excellent research-based education. The programme will support and facilitate this through activities including:

- Educating M.Sc. and PhD candidates with strong expertise in Civil Engineering and the Green Transition in the Built Environment,
- Establishment of a CEBE Research School in Sustainable Civil Engineering with the purpose of offering cutting-edge training programmes in collaboration with relevant doctoral schools at the partner universities,
- The CEBE Research school will focus on sector specific multi- and cross-disciplinary activities supplementing the more discipline-focused PhD courses at the existing doctoral schools,
- Establishment of a Global Talent Recruitment Programme with the purpose of attracting top international research talents to Danish universities through competitive fellowships,
- Network activities including career development activities and science webinars for knowledge exchange,
- Development and implementation of M.Sc. student challenges with the purpose of uniting student teams from the four universities to develop innovative solutions to specific civil engineering problems related to sustainability. Teams will collaborate across universities and with industry partners,
- Development and implementation of CEBE research-based educational modules in engineering curriculum,
- Development and implementation of M.Sc. student thesis projects within the CEBE research areas in collaboration with building sector representatives,
- Organisation of industry partnerships to leverage students part-time work in a relevant company while completing their two-year Industry Master’s programme,
- Establishment of an International Mobility Programme to support researchers and M.Sc. students each year going abroad as part of their studies.

8. Program Monitoring and Review

CEBE programme progress as well as research achievements and impact will be monitored, reviewed and reported during the programme, both quantitatively and qualitatively (see section 8.3). For external reviewing, there is established a reviewing process with the Advisory Board (AB) (see section 8.1). Likewise, an internal process has been established within CEBE to continuously review the status, progress and emerging challenges (see section 8.2).

8.1. AB review and recommendations

The AB acts as an independent body that provides strategic guidance and critical assessment to the programme. It advises both the Steering Committee (SC) and the Villum Foundation on the programme's direction, coherence, and scientific quality.

The basis for AB review is the submission of an annual status report end of March each year (starting from 2027). The annual status report include:

- Status on the CEBE programme overall and by research field,
- Annual accounts and updated budget,
- Status of key performance indicators and qualitative evaluations (see section 8.3),
- An evaluation of the programme progress by the MD.

Based on the annual status report, the normal yearly reviewing process is the following:

- An annual status meeting is held with the AB in June each year on research challenges and dilemmas, programme and research field progress, strategic considerations, adjustment of direction for next year(s), etc.,
- Based on the status report and the annual meeting AB submits a written evaluation, incl. recommendations, of the program by the end of July to the Villum Foundation,
- Based on this and the approval of the Villum Foundation Board, the programme is adjusted, and the payment for the next year is installed.

In year 2030 the reviewing process also includes a mid-term evaluation and in year 2029 and 2031 a short application for year 5-6 and 7-10, respectively.

8.2. CEBE self-monitoring and -review

Self-monitoring and the continuous review of progress are intrinsic parts of the CEBE programme and of the role of the CEBE management. Continuously, CEBE tracks employment, spendings, activities and other KPIs (see 8.3) and is in touch with the research fields and their progress.

In order to follow-up in a structured way on research field progress and identify and discuss emerging challenges, dilemmas and opportunities, CEBE management will organise a formal biannual full day status meeting per research field with presentation and discussion of the progress of on-going projects (starting October 2026). An advisory board of industry representatives and key academics from partner universities will discuss, review and evaluate project and research field progress according to the research field specific targets presented in the research field chapters in the appendix.

Moreover and formally, the CEBE management provides SC with regular progress reports to facilitate ongoing monitoring and enabling timely strategic adjustments. The annual status report is reviewed and approved by the SC before submission to the AB.

8.3. Key Performance Indicators and Qualitative Evaluations

A set of **Programme Key Performance Indicators** (KPIs) has been developed to evaluate programme progress (see table 4 and 6). In selecting the KPIs, we have aimed both to reflect the programme's main objectives and activities and to keep the number of KPIs at a level that remains manageable.

The KPIs are organized in the following relevant categories: Employment, Research Results, Follow-up projects and funding, Education and Diversity. Most of the KPIs can be evaluated by individual research field. These KPIs are to be used both for an evaluation of the performance of the overall programme as well as the individual research fields.

Moreover, in the CEBE Roadmap appendix, each research field has defined its own specific research targets (categorized as outputs, outcomes or impacts, see table in section 4.7) against which progress and realization of these targets will be monitored throughout the programme.

Some parts and objectives of the programme cannot be appropriately measured in quantitative terms. To systematically evaluate these as well, the progress of these parts of the programme will be reviewed with a set of **Programme Qualitative Evaluations** (QEs) (see table 5). The QEs will include a traffic light assessment and a qualitative evaluation, supported by text and relevant datapoints. The QEs are organized in two categories, where the first is Status on strategic goals, and the second is Status on planned programme activities.

The purpose and the intended applications of KPIs and QEs over the course of the programme is the following:

- to be used structured in the annual status report to the advisory board,
- for the CEBE management to continuously track the performance of the programme,
- to be used in the continuous reviewing of the individual research field,
- to set a focus for the overall programme and for the research fields.

The KPIs and QEs are planned to be rather consistent over the course of the programme, although they will be refined yearly at the Steering Committee Strategy Seminar.

Table 4: Programme Key Performance Indicators[1]

ID	Name	Description / definition	Target for year 10	By RF
Employment[2]				
1a	PhD FTE years	Cumulative amount of PhD FTE years employed from RF-budgets	322	Yes
1b	PostDocs FTE years	Cumulative amount of Postdocs FTE years employed from RF-budgets	153	Yes
1c	Assistant Professors FTE years	Cumulative amount of Assistant professors FTE years employed from RF-budgets	133	Yes
2	Positions funded through calls	Cumulative amount of employments from calls, reported by staff category	94	Yes
Research results				
3	Publications in high impact journals	Cumulative amount of publications in journals with rigorous peer-review standards, ensuring only well-researched, and original articles are published.	650	Yes
Follow-up projects & funding				
4	Follow-up projects for research	Cumulative amount of follow-up projects granted for research	50	Yes
5	Follow-up projects for innovation and development	Cumulative amount of follow-up projects granted for innovation and development in collaboration with external partners (e.g. industry)	200	Yes
6	Follow-up funding granted	Cumulative sum of granted follow-up funding granted. KPI will be followed but without target.	-	Yes
7	Projects involving cross-field collaboration	Share of the cumulative amount of follow-up research projects involving collaboration between multiple research fields	50%	Yes
Education				
8	M.Sc. student projects within research fields	Cumulative amount of M.Sc. Projects carried out within research field CEBE topics	500	Yes
9	CEBE Doctoral School courses and seminars	Cumulative amount of PhD courses and seminars in the CEBE Doctoral School	80 (50 co.+ 30 se.)	No
10	International participation in Doctoral School	Cumulative amount of international participants and speakers in the Doctoral School	600	No
Diversity				
11	Gender balance in CEBE-employments	Share of female in cumulative employment, reported by staff category	50%	Yes
12	International diversity in CEBE-employments	Share of respectively Danish, Western and Others of the cumulative employments in CEBE	D:40% W: 30% O: 30%	Yes

[1] See yearly targets each indicator in, table 6

[2] FTE years from RF-budgets corresponds to these numbers of positions: 107 3-years PhDs, 77 2-years PostDocs and 27 5-years assistant professors

Table 5: Programme Qualitative Evaluations

ID	Name	Description and questions	Possible data for evaluation
Status on strategic goals			
1	Research implementation in education	- To what extent is CEBE research implemented in education?	Examples of materials used and courses developed
2	Informing policy and regulation in DK and abroad	- Does CEBE inform policy and regulation, e.g. organizing policy relevant seminars?	Examples of policy/regulation interactions and relevant papers
3	Involvement in certification and standardisation	- Is CEBE involved in certification and standardisation?	Examples of concrete involvement
4	Industrial collaboration and partnerships	- Does CEBE establish collaboration with industry to bridge the gap between research and industry?	Examples of partnerships, meetings and collaborations
5	Emerging and developing country relevance, knowledge exchange and collaboration	- Does the CEBE program show relevance for emerging and developing country problems? - Does CEBE work for knowledge exchance and collaboration here?	Examples of solutions and examples of dialogue and knowledge exchange
6	Research field collaboration	- Do the research field suceed in collaborating to solve problems outside own solution scope?	Research field survey and coordination unit experience
7	Partner university collaboration	- Does the CEBE program facilitate collaboration between the universities and how is that progressing?	Partner survey and coordination unit experience
Status on planned programme activities			
8	Green Civil Engineering Data and Analytics Platform	- How is the progress of establishing the national research data and analytics platform?	Use of platform
9	Villum Infrastructure Gateway	- How is the progress of establishing the gateway?	Use of gateway
10	Student Challenges	- How is the progress of the planned 5 student challenges?	Participants in the student challenges and survey hereof
12	CEBE Doctoral School in Sustainable Civil Engineering	- How is the progress of the Doctoral School?	Arranged seminars and courses and evaluations hereof
13	Establishment of flagship case studies	- How is the progress of the CEBE vision of establishing a number of flagship case studies bringing the research into practice?	Sites and partners onboard
14	Organisation of international conferences	- Do the program succeed in the ambition of executing 5 international conferences in DK?	-
15	Attract existing international conferences to DK	- Do the program succeed in the ambition of attracting an international conference to DK?	Progress in establishing relevant contacts etc.
16	Organisation of sessions/workshops at international conferences	- How is the progress of organizing sessions and workshops at international conferences?	Number of sessions/workshops

Table 6: Yearly KPI targets

ID	Name	Target for year 10	Year	1	2	3	4	5	6	7	8	9	10
Employment													
1a	PhD FTE years	322		27	68	117	143	175	213	255	290	311	322
1b	PostDocs FTE years	153		11	24	33	47	64	76	91	109	138	153
1c	Assistant Professors FTE years	133		11	25	42	64	89	104	116	126	130	133
2	Positions funded through calls	94		0	38	38	38	56	56	94	94	94	94
Research results													
3	Publications in high impact journals	650		15	50	110	185	255	330	410	490	570	650
Follow-up projects & funding													
4	Follow-up projects for research	50		2	5	9	14	20	26	32	38	44	50
5	Follow-up projects for innovation and development	200		4	10	20	35	55	80	110	140	170	200
6	Follow-up funding granted	-		-	-	-	-	-	-	-	-	-	-
7	Projects involving cross-field collaboration	50%		20%	25%	40%	50%	50%	50%	50%	50%	50%	50%
Education													
8	M.Sc. student projects within research fields	500		50	100	150	200	250	300	350	400	450	500
9	CEBE Doctoral School courses and seminars	80 (50 courses+ 30 seminars)		4	9	18	27	36	45	54	63	72	80
10	International participation in Doctoral School	600		20	67	134	201	268	335	402	469	536	600
Diversity													
11	Gender balance in CEBE-employments	50%		50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
12	International diversity in CEBE-employments	Danish 40%		40%	40%	40%	40%	40%	40%	40%	40%	40%	40%
		Western 30%		30%	30%	30%	30%	30%	30%	30%	30%	30%	30%
		Others 30%		30%	30%	30%	30%	30%	30%	30%	30%	30%	30%

9. Risk Management

In the CEBE program we want researchers to take risks, be bold and ambitious in research and in establishing new partnerships for the green transition of the built environment. This entails an increased risk of failure and the emergence of challenges. Risk management is therefore a central element in the CEBE programme and an important aspect in achieving its ambitions. The purpose of this chapter is to describe CEBE's approach to risk management and the main risks for the programme.

The risk management in CEBE is intended to be practical and not too bureaucratic while still ensuring necessary structure and awareness of challenges and risks to enable timely action. An important principle is that researchers are encouraged to be open and transparent about risks and challenges.

The risk management includes the following elements:

- Each research field is responsible for maintaining a practical *RF Risk log* with identification of main risks, assessments and mitigation measures,
- CEBE management maintains a *CEBE Risk Log* and keeps overview of *RF risk logs,*
- Risk management and emerging challenges are embedded in the agendas of the biannual research field status meetings.

In table 7 the main cross-research field risks of the programme are presented.

Table 7: List of main risks in the CEBE programme and suggested mitigation measures

Risk	Description	Mitigation
Internal		
Expected research output (new methods, materials etc.) cannot be fully achieved	Despite careful planning, ambitious targets cannot be reached (due to e.g. scientific, technological, methodological, data limitations)	Maintaining flexibility to redirect efforts towards alternative research pathways that support the overall programme objectives
Collaboration challenges between partners	Limited collaboration or conflicts may reduce the programme's ability to leverage synergies across universities and research fields	Clear roles across program; Close involvement from leadership and a strong management team to ensure alignment and mitigate challenges early
Stakeholders		
Industry and public authorities will not take up research output as expected	A central assumption for the impact of the programme is industry collaboration and take up of research outputs, and industry resistance to take up is a risk both affecting follow up funding and impact opportunities.	Early and structured involvement of industry and contractors – both at programme and at research project level.

		Considering and adjusting planned CEBE impact levers
External		
Changing external perspectives on the importance of the green transition	External shifts in political priorities, economic conditions, or societal and market perspectives reduce the perceived importance of the green transition. Such changes may affect among others stakeholder engagement and access to complementary funding for innovation and demonstration activities as well as for collaboration with emerging and developing countries.	Maintain focus on disseminating scientific evidence through policy briefs on the benefits of the green transition for society and the planetary boundaries
Slow uptake in standards and regulations	Uptake of new research outputs in standards and regulation is in many cases a prerequisite for applicability and scalability. A slow uptake in regulation will delay uptake in industry and affect impact opportunities	Focus on strengthening the foundation for science-based policy recommendations and on informing Danish and European policies through established networks and activities

What is CEBE?

The research programme Civil Engineering and the Green Transition in the Built Environment (CEBE) has been established to create new scientific knowledge and solutions for a sustainable building sector within planetary boundaries.

CEBE brings together Aalborg University, Aarhus University, the Technical University of Denmark and the University of Southern Denmark in a partnership designed to realise this potential. Supported by a one billion DKK grant from the Villum Foundation, the initiative mobilises leading expertise to advance research, strengthen research-based education, accelerate innovation, and enhance international collaboration.

The knowledge generated through CEBE will benefit the entire building value chain, from supply chains, materials and design to construction, operation, renovation and reuse.

CEBE provides a unified platform that ensures this knowledge is translated into practical solutions, supporting the green transition of the built environment and strengthening the sector's capacity to deliver sustainable change.