Lecture Notes in Civil Engineering

Luís Bragança · Katerina Tsikaloudaki · Christina Giarma · Ricardo Mateus · Karolos Kontoleon · Rand Askar · Adriana Salles · Camila Cervantes *Editors*

ReShaping the Built Environment through Sustainability and Circularity

Proceedings of ReSBE 2026 International Conference - Volume 2

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Editors
Luís Bragança
Department of Civil Engineering
University of Minho
Guimarães, Portugal

Christina Giarma
School of Civil Engineering
Aristotle University of Thessaloniki
Thessaloniki, Greece

Karolos Kontoleon
School of Civil Engineering
Aristotle University of Thessaloniki
Thessaloniki, Greece

Adriana Salles
ISISE
University of Minho
Guimarães, Portugal

Katerina Tsikaloudaki
School of Civil Engineering
Aristotle University of Thessaloniki
Thessaloniki, Greece

Ricardo Mateus
Department of Civil Engineering
University of Minho
Guimarães, Portugal

Rand Askar
ISISE
University of Minho
Guimarães, Portugal

Camila Cervantes
ISISE
University of Minho
Guimarães, Portugal



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Preface

As Organisers of ReSBE 2026, we are honoured to present the Proceedings of the International Conference *ReShaping the Built Environment through Sustainability and Circularity*, held in Thessaloniki, Greece, from the 20th to the 23rd of October 2026.

Published in Open Access by Springer, these Proceedings reflect our commitment to making research and practical innovation at the intersection of sustainability, circularity, and the built environment widely available. By ensuring that the contributions can be consulted, cited and applied without restrictions, we hope to support informed decisions and accelerate positive change in the built environment and in society as a whole.

Society and governments require a more efficient, resilient, and regenerative built environment. Buildings and infrastructure shape patterns of resource use, energy demand, carbon emissions, social well-being, and economic development. In this context, the Circular Economy offers a vital framework for decoupling value creation from the consumption of finite resources by extending the service life of products and materials, enabling reuse and recovery, and promoting the valorisation of by-products and waste. Construction and the built environment have therefore become priority areas for policy, research, and professional practice, including within the European Commission's Circular Economy Action Plan. In parallel, the implementation of sustainability principles into the various scales of the built environment remains a primary goal of numerous policies and scientific efforts worldwide. ReSBE 2026 responds to this complex agenda by moving beyond incremental improvement and by advancing transformative approaches that drive systemic change across the design, construction, operation, and renewal of the built environment.

The conference was organised by the Laboratory of Building Construction and Building Physics of the School of Civil Engineering, Aristotle University of Thessaloniki, and the Department of Civil Engineering of the University of Minho, in collaboration with the COST Action CA21103 "Implementation of Circular Economy in the Built Environment – CircularB", with the support of the International Initiative for a Sustainable Built Environment (iiSBE).

ReSBE 2026 also marked an important moment in the journey of COST Action CircularB. Alongside presenting cutting-edge research, the conference provided an opportunity to showcase the Action's achievements, disseminate its results, and celebrate the collective efforts of its international network in advancing circularity in the built environment. More importantly, it created a platform for engaging the wider scientific, professional, and policy communities, fostering new collaborations and extending the impact of CircularB beyond the lifetime of the Action.

Within the ReSBE 2026 programme, the 1SBE event "Sustainability in the Built Environment Supported by Circular Strategies: Theory Meets Practice" further strengthened the conference's international scope. As part of the SBE Conference Series, this event created a forum for dialogue among policymakers, industry representatives, social

partners, and academics, thereby linking scientific knowledge with implementation challenges and opportunities.

ReSBE 2026 was devoted to presenting recent scientific advances, showcasing practical applications that bridge academia and industry, and discussing key issues concerning the contribution of sustainability and circularity to the modern and future built environment, its construction, and its infrastructure. A principal goal of the conference was to foster the exchange of ideas, methods, and evidence in ways that inspired innovative research paths and advanced new collaborative endeavours across disciplines, geographies, and sectors.

The conference received 541 abstracts from 1368 authors across 71 countries. Following a rigorous peer-review process, 335 full scientific papers were accepted for publication and organised into twelve thematic sections:

1. *Circular Design and Construction:* design for adaptability, reuse, and disassembly; material passports; modularity and standardisation.
2. *Sustainable Buildings, Infrastructures and Cities:* sustainability assessment frameworks, sustainable design, construction, operation and management; synergies across scales.
3. *Lifecycle Assessment, Metrics and Monitoring:* whole-life carbon, embodied energy, circularity indicators, benchmarking frameworks, multi-criteria decision-support methods, and AI/IoT-enabled lifecycle monitoring.
4. *Digitalisation and Automation:* BIM-based approaches, digital twins, digital passports, AI-powered tools, and decision-support systems.
5. *Climate Adaptation and Resilience:* climate-responsive design, resilient infrastructure, and nature-based solutions.
6. *Energy and Performance:* net-zero energy, carbon-neutral buildings, renewable energy integration, and smart grids.
7. *Materials and Innovation:* bio-based and regenerative materials, advanced composites, and secondary raw materials through industrial symbiosis.
8. *Urban and Regional Perspectives:* circular cities, heritage regeneration, and urban mining.
9. *Financing and Market Transformation:* circular business models, green financing, and innovative procurement strategies.
10. *Policy and Governance:* regulatory frameworks, certification systems, and leadership for circularity.
11. *Stakeholders and Collaboration Models:* roles, interactions, and governance mechanisms for systemic change.
12. *Societal and Educational Dimensions:* awareness, equity, skills, and capacity-building for sustainable transitions.

The contributions in these proceedings offer readers a broad and timely overview of the concepts, tools, technologies, policies, and case studies that are shaping the transition towards a sustainable and circular built environment. They address questions of direct relevance to researchers, designers, engineers, architects, policymakers, educators, and industry stakeholders, from whole-life performance and digitalisation to financing models, governance frameworks, stakeholder collaboration, and capacity-building.

Taken together, these contributions demonstrate that innovation, circularity, and sustainability are deeply interconnected. They also show that progress depends not only on technical solutions, but also on new forms of cooperation, new metrics for value and performance, and a shared willingness to rethink established practices. In light of this, the present Open Access publication aims to be a collection of high-quality research and serve as a catalyst for further inquiry, dialogue, collaboration and action.

We extend our deepest gratitude to all authors, the members of the Scientific Committee, the reviewers whose careful work upheld the excellence of the selected articles, and our publishing partners for their invaluable support. May these Proceedings inspire and facilitate the ongoing effort to engineer a sustainable, circular, and regenerative built environment for all.

The Organising Committee,

Luís Bragança
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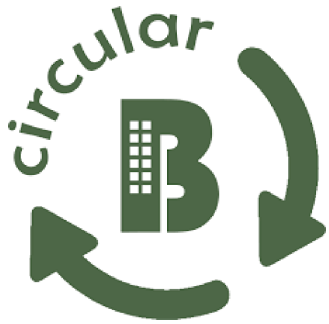
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Building Transitional Skills for a Sustainable Construction Ecosystem: Educational Innovation and Societal Impact of the BuildSkills Academy Project

Emanuele Piaia(✉)

University of Ferrara, Ferrara, Italy
emanuele.piaia@unife.it

Abstract. The twin green and digital transition is reshaping the built environment and generating urgent demand for new competences across the construction ecosystem. In this context, Vocational Education and Training (VET) must move beyond static provision models and adopt more adaptive and quality-oriented approaches. This paper analyses the BuildSkills Academy (BSA) as a transnational framework for supporting sustainable transitions through skills intelligence, curriculum enrichment, provider self-assessment and certification. It examines how BSA addresses awareness, equity, skills development and institutional capacity-building in construction. Methodologically, the paper combines literature on sustainable construction, circularity, digitalisation and VET transformation with a qualitative analysis of project materials on skills-gap analysis, BESM, pilot implementation, quality assurance and certification. Findings show that BSA contributes by translating transition priorities into structured topical areas, occupations and competences; supporting VET providers through a three-step process of self-assessment, gap identification and enrichment; testing transferability through twelve pilot courses across EQF levels and national contexts; and linking curriculum innovation with external validation and certification principles.

Keywords: Vocational Education and Training · Sustainable transitions · Built environment · Green and digital skills · Capacity-building

1 Introduction

The built environment sits at the centre of current sustainability debates because it concentrates major environmental, social and economic pressures. Construction remains highly dependent on resource extraction, energy use and fragmented decision-making, yet it is increasingly expected to deliver decarbonisation, climate adaptation, circularity, healthier living conditions and digitally enhanced performance. These expectations imply not only technological change but also a reconfiguration of professional roles, occupational standards and learning pathways.

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Recent literature shows that sustainable transformation in construction cannot be achieved through regulation and innovation alone; it also depends on whether education and training systems can anticipate and support change. Digital tools such as BIM, material databases, data-driven monitoring and digital twins are recognised as enablers of circularity and lifecycle optimisation, but their uptake remains uneven and is often constrained by skills deficits and weak coordination between training supply and labour-market demand. At the same time, VET research stresses that sustainability-oriented transitions require educational models able to connect green transformation, social justice, lifelong learning and institutional responsiveness.

In the construction sector, skills needs are evolving rapidly in areas such as energy-efficient design, circular material flows, sustainable procurement, indoor environmental quality, health and well-being, risk management and AI-supported coordination. Yet educational provision often remains slow to adapt, and the recognition of emerging green and digital competences is still fragmented across national systems. The BuildSkills Academy (BSA) addresses this gap through a pan-European architecture that combines skills-gap analysis, curriculum enrichment, provider self-assessment, quality assurance, piloting and certification.

2 Educational Transitions in the Built Environment

Research on sustainable construction increasingly emphasises that environmental performance cannot be separated from knowledge infrastructures. Çetin, De Wolf and Bocken's [2] work on the "circular digital built environment" is especially relevant because it shows that digitalisation should not be treated as an autonomous innovation stream, but as an enabling condition for circular-economy practices through improved traceability, data integration and collaborative lifecycle decision-making. This perspective is particularly important for the present paper because it supports the interpretation of digital tools not merely as technical upgrades, but as part of a broader sustainability transition in the built environment.

A second strand of literature concerns educational responses to sustainable construction. Koukou et al. [3] argue that integrated and transnational approaches are necessary to equip students and professionals with the competences required for sustainable and healthy buildings, especially when training must combine technical content, multidisciplinarity and practice-oriented learning. More broadly, this line of research suggests that energy transition, circularity, adaptive reuse and health-oriented design cannot be effectively mainstreamed through isolated modules alone, but require deeper curricular restructuring and stronger alignment between educational provision and sectoral transformation priorities.

A third strand concerns green skills and curriculum responsiveness more broadly. Recent VET scholarship shows that educational institutions often face persistent gaps between declared sustainability ambitions and the actual competences produced through curricula. The issue is not simply whether new content is added, but whether providers are able to revise course design, assessment methods, staff development and labour-market linkages in ways that remain responsive over time. In this sense, sustainable transitions reveal structural weaknesses in how educational systems sense, translate and act on changing sectoral demands.

Finally, the VET literature [1] increasingly foregrounds equity and justice. Sustainable transitions create new opportunities, but also new divides related to age, gender, educational background and access to lifelong learning. A just-transition perspective therefore requires VET not only to support employability, but also to widen access to emerging competences and reduce barriers to participation in future-oriented occupations. Avis explicitly argues for a broader conceptualisation of VET that moves beyond instrumentalism and engages more directly with just transitions.

Taken together, these debates reveal a clear analytical gap. Many initiatives address only one dimension of the transition challenge, such as digital skills, green curricula, certification or stakeholder engagement. Fewer contributions propose an integrated framework combining skills intelligence, pedagogical redesign, provider self-assessment, quality assurance and competence recognition in the construction ecosystem. It is within this gap that the present paper situates the analysis of the BuildSkills Academy.

3 Aims and Methodology

This paper investigates the educational and societal contribution of the BuildSkills Academy (BSA) as a transition-oriented VET framework for the built environment. It examines how green and digital agendas are translated into topical areas, occupations, skills and learning outcomes; how the project supports provider capacity through self-assessment, skills-gap identification and course enrichment; and how awareness, stakeholder participation, circularity and inclusion are embedded in the project logic. This perspective aligns with scholarship arguing that sustainability-oriented VET depends not only on updated technical content, but also on institutional responsiveness and collaborative learning.

Methodologically, the paper adopts a qualitative document-analysis approach within a practice-based perspective. The empirical corpus includes key BSA outputs on skills mapping, BESM, pilot syllabi, validation, adaptation, external quality assessment and certification, making it possible to trace the initiative from skills diagnosis to methodological design, piloting, validation, quality assurance and recognition.

The analysis was carried out in four steps. First, the documentary corpus was reviewed to identify recurring analytical categories across the project, including topical areas, occupations, transitional skills, quality criteria, validation mechanisms and certification pathways. Second, the internal logic of BESM was reconstructed by examining how self-assessment, custom skills-gap identification and enrichment interact within the digital platform. Third, pilot implementation evidence was compared across the course syllabi and the thematic-group validation report to assess transferability across EQF levels, national settings and thematic domains. Fourth, findings from project outputs were interpreted against the literature in order to distinguish project activities from the paper's analytical claims. This analytical design is coherent with recent work on sustainable VET, which emphasises the importance of reading educational change not only through curricular content, but also through collaborative and organisational learning processes [5].

To improve interpretive robustness, the paper triangulates methodological, validation and external-quality documents rather than treating any single deliverable as

self-sufficient evidence. This is especially important in project-based research, where implementation outputs may otherwise be mistaken for validated outcomes. The interpretive stance adopted here is therefore aligned with recent debates on VET for sustainable futures, which call for more reflective and transformative approaches to skills development rather than purely instrumental readings of training provision [4].

4 The BuildSkills Academy Framework

The evidence shows that BSA is structured as a multi-layered framework rather than as a single training package. Its first layer is the identification of sectoral needs through five main topical areas: Net-Zero Carbon Emissions, Climate Resilience and Adaptation, Circular Economy Practices, Sustainable Materials and Sourcing, and Occupant Health and Well-being. These are complemented by transversal transition domains such as Life Cycle Assessment, BIM, Digital Tools and Data Analysis, and Collaboration and Project Management. This is relevant because digitalisation is treated as a cross-cutting enabler of all transition domains instead as an isolated pillar.

The skills framework was developed through ESCO analysis, review of European and national sources, and validation activities involving surveys, roundtables and stakeholder feedback. The resulting architecture covers 38 occupations across the construction sector and the building lifecycle. Validation activities highlighted the high priority of net-zero construction, circularity, sustainable materials and climate resilience, while also revealing mismatches between industry priorities and current educational provision. This diagnostic layer is followed by BESM, which translates the skills framework into an operational device for course redesign. BESM is structured around three linked steps: self-assessment, skills-gap identification and enrichment. Through the digital platform, VET providers map their existing or planned courses, identify missing green and digital competences, and receive recommendations on how these gaps can be addressed. The methodology considers not only syllabus content, but also teaching methods, assessment practices, trainer preparedness, learner guidance and quality assurance.

A further layer is represented by piloting, validation and certification. The twelve pilot courses translate the framework into concrete educational offers across countries, EQF levels and thematic groups; thematic-group validation provides external sectoral feedback on the syllabi; and the certification component establishes a structured process for assessing curricula and training materials against defined criteria linked to learning outcomes and EQF levels.

5 Results

5.1 Transition Priorities and Competences

The first major result concerns the operationalisation of transition priorities into a structured and teachable competence architecture. BSA does not treat the twin transition as a generic policy narrative; instead, it converts it into five topical areas, 38 occupations and a refined set of occupation-linked competences for the construction ecosystem. This is significant because recent literature has shown that sustainability agendas often remain too broad unless they are translated into concrete competence domains and linked to sector-specific pedagogical decisions.

The project identifies 178 skills for transformation in Net-Zero Carbon Emissions, 110 in Climate Resilience and Adaptation, 129 in Circular Economy Practices, 97 in Sustainable Materials and Sourcing, and 104 in Occupant Health and Well-being. Particularly relevant is the fact that Circular Economy Practices emerges as one of the strongest areas for new skills and competences. In other words, BSA does not merely mention circularity; it gives it an operational structure through subareas such as renovation and retrofitting expertise, circular economy principles and practices in construction, design for deconstruction, material-flow management, waste-reduction techniques, digital material databases, and sustainable procurement.

This result is consistent with studies arguing that digital tools and circularity in the built environment should be understood together rather than as separate innovation streams. In that respect, the BSA framework reflects the logic of the "circular digital built environment", where digitalisation supports lifecycle intelligence, traceability and more effective circular practices.

5.2 Provider Capacity-Building

The second result concerns provider capacity-building. BESM is not only a course-enrichment device, but also a provider-level capacity-building mechanism. Through the digital platform, VET providers are asked to examine the content, teaching methods, assessment strategies, industry alignment and quality characteristics of an existing or planned course, and then receive a report indicating where green and digital competences are missing and how these gaps might be addressed.

BESM operationalises a model of institutional learning. The self-assessment logic includes course background, teaching methods, student assessment, quality assurance, career guidance, stakeholder consultation, staff development and learner-centred provisions. This broader scope suggests that BSA is addressing the organisational preconditions for sustainable VET transformation, not only curriculum content. This interpretation is consistent with recent VET literature, which argues that sustainable transitions cannot be addressed through isolated modules alone, but require provider adaptability, collaborative arrangements and organisational reflection.

In this sense, BSA's main educational innovation lies not only in the identification of missing skills, but in the creation of a repeatable mechanism through which providers can diagnose, revise and progressively improve their own provision. This point is particularly relevant for construction-related training, where technological and regulatory change can quickly make conventional course structures obsolete.

5.3 Pilot Transferability

A third result lies in the pilot architecture and the evidence of transferability. The project transfers its results into twelve pilot courses in six countries, involving 300 trainees and aiming to engage 100 VET providers, 1,000 companies and at least 100 VET–industry collaborations. The pilot syllabus documentation confirms that the courses span EQF levels 3 to 7 and include both enriched existing provision and newly designed courses.

The pilot portfolio demonstrates thematic breadth without losing sectoral focus. This breadth suggests that the framework is transferable across different occupational

profiles and levels of complexity while remaining anchored to strategic priorities of the built environment.

The validation report strengthens this claim. Trainers received consolidated recommendations from the thematic groups, reviewed the relevance and feasibility of each suggestion, and decided whether it should be reflected in the syllabus and/or training materials. In the circular-economy area, validation outcomes were especially strong: the review process confirmed relevance, applicability and quality of the developed syllabi, and emphasised the value of involving external experts to ensure labour-market alignment and pedagogical robustness (Table 1).

Table 1. Comparative summary of BSA pilot courses and validation outcomes.

Cluster of courses	EQF	Topics	Transition focus	Evidence of outcome
1. Resilient Buildings and Cities; 2. Smart, Resilient & Circular Cities	5	Environment / Energy Efficiency	Resilience, circularity, sustainable urban transition	Fully validated on learning outcomes, labour-market relevance, applicability and adaptability.
3. Construction Technology; 4. BIM	4–5	Design and Engineering / New Building Materials	Technical innovation, digitalisation	Supports transferability across technical and digital domains.
5. Circular Waste Management; 6. Circular Economy and Waste Management	4–7	Circular Waste Management	Circular economy, waste reduction, LCA-oriented thinking	Strong relevance to missing sector skills and practical applicability
7. Energy Management for Buildings; 8. Energy Efficient Installation in Buildings	3–4	Energy Efficiency	Decarbonisation, energy performance	Aligned with upskilling needs in energy-related construction practices
9. Work Safety in Construction; 10. Risk and Reliability in Health and Safety	3–6	Environment / Health and Safety	Safety, implementation quality, risk management	Broad applicability across occupational levels and contexts

(*continued*)

Table 1. (*continued*)

Cluster of courses	EQF	Topics	Transition focus	Evidence of outcome
11. Bio-inspired innovation and design for sustainable engineering; 12. Digitalization and Sustainable Development	6–7	Design and Engineering / New Building Materials	Advanced innovation, AI, sustainability	Demonstrates framework adaptability to emerging and higher-level topics

5.4 Quality Assurance and Certification

The fourth result concerns external alignment and recognition. BESM explicitly integrates quality-assurance thinking into the course-improvement logic, and the broader project architecture frames quality assurance as a constitutive dimension of course enrichment rather than an afterthought. The grant documentation makes clear that the methodology and adaptation procedure were designed to be underpinned by a quality-assurance cycle aligned with EQAVET.

At a second level, the project moves toward recognition infrastructure. The certification scheme is intended for the assessment and certification of curricula and training materials developed within the project, with the objective of ensuring that learning outcomes are aligned with the appropriate EQF level and that training materials meet the necessary quality standards. Project and grant documents also frame certification as part of a broader effort to bridge fragmented competence-recognition frameworks across Member States and to create a recognisable label for transitional skills and competences in the construction sector.

This result is analytically important because it moves BSA beyond the level of pedagogical experimentation toward that of institutional infrastructure. Innovative courses have greater value when the competences they generate are visible, comparable and potentially recognisable across contexts. This argument is also consistent with broader VET debates that call for stronger systemic connections between curriculum innovation, institutional quality and sustainable futures [4].

6 Discussion

The evidence suggests that the principal originality of BSA lies in the way it integrates skills intelligence, educational redesign, digital support, provider self-assessment, stakeholder validation, quality assurance and competence recognition into one coherent framework. In many existing initiatives these dimensions remain separated. BSA

is analytically relevant because it connects these layers in a way that supports both educational innovation and ecosystem coordination. In this sense, the project can be interpreted not only as a training initiative, but as an emerging governance model for transition-responsive VET in the built environment.

A particularly relevant implication concerns circularity. Circularity is not a marginal topic within BSA, but one of its strongest structured competence domains. It is embedded in the topical area "Circular Economy Practices", reinforced by "Sustainable Materials and Sourcing", and operationalised through subareas such as design for deconstruction, material-flow management, digital material databases and sustainable procurement. The pilot and validation processes further confirm that these topics were judged relevant to labour-market needs and professional application.

A second implication concerns provider capacity and institutional learning. BESM frames course revision as an iterative process of diagnosis, reflection and redesign, and the digital platform translates this into a usable workflow for providers. This matters because sustainable transitions in construction require not only updated workers, but also adaptive institutions able to revise their training supply as technologies, regulations and labour-market needs change.

7 Conclusion

The BSA represents a significant contribution to the educational dimension of sustainable transitions in the built environment. Its value lies in the way it integrates labour-market intelligence, topical and occupational skills mapping, provider self-assessment, course enrichment, digital support, quality assurance, stakeholder validation and certification logic.

BSA demonstrates that transition priorities such as climate resilience, net-zero construction, circularity, sustainable materials and occupant well-being can be translated into structured and teachable competence frameworks. BESM provides a useful model for provider-level capacity-building by turning course redesign into a systematic rather than ad hoc process. The twelve pilot courses suggest that the model is transferable across countries, EQF levels and thematic domains while still allowing contextual differentiation. Finally, the linkage with quality assurance and certification shows that educational innovation in the built environment should not stop at content reform, but also address trust, transparency and recognition mechanisms.

More broadly, reshaping the built environment requires reshaping the educational infrastructures that prepare those who design, build, maintain and transform it. Awareness, equity, skills and capacity-building are not separate themes, but interdependent dimensions of a common transition process. In this respect, the BSA project provides a persuasive example of how educational innovation can contribute to more resilient, circular and socially responsive futures in construction, while also highlighting the need for further evidence on long-term learner outcomes and scalable uptake beyond the consortium.

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