Huuhka, S. (Ed.). (2025). Circularity in the Built Environment: Proceedings of the 2025 conference held in Tampere, Finland, September 16–18 2025 (Rev. ed.). Tampere: Tampere University. https://doi.org/10.5281/zenodo.17092524

Beyond Measuring Resource-Flow - a Holistic Approach for a Framework to Assess Circularity in the Built Environment through all Life Cycle Stages

Margarete Olender*[1]

[1]FHNW University of Applied Sciences and Arts Northwestern Switzerland, School of Architecture, Construction and Geomatics, Institute of Sustainability and Energy in Construction, Hofackerstrasse 30, 4132 Muttenz, Switzerland

Keywords: Circular Construction, Circular Economy, Circularity Assessment, Sustainable Construction

ABSTRACT

The transition to a circular economy in the built environment demands more than recycling materials – it requires a rethinking of how buildings are planned, used, and valued. This paper presents a conceptual framework for a circularity index that integrates strategic planning, resource flows, and systemic impacts across environmental, social, and economic dimensions. Developed through literature review and stakeholder analysis in Switzerland, the conceptual framework includes six indicators: strategy and goals, resource flows, information transmission, and social, ecological, and economic impact and value. It provides a comprehensive yet flexible foundation for assessing circularity in construction projects. While the framework currently lacks an operational measurement system, it sets the groundwork for future development of a practical tool. This work contributes to efforts in making circularity measurable and actionable across the built environment.

INTRODUCTION

The building-and-construction-sector is one of the most resource- and emissions-intensive industries globally. According to the United Nations Environment Program (2024), the built environment accounts for approximately 37% of global energy-related CO_2 emissions and over 50% of extracted raw materials (Linde et al., 2022). This makes the transition toward a circular economy (CE) in the sector not only necessary but urgent. Circular economy principles aim to decouple economic growth from resource consumption and environmental degradation through strategies such as reuse, refurbishment, recycling, and extended product lifetimes (Geissdoerfer et al., 2017; Kirchherr et al., 2017).

Despite a growing consensus on the value of circular construction, its implementation has been hindered by the lack of standardized operational tools for evaluating circularity. While numerous approaches exist – ranging from the Material Circularity Indicator (MCI) (Ellen MacArthur Foundation et al., 2019) to Cradle-to-Cradle (C2C) certification – many remain fragmented or too narrow in scope. Recent reviews (Benachio et al., 2020; Ossio et al., 2023; Pomponi & Moncaster, 2017) have pointed out that most methods either focus exclusively on material flows or lack integration with spatial and social dimensions. Moreover, tools developed for product or material level often fail to scale up effectively to the complexity of buildings or districts.

Emerging concepts such as Circular Ecosystem Innovation provide a more integrated vision, emphasizing value creation across multiple life cycle stages, cross-sector collaboration, and feedback-based learning loops (Konietzko et al., 2020). These align well with systems thinking

* Corresponding author: margarete.olender@fhnw.ch

and sustainability transitions theory, which highlight the importance of adaptive governance, network dynamics, and multi-level interactions in shaping circular transitions (Bocken et al., 2016; Loorbach et al., 2017).

Further, scholars such as Blomsma & Brennan, (2017) and Ghisellini et al., (2016) have stressed that circularity assessments must move beyond technocentric metrics and engage with institutional, behavioral, and societal dimensions. In the construction context, this implies the need for frameworks that evaluate not only what materials are used and how, but also the underlying planning strategies, information structures, and value distribution across stakeholders.

Against this backdrop, the present study outlines a concept for a structured framework for a circularity index in the built environment. Rather than introducing yet another set of isolated metrics, it synthesizes key dimensions from existing circularity models and incorporates input from stakeholders across the Swiss construction sector. The goal is to develop a tool that combines theoretical soundness with practical relevance – supporting decisions in design, procurement, and policy while promoting circularity across environmental, societal, and economic dimensions.

Importantly, the framework also aims to recognize the systemic value of the R-strategy Refuse – understood as not building or retaining existing buildings and structures. Since this strategy results in the absence of resource flows, it cannot be captured using flow-based assessment tools. The framework therefore seeks to expand measurement logic to account for strategic non-action as a valid and high-impact circular decision, acknowledging the environmental benefit of avoided material and energy use.

The remainder of this paper presents the outcomes of the stakeholder and the literature analysis, the methodological development of the framework and its core components. It concludes with a discussion of the framework's potential applications and current limitations, outlining the next steps toward a fully operational assessment tool.

MATERIALS AND METHODS

The development of the framework is based on the synthesis of a stakeholder analysis and a literature review and analysis of existing methods and concepts.

STAKEHOLDER ANALYSIS. The stakeholder analysis formed a central component in the development of the framework for a circularity index, ensuring that it reflects not only theoretical robustness but also practical relevance. The analysis was based on a comprehensive online survey conducted between December 2023 and March 2024, which gathered responses from 158 professionals operating in the Swiss built environment sector. The total population of the sector is ~514’700. The confidence level of the sample size is therefore 95% with a margin error of 8%.

Participant Composition. Respondents came from a wide range of fields: 53% were architects and engineers, 18% were from real estate business, 14% came from construction companies, and the remaining 15% represented public administration, academia, and material manufacturers.

Interest and Motivation. The survey revealed a clear demand for a practical circularity assessment tool. A total of 81% of respondents expressed high or very high interest in the development and use of such a framework. Their primary motivations included resource conservation (89%), climate protection (88%), and innovation potential (78%). Additionally, 69% highlighted technical optimization as a key driver for supporting circularity. As further medium relevant topics new business models and attractivity for expert personnel and employees (both 56%) were voted for.

Influence and Decision-Making Power. Only 8% of respondents indicated that they hold sole decision-making authority for circularity-related topics within their projects. However, 48% reported that they could significantly influence project outcomes through collaboration. Furthermore, 32% felt they had a high to very high influence on broader developments within the sector, reflecting a notable capacity for systemic impact.

Collaboration and Implementation Potential. Stakeholders expressed a strong willingness to work together across disciplines. Up to 79% said they were open to collaborating with professionals in other areas to promote and implement circular strategies. Key partners identified for collaboration included sustainability consultants, digital planning experts, and project developers.

Expectations for the Framework. Participants emphasized the importance of a framework that is adaptable to project specifics, digitally integrable (e.g., through Building Information Modelling (BIM) or resource passports), and aligned with both ecological and economic performance indicators. There was a clear call for non-prescriptive, strategy-enabling guidance rather than rigid checklists.

Overall, the stakeholder analysis provided a strong part of the foundation for shaping the six-indicator framework, confirming the relevance of the proposed impact categories and the need for a tool that supports both strategic planning and measurable action in circular construction.

LITERATURE REVIEW. A comprehensive literature review was conducted, analyzing academic systematic overviews, including international standards (ISO 59020 - Circular economy - Measuring and assessing circularity performance, 2024), European proposition for indicators for the built environment (European Commission et al., 2023) design frameworks (Cradle-to-Cradle, Braungart et al., 2007), sector-specific rating systems (Deutschen Gesellschaft für Nachhaltiges Bauen – DGNB e.V., 2024), and practical indicators (Ellen MacArthur Foundation et al., 2019). Key gaps were identified: limited social integration, poor alignment across scales, and insufficient metrics for design quality or resource planning. These gaps informed the development of the proposed concept.

Comparative Academic Analyses. Recent reviews by Khadim et al. (2022), Benachio et al. (2020), and Ossio et al. (2023) provided a systematic overview of circularity indicators across scales. These works identified recurring limitations, including:

- A predominant focus on material flows, especially recycling, while neglecting early-phase strategies such as design for disassembly or shared use.
- Minimal coverage of societal dimensions, such as user well-being, job creation, or participatory planning.
- Weak representation of spatial and temporal dynamics, limiting adaptability across building types and life cycle stages.
- Lack of integration between material tracking (e.g., passports, digital twins) and performance indicators.

Conceptual Frameworks and Models. The concept of Circular Ecosystem Innovation complements traditional linear-to-circular transition models by emphasizing systemic collaboration across industries and life cycle stages (Konietzko et al., 2020). It focuses on creating value through integrated stakeholder ecosystems, digital resource transparency, and feedback-oriented innovation loops. Unlike conventional models that concentrate on materials or product design, this concept calls for coordinated strategies involving planning, ownership, use, and end-of-use across the entire built environment. It helped inform the development of indicators that link design strategy with societal and economic value creation. The MCI developed by the Ellen MacArthur Foundation was one of the most influential sources for circularity assessments (Ellen MacArthur Foundation et al., 2019). It measures the degree of material circularity based on input and output flows, particularly focusing on recycled content and recovery rates. While methodologically sound, MCI was found to overlook critical aspects such as service life extension, modularity, or socio-economic impact. The C2C design framework, with its regenerative philosophy, introduced important principles like material health and continuous reuse, but lacks operationalized metrics for the building scale (McDonough et al., 2003).
The R-strategies (Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover) formed the conceptual basis for prioritizing circular interventions (Kirchherr et al., 2017). Despite their comprehensiveness, they often lack project-specific application logic or measurable performance criteria.

Standards and Certification Systems. ISO 59020 (2024) served as a key reference for defining boundaries, indicator structures, and integration levels across the product and system scale. It emphasizes harmonization of measurement methods and flexibility in applying circularity metrics depending on data quality and decision context. ISO 14044 (2006) and SIA 2032 (2020) provided relevant frameworks for aligning circularity assessment with environmental life cycle analysis without conflating the two.

Existing green building rating systems like DGNB, BREEAM, and LEED include circularity as a subtopic, mostly through recyclability, material sourcing, or end-of-life waste indicators. However, they tend to treat circularity as an add-on feature rather than an integrated planning strategy. These systems typically underrepresent design adaptability, socio-economic co-benefits, and upstream avoidance measures.

Gaps and Implications for Framework Development. The review concluded that a meaningful circularity framework must bridge multiple gaps:

- It should combine qualitative assessments (e.g., strategic intent, adaptability) with quantitative data (e.g., resource flows, environmental, social or economic impacts).
- It must extend beyond building components to include planning processes, use-phase efficiency, and end-of-use scenarios.
- It should reflect all three dimensions of sustainability – environmental, social, and economic – in balanced ways.
- It must enable application at different project stages and spatial scales.
- It must allow the assessment of measures independently from resource flow.

These findings were directly used to structure the six-indicator model proposed in this paper, ensuring that it addresses conceptual, technical, and operational shortcomings observed in prior approaches.

Huuhka, S. (Ed.). (2025). Circularity in the Built Environment: Proceedings of the 2025 conference held in Tampere, Finland, September 16–18 2025 (Rev. ed.). Tampere: Tampere University. https://doi.org/10.5281/zenodo.17092524

FRAMEWORK DEVELOPMENT

The framework for a circularity index was developed to address the conceptual, technical, and practical gaps identified through literature and stakeholder analysis. It operationalizes circular-economy-principles through six overarching indicators that reflect both strategic intent and measurable impact across the life cycle of the built environment. It is strongly based on the ISO 59000 series to ensure international compatibility. The framework shall enable informed decision making for owners, architects, engineers, construction companies, material suppliers and legal authorities through all life cycle stages. Nevertheless, the significance and informative value of each indicator varies according to the stage it is used.

The indicators are not intended to prescribe specific solutions but to offer a consistent structure for evaluating diverse circular strategies. As approximately 80% of stakeholders report to have shared decision-making power, the framework must support multi-actor decision-making processes. It therefore avoids reducing complex information to single scores and instead maintains a clear distinction between qualitative assessments and quantitative measurements, allowing for transparent and context-sensitive evaluation.

Each indicator is designed to integrate qualitative reasoning with quantitative potential, ensuring that the framework is both adaptable across scales (material, component, building, and district) and applicable across all project stages: design, building, use, and valorization. The term *valorization* is deliberately chosen, as it refers not only to post-use activities such as refurbishment, disassembly, and resource recovery, but also to the pre-design phase, where existing buildings, components, or land are assessed for their potential value before initiating a new project. Valorization thus operates at both ends of the project lifecycle – as the beginning and a conclusion of one loop (Fig.1).

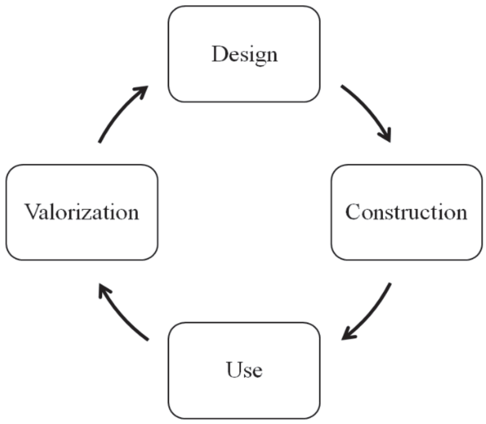

Figure 1: Life cycle Stages, with valorization referring to post-use and to pre-design

The six core indicators of the conceptual framework are as follows:

1. **Qualitative Assessment of Strategy and Goals**

This indicator evaluates how circularity is embedded in the strategic intent of a project, focusing on whether early-phase decisions and overall project goals are guided by circular thinking. It emphasizes avoidance-based approaches, such as achieving project goals without building (e.g. reorganization of floor plans), extending the use of existing structures (e.g. shared use or multifunctional spaces), or reducing material demand through spatial efficiency and sufficiency (e.g. reduced space use per person). These strategies are most influential during the valorization and design phases, where long-term impacts are shaped and the influence on the project outcome is the highest.

The indicator is aligned with ISO 59020, which supports evaluating circular actions in relation to project goals, and ISO 59010, which emphasizes design for circularity. It builds on the upper levels of the R-strategy framework, which prioritize prevention over resource recovery. It is also informed by the Circular Ecosystem Innovation model, which calls for minimizing and regenerating resource flows. The importance of this indicator is supported by stakeholder input, which highlights strong motivation for resource conservation, climate protection, and innovation potential.

2. Quantitative Measurement of Resource Flows

This indicator measures material inputs and outputs throughout the building lifecycle. It accounts for the use of primary materials, pre-use secondary materials (reused or recycled), and the potential for post-use materials to be reclaimed. Resource flows are tracked across material types – biogenic, fossil, mineral, metallic – as well as energy and water, within clearly defined temporal and spatial system boundaries. The indicator distinguishes between end-of-use strategies (reuse, repair, refurbish) and end-of-life scenarios (recycling, composting, incineration, landfill), enabling a differentiated assessment of material pathways. It is most effective during the design and construction phases, where material choices and supply logistics are defined.

The indicator is directly aligned with ISO 59020, which places resource flow measurement at the core of circularity assessment. It further builds on the Material Circularity Indicator and reflects principles from the Circular Ecosystem Innovation model, particularly slowing and closing resource loops. It also responds to stakeholder priorities, particularly the need for technical optimization in material planning and life cycle performance tracking.

3. Qualitative Assessment of Information Transmission

This indicator assesses the availability, quality, and accessibility of information related to materials, components, and building structures used in a project. It accounts for the presence of tools such as resource passports, material and building cadasters, and integration with Building Information Modeling. By ensuring transparency and traceability, the indicator supports information transition to the next loop of the life cycle. It is particularly important during the design and building stage, where data structures for material documentation and digital workflows are established and determines the quality of the transition from one cycle to the next in the valorization stage.

The indicator aligns with principles defined in ISO 59004, particularly those concerning systems thinking, resource traceability, and ecosystem resilience. It also reflects the concept of cross-sector collaboration outlined in the Circular Ecosystem Innovation model. Stakeholder insights further emphasized the importance of collaborative processes and digital integrability, underlining the need for structured and interoperable data as a foundation for scalable circularity.

4. Qualitative and Quantitative Assessment of Social Impact and Value (Performance)

This indicator assesses the social implications of circular strategies applied throughout a project. It accounts for aspects such as user health and comfort, neighborhood quality and participation, social inclusion, and accessibility, fostering a sense of identification with the built environment. In addition, it considers whether design and construction processes contribute to broader societal benefits, such as job creation, skill development, and workplace safety including physical and mental health. The indicator is most impactful during the valorization phase, where key strategic decisions have a strong influence on the project process and outcome.

This indicator is compatible with ISO 59020, which includes provisions for measuring and assessing sustainability impacts, including social dimensions. Its development addresses a key gap identified in the literature review, namely the limited integration of spatial and social factors in existing circularity metrics. Stakeholder responses further reinforced its relevance, particularly through the emphasis on attractiveness for employees as a driver for circular practices in planning and construction.

5. Qualitative and Quantitative Assessment of Ecological Impact and Value (Performance)

This indicator assesses the environmental impact of circular strategies beyond life cycle assessments. It considers the reduction and remediation of harmful substances (e.g. asbestos, PAH polycyclic aromatic hydrocarbons, PFAS Per- and polyfluorinated alkyl substances, …), biodiversity preservation (flora and fauna), water efficiency (e.g. ground water, rainwater retention, …), and avoidance of ecosystem degradation. By linking ecological performance with circular objectives, it supports the identification of regenerative design potentials. It is most effective during the design stage where the material specification takes place.

The indicator aligns with ISO 59020 for sustainability impact assessment and draws on ISO 14044 and SIA 2032 to ensure compatibility with environmental life cycle analysis. Influences from Cradle-to-Cradle and the Circular Ecosystem Innovation model – particularly the principle of regeneration (‘make clean’) guided the focus on ecological health and effectiveness. Stakeholders emphasized its relevance through strong support for climate protection and its alignment to both ecological and economic performance.

6. Qualitative and Quantitative Assessment of Economic Impact and Value (Performance)

This indicator assesses the economic implications of circular strategies from both a socio-economic and user/investor perspective. It captures socio-economic contributions such as job creation and local economic development (trades and crafts), while also accounting for project-specific factors like life cycle costing, adaptability to future needs, and exposure to price volatility. Importantly, it enables comparative assessment of interventions – including the option not to build – by the economic evaluation of scenarios of a site or building before and after the project. It is most effective during the valorization phase, where the potential for value creation or preservation is strategically assessed.

The indicator aligns with ISO 59020, which defines methods for assessing sustainability impacts in economic terms. It draws from the literature’s critique of poor alignment across spatial and stakeholder scales, and the need to clarify how circular value is distributed. The Circular Ecosystem Innovation model reinforces this by framing circularity as a driver of long-term economic resilience. Stakeholder input further emphasized the importance of aligning circularity with measurable economic performance and innovation potential.

RESULTS

The framework consists of six indicators structured in two functional groups. The first group – Strategy and Goals, Resource Flows, and Information Transmission – provides the foundation

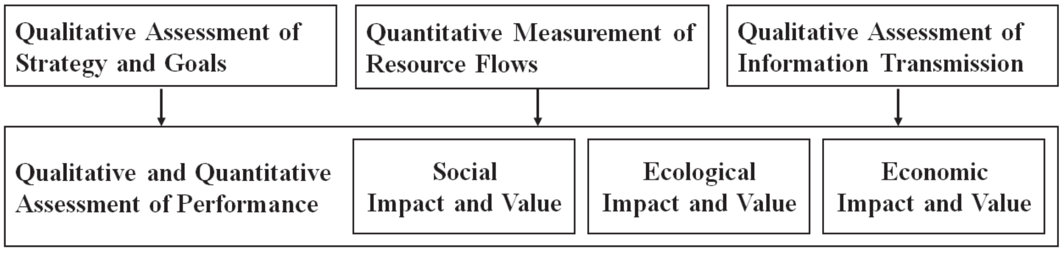

Figure 2: conceptual framework for a holistic circularity index with six indicators

for assessing circularity. These indicators focus on intent, material logic, and documentation, and can be applied independently depending on the project stage. The second group – Social, Ecological, and Economic Impact and Value – captures the systemic effects of circular strategies and is most informative when the three are assessed together. Their performance depends strongly on the decisions evaluated in the first group. The framework's logic is sequential: strategy and material/resource planning must be assessed first, followed by performance indicators (Fig. 2). Assessing not building as a circular strategy requires combined evaluation of strategic intent with its social, ecological, and economic implications.

DISCUSSION AND CONCLUSION

This paper has presented a holistic conceptual framework for a circularity index designed to operationalize the principles of the circular economy within the built environment. Developed through rigorous literature analysis and stakeholder analysis, the framework captures six interconnected indicators essential for assessing circularity.

However, it is important to acknowledge key limitations. The framework is based on stakeholder input and sectoral conditions specific to Switzerland, reflecting the current state of circular construction practices in that national context. While the structural logic of the framework is designed to be broadly applicable, its successful transfer to other countries requires a contextual review. It is recommended to assess similarities and differences between national construction practices and regulatory environments to ensure relevance and adaptability.

At present, the framework offers a well-structured and holistic foundation for assessing circularity, but does not include operational metrics, neither measurement, nor scoring system. The development of such metrics must consider each country's regulatory structures and data standards. Operationalization should rely on metrics that are compatible with existing planning procedures to ensure practical integration. For example, required calculations – such as for floor area – should align with nationally established rules to minimize additional effort for project stakeholders. Ensuring alignment with national systems can help avoid duplication, reduce complexity, and increase acceptance of circularity assessment methods across the construction industry.

Future work should focus on translating the framework into a functional assessment tool with clear criteria, data structures, and evaluation methods for each indicator. Including:

- Defining operational metrics for qualitative and quantitative evaluation.
- Developing a transparent and flexible scoring methodology.
- Testing and validating the approach through pilot projects.
- Ensuring digital integration with tools such as BIM and material passports.

Ultimately, the concept lays the groundwork for a consistent and holistic approach to measuring and assessing circularity in construction, while highlighting the need for continued development to move from theory to implementation.

REFERENCES

Benachio, G. L. F., Freitas, M. D. C. D., & Tavares, S. F. (2020). Circular economy in the construction industry: A systematic literature review. *Journal of Cleaner Production*, *260*, 121046. https://doi.org/10.1016/j.jclepro.2020.121046

Blomsma, F., & Brennan, G. (2017). The Emergence of Circular Economy: A New Framing Around Prolonging Resource Productivity. *Journal of Industrial Ecology*, *21*(3), 603–614. https://doi.org/10.1111/jiec.12603

Bocken, N. M. P., De Pauw, I., Bakker, C., & Van Der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering*, *33*(5), 308–320. https://doi.org/10.1080/21681015.2016.1172124

Braungart, M., McDonough, W., & Bollinger, A. (2007). Cradle-to-cradle design: Creating healthy emissions – a strategy for eco-effective product and system design. *Journal of Cleaner Production*, *15*(13–14), 1337–1348. https://doi.org/10.1016/j.jclepro.2006.08.003

Deutschen Gesellschaft für Nachhaltiges Bauen – DGNB e.V. (2024, Mai). *DGNB Qualitätsstandard für Zirkularitätsindizes für Bauwerke—Grundlegendes Qualitätsverständnis und DGNB Zirkularitätsindex Version 1.0*. https://www.dgnb.de/de/nachhaltiges-bauen/zirkulaeres-bauen/zirkularitaetsindizes-fuer-bauwerke

Ellen MacArthur Foundation, Goddin, J., Marshall, K., Pereira, A., & Herrmann, S. (2019). *Circularity Indicators: An Approach to Measuring Circularity—Methodology* (ANSYS Granta Design, Hrsg.). https://emf.thirdlight.com/link/3jtevhlkbukz-9of4s4/@/preview/1?o

European Commission, Council, E. I., Agency, Sme. E., Brincat, C., Graaf, I., León Vargas, C., Mitsios, A., Neubauer, N., Adams, K., & Hobbs, G. (2023). *Study on measuring the application of circular approaches in the construction industry ecosystem – Final study*. Publications Office of the European Union. https://doi.org/doi/10.2826/488711

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, *143*, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, *114*, 11–32. https://doi.org/10.1016/j.jclepro.2015.09.007

ISO 14044 – Umweltmanagement – Ökobilanz – Anforderungen und Anleitungen, ISO 14044 (2006).

ISO 59020 - Circular economy - Measuring and assessing circularity performance, ISO 59020 (2024).

Khadim, N., Agliata, R., Marino, A., Thaheem, M. J., & Mollo, L. (2022). Critical review of nano and micro-level building circularity indicators and frameworks. *Journal of Cleaner Production*, *357*, 131859. https://doi.org/10.1016/j.jclepro.2022.131859

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, *127*, 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

Konietzko, J., Bocken, N., & Hultink, E. J. (2020). Circular ecosystem innovation: An initial set of principles. *Journal of Cleaner Production*, *253*, 119942. https://doi.org/10.1016/j.jclepro.2019.119942

Linde, L., Lewis, A. N., & Sanchez, F. (2022). *Towards a sustainable global construction and buildings value chain. Policy brief. Leadership Group for Industry Transition*. https://www.industrytransition.org/insights/towards-a-sustainable-global-construction-and-buildings-value-chain/

Loorbach, D., Frantzeskaki, N., & Avelino, F. (2017). Sustainability Transitions Research: Transforming Science and Practice for Societal Change. *Annual Review of Environment and Resources*, *42*(1), 599–626. https://doi.org/10.1146/annurev-environ-102014-021340

McDonough, W., Braungart, M., Anastas, P. T., & Zimmerman, J. B. (2003). Applying the Principles of Green Engineering to Cradle-to-Cradle Design. *Environmental Science & Technology*, *37*(23), 434A-441A. https://doi.org/10.1021/es0326322

Ossio, F., Salinas, C., & Hernández, H. (2023). Circular economy in the built environment: A systematic literature review and definition of the circular construction concept. *Journal of Cleaner Production*, *414*, 137738. https://doi.org/10.1016/j.jclepro.2023.137738

Pomponi, F., & Moncaster, A. (2017). Circular economy for the built environment: A research framework. *Journal of Cleaner Production*, *143*, 710–718. https://doi.org/10.1016/j.jclepro.2016.12.055

SIA 2032:2020 - Graue Energie - Ökobilanzierung für die Erstellung von Gebäuden, SIA 2032:2020 44 (2020).

United Nations Environment Programme. (2024). *2023 Global Status Report for Buildings and Construction: Beyond foundations - Mainstreaming sustainable solutions to cut emissions from the buildings sector*. United Nations Environment Programme. https://doi.org/10.59117/20.500.11822/45095

FUNDING AND ACKNOWLEDGEMENTS

This work is based on the study 'Zirkularität Messbar Machen - Studie von Grundlagen für einen Zirkularitätsindex' (Making Circularity Measurable – A Study on the Foundations for a Circularity Index) funded by the Swiss Federal Office for the Environment FOEN.