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Defining a Framework for Holistic Life Cycle Assessment of Building Components by Considering Parameters Such as Circularity, Material Health, Biodiversity, Pollution Control, Cost, Social Impacts, and Uncertainty

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Abstract : In response to the building and construction sectors accounting for a third of all energy demand and emissions, the European Union has placed new laws and regulations in the construction sector that emphasize material circularity, energy efficiency, biodiversity, and social impact. Existing design tools assess sustainability in early-stage design for products or buildings; however, there is no standardized methodology for measuring the circularity performance of building components. Existing assessment methods for building components focus primarily on carbon footprint but lack the comprehensive analysis required to design for circularity. The research conducted in this paper covers the parameters needed to assess sustainability in the design process of architectural products such as doors, windows, and facades. It maps a framework for a tool that assists designers with real-time sustainability metrics. Considering the life cycle of building components such as façades, windows, and doors involves the life cycle stages applied to product design and many of the methods used in the life cycle analysis of buildings. The current industry standards of sustainability assessment for metal building components follow cradle-to-grave life cycle assessment (LCA), track Global Warming Potential (GWP), and document the parameters used for an Environmental Product Declaration (EPD). Developed by the Ellen Macarthur Foundation, the Material Circularity Indicator (MCI) is a methodology utilizing the data from LCA and EPDs to rate circularity, with a "value between 0 and 1 where higher values indicate a higher circularity+". Expanding on the MCI with additional indicators such as the Water Circularity Index (WCI), the Energy Circularity Index (ECI), the Social Circularity Index (SCI), Life Cycle Economic Value (EV), and calculating biodiversity risk and uncertainty, the assessment methodology of an architectural product's impact can be targeted more specifically based on product requirements, performance, and lifespan. Broadening the scope of LCA calculation for products to incorporate aspects of building design allows product designers to account for the disassembly of architectural components. For example, the Material Circularity Indicator for architectural products such as windows and facades is typically low due to the impact of glass, as 70% of glass ends up in landfills due to damage in the disassembly process. The low MCI can be combatted by expanding beyond cradle-to-grave assessment and focusing the design process on disassembly, recycling, and repurposing with the help of real-time assessment tools. Design for Disassembly and Urban Mining has been integrated within the construction field on small scales as project-based exercises, not addressing the entire supply chain of architectural products. By adopting more comprehensive sustainability metrics and incorporating uncertainty calculations, the sustainability assessment of building components can be more accurately assessed with decarbonization and disassembly in mind, addressing the large-scale commercial markets within construction, some of the most significant contributors to climate change.

Keywords : architectural products, early-stage design, life cycle assessment, material circularity indicator
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