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TOWARDS A FRAMEWORK FOR EXERGY-BASED LIFE CYCLE ASSESSMENT

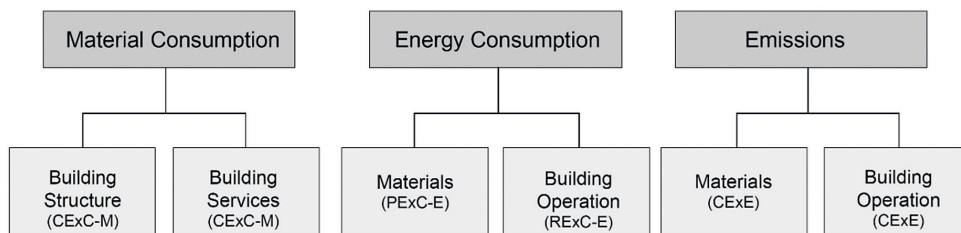
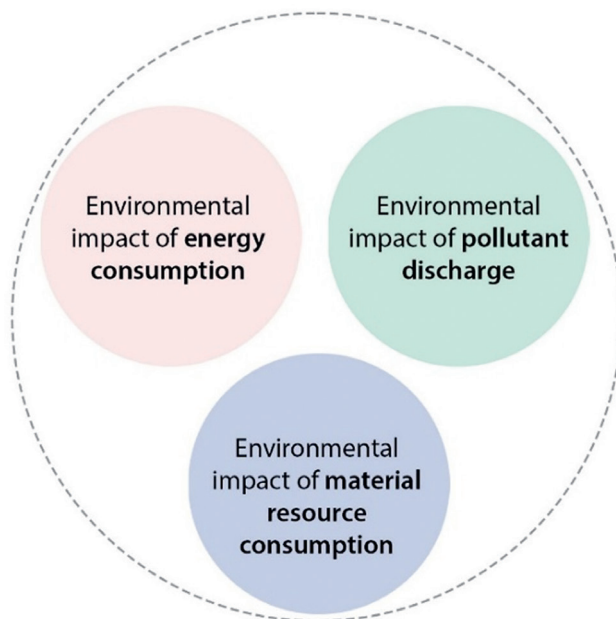
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Abstract – Life cycle assessment (LCA) is widely used to evaluate the environmental performance of buildings, yet it struggles to capture energy quality, thermodynamic irreversibility and physically grounded resource scarcity. This article proposes a comprehensive exergy based LCA methodology for buildings and contrasts it with conventional, characterization factor-dependent LCA indicators. The approach builds on an extensive review of exergy concepts and their integration into LCA for the built environment, leading to a method that combines physical and chemical resource exergy analysis with a cradle to grave building LCA. The analysis adopts a functional unit of 1 m² reference area over 50 years, while life cycle processes are explicitly separated into recurring (operational energy and related emissions) and non-recurring (material production, construction, replacements) elements to ensure consistent scenario comparison. The developed framework introduces additional indicators beyond conventional LCA: Chemical Exergy Consumption of Materials (CExC-M) which reflects both quantity and concentration of resources, Resource Exergy Consumption of Energy (RExC-E) which distinguishes between storable (on-demand) and non-storable (transient, non-dispatchable) energy forms, Primary Exergy Consumption of Energy (PExC-E), and Chemical Exergy of Emissions (CExE) expressing the work potential of pollutants discharged to the environment. These aggregate into the Overall Exergy Impact (OExI). By excluding solar, wind and similar non storable flows, the method avoids overemphasizing renewable exergy inputs and focuses on resources that are actually depleted or stored in building systems. Compared to conventional impact category indicators such as global warming potential or abiotic depletion potential, OExI provides a single, unified, thermodynamically objective scale that links material, energy and emission domains without subjective weighting, capturing energy quality, and quantifying material scarcity. Methodological prerequisites include: consistent, substance level inventory data for materials, fuels and emissions; clear reference environment definitions for all exergy calculations; transparent treatment of recurring versus non-recurring processes; and explicit disclosure of assumptions where different exergy approaches (e.g., resource exergy analysis for operations, primary energy-based exergy for materials, literature chemical exergies) are combined. Under these conditions, the proposed exergy based LCA framework can reveal tradeoffs hidden in conventional LCA, support more robust design decisions, and lay the groundwork for integrating thermodynamically rigorous indicators into future building sustainability assessments.

Keywords – *Exergetic Life Cycle Assessment; environmental indicators, Overall Exergy Impact, Resource Exergy Analysis*



Life Cycle Exergy Impact and Indicators