Towards a Framework for Exergy-Based Life Cycle Assessment

Samira Shokouhi [1*], Ingo Weidlich[1]

[1] HafenCity University Hamburg

Contact information:

Address: Henning-Voscherau-Platz 1, 20457 Hamburg, Germany
Phone number: 017621432802
E-mail: samira.shokouhi@hcu-hamburg.de

Exergy-based LCA offers a thermodynamically objective way to compare buildings by linking materials, energy, and emissions on one unified scale.

It reveals tradeoffs hidden by conventional LCA, especially where energy quality, material scarcity, and emission work potential differ.

Introduction

Why this matters

Conventional building LCA is widely used, but it does not fully capture energy quality, thermodynamic irreversibility, or resource scarcity in a physically grounded way.
Exergy analysis addresses this gap by measuring the useful work potential of resources and emissions, making it especially suitable for building sustainability assessment.

Framework

Proposed framework

The framework combines a cradle-to-grave building LCA with physical and chemical resource exergy analysis.
It uses a functional unit of 1 m² reference area over 50 years and separates life cycle processes into recurring and non-recurring parts to support fair scenario comparison.
This structure makes it possible to compare operational energy, material production, construction, replacements, and emissions within one consistent method.

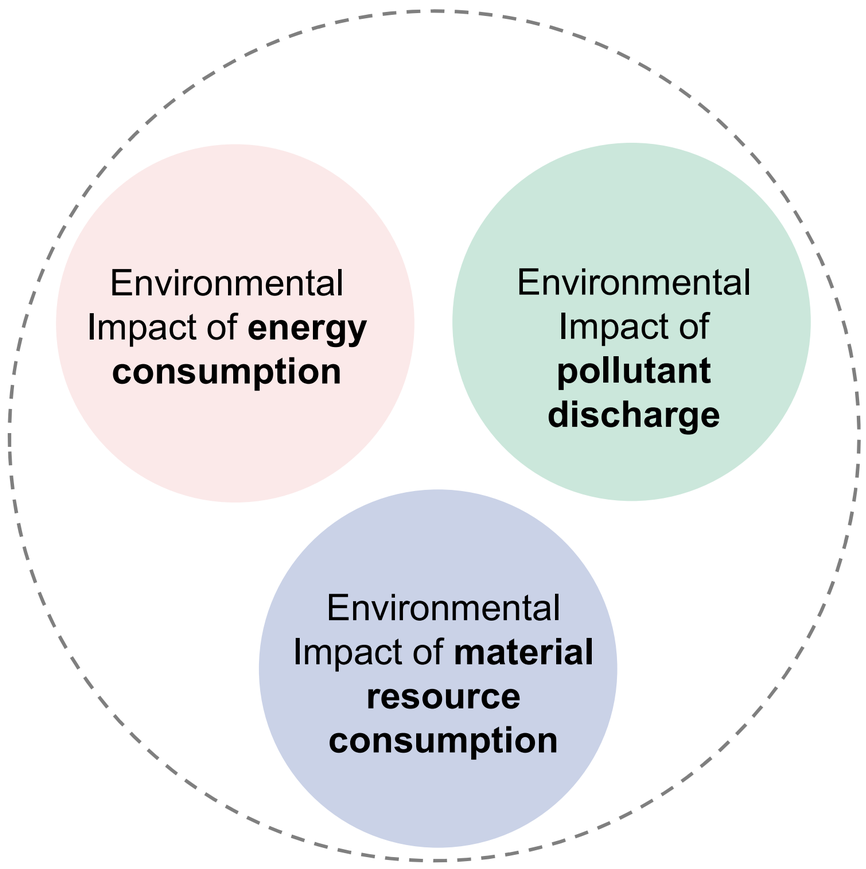

Figure 1. Life cycle Exergy Impact of different environmental impact categories

Why exergy is useful

Unlike conventional indicators such as global warming potential or abiotic depletion potential, **overall exergy impact (OExI)** avoids subjective weighting and instead provides a single objective scale grounded in thermodynamics.
It also avoids overemphasizing renewable flows such as solar and wind when those flows are non-storable and not directly depleted in the same sense as conventional resources.
That makes the method especially relevant for comparing design options in buildings where both materials and operational energy matter.

Key indicators

New indicators introduced

CExC-M: Chemical Exergy Consumption of Materials
RExC-E: Resource Exergy Consumption of Energy
PExC-E: Primary Exergy Consumption of Energy
CExE: Chemical Exergy of Emissions
OExI: Overall Exergy Impact, an aggregate indicator that unifies materials, energy, and emissions on one thermodynamic scale.

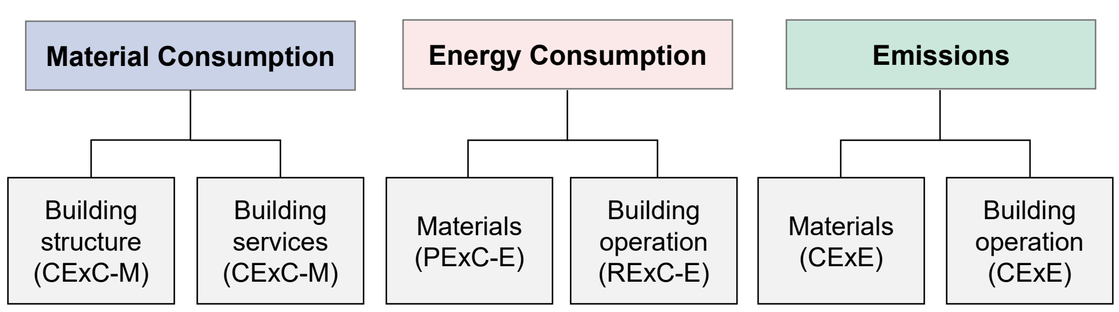

Figure 2. Proposed impact indicators

Conclusion

The proposed framework provides a basis for thermodynamic building sustainability assessment.
It can reveal tradeoffs that conventional LCA may miss and support better design decisions in renovation and new construction.
In the longer term, it helps lay the groundwork for integrating exergy-based indicators into future building assessment practice.