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bw_timex: a python package for time-explicit life cycle assessment

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Summary

bw_timex is a Python package for time-explicit Life Cycle Assessment (LCA). It enables the quantification of environmental impacts of products and processes over time, considering:

- the timing of processes throughout the supply chain (e.g., end-of-life treatment occurs 20 years after construction),
- variable and/or evolving supply chains and technologies (e.g., increasing shares of renewable electricity in the future), and
- the timing of emissions (e.g., enabling the use of dynamic characterization functions).

To achieve this, bw_timex uses graph traversal to propagate temporal information through the supply chain and then automatically re-links Life Cycle Inventories (LCIs) across LCI databases that represent specific points in time. The resulting time-explicit LCI reflects the current technology status within the product system at the actual time of each process. Moreover, bw_timex preserves the timing of emissions, enabling the application of dynamic characterization methods in addition to standard static characterization factors.

Statement of need

LCA traditionally assumes a static LCI, in which all processes occur simultaneously and do not change over time (Heijungs & Suh, 2002). To add a temporal dimension in LCA, the fields of dynamic LCA (dLCA) and prospective LCA (pLCA) have emerged. While dLCA focuses on when emissions occur and how impacts are distributed over time, it typically assumes the underlying product system remains unchanged (Beloin-Saint-Pierre et al., 2020). Conversely, pLCA tracks how processes evolve using future scenarios but generally only assesses a single (future) point in time, overlooking that processes occur at different times across a product's life cycle (Arvidsson et al., 2024). Both fields have seen open-source tool development in recent years, including Temporalis (Cardellini et al., 2018) for dLCA and premise (Sacchi et al., 2022), Futura(Joyce & Björklund, 2022) and pathways (Sacchi & Hahn-Menacho, 2024) for pLCA. However, a comprehensive open-source package for joint dynamic-prospective LCA, i.e., time-explicit LCA, is currently lacking.

bw_timex addresses this gap by providing a framework for time-explicit LCA calculations within the Brightway ecosystem (Mutel, 2017). It enables accounting for both the timing of processes and emissions as well as the state of the product system at the respective points in time. This makes bw_timex particularly useful for studies involving variable or strongly evolving product systems, long-lived products, and biogenic carbon.

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