




1 bw_timex: A Python Package for Time-Explicit Life 2 Cycle Assessment

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9 Summary

10 bw_timex is a Python package for time-explicit Life Cycle Assessment (LCA). Unlike conven-
11 tional LCA, time-explicit LCA allows the quantification of environmental impacts of products
12 and processes *over time*, considering their temporal distribution and evolution. As such,
13 bw_timex allows to account simultaneously for:

- 14 ▪ the timing of processes throughout the supply chain (e.g., end-of-life treatment occurs
15 20 years after production),
- 16 ▪ variable and/or evolving supply chains and technologies (e.g., increasing shares of
17 renewable electricity in the future), and
- 18 ▪ the timing of emissions (enabling dynamic characterization).

19 To achieve this, bw_timex uses graph traversal to convolve process-relative temporal distribu-
20 tions through the supply chain. From the resulting timeline of technosphere exchanges, Life
21 Cycle Inventories (LCIs) are automatically linked across time-specific background databases.
22 The resulting time-explicit LCI reflects the current technology status within the product system
23 at the actual time of each process. Moreover, bw_timex preserves the timing of emissions,
24 enabling both dynamic and static Life Cycle Impact Assessment.

25 Statement of need

26 LCA traditionally assumes a static system, where all processes occur simultaneously and do
27 not change over time ([Heijungs & Suh, 2002](#)). To add a temporal dimension in LCA, the
28 fields of dynamic LCA (dLCA) and prospective LCA (pLCA) have emerged. While dLCA
29 focuses on when processes and emissions occur and how impacts are distributed over time
30 (*temporal distribution*), it typically assumes that the underlying product system remains the
31 same ([Beloin-Saint-Pierre et al., 2020](#)). Conversely, while pLCA tracks how processes evolve
32 (*temporal evolution*) using future scenarios, it generally only assesses a single (future) point in
33 time, ignoring that processes occur at different times across a product's life cycle ([Arvidsson
34 et al., 2024](#)). Both fields have seen open-source tool development, including Temporalis
35 ([Cardellini et al., 2018](#)) for dLCA and premise ([Sacchi et al., 2022](#)), Futura ([Joyce & Björklund,
36 2022](#)) and pathways ([Sacchi & Hahn-Menacho, 2024](#)) for pLCA. However, a comprehensive
37 open-source package that supports consideration of both temporal distribution and evolution
38 is currently lacking.

39 bw_timex addresses this gap by providing a framework for time-explicit LCA calculations within
40 the Brightway ecosystem ([Mutel, 2017](#)). It combines considerations of temporal distribution
41 and evolution by 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, biogenic carbon and scenario analyses.

Workflow

A time-explicit LCA with `bw_timex` follows four main steps, as illustrated in Figure 1. First, a conventional product system model is temporalized by adding process-relative temporal distributions (rTDs) to the exchanges (c.f. Cardellini et al. (2018)). These rTDs describe how the amount of a technosphere or biosphere exchange is distributed over time, relative to the consuming or emitting process. In Step 2, a timeline of technosphere exchanges is constructed by convolving rTDs along the supply chain, starting from the absolute reference time for the demand, which is defined by the user. In Step 3, the exchanges in the timeline are re-linked to time-specific background databases that reflect the technology landscape at specific points in time. Based on the temporally re-linked product system, a time-explicit LCI is calculated, preserving the timing of processes and emissions. The inventory is calculated following the conventional matrix-based LCA formulation (Heijungs & Suh, 2002), with the time dimension embedded in the matrices through additional row/column pairs. In Step 4, these emissions are characterized, either using standard characterization factors or by applying dynamic characterization functions that take the emissions' timing into account.

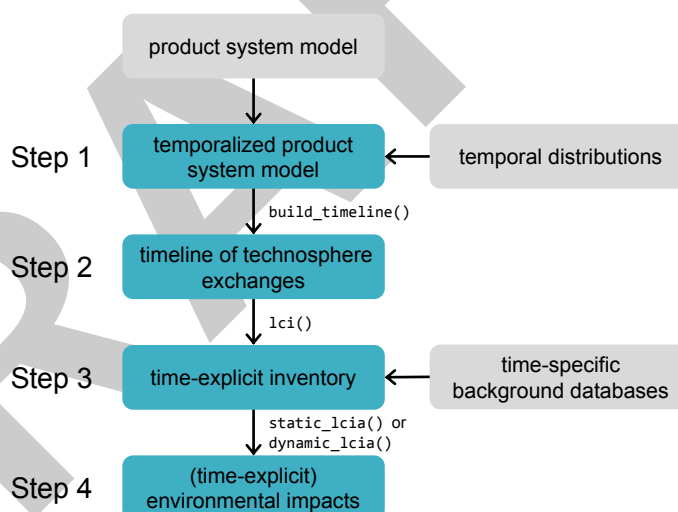


Figure 1: Workflow of a time-explicit LCA with `bw_timex`.

Further reading

The documentation of the `bw_timex` package, including installation instructions, extensive example notebooks and detailed API reference, can be found at <https://docs.brightway.dev/projects/bw-timex>. For a detailed explanation of the framework of time-explicit LCA, please refer to our accompanying publication (Müller et al., 2025).

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