

# <sup>1</sup> bw\_timex: A Python Package for Time-Explicit Life Cycle Assessment

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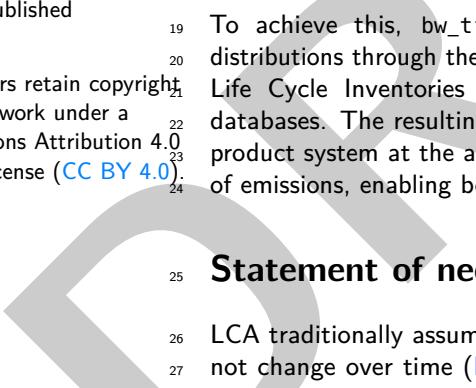
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## <sup>9</sup> Summary

<sup>10</sup> bw\_timex is a Python package for time-explicit Life Cycle Assessment (LCA). Unlike <sup>11</sup> conventional LCA, time-explicit LCA allows the quantification of environmental impacts of <sup>12</sup> products and processes *over time*, considering their temporal distribution and evolution. As <sup>13</sup> such, bw\_timex enables simultaneously accounting for:

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

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


## <sup>25</sup> Statement of need

<sup>26</sup> LCA traditionally assumes a static system, where all processes occur simultaneously and do <sup>27</sup> not change over time ([Heijungs & Suh, 2002](#)). To add a temporal dimension to LCA, the <sup>28</sup> fields of dynamic LCA (dLCA) and prospective LCA (pLCA) have emerged. While dLCA <sup>29</sup> focuses on when processes and emissions occur and how impacts are distributed over time <sup>30</sup> (*temporal distribution*), it typically assumes that the underlying product system remains the <sup>31</sup> same ([Beloin-Saint-Pierre et al., 2020](#)). Conversely, while pLCA tracks how processes evolve <sup>32</sup> (*temporal evolution*) using future scenarios, it generally only assesses a single (future) point in <sup>33</sup> time, ignoring that processes occur at different times across a product's life cycle ([Arvidsson <sup>34</sup> et al., 2024](#)).

<sup>35</sup> bw\_timex provides a framework for time-explicit LCA calculations within the Brightway <sup>36</sup> ecosystem ([Mutel, 2017](#)). It combines considerations of temporal distribution and evolution by <sup>37</sup> accounting for both the timing of processes and emissions as well as the state of the product <sup>38</sup> system at the respective points in time. This makes bw\_timex particularly useful for studies <sup>39</sup> involving variable or strongly evolving product systems, long-lived products, biogenic carbon, <sup>40</sup> and scenario analyses.

## 41 State of the field

42 Existing dLCA tools such as Temporalis (Cardellini et al., 2018) handle temporal distributions  
 43 but not system evolution. Conversely, pLCA tools like premise (Sacchi et al., 2022), Futura  
 44 (Joyce & Björklund, 2022), and pathways (Sacchi & Hahn-Menacho, 2024) model evolving  
 45 systems but not temporal distributions within the supply chain. Two recent tools combine  
 46 both temporal distribution and evolution: ProsperDyn (Lang-Quantzendorff & Beermann,  
 47 2025) and TRAILS (Sacchi, 2026). ProsperDyn is presently provided as a collection of research  
 48 notebooks with limited documentation and without a consolidated, performance-oriented  
 49 software architecture suitable for broader reuse. TRAILS, although methodologically advanced,  
 50 currently relies on annual discretization and sequential year-specific calculations rather than a  
 51 unified matrix-based integration of both dimensions.

52 bw\_timex uniquely embeds the time dimension directly into the technosphere and biosphere  
 53 matrices, enabling flexible temporal resolution within a single matrix-based framework. This  
 54 allows efficient computation and seamless integration with the broader Brightway ecosystem.

## 55 Workflow

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

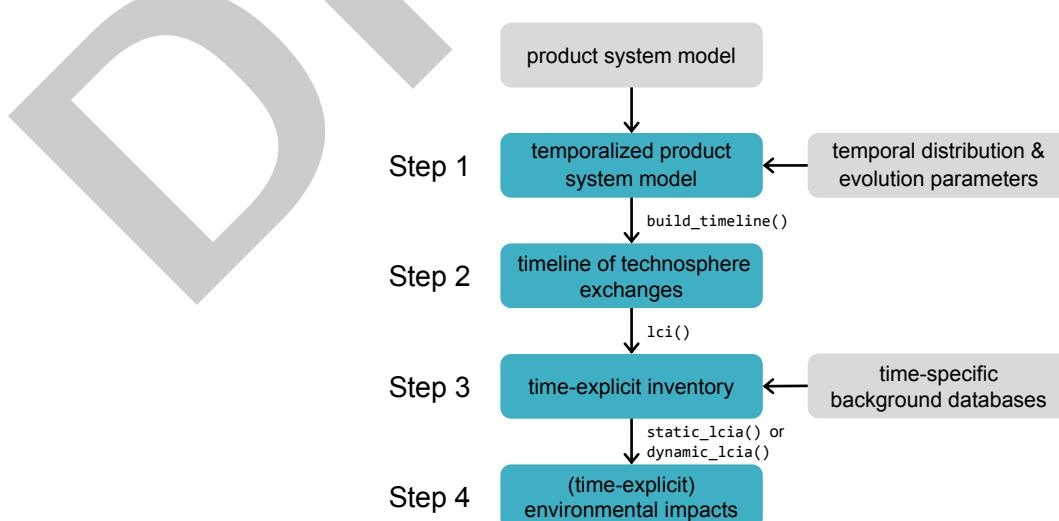


Figure 1: Workflow for a time-explicit LCA with bw\_timex.

## 71    Further reading

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

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