Building Life Cycle Assessment in openLCA

Megha Mittal, Ashrakat Hamed

openLCA

GreenDelta

Motivation

The built environment is a major contributor to global environmental impacts, with the buildings and construction sector responsible for an estimated 37% of global greenhouse gas emissions. While recent years have seen increased adoption of Environmental Product Declarations (EPDs) to evaluate the impacts of individual construction materials, comprehensive life cycle assessments (LCAs) at the building level remain limited in both practice and methodological consistency.

This study is motivated by the need to support more integrated, transparent approaches to building-level LCA that align with international standards such as EN 15804. It aims to provide a replicable framework for practitioners and researchers by demonstrating how openLCA, an open-source LCA software, can be employed to model the full life cycle of a residential building. The use of parameterization, modular structuring, and product-specific EPDs seeks to enhance both methodological clarity and adaptability.

In addition to delivering a static life cycle perspective, the study incorporates temporal modelling to account for year-by-year environmental impacts. This dynamic approach allows for a more understanding of how environmental burdens are distributed over time, particularly during the use phase, which is often a significant contributor to overall impacts.

By offering a case study template in publicly accessible data and tools, this work contributes to advancing the practical implementation of whole-building LCA and supports ongoing efforts toward more sustainable building design.

Contents

1 Introduction

The Buildings and Construction sector contributes to a staggering 37% of global greenhouse emissions (Building Materials and the Climate: Constructing a New Future. , 2023). The production and use of materials such as cement, steel and aluminium contribute significantly to emissions from this sector. While there have been attempts to make the sector greener through environmental reporting, and specifically, through emphasis on producing Environmental Product Declarations (EPDs) for products in this sector, not a lot of assessments focus on complete buildings and even fewer talk about the complete life cycle of a building. This study aims to bridge this gap by providing a template to conduct such assessments using openLCA.

As environmental rating for buildings becomes increasingly popular, practitioners also prefer to use results from EPDs of materials used in the building to calculate the impacts from a building in order to provide a more representative picture. This study attempts to serve as an example for practitioners who want to conduct such a study using openLCA.

This study tries to capture the environmental footprint of one Residential Building in Germany over time. The study captures the impact of the construction, use, demolition and subsequent waste treatment. It also captures the loads and benefits to the next product system by virtue of recycling or energy export, therefore, presenting a wholistic picture.

The study, in addition to a static overall result, also tries to present a dynamic picture by also providing year-wise impact from use of the building. It also considers dynamic impacts for biogenic carbon used in the process.

1.1 Goal & Scope Definition

Goal of the study

The goal of this study is to develop and demonstrate a transparent and replicable methodological template for conducting an LCA of an entire residential building using the openLCA software platform. This study seeks to address the current gap in whole-building LCA applications, as the majority of existing EPDs are limited to individual construction materials or components, with relatively few studies encompassing complete building systems.

By leveraging the increasing availability of product-specific EPDs, particularly those conforming to EN 15804, this study aims to integrate such data into a comprehensive assessment framework that can support the evaluation of environmental impacts at the building level. The results are intended to serve as a reference for researchers, practitioners, and policymakers aiming to perform building-level LCAs using publicly accessible tools and data.

Scope of the Study

Object of Analysis:

The object of this study is a single residential building located in Germany.

Functional Unit:

The functional unit is defined as the provision of one residential building over a reference service life of 50 years. This unit enables the comparison of different construction scenarios or material choices in terms of their environmental performance across the full building life cycle.

System Boundaries:

The study adopts a cradle-to-grave perspective and loosely follows the modular structure outlined in EN 15804. However, the construction process stage (Modules A4–A5), which includes transport to the construction site and on-site installation, has been excluded from the system boundaries due to its limited relevance to the building-level assessment. The included life cycle stages are:

- **Product stage (Modules A1–A3)**: raw material supply, transport, and manufacturing.
- **Use stage (Modules B1–B7)**: including use, maintenance, repair, replacement, refurbishment, operational energy, and water use, where applicable.
- **End-of-life stage (Modules C1–C4)**: deconstruction/demolition, transport, waste processing, and disposal.
- **Benefits and loads beyond the system boundary (Module D)** based on the materials that would undergo recycling/reuse.

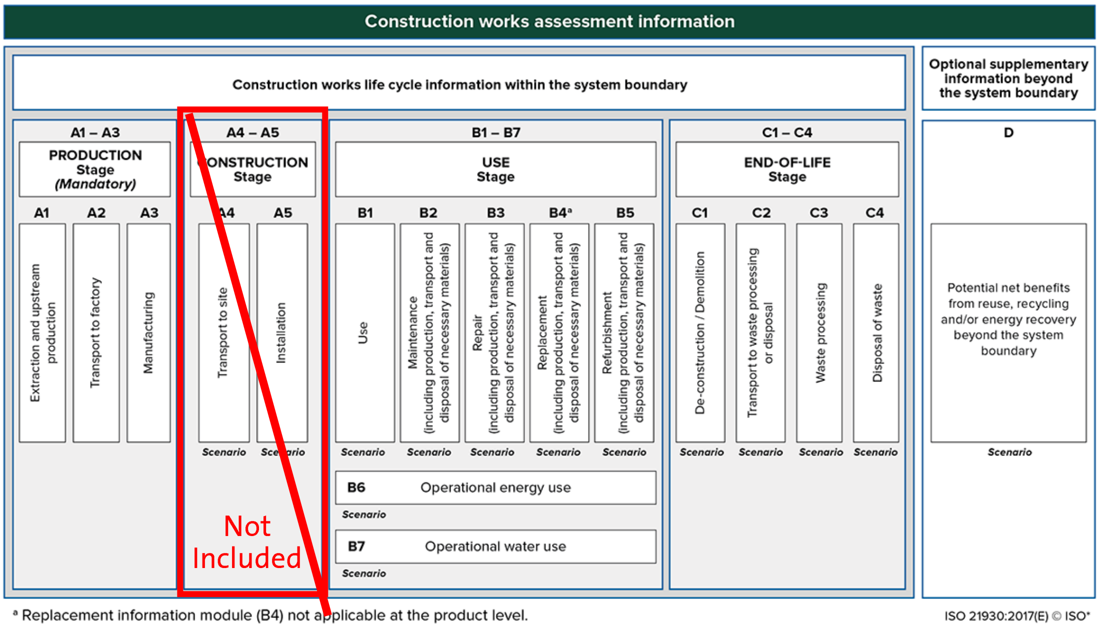


Figure 1-1: Life Cycle Modules as described by EN 15804+ A2 (Source: ISO 21930)

Geographical Coverage:

The study is geographically limited to Germany, with regional conditions, regulations, and typical construction practices considered in the modeling where data is available.

Temporal Coverage:

The reference study period is 50 years, reflecting the estimated service life of the residential building.

Intended Application:

The study is intended to provide methodological guidance and a proof of concept for conducting full building LCAs using openLCA and publicly available EPD datasets. It is not intended for comparative assertions disclosed to the public.

2 Life Cycle Inventory

This section is divided into multiple subsections to reflect the different phases of the building's life cycle and to ensure transparency in the data sourcing and modelling approach.

The LCI for this study is primarily based on data from (Ahmed Abdel Monteleb M. Ali, 2015), which presents an environmental case study of a residential building in Egypt. This source provides quantitative data on construction material quantities, energy use during the construction phase, operational energy and water demand during the use phase, as well as energy requirements in the EoL phase. Transportation distances relevant to various stages of the life cycle are also reported.

For impact assessment, the study applies the EN 15804+A2 add-on and uses the EN 15804+A2 (Environmental Footprint 3.1) impact assessment method within openLCA.

Each life cycle stage (modules A1–C4, and D where applicable) is modelled as a separate process in openLCA. These processes are then linked together within a master process titled “Building Life Cycle Assessment.” Detailed modelling procedures for each phase are presented in **Section 2.2**.

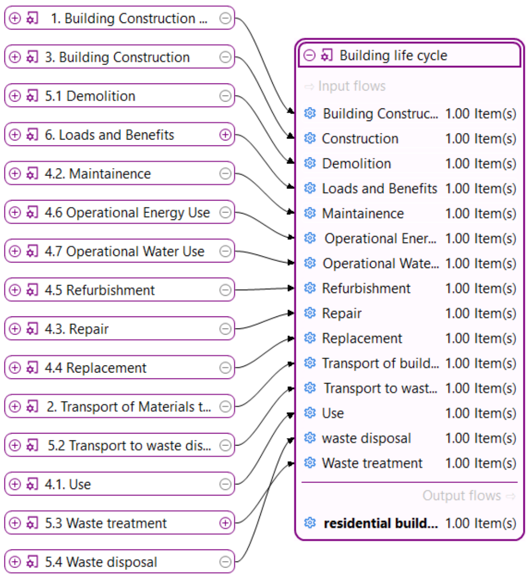


Figure 2-1 Building LCA entire model

2.1.1 Parameters

openLCA enables users to streamline their LCA models through parameterization. This study utilizes two types of parameters:

- **Input Parameters:** These are fixed values that are not dependent on other model variables (e.g., material density, number of floors).
- **Dependent Parameters:** These are defined using formulas that rely on one or more input parameters (e.g., total material mass = volume x density).

Parameterization enhances model transparency, allows for easy value adjustments, reduces errors, and facilitates sensitivity analysis. Given that this study is intended to serve as a reusable template for future full-building LCA studies, parameterization was applied wherever feasible to maximize flexibility and replicability.

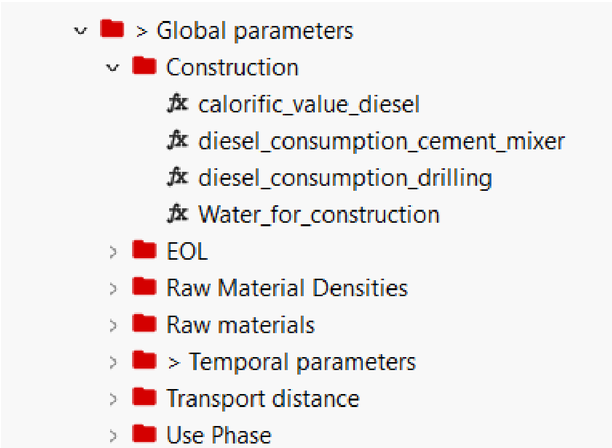


Figure 2-2 Parameters established for the building LCA model

2.1.2 Temporal Modelling

This study includes both static and dynamic modelling approaches. The static model provides an overview of environmental impacts by life cycle phase, while the dynamic model enables a year-by-year analysis, offering a more detailed understanding, particularly during the use phase, which spans several decades and often contains hidden hotspots.

To carry out the dynamic (temporal) modelling, parameter analysis in openLCA was used. This approach makes it possible to isolate and analyze environmental impacts for each individual year, regardless of the life cycle stage in which they occur.

The dynamic model is based on a user-defined input parameter called **`year`**. For each year of the building's life cycle, a dependent parameter is created (e.g., `year_01`, `year_15`, etc.). These dependent parameters take a value of 1 if the selected `year` matches their label (e.g., year = 15 makes `year_15 = 1`) and 0 otherwise.

This is implemented using the formula:

```
IF(ABS(year - xx) < epsilon; 1; 0)
```

where `xx` represents the target year, and `epsilon` is a very small number (e.g., 0.01) to allow for numerical precision.

Each process in the LCA model, except for operational energy and water use, is linked to a specific year by multiplying its inputs with the corresponding `year_xx` parameter. This ensures that only processes occurring in the selected year are active during the analysis. As a result, when the master process is run for a specific year, only the environmental impacts from that year are calculated.

Operational energy and water use, which occur continuously throughout the use phase, are modeled slightly differently. Their approach is explained in the following sections.

To generate year-wise results, the Parameter Analysis feature in openLCA is used. This allows for the sequential evaluation of impacts across the entire 50-year reference period, providing a clear temporal profile of the building's environmental performance.

2.2 Life cycle modules Phases

The study is structured into five major life cycle phases, each corresponding to a group of related modules. These are:

1. Construction Phase
2. Use Phase
3. End-of-Life Phase
4. Demolition and Waste Treatment
5. Loads and Benefits (Module D)

Each phase consists of one or more modules, which are modelled individually as separate processes in openLCA. These are later integrated into a single master process to represent the building's full life cycle. Figure 2-3 presents the structure of the phases and their associated modules. The modelling logic and assumptions for each phase are detailed in the sections that follow.

Figure 2-3 Life Cycle Stages

2.3 Construction Phase

The Construction Phase in this study aligns with the product stage (Modules A1–A3) as defined in EN 15804+A2. It includes the following three modules:

- Acquisition of construction materials
- Transport of materials to the construction site

- On-site construction activities

All activities in this phase are assumed to occur in Year 0 of the building's life cycle.

2.3.1 Acquisition of Building Construction Materials

This module covers the production and processing of the main construction materials. Inventory data is based on (Ahmed Abdel Monteleb M. Ali, 2015), and the quantities were implemented using parameters in openLCA. Table 1 lists the materials and their associated quantities.

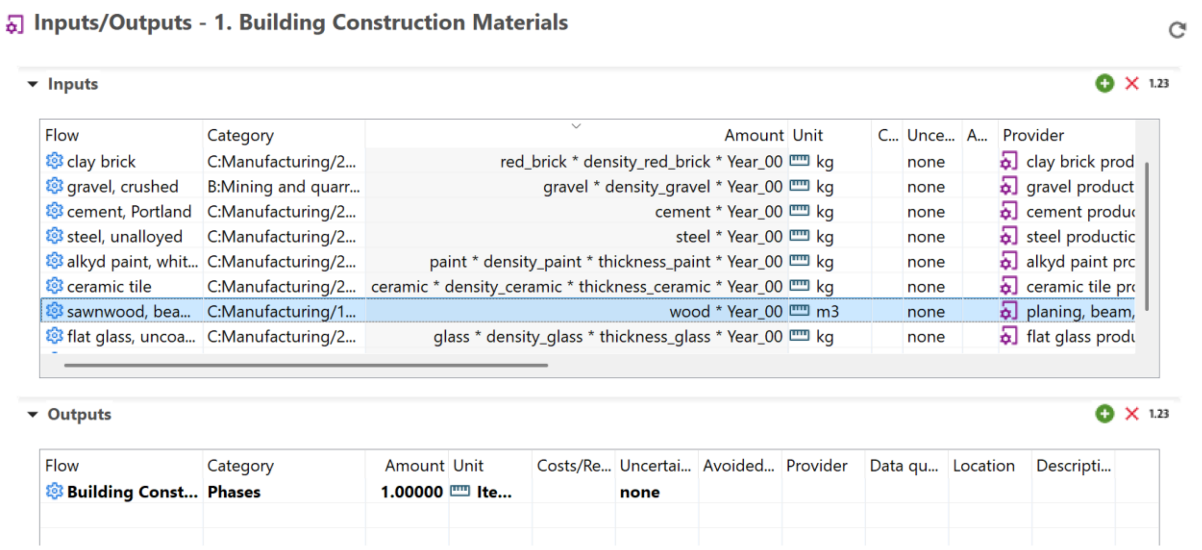


Figure 2-4: Building Construction Materials acquisition

Table 1: Building Construction Materials quantities

Material (Parameter)	Amount	Density (kg/m^3)	Thickness	Amount (kg)
Steel	1368 kg	-	-	1368
Cement	8186 kg	-	-	8186
Red Brick	17.7 m3	1920	-	33984
Sand	85.7 m3	1600	-	137120
Gravel	14.5 m3	1520	-	22040
Wood	0.7 m3	640	-	448
Glass	4 m2	2580	0.004 cm	0.4128
Ceramic	30 m2	3250	0.006 cm	5.85
Paints	170 m2	2100	0.002 cm	7.14

All these materials are acquired in year 0 for the temporal LCA. The `year_0` parameter uses the formula

```
IF(ABS(year)<epsilon;1;0)
```

to account for activities occurring in year zero. In this study, datasets from ecoinvent have been used to model the production of all construction materials. Practitioners could also use specific EPDs to make their study more representative and precise. This is demonstrated also in later chapter.

2.3.2 Transport of Raw Material to Construction Site

This module accounts for the transport of all raw construction materials to the building site. Based on (Ahmed Abdel Monteleb M. Ali, 2015), all transport is assumed to occur by road, using a 16–32 metric ton EURO6 truck.

Since both material acquisition and on-site construction occur in Year 0, all transport activities are also allocated to Year 0. To enable temporal modelling, a parameter named `year_0` is used, defined by the formula:

```
IF(ABS(year) < epsilon; 1; 0)
```

This ensures that only transport-related impacts in Year 0 are included when the temporal LCA is evaluated. The transport of each material is modelled using a mass-distance approach (kg·km). Table 2 summarizes the distances, parameters, and resulting transport loads.

Table 2: Transport modalities for construction materials

Material	Transport Distance	Distance Parameter	Amount (kg)	Transport (kg*km)
Steel	5	distance_2	1368	6840
Cement	20	distance_6	8186	163720
Red Brick	5	distance_7	33984	169920
Sand	5	distance_4	137120	685600
Gravel	5	distance_1	22040	110200
Wood	5	distance_5	448	2240
Glass	5	distance_8	0.4128	2.064
Ceramic	5	distance_3	5.85	29.25
Paints	5	distance_9	7.14	35.7

2.3.3 On-Site Construction Phase

This module includes the actual building process, involving the use of materials, fuels, and water, along with associated waste generation. Data from (Ahmed Abdel Monteleb M. Ali, 2015) was used where available, supplemented by assumptions where necessary.

Two diesel-powered machines are used:

- Cement mixer: 15 litres/hour fk 5 hours = 75 litres
- Drilling machine: 30 litres/hour fk 10 hours = 300 litres

Diesel use is modelled using the ecoinvent dataset:
"diesel, burned in building machine – GLO."

Based on the dataset and standard values:

- Diesel calorific value = 37 MJ/litre
- Diesel density = 865 kg/m^3
- Diesel energy content = 0.0234 kg/MJ

In addition to energy use, the study assumes that 100 mffi of water is required for construction activities. Moreover, 2% of the total steel and cement inputs are assumed to be wasted during construction and are

All construction activities, including fuel and water use, as well as waste generation, are allocated to Year 0 using the `year_0` parameter:

```
IF(ABS(year) < epsilon; 1; 0)
```

Table 3: Inputs & Outputs for Construction Phase

Fuel/Water/Waste	Activity	Amount	Remarks
Diesel	Cement Mixing	75 litres	Construction per hour x hours of use
Diesel	Drilling	300 litres	Construction per hour x hours of use
Water	Water for Construction	100 m^3	Assumption
Cement Waste	Waste from Construction	163.72 kg	2% of cement used
Steel Waste	Waste from Construction	27.36 kg	2% of steel used

2.4 Use Phase

The use phase covers all environmental impacts that occur during the operation of the building throughout its reference service life of 50 years (years 1 to 50). This includes material use, maintenance, repair, replacement, operational energy and water consumption. Each module is parameterised to reflect its temporal occurrence within the use phase.

2.4.1 Use

This module captures the impacts associated with furnishing and equipping the building. To demonstrate the integration of Environmental Product Declarations (EPDs) into whole-building LCA, the following assumptions are made:

- The entire ceramic tile surface (5.85 m^2) is overlaid with PET flooring.
- The building is furnished with one unit each of the following items: a locker, chair, 2-seater couch, desk, and shower faucet.

The following EPDs were used to represent these products:

1. PET Flooring: EPD-IES-0019928:001
2. Shower Faucet: EPD-IES-0006397:003 (S-P-06397)
3. Chair: EPD-IES-0011922:003 (S-P-11922) – Floater 84113
4. 2-Seater Couch: EPD-IES-0011803:003 (S-P-11803) – Floater 84211
5. Desk: EPD-IES-0013261:002 (S-P-13261) – Floater 84920
6. Locker: EPD-IES-0009735:004 (S-P-09735)

Modules A1–A5 from these EPDs are included in this stage, as impacts from production, transport, and installation occur during initial furnishing.

This setup provides a practical reference for LCA practitioners who wish to incorporate EPD data into use phase modelling.

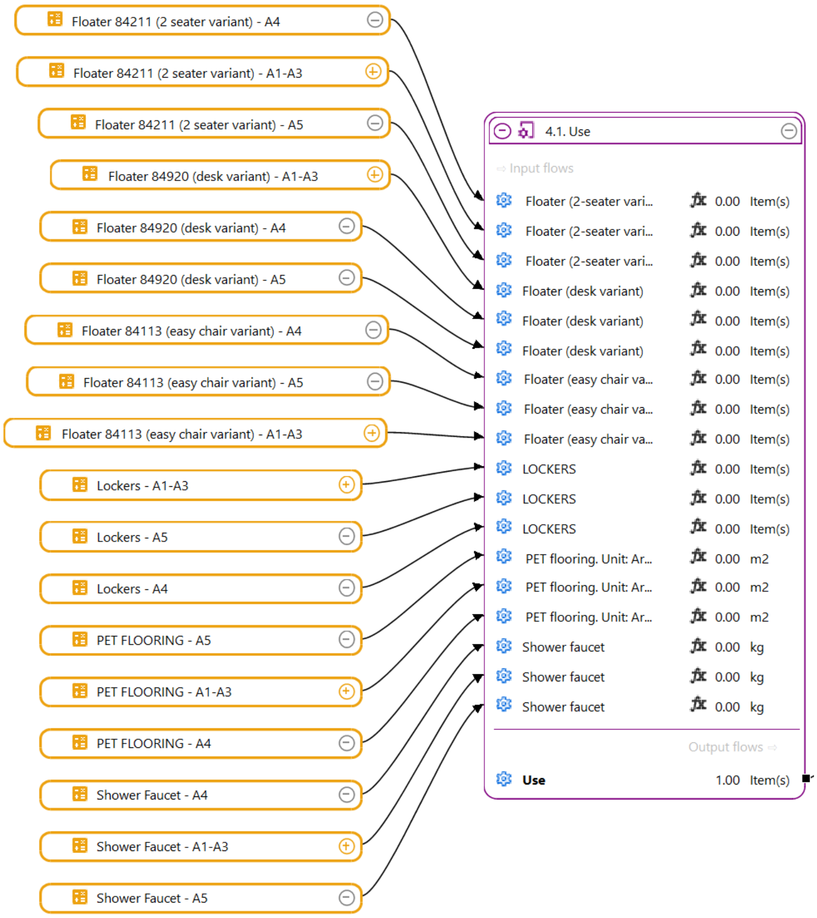


Figure 2-5: EPD Integration in the Use stage

2.4.2 Maintenance

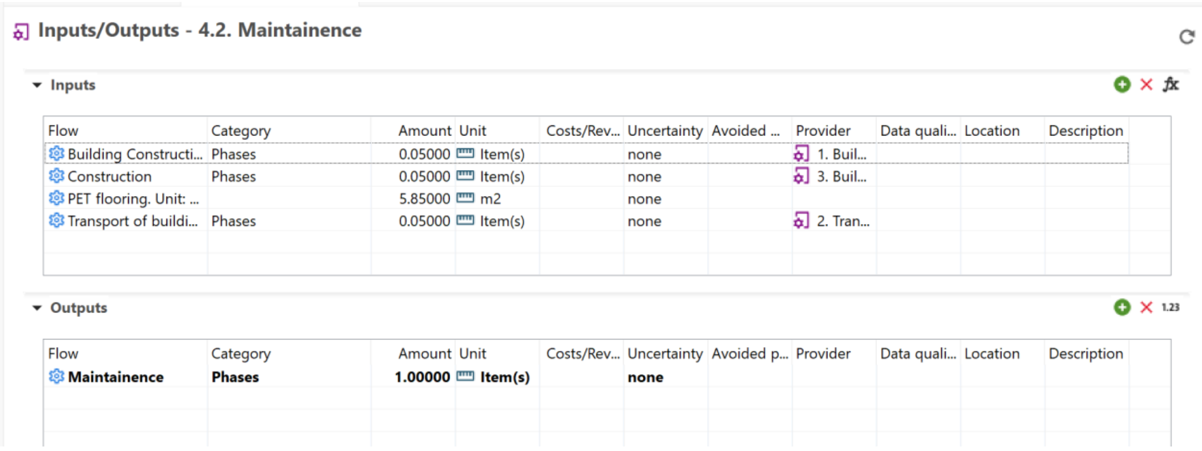
Maintenance is assumed to occur in Years 10, 20, 30, and 40. Each maintenance event accounts for 5% of the construction phase impacts, representing minor repairs and upkeep.

Since the PET flooring EPD includes non-zero values for Module B2 (Maintenance), it is fully included in this module. This reflects the EPD's built-in assumption that only a portion of the flooring requires maintenance.

To reflect the timing of these activities in openLCA, the following temporal expression is used:

```
(year_10 + year_20 + year_30 + year_40)
```

This expression ensures that maintenance-related impacts are counted only in the designated years.



Inputs/Outputs - 4.2. Maintainence

Inputs

Flow	Category	Amount	Unit	Costs/Rev...	Uncertainty	Avoided ...	Provider	Data quali...	Location	Description
Building Constructi...	Phases	0.05000	Item(s)		none		1. Buil...			
Construction	Phases	0.05000	Item(s)		none		3. Buil...			
PET flooring. Unit: ...		5.85000	m2		none					
Transport of buildi...	Phases	0.05000	Item(s)		none		2. Tran...			

Outputs

Flow	Category	Amount	Unit	Costs/Rev...	Uncertainty	Avoided p...	Provider	Data quali...	Location	Description
Maintainence	**Phases**	**1.00000**	**Item(s)**		**none**					

Figure 2-6: Maintenance

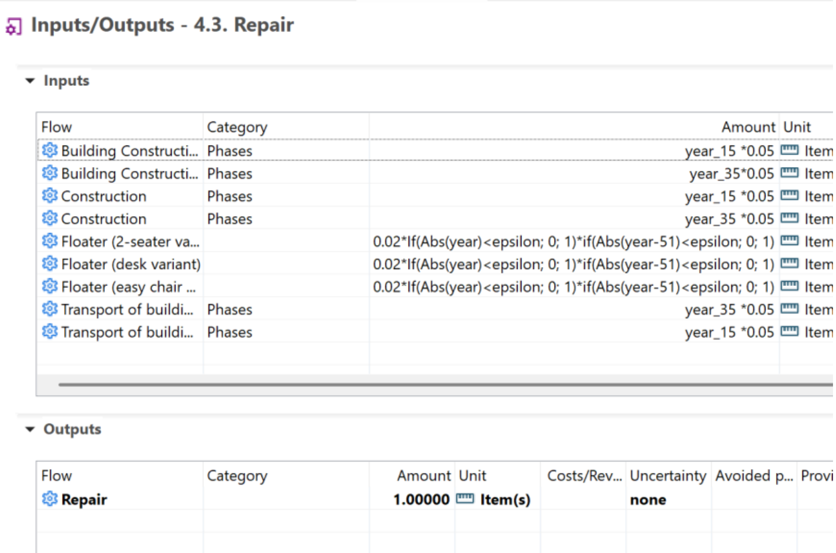
2.4.3 Repair

Repair activities are scheduled for Years 15 and 35. Similar to maintenance, each event contributes 5% of the construction phase impacts.

In addition, certain furniture items, the desk, chair, and 2-seater couch, are assumed to undergo minor repairs annually. To represent this, 2% of each item is replaced every year, leading to 100% replacement over a 50-year lifespan (aligned with the assumption of a 100-year service life).

To restrict these impacts to the correct timeframe and avoid allocations to years outside the use phase, the following expressions are applied:

```
IF(ABS(year) < epsilon; 0; 1)
IF(ABS(year - 51) < epsilon; 0; 1)
IF(ABS(year - 52) < epsilon; 0; 1)
```



Inputs/Outputs - 4.3. Repair

Inputs

Flow	Category	Amount	Unit
Building Constructi...	Phases	year_15 *0.05	Item
Building Constructi...	Phases	year_35*0.05	Item
Construction	Phases	year_15 *0.05	Item
Construction	Phases	year_35 *0.05	Item
Floater (2-seater va...		0.02*If(Abs(year)<epsilon; 0; 1)*if(Abs(year-51)<epsilon; 0; 1)	Item
Floater (desk variant)		0.02*If(Abs(year)<epsilon; 0; 1)*if(Abs(year-51)<epsilon; 0; 1)	Item
Floater (easy chair ...		0.02*If(Abs(year)<epsilon; 0; 1)*if(Abs(year-51)<epsilon; 0; 1)	Item
Transport of buildi...	Phases	year_35 *0.05	Item
Transport of buildi...	Phases	year_15 *0.05	Item

Outputs

Flow	Category	Amount	Unit	Costs/Rev...	Uncertainty	Avoided p...	Provi
Repair		**1.00000**	**Item(s)**		**none**		

Figure 2-7: Repair

2.4.4 Replacement & Refurbishment

This module captures the replacement and refurbishment of building components that degrade over time. Activities are scheduled for Years 15, 30, and 45.

It is assumed that 100% of the use phase impacts for installed components reoccur during these events. This includes the desk, chair, and 2-seater couch, which have non-zero values reported in Module B4 (Replacement) of their EPDs.

2.4.5 Operational Energy Use

This module accounts for the building's energy consumption from heating and electrical use during the use phase.

According to (Ahmed Abdel Monteleb M. Ali, 2015), the building consumes:

- 16 m^3 of natural gas/month (for heating)
- 492 kWh of electricity/month (for general use)

To model future energy transitions, two electricity mixes are used:

1. Standard German Grid Mix (ecoinvent dataset: *market for electricity, low voltage | EN15804GD, U – DE*)
2. Green Mix, based on the ecoinvent consequential system model (details in Figure 2-8)

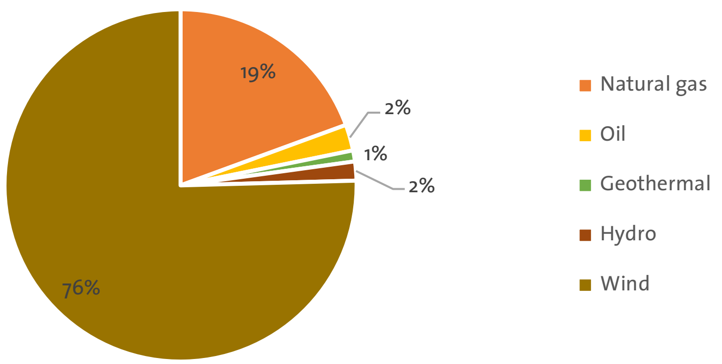


Figure 2-8: Composition of Green Electricity Mix

The share of electricity sourced from the green mix increases every 10 years, as follows:

Year Range	Green Mix Share
1–10	10%
11–20	25%
21–30	50%
31–40	75%
41–50	100%

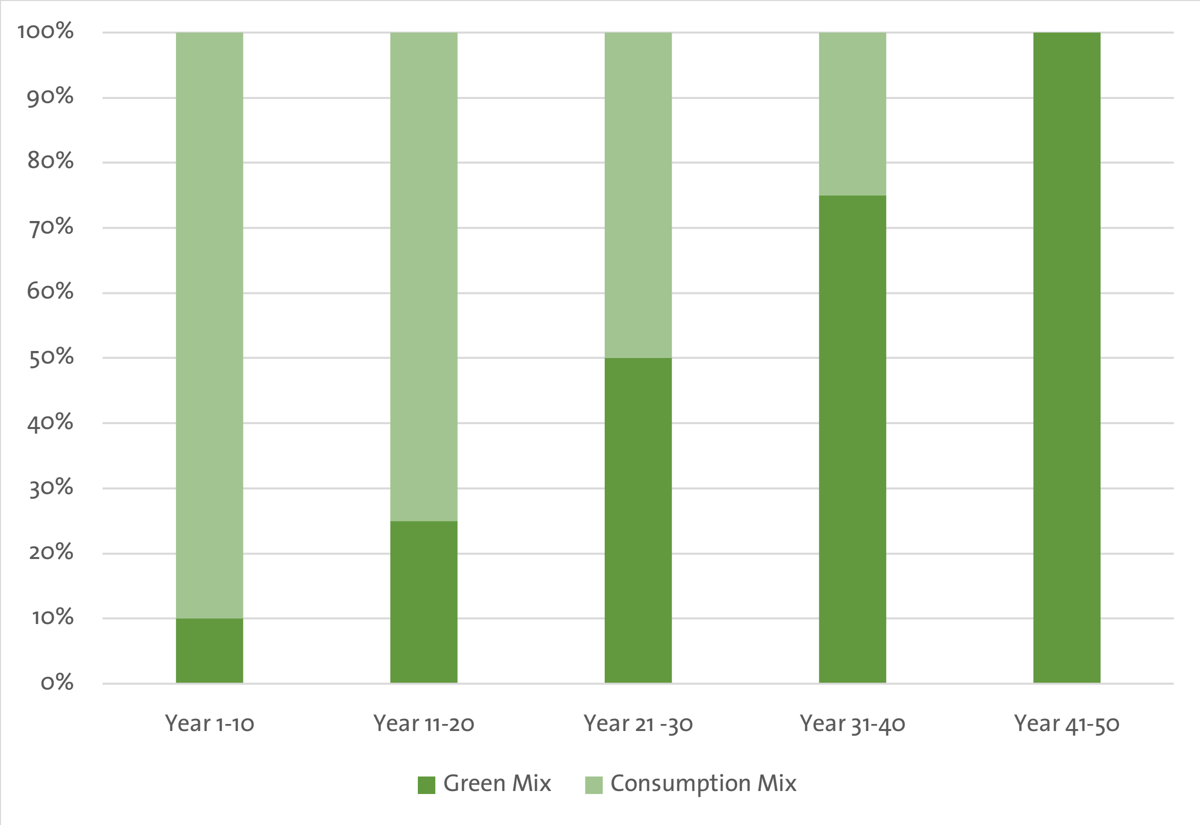


Figure 2-9: Share of Green Electricity Mix in total electricity consumed over the Use phase along 50 years

This transition is modelled in openLCA using the following parameterised expression:

```
electricity_consumption *
IF(ABS(year) < epsilon; 0; 1) *
IF(year > 40; 0.25; IF(year > 30; 0.5; IF(year > 20; 0.75; IF(year > 10;
0.9; 1)))) *
IF(ABS(year - 51) < epsilon; 0; 1) *
IF(ABS(year - 52) < epsilon; 0; 1)
```

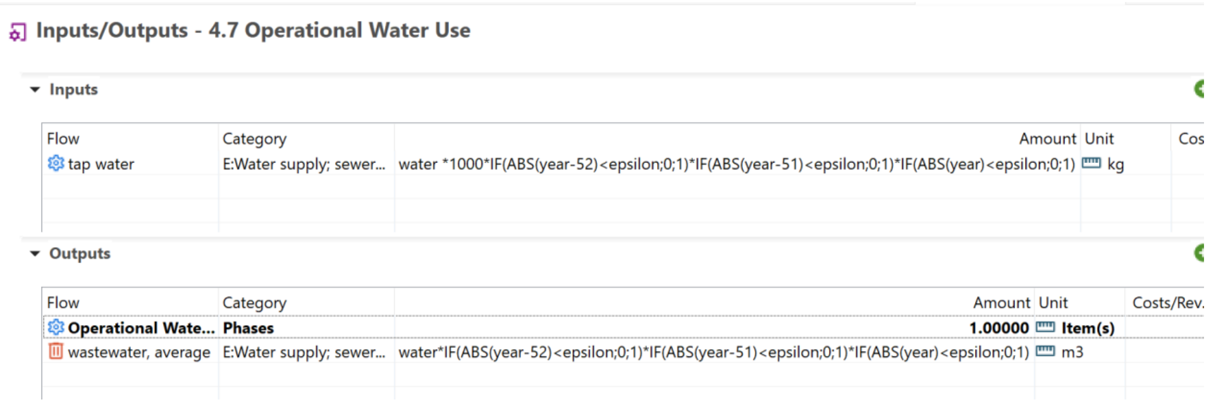
Where:

- `electricity_consumption` = 5904 kWh/year (492 x 12)
- The conditional structure controls grid mix proportions based on the selected year.

A similar model is applied to the green mix share, allowing the total electricity impact to be split by source.

2.4.6 Operational Water Use

This module considers water use during building operation. Based on (Ahmed Abdel Monteleb M. Ali, 2015), a constant consumption of 100 m^3/month is assumed from Year 1 to Year 50.



Inputs/Outputs - 4.7 Operational Water Use

Inputs

Flow	Category	Amount	Unit	Cos
tap water	E:Water supply; sewer...	water *1000*IF(ABS(year-52)<epsilon;0;1)*IF(ABS(year-51)<epsilon;0;1)*IF(ABS(year)<epsilon;0;1)	kg	

Outputs

Flow	Category	Amount	Unit	Costs/Rev.
Operational Wate...	**Phases**	**1.00000**	**Item(s)**	
wastewater, average	E:Water supply; sewer...	water*IF(ABS(year-52)<epsilon;0;1)*IF(ABS(year-51)<epsilon;0;1)*IF(ABS(year)<epsilon;0;1)	m3	

Figure 2-10: Operational Water Use

Wastewater generation is also included. To restrict the impacts to within the defined use phase, the following temporal filters are applied:

```
IF(ABS(year) < epsilon; 0; 1)
IF(ABS(year - 51) < epsilon; 0; 1)
IF(ABS(year - 52) < epsilon; 0; 1)
```

These prevent impacts from being counted in Year 0 (pre-use phase) or beyond the reference service life.

2.5 End-of-Life Phase

The end-of-life (EoL) phase captures the environmental impacts associated with the decommissioning, transport, treatment, and final disposal of building materials after the use phase. All activities in this phase are allocated to **Year 51**, immediately following the building's 50-year reference service life.

2.5.1 Demolition

In this module, the building is demolished using a hydraulic excavator. The activity consumes 10 litres of diesel over a 3-hour operation period.

Demolition is modelled using the ecoinvent dataset:
"excavation, hydraulic digger | EN15804GD, U – RER."

According to the dataset, 0.131 litres of diesel are required to demolish 1 m^3 of building structure. Based on this, the total volume of the demolished structure is estimated as:

$$\text{Demolished Volume} = 10 \text{ litres} / 0.131 \text{ litres per } m^3 \approx 76.34 \text{ } m^3$$

All impacts associated with this demolition activity are assigned to Year 51, using temporal parameters described in earlier sections.

2.5.2 Transport to Waste Treatment Site

This module includes the transport of demolition waste to a waste treatment site located 30 km from the demolition site. All EPD data corresponding to Module C2 (Transport to EoL processing) is included in this stage.

Transport emissions are modelled using appropriate freight transport datasets from ecoinvent. The impacts are scheduled for Year 51, aligned with the demolition activities.

2.5.3 Waste Treatment & Disposal

This module models the processing and final disposal of waste materials at the treatment facility. The following waste management assumptions are made:

- Steel is fully recycled.
- Cement, sand, bricks, and gravel are partially recycled.
- All other materials, including PET, plastic components, and furnishings, are landfilled.

The impacts from Module C3 (Waste treatment) of all included EPDs are integrated here.

C4 module accounts for the final disposal of non-recyclable materials. It includes emissions and resource depletion from landfill operations or other terminal waste management activities. Only Module C4 (Disposal) results from all relevant EPDs are included in this stage. As with other end-of-life activities, final disposal is set for Year 51.

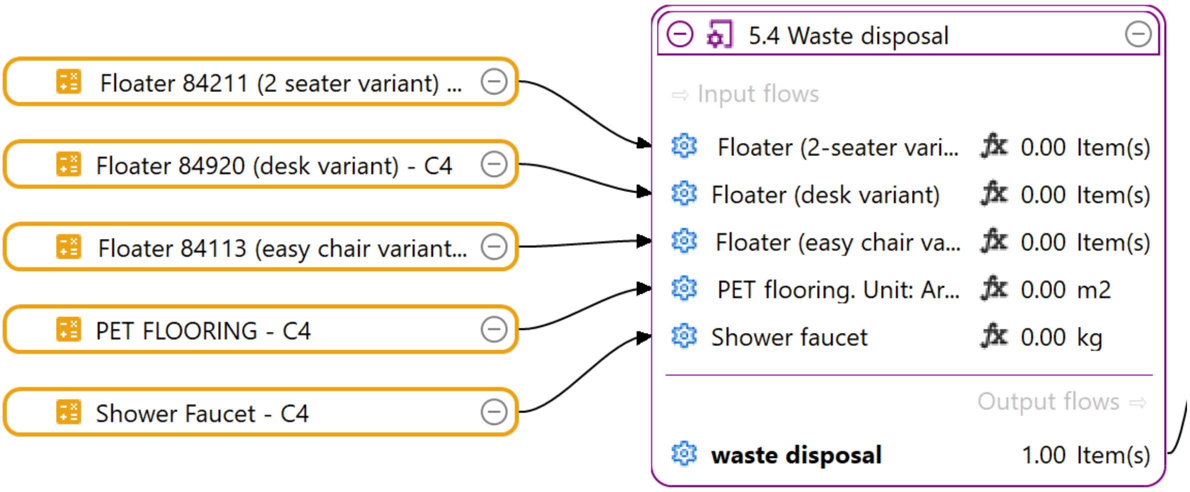


Figure 2-11 Module C4- Waste Disposal

2.6 Loads & Benefits

This module captures the environmental loads and benefits associated with the recovery, reuse, and recycling of materials at the end of the building's life cycle. These are modelled in accordance with Module D of EN 15804, which accounts for potential avoided impacts beyond the system boundary.

Although Module D activities do not occur at a specific time within the building life cycle, they are allocated to Year 52 in this study to support clarity in temporal modelling and results interpretation.

Table 4 summarizes the materials for which benefits are considered, along with the corresponding avoided products:

Table 4: Loads and Benefits

Material	Load	Avoided Product
Steel	Recycling	Virgin Steel
Cement	Recycling	Gravel used for Backfilling
Sand	Recycling	Gravel used for Backfilling
Red Bricks	Recycling	Gravel used for Backfilling
Gravel	Recycling	Gravel used for Backfilling

For these materials, benefits from recycling and material substitution are credited to the system, reducing the overall environmental burden. For example, the recycling of steel results in avoided production of virgin steel, while the recycling of mineral materials (cement, sand, bricks, and gravel) contributes to avoided use of natural gravel in backfilling applications.

All Module D results from relevant EPDs are included in this stage to ensure consistency with product-specific data and to maintain methodological alignment with EN 15804+A2.

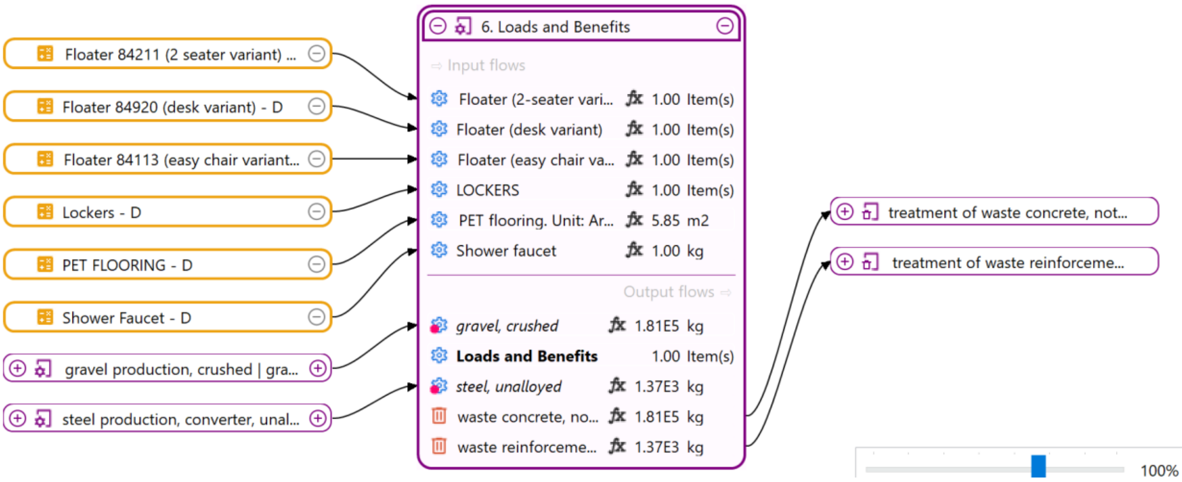


Figure 2-12: Loads and Benefits over the Life Cycle of the entire building

3 Dynamic Characterisation Factors

To incorporate temporal dynamics, we adopted the time-dependent discounting factor proposed by Resch et al. (2021) and reproduced as Eq. 3 in (Andersen, 2024). The discounting factor for an emission occurring in year y within a total time horizon (TH) is defined as:

$$Discounting\ factor_{TH}(y) = 2 - e^{\frac{\ln(2)}{TH}y}$$

Where, `TH = Time Horizon (typically 100)`
`y = years`

In this study, we implemented this dynamic characterization factor exclusively for biogenic CO_2 emissions, where data on carbon uptake and release over time are most robust while all other greenhouse gas flows were assessed using traditional, time-static factors. The changes were implemented in the ‘characterisation factors’ tab as seen in the Figure 3-1 below where the parameter temporal_factor equated to discounting factor.

Characterization factors - EN15804 (EF 3.1) | Global Warming Potential - biogenic (GWP-biogenic)

Characterization factors

Flow	Category	Factor	Unit	Uncertainty	Location
Carbon dioxide, in air	Elementary flows/Resource/in air	1.0*temporal_factor	kg CO2 eq./kg	none	
Carbon dioxide, non-fossil	Elementary flows/Emission to air/high ...	1.0*temporal_factor	kg CO2 eq./kg	none	
Carbon dioxide, non-fossil	Elementary flows/Emission to air/low ...	1.0*temporal_factor	kg CO2 eq./kg	none	
Carbon dioxide, non-fossil	Elementary flows/Emission to air/low ...	1.0*temporal_factor	kg CO2 eq./kg	none	
Carbon dioxide, non-fossil	Elementary flows/Emission to air/unsp...	1.0*temporal_factor	kg CO2 eq./kg	none	
Carbon dioxide, non-fossil, resource ...	Elementary flows/Resource/in air	1.0*temporal_factor	kg CO2 eq./kg	none	
Methane, non-fossil	Elementary flows/Emission to air/high ...	29.8*temporal_factor	kg CO2 eq./kg	none	
Methane, non-fossil	Elementary flows/Emission to air/low ...	29.8*temporal_factor	kg CO2 eq./kg	none	
Methane, non-fossil	Elementary flows/Emission to air/low ...	29.8*temporal_factor	kg CO2 eq./kg	none	
Methane, non-fossil	Elementary flows/Emission to air/unsp...	29.8*temporal_factor	kg CO2 eq./kg	none	

Figure 3-1: Applying discounting factor to characterization factor of GWP potential

By doing so, we capture the temporal distribution of biogenic carbon sequestration and emissions without extending dynamic factors to impact categories for which reliable time-series characterization is not yet established.

As seen in Figure 3-2, for the static CF results, where the CF’s where not changed, the biogenic GWP shows distinct plateaus for set of iterations then stepping down every 10 iterations reflecting the changes in the electricity mix while the dynamic CF is shown Figure 3-3 to change every single iteration of every single year. Users are thus recommended to explore potential changes in other impact categories’ CFs as they change with time.

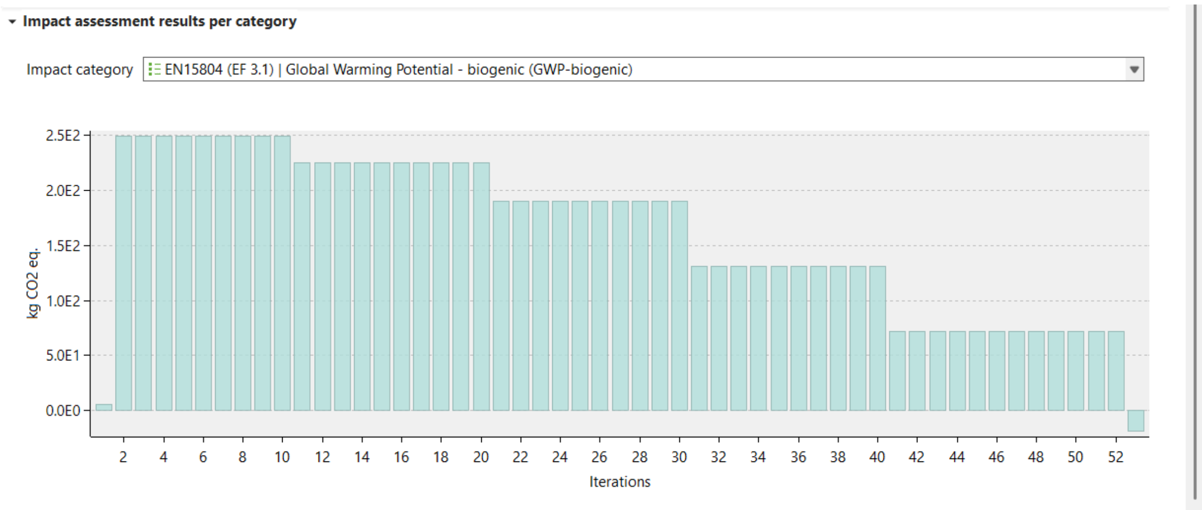


Figure 3-2: Static GWP-biogenic results across lifetime of the building

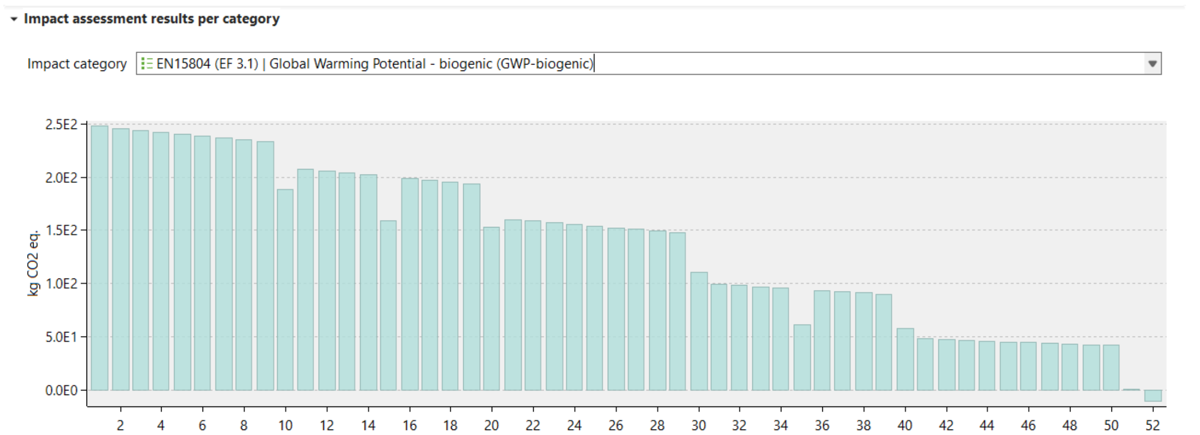
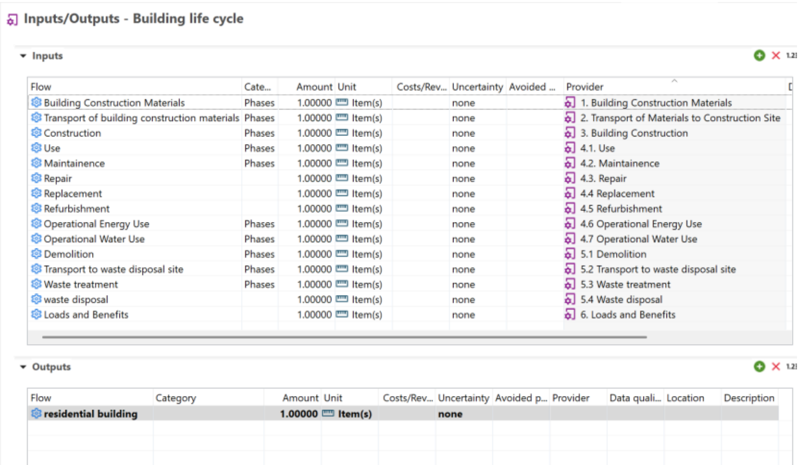


Figure 3-3 Dynamic GWP-biogenic results across lifetime of the building

4 Calculation setup

After modelling all life cycle phases and modules, they are integrated into a master process titled “Building Life Cycle.” This master process consolidates the entire system and forms the basis for impact assessment.


Inputs/Outputs - Building life cycle

Inputs

Flow	Cate...	Amount	Unit	Costs/Rev...	Uncertainty	Avoided ...	Provider
Building Construction Materials	Phases	1.00000	Item(s)		none		1. Building Construction Materials
Transport of building construction materials	Phases	1.00000	Item(s)		none		2. Transport of Materials to Construction Site
Construction	Phases	1.00000	Item(s)		none		3. Building Construction
Use	Phases	1.00000	Item(s)		none		4.1. Use
Maintainence	Phases	1.00000	Item(s)		none		4.2. Maintainence
Repair		1.00000	Item(s)		none		4.3. Repair
Replacement		1.00000	Item(s)		none		4.4 Replacement
Refurbishment		1.00000	Item(s)		none		4.5 Refurbishment
Operational Energy Use	Phases	1.00000	Item(s)		none		4.6 Operational Energy Use
Operational Water Use	Phases	1.00000	Item(s)		none		4.7 Operational Water Use
Demolition	Phases	1.00000	Item(s)		none		5.1 Demolition
Transport to waste disposal site	Phases	1.00000	Item(s)		none		5.2 Transport to waste disposal site
Waste treatment	Phases	1.00000	Item(s)		none		5.3 Waste treatment
waste disposal		1.00000	Item(s)		none		5.4 Waste disposal
Loads and Benefits		1.00000	Item(s)		none		6. Loads and Benefits

Outputs

Flow	Category	Amount	Unit	Costs/Rev...	Uncertainty	Avoided p...	Provider	Data quali...	Location	Description
residential building		**1.00000**	**Item(s)**		**none**					

Figure 4-1: Building Life Cycle Process

To accommodate both types of assessment, static and dynamic, two separate product systems were created:

- Static Product System: excludes temporal variables and is used for phase- and module-wise impact analysis.
- Dynamic Product System: incorporates temporal variables and is used for year-by-year impact analysis.

4.1 Static Assessment

For the static assessment, the EN 15804+A2 (EF 3.1) impact assessment method was applied directly to the product system. This provides a comprehensive overview of environmental impacts across the entire life cycle, without considering when those impacts occur.

The contribution tree feature in openLCA can be used to break down results by life cycle phase, i.e., production, use, and end-of-life, offering clear insights into phase-wise contributions.

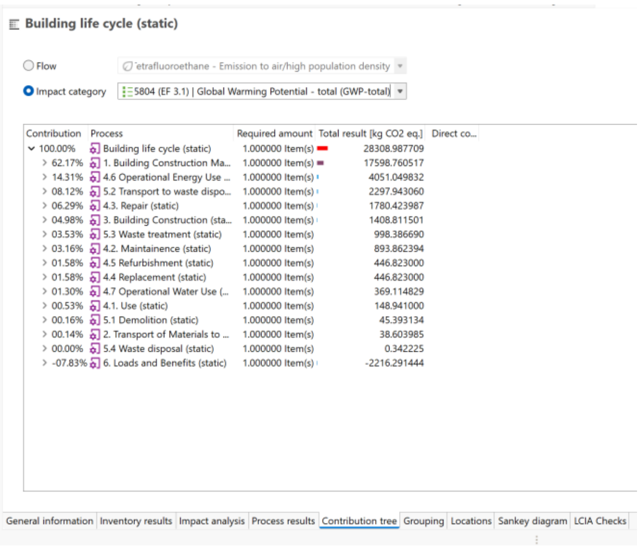


Figure 4-2: Results from static LCA

4.1 Dynamic Assessment

To analyse environmental impacts over time, Parameter Analysis was used in openLCA. As detailed in earlier sections, all life cycle inputs were multiplied by their corresponding year_xx parameters, ensuring that each activity is only active in the year it occurs.

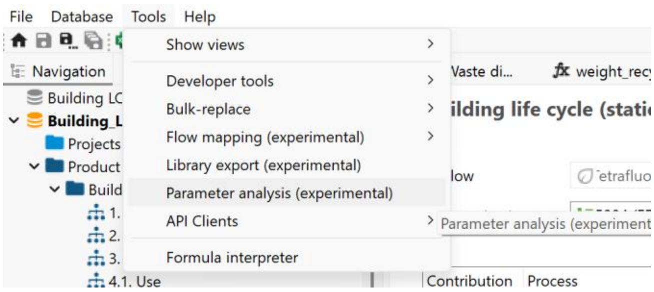


Figure 4-3: Conducting a Parameter Analysis Assessment

The following setup was used to perform the year-wise assessment:

- Method: EN 15804+A2 (EF 3.1)
- Parameter: `year`
- Range: 0 to 52 (i.e., 53 iterations to include construction, use, end-of-life, and post-life modules)

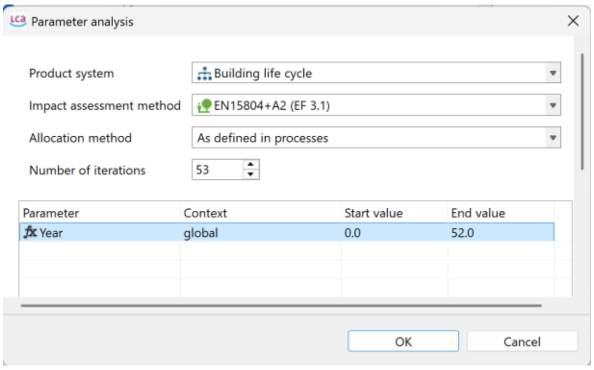


Figure 4-4: Defining parameters

Upon completing the iterations, results can be viewed for each year and impact category (e.g., GWP, ADP, AP). This allows for a granular temporal understanding of environmental performance throughout the 52-year life cycle.

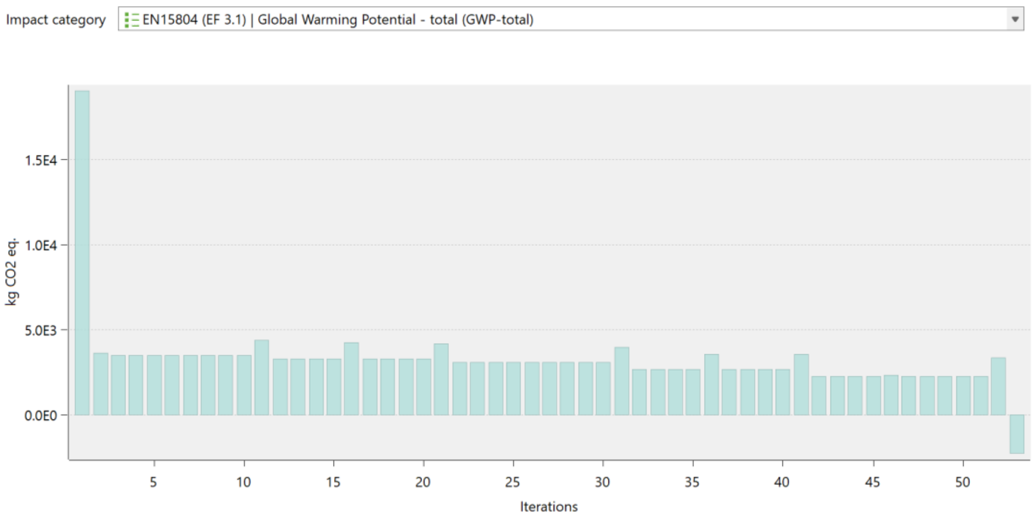


Figure 4-5 Parameter Analysis

5 Considerations for Users

This study serves as a foundational template for conducting whole-building life cycle assessments using openLCA. While it provides a structured and replicable modelling approach, users applying or adapting this model should remain aware of certain areas where further contextualisation may be necessary, depending on the goals of their specific study.

Users are encouraged to tailor operational inputs, such as electricity and water consumption, based on actual data rather than relying on default values. Parameters such as occupancy levels, regional climate, and building operation schedules can significantly influence these inputs and, consequently, the overall impact profile.

During the construction phase, the treatment of material waste has been simplified for clarity. Users aiming for greater accuracy should consider collecting more detailed waste estimates, either from construction reports, local benchmarks, or empirical data, especially if waste generation is a key focus area. Similarly, while recycling is modelled in this template, users are advised to assess the quality of recycling processes and substitution ratios more carefully. Factors such as downcycling, contamination, and regional variations in recycling infrastructure can influence both environmental impacts and credits claimed under Module D.

For those interested in modelling end-of-life scenarios with higher fidelity, additional steps such as dismantling, sorting, and cleaning of materials can be incorporated. These pre-treatment activities are often necessary in practice and may carry non-negligible environmental burdens that are worth capturing, especially when evaluating circularity or recovery rates.

The use phase includes a selection of EPDs to demonstrate how product-level declarations can be integrated. However, users should feel free to expand this set to match the specific features of their own building case study. Using more region-specific or product-specific EPDs can improve the model's representativeness and provide more granular insights.

Additionally, the assumptions applied in Module C1 (Demolition) and related energy inputs have been kept simple for demonstration purposes. Users interested in end-of-life modelling should evaluate whether more detailed inputs, such as electricity use, equipment types, or regional practices, are needed for their context.

While this template employs the EN 15804+A2 (EF 3.1) impact assessment method for consistency, users may choose to apply alternative characterisation models depending on regulatory requirements, audience expectations, or desired impact categories. Likewise, while ecoinvent serves as the primary background database here, combining datasets from regional or national sources can improve the geographic accuracy of the model, provided that harmonisation is maintained in terms of system boundaries and data quality.

In conclusion, this template is intended as a starting point rather than a fixed model. Users are encouraged to critically assess each module and adapt the assumptions, data sources, and modelling scope according to their specific objectives and context.

6 References

Ahmed Abdel Monteleb M. Ali, A. M. (2015). Environmental Life Cycle Assessment of a Residential *Building in Egypt: A case study.* (2015). *Procedia Technology, 19*, 349–356. https://doi.org/10.1016/j.protcy.2015.02.050

Andersen, C. E. (2024). Temporal considerations in life cycle assessments of wooden buildings: Implications for design incentives. *Journal of Cleaner Production, 445*, 141260. https://doi.org/10.1016/j.jclepro.2024.141260

European Committee for Standardization. (2019). *EN 15804:2012+A2:2019. Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products.*

Resch, E., Andresen, I., Cherubini, F., & Brattebø, H. (2021). Estimating dynamic climate change effects of material use in buildings—Timing, uncertainty, and emission sources. *Building and Environment, 187*, 107399. https://doi.org/10.1016/j.buildenv.2020.107399

United Nations Environment Programme, & Yale Center for Ecosystems + Architecture. (2023). *Building materials and the climate: Constructing a new future.* https://www.unep.org/resources/report/building-materials-and-climate-constructing-new-future

7 Annexures

7.1 Annexure 1: Parameters

Parameter	Value/Formula	Description
Raw Materials		
Steel	1368 kg	Amount of Steel required in kg
Cement	8186 kg	Amount of Cement required in kg
Red Brick	17.7 m3	Amount of Red_Brick required in m3
Sand	85.7 m3	Amount of Sand required in m3
Gravel	14.5 m3	Amount of Gravel required in m3
Wood	0.7 m3	Amount of Wood required in m3
Glass	4 m2	Amount of Glass required in m2
Ceramic	30 m2	Amount of Ceramic required in m2
Paints	170 m2	Amount of Paints required in m2
Densities & Thicknesses of Raw Materials		
density_Red_Brick	1920 kg/m3	Density of Red Brick
density_Sand	1600 kg/m3	Density of Sand
density_Gravel	1520 kg/m3	Density of Gravel
density_Wood	640 kg/m3	Density of Wood
density_Glass	2580 kg/m3	Density of Glass
density_Ceramic	3250 kg/m3	Density of Ceramic
density_Paints	2100 kg/m3	Density of Paints
Thickness_Glass	0.004 cm	Thickness of Glass
Thickness_Ceramic	0.006 cm	Thickness of Ceramic
Thickness_Paints	0.002 cm	Thickness of Paints
Distances for transportation of raw material to construction site		
distance_1	5	Distance travelled by Gravel
distance_2	5	Distance travelled by Steel
distance_3	5	Distance travelled by Ceramic
distance_4	5	Distance travelled by Sand
distance_5	5	Distance travelled by Wood

distance_6	20	Distance travelled by Cement
distance_7	5	Distance travelled by Red Brick
distance_8	5	Distance travelled by Glass
distance_9	5	Distance travelled by Paints
Construction Process		
Calorific_value_diesel	37 MJ/litre	Calorific value of diesel used for construction
Diesel_consumption_cement_mixer	15 Litres/hour	Diesel consumption of cement mixer per hour
Cement_mixing_time	5 hours	Duration of use of cement mixer
Diesel_consumption_drilling	30 Litres/hour	Diesel consumption of drilling machine per hour
Drilling_time	10 hours	Duration of use of drilling machine
Water_for_construction	100 m3	Water used for construction
Use Phase		
Calorific_Value_natural_gas	84.60 MJ/m3	Calorific value of natural gas used for heating
Electricity_consumption	5904 kWh	Operational electricity consumed per year
Heating	192 m3	Amount of natural gas consumed for heating the building per year
Water	1200 m3	Operational water use per year
End-of-Life Phase		
Diesel_consumption_demolition	10 litres	Diesel consumed in demolition of the building
Recycling_rate	0.9	Rate of recycling for cement, red brick, sand and gravel
Landfilling_rate	1-recycling_rate	Rate of landfilling for cement, red brick, sand and gravel
weight_recycled_materials	Cement+sand *density_sand +red_brick *density_red_brick +Gravel *density_gravel	Weight of cement, red brick, sand and gravel
Weight_landfilled_items	Cement+sand *density_sand +red_brick *density_red_brick +Gravel *density_gravel	Weight of cement, red brick, sand and gravel
weight_glass_ceramic_paint	Glass *thickness_glass *density_glass +Ceramic	Weight of glass ceramic and paints

	*density_ceramic *thickness_ceramic +paint *thickness_paint *density_paint	
Temporal Parameters		
Temporal factor	2-(2)^(year/time_Horizon)	Discounting factor discussed in Section 3
Time Horizon	100 years	Time Horizon discussed in Section 3
Year	Dynamic (0 to 52)	Year under consideration
Year_0	IF(ABS(year)<epsilon ;1;0)	Year Parameter for year 0
Year_1	IF(ABS(year-1)<epsilon ;1;0)	Year Parameter for year 1
Year_15	IF(ABS(year-15)<epsilon ;1;0)	Year Parameter for year 15
Year_30	IF(ABS(year-30)<epsilon ;1;0)	Year Parameter for year 30
Year_35	IF(ABS(year-35)<epsilon ;1;0)	Year Parameter for year 35
Year_45	IF(ABS(year-45)<epsilon ;1;0)	Year Parameter for year 45
Year_51	IF(ABS(year-51)<epsilon ;1;0)	Year Parameter for year 51
Epsilon	0.1	A small number to calculate year parameters

** Year parameter for a particular year takes a value of 1 when the parameter "Year" takes the value of that particular year and zero in all others*