Impact Assessment of LCA background databases

Study on four construction products

Report SGS INTRON B.V.

Status: Final version
Date: 17-10-2025
Document number: A158510/R20251286

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Summary

The revised Construction Products Regulation (CPR 2024/3110), effective from January 2025, aims to establish a transparent and harmonized European market for construction products while promoting sustainability. It applies to manufacturers and distributors placing products on the EU market, as defined in Annex VII of CPR 2024/3110 and Annex IV of CPR 305/2011. Where a harmonized standard exists, CE marking is mandatory, accompanied by a Declaration of Performance (DoP) that includes Environmental Indicators. The CO_2 emissions specified in the DoP are incorporated into the energy performance calculation in accordance with the requirements set out in EPBD IV, as mandated by the European Commission.

The CPR provides for harmonised product standards and recording performance uniformly, including the environmental impact using the LCA standard EN 15804. The draft CPR decision states that all LCI (life Cycle Inventory) databases that comply with EN15941 (data quality standard) are suitable for calculating the environmental performance for the Declaration of Performance (DoP).

Scientific research[1] has shown that CO_2 emissions for identical products can vary significantly in life cycle assessments (LCAs), depending on the database used. The differences in other environmental indicators can be even more pronounced.

Goal

The project aims to provide a deeper understanding of how environmental impact scores vary depending on the background database used in Life Cycle Assessments (LCAs), and how these differences affect the overall environmental impact profile of construction products. By highlighting the influence of database selection on LCA outcomes, the project seeks to raise awareness among stakeholders about the implications for environmental reporting and decision-making. The research is structured into three distinct parts, each with a specific sub-objective:

- Identification and mapping of LCA databases that may be used to calculate environmental impacts within a Declaration of Performance (DoP).
- Quantitative analysis of impact variation across three selected background databases.
- Evaluation of the consequences for environmental performance assessments and green procurement practices.

Executed work

Four construction products were selected for the LCA calculations with different databases:

- Construction profiles (steel)
- ZOAB (asphalt)
- Retaining wall (concrete)
- Bridge (wood)

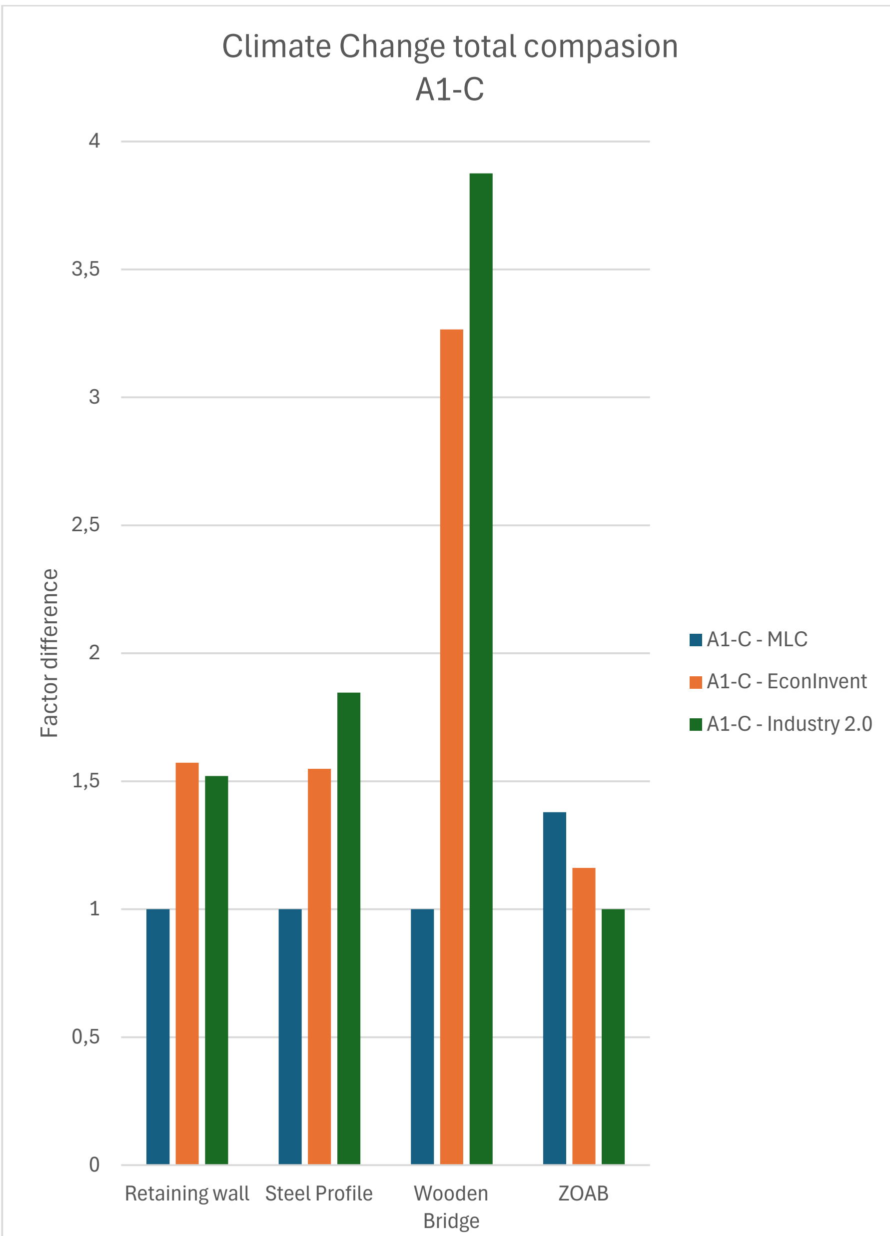
These products/materials are widely used in both building and infrastructure applications, making them representative examples. Furthermore, these product groups are among the first to be subjected to the CPR Technical Acquis process.
The background databases that were used in the study are EcoInvent 3.9, MLC (Sphera, formerly GaBi database) and Industry data 2.0 (World Steel, CEMbureau, Ecoplatform, Eurobitume).

[1] Comparison of life cycle assessment databases: A case study on building assessment, Atushi Takano et al, Building and Environment 79 (2014), pp20-30

In this study the effect in environmental profiles based on different background databases has been evaluated. For the four different products (steel construction profile, ZOAB, retaining wall and a wooden bridge) a model was developed based on the existing PCR documents for these products. The impact profiles were analysed to determine the effects on the EN15804:2012+A2:2019.

Results

Differences were found between the impact indicators for all products. The differences for the environmental impact indicators performances vary up to a factor 10.000 for the same product. The effects on the environmental impact indicator scores vary per product and LCI database. In figure below the factor differences are depicted for the core environmental impact indicator Global Warming Potential (CC_{total}) for the LCA modules (A1-C) except D.



As depicted in the figure the CC_{total} impact indicator differences ranged from a factor 1.2 to 3.9. Whereas the MLC databased resulted in the lowest Climate Change impact for the three oft products/materials (retaining wall, steel profile and wooden bridge), the CC_{total} impact indicator based on the Eurobitume was lowest for ZOAB.
When benefits and loads beyond the system boundaries (module D) are included the factor difference ranges from 1.5 to 3.1 with the MLC database resulting in the lowest impact indicators for all products/materials.

No consistent pattern could be identified in which one database systematically produced higher or lower impact scores across all indicators.

These large variations in the environmental impact profile due to the background databases have impact on the usability of the Environmental Indicators. Firstly, it makes a clear comparison between construction products complicated. Which is hampering the possibility to create a business case for green building products. And secondly, it complicates the possibility of imposing unambiguous requirements on construction products or built structures following EPBD IV (WLC-GWP) or other environmental requirements in legislation or in Green Procurement.

The absence of a discernible pattern across databases makes it impossible to apply uniform corrections. Environmental Indicators are only valid for comparative analysis or construction calculations if they are based on the same background database, highlighting the urgent need for harmonisation of databases.

1. Preface

Since the beginning of Life Cycle Assessment (LCA), practitioners were discussing the effects of different life cycle inventory databases. Scientific studies [1] [2] describe the impact of the use of different databases on the environmental impact indicators. This study explores for three of the most used databases (MLC, EcoInvent and Industry 2.0) whether variation still exists (and to what extent) by comparing the environmental impact for the same product based on the different background databases. To minimise side-effects a comparative LCA modelling for each of the four different construction products was developed based on the prerequisites stated in the Product Category Rules for the products.
Then the impact profiles of the products are compared for all EN15804:2012+A2:2019 impact indicators. The results provide new insights in the differences in the scores for Environmental Indicators due to the LCI databases applied.

This report explores the impact of the CPR decision to allow for the use of several background databases regarding the usability of Declarations of Performance (DoP), Environmental Product Declarations and Environmental Indicators (in the remainder of the report the term Environmental Indicator of Impact Indicator will be used) for comparison of Building or Infrastructure calculations - and thus for green procurement or legislation.

2. Inventory databases

LCA background databases (Life Cycle Inventory; LCI) provide generic environmental data on processes such as production, transportation, energy use, and waste management. These databases (LCI) are essential for conducting Life Cycle Assessments (LCAs) of products and construction works, enabling the calculation of environmental impacts across various life cycle stages and provide data when product specific data is not available. LCI databases enable practitioners to conduct life cycle assessments by offering standardized data that can be applied across various studies and regions.

The diversity of LCI databases is caused by a range of reasons; like regional needs, methodological differences, software compatibilization and standardization efforts. Different countries have developed their own LCI databases to address local environmental concerns, regulatory requirements, and industry practices. For instance, the GaBi (Ganzheitliche Bilanzierung) database (rebranded to Sphera Managed LCA Content (MLC, hereafter called MLC)) was developed in Germany and is still widely utilized in Germany for evaluating the environmental impacts of products, processes, and services. With over 15,000 datasets covering various sectors. The MLC database is integrated in the Sphera LCA for Experts ((LCA FE) formerly Thinkstep) software. Other LCI databases, like EcoInvent can be used with several software systems. The software generally can use more than one LCI databases. To get access subscription costs have to be paid, depending on the database.
Life Cycle Assessment (LCA) relies heavily on background databases to provide standardized environmental data across various sectors. These databases offer critical information on materials, processes, and services, enabling consistent and comparable assessments. Different industries have developed specialized LCI background databases tailored to their specific needs. Many of these datasets are collected in the Industry 2.0 databases.

The draft CPR decision states that all LCI databases that comply with EN15941 (data quality) are suitable for calculating the Declaration of Performance (DoP). The EN 15941:2024 provides guidelines for selecting and using data in LCA studies. It outlines criteria for data quality, emphasizing the importance of temporal, technological, and geographical representativeness to ensure the reliability and relevance of the data. Many LCI databases state that they are compliant to EN15941:2024 with an external reviewed statement. Although some of the LCI databases enable Data quality assessment of their datasets by supplying verifiable information of the datasets, overall, it is very labour-intensive to determine whether the datasets comply to EN15941:2024. Therefore, if stated that the databases are compliant with the EN15941:2024, this is generally not confirmed for the specific datasets used within a LCA study or during review of the LCA.

In Table 1, an overview is made of the most widely used LCI databases. The list does not compile all LCI databases available globally but supplies a general idea about the availability of background datasets. For this research the MLC database was chosen as an alternative for the EcoInvent database as is widely used in Europe, especially in Germany, it has a comparable number of datasets and is compliant to EN15941:2024. Therefor it is expected that the MLC database will be frequently used to verify environmental data for the DoP conform the CPR in the future.

The other LCI database used in this study is the Industry 2.0 database. This database is a combination of datasets supplied by the industry. For instance, the Industry 2.0 database contains the datasets of PlasticEurope, the Alliance for Beverage Cartons and the Environment, and Worldsteel. The data is developed by the specific sectors of the industry. As the data is from the industry it is perceived as accurate and therefore broadly used. However, for wood there was no suitable dataset available in this database. Therefore, the environmental profile for an Environmental Product Declaration for Cross Laminated Timber (CLT) was used in the comparison.

Table 1, Overview LCI databases

LCI Database	Owner	Applicable Software	Origin	Datasets	EN15941
EcoInvent	EcoInvent	SimaPro/ Sphera /OpenLCA/Helix and Mobius	Switzerland	20.000	Yes
MLC	Sphera	Sphera/OpenLCA	Germany	15.000	Yes
PEF/ ELCD	European commission	SimaPro/ Sphera /OpenLCA/ Mobius	Belgium	3.200	Yes
BEDEC	ITeC	SimaPro/Sphera/OpenLCA	Spain		Yes
CPM-database / SPINE	Chalmers University of Technology	SimaPro/Sphera/OpenLCA	Sweden	748	Yes
Athena	Athena Institute	Athena EcoCalculator/ SimaPro	Canada	50	Yes
ProBas	Umwelt Bundesamt	OpenLCA/ GreenDelta/Sphera	Germany	8.000	Yes
GEMIS	Öko Institut	GEMIS software	Germany	5.000	?
Bilan CarboneTM	ADEME	Bilan CarboneTM software	France	200	?
Canadian Raw Materials Database	University of Waterloo	SimaPro/Sphera/OpenLCA	Canada	18	No
Carbon Minds	Carbon Minds	Umberto/ SimaPro/Sphera	Canada	1500	Yes
USLCI	NREL	SimaPro/OpenLCA/Earthster	USA	550	?
IDEAv.2	AIST	SimaPro/OpenLCA	Japan	3800	?

ICE (inventory of carbon & energy)	Circular ecology	SimaPro/Sphera/OpenLCA	United Kingdom	200	?
AusLCI	ALCAS	SimaPro/OpenLCA/Earthster	Australia	600	
CLCD	Chinese Life Cycle Database	eBalance/OpenLCA/Sphera	China	600	?
BRANZ	BRANZ CO 2 NSTRUCT	LCAQuick	New Zeeland	?	?
Industry 2.0		SimaPro		300	Yes
Worldsteel	International Iron and Steel Institute (IISI)	SimaPro/Sphera/OpenLCA	Belgium	47	Yes
PlasticsEurope Eco-profiles	PlasticsEurope	SimaPro/Sphera/OpenLCA	Belgium	85	Yes

This study is set up to get insight in the effect of these databases on the impact profile of four construction products. The selected products, a steel construction profile, ZOAB, a concrete retaining wall, and a wooden bridge, are not only commonly used in infrastructure and construction projects but also serve as representative examples for assessing the environmental impact of the materials they are made from. For each of the products a model was developed based on the PCR for the product. This enables a comparison with similar conditions for lifespan, transport distances. The effects found in the LCA results will therefore be mainly caused by the datasets.

In the next chapters (3 and 4) the approach for and the lifecycle analysis of four building materials has been carried out based on the sector rules stated in PCR documents for the specific products (paragraph 4.1 steel profile, paragraph 4.2 ZOAB, paragraph 4.3 retainer wall, and paragraph 4.4 wooden bridge). The prescribed model and system boundaries are followed as closely as possible for all three background LCI databases. The results and variation between the results of the different LCI databases are discussed in the specific appendixes (B-E).

3. LCA results based on different background databases

3.1. Approach

To analyse the effects of different background databases a LCA study was performed on the four different products (steel profile, ZOAB, retainer wall, and wooden bridge).
The aim of the project as to gain insight in the effects caused by using different background databases. To prevent, as much as possible, the effect of other influences decomposition models are developed for each product. The decomposition models were created based on relevant Product Category Rules (PCR) and public available LCA reports from https://milieudatabase.nl/nl/rapporten-tool/, as described in detail in appendices B to E. The models enable insight in the different processes, raw materials and system boundaries ensuring similar process and amounts are used in the comparison.
The models are based on the usage of the Simapro software and EcoInvent databases. The developed models could also be used for the Industry 2.0 database. As this database contained datasets for similar processes whereas the MLC datasets require adaptations of the model these adaptations are described in more detail in appendices B to E. Using similar models for each products ensures that the differences are cause by differences in the background databases.

Based on the models the environmental impact indicators performance (for all EN15804:2012+A2:2019 impact indicators) has been determined. For the EcoInvent database and Industry 2.0 database the Simapro software was used whereas for the MLC database the FE software was used.
The environmental impact performance for all EN15804:2012+A2:2019 impact indicators was scored in an unweighted score enabling a comparison between the result of the different background databases for the specific impact factor.

One of the nineteen impact categories is Climate Change (CC), this impact indicator quantifies the amount of carbon dioxide equivalents (CO_2 eq).
Among the various impact categories assessed in LCA, carbon dioxide (CO_2) emissions, also referred to as Global Warming Potential (GWP), stand out as one of the most critical and universally recognized impact indicators. Its widespread recognition and direct link to climate change make it a priority indicator in corporate reporting, product labeling (e.g., carbon footprint labels), and regulatory frameworks like the EU Green Deal and ISO 14067. Furthermore, Global Warming Potential (GWP) is present in all life cycle phases of a product as assessed through Life Cycle Assessment (LCA), from raw material extraction, manufacturing, and transportation, to the use module and end-of-life treatment, each stage contributes greenhouse gas emissions that impact climate change. For these reasons the CC-impact indicator is chosen to visualise the differences between background databases in each life cycle stage.

Comparison between the environmental impact performance based on the different background database will be discussed in chapters below for the specific products. Detail information on the analysis and the environmental impact performance can be found in appendices B to E for the individual products and background databases.

4. Results

4.1. Steel profile

Climate Change impact indicator
The environmental impact for a construction steel profile (1 kg) using each of the background databases (EcoInvent 3.9.1, MLC, and Worldsteel 2.0) are determined for all EN15804:2012+A2:2019 impact indicators. For WorldSteel, the EPDs for steel production were used all other materials and processes in the life cycle (such as galvanization and transport) were taken from the EcoInvent database. Detailed information on the modelling and results can be found in Appendix B.
The results of the different background databases for the Climate Change impact indicator are compared in Figure 1.

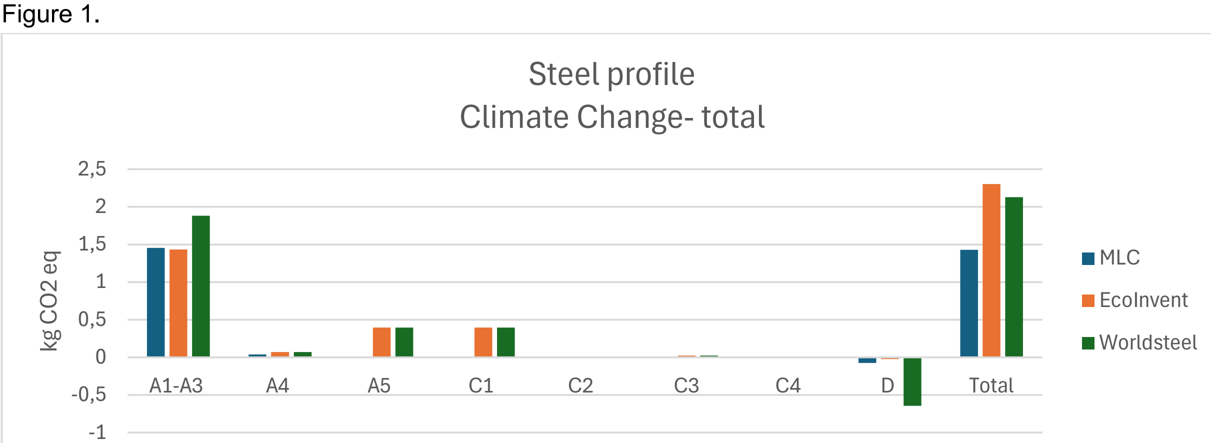


Figure 1, Climate Change impact based on the different background databases for the steel profile.

The MLC database resulted in a lower CO_2-eq emission in almost all modules, resulting in a significant lower total emission of 1,4 kg CO_2-eq compared to 2,3 kg CO_2-eq and 2,1 kg CO_2-eq, respectively for EcoInvent and Worldsteel.

Differences per impact indicator
As the impact indicators each have their own united it is only possible to compare the results for each factor separately. The difference between the impact indicators for the three background databases is depicted as factor of the lowest (positive) result in Figure 2.

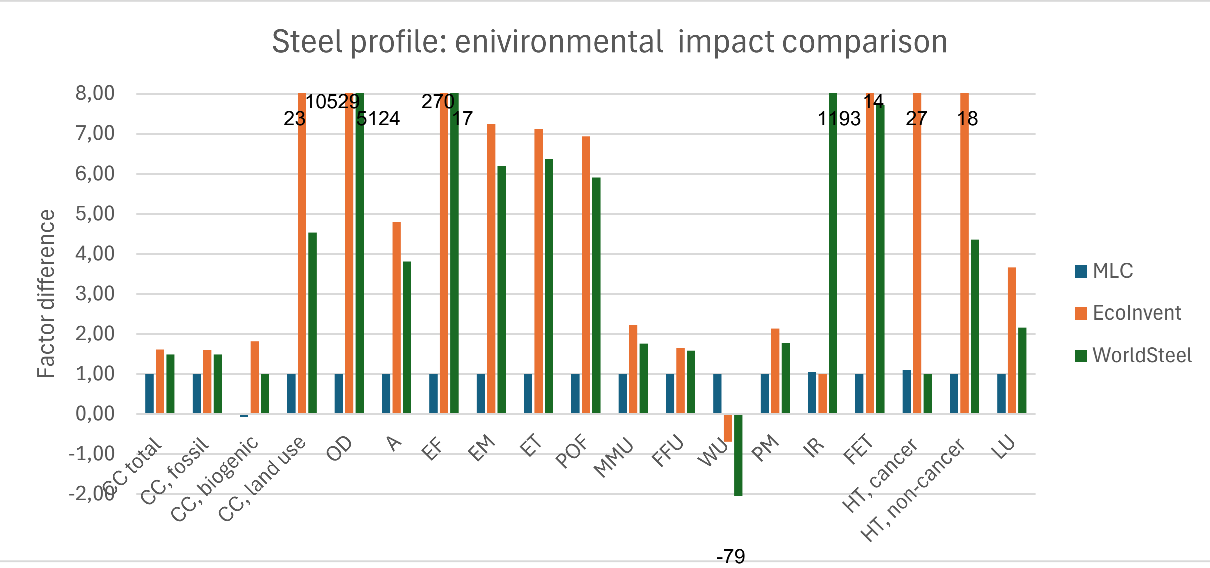


Figure 2, Environmental impact indicators based on the different background databases for steel profile.

For all impact indicators there are found differences between all three databases, this difference ranges between a factor over ten thousand higher (OD) and eighty times decrease (WU). The negative score for WU (EcoInvent and Worldsteel) arises from the use of different steel datasets in modules A compared to C (end-of-life), which leads to an overestimated compensation in module D. Typically, this compensation is manually adjusted to zero to avoid distortion; however, in this analysis, no such correction was applied in order to highlight the discrepancies between the databases. The factor difference between the MLC results and the EcoInvent and Worldsteel for the CC impact indicator is respectively 1,6 and 1,5. Except for two indicators (Climate Change, biogenic and Water Use, which negative score indicates a fault in modelling) MLC shows the lowest environmental impact scores. However, these cannot be corrected for, as the differences between databases vary for each impact indicator. EcoInvent reports the highest scores for most indicators, but not for ionizing radiation (IR). For IR, the Worldsteel Impact database gives a score nearly 1200 times higher. The variation between EcoInvent and WorldSteel could be much greater if EPD data were applied to all processes in the life cycle.

4.2. ZOAB asphalt

Climate Change impact indicator
ZOAB is a road surface with a high percentage of voids (approximately 20%). The environmental impact for a ZOAB asphalt (1 metric ton) using each of the background databases (EcoInvent 3.9.1, MLC, and Eurobitume) are determined for all EN15804:2012+A2:2019 impact indicators. For Eurobitume, the EPD for bitumen was used all other materials and processes in the life cycle (such as energy consumption at the asphalt plant and the impact of aggregate production and transport) were taken from the EcoInvent database. Detailed information on the modelling and results can be found in Appendix C.
The results of the different background databases for the Climate Change impact indicator are compared in Figure 3.

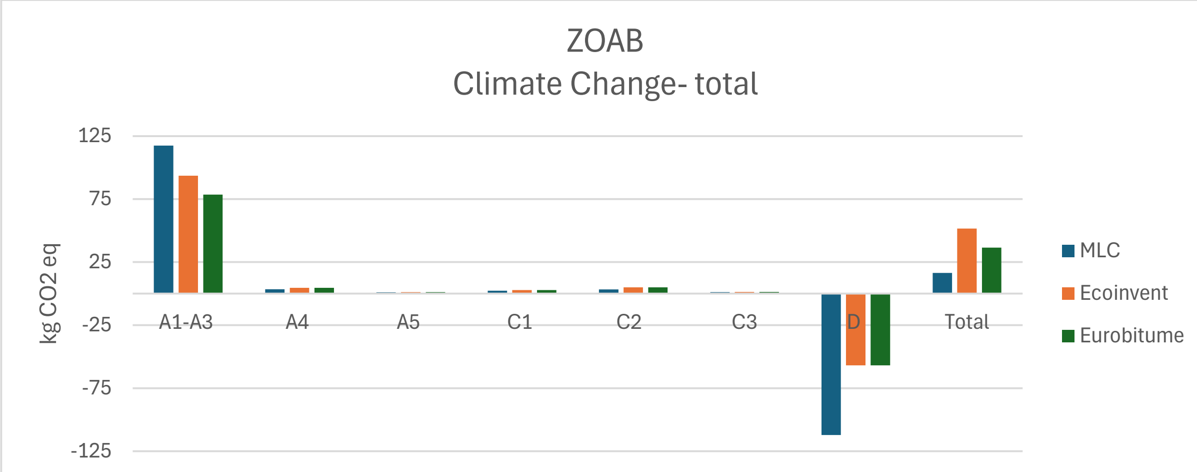


Figure 3, Climate Change impact based on the different background databases for ZOAB.

The MLC database results in the lowest CC impact over all Imodules of 16 kg CO_2 eq. compared to 52 kg CO_2-eq and 36 kg CO_2-eq, for respectively EcoInvent and Eurobitume. The low CC impact for MLC is caused by a larger compensation in module D as the emission during production (A1-A3) is the highest when the MLC database is used.

Differences per impact indicator

As the impact indicators each have their own united it is only possible to compare the results for each factor separately. The difference between the impact indicators for the three background databases is depicted as factor of the lowest (positive) result in Figure 4.

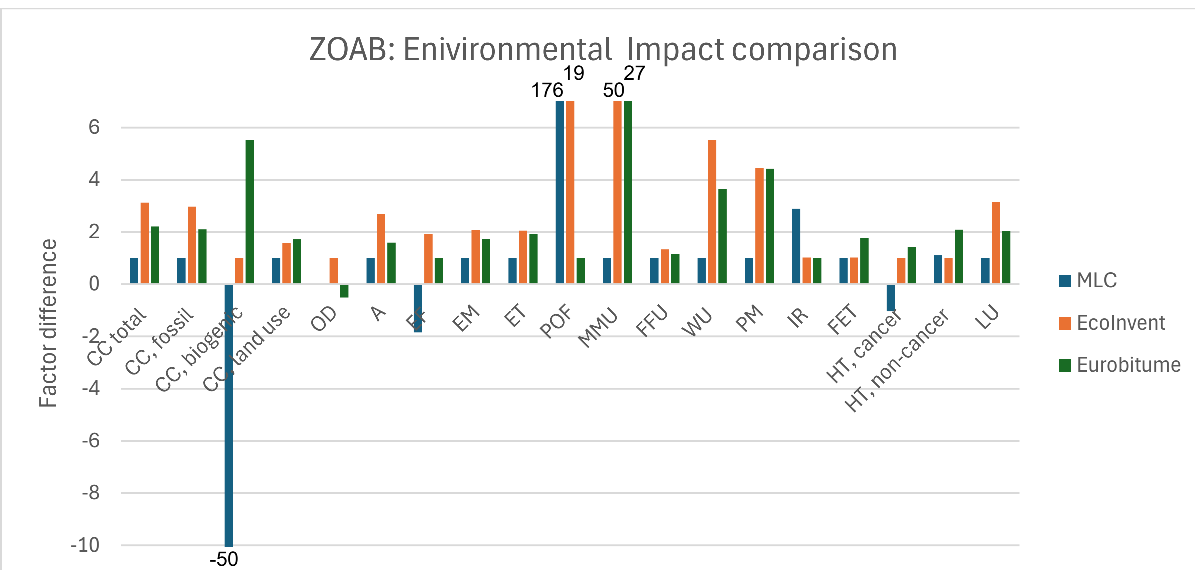


Figure 4, Environmental impact indicators based on the different background databases for ZOAB.

For all impact indicators there are found differences between all three databases, this difference ranges between a factor of almost one hundred and eighty higher (POF) and fifty decrease ($CC_{biogenic}$).The negative scores for $CC_{biogenic}$, EF, HT in the MLC results are due to lack of correction. Although the factor difference for CCbiogenic is large this only reprecents a small absolute amount (only 5% of the CC_{total}). The factor difference between the MLC results and the EcoInvent and Eurobitume for the CC impact indicator is respectively 3,1 and 2,2. No pattern was detected, as MLC shows the lowest indicators for, among others, CC, ET, and PM, but the highest scores for POF and IR. EcoInvent shows the lowest score for HT non-cancer, but the highest scores for, among others, CC, A, and LU. The variation between EcoInvent and Eurobitume could be much greater if not only one EPD but multiple material or process EPDs were used.

4.3. Retaining wall

Retaining walls are precast reinforced concrete structures with a wide base which gives the structure a high load-bearing capacity. In this study one linear meter of model 1980 type 1540 producent Strukton (870kg incl. reinforcement) is used as functional unit. The environmental impact for the retaining wall using each of the background databases (EconInvent 3.9.1, MLC, and CEMBureau) are determined for all EN15804:2012+A2:2019 impact indicators. For CEMBureau, the dataset for cement was used all other materials and processes in the life cycle (such as sand, gravel, aggregates, and reinforcement steel and transport) were taken from the EcoInvent database. Detailed information on the modelling and results can be found in Appendix D.

Climate Change impact indicator
The results of the different background databases for the Climate Change impact indicator are compared in Figure 5 per life cycle stage.

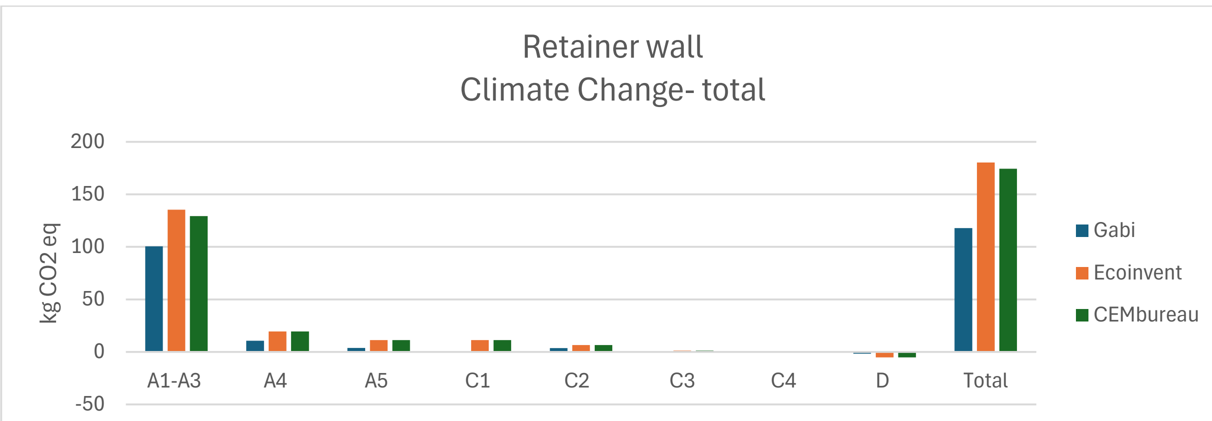


Figure 5, Climate Change impact based on the different background databases for the retaining wall.

The MLC database resulted in a lower CO_2-eq emission in almost all modules, resulting in a significant lower total emission of 118 kg CO_2-eq compared to 180 kg CO_2-eq and 174 kg CO_2-eq, respectively for EcoInvent and CEMbureau.

Differences per impact indicator
As the impact indicators each have their own united it is only possible to compare the results for each factor separately. The difference between the impact indicators for the three background databases is depicted as factor of the lowest (positive) result in Figure 6.

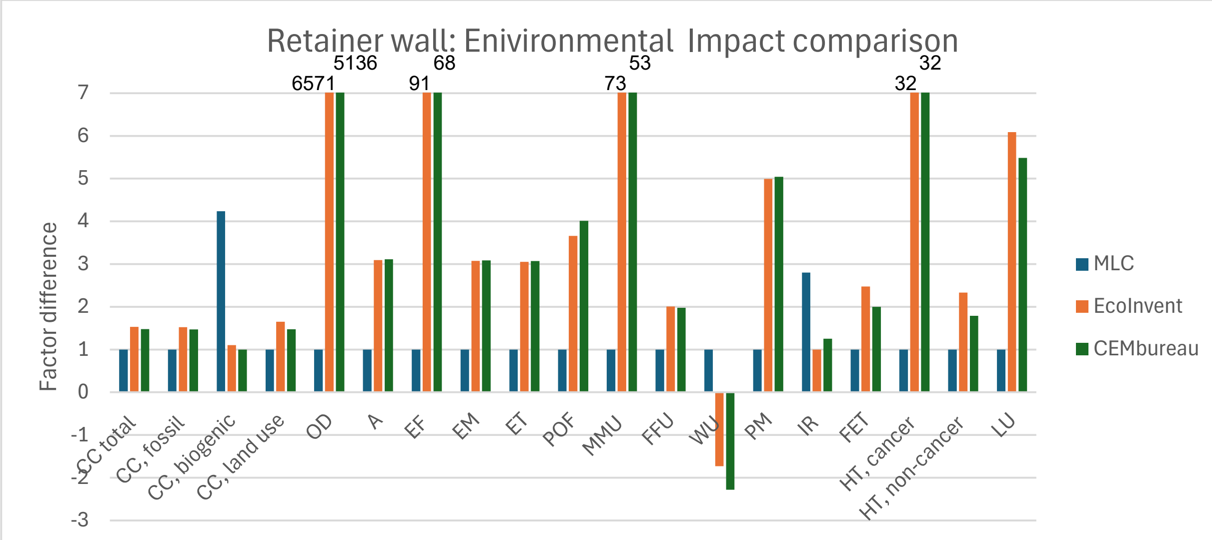


Figure 6, Environmental impact indicator based on the different background databases for the retaining wall.

For all impact indicators there are found differences between all three databases, this difference ranges between a factor of over six thousand five hundred (OD) and two decrease (WU) .The negative results for WU are not manually corrected to visualise the difference between EcoInvent result and the CEMbureau result. Again, no pattern can be found which LCI background database results in the highest or lowest environmental indicators.
MLC results in the lowest indicators for almost all indicators except for WU (where the other databases result in incorrect negative scores) indicator IR and $CC_{biogenic}$. For these three indicators MLC database results in the highest indicator. The EcoInvent database results in de lowest indicator for IR, but the highest indicator for OD and MMU. The data from CEMbureau result in the lowest indicator for CC biogenic, while other indicators result in impacts that are more or less comparable to EcoInvent (and much higher compared to MLC). The variation between EcoInvent and CEMBureau could be much greater if also EPDs for other materials and processes were used.
The factor difference between the MLC results and the EcoInvent and Eurobitume for the CC impact indicator is 1,5 for both.

4.4. Wooden bridge

A bridge is a fixed or movable connection for traffic between two points that are separated fer example by water. For this study a fix bridge with a span of approximately 15 metres (approximately 11tons) was used as model. The environmental impact for the retaining wall using each of the background databases (EconInvent 3.9.1, MLC, and EPD) are determined for all EN15804:2012+A2:2019 impact indicators The EPD for cross laminated timber was used, all other materials and processes in the life cycle (such as energy consumption at the asphalt plant and the impact of aggregate production and transport) in the analysis EPD were taken from the EcoInvent database. Detailed information on the modelling and results can be found in Appendix E.

Climate Change impact indicator

The results of the different background databases for the Climate Change impact indicator are compared in per life cycle module Figure 7.

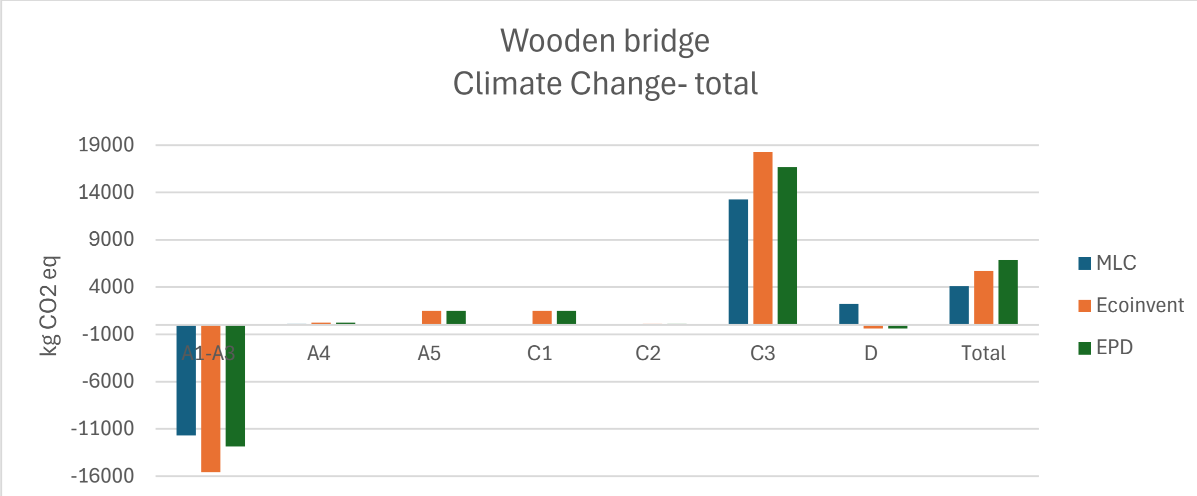


Figure 7, Climate Change impact based on the different background databases for the wooden bridge.

The MLC database resulted in a lower CO_2-eq emission in almost all modules, resulting in a significant lower total emission of 4096 kg CO_2-eq compared to 5725 kg CO_2-eq and 6863 kg CO_2-eq, respectively for EcoInvent and EPD.

Differences per impact indicator
As the impact indicators each have their own united it is only possible to compare the results for each factor separately. The difference between the impact indicators for the three background databases is depicted as factor of the lowest (positive) result in Figure 8.

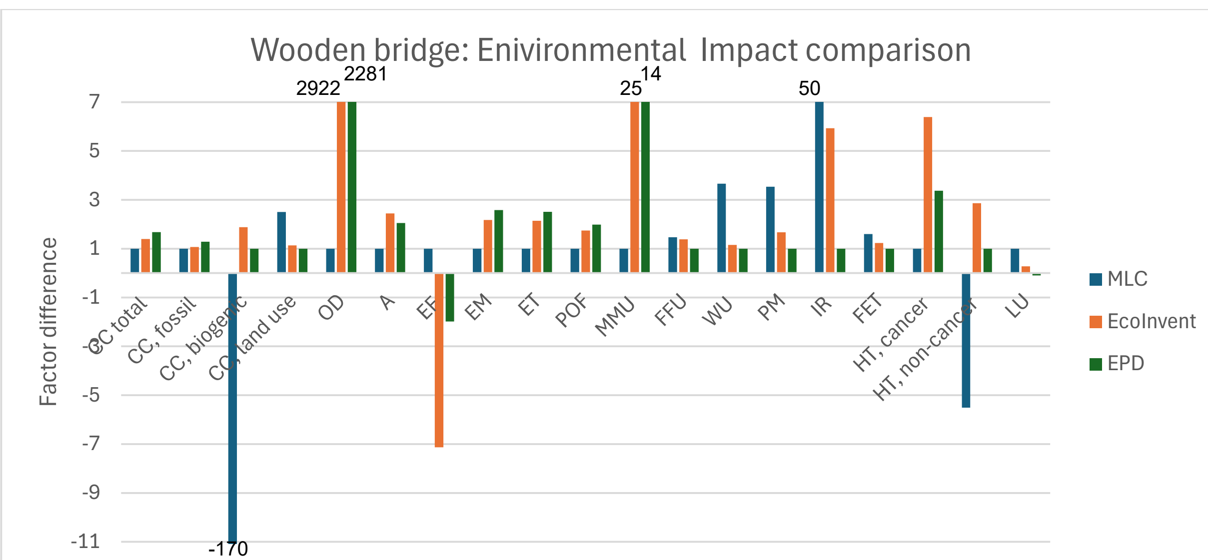


Figure 8, Environmental impact indicators based on the different background databases for the wooden bridge.

For all impact indicators there are found differences between all three databases, this difference ranges between a factor of almost three thousand (OD) and a one hundred and seventy decrease ($CC_{biogenic}$). The negative scores for $CC_{biogenic}$, EF, HT results are due to lack of correction. The factor difference between the MLC results and the EcoInvent and the EPD for the CC impact indicator is respectively 1,4 and 1,7.
Again, no consistent pattern can be found between the environmental indicators. MLC results in the lowest indicator on EM or CC total, but the highest indicators for CC land use, WU and PM. EcoInvent results in the lowest indicators for CC fossil, but the highest indicators for OD, MMU and HT. Using cross laminated timber

EPD results in the lowest indicators for CC_{land} use, FFU, IR and FET, but the highest indicators for EM, ET and POF. The variation between EcoInvent and EPD could be much greater if also EPDs for other materials and processes were used.

4.5. Global Warming Potential

For some Environmental performance assessments, like the Energy Performance of Buildings Directive (EPBD-VI) and the Corporate Sustainability Reporting Directive (CSRD), a grand total for all declared life cycle modules (cradle-to-grave; A1-C excluding D) must be declared. Here module D is reported separately as it does not directly impact the product's life cycle but represents benefits and loads beyond the system boundary like reuse and energy recovery. In figure 9 the Climate $Change_{total}$ impact indicator for each product is depicted as a total for all modules except module D.

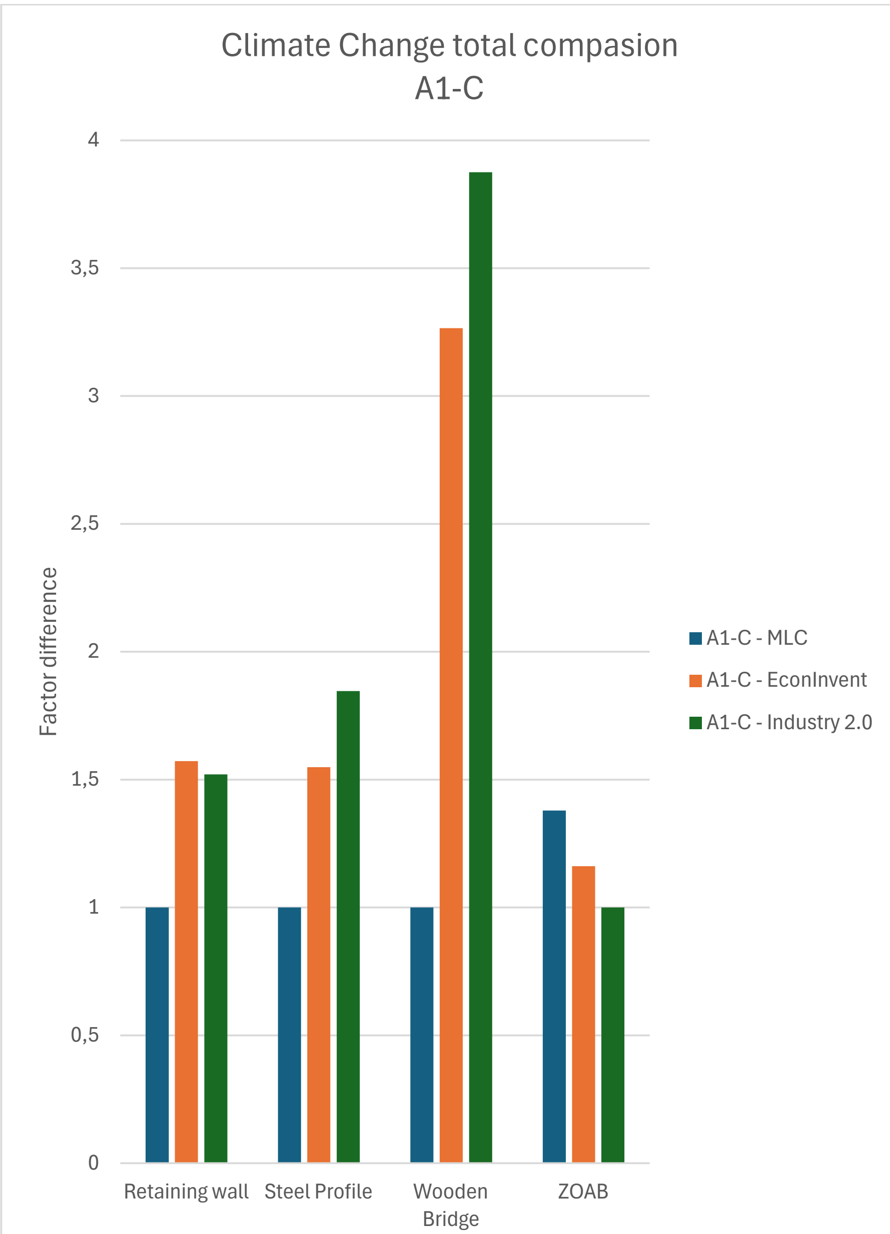


Figure 9, Overview differences for Climate Change for all products for all modules (A1-C).

As indicated in figure 9, Climate Change$_{total}$ impact differences between all databases and across all products. Differences vary between the environmental indicator from a factor 1,2 to 3,9. For three products the MLC database results in the lowest impact score for CC$_{total}$, whereas for ZAOB, the Eurobitume databases has the lowest impact score. .For two products the Industry2.0 database resulted in the highest impact score however for the retaining wall and ZOAB the other databases resulted in the highest scores, respectively EcoInvent and MLC.

When all modules (A1-D0 are considered the Global Warming Potential (Climate Change$_{total}$ impact indicator) differences were observed between all databases and across all products Figure 10.

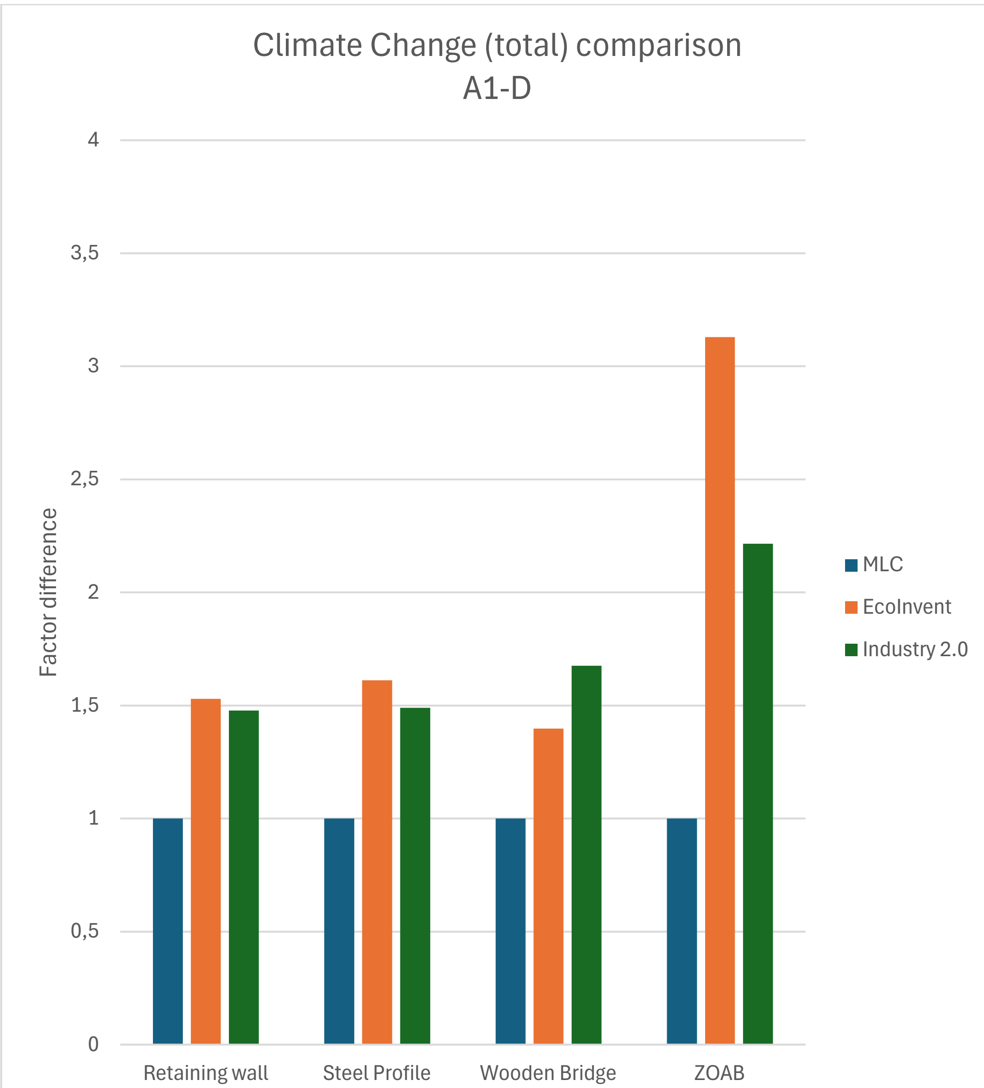


Figure 10, Overview differences for Climate Change for all products for all modules (A1-D).

Differences vary between the environmental impact from a factor 1,5 to 3,1. Although this varies for other impact indicators the Climate Change impact based on the MLC database consistently yielded the lowest total CO_2-equivalent emissions across all products examined. Including module D, which might have eighter positive or negative effect on the total impact score for an impact indicator, does not change the overall effects found in that differences were found for all products, although the factor difference changed.

4.6. LCA based Green procurement

LCA based green procurement can be a powerful tool for reduction of environmental impact. A large national road authority has estimated that the environmental impact indicator CC_{total} of for top layers asphalt has been reduced in the last 10 years between 20% and 40% as a result of green procurement.
The experience in LCA based green procurement is that the differences in environmental impact are relatively small between competing bids and estimated to be less than 10%. Still that small difference is often deciding which contractor is winning the bid. The difference in impact score found caused by the different background databases, as low as a factor 1,2, are significantly larger, which impairs green procurement.

5. Conclusions

The revised Construction Products Regulation (CPR 2024/3110), effective from January 2025, aims to establish a transparent and harmonised European market for construction products while promoting sustainability. The CPR provides for harmonised product standards and recording performance uniformly, including the environmental impact using the LCA standard EN 15804.
The CPR, however, does not designate a specific background database. The draft CPR decision states that all LCI (life Cycle Inventory) databases that comply with EN15941 (data quality standard) are suitable for calculating the environmental performance for the Declaration of Performance (DoP).

In this study the effects of different Life Cycle Inventory (LCI) databases on the environmental impact are determined and evaluated for four widely used construction products among the first product groups subjected to the CPR Technical Acquis Process. The LCI databases used contain datasets aligned to EN15941:2024 and therefore might be used conform the PCR. The background databases that were used in the study are EcoInvent 3.9, MLC (Sphera, formerly GaBi database) and Industry data 2.0 (World Steel, CEMbureau, Ecoplatform, Eurobitume).

This research clearly indicates that different background datasets can result in different environmental indicators and EPD's, as differences were found in all the EN15804:2012+A2:2019 factors when comparing the environmental indicators, for the same product, based on different databases. The differences for the environmental indicators vary in most cases between 1,5 and 3 up to a factor 10.000 for the same product. No consistent pattern could be identified in which one database systematically produced higher or lower impact scores across all environmental indicators. For example, the POF-impact indicator for the steel profile based on Worldsteel is a factor 7 higher as based on MLC whereas for ZOAB the Eurobitume results in a factor 176 lower compared to the MLC impact. For the Industry 2.0 database only one dataset was replaced, comparable with the use of an EPD. Still significant differences were found for all impact indicators.

These large variations in the environmental impact profile due to the background databases has impact on the usability of the Environmental Indicators. Firstly, it makes a clear comparison between construction products complicated. Which is hampering the possibility to create a business case for green building products. And secondly, it prevents the possibility of imposing unambiguous requirements on construction products or built structures following EPBD IV (the WLC-GWP) or other environmental requirements in legislation or in Green Procurement.

The absence of a discernible pattern across databases makes it impossible to apply uniform corrections. Environmental Indicators are only valid for comparative analysis or construction calculations if they are based on the same background database, highlighting the urgent need for harmonisation of databases.

6. Sources

Reference list:

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[3] NMD, „PRoduct Catagory Rules voor bitumineuze materialen in verkeersdragers en waterwerken in Nederladn ("PCR Asfalt") versie 2.0," 2022.

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[5] NMD, „LCA Rapportage Categorie 3 data Nationale Milieudatabase. Perron spoor," 2020.

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[11] CEN, *NEN-EN 15804:2012+A2:2019 en Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products,* 2019.

[12] ISO, *ISO 14040:2006 Environmental management — Life cycle assessment — Principles and framework,* 2006.

[13] ISO, *ISO 14044:2006 Environmental management - Life cycle assessment - Requirements and guidelines,* 2006.

[14] W. Associantion, „Worldsteel LCA eco-profile Europe Sections -other," 2022.

[15] A. e. a. Takano, „Compairson of lif cycle assessment databases: A case sudy on building assessment.," *Build. Environ. ,* vol. 79, pp. 20-30, 2014.

Appendix A.

Impact indicators EN15804:2012+A2:2019	Abbreviation
Climate Change - total [kg CO2 eq.]	CC total
Climate Change, fossil [kg CO2 eq.]	CC, fossil
Climate Change, biogenic [kg CO2 eq.]	CC, biogenic
Climate Change, land use and land use change [kg CO2 eq.]	CC, land use
Ozone depletion [kg CFC-11 eq.]	OD
Acidification [Mole of H+ eq.]	A
Eutrophication, freshwater [kg P eq.]	EF
Eutrophication, marine [kg N eq.]	EM
Eutrophication, terrestrial [Mole of N eq.]	ET
Photochemical ozone formation, human health [kg NMVOC eq.]	POF
Resource use, mineral and metals [kg Sb eq.]	MMU
Resource use, fossils [MJ]	FFU
Water use [m^3 world equiv.]	WU
Particulate matter [Disease incidences]	PM
Ionising radiation, human health [kBq U235 eq.]	IR
Ecotoxicity, freshwater [CTUe]	FET
Human toxicity, cancer [CTUh]	HT, cancer
Human toxicity, non-cancer [CTUh]	HT, non-cancer
Land Use [Pt]	LU

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Appendix B. Steel construction profile

6.1. Decomposition model steel profile for EcoInvent

The guidelines for this study on construction steel are based on the LCA Rapportage categorie 3 data Nationale Milieudatabase, Hoofdstuk 43 Staalconstructies: Dragende staalconstructies voor GWW (profielen en plaatstaal) [1] The Cat 3 Chapter 43 document is set up to supplement and improve the category 3 product cards in the National Environmental Database (NMD) by justification for choices made in materials and environmental data for heavier construction profiles as part of steel constructions 'Steel structures' concerns the collection of steel structures that have a constructive function for civil engineering, road construction and hydraulic engineering, including bridges. This concerns the entirety of the materials required for the construction of structures or bridges such as girders, beams and columns made of steel including attachments, connections and anchorages. However, this report only considers steel profiles and composite structures made of sheet steel. The steel construction profiles are modelled without surface treatment (bare steel). Based on profile the surface area the amount of surface treatment was determined. The H-profile steel (H-beam) is a steel beam in which an H can be read in cross-section. These are often used as a girder or as a column in a construction.

Reference Unit steel profile

The functional unit of the product is 1 kg of steel construction profile (100 kg/m (0,014 m2/kg)) with a lifespan of 100 years, this lifespan is equal to the design lifespan of bridges.

Stages of the life cycle and system boundaries steel profile

The processes that are examined within the LCA are demarcated with so-called system boundaries. The system boundaries determine which phases and processes of the life cycle are included in the LCA. Tabel 1, which follows from EN 15804 and the Determination Method, specifies which information must be considered per life cycle module. In this LCA, the environmental impact over the entire life cycle is included, except for the use module. As the rusting of the material is considered insignificant. The steel structures are almost always provided with a corrosion-resistant surface treatment (often a coating). Any side effects of surface treatment of the steel structures fall outside the scope of these products.

*Table 2, **System boundaries steel profile according to the EN 15804+A2** (X = declared; ND = Not Declared)*

Product			Construction		Use							End of life				Beyond system boundary
Raw material supply	Transport	Manufacturing	Transport	Construction - Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction demolition	Transport	Waste processing	Disposal	Reuse, recovery, recycling potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	X	X	ND	ND	ND	ND	ND	ND	ND	X	X	X	X	X

Decomposition in materials and process steel profile

Production module (A1-3)
- Steel construction profiles are produced from hot-rolled construction steel.
– 1 kg of construction steel has been used as a reference product for the different variants. The selected Environmental Product Declaration (EPD) is the most representative for the Dutch market, this includes any transport.

Transport to construction site (A4)
- For the transport distances (A4) for profiles the average transport distance from European manufacturers of construction steel is used. For this purpose, use was made of scenario information available from the category 2 basic profiles that have been drawn up for various steel semi-finished products on behalf of the Steel Federation. For hot-rolled construction profiles, this concerns a distance of 470 km (heavy freight traffic).

Construction process (A5)
- The installation and assembly of the construction profiles (A5) is carried out using a hoisting machine and welding equipment. A conservative scenario was chosen in which 30 litres of diesel per hour and the placement of 2 tonnes of steel per hour were assumed. This is comparable to moving different materials of the same mass with construction equipment (excavator). For welding, 4 metres of welding per hour and 1/156 m1 of welding per kg were assumed. This brings the total welding time to 0.0016 hours per kg of construction steel. The energy supply on site is provided by a diesel-powered generator. The welding speed is also a conservative estimate based on public sources.

Use module (B1-B5)
As indicated, rusting of the material is considered insignificant, because the material is often provided with a protective surface treatment. The surface treatment is not part of this product card. Because there is variation in this, it must be calculated separately using the supplied scaling formula and available product cards. Any maintenance of the surface treatment of the steel structures is also not part of the product card. The lifespan is set at 100 years.

Demolition and processing module (C1-C4)
The following table shows the relevant end-of-life scenario per variant. These are based on the standard values for end-of-life processing scenarios. This improves comparable processing between the different models.

Table 3, End-of-life scenarios, Steel profile

Product	Landfill	Recycling	Re-use
Steel profile	1%	94%	5%

Surface treatment hot dip galvanization

The lifespan of the zinc layer in the cat.3. report H56 [2] is specified as between 20 and 35 years. The end-of-life of the zinc layer is modelled in accordance with cat. 3. Report H56 preservation works. However, it is not realistic that the zinc layer is replaced on a construction profile. Therefore, no replacements of the zinc layer have been modelled. For this reason, the layer thickness has been conservatively estimated at 130um. No benefits (module D) have been calculated for saving zinc when reusing the construction profiles, but for the share that is recycled.
Synthesis steel profile

Short description: Construction profile consisting of steel and zinc preservation.
Application in the work: Construction application in civil engineering
Functional unit: kg
Lifespan: 100 years,
Surface area for coating: 1, 822 m2 of preservation

Process tree steel profile.

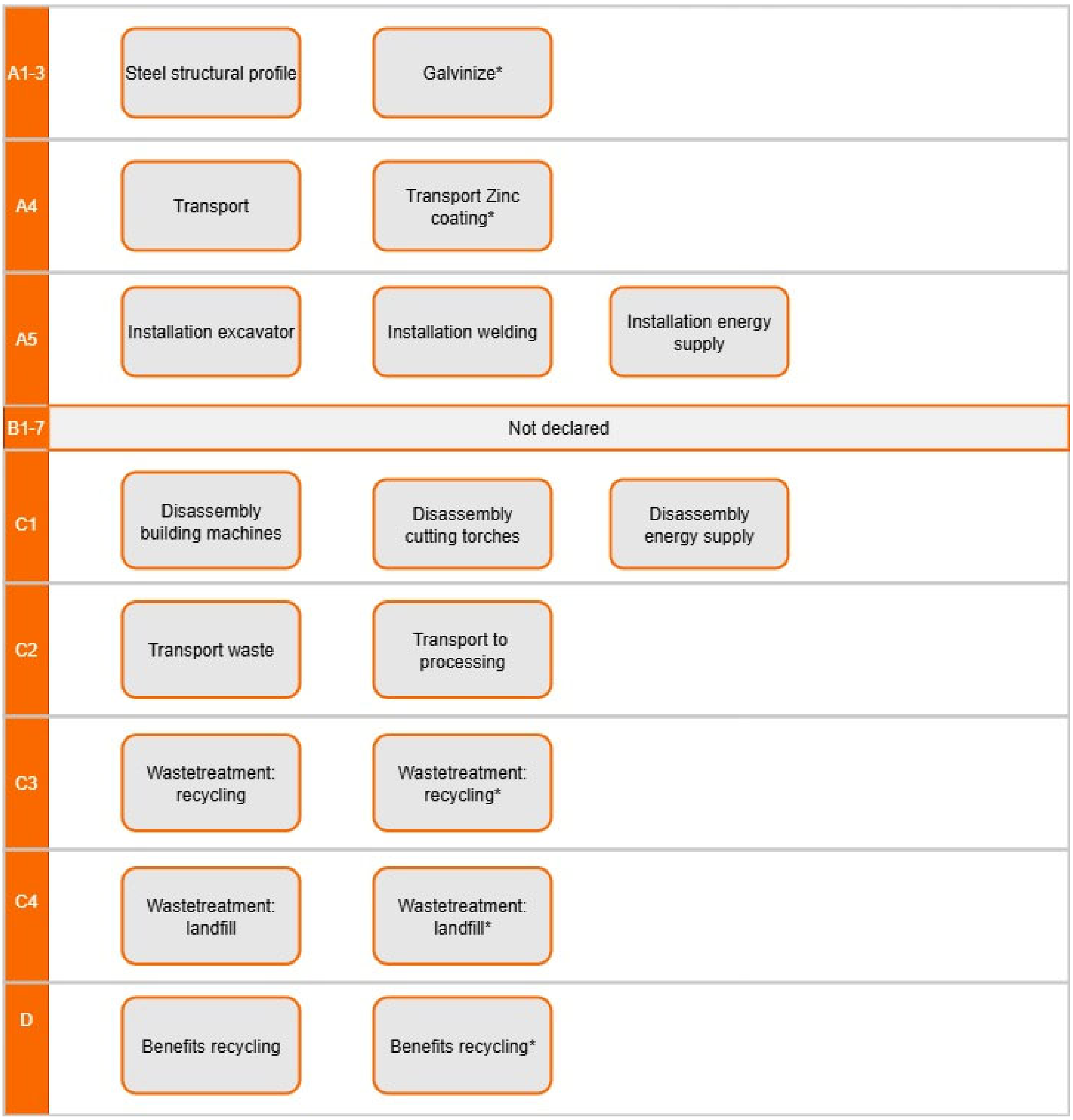


Figure 10, Decomposition model steel profile.

Datasets from EcoInvent
Based on the process tree for the steel profile, the EcoInvent database is searched to identify the environmental profiles for the corresponding materials and processes. This chapter shows which datasets are used in the different life-modules.

A1-3 Production

This module includes everything needed to procure the raw materials needed in the production of the profile. This includes extraction, treatment, processing, electricity and heat consumption. The raw materials included are shown in Table 4.

Table 4, Datasets EcoInvent used for A1-A3, steel profile.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Production Steel profile	A1	Steel structural profiles {RER}	EcoInvent 3.9.1	0,28635	kg
		Steel, unalloyed {RER}|steel production, converter, unalloyed | Cut-off, U	EcoInvent 3.9.1	0,0317	kg/ kg Steel structural profiles {RER}
		Steel, low-alloyed {Europe without Switzerland and Austria}| steel production, electric, low-alloyed | Cut-off, U	EcoInvent 3.9.1	0,9683	kg/ kg Steel structural profiles {RER}
		Section bar rolling, steel {RER}| section bar rolling, steel | Cut-off, U	EcoInvent 3.9.1	1	kg/ kg Steel structural profiles {RER}
Production Steel profile	A1	Steel structural profiles {RoW}	EcoInvent 3.9.1	0,71365	kg
		Steel, unalloyed {RoW}|steel production, converter, unalloyed | Cut-off, U	EcoInvent 3.9.1	0,0317	kg/ kg Steel structural profiles {RoW}
		Steel, low-alloyed {RoW}| steel production, electric, low-alloyed | Cut-off, U	EcoInvent 3.9.1	0,9683	kg/ kg Steel structural profiles {RoW}
		Section bar rolling, steel {RoW}| processing | Cut-off, U	EcoInvent 3.9.1	1	kg/ kg Steel structural profiles {RoW}
Galvinize	A1-A3	Zinc coat, pieces, adjustment per micro-m {GLO}| market for zinc coat, pieces, adjustment per micro-m | Cut-off, U	EcoInvent 3.9.1	1,822	m^2

A4 Transport to construction site

The default distance for transport to the construction site is 470 km using heavy transport.

Table 5, Datasets EcoInvent used for A4, steel profile.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Transport	A4	Transport, freight, lorry, unspecified {GLO}| market group for transport, freight, lorry, unspecified | Cut-off, U	EcoInvent 3.9.1	0,47	tkm
Transport zinc coating	A4	Transport, freight, lorry, unspecified {GLO}| market group for transport, freight, lorry, unspecified | Cut-off, U	EcoInvent 3.9.1	1,96E-03	tkm

A5 Construction process

This module is included the installation of the construction.

Table 6, Datasets EcoInvent used for Aa, steel profile.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Installation: excavator	A5	Diesel, burned in building machine {GLO}| market for diesel, burned in building machine | Cut-off, U (35,9 MJ/L)	EcoInvent 3.9.1	0,015	l
Installation: welding	A5	Welding, arc, steel {GLO}| market for welding, arc, steel | Cut-off, U	EcoInvent 3.9.1	0,00641	m
Installation: energy supply	A5	Diesel, burned in building machine {GLO}| market for diesel, burned in building machine | Cut-off, U (2140 MJ/h)	EcoInvent 3.9.1	0,0016025	h

B Use

The steel profile has a reference service lifetime of 100 years minimum during the application period, no maintenance is normally required. The steel profiles are coated with a zinc layer of 130 μm thickness. The zinc layer has a lifespan of 20 to 30 years; however, it is not possible to replace it on an installed construction profile. For this reason, no replacements for the zinc coat were modelled.

C1 Demolition

Table 7, Datasets EcoInvent used for C1, steel profile.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Disassembly/Demolitio n	C1	Diesel, burned in building machine {GLO}| market for diesel, burned in building machine | Cut-off, U (35,9 MJ/l)	EcoInvent 3.9.1	0,015	l
Disassembly/Demolitio n: cutting torches	C1	Welding, arc, steel {GLO}| market for welding, arc, steel | Cut-off, U	EcoInvent 3.9.1	0,00641	m
Demontage/Demolitio n: energy supply	C1	Diesel, burned in building machine {GLO}| market for diesel, burned in building machine | Cut-off, U (2140 MJ/h)	EcoInvent 3.9.1	0,0016	h

C2 Transport to waste processing facilities or disposal site

Table 8, Datasets EcoInvent used for C2, steel profile.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Transport: waste	C2	Transport, freight, lorry, unspecified {GLO}| market group for transport, freight, lorry, unspecified | Cut-off, U	EcoInvent 3.9.1	0,05	tkm
Transport to processing (Zinc)	C2	Transport, freight, lorry, unspecified {GLO}| market group for transport, freight, lorry, unspecified | Cut-off, U	EcoInvent 3.9.1	6,54E-04	tkm

C3 Waste processing

Table 9, Datasets used for C3, steel profile.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Recycling	C3	Iron scrap, sorted, pressed {RER}| sorting and pressing of iron scrap | Cut-off, U	EcoInvent 3.9.1	0,94	kg
Waste treatment recycling	C3	Iron scrap, sorted, pressed {RER}| sorting and pressing of iron scrap | Cut-off, U	EcoInvent 3.9.1	3,07E-03	kg

C4 Disposal site

Part of the released waste material is disposed of at a landfill.

Table 10, Datasets EcoInvent used for C4, steel profile.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Waste treatment: landfill	C4	Scrap steel {Europe without Switzerland}| treatment of scrap steel, inert material landfill | Cut-off, U	EcoInvent 3.9.1	0,01	kg
Waste treatment: landfill (zinc)	C4	Scrap tin sheet {CH}| treatment of scrap tin sheet, sanitary landfill | Cut-off, U	EcoInvent 3.9.1	3,27E-05	kg

Module D

Tabel 1 contain the data used for module D. shows the amount of material recovery per kg of recycled product, which is based on the amount of secondary steel.

Table 11, Datasets EcoInvent used for D, steel profile.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Benefits Recycling	D	Recycling steel		0,032	kg
		Steel, unalloyed {RoW}| steel production, converter, unalloyed | Cut-off, U	EcoInvent 3.9.1	-0,94634586	kg/ kg recycling steel
		Steel, unalloyed {RER}| steel production, converter, unalloyed | Cut-off, U	EcoInvent 3.9.1	-0,17405414	kg/ kg recycling steel
		Steel, low-alloyed {Europe without Switzerland and Austria}| steel production, electric, low-alloyed | Cut-off, U	EcoInvent 3.9.1	0,17405414	kg/ kg recycling steel
		Steel, low-alloyed {RoW}| steel production, electric, low-alloyed | Cut-off, U	EcoInvent 3.9.1	0,94634586	kg/ kg recycling steel
		Ferrosilicon {GLO}| market for ferrosilicon | Cut-off, U	EcoInvent 3.9.1	-0,00687736	kg/ kg recycling steel
		Ferromanganese, high-coal, 74.5% Mn {GLO}| market for ferromanganese, high-coal, 74.5% Mn | Cut-off, U	EcoInvent 3.9.1	-0,00902062	kg/ kg recycling steel
		Ferrochromium, high-carbon, 68% Cr {GLO}| market for ferrochromium, high-carbon, 68% Cr | Cut-off, U	EcoInvent 3.9.1	-0,00060983	kg/ kg recycling steel
		Pig iron {RoW}| market for pig iron | Cut-off, U	EcoInvent 3.9.1	-0,1355165	kg/ kg recycling steel
Benefits Recycling (zinc)	D	Benefits Recycling		1,23E-02	kg
		Zinc concentrate {GLO}| market for zinc concentrate | Cut-off, U	EcoInvent 3.9.1	0,68	kg/ kg Benefits recycling
		Zinc oxide {RER}| zinc oxide production | Cut-off, U	EcoInvent 3.9.1	8,47E-01	kg/ kg Benefits recycling

Calculation procedures

- The environmental interventions have been determined using the methods described in the Determination Method. The LCA calculations are performed in accordance with EN 15804:2012+A2:2019;
- When calculating the energy flows, the fuels and electricity sources used, extraction and transport of the fuels, efficiency of the conversion and distribution of the energy flow are taken into account. The calorific net value (LHV) has also been calculated.
- The rules for allocation for multi-input, -output, recycling and reuse processes from the Assessment Method have been followed for all materials.
- EcoInvent processes are calculated including the infrastructure processes (capital goods)
- EcoInvent processes for landfill are calculated excluding long-term emissions.

6.1.1. Results LCA for the steel profile using EcoInvent

This paragraph presents the results of the LCA. These are set out in section the environmental profile below for the parameters A2 for the environmental impact united.

Table 12, Environmental profile, EcoInvent, steel profile

EcoInvent	A1-A3	A4	A5	C1	C2	C3	C4	D	Total
CC total [kg CO2 eq.]	1,43E+00	7,03E-02	3,95E-01	3,95E-01	7,55E-03	2,45E-02	6,12E-05	-2,42E-02	2,30E+00
CC, fossil [kg CO2 eq.]	1,42E+00	7,01E-02	3,95E-01	3,94E-01	7,52E-03	2,44E-02	6,11E-05	-2,43E-02	2,29E+00
CC, biogenic [kg CO2 eq.]	3,49E-03	2,28E-05	5,67E-05	5,67E-05	2,45E-06	7,34E-05	2,71E-08	6,74E-05	3,77E-03
CC, land use [kg CO2 eq.]	5,69E-03	2,50E-04	4,58E-05	4,57E-05	2,68E-05	3,58E-05	3,68E-08	6,29E-06	6,10E-03
OD [kg CFC-11 eq.]	1,88E-08	1,25E-09	6,28E-09	6,27E-09	1,34E-10	3,88E-10	1,77E-12	-8,60E-10	3,22E-08
A [Mole of H+ eq.]	6,66E-03	3,35E-04	3,65E-03	3,65E-03	3,60E-05	2,74E-04	4,60E-07	-1,04E-04	1,45E-02
EF [kg P eq.]	1,93E-04	6,97E-07	1,49E-06	1,49E-06	7,48E-08	1,12E-06	5,96E-10	1,82E-06	2,00E-04
EM [kg N eq.]	1,52E-03	1,27E-04	1,69E-03	1,69E-03	1,37E-05	6,24E-05	1,76E-07	-1,98E-05	5,09E-03
ET [Mole of N eq.]	1,47E-02	1,36E-03	1,84E-02	1,84E-02	1,46E-04	7,13E-04	1,89E-06	-3,34E-04	5,34E-02
POF [kg NMVOC eq.]	5,52E-03	4,64E-04	5,45E-03	5,44E-03	4,98E-05	2,13E-04	6,60E-07	-2,04E-04	1,69E-02
MMU [kg Sb eq.]	4,79E-05	2,19E-07	1,44E-07	1,44E-07	2,35E-08	1,51E-06	8,52E-11	-9,04E-06	4,09E-05
FFU [MJ]	1,58E+01	1,00E+00	5,17E+00	5,16E+00	1,08E-01	3,31E-01	1,52E-03	-1,72E-01	2,74E+01
WU [m³ world equiv.]	-1,97E-01	5,48E-03	1,16E-02	1,16E-02	5,88E-04	4,02E-03	6,69E-05	-4,00E-02	-2,04E-01
PM [Disease incidences]	1,28E-07	6,92E-09	1,02E-07	1,02E-07	7,42E-10	3,75E-09	1,01E-11	-2,76E-09	3,41E-07
IR [kBq U235 eq.]	4,21E-02	3,91E-04	1,10E-03	1,10E-03	4,20E-05	8,82E-04	4,12E-07	6,30E-04	4,62E-02
FET[CTUe]	2,69E+01	7,40E-01	2,47E+00	2,47E+00	7,95E-02	2,60E-01	9,90E-04	-2,22E+00	3,07E+01
HT, cancer [CTUh]	2,43E-08	3,71E-11	1,28E-10	1,28E-10	3,98E-12	3,73E-11	2,62E-14	2,46E-10	2,49E-08
HT, non-cancer [CTUh]	8,78E-08	8,06E-10	8,60E-10	8,58E-10	8,65E-11	1,68E-09	3,51E-13	1,41E-09	9,35E-08
LU [Pt]	4,84E+00	7,92E-01	3,51E-01	3,50E-01	8,50E-02	5,88E-01	3,03E-03	-1,06E-01	6,91E+00

6.2. Decomposition model steel profile for MLC

As the MLC database is not compatible with the Simapro software the modelling and calculation are done in the Sphera software. This requires some adjustments to the dissemination model, however system boundaries, life cycle stages are made however specifications indicated in the cat 3 data [1] are adopted as closely as possible. With the Sphera software the process for the steel profile and galvanization are modelled separately

Process trees

Using Sphera the existing dissemination model was rebuilt as closely as possible. However, in some cases a one-to-one implementation was not feasible, or modelling within LCA FE/Sphera is typically conducted differently. For example, the transport is in EcoInvent datasets are set in ton/km whereas in the MLC databased a model, based on different datasets for the specific truck, fuel and load, has to be developed to obtain the same united.
The developed model for the steel profile is shown in and for galvanization is shown in Figure 12.

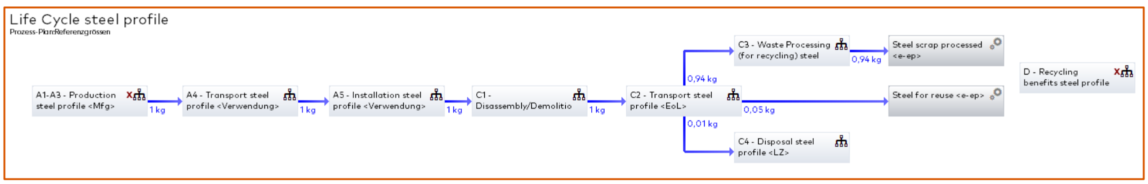


Figure 11, MLC model steel profile.

In these cases, the differences in the modelling approach are explained in the following sections for steel profile and galvanization; 4.4.1 and 4.4.2 respectively.

A1-3: Production

As there is no dataset for steel profiles in EcoInvent, therefor this was manually modelled a typical steel profile using steel production datasets and an additional rolling process.
In contrast, the MLC 2025 Core database provides two datasets for steel profiles – one for Europe and one for the global region – in which the steel production via BF and EAF and the rolling process is already integrated.

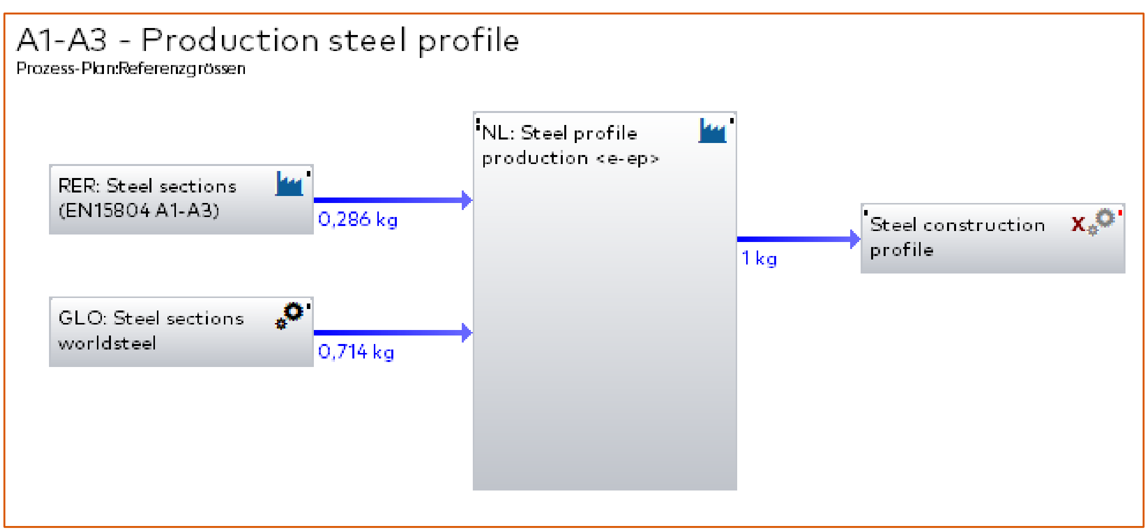


Figure 12, MLC model A1-A3, steel profile.

To be as close to the decomposition model as possible, the production mix, here the proportion of steel from Europe (RER) and Rest of World (RoW) regions were incorporated into the modelling.
The datasets used in this module are shown in Table 13.

Table 13, MLC datasets A1-A3, steel profile

MLC dataset	Weighting
RER: Steel sections (EN15804 A1-A3)	28.635 %
GLO: Steel sections	71.365 %

A4: Transport

The transport dataset selected by SGS covers 'a fleet average that includes different lorry classes as well as EURO classes'.
As steel transport is a heavy freight traffic, three corresponding MLC datasets for different truck sizes could be identified of which the middle one was selected. The open fuel input was closed using a suitable diesel process.

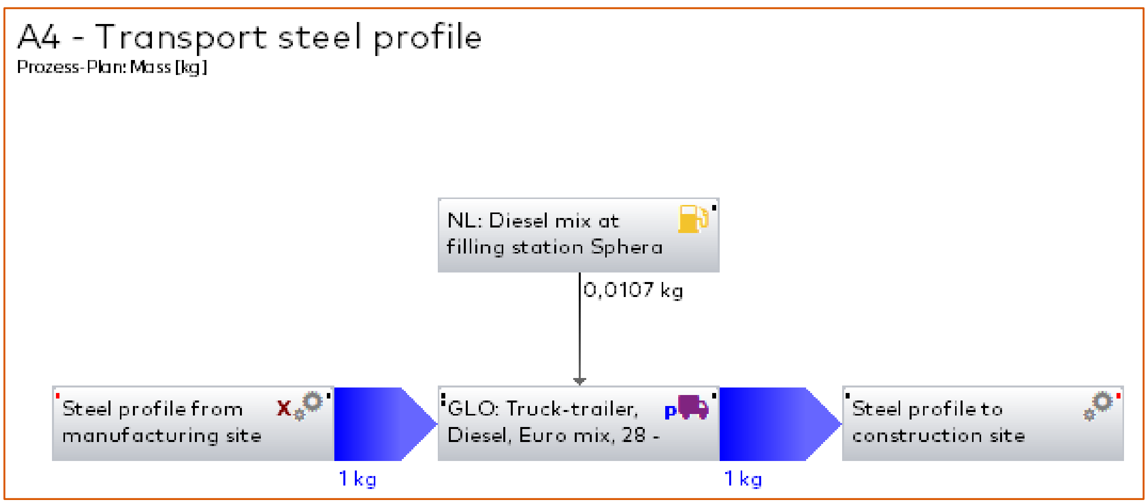


Figure 13,MLC model A4, steel profile.

The datasets used in this module are shown in Table 14.

Table 14, MLC datasets A4, steel profile

Material/process	Module	Environmental profile	Source	Quantity	Unit
Transport	A4	GLO: Truck-trailer, Diesel, Euro mix, 28 - 34t gross weight	MLC 2025	1	kg
Transport	A4	NL: Diesel mix at filling station	MLC 2025	0.0107	Kg

A5: Installation

In the dissemination model the installation process by using a welding process and a customized model for the hoisting process comparable to an excavator.

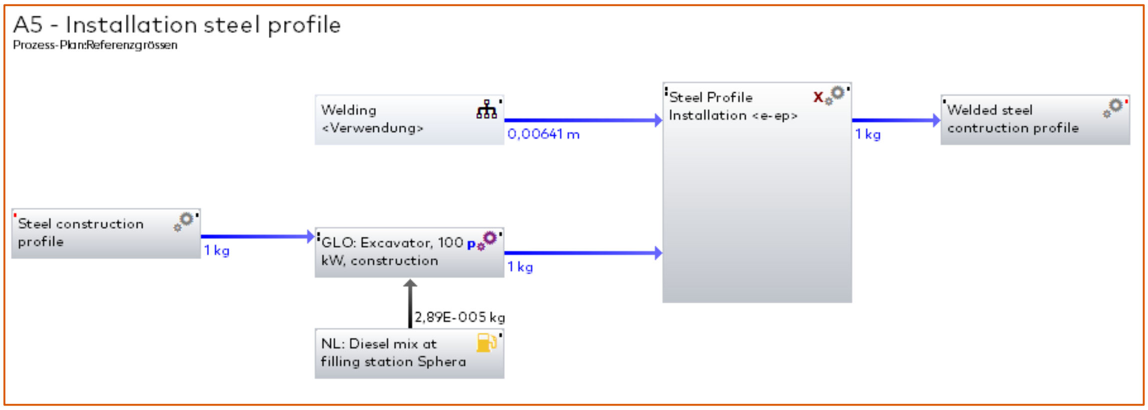


Figure 14, MLC model A5, steel profile.

Welding

The welding process in the EcoInvent dataset selected in the model refers to MAG (Metal Active Gas) welding technology and already includes the associated inputs of electricity, steel wire, argon, and carbon dioxide within the process itself.
Within the MLC 2025 Core database, a dataset was identified that corresponds to this specific welding method. To obtain the environmental impacts of the welding process, it was necessary to link the MLC welding process to relevant background datasets, namely: argon, carbon dioxide, electricity, and welding wire.

Hoisting equipment

The MLC dataset ‘excavator” is used as it best reflects the use of diesel-powered construction machinery and explicitly includes the combustion of diesel fuel. Notably, the output of this MLC dataset is the excavated material rather than burned diesel as in EcoInvent. To address this, the free parameters of the MLC process were customized based on the decomposition model.

The datasets used in this module are shown in Table 15**Fout! Verwijzingsbron niet gevonden.**.

Table 15, MLC datasets A5, steel profile

Material/process	Module	Environmental profile	Source	Quantity	Unit
Welding	A5	GLO: Steel sheet (1mm) MAG welding	MLC 2025	0,00641	m
	A5	DE: Argon (liquid)	MLC 2025	0,00641	m
	A5	DE: Carbon dioxide (CO2) by-product ammonia (NH3) (economic allocation)	MLC 2025	0,00641	m
	A5	NL: Electricity grid mix	MLC 2025	0,00641	m
	A5	RER: Steel wire rod	MLC 2025	0,00641	m
Hoisting	A5	GLO: Excavator, 100 kW, construction	MLC 2025	1	kg
	A5	NL: Diesel mix at filling station	MLC 2025	2,89E-5	kg

C1: Deconstruction

Similar to the dissemination model the same dataset and input quantities used for the installation of the steel construction profiles (Module A5) were also applied to model their disassembly in module C1.

Welding

Welded steel structures are usually cut and dismantled using cutting torches. As there is no dataset for this in MLC, the welding process used above (without the use of welding wire rod) was accepted as a substitute.

Hoisting equipment

For the dismantling process, the above mentioned *'excavator"* dataset from the MLC 2025 Core database was used.

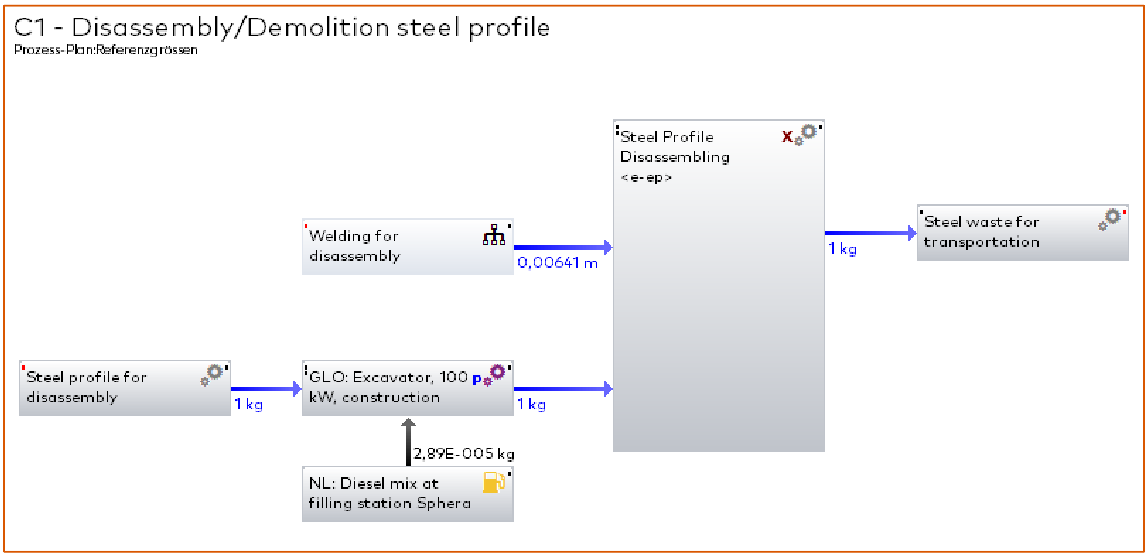


Figure 15, MLC model C1, steel profile.

Table 16, MLC datasets C1, steel profile

Material/process	Module	Environmental profile	Source	Quantity	Unit
Welding	C1	GLO: Steel sheet (1mm) MAG welding	MLC 2025	1	kg
	C1	DE: Argon (liquid)	MLC 2025	1	kg
	C1	DE: Carbon dioxide (CO_2) by-product ammonia (NH_3) (economic allocation)	MLC 2025	1	kg
	C1	NL: Electricity grid mix	MLC 2025	1	kg
Hoisting	C1	GLO: Excavator, 100 kW, construction	MLC 2025	1	kg
	C1	NL: Diesel mix at filling station	MLC 2025	2,89E-5	kg

C2: Transport

End-of-life transport was modelled using the same datasets as in module A4.

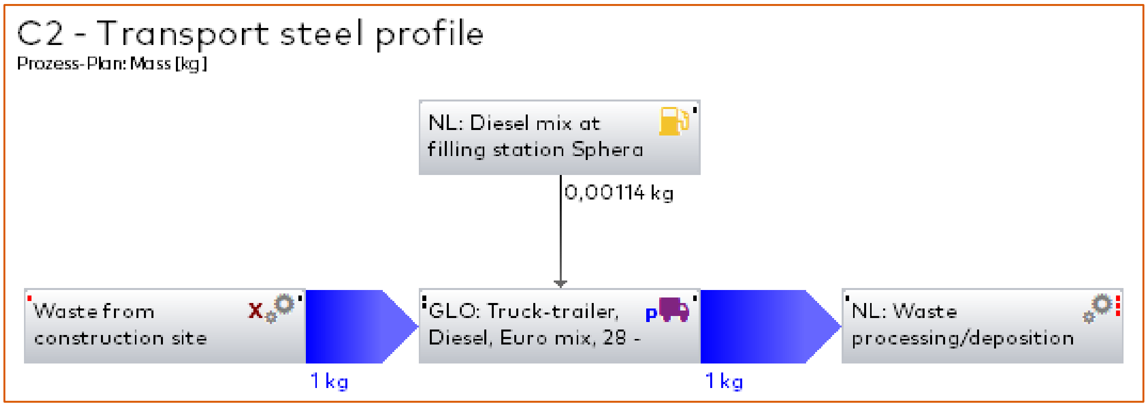


Figure 16, MLC model C2, steel profile.

Table 17, MLC datasets C2, steel profile

Material/process	Module	Environmental profile	Source	Quantity	Unit
Transport	C2	GLO: Truck-trailer, Diesel, Euro mix, 28 - 34t gross weight	MLC 2025	1	kg
Transport	C2	NL: Diesel mix at filling station	MLC 2025	0.0107	Kg

C3: Waste processing

In the MLC 2025 Core database, no suitable dataset was identified to represent the sorting and processing of steel scrap. Therefore, a custom model developed for this process based on the EcoInvent documentation.

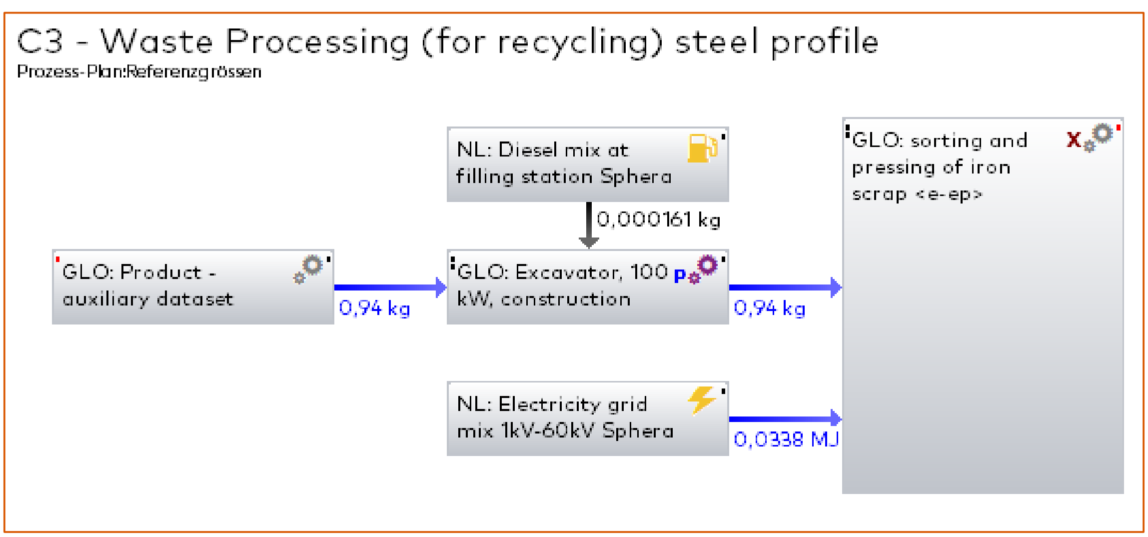


Figure 17, MLC model C3, steel profile.

Due to the limited availability of dedicated diesel-burning datasets in the MLC 2025 Core database, the 'excavator" dataset was selected. This dataset captures the emissions from diesel use in construction equipment and aligns well with the described application in the EcoInvent dataset.
The datasets used in this module are shown in Table 18.

Table 18, MLC datasets C3, steel profile

Material/process	Module	Environmental profile	Source	Quantity	Unit
	C3	GLO: Excavator, 100 kW, construction	MLC 2025	0,94	kg
	C3	NL: Electricity grid mix 1kV-60kV	MLC 2025	0,0338	MJ
	C3	NL: Diesel mix at filling station	MLC 2025	0.000161	Kg

C4: Disposal

The MLC database includes a dataset for the landfilling of ferrous metals, which has been used.

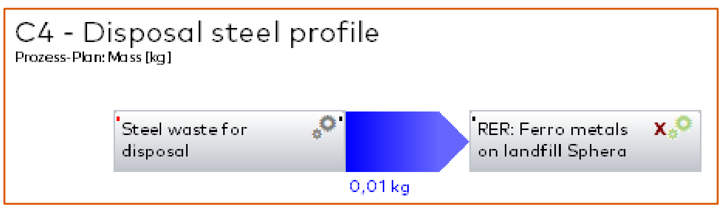


Figure 18, MLC model C4, steel profile.

Table 19, MLC datasets C4, steel profile

Material/process	Module	Environmental profile	Source	Quantity	Unit
Disposal	C4	RER: Ferro metals on landfill	MLC 2025	0,01	kg

D: Benefits beyond system boundary

The steel mix used from the MLC database contains 0.776 kg of steel scrap as secondary material. After dismantling, a total of 0.99 kg of material per kg of profile used is available for reuse and recycling – according to EcoInvent specifications, 1% of material is lost. Of the 0.99 kg steel scrap, 0.776 kg has no recycling potential. For the remaining 0.214 kg/kg, a corresponding recycling potential has been calculated. The amount of potential depends on the type of use: in the case of reuse, usually the full production of the steel section is avoided and credited accordingly. In the case of recycling by melting, the difference between the environmental impacts of primary steel production in a blast furnace (BF) and the production in an electric arc furnace (EAF) is taken into account.
Nevertheless, to remain as close as possible to the information stated by the dissemination model, in both cases the recycling potential was not determined by the delta of BF and EAF, but by the production of a low-alloy steel billet in the EAF.

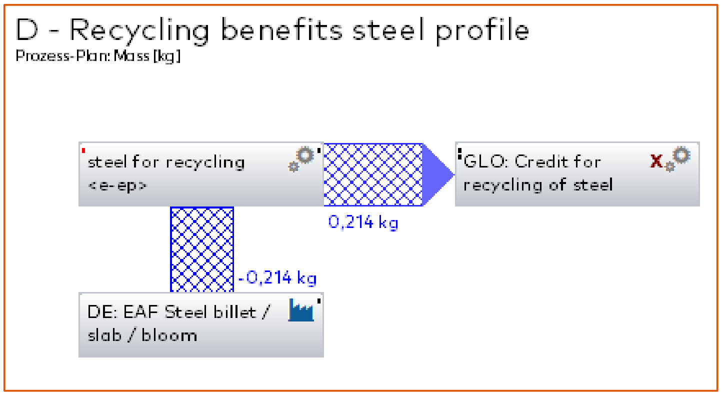


Figure 19, MLC model D, steel profile.

The datasets used in this module are shown in Table 20.

Table 20, MLC datasets D, steel profile

Material/process	Module	Environmental profile	Source	Quantity	Unit
Recycling	D	DE: EAF Steel billet / slab / bloom (low-alloyed)	MLC 2025	0,214	kg

Model for galvanization of MLC

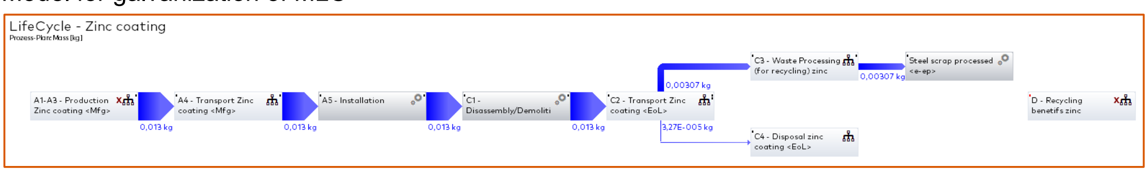


Figure 20, MLC model for galvanization.

A1-A3: Galvanisation process

Unlike EcoInvent, the MLC database used does not include datasets for the piece galvanizing of components. However, a comparable dataset could be reconstructed in all essential aspects based on the documentation of the EcoInvent dataset ‘zinc coating, pieces”.

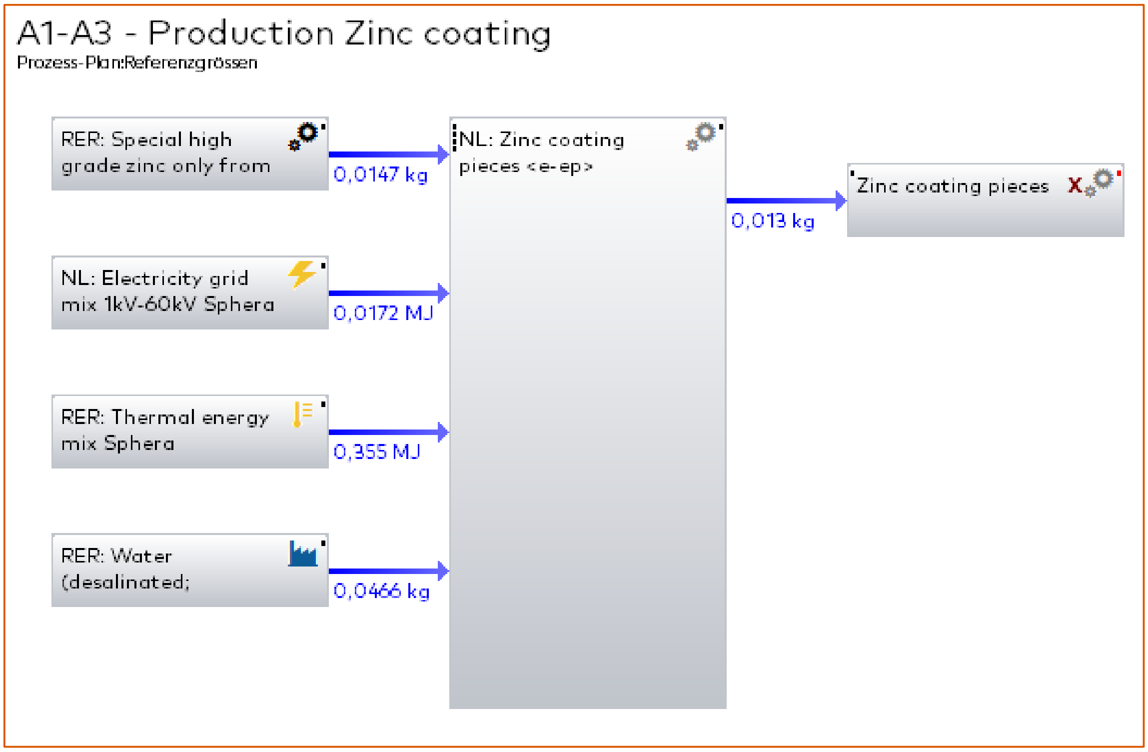


Figure 21, MLC model A1-A3, galvanization.

Table 21, MLC datasets A1-A3, Galvanization

Material/process	Module	Environmental profile	Source	Quantity	Unit
Production	A1-A3	RER: Special high-grade zinc only from Zn concentrate IZA	MLC 2025	0,0147	kg
Production	A1-A3	NL: Electricity grid mix 1kV-60kV	MLC 2025	0,0172	MJ
Production	A1-A3	RER: Thermal energy mix	MLC 2025	0,355	MJ
Production	A1-A3	RER: Water (desalinated; deionised)	MLC 2025	0,0466	Kg

A4: Transport to construction site

The transport dataset selected in the EcoInvent database covers ‘a fleet average that includes different lorry classes as well as EURO classes’.
As steel transport is a heavy freight traffic, three corresponding MLC datasets for different truck sizes could be identified of which the middle one was selected. The open fuel input was closed using a suitable diesel process.

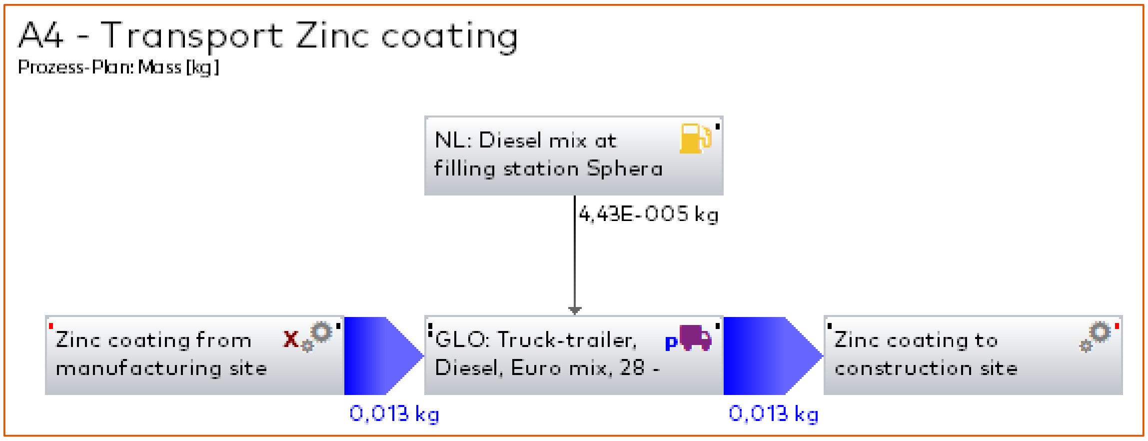


Figure 22, MLC model A4, galvanization.

Table 22, MLC datasets A4, Galvanization

Material/process	Module	Environmental profile	Source	Quantity	Unit
Transport	A4	GLO: Truck-trailer, Diesel, Euro mix, 28 - 34t gross weight	MLC 2025	0,013	kg
Transport	A4	NL: Diesel mix at filling station	MLC 2025	0,013	Kg

A5: Construction

Similar to the dissemination model no construction module was considered.

C1: Deconstruction

Similar to the EcoInvent model no deconstruction module was considered as indicated by SGS.

C2: Transport

The transport dataset selected from the EcoInvent database covers 'a fleet average that includes different lorry classes as well as EURO classes'.
As steel transport is a heavy freight traffic, three corresponding MLC datasets for different truck sizes could be identified of which the middle one was selected. The open fuel input was closed using a suitable diesel process.

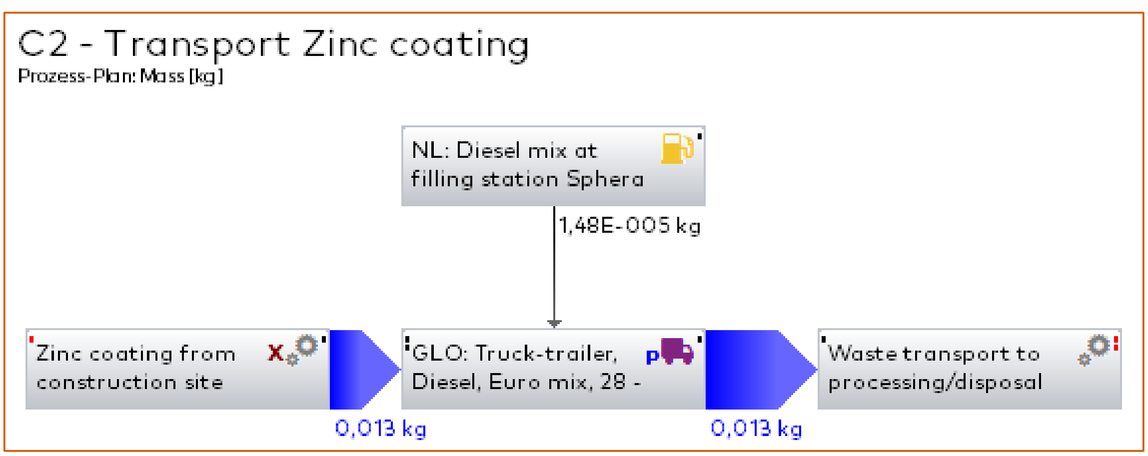


Figure 23, MLC model C2, galvanization.

Table 23, MLC datasets A4, Galvanization

Material/process	Module	Environmental profile	Source	Quantity	Unit
Transport	C2	GLO: Truck-trailer, Diesel, Euro mix, 28 - 34t gross weight	MLC 2025	0,013	kg
Transport	C2	NL: Diesel mix at filling station	MLC 2025	0,013	Kg

C3: Waste processing

In the MLC database, no suitable dataset was identified to represent the sorting and processing of steel scrap. Therefore, SDG built a custom model for this process based on the EcoInvent documentation. Due to the limited availability of dedicated diesel-burning datasets in the MLC database, the 'excavator" dataset was selected. This dataset captures the emissions from diesel use in construction equipment and aligns well with the described application in the EcoInvent dataset.

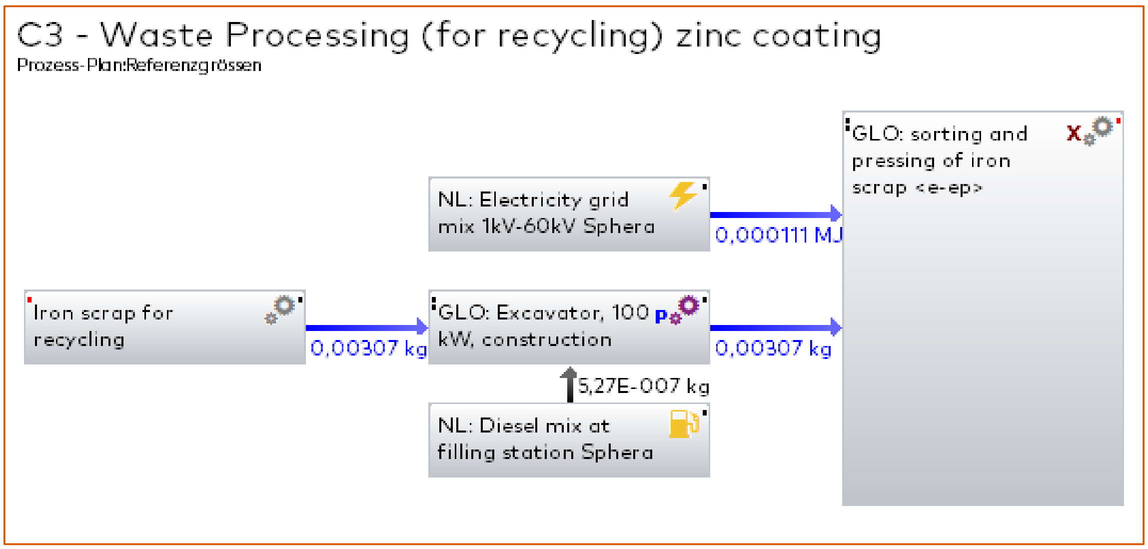


Figure 24, MLC model C3, galvanization.

C4: Disposal

In MLC 2025, no dataset is available for the disposal of galvanised materials. Therefore, the dataset 'Ferro metals on landfill' was selected as the closest possible proxy for the disposal of (galvanised) steel profiles.

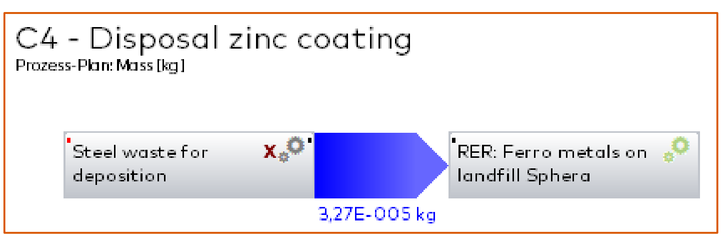


Figure 25, MLC model C4, galvanization.

Table 24, MLC datasets C4, Galvanization

Material/process	Module	Environmental profile	Source	Quantity	Unit
Disposal	C4	RER: Ferro metals on landfill	MLC 2025	3,27E-5	kg

D: Benefits beyond system boundary

SGS used the datasets ‘zinc concentrate’ and ‘zinc oxide’ to calculate the recycling potential of zinc. For the latter, no suitable dataset is available in MLC. The selected dataset shows a zinc oxide content of 13%.
Used MLC datasets:

- RER: Special high-grade zinc only from Zn concentrate
- RER: Special high-grade zinc including 13% Waelz oxide

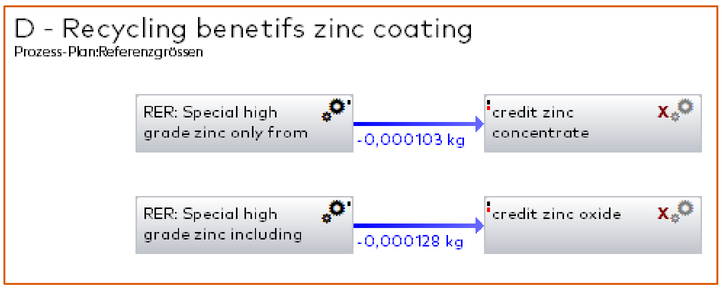


Figure 26, MLC model D, galvanization.

Table 25, MLC datasets D, Galvanization

Material/process	Module	Environmental profile	Source	Quantity	Unit
Recycling	D	RER: Special high-grade zinc only from Zn concentrate	MLC 2025	1,06E-4	kg
Recycling	D	RER: Special high-grade zinc including 13% Waelz oxide	MLC 2025	1,28E-4	kg

6.2.1. Results LCA steel profile using MLC

The results of the LCA based on MLC using the Sphera software are presented in the table below.

Table 26, Environmental impact based on MLC, steel profile.

	A1-A3	A4	A5	C1	C2	C3	C4	D	Total
CC total [kg CO2 eq.]	1,45E+00	3,85E-02	6,89E-04	3,93E-04	4,13E-03	3,95E-03	2,14E-04	-7,39E-02	1,43E+00
CC, fossil [kg CO2 eq.]	1,45E+00	3,97E-02	6,90E-04	3,93E-04	4,26E-03	3,95E-03	2,13E-04	-7,32E-02	1,43E+00
CC, biogenic [kg CO2 eq.]	1,82E-03	-1,22E-03	-1,26E-06	-1,08E-06	-1,31E-04	-1,26E-06	-3,02E-07	-6,18E-04	-1,50E-04
CC, land use [kg CO2 eq.]	3,20E-04	1,46E-06	4,13E-07	3,71E-07	1,56E-07	5,49E-06	6,70E-07	-6,07E-05	2,68E-04
OD [kg CFC-11 eq.]	4,35E-12	1,05E-14	9,76E-15	9,21E-15	1,13E-15	1,22E-13	6,91E-16	-1,44E-12	3,06E-12
A [Mole of H+ eq.]	3,14E-03	6,52E-05	2,50E-06	1,54E-06	7,00E-06	8,22E-06	1,33E-06	-2,01E-04	3,03E-03
EF [kg P eq.]	8,75E-07	9,63E-09	1,20E-09	9,37E-10	1,03E-09	1,17E-08	3,01E-10	-1,60E-07	7,40E-07
EM [kg N eq.]	7,18E-04	2,83E-05	8,42E-07	6,98E-07	3,04E-06	3,26E-06	3,24E-07	-5,27E-05	7,02E-04
ET [Mole of N eq.]	7,68E-03	3,11E-04	9,20E-06	7,71E-06	3,34E-05	3,69E-05	3,54E-06	-5,80E-04	7,50E-03
POF [kg NMVOC eq.]	2,54E-03	6,95E-05	2,36E-06	1,84E-06	7,46E-06	7,65E-06	1,01E-06	-1,91E-04	2,44E-03
MMU [kg Sb eq.]	1,87E-05	1,42E-09	-6,36E-10	7,57E-11	1,52E-10	9,84E-10	1,45E-11	-2,92E-07	1,84E-05
FFU [MJ]	1,69E+01	5,03E-01	8,94E-03	5,43E-03	5,40E-02	5,54E-02	3,49E-03	-9,38E-01	1,66E+01
WU [m³ world equiv.]	2,98E-01	5,04E-05	1,01E-04	9,52E-06	5,41E-06	1,30E-04	2,49E-05	-2,80E-03	2,96E-01
PM [Disease incidences]	1,62E-07	6,06E-10	5,82E-11	1,71E-11	6,51E-11	8,47E-11	1,53E-11	-2,77E-09	1,60E-07
IR [kBq U235 eq.]	5,42E-02	4,70E-05	3,83E-05	3,04E-05	5,04E-06	3,31E-04	6,49E-06	-6,48E-03	4,82E-02
FET[CTUe]	2,11E+00	3,24E-01	2,00E-03	1,56E-03	3,48E-02	1,01E-02	2,65E-03	-2,22E-01	2,27E+00
HT, cancer [CTUh]	1,05E-09	4,98E-12	1,70E-13	1,22E-13	5,34E-13	1,14E-12	4,49E-14	-3,01E-11	1,03E-09
HT, non-cancer [CTUh]	7,03E-09	8,08E-11	3,51E-12	2,46E-12	8,67E-12	2,99E-11	1,31E-12	-1,99E-09	5,17E-09
LU [Pt]	2,28E+00	2,86E-03	2,86E-03	2,52E-03	3,07E-04	3,28E-02	5,81E-04	-4,30E-01	1,89E+00

6.3. Decomposition model steel profile for World steel database

The World Steel Database is a comprehensive global resource that compiles detailed statistical data on the production, use, trade, and environmental performance of steel. Managed and published primarily by the World Steel Association (Worldsteel), the database serves as a central reference point for anyone involved in the steel industry. The database includes a wide range of data, such as crude steel production by country and company, apparent steel use per capita or by sector, trade flows of finished and semi-finished steel products, raw material inputs like scrap and iron ore, as well as energy use and CO_2 emissions data. It covers various steel categories, including carbon steel, stainless steel, and specialty steels. As such the background data supplied by World steel is commonly used when specific product data is not available.

Datasets

The dissemination model is identical to the dissemination model used for the EcoInvent database. For the production process the environmental profile from World Steel is used (Table 27**Fout! Verwijzingsbron niet gevonden.**). The datasets used in all other modules of the lifecycle are similar to the ones used in the EcoInvent analysis.

Table 27, Datasets used for A1-A3 Worldsteel, steel profile.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Production steel profile	A1	Steel sections {RER} | blast furnace route and electric arc furnace route | production mix, at plant | 1kg | LCI result	Industry data 2.0	0,28635	kg
Production steel profile	A1	Steel sections {GLO} | blast furnace route and electric arc furnace route | production mix, at plant | 1kg | LCI result	Industry data 2.0	0,71365	kg
Galvanize	A1-A3	Zinc coat, pieces, adjustment per micro-m {GLO}| market for zinc coat, pieces, adjustment per micro-m | Cut-off, U	EcoInvent 3.9.1	1,822	m^2

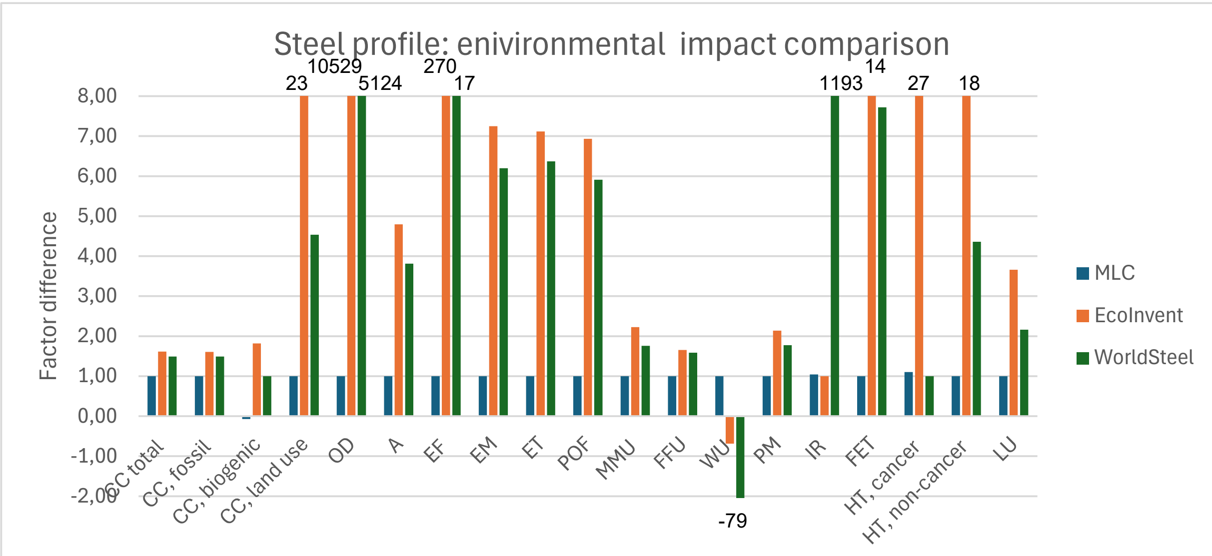
6.3.1. Results LCA steel profile using Worldsteel

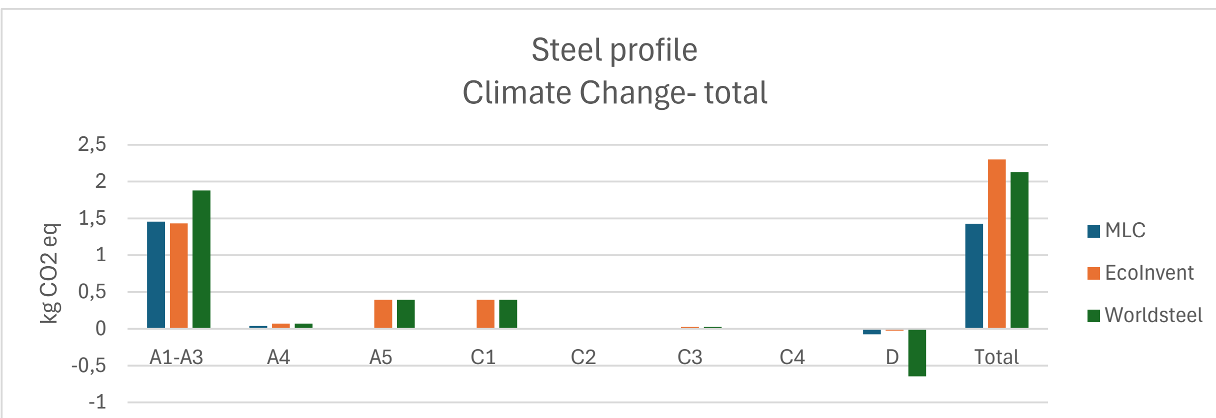
Table 28, Environmental profile, Worldsteel, steel profile

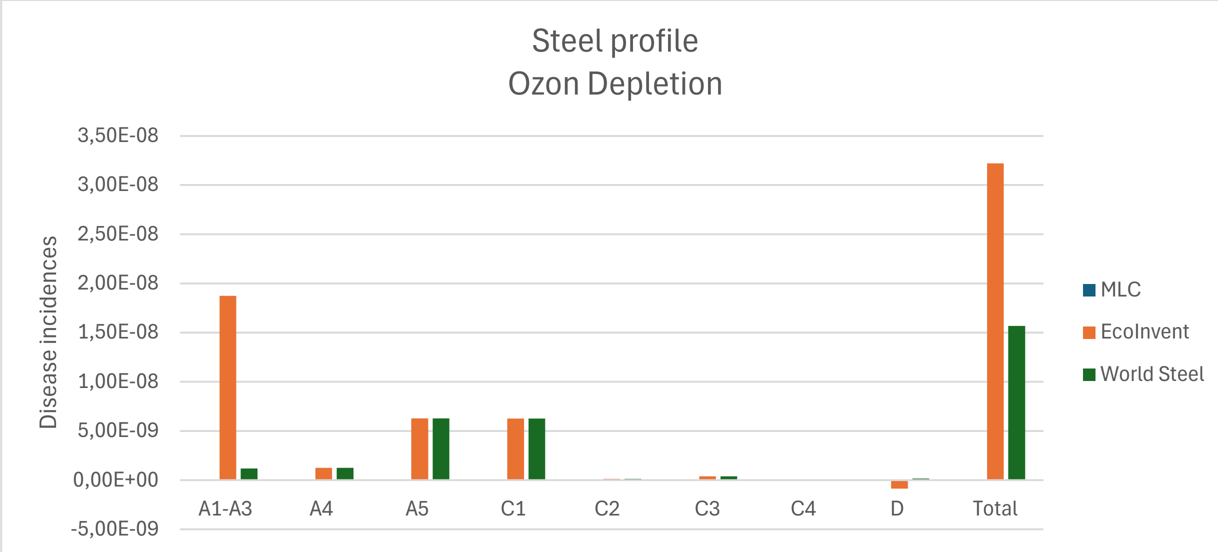
Worldsteel	A1-A3	A4	A5	C1	C2	C3	C4	D	Total
CC total [kg CO2 eq.]	1,88E+00	7,03E-02	3,95E-01	3,95E-01	7,55E-03	2,45E-02	6,12E-05	-6,45E-01	2,13E+00
CC, fossil [kg CO2 eq.]	1,88E+00	7,01E-02	3,95E-01	3,94E-01	7,52E-03	2,44E-02	6,11E-05	-6,45E-01	2,12E+00
CC, biogenic [kg CO2 eq.]	1,60E-03	2,28E-05	5,67E-05	5,67E-05	2,45E-06	7,34E-05	2,71E-08	2,66E-04	2,08E-03
CC, land use [kg CO2 eq.]	8,29E-04	2,50E-04	4,58E-05	4,57E-05	2,68E-05	3,58E-05	3,68E-08	-1,85E-05	1,21E-03
OD [kg CFC-11 eq.]	1,19E-09	1,25E-09	6,28E-09	6,27E-09	1,34E-10	3,88E-10	1,77E-12	1,68E-10	1,57E-08
A [Mole of H+ eq.]	5,05E-03	3,35E-04	3,65E-03	3,65E-03	3,60E-05	2,74E-04	4,60E-07	-1,47E-03	1,15E-02
EF [kg P eq.]	8,25E-06	6,97E-07	1,49E-06	1,49E-06	7,48E-08	1,12E-06	5,96E-10	-6,51E-07	1,25E-05
EM [kg N eq.]	1,03E-03	1,27E-04	1,69E-03	1,69E-03	1,37E-05	6,24E-05	1,76E-07	-2,60E-04	4,35E-03
ET [Mole of N eq.]	1,11E-02	1,36E-03	1,84E-02	1,84E-02	1,46E-04	7,13E-04	1,89E-06	-2,30E-03	4,77E-02
POF [kg NMVOC eq.]	3,86E-03	4,64E-04	5,45E-03	5,44E-03	4,98E-05	2,13E-04	6,60E-07	-1,05E-03	1,44E-02
MMU [kg Sb eq.]	4,11E-05	2,19E-07	1,44E-07	1,44E-07	2,35E-08	1,51E-06	8,52E-11	-1,08E-05	3,23E-05
FFU [MJ]	2,06E+01	1,00E+00	5,17E+00	5,16E+00	1,08E-01	3,31E-01	1,52E-03	-6,12E+00	2,63E+01
WU [m³ world equiv.]	-1,53E+01	5,48E-03	1,16E-02	1,16E-02	5,88E-04	4,02E-03	6,69E-05	-8,06E+00	-2,33E+01
PM [Disease incidences]	9,21E-08	6,92E-09	1,02E-07	1,02E-07	7,42E-10	3,75E-09	1,01E-11	-2,44E-08	2,83E-07
IR [kBq U235 eq.]	4,00E+01	3,91E-04	1,10E-03	1,10E-03	4,20E-05	8,82E-04	4,12E-07	1,51E+01	5,51E+01
FET[CTUe]	1,43E+01	7,40E-01	2,47E+00	2,47E+00	7,95E-02	2,60E-01	9,90E-04	-2,80E+00	1,75E+01
HT, cancer [CTUh]	9,48E-10	3,71E-11	1,28E-10	1,28E-10	3,98E-12	3,73E-11	2,62E-14	-3,48E-10	9,33E-10
HT, non-cancer [CTUh]	1,86E-08	8,06E-10	8,60E-10	8,58E-10	8,65E-11	1,68E-09	3,51E-13	-3,48E-10	2,25E-08
LU [Pt]	1,88E+00	7,92E-01	3,51E-01	3,50E-01	8,50E-02	5,88E-01	3,03E-03	3,32E-02	4,08E+00

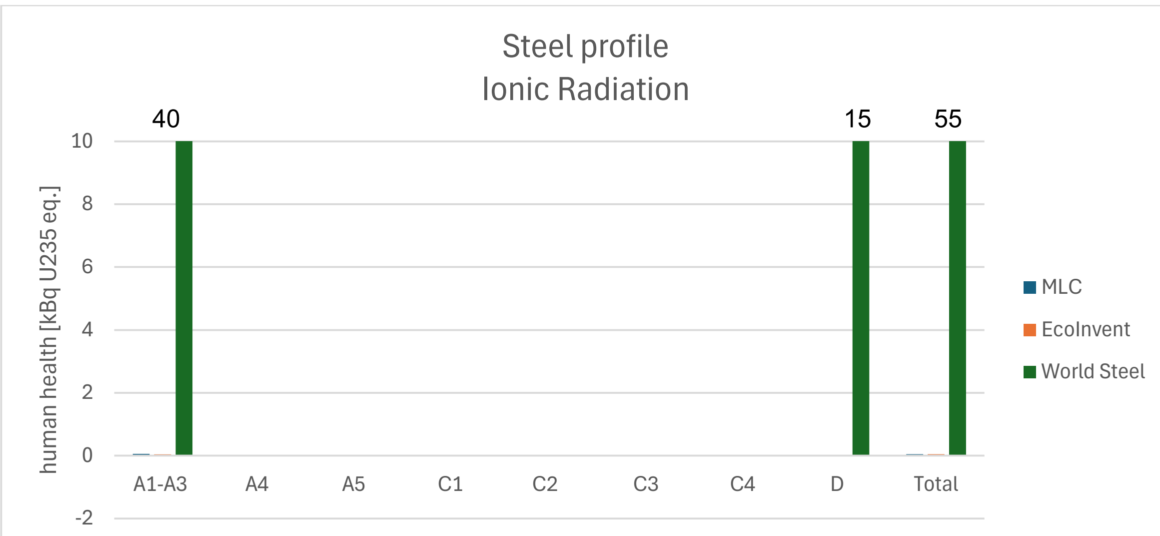
6.4. Comparison Environmental Impact steel profile

The figures below illustrate the differences in impact indicatorss based on the different background databases, as well as the absolute values for the Climate Change$_{total}$ and the two impact indicators showing the greatest variation.






Steel profile
Ozon Depletion
Disease incidences
3,50E-08
3,00E-08
2,50E-08
2,00E-08
1,50E-08
1,00E-08
5,00E-09
0,00E+00
-5,00E-09
A1-A3
A4
A5
C1
C2
C3
C4
D
Total
MLC
EcoInvent
World Steel


Steel profile
Ionic Radiation
human health [kBq U235 eq.]
40
15
55
10
8
6
4
2
0
-2
A1-A3
A4
A5
C1
C2
C3
C4
D
Total
MLC
EcoInvent
World Steel

Appendix C. ZOAB

6.5. Decomposition model ZOAB for EcoInvent

ZOAB is a road surface with a high percentage of voids (approximately 20%). On Dutch highways ZOAB (very open asphalt concrete) is the most commonly used type of asphalt. The guidelines for this study on ZOAB asphalt are based on the Product Category Rules for bituminous materials in road carriers and waterworks in the Netherlands [3]. This document contains specific calculation rules ("Product Category Rules", PCR) for environmental profiles (LCAs) of asphalt products in the Netherlands, in addition to the generic calculation rules prescribed by the Determination Method2. The purpose of the PCR document is to create a level playing field in the asphalt sector, in which all parties use the same principles and a distinction can be made on the basis of sustainability. All parties that draw up an environmental profile for use in the Dutch Civil Engineering sector (GWW sector) must follow these calculation rules.

Reference Unit ZOAB
The product unit should be reported as the sum of the environmental impact of one metric ton: 'The production, construction, maintenance activities, demolition and waste processing (modules A1 to D) of 1 metric ton'. With a technical life expectancy of 12 years.

Stages of the life cycle and system boundaries ZOAB
The processes that are examined within the LCA are demarcated with so-called system boundaries. The system boundaries determine which modules and processes of the life cycle are included in the LCA. Table 3, which follows from EN 15804 and the Determination Method, specifies which information must be considered per life cycle module. In this LCA, the environmental impact over the entire life cycle is included.

System boundaries according to the EN 15804+A2 *(X = declared; ND = Not Declared)*

Product			**Constructio n**		**Use**							**End of life**				**Beyond system boundary**
Raw material supply	Transport	Manufacturing	Transport	Construction - Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction demolition	Transport	Waste processing	Disposal	Reuse, recovery, recycling potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	X	X	X	X	X	ND	ND	ND	ND	X	X	X	X	X

Decomposition in materials and process for ZOAB
A1
The project follows NL PCR Asphalt v2.0 and the associated reporting from the Determination Method (shown in Annex III of the Determination Method) which provide specific additions for the use of materials and associated process maps.
For material the mixture composition as indicated of ZOAB in the NL PCR Asphalt is used; Bitumen 4,3%, crushed stone 70,3%, sand 17,5%, and filler 7,9% which is based on industry averages.

A2

The transport is done by truck and distances used as indicated of ZOAB in the NL PCR Asphalt; Bitumen 70/100 250km, crushed stone 25km, sand 25km and filler 136km which is based on industry averages. These processes assume a full load outbound journey and an empty return journey.

A3
The NL-PCR follows the Determination Method and provides specific supplements for the calculation of energy consumption and the process maps to be used. In addition, the NL-PCR provides a divergent provision regarding production losses.
Bitumen heating, which takes place with electricity resulting in an estimation of the electricity consumption for the bitumen heating in the Virtual Asphalt Plant (VAC) of 400,000 kWh annually.
The other heating processes that take place with gas, first of all the average gas consumption for asphalt production in the Netherlands (8.88 m3/ton of asphalt according to the MJA report 2017)
Shovels and cranes are to use a diesel consumption of 0,12 liters per ton of asphalt (VBW Asphalt, 1999).
The 'electricity use, other' is the average electricity consumption for asphalt production in the Netherlands (5.24 kWh/ton of asphalt according to MJA report 2017) to be multiplied by 200,000 tons (total production volume in VAC) minus Total consumption the electricity consumption for bitumen heating should be deducted, and the remaining electricity consumption should be divided by the total production quantity.

In addition to these energy consumptions, the emissions of polycyclic hydrocarbons (PAHs) in particular, which occur as a result of the heating of materials in the asphalt plant, are relevant to the environmental impact.
The PCR prescribes that PAH emissions for all asphalt mixtures (industry reference, supplier-specific and project-specific) are included in the same way, based on the worst-case scenario: the limit value from the “air regulations for asphalt mixing plants”.

Other emissions (including benzene) may be disregarded.
The PAH emissions per ton of asphalt should be modelled in LCA software as follows: a total PAH emission17 to air of 17 mg/ton asphalt, modelled as:
- 56.7% non-carcinogenic PAHs
- 42.9% naphthalene
- 0.4% benzo(a)pyrene.

Because the production losses are considered to be very small (approximately 0.5%) and it is currently not possible to substantiate any differences between asphalt plants, these are not included.

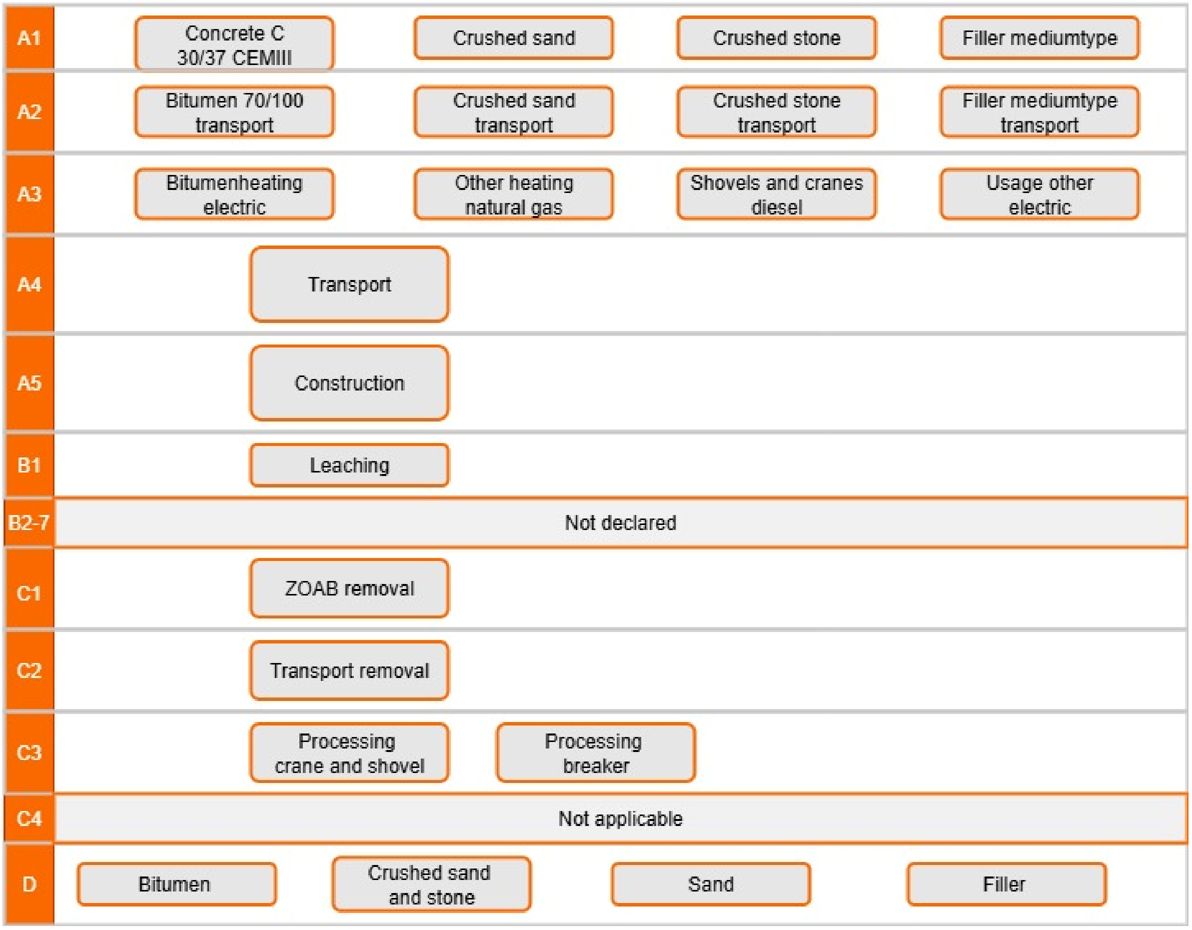
A4
Because the material losses during the transport module are considered to be very small (approximately 0.5%) and there is currently no good substantiation possible for any differences between asphalt plants, these are not included.
For transport with diesel trucks are used and the following conditions apply:
- 75% Euro 5 and 25% Euro 6 are assumed.
- A fixed distance of 50 km is used.
- For return transport, a fixed loading rate is used, from which an effective transport distance follows that must be used, as shown in Table **, whereby for road construction mixtures, 70% of the return journeys are made with empty loads and 30% of the return journeys with full loads. According to the Determination Method, 62.5%*30% + 100%*70% = 89% of the transport distance must be calculated. Effectively, 0.89*50 = 44.4 km is calculated for road construction mixtures.

The diesel consumption of the construction set per production volume and asphalt mixture is based on the assumption that for road construction mixtures 75% of the machines have stage class IIIb and 25% stage class IV.

B1
During the use module (B1) of asphalt, two processes occur that affect the environment: leaching and material loss. Both are only relevant for top layers, because these are the layers that come into contact with the air and rainwater. In addition, leaching is also relevant for water construction mixtures, because these also come into contact with water.
Leaching should be included in the LCA based on the results of leaching tests, as prescribed in the Soil Quality Decree. The results of this calculation are only intended for the LCA and are not intended for statements about soil quality. The results of leaching tests of standard measurements have been collected at TOP Management Consultants. For the LCA of road construction mixtures, it is assumed that the substances leach to fresh water (unspecified).

C1-3 and D
For the determination of the leaching for shaped mixtures, the conversion is made from m^2 to kg material using fixed densities of 2000kg/m^3 and layer thicknesses of 0,05m.
For the leaching quantities, the bitumen loss is neglected and 100% of the mass is included.
The loss of bitumen due to erosion in top layers results in a limited mass loss of less than 1% compared to the entire mixture and is therefore neglected in the amount of asphalt granulate that becomes available in modules C and D. Because the asphalt granulate that becomes available contains relatively less bitumen due to the erosion of bitumen, fewer environmental benefits can be attributed to the released asphalt granulate in module D.

Process tree ZOAB:



LCA ZOAB with EcoInvent 3.9
Based on the develop process tree for the ZOAB, the EcoInvent database is searched to identify the environmental profiles for the corresponding materials and processes. This chapter shows which datasets are used in the different life-modules.

A1-3 Production

This module includes everything needed to procure the raw materials needed in the production of the profile. This includes extraction, treatment, processing, electricity and heat consumption. The raw materials included are shown in Table 23.

Table 29, EcoInvent datasets used for A1-A3 ZOAB

Material/process	Module	Environmental profile	Source	Quantity	Unit
Bitumen 70/100	A1	Bitumen adhesive compound, hot {RER}| bitumen adhesive compound production, hot | Cut-off, U	EcoInvent 3.9.1	45	kg
Crushed sand	A1	Gravel, crushed {RoW}| gravel production, crushed | Cut-off, U	EcoInvent 3.9.1	43	kg
Crushed stone	A1	Gravel, crushed {RoW}| gravel production, crushed | Cut-off, U	EcoInvent 3.9.1	860	kg
Filler mediumtype + hydroxide	A1	Filler mediumtype + hydroxide	EcoInvent 3.9.1	52	kg
		Lime, hydrated, packed {RER}| market for lime, hydrated, packed | Cut-off, U	EcoInvent 3.9.1	0,3	kg/ kg Filler mediumtype + hydroxide
		Lime {Europe without Switzerland}| lime production, milled, loose | Cut-off, U	EcoInvent 3.9.1	0,7	kg/ /kg Filler mediumtype + hydroxide
Transport Bitumen 70/100	A2	Transport, freight, lorry, unspecified {GLO}| market group for transport, freight, lorry, unspecified | Cut-off, U	EcoInvent 3.9.1	11,25	tkm
Transport Crushed sand	A2	Transport, freight, lorry, unspecified {GLO}| market group for transport, freight, lorry, unspecified | Cut-off, U	EcoInvent 3.9.1	1,075	tkm
Transport Crushed stone	A2	Transport, freight, lorry, unspecified {GLO}| market group for transport, freight, lorry, unspecified | Cut-off, U	EcoInvent 3.9.1	21,5	tkm
Transport Filler mediumtype + hydroxide	A2	Transport, freight, lorry, unspecified {GLO}| market group for transport, freight, lorry, unspecified | Cut-off, U	EcoInvent 3.9.1	7,072	tkm
Electricity (Bitumenheating)	A3	Electricity, low voltage {NL}| market for electricity, low voltage | Cut-off, U (3,6 MJ/kWh)	EcoInvent 3.9.1	2	kWh
Diesel (Shovels and cranes)	A3	Diesel, burned in building machine {GLO}| diesel, burned in building machine | Cut-off, U(35,8 MJ/L)	EcoInvent 3.9.1	0,12	l
Natural gas (other heatingprocesses)	A3	Heat, district or industrial, natural gas {Europe without Switzerland}| heat production, natural gas, at industrial furnace >100kW | Cut-off, U (31,65 MJ/m^3)	EcoInvent 3.9.1	8,88097	m3
Electric usage (other)	A3	Electricity, low voltage {NL}| market for electricity, low voltage | Cut-off, U (3,6 MJ/kWh)	EcoInvent 3.9.1	3,240325	kWh

A4 Transport to construction site

The default distance for transport to the construction site is 470km using heavy transport.

Table 30, EcoInvent datasets used for A4, ZOAB

Material/process	Module	Environmental profile	Source	Quantity	Unit
Transport	A4	Transport, freight, lorry >32 metric ton, euro5 {RER}| market for transport, freight, lorry >32 metric ton, EURO5 | Cut-off, U	EcoInvent 3.9.1	33,3	tkm
Transport	A4	Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, U	EcoInvent 3.9.1	11,1	tkm

A5 Construction process

This module is included the installation of the construction.

Table 31, EcoInvent datasets used for A5, ZOAB

Material/process	Module	Environmental profile	Source	Quantity	Unit
Construction stage	A5	Diesel, burned in building machine {GLO}| processing | Cut-off, U (35,9 MJ/L)	EcoInvent 3.9.1	0,32	l

B Use

C1 Demolition

Table 32, EcoInvent datasets used for C1, ZOAB

Material/process	Module	Environmental profile	Source	Quantity	Unit
ZOAB removal	C1	Diesel, burned in building machine {GLO}| processing | Cut-off, U (35,9 MJ/L)	EcoInvent 3.9.1	0,77	l

C2 Transport to waste processing facilities or disposal site

Table 33, EcoInvent datasets used for C2, ZOAB

Material/process	Module	Environmental profile	Source	Quantity	Unit
Transport removal	C2	Transport, freight, lorry >32 metric ton, euro6 {RER}| market for transport, freight, lorry >32 metric ton, EURO6 | Cut-off, U	EcoInvent 3.9.1	33,3	tkm
Transport removal	C2	Transport, freight, lorry, unspecified {GLO}| market group for transport, freight, lorry, unspecified | Cut-off, U	EcoInvent 3.9.1	11,1	tkm

C3 Waste processing

Table 34, EcoInvent datasets used for C3, ZOAB

Material/process	Module	Environmental profile	Source	Quantity	Unit
Processing Crane and shovel	C3	Diesel, burned in building machine {GLO}| diesel, burned in building machine | Cut-off, U (35,9 MJ/L)	EcoInvent 3.9.1	0,185	l
Processing Breaker	C3	Diesel, burned in building machine {GLO}| diesel, burned in building machine | Cut-off, U(35,9 MJ/L)	EcoInvent 3.9.1	0,185	l

Module D

Table 35, EcoInvent datasets used for D, ZOAB

Material/process	Module	Environmental profile	Source	Quantity	Unit
Bitumen 70/100	D	Bitumen adhesive compound, hot {RER}| bitumen adhesive compound production, hot | Cut-off, U	EcoInvent 3.9.1	32,6	kg
Crushed sand/ crushed stone	D	Gravel, crushed {RoW}| gravel production, crushed | Cut-off, U	EcoInvent 3.9.1	554	kg
Filler	D	Filler mediumtype + hydroxide	EcoInvent 3.9.1	79	kg
		Lime, hydrated, packed {RER}| market for lime, hydrated, packed | Cut-off, U	EcoInvent 3.9.1	0,3	kg/ kg Filler mediumtype + hydroxide
		Lime {Europe without Switzerland}| lime production, milled, loose | Cut-off, U	EcoInvent 3.9.1	0,7	kg/ /kg Filler mediumtype + hydroxide

Calculation procedures

- The LCA calculations are performed in accordance with EN 15804:2012+A2:2019;
- When calculating the energy flows, the fuels and electricity sources used, extraction and transport of the fuels, efficiency of the conversion and distribution of the energy flow are considered. The calorific net value (LHV) has also been calculated.
- The rules for allocation for multi-input, -output, recycling and reuse processes from the Assessment Method have been followed for all materials.
- EcoInvent processes are calculated including the infrastructure processes (capital goods)
- EcoInvent processes for landfill are calculated excluding long-term emissions.

6.5.1. Results LCA ZOAB using EcoInvent

This pharagraph presents the results of the LCA. These are set out in section the environmental profile below for the A2 parameters.

Table 36, Environmental profile, based on EcoInvent datasets, ZOAB.

EcoInvent	A1-A3	A4	A5	C1	C2	C3	D	Total
CC total [kg CO2 eq.]	9,36E+01	4,57E+00	1,14E+00	2,74E+00	4,99E+00	1,32E+00	-5,68E+01	5,15E+01
CC, fossil [kg CO2 eq.]	9,35E+01	4,57E+00	1,14E+00	2,74E+00	4,98E+00	1,32E+00	-5,68E+01	5,15E+01
CC, biogenic [kg CO2 eq.]	4,57E-02	1,49E-03	1,58E-04	3,81E-04	1,65E-03	1,83E-04	-3,19E-02	1,77E-02
CC, land use [kg CO2 eq.]	4,42E-02	2,17E-03	1,28E-04	3,09E-04	7,50E-03	1,48E-04	-1,47E-02	3,98E-02
OD [kg CFC-11 eq.]	5,03E-06	1,01E-07	1,81E-08	4,36E-08	1,05E-07	2,10E-08	-2,87E-06	2,45E-06
A [Mole of H+ eq.]	2,84E-01	1,44E-02	1,06E-02	2,54E-02	1,61E-02	1,22E-02	-1,75E-01	1,87E-01
EF [kg P eq.]	8,96E-04	3,73E-05	4,12E-06	9,91E-06	4,43E-05	4,76E-06	-5,10E-04	4,86E-04
EM [kg N eq.]	6,70E-02	4,72E-03	4,89E-03	1,18E-02	5,20E-03	5,66E-03	-3,67E-02	6,25E-02
ET [Mole of N eq.]	6,86E-01	5,03E-02	5,32E-02	1,28E-01	5,51E-02	6,16E-02	-3,68E-01	6,66E-01
POF [kg NMVOC eq.]	5,52E-01	2,26E-02	1,58E-02	3,79E-02	2,44E-02	1,82E-02	-3,53E-01	3,18E-01
MMU [kg Sb eq.]	1,52E-04	1,24E-05	3,98E-07	9,57E-07	1,45E-05	4,60E-07	-7,35E-05	1,07E-04
FFU [MJ]	2,85E+03	6,74E+01	1,49E+01	3,59E+01	7,42E+01	1,73E+01	-1,79E+03	1,27E+03
WU [m³ world equiv.]	1,88E+01	3,22E-01	3,22E-02	7,74E-02	3,71E-01	3,72E-02	-1,26E+01	7,01E+00
PM [Disease incidences]	2,99E-06	4,58E-07	2,95E-07	7,09E-07	4,92E-07	3,41E-07	-1,58E-06	3,71E-06
IR [kBq U235 eq.]	1,03E+00	3,25E-02	3,05E-03	7,34E-03	3,36E-02	3,53E-03	-7,12E-01	3,98E-01
FET[CTUe]	1,11E+03	3,24E+01	7,13E+00	1,72E+01	4,18E+01	8,25E+00	-7,57E+02	4,55E+02
HT, cancer [CTUh]	2,99E-08	1,99E-09	3,49E-10	8,40E-10	2,36E-09	4,04E-10	-1,63E-08	1,95E-08
HT, non-cancer [CTUh]	5,13E-07	4,84E-08	2,43E-09	5,84E-09	5,51E-08	2,81E-09	-2,84E-07	3,43E-07
LU [Pt]	3,21E+02	6,85E+01	1,01E+00	2,42E+00	7,00E+01	1,16E+00	-1,84E+02	2,80E+02

6.6. Decomposition model ZOAB for Eurobitume

Eurobitume is the European association representing the bitumen industry. It serves as a platform for collaboration among bitumen producers and stakeholders across Europe. The organization focuses on promoting the efficient, economic, effective, safe, and sustainable use of refined bitumen. They conduct Life Cycle Assessments (LCA) to evaluate the environmental impact of bitumen production and identify opportunities for sustainability improvements. This industry data is used as dataset for an LCA for ZOAB.

Datasets from Eurobitume

The dissemination model is identical to the decimation model used for EcoInvent. For the production process the environmental profile from Eurobitume [4].

Table 37, Eurobitume datasets used for A1-A3, ZOAB

Material/process	Module	Environmental profile	Source	Quantity	Unit
Bitumen 70/100	A1	The Eurobitume Life Cycle Assessment 4.0 for bitumen	Eurobitume	45	kg

6.6.1. Results LCA ZOAB with Eurobitume

Table 38, Environmental profile, based on Eurobitume dataset, ZOAB.

Eurobitume	A1-A3	A4	A5	C1	C2	C3	D	Total
CC total [kg CO2 eq.]	7,85E+01	4,57E+00	1,14E+00	2,74E+00	4,99E+00	1,32E+00	-5,68E+01	3,65E+01
CC, fossil [kg CO2 eq.]	7,84E+01	4,57E+00	1,14E+00	2,74E+00	4,98E+00	1,32E+00	-5,68E+01	3,64E+01
CC, biogenic [kg CO2 eq.]	1,26E-01	1,49E-03	1,58E-04	3,81E-04	1,65E-03	1,83E-04	-3,19E-02	9,78E-02
CC, land use [kg CO2 eq.]	4,75E-02	2,17E-03	1,28E-04	3,09E-04	7,50E-03	1,48E-04	-1,47E-02	4,30E-02
OD [kg CFC-11 eq.]	1,34E-06	1,01E-07	1,81E-08	4,36E-08	1,05E-07	2,10E-08	-2,87E-06	-1,24E-06
A [Mole of H+ eq.]	2,08E-01	1,44E-02	1,06E-02	2,54E-02	1,61E-02	1,22E-02	-1,75E-01	1,11E-01
EF [kg P eq.]	6,61E-04	3,73E-05	4,12E-06	9,91E-06	4,43E-05	4,76E-06	-5,10E-04	2,52E-04
EM [kg N eq.]	5,67E-02	4,72E-03	4,89E-03	1,18E-02	5,20E-03	5,66E-03	-3,67E-02	5,22E-02
ET [Mole of N eq.]	6,41E-01	5,03E-02	5,32E-02	1,28E-01	5,51E-02	6,16E-02	-3,68E-01	6,21E-01
POF [kg NMVOC eq.]	2,51E-01	2,26E-02	1,58E-02	3,79E-02	2,44E-02	1,82E-02	-3,53E-01	1,66E-02
MMU [kg Sb eq.]	1,05E-04	1,24E-05	3,98E-07	9,57E-07	1,45E-05	4,60E-07	-7,35E-05	6,02E-05
FFU [MJ]	2,68E+03	6,74E+01	1,49E+01	3,59E+01	7,42E+01	1,73E+01	-1,79E+03	1,10E+03
WU [m³ world equiv.]	1,64E+01	3,22E-01	3,22E-02	7,74E-02	3,71E-01	3,72E-02	-1,26E+01	4,63E+00
PM [Disease incidences]	2,98E-06	4,58E-07	2,95E-07	7,09E-07	4,92E-07	3,41E-07	-1,58E-06	3,69E-06
IR [kBq U235 eq.]	1,02E+00	3,25E-02	3,05E-03	7,34E-03	3,36E-02	3,53E-03	-7,12E-01	3,88E-01
FET[CTUe]	1,43E+03	3,24E+01	7,13E+00	1,72E+01	4,18E+01	8,25E+00	-7,57E+02	7,84E+02
HT, cancer [CTUh]	3,83E-08	1,99E-09	3,49E-10	8,40E-10	2,36E-09	4,04E-10	-1,63E-08	2,79E-08
HT, non-cancer [CTUh]	8,86E-07	4,84E-08	2,43E-09	5,84E-09	5,51E-08	2,81E-09	-2,84E-07	7,17E-07
LU [Pt]	2,23E+02	6,85E+01	1,01E+00	2,42E+00	7,00E+01	1,16E+00	-1,84E+02	1,82E+02

6.7. Decomposition model ZOAB for MLC

As the MLC database is not compatible with the Simapro modelling and calculation are done in the Sphera software. This requires some adjustments to the decomposition model, however system boundaries, life cycle stages are made however specifications indicated in the cat 3 data [1] are adopted as closely as possible. With the Sphera software the processes for ZOAB are modelled separately

Process trees

Using Sphera the existing decomposition model was rebuilt as closely as possible. However, in some cases a one-to-one implementation was not feasible, or modelling within LCA FE is typically conducted differently. The developed model for the ZOAB is shown in Figure 28**Fout! Verwijzingsbron niet gevonden.**.

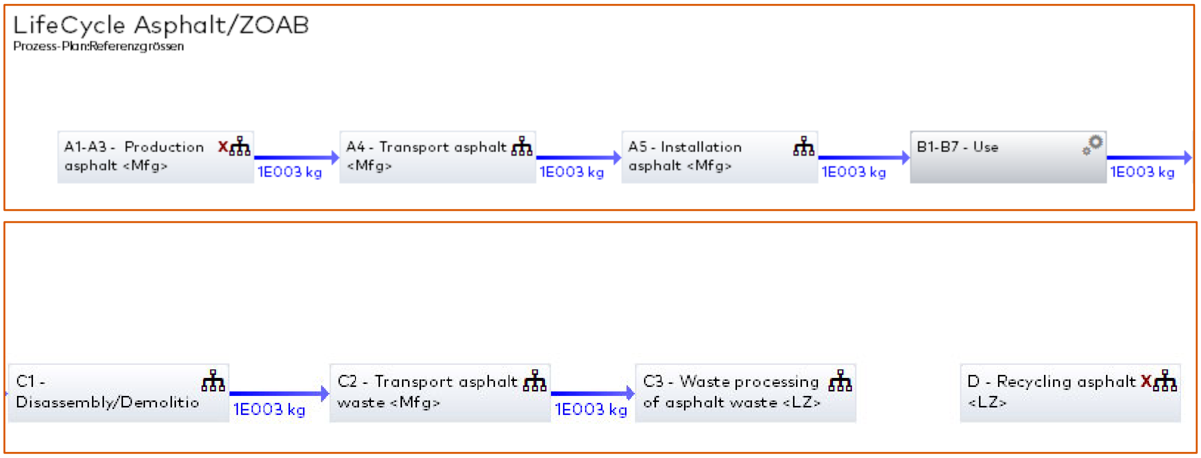


Figure 27, MLC model for ZOAB.

MLC model for ZOAB
This chapter explains the choice of used MLC datasets for ZOAB.

A1-3: Production

The EcoInvent datasets selected for modelling the production module could largely be substituted with corresponding datasets from the MLC database. No corresponding dataset was available in the MLC database for 'bitumen hot'. Therefor 'bitumen cold' was used without further energy input to avoid double heating. The model (Figure 29) below demonstrates that, unlike the EcoInvent model, distinct datasets could be used for crushed sand and crushed stone.

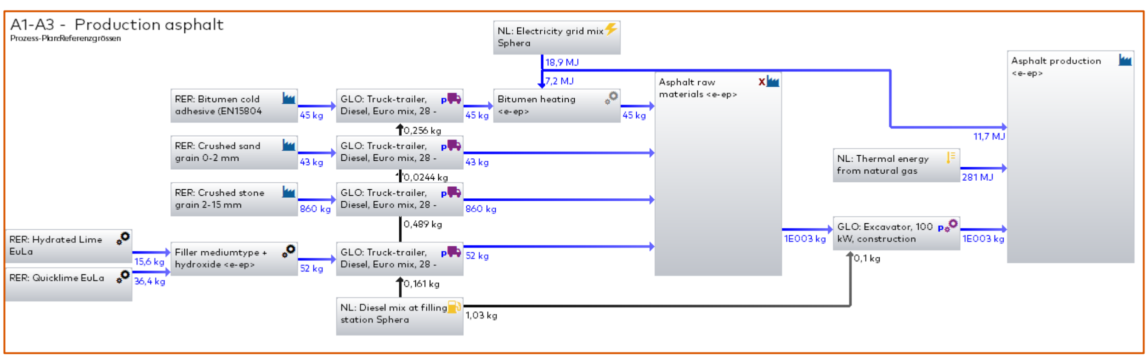


Figure 28, MLC model for A1-A3, ZOAB

Table 39, MLC datasets used for A1-A3, ZOAB

Material/process	Module	Environmental profile	Source	Quantity	Unit
Material	A1-A3	RER: Bitumen cold adhesive (EN15804 A1-A3)	MLC 2025	45	kg
Material	A1-A3	RER: Crushed sand grain 0-2 mm (EN15804 A1-A3)	MLC 2025	43	kg
Material	A1-A3	RER: Crushed stone grain 2-15 mm (undried) (EN15804 A1-A3)	MLC 2025	860	kg
Material	A1-A3	RER: Hydrated Lime	MLC 2025	15,6	kg
Material	A1-A3	RER: Quicklime	MLC 2025	36,4	kg
Process	A1-A3	GLO: Truck-trailer, Diesel, Euro mix, 28 - 34t gross weight	MLC 2025	1000	kg
Process	A1-A3	GLO: Excavator, 100 kW, construction	MLC 2025	1000	kg
Process	A1-A3	NL: Diesel mix at filling station	MLC 2025	1,03	kg
Process	A1-A3	NL: Electricity grid mix	MLC 2025	18,9	MJ
	A1-A3	NL: Thermal energy from natural gas	MLC 2025		

A4: Transport

For the EURO 5 truck, the corresponding dataset from the MLC database was used. Regarding the EURO 6 truck, two datasets are available in MLC. To determine the most appropriate one, their global warming potential (GWP) values were compared with those from EcoInvent and selected the dataset with the closest match. For both transport processes, the corresponding fuel dataset (diesel) was used.

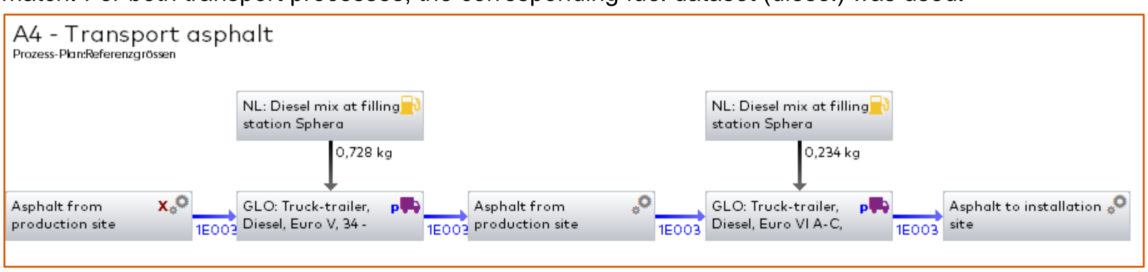


Figure 29, MLC model for A4, ZOAB

The datasets used in this module are shown in Table 40.

Table 40, MLC datasets used for A4, ZOAB

Material/process	Module	Environmental profile	Source	Quantity	Unit
Transport	A4	GLO: Truck-trailer, Diesel, Euro V, 34 – 40t gross weight	MLC 2025	1000	kg
Transport	A4	GLO: Truck-trailer, Diesel, Euro VI A-C, 34 – 40t gross weight	MLC 2025	1000	kg
Transport	A4	NL: Diesel mix at filling station	MLC 2025	0,952	kg

A5: Installation

As described above, the excavator dataset was used for the diesel-burning process. The parameters have been adjusted to the specified diesel consumption.

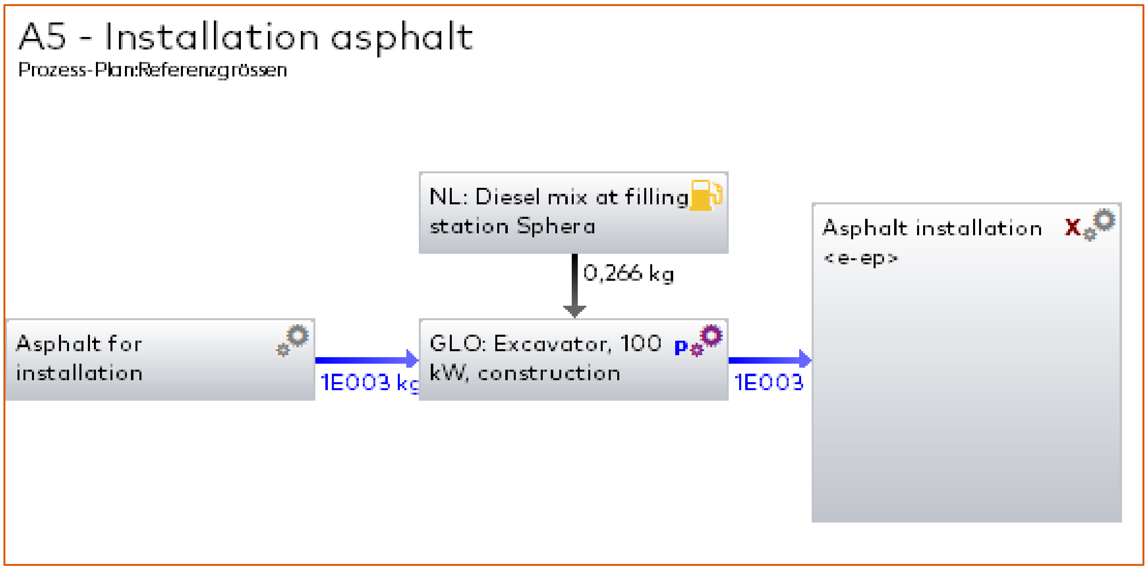


Figure 30, MLC model for A5, ZOAB

Table 41, MLC datasets used for A5, ZOAB

Material/process	Module	Environmental profile	Source	Quantity	Unit
Transport	A5	GLO: Excavator, 100 kW, construction	MLC 2025	1000	kg
Transport	A5	NL: Diesel mix at filling station	MLC 2025	0.266	kg

B1-B3 Use module

Due to the absence of maintenance and replacement activities, the B-modules are set to zero. This life cycle stage is represented in the model by a placeholder process to ensure completeness of the modular structure.

C1: Deconstruction

Similar to the decomposition model the same dataset and input quantities used for the installation, the excavator dataset was used for the diesel-burning process. The parameters have been adjusted to the specified diesel consumption.

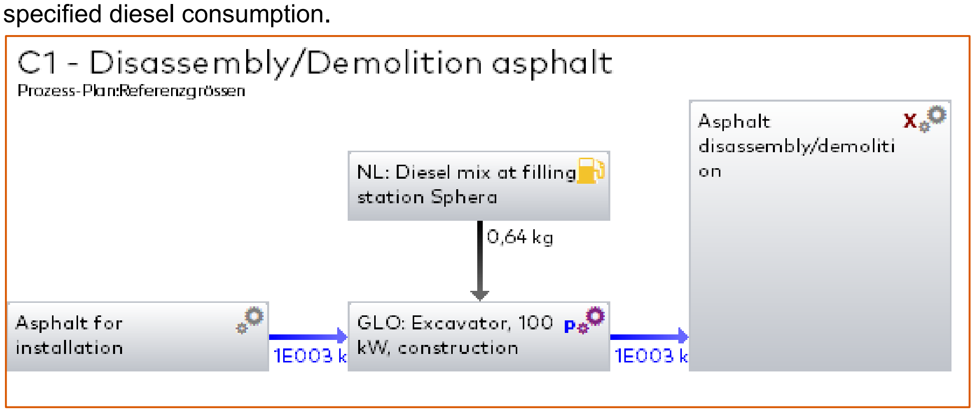


Figure 31, MLC model for C1, ZOAB

Table 42, MLC datasets used for C1, ZOAB

Material/process	Module	Environmental profile	Source	Quantity	Unit
Deconstruction	C1	GLO: Excavator, 100 kW, construction	MLC 2025	1000	kg
Deconstruction	C1	NL: Diesel mix at filling station	MLC 2025	0.64	kg

C2: Transport

End-of-life transport was modelled using the same datasets as in module A4.

Figure 32, MLC model for C2, ZOAB

Table 43, MLC datasets used for C2, ZOAB

Material/process	Module	Environmental profile	Source	Quantity	Unit
Transport	C2	GLO: Truck-trailer, Diesel, Euro mix, 28 - 34t gross weight	MLC 2025	1000	kg
Transport	C2	GLO: Truck-trailer, Diesel, Euro VI A-C, 34 – 40t gross weight	MLC 2025	1000	kg
Transport	C2	NL: Diesel mix at filling station	MLC 2025	0.954	kg

C3: Waste processing

As outlined above, the diesel combustion process was modelled using the excavator dataset, with parameter adjustments reflecting the specified diesel consumptions for crane/shovel and breaker.

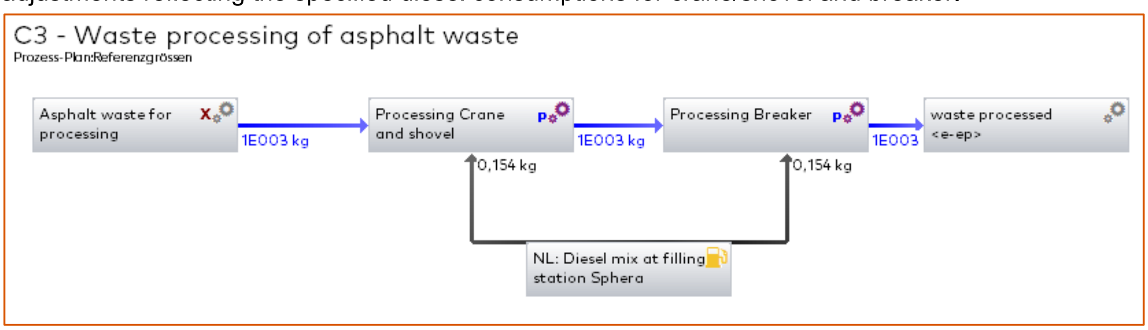


Figure 33, MLC model for C3, ZOAB

Table 44, MLC datasets used for C3, ZOAB

Material/process	Module	Environmental profile	Source	Quantity	Unit
Deconstruction	C3	GLO: Excavator, 100 kW, construction	MLC 2025	1000	kg
Deconstruction	C3	NL: Diesel mix at filling station	MLC 2025	0,308	kg

D: Benefits beyond system boundary

For the modelling of benefits, the same datasets were selected as those used in Modules A1-A3.

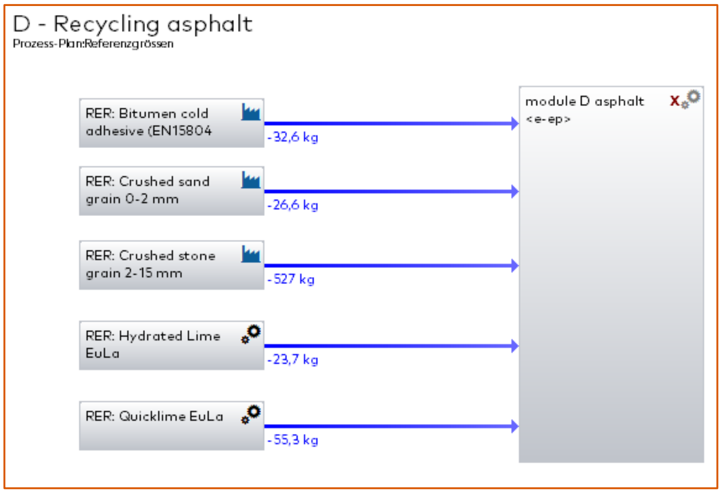


Figure 34, MLC model for D, ZOAB

The datasets used in this module are shown in Tabel 51.

Table 45, MLC datasets used for D, ZOAB

Material/process	Module	Environmental profile	Source	Quantity	Unit
Recycling	D	RER: Bitumen cold adhesive (EN15804 A1-A3)	MLC 2025	-32,6	kg
Recycling	D	RER: Crushed sand grain 0-2 mm (EN15804 A1-A3)	MLC 2025	-26,6	kg
Recycling	D	RER: Crushed stone grain 2-15 mm (undried) (EN15804 A1-A3)	MLC 2025	-527	kg
Recycling	D	RER: Hydrated Lime	MLC 2025	-23,7	kg
Recycling	D	RER: Quicklime	MLC 2025	-55,3	kg

6.7.1. Results LCA ZOAB using MLC

The results of the LCA based on MLC are presented in Table 46.

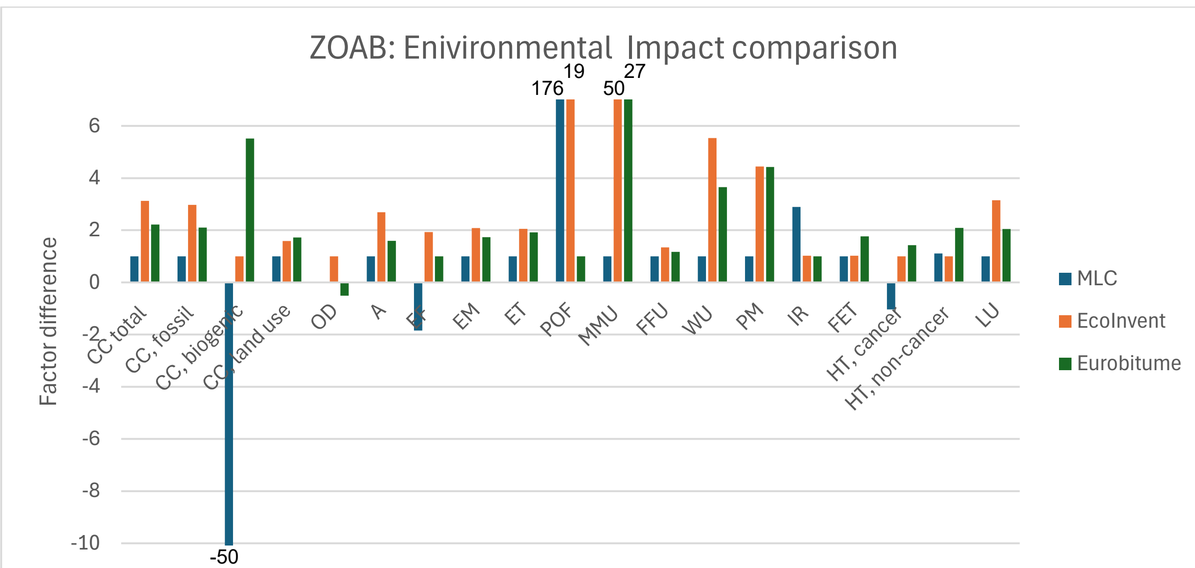
Table 46, Environmental profile, based on MLC dataset, ZOAB.

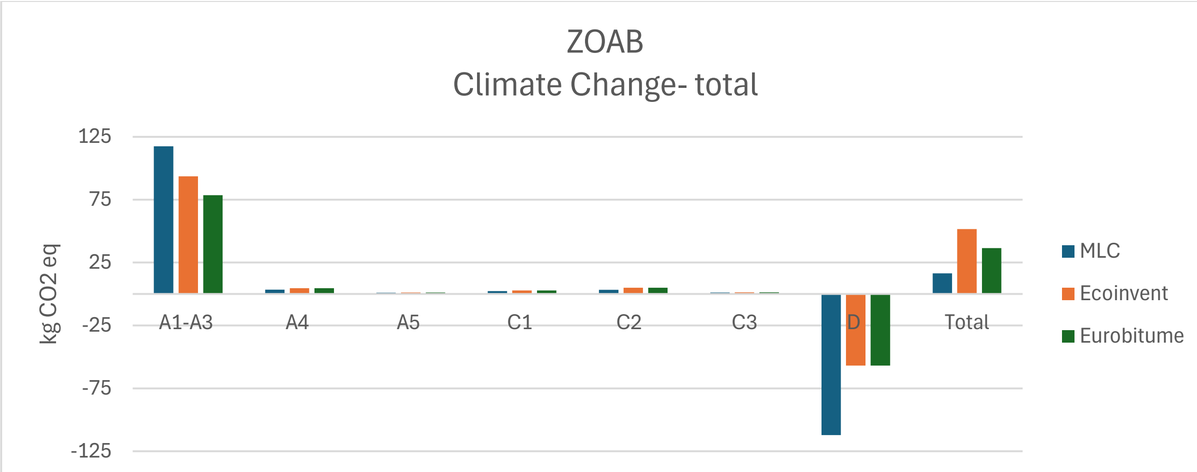
MLC	A1-A3	A4	A5	C1	C2	C3	D	Total
CC total [kg CO2 eq.]	1,17E+02	3,45E+00	9,69E-01	2,33E+00	3,42E+00	1,12E+00	-1,12E+02	1,65E+01
CC, fossil [kg CO2 eq.]	1,19E+02	3,56E+00	9,98E-01	2,40E+00	3,53E+00	1,15E+00	-1,13E+02	1,73E+01
CC, biogenic [kg CO2 eq.]	-1,41E+00	-1,09E-01	-2,94E-02	-7,05E-02	-1,08E-01	-3,39E-02	8,73E-01	-8,83E-01
CC, land use [kg CO2 eq.]	7,61E-02	1,31E-04	3,62E-05	8,68E-05	1,29E-04	4,17E-05	-5,15E-02	2,50E-02
OD [kg CFC-11 eq.]	9,88E-08	9,41E-13	2,61E-13	6,26E-13	9,33E-13	3,01E-13	-1,50E-07	-5,10E-08
A [Mole of H+ eq.]	1,85E-01	1,53E-02	4,83E-03	1,16E-02	4,70E-03	5,58E-03	-1,57E-01	6,96E-02
EF [kg P eq.]	1,19E-03	8,64E-07	2,39E-07	5,75E-07	8,57E-07	2,76E-07	-1,66E-03	-4,65E-04
EM [kg N eq.]	5,93E-02	7,48E-03	2,32E-03	5,58E-03	1,90E-03	2,68E-03	-4,92E-02	3,00E-02
ET [Mole of N eq.]	6,17E-01	8,23E-02	2,55E-02	6,11E-02	2,12E-02	2,94E-02	-5,12E-01	3,25E-01

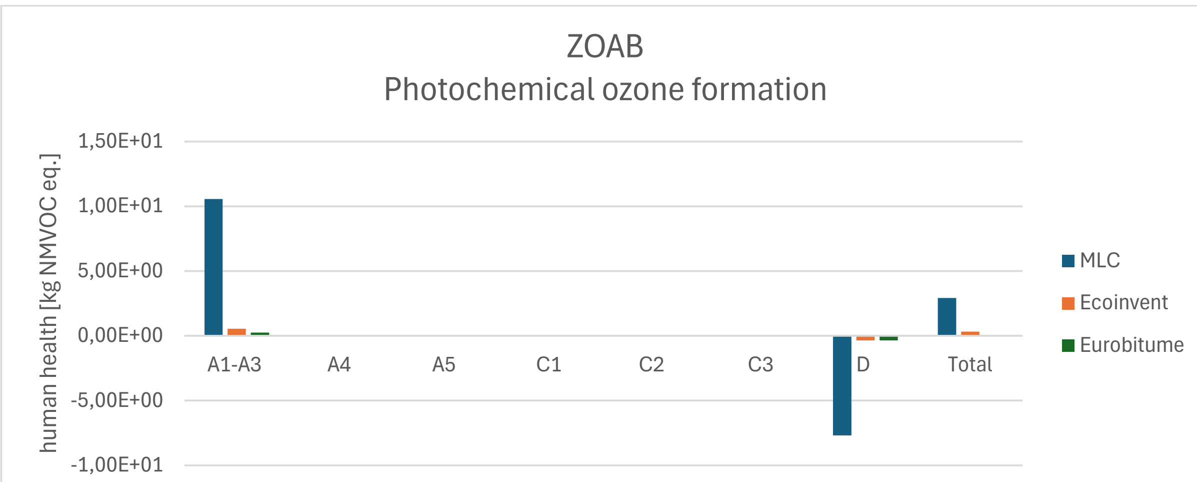
POF [kg NMVOC eq.]	1,06E+01	1,54E-02	6,62E-03	1,59E-02	5,09E-03	7,65E-03	-7,68E+00	2,92E+00
MMU [kg Sb eq.]	8,76E-06	1,27E-07	3,52E-08	8,46E-08	1,26E-07	4,07E-08	-7,01E-06	2,16E-06
FFU [MJ]	2,48E+03	4,51E+01	1,25E+01	3,00E+01	4,48E+01	1,44E+01	-1,69E+03	9,44E+02
WU [m³ world equiv.]	5,94E+00	4,52E-03	1,25E-03	3,01E-03	4,48E-03	1,44E-03	-4,68E+00	1,27E+00
PM [Disease incidences]	2,17E-06	7,85E-08	5,88E-08	1,41E-07	4,74E-08	6,79E-08	-1,72E-06	8,35E-07
IR [kBq U235 eq.]	4,73E+00	4,22E-03	1,17E-03	2,80E-03	4,18E-03	1,35E-03	-3,62E+00	1,12E+00
FET[CTUe]	1,88E+03	2,91E+01	8,05E+00	1,93E+01	2,88E+01	9,30E+00	-1,53E+03	4,45E+02
HT, cancer [CTUh]	8,82E-08	4,47E-10	1,24E-10	2,97E-10	4,43E-10	1,43E-10	-1,10E-07	-2,02E-08
HT, non-cancer [CTUh]	1,38E-06	7,25E-09	2,02E-09	4,86E-09	7,18E-09	2,34E-09	-1,02E-06	3,80E-07
LU [Pt]	2,54E+02	2,57E-01	7,11E-02	1,71E-01	2,55E-01	8,21E-02	-1,66E+02	8,88E+01

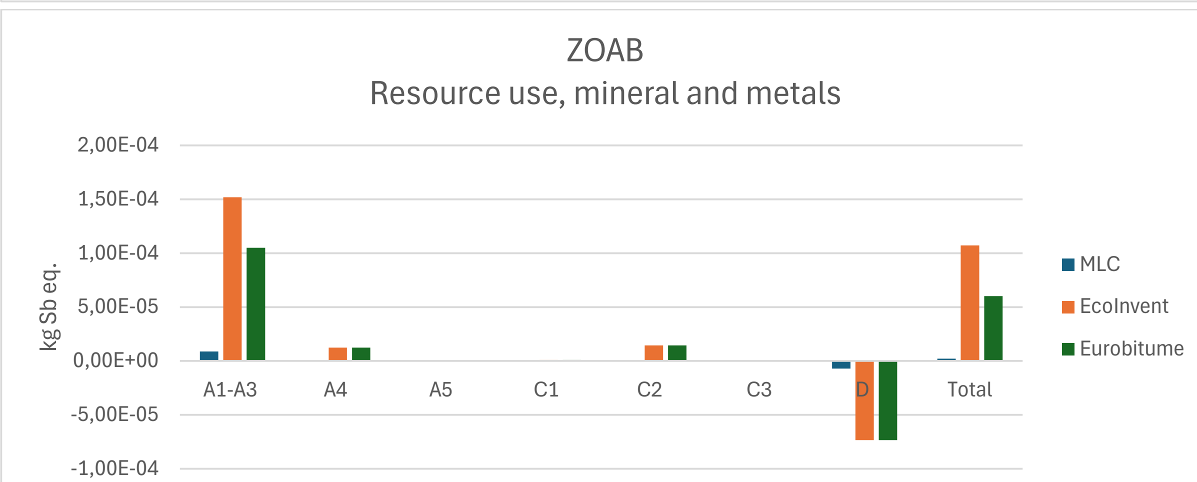
6.8. Comparison Environmental Impact ZOAB

The figures below illustrate the differences in impact indicators based on the different background databases, as well as the absolute values for the Climate Change$_{total}$ and the two impact indicators showing the greatest variation.




ZOAB
Climate Change- total
kg CO2 eq
125
75
25
-25
-75
-125
A1-A3
A4
A5
C1
C2
C3
D
Total
MLC
Ecoinvent
Eurobitume


ZOAB
Photochemical ozone formation
human health [kg NMVOC eq.]
1,50E+01
1,00E+01
5,00E+00
0,00E+00
-5,00E+00
-1,00E+01
A1-A3
A4
A5
C1
C2
C3
D
Total
MLC
Ecoinvent
Eurobitume


ZOAB
Resource use, mineral and metals
kg Sb eq.
2,00E-04
1,50E-04
1,00E-04
5,00E-05
0,00E+00
-5,00E-05
-1,00E-04
A1-A3
A4
A5
C1
C2
C3
D
Total
MLC
EcoInvent
Eurobitume

Appendix D. Retaining wall

6.9. Decomposition model Retaining wall for EcoInvent

Retaining walls are precast reinforced concrete structures with a wide base, which gives the structure a high load-bearing capacity. The guidelines for this study on retaining wall (model 1980 type 1540 producent Strukton) are based on the LCA Rapportage Categorie 3 data Nationale Milieudatabase, Perron spoor [5]. This document is set up to supplement and improve the category 3 product cards in the National Environmental Database (NMD) by justification for choices made in materials and environmental data.

Reference Unit of the retaining wall
The functional unit of the retaining wall is one linear meter, with a lifespan of 50 years.

Stages of the life cycle and system boundaries of the retaining wall

The processes that are examined within the LCA are demarcated with so-called system boundaries. The system boundaries determine which modules and processes of the life cycle are included in the LCA. Table 3, which follows from EN 15804 and the Determination Method, specifies which information must be considered per life cycle module. In this LCA, the environmental impact over the entire life cycle is included.

Table 47, System boundaries according to the EN 15804+A2 (X = declared; ND = Not Declared)

Product			Construction		Use							End of life				Beyond system boundary
Raw material supply	Transport	Manufacturing	Transport	Construction - Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction demolition	Transport	Waste processing	Disposal	Reuse, recovery, recycling potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Decomposition in materials and process of the retaining wall

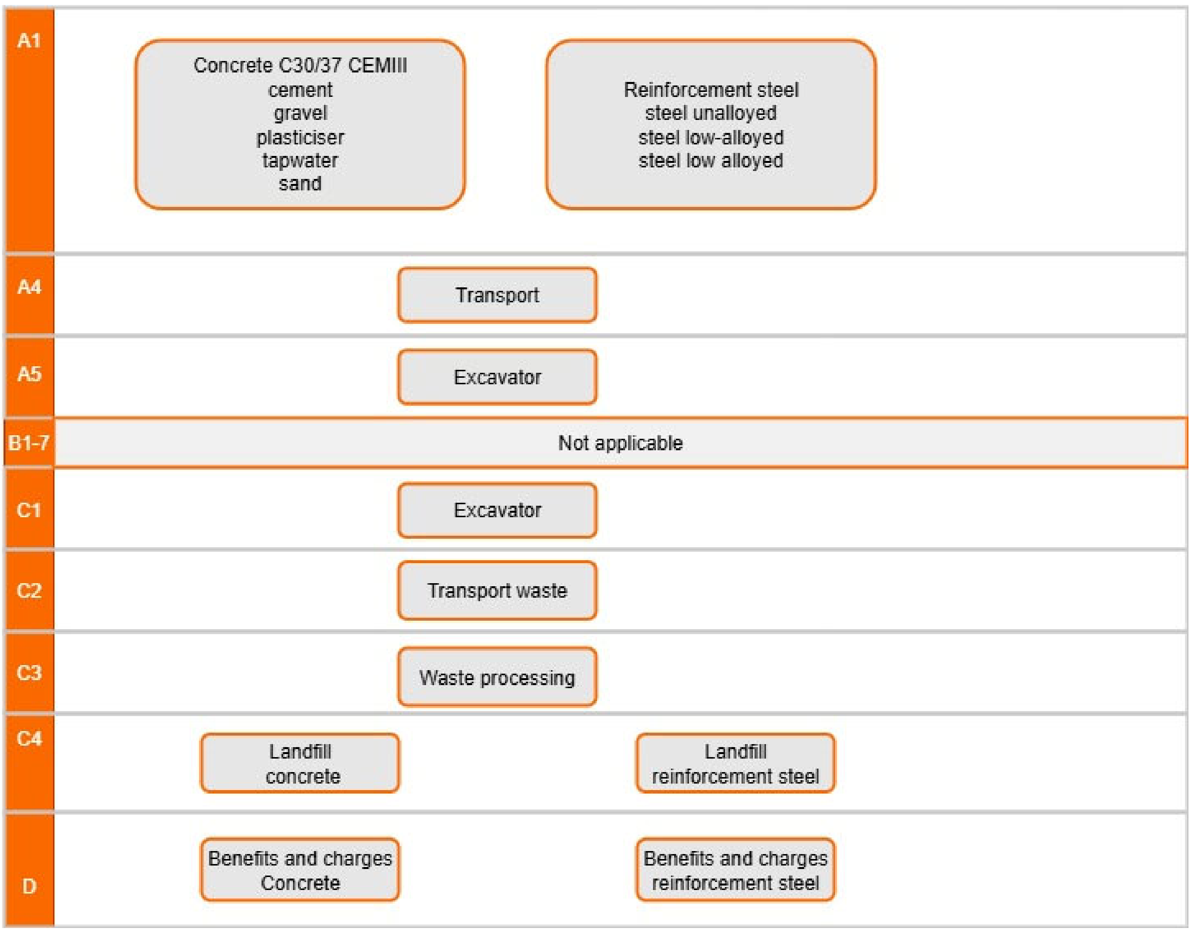
Production module (A1-3)
Based on drawings, it was determined that the volume of the retaining wall is approximately 0.35 m3. Inventory also shows that 63.8 kg/m3 reinforcement is present. This is in accordance with SPC for retaining walls. The total weight of one metre of retaining wall of the model used is 870 kg.

Construction module (A4-A5)
Calculations were based on a fixed transport (150 km) by truck. The retaining walls are installed using a roller. The production standard has been set at 5 metres per hour. A fixed 3% construction waste has also been calculated to cover losses.

Usage module (B1-B7)
During the lifespan of the retaining wall, no parts need to be replaced and no maintenance is necessary.

Demolition and processing module (C1-C4) + Benefits and costs outside the system boundaries (D)
The retaining wall is removed using the same roller, with the same time commitment. The processing of the various materials of the retaining wall is based on fixed scenarios. The starting point is that the retaining wall is not reused after its lifespan of 50 years. After the end of the life cycle, concrete rubble is broken into concrete granulate. As coarse aggregate in new concrete, the concrete granulate replaces river gravel.

Process tree of the retaining wall



LCA of the retaining wall with EcoInvent 3.9
Based on the develop process tree for the steel profile, the EcoInvent database is searched to identify the environmental profiles for the corresponding materials and processes. This chapter shows which datasets are used in the different life-modules.

A1-3 Production
This module includes everything needed to procure the raw materials needed in the production of the profile. This includes extraction, treatment, processing, electricity and heat consumption. The raw materials included are shown in Table 56.

Table 48, EcoInvent datasets used for A1-A3, Retaining wall.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Concrete C30/37 CEM III	A1	Concrete C30/37 CEM I		847,67	kg
		Cement, Portland {Europe without Switzerland}| cement production, Portland | Cut-off, U	EcoInvent	320	kg/ m^3 concrete C30/37 CEM III (1m^3=2385,5 kg)
		Gravel, round {RoW}| market for gravel, round | Cut-off, U	EcoInvent	1090	kg/ m^3 concrete C30/37 CEM III (1m^3=2385,5 kg)
		Plasticiser, for concrete, based on sulfonated melamine formaldehyde {GLO}| market for plasticiser, for concrete, based on sulfonated melamine formaldehyde | Cut-off, U	EcoInvent	0,5	kg/ m^3 concrete C30/37 CEM III (1m^3=2385,5 kg)
		Tap water {RER}| market group for tap water | Cut-off, U	EcoInvent	160	kg/ m^3 concrete C30/37 CEM III (1m^3=2385,5 kg)
		Sand {RoW}| market for sand | Cut-off, U	EcoInvent	815	kg/ m^3 concrete C30/37 CEM III (1m^3=2385,5 kg)
Reinforcement steel	A1	Reinforcement steel		22,33	kg
		Steel, unalloyed {GLO}| market for steel, unalloyed | Cut-off, U	EcoInvent	0,2153	kg/ kg reinforcement steel
		Steel, low-alloyed {Europe without Switzerland and Austria}| steel production, electric, low-alloyed | Cut-off, U	EcoInvent	0,2082	kg/ kg reinforcement steel
		Steel, low-alloyed {RoW}| steel production, electric, low-alloyed | Cut-off, U	EcoInvent	0,5765	kg/ kg reinforcement steel

A4 Transport to construction site

The default distance for transport to the construction site is 150km using heavy transport.

Table 49, EcoInvent datasets used for A4, Retaining wall.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Transportation to construction site	A4	Transport, freight, lorry, unspecified {GLO}| market group for transport, freight, lorry, unspecified | Cut-off, U	EcoInvent	131	tkm

A5 Construction process

This module is included the installation of the construction.

Table 50, EcoInvent datasets used for A5, Retaining wall.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Excavator	A5	Diesel, burned in building machine {GLO}| market for diesel, burned in building machine | Cut-off, U (572 MJ/h)	EcoInvent	0,2	h

B Use

During the lifespan of the retaining wall, no parts need to be replaced, and no maintenance is necessary.

C1 Demolition

Table 51, EcoInvent datasets used for C1, Retaining wall.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Excavator	C1	Diesel, burned in building machine {GLO}| market for diesel, burned in building machine | Cut-off, U (572 MJ/h)	EcoInvent	0,2	h

C2 Transport to waste processing facilities or disposal site

Table 52, EcoInvent datasets used for C2, Retaining wall.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Transport to demolition/recycling	C2	Transport, freight, lorry, unspecified {GLO}| market group for transport, freight, lorry, unspecified | Cut-off, U	EcoInvent	43,935	tkm

C3 Waste processing

Table 53, EcoInvent datasets used for C3, retaining wall.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Waste processing concrete	C3	Waste processing concrete		870	kg
		Electricity, low voltage {NL}| market for electricity, low voltage | Cut-off, U	EcoInvent	0,00129	kWh/ kg Waste processing concrete
		Diesel, burned in building machine {GLO}| market for diesel, burned in building machine | Cut-off, U	EcoInvent	0,008616	MJ/ kg Waste processing concrete
		Demolition waste, unspecified	EcoInvent	0,001	kg/ kg Waste processing concrete
		Waste, unspecified	EcoInvent	0,003	kg/ kg Waste processing concrete

C4 Disposal site

Part of the released waste material is disposed of.

Table 54, EcoInvent datasets used for C4, Retaining wall.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Dump concrete	C4	Waste concrete {Europe without Switzerland}| treatment of waste concrete, inert material landfill | Cut-off, U	EcoInvent	8,48	kg
Dump steel	C4	Scrap steel {Europe without Switzerland}| treatment of scrap steel, inert material landfill | Cut-off, U	EcoInvent	1,12	kg

Module D

The Table 55 below contain the data used for module D. shows the amount of material recovery per kg of recycled product.

Table 55, EcoInvent datasets used for D, Retaining wall.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Benefits and charges outside system boundaries: concrete	D	Gravel, round {RoW}| gravel and sand quarry operation | Cut-off, U	EcoInvent	839,2	kg
Benefits and charges outside system boundaries: reinforcement steel	D	Benefits and charges outside system boundaries: reinforcement steel		2,858	kg
		Steel, unalloyed {RER}| steel production, converter, unalloyed | Cut-off, U	EcoInvent	-0,174	kg/ kg Benefits and charges outside system boundaries: reinforcement steel
		Steel, unalloyed {RoW}| steel production, converter, unalloyed | Cut-off, U	EcoInvent	-0,946	kg/ kg Benefits and charges outside system boundaries: reinforcement steel
		Steel, low-alloyed {Europe without Switzerland and Austria}| steel production, electric, low-alloyed | Cut-off, U	EcoInvent	0,174	kg/ kg Benefits and charges outside system boundaries: reinforcement steel
		Steel, low-alloyed {RoW}| steel production, electric, low-alloyed | Cut-off, U	EcoInvent	0,946	kg/ kg Benefits and charges outside system boundaries: reinforcement steel

Calculation procedures

- The LCA calculations are performed in accordance with EN 15804:2012+A2:2019;
- When calculating the energy flows, the fuels and electricity sources used, extraction and transport of the fuels, efficiency of the conversion and distribution of the energy flow are taken into account. The calorific net value (LHV) has also been calculated.
- The rules for allocation for multi-input, -output, recycling and reuse processes from the Assessment Method have been followed for all materials.
- EcoInvent processes are calculated including the infrastructure processes (capital goods)
- EcoInvent processes for landfill are calculated excluding long-term emissions.

6.9.1. Results LCA of the retaining wall with EcoInvent

This paragraph presents the results of the LCA. These are set out in section the environmental profile below for the A2 parameters.

Table 56, Environmental profile based on EcoInvent, retaining wall.

EcoInvent	A1-A3	A4	A5	C1	C2	C3	C4	D	Total
CC total	1,35E+02	1,95E+01	1,14E+01	1,14E+01	6,55E+00	1,30E+00	5,84E-02	-5,09E+00	1,80E+02
CC, fossil	1,35E+02	1,94E+01	1,14E+01	1,14E+01	6,52E+00	1,29E+00	5,83E-02	-5,09E+00	1,80E+02
CC, biogenic	8,99E-02	6,33E-03	1,58E-03	1,58E-03	2,12E-03	1,18E-03	2,55E-05	-6,04E-04	1,02E-01
CC, land use	5,34E-02	6,93E-02	1,28E-03	1,28E-03	2,32E-02	2,92E-04	3,52E-05	-2,79E-03	1,46E-01
OD	9,04E-07	3,46E-07	1,81E-07	1,81E-07	1,16E-07	2,91E-08	1,69E-09	-1,11E-07	1,65E-06
A	3,91E-01	9,31E-02	1,05E-01	1,05E-01	3,12E-02	8,17E-03	4,40E-04	-2,73E-02	7,07E-01
EF	4,25E-03	1,93E-04	4,10E-05	4,10E-05	6,49E-05	2,56E-05	5,69E-07	1,33E-04	4,75E-03
EM	1,06E-01	3,54E-02	4,87E-02	4,87E-02	1,19E-02	3,46E-03	1,68E-04	-7,69E-03	2,47E-01
ET	1,17E+00	3,77E-01	5,30E-01	5,30E-01	1,27E-01	3,79E-02	1,81E-03	-9,79E-02	2,68E+00
POF	3,74E-01	1,29E-01	1,57E-01	1,57E-01	4,32E-02	1,12E-02	6,30E-04	-3,75E-02	8,35E-01
MMU	2,06E-04	6,09E-05	3,96E-06	3,96E-06	2,04E-05	5,24E-06	8,10E-08	-8,38E-06	2,92E-04
FFU	8,16E+02	2,78E+02	1,49E+02	1,49E+02	9,34E+01	1,77E+01	1,45E+00	-5,48E+01	1,45E+03
WU	3,57E+01	1,52E+00	3,20E-01	3,20E-01	5,10E-01	9,71E-02	6,42E-02	-5,39E+01	-1,54E+01
PM	4,83E-06	1,92E-06	2,93E-06	2,93E-06	6,44E-07	1,98E-07	9,61E-09	-4,78E-07	1,30E-05
IR	1,74E+00	1,09E-01	3,04E-02	3,04E-02	3,64E-02	2,02E-02	3,84E-04	-4,54E-02	1,92E+00
FET	4,52E+02	2,06E+02	7,10E+01	7,10E+01	6,89E+01	5,95E+00	6,82E-01	1,21E+01	8,87E+02
HT, cancer	4,84E-07	1,03E-08	3,48E-09	3,48E-09	3,45E-09	4,10E-10	2,48E-11	3,64E-08	5,42E-07
HT, non-cancer	2,12E-06	2,24E-07	2,42E-08	2,42E-08	7,50E-08	8,25E-09	3,11E-10	2,09E-07	2,68E-06
LU	4,55E+02	2,20E+02	1,00E+01	1,00E+01	7,37E+01	2,38E+00	2,89E+00	-5,62E+01	7,18E+02

6.10. Decomposition model Retaining wall for CEMBUREAU

CEMBUREAU is the European Cement Association, representing the cement industry in Europe. Based in Brussels, it acts as the spokesperson for the industry, communicating its views on various issues such as technical, environmental, energy, and sustainability matters to EU institutions and other public authorities. CEMBUREAU integrates Life Cycle Assessment (LCA) to evaluate and improve the environmental impact of cement production.

Datasets from the CEMBUREAU data
The dissemination model is identical to the decimation model of the EcoInvent database. For the cement the environmental profile from CEMBUREAU is used. All other datasets and the model are identical to that of the EcoInvent analysis.

Table 57, Dataset CEMBUREAU used for A1-A3, retaining wall.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Concrete C30/37 CEM III	A1	Concrete C30/37 CEM I		847,67	kg
		EPD Portland Cement (CEM I) produced in Europe	**CEMBUREAU**	320	kg/ m^3 concrete C30/37 CEM I (1m^3=2385,5 kg)
		Gravel, round {RoW}| market for gravel, round | Cut-off, U	EcoInvent	1090	kg/ m^3 concrete C30/37 CEM I (1m^3=2385,5 kg)
		Plasticiser, for concrete, based on sulfonated melamine formaldehyde {GLO}| market for plasticiser, for concrete, based on sulfonated melamine formaldehyde | Cut-off, U	EcoInvent	0,5	kg/ m^3 concrete C30/37 CEM I (1m^3=2385,5 kg)
		Tap water {RER}| market group for tap water | Cut-off, U	EcoInvent	160	kg/ m^3 concrete C30/37 CEM I (1m^3=2385,5 kg)
		Sand {RoW}| market for sand | Cut-off, U	EcoInvent	815	kg/ m^3 concrete C30/37 CEM I (1m^3=2385,5 kg)

6.10.1. Results LCA retaining wall using CEMBUREAU

Table 58, Environmental impact based on CEMBUREAU, retaining wall.

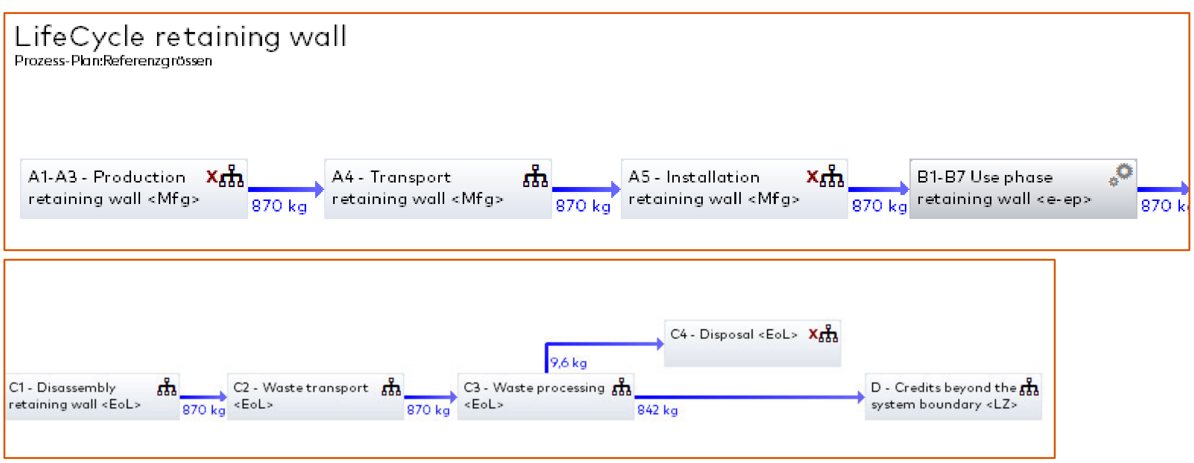
	A1-A3	A4	A5	C1	C2	C3	C4	D	Total
CC total	1,29E+02	1,95E+01	1,14E+01	1,14E+01	6,55E+00	1,30E+00	5,84E-02	-5,09E+00	1,74E+02
CC, fossil	1,29E+02	1,94E+01	1,14E+01	1,14E+01	6,52E+00	1,29E+00	5,83E-02	-5,09E+00	1,74E+02
CC, biogenic	8,07E-02	6,33E-03	1,58E-03	1,58E-03	2,12E-03	1,18E-03	2,55E-05	-6,04E-04	9,29E-02
CC, land use	3,79E-02	6,93E-02	1,28E-03	1,28E-03	2,32E-02	2,92E-04	3,52E-05	-2,79E-03	1,31E-01
OD	5,45E-07	3,46E-07	1,81E-07	1,81E-07	1,16E-07	2,91E-08	1,69E-09	-1,11E-07	1,29E-06
A	3,95E-01	9,31E-02	1,05E-01	1,05E-01	3,12E-02	8,17E-03	4,40E-04	-2,73E-02	7,11E-01
EF	3,03E-03	1,93E-04	4,10E-05	4,10E-05	6,49E-05	2,56E-05	5,69E-07	1,33E-04	3,53E-03
EM	1,07E-01	3,54E-02	4,87E-02	4,87E-02	1,19E-02	3,46E-03	1,68E-04	-7,69E-03	2,47E-01
ET	1,19E+00	3,77E-01	5,30E-01	5,30E-01	1,27E-01	3,79E-02	1,81E-03	-9,79E-02	2,69E+00
POF	4,55E-01	1,29E-01	1,57E-01	1,57E-01	4,32E-02	1,12E-02	6,30E-04	-3,75E-02	9,15E-01
MMU	1,23E-04	6,09E-05	3,96E-06	3,96E-06	2,04E-05	5,24E-06	8,10E-08	-8,38E-06	2,10E-04
FFU	7,93E+02	2,78E+02	1,49E+02	1,49E+02	9,34E+01	1,77E+01	1,45E+00	-5,48E+01	1,43E+03
WU	3,08E+01	1,52E+00	3,20E-01	3,20E-01	5,10E-01	9,71E-02	6,42E-02	-5,39E+01	-2,03E+01
PM	4,96E-06	1,92E-06	2,93E-06	2,93E-06	6,44E-07	1,98E-07	9,61E-09	-4,78E-07	1,31E-05
IR	2,23E+00	1,09E-01	3,04E-02	3,04E-02	3,64E-02	2,02E-02	3,84E-04	-4,54E-02	2,41E+00
FET	4,55E+02	2,20E+02	1,00E+01	1,00E+01	7,37E+01	2,38E+00	2,89E+00	-5,62E+01	7,18E+02
HT, cancer	4,70E-07	1,03E-08	3,48E-09	3,48E-09	3,45E-09	4,10E-10	2,48E-11	3,64E-08	5,28E-07
HT, non-cancer	1,49E-06	2,24E-07	2,42E-08	2,42E-08	7,50E-08	8,25E-09	3,11E-10	2,09E-07	2,06E-06
LU	3,84E+02	2,20E+02	1,00E+01	1,00E+01	7,37E+01	2,38E+00	2,89E+00	-5,62E+01	6,47E+02

6.11. Decomposition model Retaining wall for MLC

As the MLC database is not compatible with the EcoInvent the modelling and calculation are done in the Sphera software. This requires some adjustments to the model, however system boundaries, life cycle stages are made however specifications indicated in the cat 3 data [5] are adopted as closely as possible. With the Sphera software the process for the steel profile and galvanization are modelled separately.

Process trees

Using Sphera the existing EcoInvent model was rebuild as closely as possible. However, in some cases a one-to-one implementation was not feasible, or modelling within LCA FE is typically conducted differently. The developed model for the steel profile is shown in the figure below.



MLC model for the retaining wall
This chapter explains the choice of used MLC datasets for the steel profile.

A1-3: Production

For steel and concrete, suitable ready-made process datasets from the MLC database were used. Therefore, it was not necessary to compile individual components, as was done in the EcoInvent model.

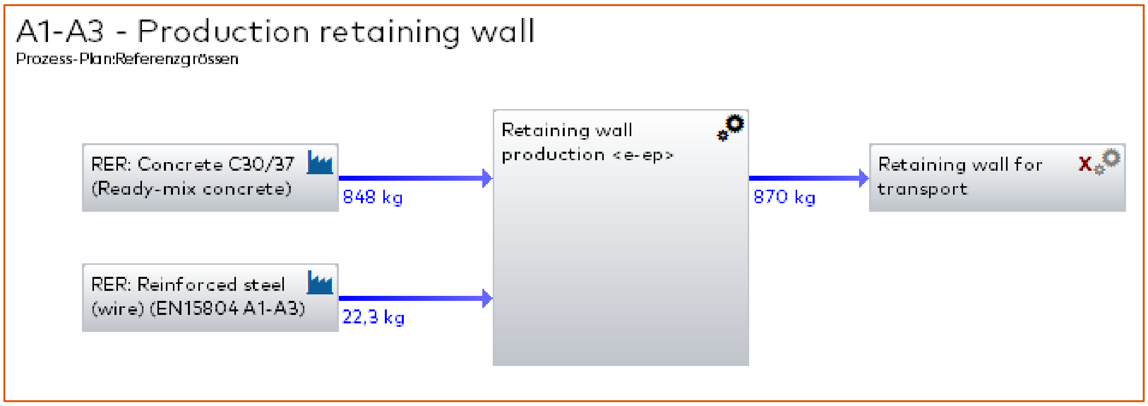
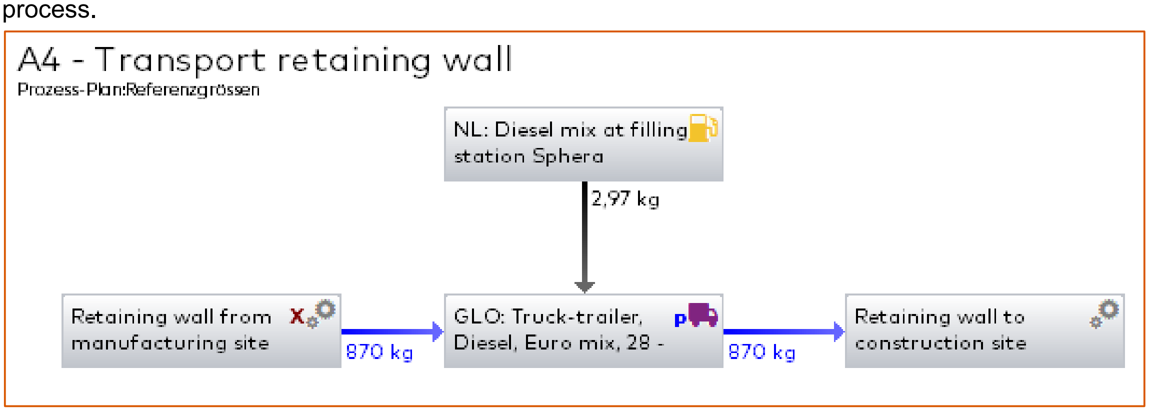


Table 59, MLC datasets used for A1-A3, retaining wall.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Material/process	A1-A3	RER: Concrete C30/37 (Ready-mix concrete) (EN15804 A1-A3)	LCM 2025	22,3	kg
Material/process	A1-A3	RER: Reinforced steel (wire) (EN15804 A1-A3)	LCM 2025	848	kg

A4: Transport

The transport dataset selected from based on the decomposition model average that includes different lorry classes as well as EURO classes.
As the transport is a heavy freight traffic, three corresponding MLC datasets for different truck sizes could be identified of which the middle one was selected. The open fuel input was closed using a suitable diesel process.



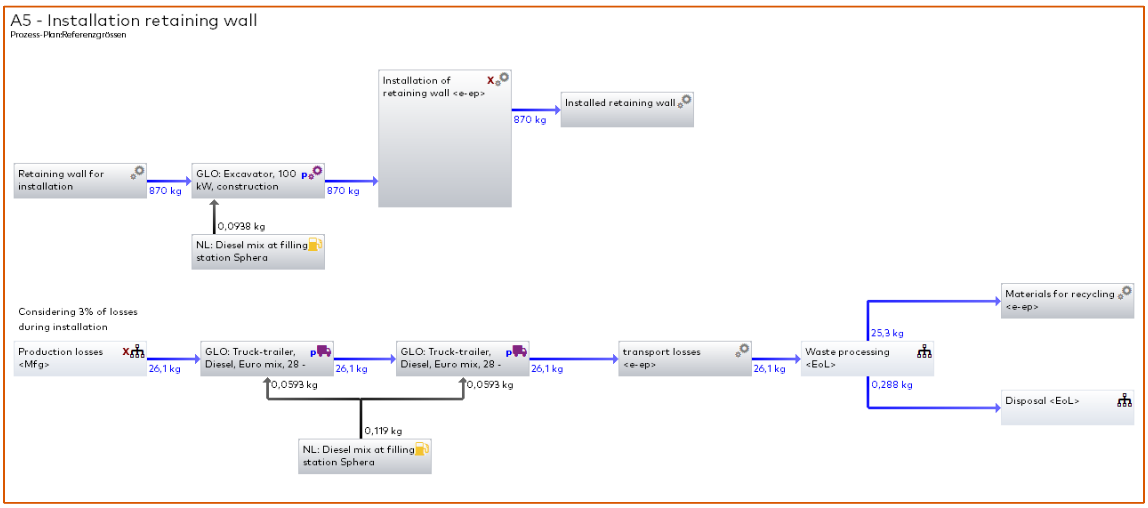
The datasets used in this phase are shown in Table 70.

Table 60, MLC datasets used for A4, retaining wall.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Transport	A4	GLO: Truck-trailer, Diesel, Euro mix, 28 - 34t gross weight	LCM 2025	870	kg
Transport	A4	NL: Diesel mix at filling station	LCM 2025	2,97	kg

A5: Installation

As with the steel profile, an excavator dataset with adapted free parameters was used as a substitute for a crane during installation.



The datasets used in this phase are shown in Table 71.

Table 61, MLC datasets used for A5, retaining wall.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Installation	A5	GLO: Excavator, 100 kW, construction	LCM 2025	870	kg
Installation	A5	NL: Diesel mix at filling station	LCM 2025	2,97	kg

B1-B7

Due to the absence of maintenance and replacement activities, all B-modules are set to zero. This life cycle stage is represented in the model by a placeholder process to ensure completeness of the modular structure.

C1: Deconstruction

The same processes were used for dismantling as for installation.

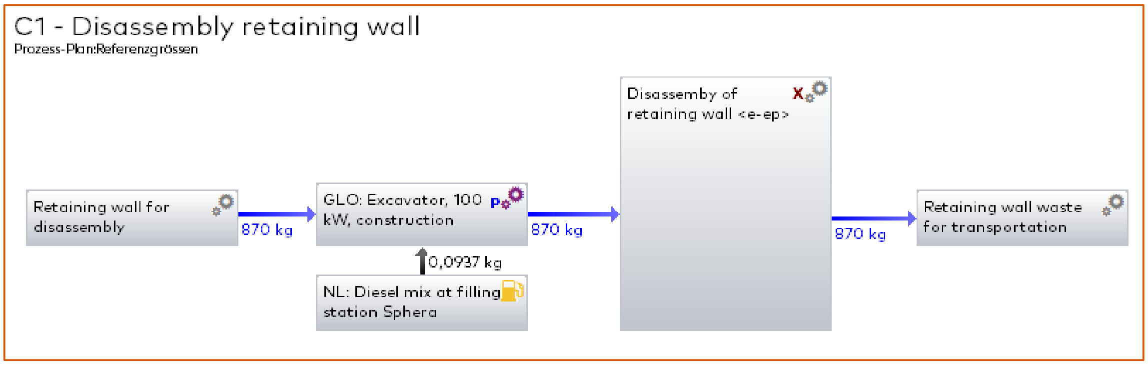


Table 62, MLC datasets used for C1, retaining wall.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Installation	C1	GLO: Excavator, 100 kW, construction	LCM 2025	870	kg
Installation	C1	NL: Diesel mix at filling station	LCM 2025	0,0937	kg

C2: Transport

End-of-life transport was modelled using the same datasets as in module A4.

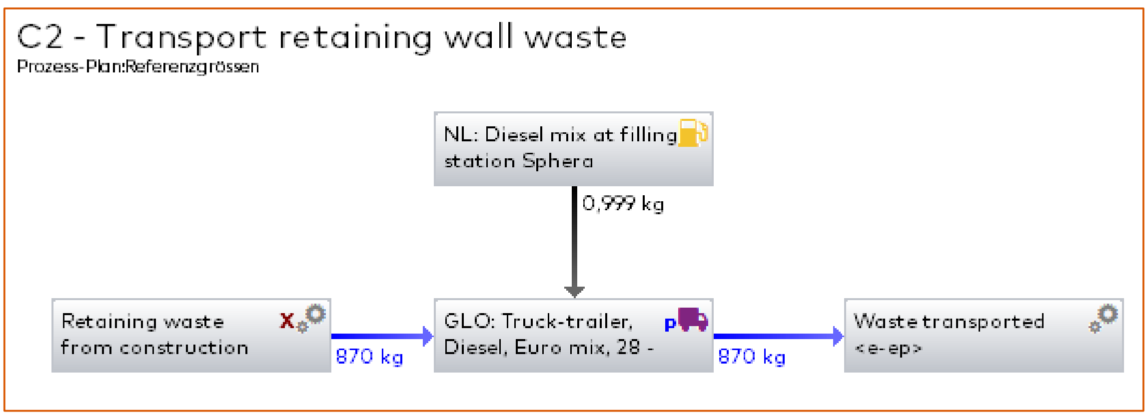
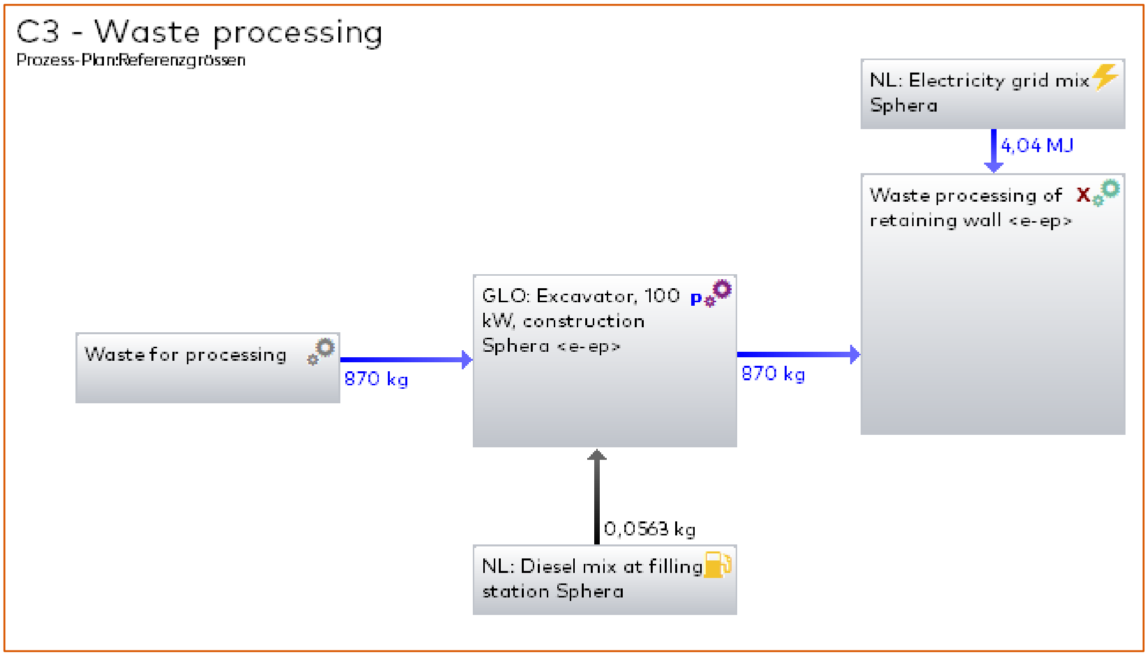


Table 63, MLC datasets used for C2, retaining wall.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Waste Transport	C2	GLO: Truck-trailer, Diesel, Euro mix, 28 - 34t gross weight	LCM 2025	870	kg
Waste Transport	C2	NL: Diesel mix at filling station	LCM 2025	0,99	kg

C3: Waste processing

As an alternative to the EcoInvent 'diesel burned' dataset, the 'excavator dataset' was used. The free parameters have been adjusted following Cat 3 specifications.



The datasets used in this module are shown in Table 74.

Table 64, MLC datasets used for C3, retaining wall.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Waste processing	C3	NL: Electricity grid mix	LCM 2025	4,04	MJ
Waste processing	C3	NL: Diesel mix at filling station	LCM 2025	870	kg
Waste processing	C3	GLO: Excavator, 100 kW, construction	LCM 2025	0,0563	kg

C4: Disposal

Suitable MLC data sets were used to model the deposition of concrete and reinforcing steel.

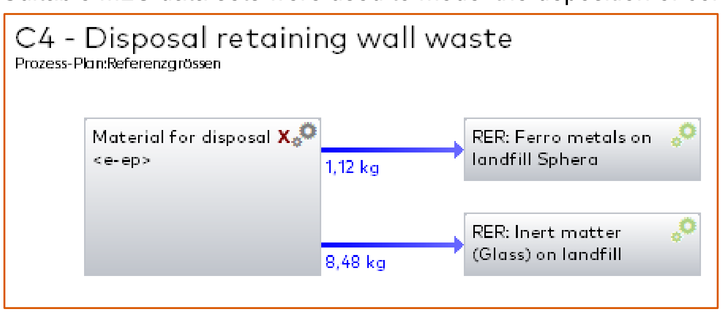
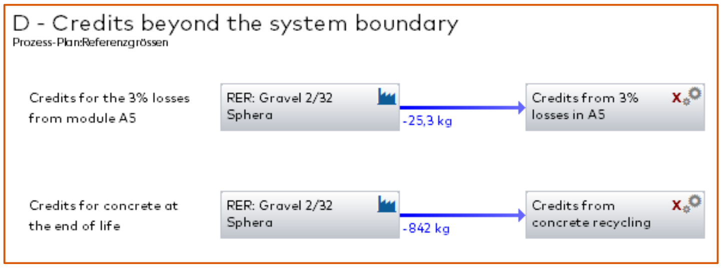


Table 65, MLC datasets used for C4, retaining wall.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Disposal	C4	RER: Inert matter (Glass) on landfill	LCM 2025	8,48	kg
Disposal	C4	RER: Ferro metals on landfill	LCM 2025	1,12	kg

D: Benefits beyond system boundary

Since the MLC dataset for reinforcing steel is based on electric arc furnace (EAF) production, no recycling potential has been calculated. The following dataset was used for concrete recycling, both for the benefits from A5 and those from end of life.



The datasets used in this module are shown in Table 76

Table 66, MLC datasets used for D, retaining wall.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Recycling	D	RER: Gravel 2/32 Sphera	LCM 2025	-867,3	kg

6.11.1. Results LCA of the retaining wall with MLC

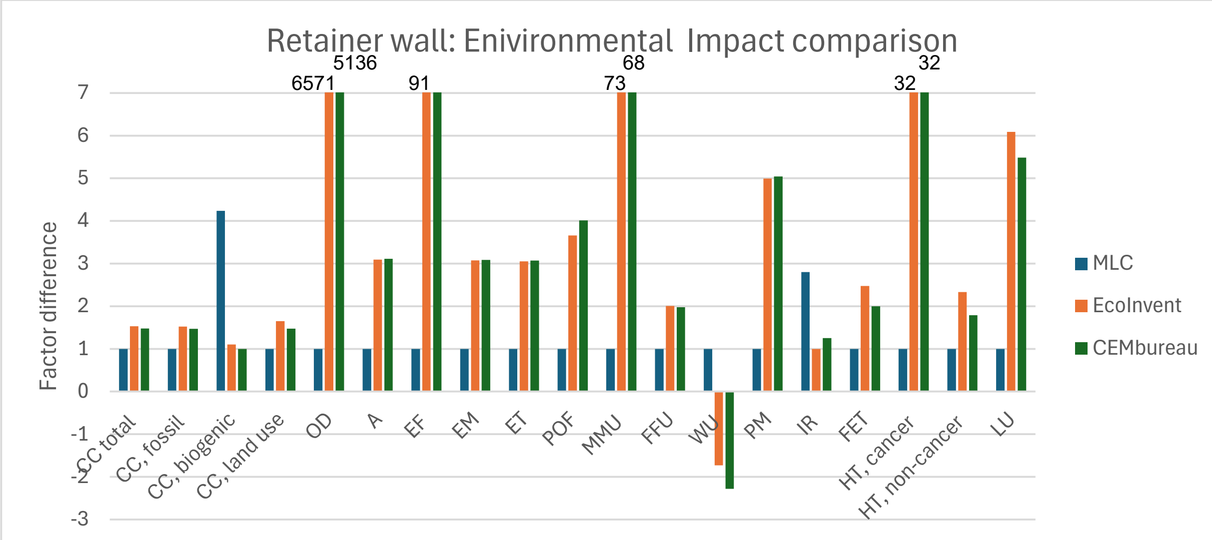
The results of the LCA based on MLC using the Sphera software are presented in the Table 77.

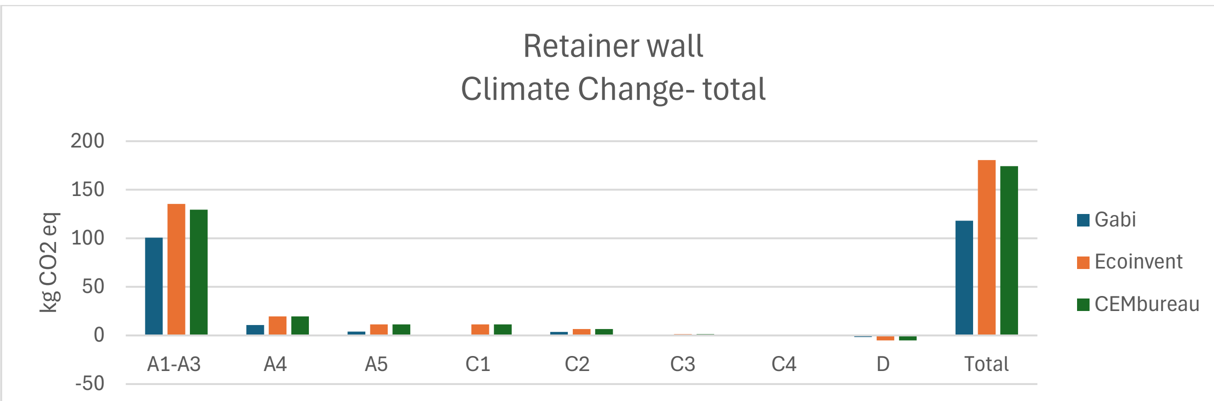
Table 67, Environmental profile based on MLC, Retaining wall.

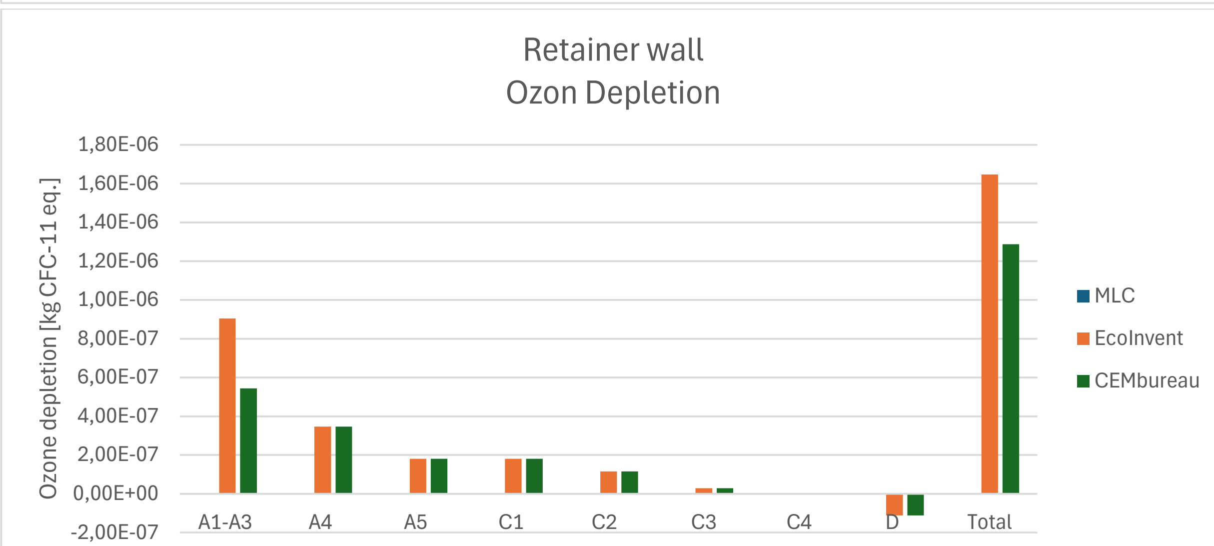
	A1-A3	A4	A5	C1	C2	C3	C4	D	Total
CC total	1,01E+02	1,06E+01	3,81E+00	3,44E-01	3,58E+00	6,16E-01	1,50E-01	-1,69E+00	1,18E+02
CC, fossil	1,00E+02	1,10E+01	3,83E+00	3,54E-01	3,69E+00	6,20E-01	1,50E-01	-1,71E+00	1,18E+02
CC, biogenic	6,17E-02	-3,36E-01	-2,21E-02	-1,03E-02	-1,13E-01	-4,18E-03	-4,44E-04	3,16E-02	-3,93E-01
CC, land use	9,42E-02	4,02E-04	2,89E-03	1,27E-05	1,35E-04	6,74E-04	5,94E-04	-1,03E-02	8,86E-02
OD	2,37E-10	2,90E-12	7,77E-12	9,16E-14	9,77E-13	1,48E-11	4,29E-13	-1,29E-11	2,51E-10
A	1,97E-01	1,80E-02	9,74E-03	3,00E-03	6,08E-03	2,45E-03	1,04E-03	-8,84E-03	2,28E-01
EF	4,94E-05	2,66E-06	1,72E-06	8,41E-08	8,97E-07	1,46E-06	2,22E-07	-4,30E-06	5,21E-05
EM	6,61E-02	7,83E-03	3,84E-03	1,50E-03	2,64E-03	1,13E-03	2,70E-04	-3,19E-03	8,01E-02
ET	7,24E-01	8,60E-02	4,21E-02	1,64E-02	2,90E-02	1,25E-02	2,95E-03	-3,48E-02	8,78E-01
POF	1,92E-01	1,92E-02	1,09E-02	4,21E-03	6,47E-03	2,97E-03	8,13E-04	-8,40E-03	2,28E-01
MMU	3,37E-06	3,92E-07	1,33E-07	1,24E-08	1,32E-07	1,25E-07	9,44E-09	-1,85E-07	3,99E-06
FFU	5,22E+02	1,39E+02	2,59E+01	4,39E+00	4,68E+01	8,46E+00	2,05E+00	-2,57E+01	7,23E+02
WU	8,75E+00	1,39E-02	2,65E-01	4,40E-04	4,69E-03	1,60E-02	1,65E-02	-1,87E-01	8,88E+00
PM	2,68E-06	1,68E-07	1,25E-07	3,64E-08	5,65E-08	2,79E-08	1,28E-08	-5,08E-07	2,60E-06
IR	5,43E+00	1,30E-02	1,65E-01	4,10E-04	4,38E-03	4,05E-02	2,66E-03	-2,75E-01	5,38E+00
FET	2,38E+02	8,96E+01	1,37E+01	2,83E+00	3,02E+01	2,34E+00	1,58E+00	-1,97E+01	3,59E+02
HT, cancer	1,45E-08	1,38E-09	5,40E-10	4,34E-11	4,63E-10	1,56E-10	2,71E-11	-4,38E-10	1,67E-08
HT, non-cancer	1,10E-06	2,23E-08	3,47E-08	7,18E-10	7,52E-09	3,92E-09	9,72E-10	-1,98E-08	1,15E-06
LU	1,17E+02	7,92E-01	3,70E+00	2,50E-02	2,67E-01	4,01E+00	4,75E-01	-8,13E+00	1,18E+02

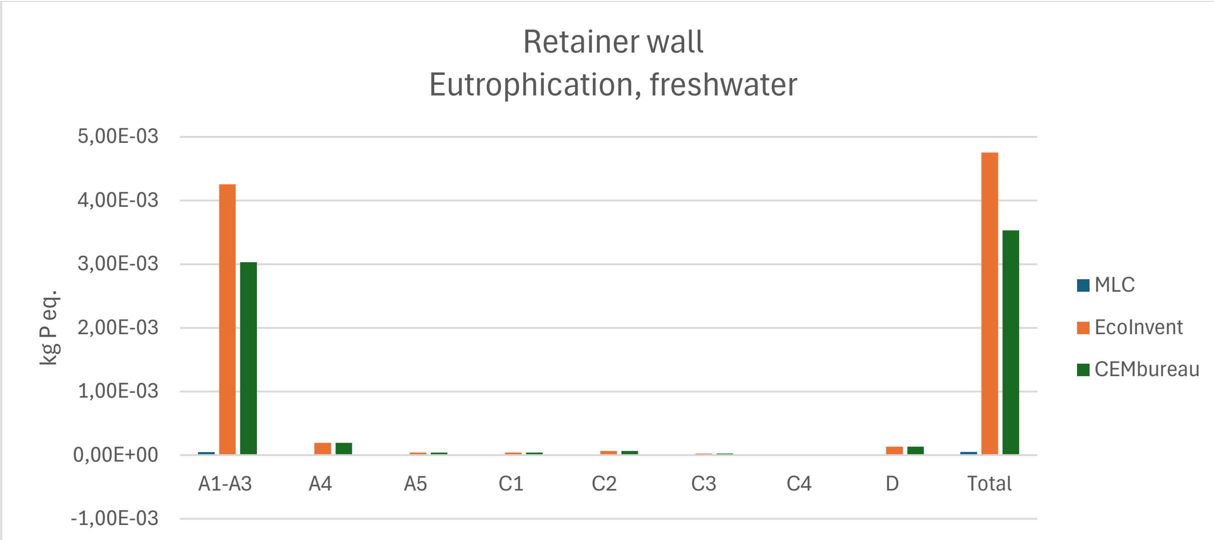
6.12. Comparison Environmental Impact Retaining wall

The figures below illustrate the differences in impact indicators based on the different background databases, as well as the absolute values for the Climate Change$_{total}$ and the two impact indicatorsr showing the greatest variation.


Retainer wall: Enivironmental Impact comparison
Factor difference
MLC
EcoInvent
CEMbureau
6571
5136
91
73
68
32
32
CC total
CC, fossil
CC, biogenic
CC, land use
OD
A
EF
EM
ET
POF
MMU
FFU
WU
PM
IR
FET
HT, cancer
HT, non-cancer
LU


Retainer wall
Climate Change- total
kg CO2 eq
Gabi
Ecoinvent
CEMbureau
A1-A3
A4
A5
C1
C2
C3
C4
D
Total


Retainer wall
Ozon Depletion
Ozone depletion [kg CFC-11 eq.]
MLC
EcoInvent
CEMbureau
A1-A3
A4
A5
C1
C2
C3
C4
D
Total


Retainer wall
Eutrophication, freshwater
5,00E-03
4,00E-03
3,00E-03
2,00E-03
1,00E-03
0,00E+00
-1,00E-03
kg P eq.
A1-A3
A4
A5
C1
C2
C3
C4
D
Total
MLC
EcoInvent
CEMbureau

Appendix E. Wooden bridge

6.13. Decomposition model Wooden bridge for EcoInvent

A bridge is a fixed or movable connection for traffic between two points that are separated fer example by water. For this study a fix bridge with a span of approximately 15 metres was used as model. The guidelines for this study on wooden bridges are based on the LCA Rapportage Categorie 3 data Nationale Milieudatabase, Hoofdstuk 47 Kleine kunstwerken [6]. This document is set up to supplement and improve the category 3 product cards in the National Environmental Database (NMD) by justification for choices made in materials and environmental data.

Reference Unit wooden bridge
The functional unit of the wooden bridge is the total of materials required for 1 bridge, however for this study only the wood has been taken in account. The technical lifespan of the bridge is 30 years.

Stages of the life cycle and system boundaries wooden bridge
The processes that are examined within the LCA are demarcated with so-called system boundaries. The system boundaries determine which modules and processes of the life cycle are included in the LCA. Table , which follows from EN 15804 and the Determination Method, specifies which information must be considered per life cycle module. In this LCA, the environmental impact over the entire life cycle is included.

Table 68, System boundaries for the wooden bridge according to the EN 15804+A2 (X = declared; ND = Not Declared)

Product			**Construction**		**Use**							**End of life**				**Beyond system boundary**
Raw material supply	Transport	Manufacturing	Transport	Construction - Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction demolition	Transport	Waste processing	Disposal	Reuse, recovery, recycling potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	X	X	ND	ND	ND	ND	ND	ND		X	X	X	X	X

Decomposition in materials and process wooden bridge
It has been assumed that the wooden bridge is made of Cross laminated timber with a specific mass of 1 ton/m3. The decomposition of the wooden bridge is based on the decomposition that was also used in the report ‘Comparative LCA study bridges’, carried out by Beco in 2013. This decomposition was then checked by a constructor from Witteveen+Bos for representativeness. The starting point for the small wooden bridge is a bridge with a span of 15m. The bridge weighs a total of 10,693 tonnes.

Production module (A1-3)
The bridge elements are delivered prefabricated. The wearing course and railings have been applied in advance. The starting point is that the railings of the wooden bridge are also made of wood. Transport includes 7000 km of transport by freight ship from the west coast of Africa.

Transport to construction site (A4)
Transport (A4) The transport to the work site over a distance of 150 km by truck has been assumed.

Construction process (A5)
In the construction module, 3% loss is calculated for prefabricated products in accordance with the SBK determination method. This means that 3% extra A1-A4 and C2-D is calculated in this module. This covers, among other things, incorrect orders, breakage and manufacturing errors.

Use module (B1-B5)
The wearing course has a lifespan of approx. 15 years. During the lifespan of the bridge (approx. 30 years), the wearing course is manually maintained once. However, in this study this process is not taken in account.

End of life, waste scenario and benefits and costs outside system boundaries (C3, C4 and D)
At the end of the life, it is assumed that the wooden bridge is processed according to the waste scenario determination method for 'clean' wooden planks and beams. 'Clean' wood means that it has not been treated with a preservative, which is not necessary for hardwood; the wear layer can be removed before burning. 80% is burned, 10% recycled, 5% reused and 5% landfilled. It is assumed that recycling will involve machining.

Synthesis wooden bridge
Short description: Construction profile consisting of steel and zinc preservation.
Application in the work: Construction application in civil engineering
Functional unit: 1 wooden bridge (10,693ton)
Lifespan: 30 years,

Process tree wooden bridge

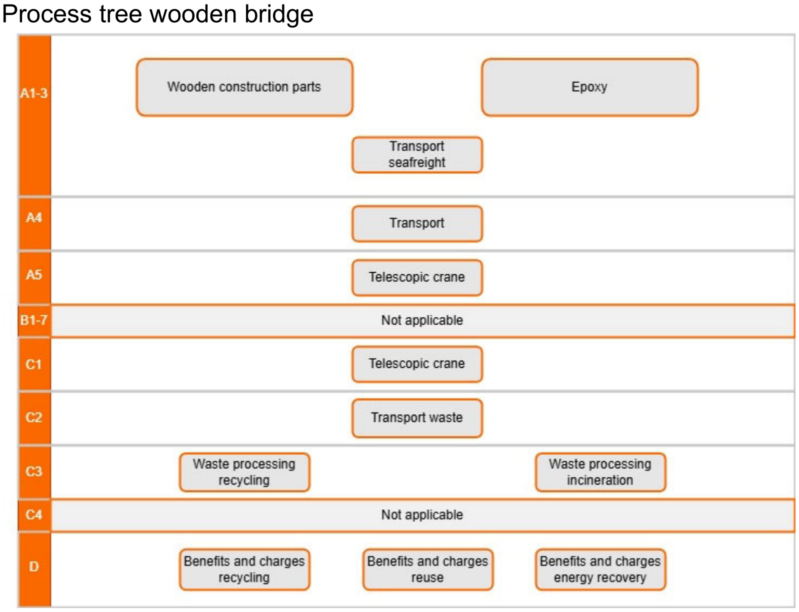


Figure 35, Process tree according to PCR.

LCA wooden bridge with EcoInvent 3.9
Based on the develop process tree for the wooden bridge, the EcoInvent 3.9.1 database is searched to identify the environmental profiles for the corresponding materials and processes. This chapter shows which datasets are used in the different life-modules.

A1-3 Production

This module includes everything needed to procure the raw materials needed in the production of the profile. This includes extraction, treatment, processing, electricity and heat consumption. The raw materials included are shown in Table 69.

Table 69, EcoInvent datasets EcoInvent used for A1-A3, Wooden bridge.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Wooden construction parts	A1	e	EcoInvent	10,2	ton
Transport	A2	Transport, freight, sea, container ship {GLO}| market for transport, freight, sea, container ship | Cut-off, U	EcoInvent	71400	tkm
Epoxy	A1-A3	Epoxy		113	kg
		Epoxy resin, liquid {RER}| epoxy resin production, liquid | Cut-off, U	EcoInvent	0,5	kg/ kg Epoxy
		Fatty alcohol {RER}| fatty alcohol production, petrochemical | Cut-off, U	EcoInvent	0,45	kg/ kg Epoxy
		Ethylenediamine {RER}| market for ethylenediamine | Cut-off, U	EcoInvent	0,05	kg/ kg Epoxy
		Chemical factory, organics {RER}| chemical factory construction, organics | Cut-off, U	EcoInvent	4E-10	p/ kg Epoxy
		Electricity, medium voltage {ENTSO-E}| market group for electricity, medium voltage | Cut-off, U	EcoInvent	0,164	kWh/ kg Epoxy
		Heat, district or industrial, other than natural gas {Europe without Switzerland}| heat production, light fuel oil, at industrial furnace 1MW | Cut-off, U	EcoInvent	0,363	MJ/ kg Epoxy

A4 Transport to construction site

The distance for transport to the construction site is 150km using heavy transport.

Table 70, EcoInvent datasets used for A4, Wooden bridge.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Transport	A4	Transport, freight, lorry, unspecified {GLO}| market group for transport, freight, lorry, unspecified | Cut-off, U	EcoInvent	1604	tkm

A5 Construction process

This module is included the installation of the construction.

Table 71, EcoInvent datasets used for A5, Wooden Bridge

Material/process	Module	Environmental profile	Source	Quantity	Unit
Telescopic crane	A5	Diesel, burned in building machine {GLO}| market for diesel, burned in building machine | Cut-off, U (263 kWh/h)	EcoInvent	16	h

B Use

Not declared

C1 Demolition

Table 72, EcoInvent datasets used for C1, Wooden bridge.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Telescopic crane	C1	Diesel, burned in building machine {GLO}| market for diesel, burned in building machine | Cut-off, U (263 kWh/h)	EcoInvent	16	h

C2 Transport to waste processing facilities or disposal site

Table 73, EcoInvent datasets used for C2, Wooden bridge.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Transport	C2	Transport, freight, lorry, unspecified {GLO}| market group for transport, freight, lorry, unspecified | Cut-off, U	EcoInvent	942,6	tkm

C3 Waste processing

Table 74, EcoInvent datasets used for C3, Wooden bridge.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Waste treatment - Recycling Wood	C3	Wood chipping, industrial residual wood, stationary electric chipper {GLO}| market for wood chipping, industrial residual wood, stationary electric chipper | Cut-off, U	EcoInvent	1,02	ton
Waste treatment - AVI Wood	C3	Waste wood, untreated {CH}| treatment of waste wood, untreated, municipal incineration | Cut-off, U	EcoInvent	8,16	ton

Module D

Table 75, EcoInvent datasets used for D, Wooden bridge.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Benefits and charges outside system boundaries - Reuse wood	D	Benefits and charges outside system boundaries - Reuse wood		0,51	ton
		Sawnwood, azobe, dried (u=15%), planed {RoW}| market for sawnwood, azobe, dried (u=15%), planed | Cut-off, U	EcoInvent	0,00087	m3/ kg Benefits and charges outside system boundaries - Reuse wood
		Transport, freight, sea, container ship {GLO}| market for transport, freight, sea, container ship | Cut-off, U	EcoInvent	7	tkm/ kg Benefits and charges outside system boundaries - Reuse wood
Benefits and charges outside system boundaries - Recycling wood	D	Wood chips, dry, measured as dry mass {RER}| three and five layered board production | Cut-off, U	EcoInvent	1,02	ton

		Benefits and burdens beyond system boundaries - Energy recovery burning wood		11420	MJ
		Electricity, high voltage {NL}| heat and power co-generation, wood chips, 6667 kW, state-of-the-art 2014 | Cut-off, U	EcoInvent	0,18	kWh/ MJ Benefits and burdens beyond system boundaries - Energy recovery burning wood
Benefits and burdens beyond system boundaries - Energy recovery burning wood	D	Heat, district or industrial, other than natural gas {NL}| heat and power co-generation, wood chips, 6667 kW, state-of-the-art 2014 | Cut-off, U	EcoInvent	0,31	MJ/ MJ Benefits and burdens beyond system boundaries - Energy recovery burning wood

Calculation procedures

- The environmental interventions have been determined using the methods described in the Determination Method. The LCA calculations are performed in accordance with EN 15804:2012+A2:2019;
- When calculating the energy flows, the fuels and electricity sources used, extraction and transport of the fuels, efficiency of the conversion and distribution of the energy flow are taken into account. The calorific net value (LHV) has also been calculated.
- The rules for allocation for multi-input, -output, recycling and reuse processes from the Assessment Method have been followed for all materials.
- EcoInvent processes are calculated including the infrastructure processes (capital goods)
- EcoInvent processes for landfill are calculated excluding long-term emissions.

6.13.1. Results LCA wooden bridge using EcoInvent

This paragraph presents the results of the LCA. These are set out in section the environmental profile below for the parameters A2 for the environmental impact united.

Table 76, Environmental profile based on EcoInvent, Wooden bridge.

EcoInvent	A1-A3	A4	A5	C1	C2	C3	D	Total
CC total	-1,56E+04	2,39E+02	1,50E+03	1,50E+03	1,40E+02	1,83E+04	-3,72E+02	5,72E+03
CC, fossil	2,56E+03	2,38E+02	1,50E+03	1,50E+03	1,40E+02	9,46E+01	-3,39E+02	5,70E+03
CC, biogenic	-1,82E+04	7,76E-02	2,09E-01	2,09E-01	4,56E-02	1,82E+04	-3,11E+01	1,41E+01
CC, land use	1,08E+01	8,49E-01	1,69E-01	1,69E-01	4,99E-01	5,72E-02	-2,04E+00	1,05E+01
OD	8,04E-05	4,24E-06	2,39E-05	2,39E-05	2,49E-06	3,95E-06	-2,25E-05	1,16E-04
A	3,32E+01	1,14E+00	1,39E+01	1,39E+01	6,70E-01	2,62E+00	-7,45E+00	5,81E+01
EF	1,82E-01	2,37E-03	5,43E-03	5,43E-03	1,39E-03	2,31E-03	-3,12E-02	1,68E-01
EM	8,93E+00	4,33E-01	6,45E+00	6,45E+00	2,55E-01	1,23E+00	-2,11E+00	2,16E+01
ET	9,81E+01	4,62E+00	7,02E+01	7,02E+01	2,72E+00	1,39E+01	-3,07E+01	2,29E+02
POF	2,98E+01	1,58E+00	2,08E+01	2,08E+01	9,27E-01	3,70E+00	-6,49E+00	7,11E+01
MMU	1,01E-02	7,46E-04	5,25E-04	5,25E-04	4,38E-04	2,09E-04	-7,42E-04	1,18E-02
FFU	4,20E+04	3,41E+03	1,97E+04	1,97E+04	2,00E+03	1,07E+03	-4,40E+03	8,35E+04
WU	7,62E+02	1,86E+01	4,24E+01	4,24E+01	1,09E+01	2,87E+01	-4,35E+01	8,62E+02
PM	5,61E-04	2,35E-05	3,88E-04	3,88E-04	1,38E-05	2,18E-05	-1,02E-04	1,29E-03
IR	1,02E+02	1,33E+00	4,02E+00	4,02E+00	7,82E-01	1,81E+00	-7,77E+00	1,06E+02
FET	2,57E+04	2,52E+03	9,41E+03	9,41E+03	1,48E+03	1,07E+03	-2,91E+03	4,67E+04
HT, cancer	4,03E-06	1,26E-07	4,60E-07	4,60E-07	7,41E-08	2,42E-06	-6,20E-07	6,95E-06
HT, non-cancer	2,55E-05	2,74E-06	3,20E-06	3,20E-06	1,61E-06	4,90E-06	-1,43E-05	2,69E-05
LU	1,15E+06	2,69E+03	1,33E+03	1,33E+03	1,58E+03	5,42E+02	-3,04E+05	8,50E+05

6.14. LCA wooden bridge with EPD data

For Cross Laminated Timber no dataset was found in the Industry2.0 database. Therefore, the data of a producer was used to generate a third environmental profile for the wooden bridge. The EPD used was generated based on producer specific data [7] verified and published in Eco Platform. The EPD was prepared according to the specifications of EN 15804+A2 and the MLC 2023.2 background databases. As such this data is available of the calculation of the environmental cost of the wooden bridge.

6.14.1. Data sets steel profile from EPD

The dissemination model is identical to the decimation model of the EcoInvent database. For the production process the environmental profile from a commercially available wood is used [3]. This dataset replaces the EcoInvent dataset for wood in A1, all other datasets and the model are identical to the analysis based on the EcoInvent database.

Table 77, EPD dataset used for A1, Wooden bridge

Material/process	Module	Environmental profile	Source	Quantity	Unit
Wooden construction parts	A1	SJABLOON NMD 3.10 Hout Mayr-Melnhof Holz Holding AG 470 kg/m^3	EPD Brettsperrholz Mayr-Melnhof Holz Holding AG	10,2	ton

6.14.2. Results LCA wooden bridge using EPD

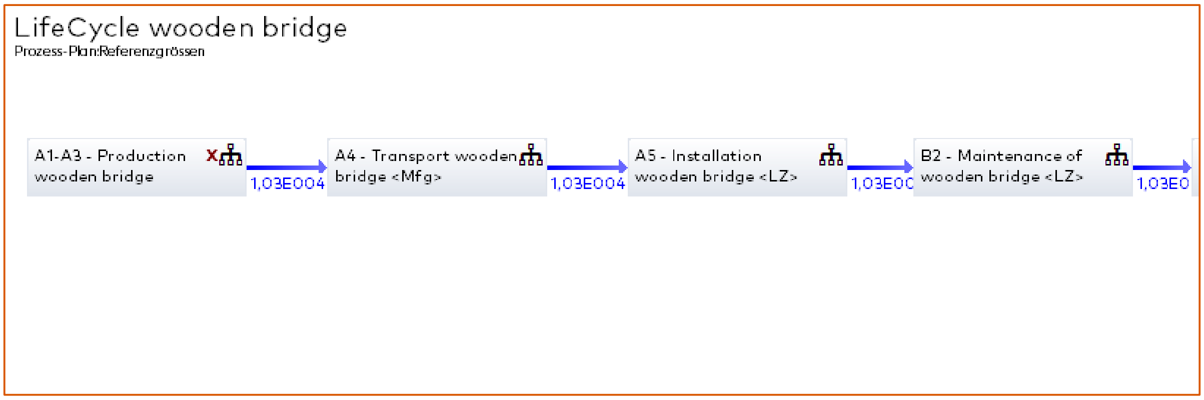
Table 78, Environmental profile based EPD, Wooden bridge

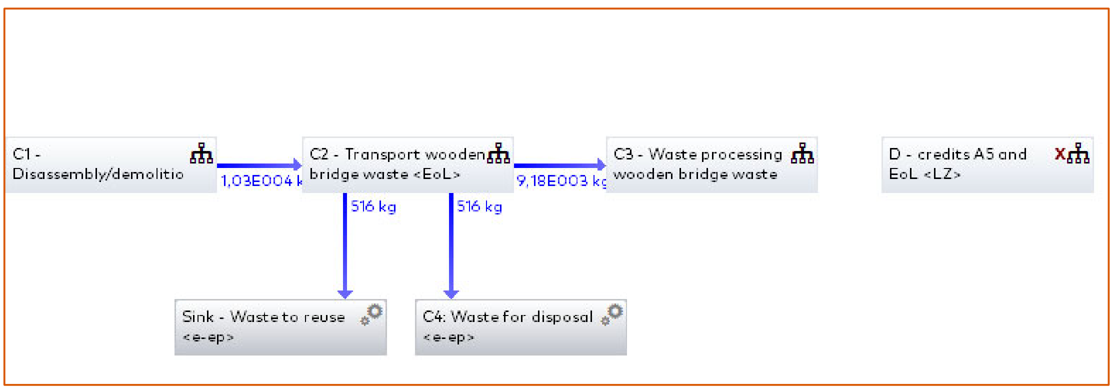
	A1-A3	A4	A5	C1	C2	C3	D	Total
CC total	-2,93E+04	2,39E+02	1,50E+03	1,50E+03	1,40E+02	1,67E+04	-3,72E+02	-9,62E+03
CC, fossil	3,71E+03	2,38E+02	1,50E+03	1,50E+03	1,40E+02	9,46E+01	-3,39E+02	6,85E+03
CC, biogenic	-3,31E+04	-1,66E+04	7,76E-02	2,09E-01	2,09E-01	4,56E-02	1,66E+04	7,52E+00
CC, land use	9,57E+00	8,49E-01	1,69E-01	1,69E-01	4,99E-01	5,72E-02	-2,04E+00	9,27E+00
OD	5,48E-05	4,24E-06	2,39E-05	2,39E-05	2,49E-06	3,95E-06	-2,25E-05	9,08E-05
A	2,39E+01	1,14E+00	1,39E+01	1,39E+01	6,70E-01	2,62E+00	-7,45E+00	4,87E+01
EF	6,08E-02	2,37E-03	5,43E-03	5,43E-03	1,39E-03	2,31E-03	-3,12E-02	4,66E-02
EM	1,30E+01	4,33E-01	6,45E+00	6,45E+00	2,55E-01	1,23E+00	-2,11E+00	2,57E+01
ET	1,37E+02	4,62E+00	7,02E+01	7,02E+01	2,72E+00	1,39E+01	-3,07E+01	2,68E+02
POF	3,97E+01	1,58E+00	2,08E+01	2,08E+01	9,27E-01	3,70E+00	-6,49E+00	8,10E+01
MMU	5,02E-03	7,46E-04	5,25E-04	5,25E-04	4,38E-04	2,09E-04	-7,42E-04	6,72E-03
FFU	1,91E+04	3,41E+03	1,97E+04	1,97E+04	2,00E+03	1,07E+03	-4,40E+03	6,05E+04
WU	6,49E+02	1,86E+01	4,24E+01	4,24E+01	1,09E+01	2,87E+01	-4,35E+01	7,48E+02
PM	4,05E-05	2,35E-05	3,88E-04	3,88E-04	1,38E-05	2,18E-05	-1,02E-04	7,74E-04
IR	1,37E+01	1,33E+00	4,02E+00	4,02E+00	7,82E-01	1,81E+00	-7,77E+00	1,79E+01
FET	1,68E+04	2,52E+03	9,41E+03	9,41E+03	1,48E+03	1,14E+03	-2,91E+03	3,79E+04
HT, cancer	7,45E-07	1,26E-07	4,60E-07	4,60E-07	7,41E-08	2,42E-06	-6,20E-07	3,66E-06
HT, non-cancer	8,05E-06	2,74E-06	3,20E-06	3,20E-06	1,61E-06	4,90E-06	-1,43E-05	9,39E-06
LU	1,80E+03	2,69E+03	1,33E+03	1,33E+03	1,58E+03	5,42E+02	-3,04E+05	-2,94E+05

6.15. Decomposition model Wooden bridge for MLC

As the MLC database is not compatible with the Simapro software the modelling and calculation are done in the Sphera software. This requires some adjustments to the decomposition model, however system boundaries, life cycle stages are made however specifications indicated in the cat 3 data [1] are adopted as closely as possible. With the Sphera software the process for the steel profile and galvanization are modelled separately

Process trees
Using Sphera the existing decomposition model was rebuilt as closely as possible. However, in some cases a one-to-one implementation was not feasible, or modelling within LCA FE is typically conducted differently. The developed model for the wooden bridge is shown in .

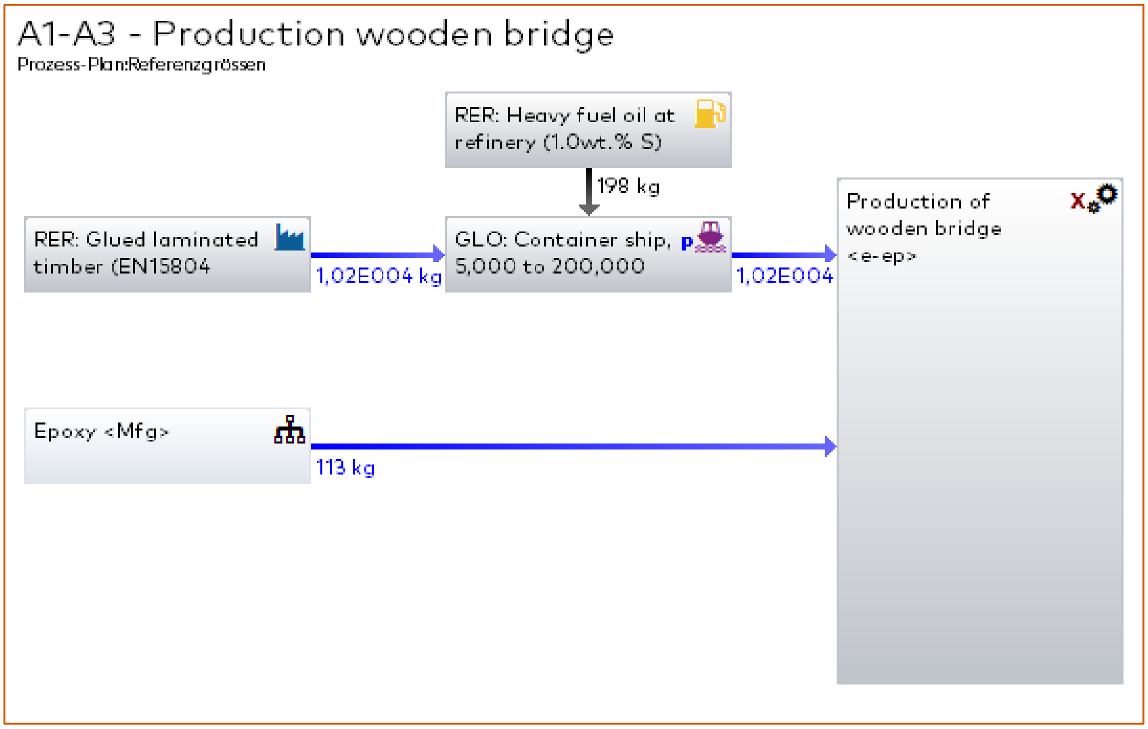




MLC model for wooden bridge
This chapter explains the choice of used MLC datasets for the wooden bridge.

A1-3: Production

The MLC database used does not contain any data specifically for outdoor use. Therefore, the following dataset was selected.
A suitable transport process with the appropriate fuel was used for transport by ship.
The epoxy dataset was reproduced in MLC to the extent possible. A replacement for the dataset ‘Chemical factory, organics {RER}| construction’ could not be identified. However, including production infrastructure in product life cycle assessments is uncommon, as it generally falls outside the system boundaries.
No dataset for ethylenediamine was found in the MLC 2025 Core database. This dataset was modelled according to the documentation in EcoInvent.



All inputs were considered, except for the chemical factory (see above).

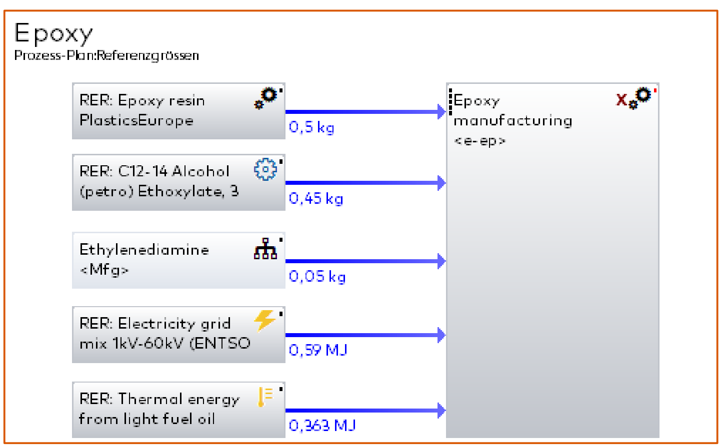


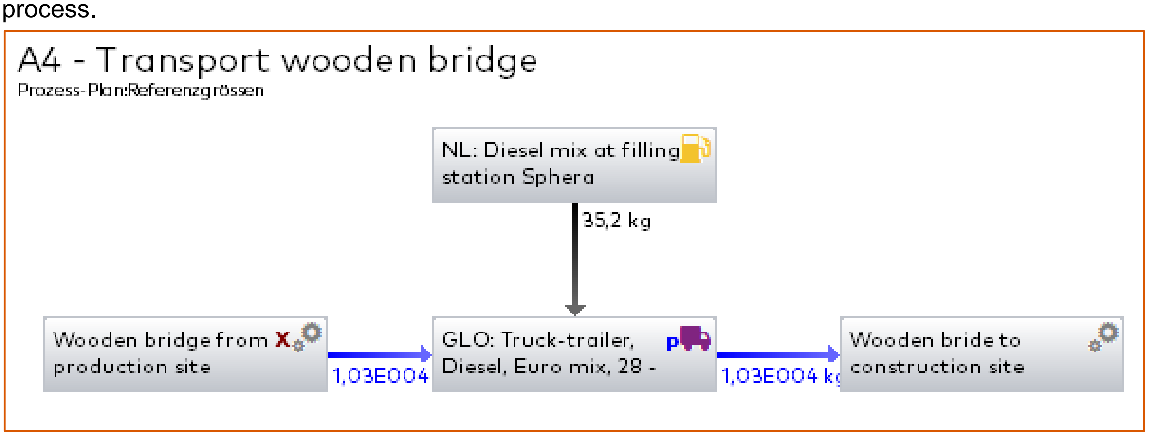
Table 79, MLC datasets used for A1-A3, Wooden bridge.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Material	A1	RER: Glued laminated timber (EN15804 A1-A3)	MLC 2025	1,02E4	kg
Transport	A2	GLO: Container ship, 5,000 to 200,000 dwt payload capacity, deep sea	MLC 2025	1,02E4	kg
Transport	A2	RER: Heavy fuel oil at refinery (1.0wt.% S	MLC 2025	198	kg
Material	A2	Epoxy resin; technology mix	MLC 2025	0,5	kg
Material	A2	RER: C12-14 Alcohol (petro) Ethoxylate, 3 moles EO	MLC 2025	0,45	kg

Material	A2	RER: Electricity grid mix 1kV-60kV	MLC 2025	0,59	MJ
Material	A2	RER: Thermal energy from light fuel oil	MLC 2025	0,363	MJ
Ethylenediamine (customised)	A3	RER: Ammonia (NH3) production mix, without CO2 recovery (carbon dioxide emissions to air)	MLC 2025		
	A3	RER: Residual gid mix 1kV-60kV	MLC 2025		
	A3	RER: Thermal energy mix	MLC 2025		
	A3	RER: Ethylene oxide	MLC 2025		
	A3	RER: Dichloroethane (ethylene dichloride)	MLC 2025		
	A3	RER: Nitrogen (liquid)	MLC 2025		
	A3	RER: Sodium hydroxide mix (50%)	MLC 2025		
	A3	RER: Tap water from surface water	MLC 2025		
	A3	RER: Electricity grid mix 1kV-60kV	MLC 2025		
	A3	RER: Thermal energy from light fuel oil	MLC 2025		

A4: Transport

As the transport is a heavy freight traffic, three corresponding MLC datasets for different truck sizes could be identified of which the middle one was selected. The open fuel input was closed using a suitable diesel process.



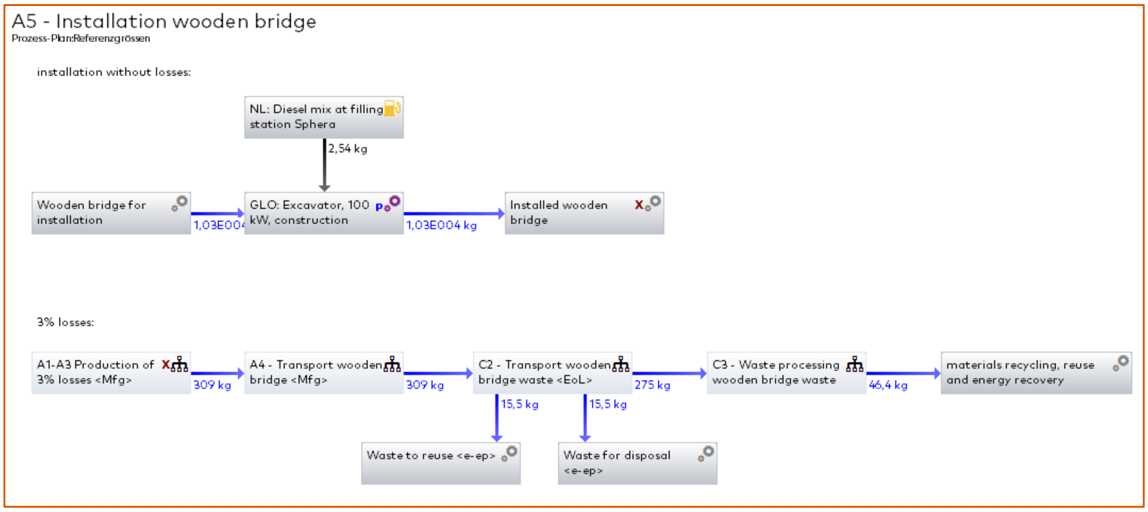
The datasets used in this module are shown in Table 93.

Table 80, MLC datasets used for A4, Wooden bridge.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Transport	A4	GLO: Truck-trailer, Diesel, Euro mix, 28 - 34t gross weight	MLC 2025	1,03 E4	kg
Transport	A4	NL: Diesel mix at filling station	MLC 2025	35,2	kg

A5: Installation

An excavator dataset with adapted free parameters was used as a substitute for a crane during installation.



The datasets used in this module are shown in Table 94.

Table 81, MLC datasets used for AA, Wooden bridge.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Construction	A5	GLO: Excavator, 100 kW, construction	MLC 2025	1,03 E4	kg
Construction	A5	NL: Diesel mix at filling station	MLC 2025	2,54	kg

The losses were modelled based on the same data used for the life cycle of the bridge.

B1-B7

No efforts were accounted for the manual maintenance.

C1: Deconstruction

The same processes were used for dismantling as for construction.

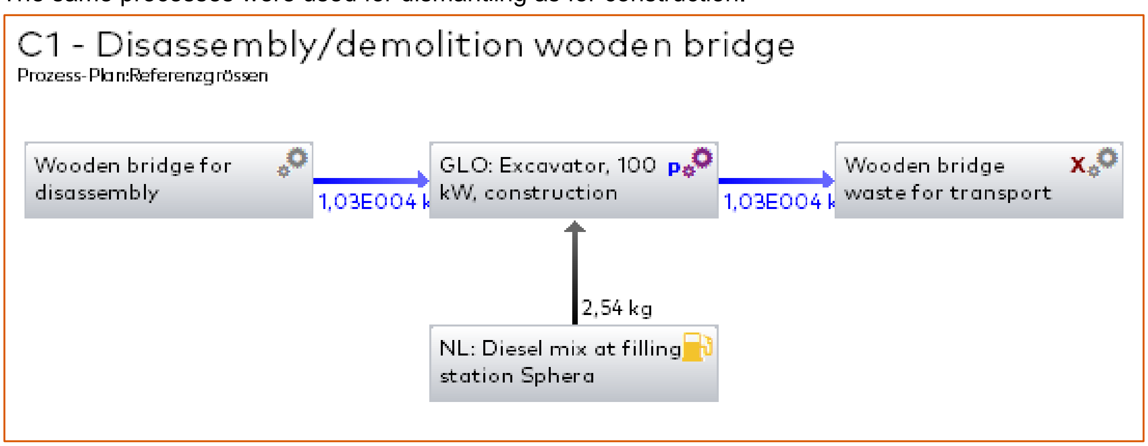


Table 82, MLC datasets used for C1, Wooden bridge.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Disassembly	C1	GLO: Excavator, 100 kW, construction	MLC 2025	1,03 E4	kg
Disassembly	C1	NL: Diesel mix at filling station	MLC 2025	2,54	kg

C2: Transport

End-of-life transport was modelled using the same datasets as in module A4.

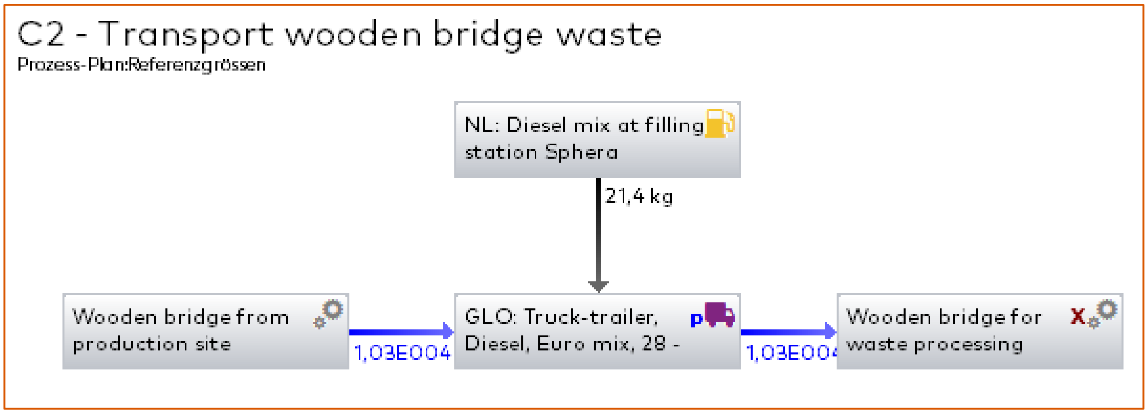


Table 83, MLC datasets used for C2, Wooden bridge.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Transport waste	C2	GLO: Truck-trailer, Diesel, Euro mix, 28 - 34t gross weight	MLC 2025	1,03 E4	kg
Transport waste	C2	NL: Diesel mix at filling station	MLC 2025	35,2	kg

C3: Waste processing

The end-of-life module was modelled in accordance with the specifications provided by the model.

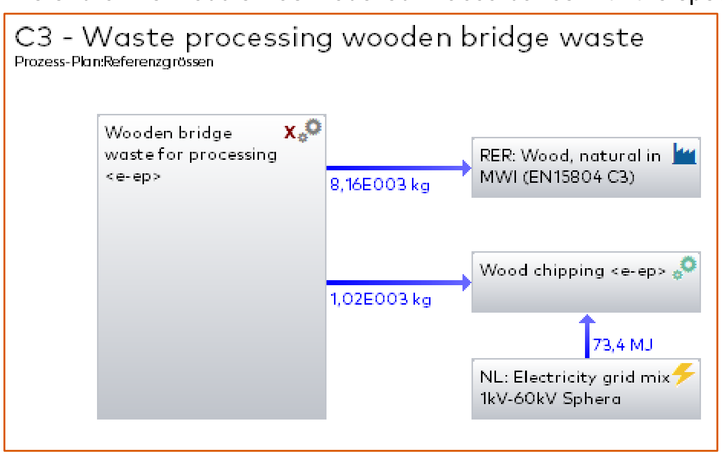


Table 84, MLC datasets used for C3, Wooden bridge.

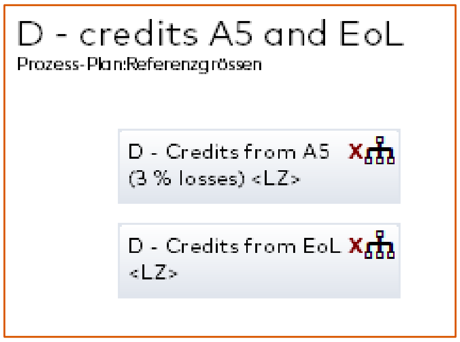
Material/process	Module	Environmental profile	Source	Quantity	Unit
Waste processing	C3	RER: Wood, natural in MWI (EN15804 C3)	MLC 2025	8,16 E3	kg
Waste processing	C3	NL: Electricity grid mix 1kV-60kV	MLC 2025	73,4	MJ

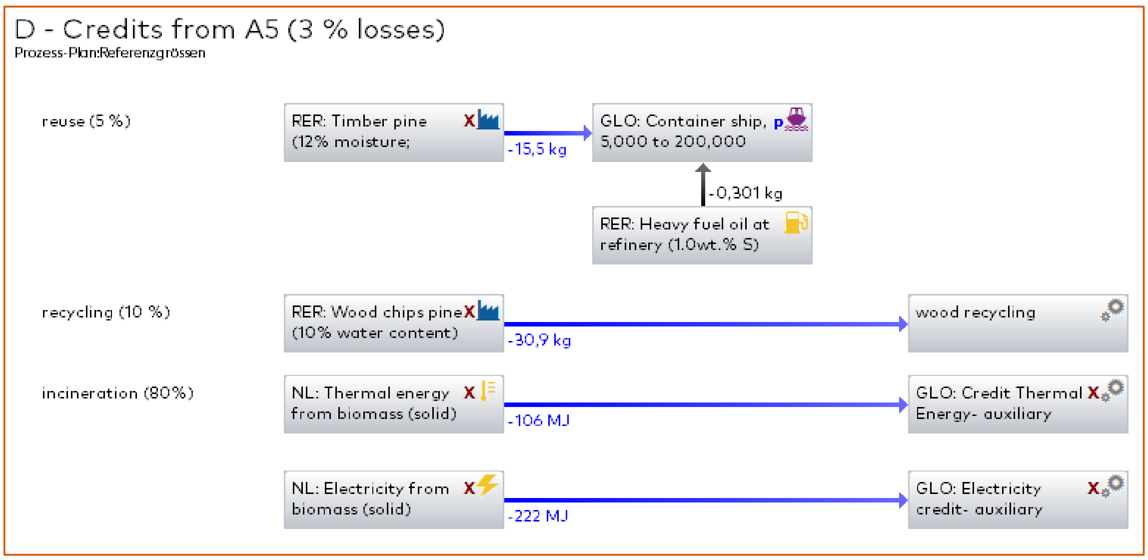
C4: Disposal

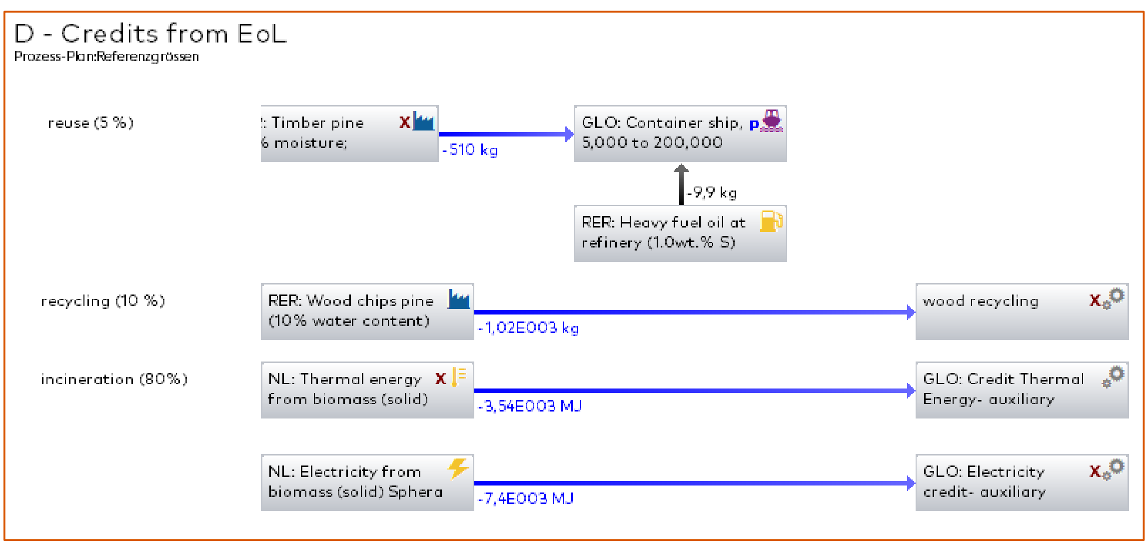
In accordance with the Cat 3 data, disposal was not considered.

D: Benefits beyond system boundary

The benefits beyond system boundaries result from the credits from Module A5 and from dismantling the bridge structure at the end of its service life.







As there was no matching dataset for wood chips Wood chips**:** All suitable wood datasets in the MLC 2025 Core database were compared to the selected SGS EcoInvent dataset. The MLC dataset was chosen based on the similarity with the EcoInvent dataset.

Electricity and thermal energy: No dataset on the energy and heat produced by burning wood chips was found in the MLC database. Instead, the datasets “NL: Electricity from biomass (solid)” and “NL: Thermal energy from biomass (solid)” were chosen based on the geography of the EcoInvent dataset.
Azobe wood: The MLC database used lists only four types of wood: spruce, beech, oak, and pine. We compared the LCA values of these four MLC datasets with those of the corresponding EcoInvent dataset and selected the MLC dataset whose GWP value was closest to that of the EcoInvent dataset.

Table 85, MLC datasets used for D, wooden bridge.

Material/process	Module	Environmental profile	Source	Quantity	Unit
Recycling	D	RER: Wood chips pine (10% water content) (Scandinavian silviculture)	MLC 2025	-15,5	kg
Recycling	D	NL: Thermal energy from biomass (solid)	MLC 2025	-3,4 E3	MJ
Recycling	D	NL: Electricity from biomass (solid)	MLC 2025	-7,4 E3	MJ
Recycling	D	RER: Timber pine (12% moisture; 10.7% H2O content) (EN15804 A1-A3) 1kg	MLC 2025	-1,02 E3	Kg
Recycling	D	GLO: Container ship, 5,000 to 200,000 dwt payload capacity, deep sea	MLC 2025	-525	kg
Recycling	D	RER: Heavy fuel oil at refinery (1.0wt.% S)	MLC 2025	-10,2	kg

6.15.1. Results LCA wooden bridge using MLC

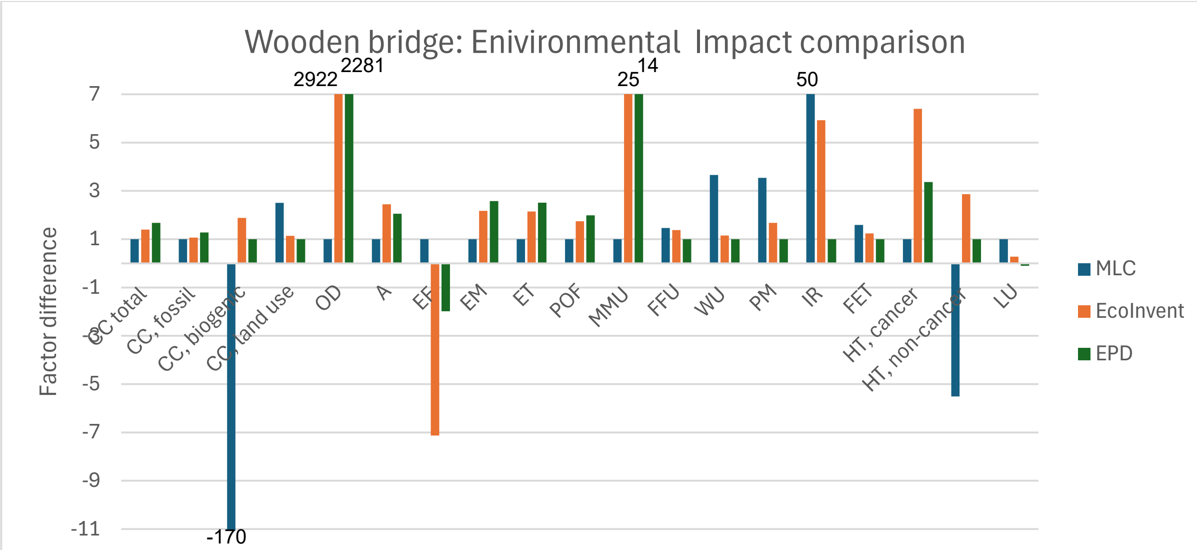
The results of the LCA based on MLC using the Sphera software are presented in Table 86.

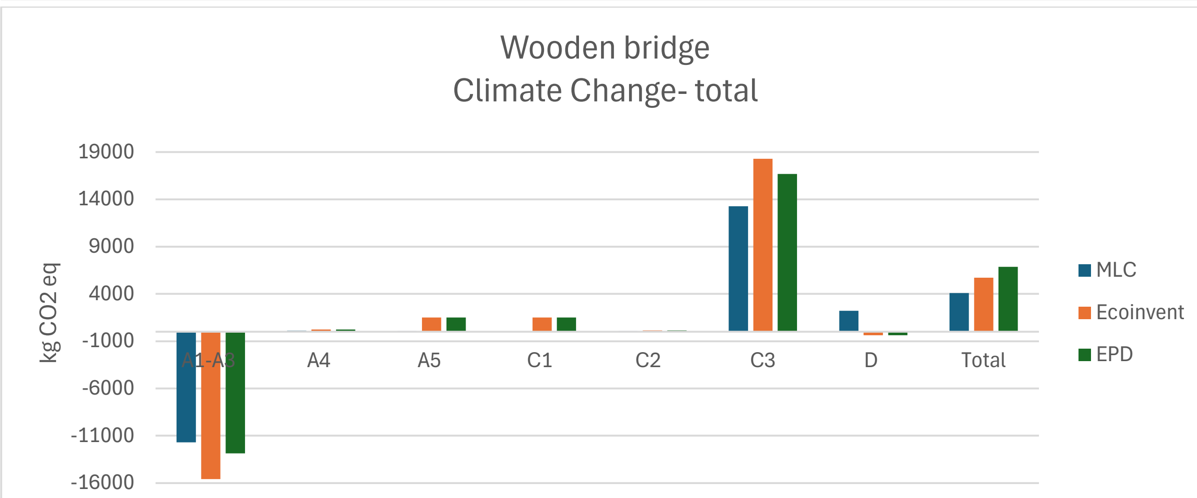
Table 86, Environmental profile based on MLC.

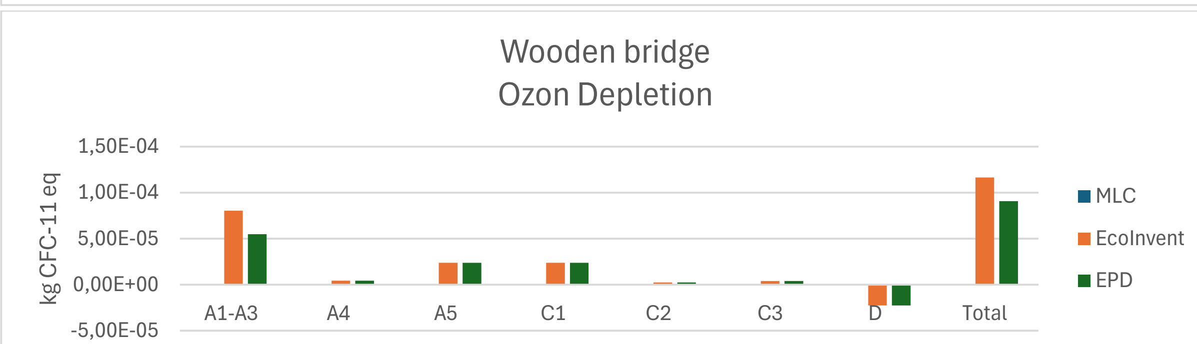
	A1-A3	A4	A5	C1	C2	C3	C4	D	Total
CC total	-1,17E+04	1,26E+02	7,52E+01	9,26E+00	7,68E+01	1,33E+04	2,23E+03	4,10E+03	-1,17E+04
CC, fossil	5,10E+03	1,30E+02	1,70E+02	9,54E+00	7,93E+01	2,39E+02	-3,74E+02	5,35E+03	5,10E+03
CC, biogenic	-1,68E+04	-3,99E+00	-9,60E+01	-2,80E-01	-2,43E+00	1,30E+04	2,61E+03	-1,28E+03	-1,68E+04
CC, land use	2,57E+01	4,77E-03	7,53E-01	3,45E-04	2,91E-03	3,28E-01	-3,58E+00	2,32E+01	2,57E+01
OD	3,78E-08	3,44E-11	1,15E-09	2,49E-12	2,10E-11	1,80E-09	-9,77E-10	3,98E-08	3,78E-08
A	3,21E+01	2,14E-01	1,06E+00	5,23E-02	1,30E-01	2,24E+00	-1,21E+01	2,37E+01	3,21E+01
EF	1,89E-02	3,16E-05	5,59E-04	2,28E-06	1,92E-05	2,70E-04	-4,33E-02	-2,35E-02	1,89E-02
EM	1,28E+01	9,28E-02	4,20E-01	2,54E-02	5,66E-02	6,54E-01	-4,10E+00	9,95E+00	1,28E+01
ET	1,40E+02	1,02E+00	4,66E+00	2,78E-01	6,21E-01	9,35E+00	-4,93E+01	1,07E+02	1,40E+02
POF	4,19E+01	2,28E-01	1,35E+00	7,21E-02	1,39E-01	1,79E+00	-4,69E+00	4,08E+01	4,19E+01
MMU	6,68E-04	4,65E-06	2,05E-05	3,36E-07	2,83E-06	1,97E-05	-2,47E-04	4,69E-04	6,68E-04
FFU	8,36E+04	1,65E+03	2,72E+03	1,19E+02	1,00E+03	3,39E+03	-3,69E+03	8,88E+04	8,36E+04
WU	1,29E+03	1,65E-01	8,12E+01	1,19E-02	1,01E-01	1,46E+03	-9,88E+01	2,74E+03	1,29E+03
PM	2,87E-03	1,99E-06	8,42E-05	6,36E-07	1,21E-06	1,50E-05	-2,35E-04	2,74E-03	2,87E-03
IR	8,53E+02	1,54E-01	2,56E+01	1,11E-02	9,39E-02	2,88E+01	-2,22E+01	8,85E+02	8,53E+02
FET	6,04E+04	1,06E+03	1,92E+03	7,69E+01	6,47E+02	1,31E+03	-5,15E+03	6,03E+04	6,04E+04
HT, cancer	2,28E-06	1,63E-08	7,20E-08	1,18E-09	9,94E-09	1,38E-07	-1,43E-06	1,09E-06	2,28E-06
HT, non-cancer	3,72E-05	2,65E-07	1,32E-06	1,93E-08	1,61E-07	7,09E-06	-9,78E-05	-5,18E-05	3,72E-05
LU	3,29E+06	9,38E+00	9,52E+04	6,79E-01	5,72E+00	1,07E+03	-3,01E+05	3,09E+06	3,29E+06

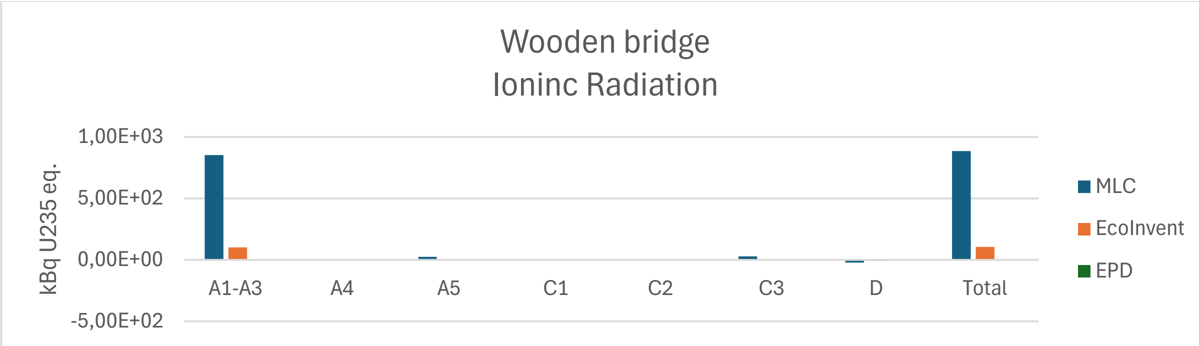
6.16. Comparison Environmental Impact

The figures below illustrate the differences in impact indicators based on the different background databases, as well as the absolute values for the Climate Change$_{total}$ and the two impact indicators showing the greatest variation.


Wooden bridge: Enivironmental Impact comparison
Factor difference
7
5
3
1
-1
-3
-5
-7
-9
-11
2922
2281
25
14
50
-170
CC total
CC, fossil
CC, biogenic
CC, land use
OD
A
EF
EM
ET
POF
MMU
FFU
WU
PM
IR
FET
HT, cancer
HT, non-cancer
LU
MLC
EcoInvent
EPD


Wooden bridge
Climate Change- total
kg CO2 eq
19000
14000
9000
4000
-1000
-6000
-11000
-16000
A1-A3
A4
A5
C1
C2
C3
D
Total
MLC
Ecoinvent
EPD


Wooden bridge
Ozon Depletion
kg CFC-11 eq
1,50E-04
1,00E-04
5,00E-05
0,00E+00
-5,00E-05
A1-A3
A4
A5
C1
C2
C3
D
Total
MLC
EcoInvent
EPD


Wooden bridge
Ioninc Radiation
kBq U235 eq.
1,00E+03
5,00E+02
0,00E+00
-5,00E+02
A1-A3
A4
A5
C1
C2
C3
D
Total
MLC
EcoInvent
EPD

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