Life Cycle Assessment Report

LEED

Date: 16 October 2024
Author: Sabrina Oliveira
Peer Reviewer: Larissa Calixto
Report Id: Uncontrolled Document

This LCA Study was conducted as part - LEED project. The LCA modeling within eTool is being managed by PARSUS. For more information see contact details below.

PARSUS
Ana Costa 61, Santos-SP, Brazil
henrique.mendonca@parsus.com.br
+5513981484676

eTool Disclaimer

The predictions of embodied and operational impacts (including costs) conducted in eTool software, by their very nature, cannot be exact. It is not possible to accurately track all the impacts associated with a product or service over the life of a building or structure. eTool software and the modelling workflow has been built and tested to enable informed decisions when comparing design options. Environmental impact coefficients and generic costs do not necessarily correspond to those of individual brands of the same product or service due to differences within industries in the way these products and services are delivered.

eTool PTY LTD cannot make assurances regarding the accuracy of these reports for the above reasons.

Executive Summary

This Life Cycle Assessment has been completed for the Whole Building, located The lead author is Sabrina Oliveira of PARSUS and an independent review has been conducted by Larissa Calixto of Cerclos. The goal of this study is to profile and improve the environmental performance of the construction works. The study has been conducted in accordance with ISO 14044 and EN15978 with any deviations noted in the Independent Reviewer Statement. .

About the Design

The following designs were modelled in these reports:

- **Final Design**: The final design agreed for construction at the time the modelling occurred.
- **Business as Usual**: An equivalent benchmark design (or weighted statistical mix of designs) with conventional products, construction methods and use patterns.

Results

The results of the study are shown in the table below with savings highlighted in green text and increased impacts highlighted in red.

Characterised Impacts per Gross Floor Area, No Time Scale		Business as Usual	Final Design	Final Design Savings
Environmental Impacts				
Global Warming Potential Total, GWP	kg CO_2 eq	2.41E+2	1.80E+2	25.13%
Ozone Depletion Potential, ODP	kg CFC-11 eq	1.31E-5	1.10E-5	15.95%
Acidification Potential for Soil and Water, AP	kg SO_2 eq.	1.50E0	1.27E0	15.22%
Eutrophication potential, EP	kg PO_4 eq	2.98E-1	2.56E-1	14.06%
Photochemical Ozone Creation Potential, POCP	kg ethylene	6.21E-2	5.68E-2	8.49%
Abiotic Depletion Potential - Fossil Fuels, ADPF	MJ	2.13E+3	1.67E+3	21.55%

Analysis

The report shows that the Final Design has lower Global Warming Potential Total, GWP impact than the Business as Usual Design. The **Product Stage (A1A3)** GWP Impacts are the most dominant life cycle module in the Final Design Design followed by the **Transport of Waste Offsite (C2)** and then **Deconstruction / Demolition (C1)**.

Further analysis reveals:

- The **Super structure** is the highest impact construction category,
- **Concrete | Unreinforced | Blast Furnace Slag Blends | 40 MPa | 10% BFS** is the highest impact material category,
- **Excavator, 25t, Diesel** is the highest people and equipment impact

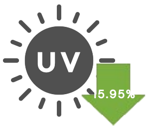
Seven strategies were modelled in the Final Design, the **Remove render finish** strategy had the highest saving , followed by **Ground floor construction optimisation** . See the below table for details.

	Scenario	GWP	ODP	AP	EP	POCP	ADPF
●	<Business as Usual>						
●	Steel Reinforcement - ArcelorMittal EPD	0.07%	0.09%	0.05%	0.26%	-0.04%	0.18%
●	Steel Reinforcement - Gerdau EPD	0.82%	0.88%	-0.23%	2.11%	-11.76%	0.49%
●	Cement with 13% FlyAsh in Superstructure	0.26%	0.00%	0.21%	0.06%	0.23%	0.08%
●	Replacement of Roof Insulation	0.13%	-0.21%	0.48%	0.30%	-1.13%	0.07%
●	Roof Covering - ArcelorMittal EPD	1.78%	-3.81%	-1.45%	-2.33%	2.60%	1.54%
●	Remove render finish	11.91%	11.60%	8.05%	8.55%	9.14%	11.58%
●	Ground floor construction optimisation	10.16%	7.40%	8.12%	5.10%	9.46%	7.61%
●	<Final Design>						

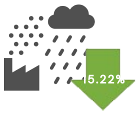
● Strategies included in Final Design ● Strategies not included in Final Design

Final Design Performance against Business as Usual

Global Warming Potential Total, GWP



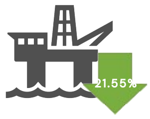
Ozone Depletion Potential, ODP



Acidification Potential for Soil and Water, AP

Eutrophication potential, EP

Photochemical Ozone Creation Potential, POCP



Abiotic Depletion Potential – Fossil Fuels, ADPF

Table Of Contents

1 Introduction

Managing the environmental impacts that arise from the construction and operation of buildings and infrastructure is of key importance in mitigating the damage caused directly and indirectly on the biosphere. Life Cycle Assessment (LCA) is the leading industry standard in clearly identifying optimum strategies for reducing environmental impacts. This report presents the results of the LCA completed for

The study has been conducted in accordance with the following standards:

- International Standards 14040 and 14044.
- European Standard EN 15978: *Sustainability of Construction Works – Assessment of Environmental Performance of Buildings – Calculation Method*

The Author of the study is Sabrina Oliveira of PARSUS, and reviewed by Larissa Calixto of Cerclos.

2 Goal of the Study

The goal of this study is to profile and improve the environmental performance of the construction works at . The life cycle performance of the project is compared to other designs and as such this is a comparative study. The study has been conducted on assumption the results may be made public.

3 Scope of the Study

The LCA study has been conducted in accordance with the EN 15978 standard to assess the direct and indirect potential environmental impacts associated with the construction works at

3.1 Functional Unit

The function of the Building must reflect the core purpose of the asset such that it can be compared accurately to different designs. In this case, the functional focus is the Whole Building and the chosen functional unit is the provision of this function for one Gross Floor Area over its life span.

The estimated design life of the design is 60 years which has been adopted for the LCA study period.

Note that products with expected service lives of less than the life span of the project are assumed to be replaced at increments reflecting their service life.

3.2 System Boundary

The system boundary, shown in Figure 1, follows guidance given in EN15978 (EN15804+A2).

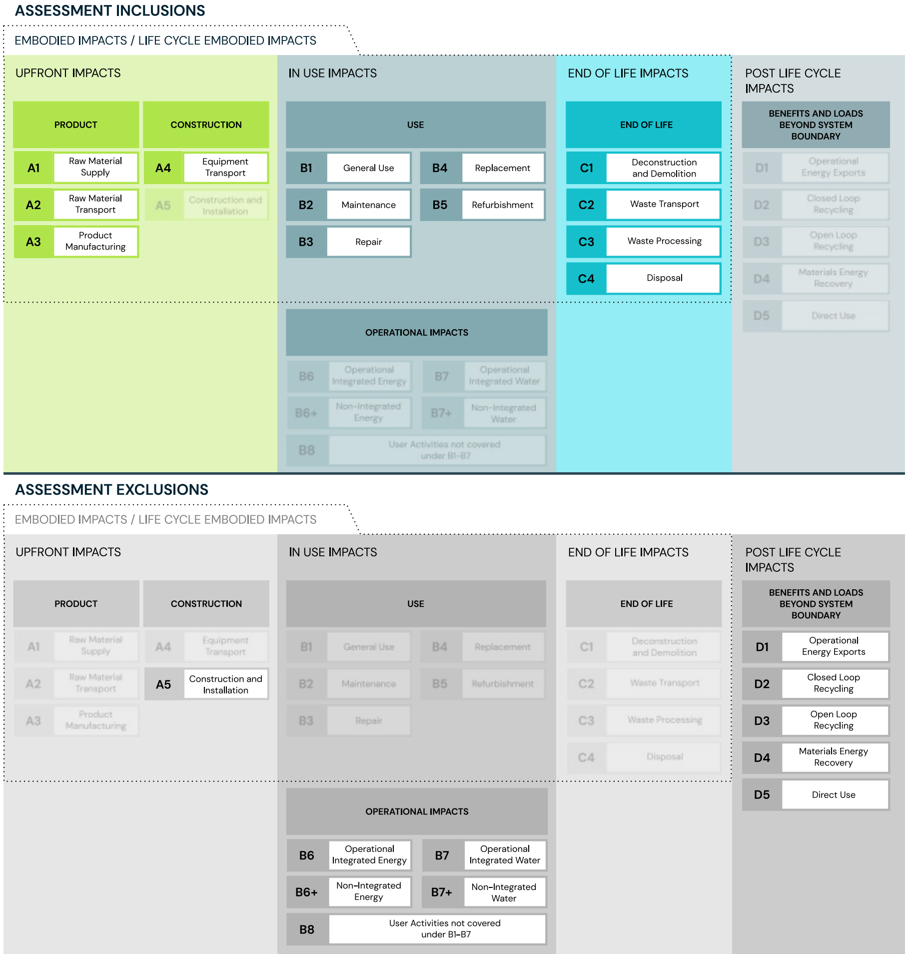


Figure 1: System Boundary Diagram

3.3 Environmental Indicators

The environmental indicators have been included in the study are detailed in Table 1. For further information regarding the environmental indicators please refer to Appendix A.

Environmental Indicator	Unit	Abbreviation	Characterisation Method
Environmental Impacts			
Global Warming Potential Total, GWP	kg CO_2 eq	GWP	CML-IA baseline V4.5
Ozone Depletion Potential, ODP	kg CFC-11 eq	ODP	CML-IA baseline V4.5
Acidification Potential for Soil and Water, AP	kg SO_2 eq.	AP	CML-IA baseline V4.5
Eutrophication potential, EP	kg PO_4 eq	EP	CML-IA baseline V4.5
Photochemical Ozone Creation Potential, POCP	kg ethylene	POCP	Institute of Environmental Sciences (CML)
Abiotic Depletion Potential - Fossil Fuels, ADPF	MJ	ADPF	CML-IA baseline V4.5

Table 1: Environmental Indicators Included in LCA study.

3.4 Cutoff Criteria

The EN15978 cut-off criteria were used to ensure that all relevant potential environmental impacts were appropriately represented:

- Mass – if a flow is less than 1% of the mass at either a product-level or individual-process level, then it has been excluded, provided its environmental relevance is not of concern.
- Energy – if a flow is less than 1% of the energy at either a product-level or individual-process level, then it has been excluded, provided its environmental relevance is not a concern.
- The total of neglected input flows per module, e.g. per module A1-A3, A4-A5, B1-B5, B6-B7, C1-C4 and module D shall be a maximum of 5% of energy usage and mass.
- Environmental relevance – if a flow meets the above criteria for exclusion, but is considered to potentially have a significant environmental impact, it has been included. All material flows which leave the system (emissions) and whose environmental impact is higher than 1% of an impact category, have been included.

The Operational Guidance for Life Cycle Assessment Studies (Wittstock et al. 2012) states:

The apparent paradox is that one must know the final result of the LCA (so one can show that the omission of a certain process is insignificant for the overall results) to be able to know which processes, elementary flows etc. can be left out.

The approach taken in this study is to continue modelling smaller inputs until confidence is gained that the criteria is safely met.

3.5 Allocation

Allocation rules follow those of EN15804 as given below:

- Allocation will respect the main purpose of the studied processes. If the main purpose of combined processes cannot be defined (e.g. combined mining and extraction of nickel and precious metals), economic allocation may be used to divide resources and emissions between the products.
- The principle of modularity is maintained. Where processes influence the product's environmental performance during its life cycle, they will be assigned to the module where they occur.
- The sum of the allocated inputs and outputs of a unit process are equal to the inputs and outputs of the unit process before allocation. This means no double counting of inputs or outputs is permissible.

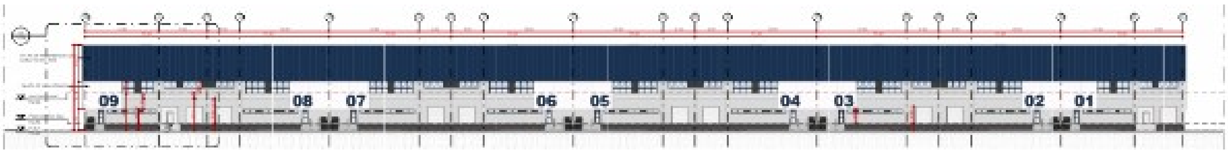
3.6 Independent Review

The critical review has been undertaken in accordance with ISO14044.

3.7 System Description Introduction

The object of the assessment is the Whole Building, located at The assessment includes all the upstream and downstream processes needed to provide the primary function of the structure from construction, maintenance, operation, and finally demolition and disposal. The inventory includes the extraction of raw materials or energy and the release of substances back to the environment or to the point where inventory items exit the system boundary either during or at the end of the project life cycle.

The consist of a new warehouse construction. The warehouse has 12,070.36 m² in total area. The project is seeking LEED v.4.1 Core and Shell rating and this study goal is to meet the Building Life Cycle Impact Reduction credit requirements - option 4 Whole of Building LCA.



The project location is shown in figures 2 and 3.

Figure 2: Location of the project - Global View.

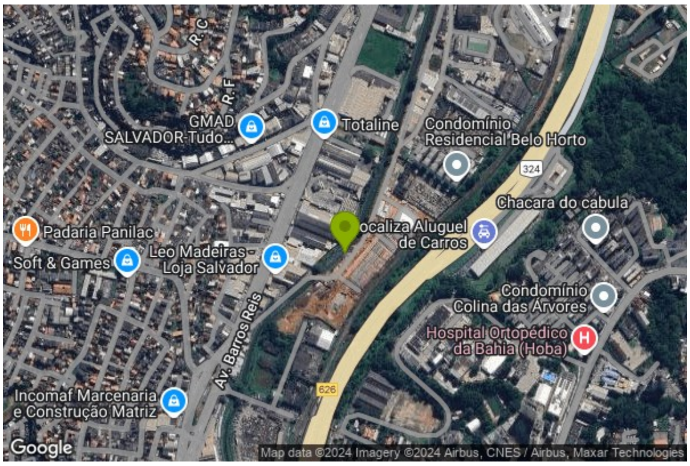


Figure 3: Location of the project - Locality View.

The project consists of a new warehouse building construction. The building has 12,070.36 m² in total area.

Reference design is the baseline design, business as usual standard practice. Proposed design is the design that is going to be constructed with the improvement strategies and reduced impacts. Details of construction components included in the scope of the baseline design:

- Foundation - Reinforced concrete piles, blocks and footings.
- Structure - Reinforced precast concrete columns and beams; steel columns and beams.

- Envelope - Reinforced concrete blocks, concrete blocks. Aluminium windows and aluminium doors.
- Roof structure and covering -reinforced slab and waterproofing.

Details of construction components included in the scope of the final design:

- Foundation - Reinforced concrete piles, blocks and footings.
- Structure - Reinforced precast concrete columns and beams; steel columns and beams.
- Envelope - Reinforced concrete blocks, concrete blocks. Aluminium windows and aluminium doors.
- Roof structure and covering -reinforced slab and waterproofing.

*At baseline already contains 10% BFS in concrete, in accordance with standard practice.

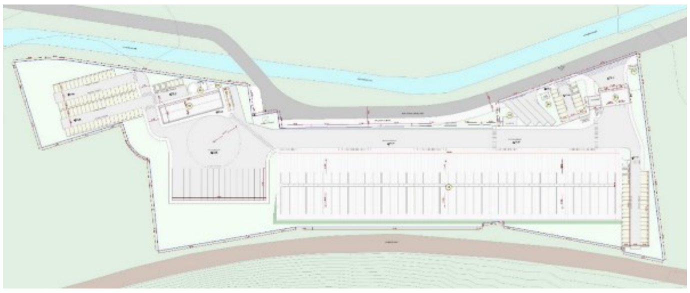
MEP equipment and controls, fire detection / alarm system fixtures, elevators, conveying systems, excavation, site development, and parking lots have been excluded from the study.

Some improvements modeled in this study focusing on materials impact reduction. The design team confirmed final design improvements in preparation for the detailed LCA analysis.

- Steel Reinforcement - ArcelorMittal EPD;
- Steel Reinforcement - Gerdau EPD;
- Cement with 13% FA in Superstructure;
- Replacement of Roof Insulation;
- Roof Covering - ArcelorMittal EPD;
- Remove render finish;
- Ground Floor Construction Optimisation.

For the development of the project, the requirements established as a goal of the LEED Reference Guide for Design and Construction of Buildings version 4 were considered. For the achievement of the MR Credit: Building Life-Cycle Impact Reduction, was considered the version LEED v4.1, Option 4 - Whole-Building Life-Cycle Assessment.

Improvement Strategies	Savings GWP (kgCO2e)	Savings Percent (%)
Steel Reinforcement - ArcelorMittal EPD;	-2,032	0.07
Steel Reinforcement - Gerdau EPD;	-23,903	0.82
Cement with 13% FA in Superstructure;	-7,631	0.26
Replacement of Roof Insulation;	-3,726	0.13
Roof Covering - ArcelorMittal EPD;	-51,668	1.78
Remove render finish;	-345,979	11.91
Ground Floor Construction Optimisation.	-295,063	10.16



3.8 Building Characteristics Table

Table 2 below shows the key characteristics of the designs.

	Business as Usual	Final Design

Design Details		
Design Name	Baseline	Final Design
Stories (#)	1	1
Functional Focus	Warehouse	Warehouse
Structural Service Life Limit	150	150
Predicted Design Life	60	60
Functional Characteristics		
Occupants	1	1
Tenancies	1	1
Work Stations	1	1
Total Floor Areas		
Usable Floor Area	0	0
Net Lettable Area	12,070	12,070
Fully Enclosed Covered Area	12,070	12,070
Unenclosed Covered Area	0	0
Gross Floor Area	12,070	12,070
Usable and Lettable Yield	100 %	100 %

Table 2 : Design Characteristics Compared

3.9 Structure Scope Table

Table 3 shows the structural scope of the inventory collection for the LCA. For further details on structure scope please refer to Appendix B.

Summary Structure Scope Diagram

Key: ✓ In Scope ✓ Partial ✗ Out of Scope

Category Name	Business as Usual	Final Design
Facilitating works	Partial	Partial
Sub-structure	✓	✓
Super structure	Partial	Partial
Finishes	Partial	Partial
FF&E	✗	✗
Services equipment	✗	✗
Pre-fabricated buildings and units	✗	✗
Works to existing buildings	✗	✗
External works	✗	✗
Undefined	✗	✗

Table 3 : Structural scope of LCI collection

3.10 Operational Scope Table

Table 4 shows the operational scope of the inventory collection for the LCA. For further details on structure scope please refer to Appendix B.

Operational Scope diagram

Key: ✓ In Scope ✗ Out of Scope

Category Name	Business as Usual	Final Design
Appliances | Dishwashers	✗	✗
Appliances | Entertainment	✗	✗
Appliances | Laundry Appliances	✗	✗
Appliances | Office Workstations	✗	✗
Communications	✗	✗
Cooking and Food Preparation	✗	✗
Domestic Water Heating	✗	✗
Electrical Parasitic Loads	✗	✗
Emergency Generator Use	✗	✗
Fire Protection	✗	✗
HVAC	✗	✗
HVAC | Cooling	✗	✗
HVAC | Heating	✗	✗
HVAC | Humidification	✗	✗
HVAC | Mechanical Ventilation	✗	✗
HVAC | Pumping	✗	✗
Industrial & Manufacturing Equipment	✗	✗
Lifts, Elevators and Conveying	✗	✗
Lighting	✗	✗
Miscellaneous	✗	✗
Monitoring, Control and Automation	✗	✗
Power Generation and Storage	✗	✗
Refrigeration	✗	✗
Safety and Security	✗	✗
Swimming Pools	✗	✗
Water Pumping	✗	✗
Water Removal and Treatment	✗	✗
Water Supply	✗	✗
Workshops, Garage & Misc	✓	✓

Table 4: Operational scope of LCI collection

4 Inventory Analysis

The inventory analysis was aided by the following design documents:

- Environmental Documentation: Projeto BP_Project Take-off information_worksheet (1), April 2024
- Civil Documentation: ABC BNB rev.00 (1), April 2024
- Environmental Documentation: Reinforcement bar - Average recycled content Brazil_April2020, April 2024
- Civil Documentation: Quadro de áreas, April 2024
- Architectural Documentation: BAY-ARQ-PB-300-002-PLA-R00, April 2024
- Architectural Documentation: BAY-ARQ-PB-100-001-COB-R00, April 2024
- Architectural Documentation: BAY-ARQ-PB-100-002-PLA-R00, April 2024

The design has been modelled using the available eToolLCD elements, templates and EPDs as shown in Table 5.

eToolLCD Item Type	Count in Design	
	Business as Usual	Final Design
Design Templates	32	36
Equipment and People Elements	53	56
Material Elements	52	56
Energy Elements	0	0
Water Elements	0	0
EPDs	7	10

Table 5: Count of elements, templates and EPDs in the design

The eToolLCD library templates are customisable and users may submit templates for validation. The template validation process is undertaken by experienced LCA practitioners and is a process of checking the user inputs and ensuring the assumptions are adequately referenced. Table 6 shows the extent to which validated templates were used in the model.

eToolLCD Item Type	Validated (%)	
	Business as Usual	Final Design
Total Design Templates	31.25	30.56
Equipment and People Elements	37.74	35.71
Material Elements	25	25
Energy Elements	NaN	NaN
Water Elements	NaN	NaN

Table 6: Use of validated templates

4.1 Templates Comparison

The eToolLCD templates found in each design are provided in Table 7.

Parent Template Name	Units	Quantity		
		Business as Usual	Final Design	Difference
Super structure				
[BRAZIL] Reinforcement Bar - Substructure (kg) - Bloco	kg	1144.71	1144.71	0%
[BRAZIL] Reinforcement Bar - Substructure (kg) - Estaca Helice	kg	613	613	0%
[BRAZIL] Reinforcement Bar - Substructure (kg) - Lowest Floor	kg	143876.25	161.78	-100%
[BRAZIL] Reinforcement Bar - Substructure (kg) - Radier	kg	4459.18	4459.18	0%
[BRAZIL] Reinforcement Bar - Substructure (kg) - Sapata	kg	962.43	962.43	0%
[BRAZIL] Reinforcement Bar - Superstructure (kg) - Armação alvenaria	kg	1937.38	1937.38	0%
[BRAZIL] Reinforcement Bar - Superstructure (kg) - Pilares e Vigas	kg	842.53	842.53	0%
200mm Hollow Concrete Block unfinished - Estrutural	m2	1107.08	1107.08	0%
200mm Hollow Concrete Block unfinished - Vedaçao	m2	5109.11	5109.11	0%
Demolition - Large Scale (End-of-Life)	m2	12070.36	12070.36	0%
External Finish - 13mm Render Cement (m2)	m2	12432.366	2214.14	-82%
Frame - Structural Steel. Galvanised (kg) - Pilar	kg	1644	1644	0%
Frame - Structural Steel. Galvanised (kg) - Viga	kg	2202.2	2202.2	0%
Poured Concrete - Frames/Columns/Beams 25MPa (m3) - Pilares	m3	24.07	24.07	0%
Poured Concrete - Frames/Columns/Beams 25MPa (m3) - Vigas	m3	36.08	36.08	0%
Prestressed alveolar concrete slab 25cm	m2	593.28	593.28	0%
Roof Covering - Spray on Waterproofing (External Use)	m2	593.28	593.28	0%
Roof Covering and rockwool Insulation. 50mm. 75 years (m2)	m2	10977.84	0	-100%
Steel Roller Shutter Door	m2	161.48	161.48	0%
Wall Cladding - Zinc Coated Steel Sheeting 0.48mm Trimdek Profile (50 yrs)	m2	410	410	0%
Windows Commercial Aluminium Single Glaze no fly-screen (m2)	m2	175.08	175.08	0%
Windows Commercial no glaze	m2	6	6	0%
[BRAZIL] Reinforcement Bar - ArcelorMittal EPD - Substructure (kg)	kg	0	10324	100%
[BRAZIL] Reinforcement Bar - Superstructure - Gerdau EPD (kg)	kg	0	83863	100%
[BRAZIL] Reinforcement Bar - Superstructure (kg) - aço em tela	kg	0	4803.56	100%
Roof Covering and Fiberglass Insulation, 50mm, 75 years (m2)	m2	0	10977.84	100%
Sub-structure				
[BRAZIL] Staircase. Steel frame and steel treads (lm)	lm	9.72	9.72	0%
Poured Concrete - Foundations 30MPa (m3) - Bloco	m3	32.71	32.71	0%
Poured Concrete - Foundations 30MPa (m3) - Estaca Helice	m3	22.71	22.71	0%
Poured Concrete - Foundations 30MPa (m3) - Radier	m3	154.78	154.78	0%
Poured Concrete - Foundations 30MPa (m3) - Sapata	m3	12.03	12.03	0%
Poured Concrete - Lowest Floor 35MPa (m3)	m3	1438.76	1018	-29%
Roads, paths, pavings, surfaces; Fencing, railings, walls; External fixtures				
Wall Finish Paint (2 coats) external m2	m2	2407.24	2407.24	0%
External Works - Glass fibre reinforced polymer, Material Only, No Construction Waste Factors/Lost in transport/Assembly (tons)	t	0	5.6	100%

Table 7: Templates Comparison (showing master templates only)

4.2 eTool software

eTool software was used to model life cycle impacts of the project. eToolLCD uses third party background processes aggregated as mid-point indicators and stored in a number of libraries within the software which are coupled with algorithms and user inputs to output the environmental impact assessment. A map of user inputs, data sources and algorithms (outputs) is given in Figure 4.

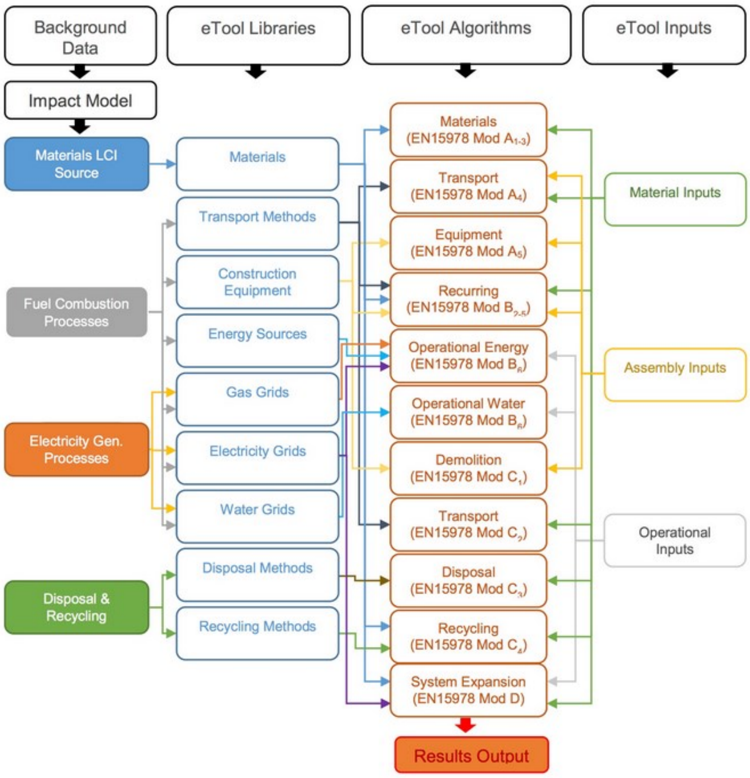


Figure 4: Relationship between LCI background data, eToolLCD software library, inputs and algorithms.

4.3 Data Quality

The data quality requirements for the background data are detailed in Table 8. Each of the criteria has been assessed for compliance and results presented below.

Criteria	Background Data Requirement	Compliance	
		Business as Usual	Final Design
Temporal Relevancy	For annually fluctuating processes like Grid electricity fuel mixes the datasets must have been updated within the last 2 years. More static processes like materials production must have been updated within the last 10 years. Product specific EPDs must have been updated in the last 5 years.	Failed Grid Passed Materials	Failed Grid Passed Materials
Geographical Relevancy	The background data should be specifically compiled for the same country (preferable) or continent as the project location.	Failed	Failed
Precision	No requirement specified however a qualitative review undertaken to ensure no erroneous values.	Passed	Passed
Completeness	Qualitative assessment of the process to ensure no obvious exclusions.	Passed	Passed
Technological Relevancy	Ensure that technology assumptions are representative for the product or product group.	Passed	Passed
Consistency	The study methodology holds for the background data.	Passed	Passed
Reproducibility	The information available about the methodology and the data values reported should allow an independent practitioner to reproduce the results reported in the study.	Passed	Passed

Table 8: Summary of data quality requirements for the study.

Criteria	Inventory Collection Requirement (eToolLCD User Inputs)	Compliance	
		Business as Usual	Final Design
Temporal Relevancy	All inputs into eToolLCD to be reflective of the project being assessed and if assumptions are made these are to be based on industry practices that are consistent with the project commissioning date.	Passed 5/5 Checks	Passed 2/2 Checks
Geographical Relevancy	All inputs into eToolLCD must be reflective of the project being assessed and if assumptions are made these are based on the current practices employed in the project country.	Passed 4/5 Checks	Passed 3/3 Checks
Precision	To avoid aggregated errors a high level of precision is expected inputs into eToolLCD software, being either to 3 significant figures or: • Two significant figures or nearest 10 hours for equipment run time • Two significant figures or nearest 10kg for material quantities • Two significant figures or nearest 100MJ / annum for operational energy • Two significant figures or nearest 100kL / annum for operational water use	Passed 3/4 Checks	Passed 1/2 Checks
Completeness	Inputs to cover all life cycle phases and elements identified in the system boundary. The link between background data, eToolLCD algorithms and subsequent LCA results is not to introduce significant gaps in the data.	Passed 5/10 Checks	Passed 3/6 Checks
Technological Relevancy	All inputs into eToolLCD must be reflective of the project being assessed and if assumptions are made these must be drawn from appropriate examples of like technology.	Passed 1/5 Checks	Passed 1/1 Checks
Consistency	All inputs into eToolLCD must be reflective of the project being assessed and if assumptions are made these are drawn from the same reference library.	Passed 7/11 Checks	Passed 4/6 Checks
Reproducibility	The information available about the methodology and the data values reported should allow an independent practitioner to reproduce the results reported in the study.	Passed 6/9 Checks	Passed 3/3 Checks

Table 9: Summary of data quality requirements for the study.

4.4 Completeness

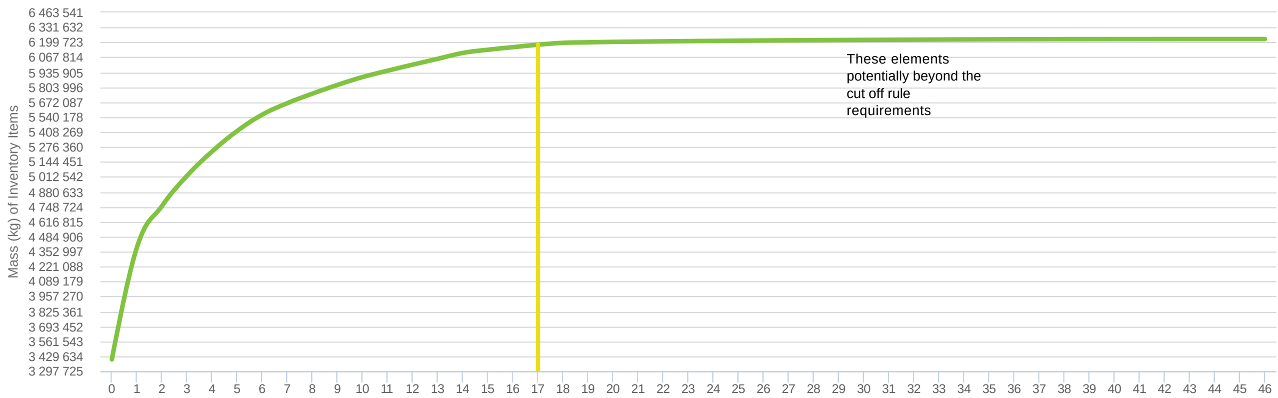
The study aims to follow EN15804 procedures for exclusion of inputs and outputs:

- All inputs and outputs to a (unit) process shall be included in the calculation, for which data are available.
- Data gaps may be filled by conservative assumptions with average or generic data. Any assumptions for such choices shall be documented.
- In case of insufficient input data or data gaps for a unit process, the cut-off criteria shall be 1 % renewable and non-renewable primary energy usage and 1 % of the total mass input of that unit process.
- The total of neglected input flows per module, e.g. per module shall be a maximum of 5 % of energy usage and mass.
- Conservative assumptions in combination with plausibility considerations and expert judgement can be used to demonstrate compliance with these criteria.
- Particular care should be taken to include material and energy flows known to have the potential to cause significant emissions into air and water or soil related to the environmental indicators.

Two major tests were run to determine the compliance with the above cut-off rules.

4.4.1 Inventory Mass Quantities

The cumulative mass of inventory entries is shown in Figure 5. Given that 29 material elements within the LCA base design make up the last 1% of mass inventory entries a high level of confidence exists that the cut off rules have been upheld.



Cumulative Mass Inventory Inputs — 99% of Mass (Cut off rule requirement)

Figure 5: Cumulative Mass Inventory Entries. In this case 61.70% make up the last 5% of mass inventory entries.

4.4.2 Inventory Energy Analysis

The cumulative embodied energy of inventory entries is shown in Figure 6. Given that 104 elements within the LCA base design make up the last 1% of embodied energy inventory entries a high level of confidence exists that the cut off rules have been upheld.

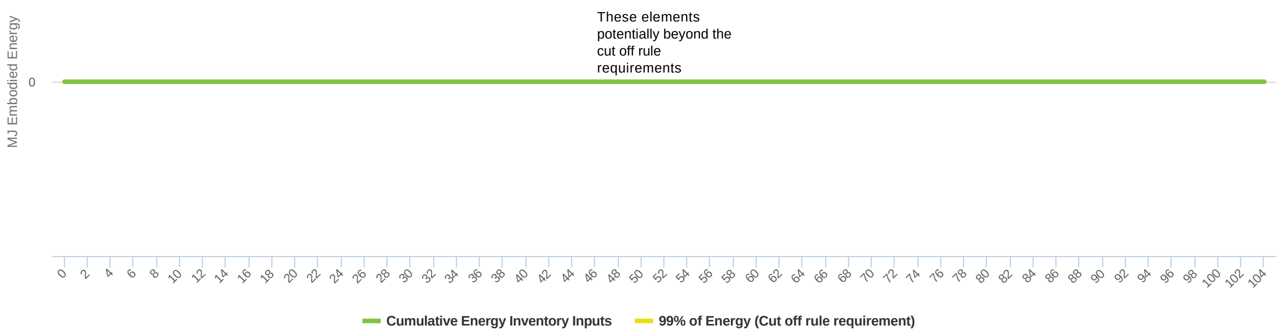


Figure 6 : Cumulative Energy Inventory Entries. In this case 99.05% make up the last 5% of energy inventory entries.

5 Life Cycle Impact Assessment

The Life Cycle Impact Assessment (LCIA) results are provided in Table 10 in the EN15978 reporting format. The red and orange figures within each row highlight the largest and second largest contributing life cycle modules for the indicator. Modules not assessed are abbreviated with "MNA".

The green figures in the comparison section highlight the most improved life cycle modules for the indicator.

5.1 Environmental Impacts

Table 10: Business as Usual vs Final Design, Environmental Impacts of Each Life Cycle Phase.

Characterised Impacts Per Gross Floor Area Per No Time Scale		Construction Phases			Use Phases										End of Life Phases				Benefits and Loads Beyond the System Boundary	Total
		A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B6+	B7	B7+	B8	C1	C2	C3	C4	D	
Business as Usual																				
GWP	kg CO_2 eq	1.88E+2	6.87E0	MNA	0.00E0	0.00E0	0.00E0	2.03E+1	0.00E0	MNA	MNA	MNA	MNA	MNA	7.72E0	1.40E+1	2.91E-2	4.15E0	MNA	2.41E+2
ODP	kg CFC-11 eq	6.99E-6	8.07E-7	MNA	0.00E0	0.00E0	0.00E0	1.49E-6	0.00E0	MNA	MNA	MNA	MNA	MNA	1.21E-6	1.66E-6	3.64E-9	9.41E-7	MNA	1.31E-5
AP	kg SO_2 eq.	1.25E0	3.26E-2	MNA	0.00E0	0.00E0	0.00E0	9.81E-2	0.00E0	MNA	MNA	MNA	MNA	MNA	2.66E-2	5.92E-2	5.92E-5	3.12E-2	MNA	1.50E0
EP	kg PO_4 eq	2.38E-1	7.70E-3	MNA	0.00E0	0.00E0	0.00E0	2.32E-2	0.00E0	MNA	MNA	MNA	MNA	MNA	6.20E-3	1.59E-2	9.38E-6	6.80E-3	MNA	2.98E-1
POCP	kg ethylene	4.82E-2	1.89E-3	MNA	0.00E0	0.00E0	0.00E0	4.67E-3	0.00E0	MNA	MNA	MNA	MNA	MNA	2.14E-3	3.78E-3	3.17E-6	1.37E-3	MNA	6.21E-2
ADPF	MJ	1.39E+3	1.03E+2	MNA	0.00E0	0.00E0	0.00E0	1.85E+2	0.00E0	MNA	MNA	MNA	MNA	MNA	1.17E+2	2.21E+2	4.32E-1	1.14E+2	MNA	2.13E+3
Final Design																				
GWP	kg CO_2 eq	1.45E+2	6.44E0	MNA	0.00E0	0.00E0	0.00E0	6.14E0	0.00E0	MNA	MNA	MNA	MNA	MNA	7.70E0	1.12E+1	4.07E-2	3.33E0	MNA	1.80E+2
ODP	kg CFC-11 eq	6.20E-6	7.47E-7	MNA	0.00E0	0.00E0	0.00E0	7.79E-7	0.00E0	MNA	MNA	MNA	MNA	MNA	1.21E-6	1.33E-6	3.76E-9	7.41E-7	MNA	1.10E-5
AP	kg SO_2 eq.	1.10E0	3.06E-2	MNA	0.00E0	0.00E0	0.00E0	4.21E-2	0.00E0	MNA	MNA	MNA	MNA	MNA	2.65E-2	4.75E-2	1.34E-4	2.45E-2	MNA	1.27E0
EP	kg PO_4 eq	2.13E-1	7.59E-3	MNA	0.00E0	0.00E0	0.00E0	1.14E-2	0.00E0	MNA	MNA	MNA	MNA	MNA	6.19E-3	1.27E-2	1.15E-5	5.35E-3	MNA	2.56E-1
POCP	kg ethylene	4.60E-2	2.58E-3	MNA	0.00E0	0.00E0	0.00E0	1.92E-3	0.00E0	MNA	MNA	MNA	MNA	MNA	2.14E-3	3.04E-3	3.32E-5	1.09E-3	MNA	5.68E-2
ADPF	MJ	1.13E+3	9.51E+1	MNA	0.00E0	0.00E0	0.00E0	6.70E+1	0.00E0	MNA	MNA	MNA	MNA	MNA	1.17E+2	1.77E+2	5.48E-1	8.95E+1	MNA	1.67E+3
Savings (Business as Usual Compared to Final Design)																				
GWP	kg CO_2 eq	4.23E+1	4.33E-1	MNA	0.00E0	0.00E0	0.00E0	1.42E+1	0.00E0	MNA	MNA	MNA	MNA	MNA	2.38E-2	2.81E0	-1.15E-2	8.14E-1	MNA	**25.13%**
ODP	kg CFC-11 eq	7.90E-7	6.03E-8	MNA	0.00E0	0.00E0	0.00E0	7.10E-7	0.00E0	MNA	MNA	MNA	MNA	MNA	4.66E-19	3.30E-7	-1.26E-10	2.00E-7	MNA	**15.95%**
AP	kg SO_2 eq.	1.52E-1	2.00E-3	MNA	0.00E0	0.00E0	0.00E0	5.60E-2	0.00E0	MNA	MNA	MNA	MNA	MNA	4.32E-5	1.17E-2	-7.48E-5	6.63E-3	MNA	**15.22%**
EP	kg PO_4 eq	2.54E-2	1.16E-4	MNA	0.00E0	0.00E0	0.00E0	1.18E-2	0.00E0	MNA	MNA	MNA	MNA	MNA	1.69E-6	3.14E-3	-2.12E-6	1.44E-3	MNA	**14.06%**
POCP	kg ethylene	2.23E-3	-6.90E-4	MNA	0.00E0	0.00E0	0.00E0	2.74E-3	0.00E0	MNA	MNA	MNA	MNA	MNA	1.96E-6	7.37E-4	-3.00E-5	2.81E-4	MNA	**8.49%**
ADPF	MJ	2.65E+2	7.82E0	MNA	0.00E0	0.00E0	0.00E0	1.18E+2	0.00E0	MNA	MNA	MNA	MNA	MNA	3.02E-1	4.44E+1	-1.16E-1	2.42E+1	MNA	**21.55%**

6 Detailed Analysis

This section provides a more detailed results of the life cycle impacts with the aim of identifying the hotspots by analysing temporal, spatial, functional, end-use demand and supply chain dimensions.

For each indicator being assessed the following charts are provided

The Time Series Charts articulate when impacts occur during the life of the design. This exposes insights such as the temporal hotspots signified by jumps in the plot during the life of the project (for example, relating to a large replacement item) and the payback period of design options

The Top Five Life Cycle Charts express impacts by different modules, categories and classes enabling a detailed understanding of what is responsible for the greatest impacts and also compares these impacts between designs . The pie chart within each bar chart shows the proportion of the life cycle impacts represented in the bar chart. A brief description of the categories is provided below:

- **LC Module Impacts:** The EN15978 Life Cycle Modules. Generally 100% building impacts will be included in the bar chart.
- **Construction Category:** The breakdown of the impacts by construction category. The bar chart will generally only part of the total building impacts.
- **Operational Demand:** The building end use demands that are driving environmental impacts.
- **Energy Supply:** The supply of fuels to the building, in effect the upstream fuel sources supplying energy for on site use during construction, operational and demolition.
- **Materials:** The materials (grouped into common categories) that are driving the environmental impacts.
- **Equipment and People:** The equipment and people required during construction, maintenance and demolition and all associated transport trips that are driving the environmental impacts

All impact figures are quoted per Gross Floor Area for the study.

6.1 Global Warming Potential Total, GWP (kg CO_2 eq)

Figure 7: Time series Global Warming Potential Total, GWP chart

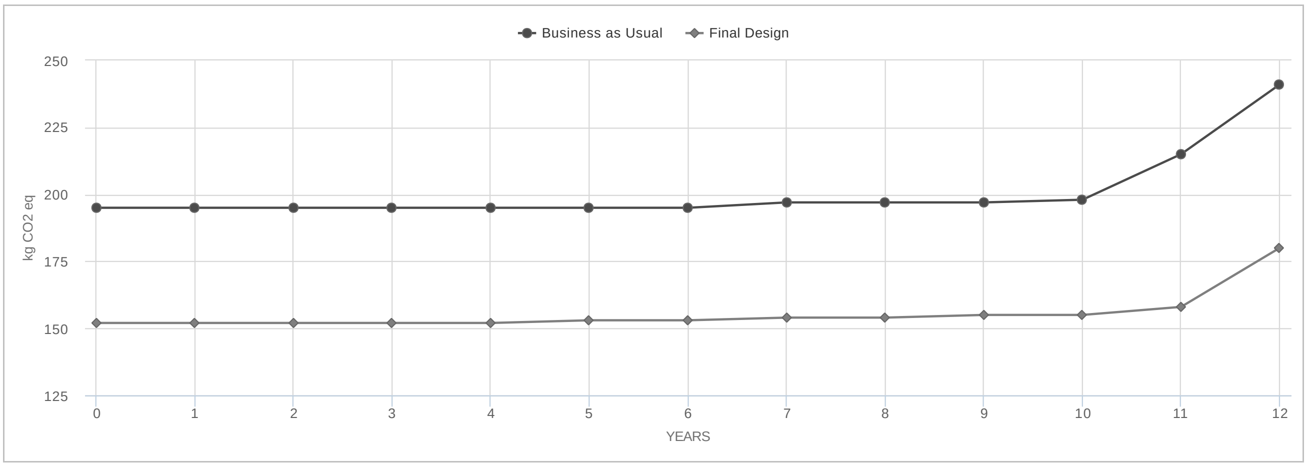
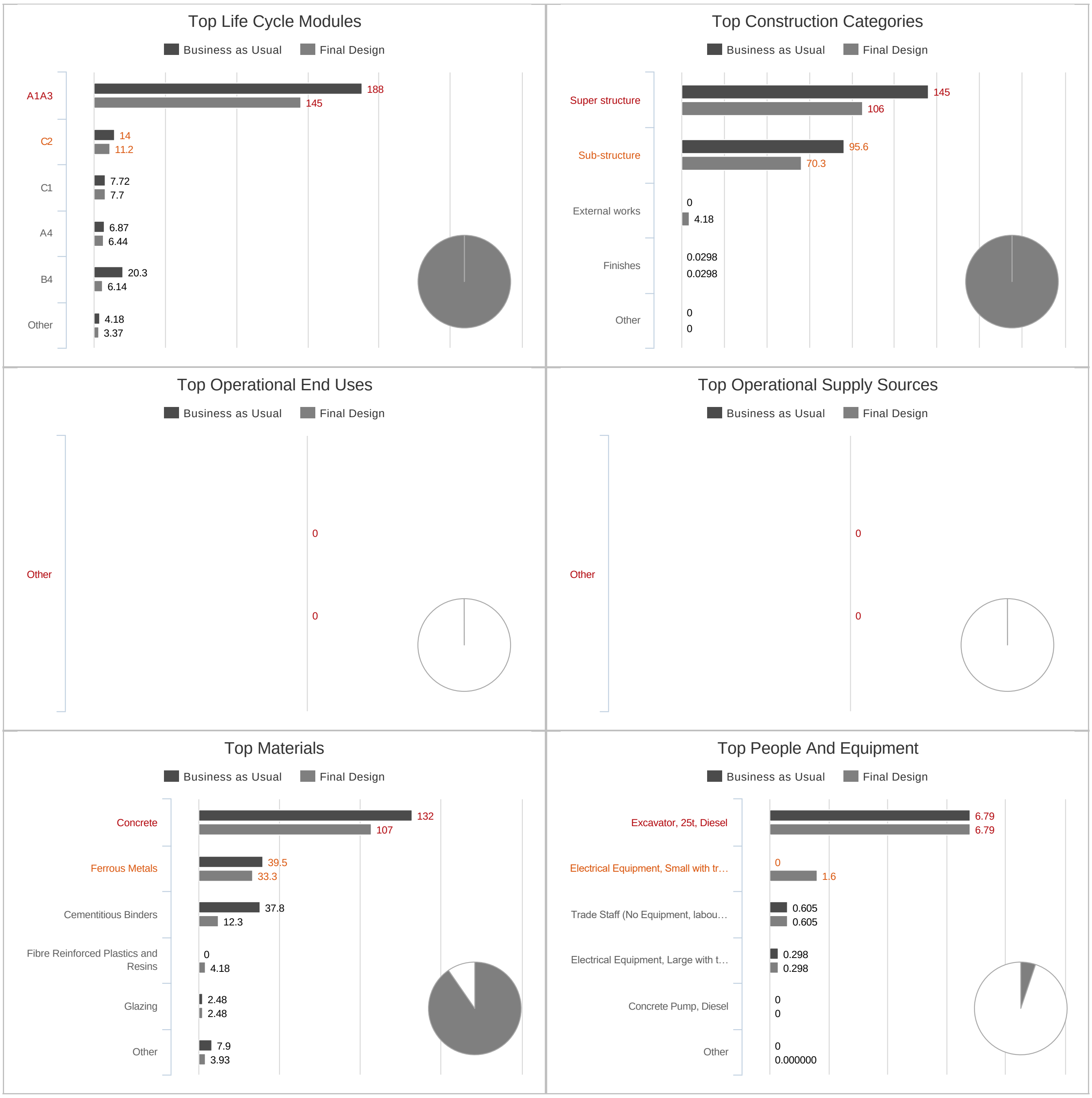


Figure 8: Top Five Global Warming Potential Total, GWP chart



Highest and Lowest Impact Materials (kg CO_2 eq)

	Initial Materials & Construction (A1-A5)	Use Stage Materials & Construction (B1-B5)	End of Life (C1-C4)	Recycling & Energy Export (D)	Total
Top 10 Impact Materials					
Concrete | Unreinforced | Blast Furnace Slag Blends | 40 MPa | 10% BFS	626275.73	0	82537.1	0	708812.83
Concrete | Unreinforced | Portland Cement Blends | Unspecified	301168.68	0	41279.54	0	342448.22
Ferrous Metals | Steel | Coated Sheet | Zinc Coated & Coloured Sheet 0.56mm	306385.32	0	6601.42	0	312986.74
Cementitious Binders | Mortars and Renders | 1 cement : 4 sand	108062.84	34863.18	5823.2	0	148749.22
Concrete | Unreinforced | Blast Furnace Slag Blends | 30 MPa | 10% BFS	119716.94	0	17929.59	0	137646.53
Concrete | Unreinforced | Fly Ash Blends | 30 MPa | 15% FA	86050.14	0	12360.85	0	98410.99
EPD-Reinforcing Steel Bar Gerdau GG 50 (URS (Sapucaia do Sul))	71283.55	0	518.27	0	71801.82
Fibre Reinforced Plastics and Resins | Fibre reinforced plastic (FRP)	50051.21	0	374.76	0	50425.97
Ferrous Metals | Steel | General | Unspecified	48032.58	0	1750.3	0	49782.88
Glazing | Windows | Aluminium Framed | Thermal Break | Single Glaze | Commercial Fixed	14048.95	15650.06	185.46	0	29884.47
Bottom 5 Impact Materials					
Asphalt and Bitumen | Asphalt Mastic Roof Covering	136.06	166	14.86	0	316.92
Timber | Sustainably Sourced | Hardwood | Unspecified	-703.83	0	970.02	0	266.19
Paints and Finishes | Unspecified | 2 Coats	76.4	99.14	9.88	0	185.41
Paints and Finishes | Wood Stains and Finishes | General	20.84	72.76	0.26	0	93.86
Resins and Adhesives | Urea Formaldehyde	8.03	9.77	0.12	0	17.92

Highest and Lowest Impact Templates (kg CO_2 eq)

	Initial Materials & Construction (A1-A5)	Use Stage Materials & Construction (B1-B5)	Integrated Energy Use (B6)	Plug Load Energy Use (B6+)	Water Supply & Treatment (B7)	End of Life (C1-C4)	Recycling & Energy Export (D)	Total
Top 10 Impact Templates								
Poured Concrete - Lowest Floor 35MPa (m3)	626275.73	0	0	0	0	82537.1	0	708812.83
200mm Hollow Concrete Block unfinished - Vedaçao	364398.02	0	0	0	0	39097.96	0	403495.98
Roof Covering and Fiberglass Insulation, 50mm, 75 years (m2)	345222.28	0	0	0	0	7035.4	0	352257.68
Poured Concrete - Foundations 30MPa (m3) - Radier	83381.12	0	0	0	0	12487.7	0	95868.83
Demolition - Large Scale (End-of-Life)	0	0	0	0	0	92872.07	0	92872.07
200mm Hollow Concrete Block unfinished - Estrutural	69572.93	0	0	0	0	8129.96	0	77702.89
[BRAZIL] Reinforcement Bar - Superstructure - Gerdau EPD (kg)	71297.39	0	0	0	0	3286.06	0	74583.45
Prestressed alveolar concrete slab 25cm	64225.55	0	0	0	0	7826.41	0	72051.96
External Finish - 13mm Render Cement (m2)	31632.13	36722.55	0	0	0	1628.45	0	69983.13
External Works - Glass fibre reinforced polymer, Material Only, No Construction Waste Factors/Lost in transport/Assembly (tons)	50051.21	0	0	0	0	374.76	0	50425.97
Bottom 5 Impact Templates								
[BRAZIL] Reinforcement Bar - Superstructure (kg) - Pilares e Vigas	952.57	0	0	0	0	36.87	0	989.45
[BRAZIL] Reinforcement Bar - Substructure (kg) - Estaca Helice	693.06	0	0	0	0	26.83	0	719.89
[BRAZIL] Staircase. Steel frame and steel treads (lm)	-452.47	82.53	0	0	0	978.5	0	608.57
Roof Covering - Spray on Waterproofing (External Use)	136.06	166	0	0	0	14.86	0	316.92
[BRAZIL] Reinforcement Bar - Substructure (kg) - Lowest Floor	182.91	0	0	0	0	7.08	0	189.99

6.2 Ozone Depletion Potential, ODP (kg CFC-11 eq)

Figure 9: Time series Ozone Depletion Potential, ODP chart

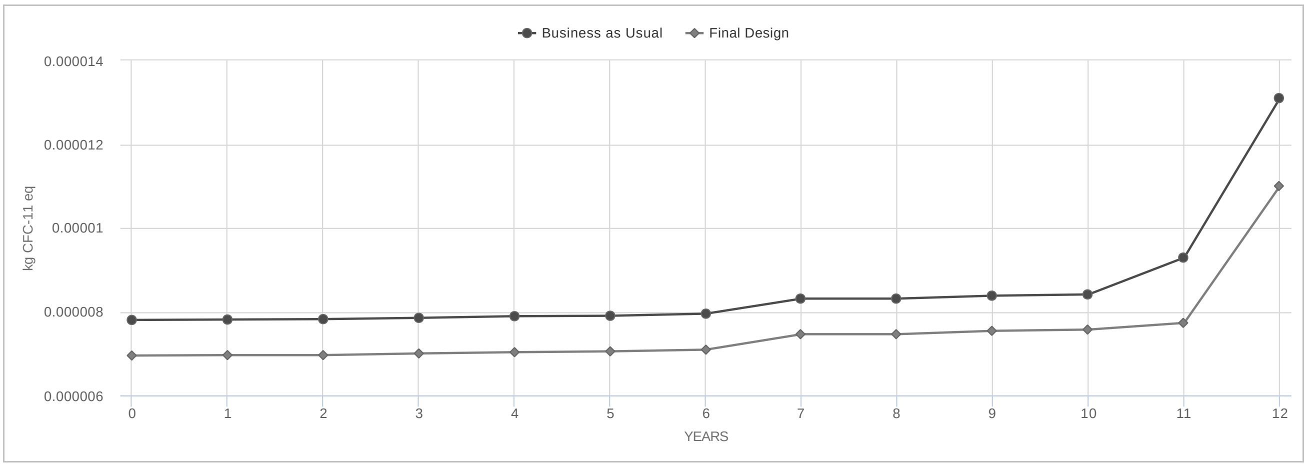


Figure 10: Top Five Ozone Depletion Potential, ODP chart

Highest and Lowest Impact Materials (kg CFC-11 eq)

	Initial Materials & Construction (A1-A5)	Use Stage Materials & Construction (B1-B5)	End of Life (C1-C4)	Recycling & Energy Export (D)	Total
Top 10 Impact Materials					
Ferrous Metals | Steel | Coated Sheet | Zinc Coated & Coloured Sheet 0.56mm	0.03	0	0	0	0.03
Concrete | Unreinforced | Blast Furnace Slag Blends | 40 MPa | 10% BFS	0.02	0	0.01	0	0.03
Concrete | Unreinforced | Portland Cement Blends | Unspecified	0.01	0	0.01	0	0.01
Glazing | Windows | Aluminium Framed | Thermal Break | Single Glaze | Commercial Fixed	0	0	0	0	0.01
Cementitious Binders | Mortars and Renders | 1 cement : 4 sand	0.01	0	0	0	0.01
Concrete | Unreinforced | Blast Furnace Slag Blends | 30 MPa | 10% BFS	0	0	0	0	0.01
Concrete | Unreinforced | Fly Ash Blends | 30 MPa | 15% FA	0	0	0	0	0
Ferrous Metals | Steel | General | Unspecified	0	0	0	0	0
Paints and Finishes | Unspecified | 1 Coat	0	0	0	0	0
Ferrous Metals | Steel | Galvanised Structural | Unspecified	0	0	0	0	0
Bottom 5 Impact Materials					
Plastics | High Density Polyethylene (HDPE) | Unspecified	0	0	0	0	0
Plastics | Acrylic | Unspecified	0	0	0	0	0
Paints and Finishes | Wood Stains and Finishes | General	0	0	0	0	0
Resins and Adhesives | Urea Formaldehyde	0	0	0	0	0
EPD-ArcelorMittal Brasil 2026	0	0	0	0	0

Highest and Lowest Impact Templates (kg CFC-11 eq)

	Initial Materials & Construction (A1-A5)	Use Stage Materials & Construction (B1-B5)	Integrated Energy Use (B6)	Plug Load Energy Use (B6+)	Water Supply & Treatment (B7)	End of Life (C1-C4)	Recycling & Energy Export (D)	Total
Top 10 Impact Templates								
Roof Covering and Fiberglass Insulation, 50mm, 75 years (m2)	0.04	0	0	0	0	0	0	0.04
Poured Concrete - Lowest Floor 35MPa (m3)	0.02	0	0	0	0	0.01	0	0.03
200mm Hollow Concrete Block unfinished - Vedaçao	0.01	0	0	0	0	0.01	0	0.02
Demolition - Large Scale (End-of-Life)	0	0	0	0	0	0.01	0	0.01
Windows Commercial Aluminium Single Glaze no fly-screen (m2)	0	0	0	0	0	0	0	0.01
Poured Concrete - Foundations 30MPa (m3) - Radier	0	0	0	0	0	0	0	0
External Finish - 13mm Render Cement (m2)	0	0	0	0	0	0	0	0
200mm Hollow Concrete Block unfinished - Estrutural	0	0	0	0	0	0	0	0
Prestressed alveolar concrete slab 25cm	0	0	0	0	0	0	0	0
Wall Finish Paint (2 coats) external m2	0	0	0	0	0	0	0	0
Bottom 5 Impact Templates								
[BRAZIL] Reinforcement Bar - Substructure (kg) - Bloco	0	0	0	0	0	0	0	0
[BRAZIL] Reinforcement Bar - Substructure (kg) - Sapata	0	0	0	0	0	0	0	0
[BRAZIL] Reinforcement Bar - Superstructure (kg) - Pilares e Vigas	0	0	0	0	0	0	0	0
[BRAZIL] Reinforcement Bar - Substructure (kg) - Estaca Helice	0	0	0	0	0	0	0	0
[BRAZIL] Reinforcement Bar - Substructure (kg) - Lowest Floor	0	0	0	0	0	0	0	0

6.3 Acidification Potential for Soil and Water, AP (kg SO_2 eq.)

Figure 11: Time series Acidification Potential for Soil and Water, AP chart

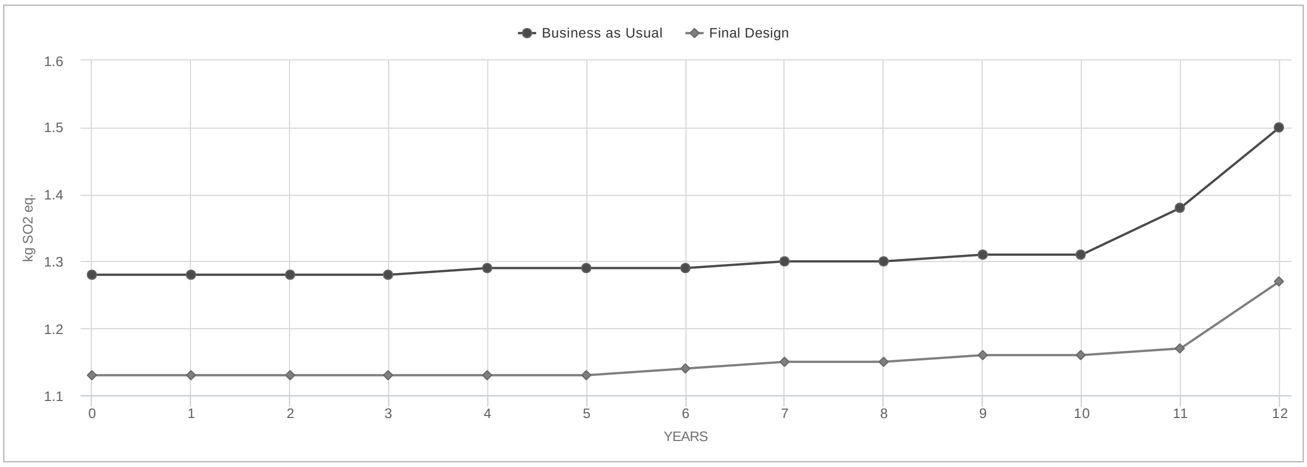
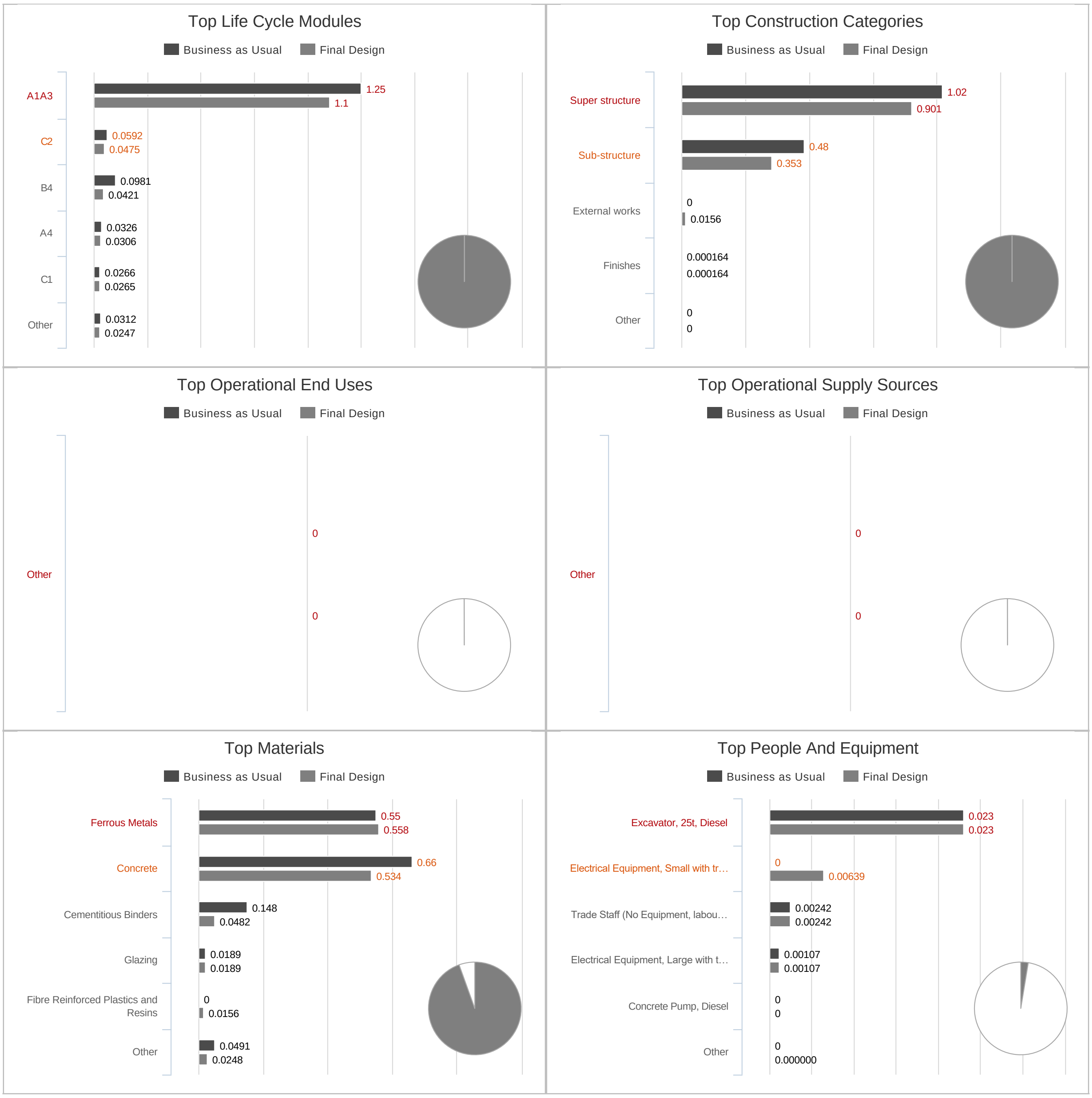


Figure 12: Top Five Acidification Potential for Soil and Water, AP chart



Highest and Lowest Impact Materials (kg SO_2 eq.)

	Initial Materials & Construction (A1-A5)	Use Stage Materials & Construction (B1-B5)	End of Life (C1-C4)	Recycling & Energy Export (D)	Total
Top 10 Impact Materials					
Ferrous Metals | Steel | Coated Sheet | Zinc Coated & Coloured Sheet 0.56mm	5940.39	0	25.81	0	5966.21
Concrete | Unreinforced | Blast Furnace Slag Blends | 40 MPa | 10% BFS	3150.97	0	419.84	0	3570.81
Concrete | Unreinforced | Portland Cement Blends | Unspecified	1496.8	0	210.12	0	1706.92
Concrete | Unreinforced | Blast Furnace Slag Blends | 30 MPa | 10% BFS	595.36	0	91.23	0	686.59
Cementitious Binders | Mortars and Renders | 1 cement : 4 sand	416.03	136.47	29.76	0	582.26
Concrete | Unreinforced | Fly Ash Blends | 30 MPa | 15% FA	428.39	0	57.94	0	486.33
EPD-Reinforcing Steel Bar Gerdau GG 50 (URS (Sapucaia do Sul))	363.13	0	1.98	0	365.11
Ferrous Metals | Steel | Galvanised Structural | Unspecified	231.67	66.11	2.38	0	300.16
Ferrous Metals | Steel | Coated Sheet | Zinc Coated & Coloured Sheet 0.43mm	116.11	122.42	0.5	0	239.03
Glazing | Windows | Aluminium Framed | Thermal Break | Single Glaze | Commercial Fixed	107.7	119.46	0.95	0	228.11
Bottom 5 Impact Materials					
Asphalt and Bitumen | Asphalt Mastic Roof Covering	0.9	1.08	0.08	0	2.06
Timber | Sustainably Sourced | Hardwood | Unspecified	1.27	0	0.11	0	1.38
Paints and Finishes | Unspecified | 2 Coats	0.47	0.55	0	0	1.02
Paints and Finishes | Wood Stains and Finishes | General	0.13	0.46	0	0	0.6
Resins and Adhesives | Urea Formaldehyde	0.06	0.08	0	0	0.14

Highest and Lowest Impact Templates (kg SO_2 eq.)

	Initial Materials & Construction (A1-A5)	Use Stage Materials & Construction (B1-B5)	Integrated Energy Use (B6)	Plug Load Energy Use (B6+)	Water Supply & Treatment (B7)	End of Life (C1-C4)	Recycling & Energy Export (D)	Total
Top 10 Impact Templates								
Roof Covering and Fiberglass Insulation, 50mm, 75 years (m2)	6146.04	0	0	0	0	27.65	0	6173.68
Poured Concrete - Lowest Floor 35MPa (m3)	3150.97	0	0	0	0	419.84	0	3570.81
200mm Hollow Concrete Block unfinished - Vedaçao	1739.01	0	0	0	0	198.22	0	1937.23
Poured Concrete - Foundations 30MPa (m3) - Radier	414.66	0	0	0	0	63.54	0	478.2
Prestressed alveolar concrete slab 25cm	380.83	0	0	0	0	34.65	0	415.48
[BRAZIL] Reinforcement Bar - Superstructure - Gerdau EPD (kg)	363.2	0	0	0	0	16.17	0	379.36
200mm Hollow Concrete Block unfinished - Estrutural	334.12	0	0	0	0	41.52	0	375.64
Demolition - Large Scale (End-of-Life)	0	0	0	0	0	320.19	0	320.19
External Finish - 13mm Render Cement (m2)	124.51	146.91	0	0	0	8.32	0	279.75
Wall Cladding - Zinc Coated Steel Sheeting 0.48mm Trimdek Profile (50 yrs)	116.21	122.52	0	0	0	0.51	0	239.24
Bottom 5 Impact Templates								
[BRAZIL] Reinforcement Bar - Superstructure (kg) - Pilares e Vigas	3.23	0	0	0	0	0.16	0	3.39
[BRAZIL] Staircase. Steel frame and steel treads (lm)	2.48	0.54	0	0	0	0.15	0	3.16
[BRAZIL] Reinforcement Bar - Substructure (kg) - Estaca Helice	2.35	0	0	0	0	0.12	0	2.47
Roof Covering - Spray on Waterproofing (External Use)	0.9	1.08	0	0	0	0.08	0	2.06
[BRAZIL] Reinforcement Bar - Substructure (kg) - Lowest Floor	0.62	0	0	0	0	0.03	0	0.65

6.4 Eutrophication potential, EP (kg PO_4 eq)

Figure 13: Time series Eutrophication potential, EP chart

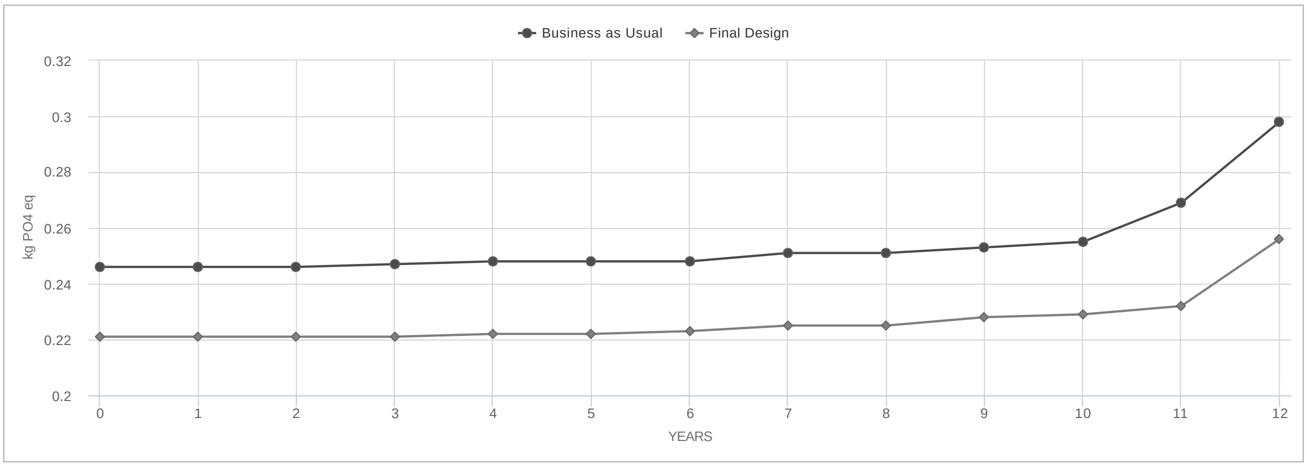
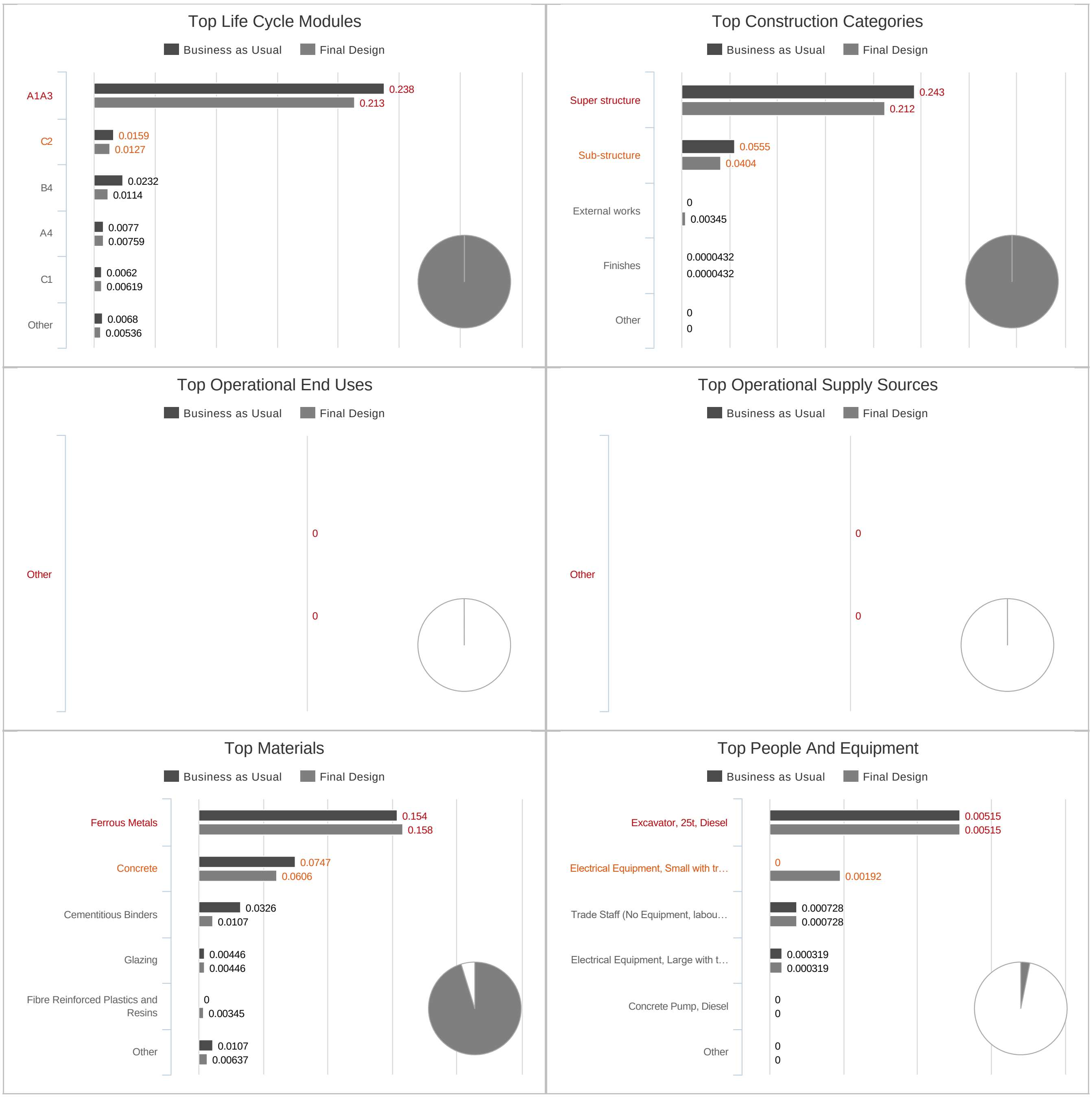


Figure 14: Top Five Eutrophication potential, EP chart



Highest and Lowest Impact Materials (kg PO_4 eq)

	Initial Materials & Construction (A1-A5)	Use Stage Materials & Construction (B1-B5)	End of Life (C1-C4)	Recycling & Energy Export (D)	Total
Top 10 Impact Materials					
Ferrous Metals | Steel | Coated Sheet | Zinc Coated & Coloured Sheet 0.56mm	1577.3	0	6.91	0	1584.21
Concrete | Unreinforced | Blast Furnace Slag Blends | 40 MPa | 10% BFS	299.29	0	105.33	0	404.61
Concrete | Unreinforced | Portland Cement Blends | Unspecified	138.56	0	52.71	0	191.28
Ferrous Metals | Steel | General | Unspecified	134.97	0	1.96	0	136.93
Cementitious Binders | Mortars and Renders | 1 cement : 4 sand	90.96	30.13	7.47	0	128.56
Ferrous Metals | Steel | Galvanised Structural | Unspecified	97.62	27.74	0.64	0	125.99
Concrete | Unreinforced | Blast Furnace Slag Blends | 30 MPa | 10% BFS	57.33	0	22.89	0	80.21
Ferrous Metals | Steel | Coated Sheet | Zinc Coated & Coloured Sheet 0.43mm	30.83	32.51	0.13	0	63.47
Concrete | Unreinforced | Fly Ash Blends | 30 MPa | 15% FA	41.01	0	14.82	0	55.83
Glazing | Windows | Aluminium Framed | Thermal Break | Single Glaze | Commercial Fixed	25.43	28.22	0.24	0	53.89
Bottom 5 Impact Materials					
Asphalt and Bitumen | Asphalt Mastic Roof Covering	0.17	0.21	0.02	0	0.4
Paints and Finishes | Unspecified | 2 Coats	0.16	0.19	0	0	0.36
Timber | Sustainably Sourced | Hardwood | Unspecified	0.32	0	0.03	0	0.35
Paints and Finishes | Wood Stains and Finishes | General	0.04	0.13	0	0	0.17
Resins and Adhesives | Urea Formaldehyde	0.01	0.01	0	0	0.02

Highest and Lowest Impact Templates (kg PO_4 eq)

	Initial Materials & Construction (A1-A5)	Use Stage Materials & Construction (B1-B5)	Integrated Energy Use (B6)	Plug Load Energy Use (B6+)	Water Supply & Treatment (B7)	End of Life (C1-C4)	Recycling & Energy Export (D)	Total
Top 10 Impact Templates								
Roof Covering and Fiberglass Insulation, 50mm, 75 years (m2)	1635.54	0	0	0	0	7.38	0	1642.92
Poured Concrete - Lowest Floor 35MPa (m3)	299.29	0	0	0	0	105.33	0	404.61
200mm Hollow Concrete Block unfinished - Vedaçao	308.9	0	0	0	0	49.69	0	358.59
Prestressed alveolar concrete slab 25cm	71.2	0	0	0	0	8.99	0	80.19
Demolition - Large Scale (End-of-Life)	0	0	0	0	0	74.76	0	74.76
Wall Cladding - Zinc Coated Steel Sheeting 0.48mm Trimdek Profile (50 yrs)	30.87	32.55	0	0	0	0.14	0	63.56
External Finish - 13mm Render Cement (m2)	26.11	31.08	0	0	0	2.09	0	59.28
Poured Concrete - Foundations 30MPa (m3) - Radier	39.93	0	0	0	0	15.94	0	55.87
Windows Commercial Aluminium Single Glaze no fly-screen (m2)	24.59	27.29	0	0	0	0.23	0	52.1
200mm Hollow Concrete Block unfinished - Estrutural	40.56	0	0	0	0	10.38	0	50.94
Bottom 5 Impact Templates								
[BRAZIL] Staircase. Steel frame and steel treads (lm)	0.99	0.15	0	0	0	0.04	0	1.18
[BRAZIL] Reinforcement Bar - Superstructure (kg) - Pilares e Vigas	1.06	0	0	0	0	0.04	0	1.09
[BRAZIL] Reinforcement Bar - Substructure (kg) - Estaca Helice	0.77	0	0	0	0	0.03	0	0.79
Roof Covering - Spray on Waterproofing (External Use)	0.17	0.21	0	0	0	0.02	0	0.4
[BRAZIL] Reinforcement Bar - Substructure (kg) - Lowest Floor	0.2	0	0	0	0	0.01	0	0.21

6.5 Photochemical Ozone Creation Potential, POCP (kg ethylene)

Figure 15: Time series Photochemical Ozone Creation Potential, POCP chart

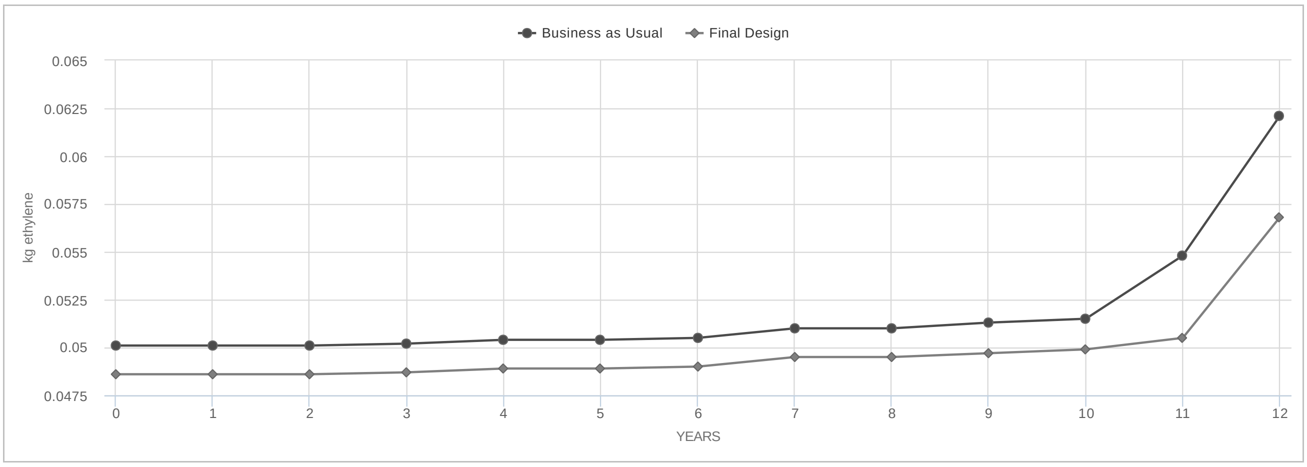
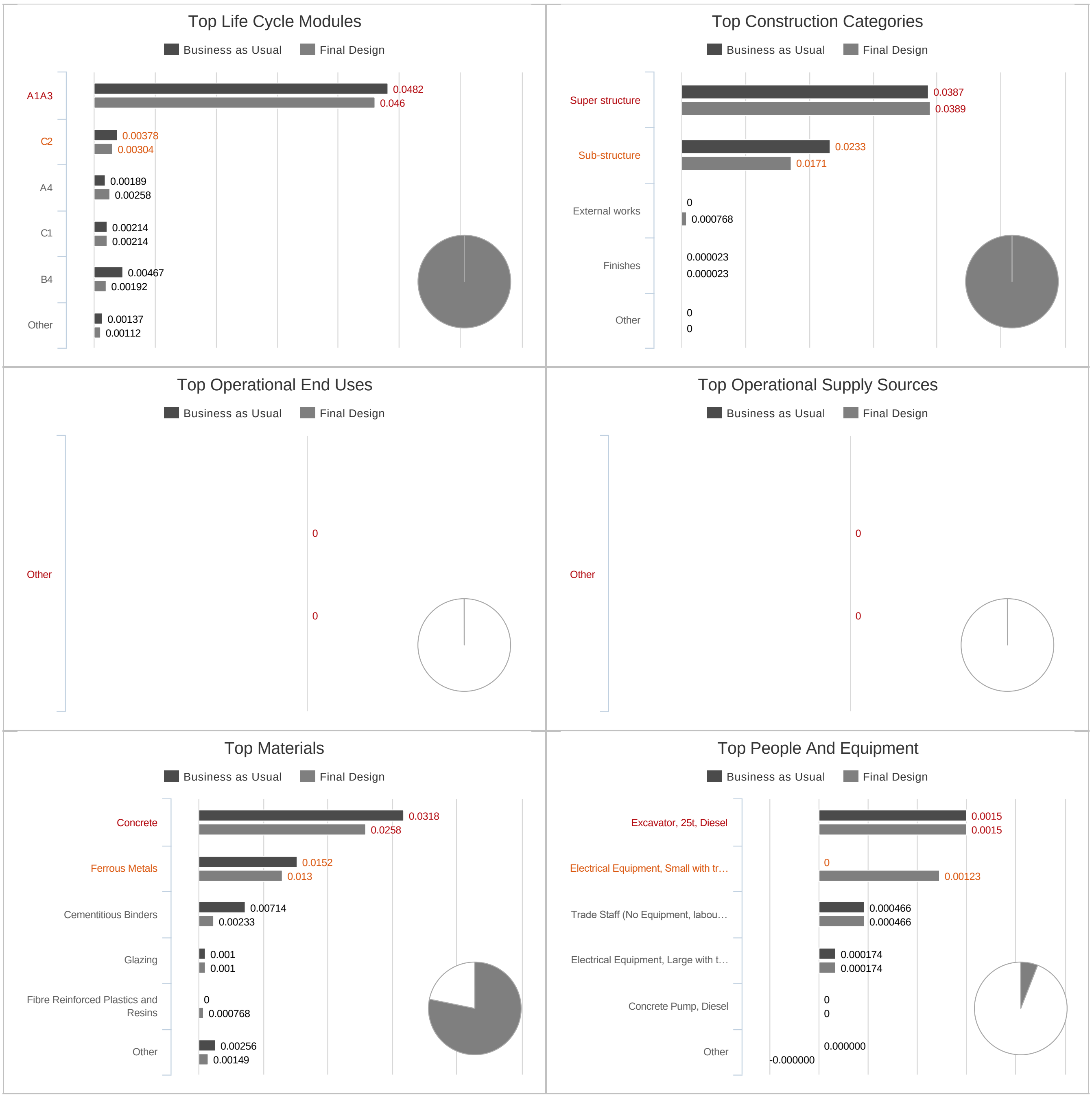


Figure 16: Top Five Photochemical Ozone Creation Potential, POCP chart



Highest and Lowest Impact Materials (kg ethylene)

	Initial Materials & Construction (A1-A5)	Use Stage Materials & Construction (B1-B5)	End of Life (C1-C4)	Recycling & Energy Export (D)	Total
Top 10 Impact Materials					
Concrete | Unreinforced | Blast Furnace Slag Blends | 40 MPa | 10% BFS	148.65	0	23.91	0	172.56
Ferrous Metals | Steel | Coated Sheet | Zinc Coated & Coloured Sheet 0.56mm	114.93	0	1.37	0	116.3
EPD-Reinforcing Steel Bar Gerdau GG 50 (URS (Sapucaia do Sul))	103.15	0	0.72	0	103.87
Concrete | Unreinforced | Portland Cement Blends | Unspecified	69.99	0	11.97	0	81.96
Concrete | Unreinforced | Blast Furnace Slag Blends | 30 MPa | 10% BFS	28.13	0	5.2	0	33.32
Cementitious Binders | Mortars and Renders | 1 cement : 4 sand	19.83	6.59	1.69	0	28.11
Concrete | Unreinforced | Fly Ash Blends | 30 MPa | 15% FA	20.1	0	3.44	0	23.54
Ferrous Metals | Steel | General | Unspecified	22.31	0	0.39	0	22.7
Ferrous Metals | Steel | Galvanised Structural | Unspecified	10.44	2.99	0.13	0	13.56
Glazing | Windows | Aluminium Framed | Thermal Break | Single Glaze | Commercial Fixed	5.71	6.34	0.05	0	12.11
Bottom 5 Impact Materials					
Timber | Sustainably Sourced | Hardwood | Unspecified	0.12	0	0.1	0	0.22
Asphalt and Bitumen | Asphalt Mastic Roof Covering	0.05	0.06	0	0	0.11
Paints and Finishes | Unspecified | 2 Coats	0.04	0.05	0	0	0.09
Paints and Finishes | Wood Stains and Finishes | General	0.01	0.04	0	0	0.06
Resins and Adhesives | Urea Formaldehyde	0	0.01	0	0	0.01

Highest and Lowest Impact Templates (kg ethylene)

	Initial Materials & Construction (A1-A5)	Use Stage Materials & Construction (B1-B5)	Integrated Energy Use (B6)	Plug Load Energy Use (B6+)	Water Supply & Treatment (B7)	End of Life (C1-C4)	Recycling & Energy Export (D)	Total
Top 10 Impact Templates								
Poured Concrete - Lowest Floor 35MPa (m3)	148.65	0	0	0	0	23.91	0	172.56
Roof Covering and Fiberglass Insulation, 50mm, 75 years (m2)	136.08	0	0	0	0	1.47	0	137.55
200mm Hollow Concrete Block unfinished - Vedaçao	93.99	0	0	0	0	11.24	0	105.23
[BRAZIL] Reinforcement Bar - Superstructure - Gerdau EPD (kg)	103.16	0	0	0	0	1.52	0	104.68
Demolition - Large Scale (End-of-Life)	0	0	0	0	0	25.85	0	25.85
Poured Concrete - Foundations 30MPa (m3) - Radier	19.59	0	0	0	0	3.62	0	23.21
Prestressed alveolar concrete slab 25cm	17.67	0	0	0	0	2.11	0	19.78
200mm Hollow Concrete Block unfinished - Estrutural	16.01	0	0	0	0	2.36	0	18.37
External Finish - 13mm Render Cement (m2)	5.92	7.07	0	0	0	0.47	0	13.46
Windows Commercial Aluminium Single Glaze no fly-screen (m2)	5.52	6.13	0	0	0	0.05	0	11.71
Bottom 5 Impact Templates								
[BRAZIL] Reinforcement Bar - Substructure (kg) - Sapata	0.18	0	0	0	0	0.01	0	0.19
[BRAZIL] Reinforcement Bar - Superstructure (kg) - Pilares e Vigas	0.16	0	0	0	0	0.01	0	0.17
[BRAZIL] Reinforcement Bar - Substructure (kg) - Estaca Helice	0.11	0	0	0	0	0.01	0	0.12
Roof Covering - Spray on Waterproofing (External Use)	0.05	0.06	0	0	0	0	0	0.11
[BRAZIL] Reinforcement Bar - Substructure (kg) - Lowest Floor	0.03	0	0	0	0	0	0	0.03

6.6 Abiotic Depletion Potential - Fossil Fuels, ADPF (MJ)

Figure 17: Time series Abiotic Depletion Potential - Fossil Fuels, ADPF chart

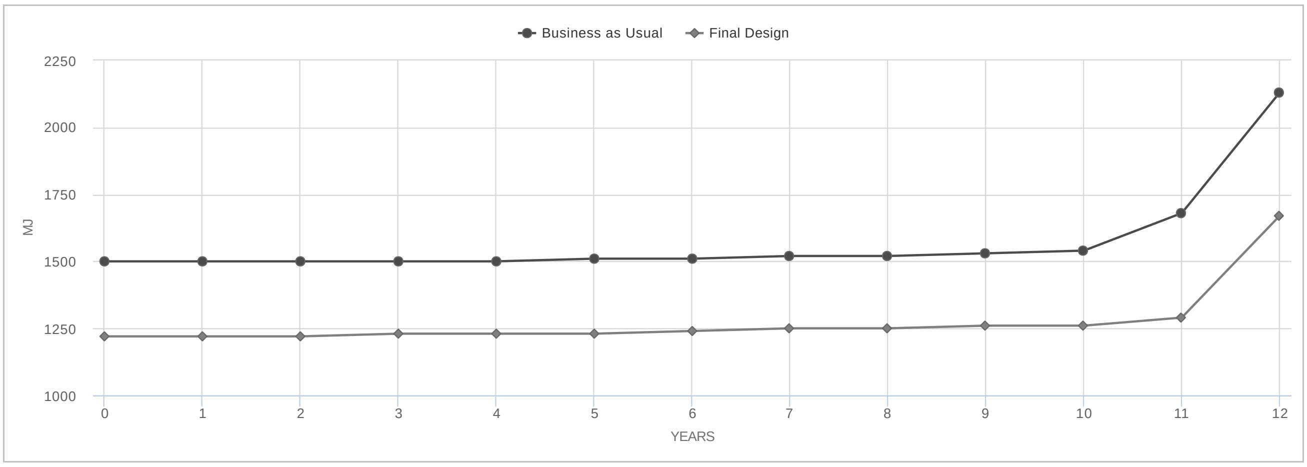


Figure 18: Top Five Abiotic Depletion Potential - Fossil Fuels, ADPF chart

Highest and Lowest Impact Materials (MJ)

	Initial Materials & Construction (A1-A5)	Use Stage Materials & Construction (B1-B5)	End of Life (C1-C4)	Recycling & Energy Export (D)	Total
Top 10 Impact Materials					
Concrete | Unreinforced | Blast Furnace Slag Blends | 40 MPa | 10% BFS	3563498.02	0	1560303.09	0	5123801.1
Ferrous Metals | Steel | Coated Sheet | Zinc Coated & Coloured Sheet 0.56mm	4045826.21	0	84892.27	0	4130718.48
Concrete | Unreinforced | Portland Cement Blends | Unspecified	1686736.73	0	780871.75	0	2467608.48
Cementitious Binders | Mortars and Renders | 1 cement : 4 sand	789614.72	275574.55	110592.64	0	1175781.91
Concrete | Unreinforced | Blast Furnace Slag Blends | 30 MPa | 10% BFS	685646.92	0	339030.16	0	1024677.08
EPD-Reinforcing Steel Bar Gerdau GG 50 (URS (Sapucaia do Sul))	832759.59	0	6600.02	0	839359.61
Concrete | Unreinforced | Fly Ash Blends | 30 MPa | 15% FA	502747.41	0	218691.66	0	721439.07
Fibre Reinforced Plastics and Resins | Fibre reinforced plastic (FRP)	697602.04	0	3630.8	0	701232.83
Ferrous Metals | Steel | General | Unspecified	549896.74	0	24117.1	0	574013.84
Glazing | Windows | Aluminium Framed | Thermal Break | Single Glaze | Commercial Fixed	145476.04	163816.49	3522.13	0	312814.65
Bottom 5 Impact Materials					
Asphalt and Bitumen | Asphalt Mastic Roof Covering	3041.28	3656.89	283.17	0	6981.34
Paints and Finishes | Unspecified | 2 Coats	1801.36	2087.96	15.61	0	3904.93
Timber | Sustainably Sourced | Hardwood | Unspecified	3375.48	0	342.6	0	3718.08
Paints and Finishes | Wood Stains and Finishes | General	315.61	1105.25	4.99	0	1425.86
Resins and Adhesives | Urea Formaldehyde	162.05	196.74	2.06	0	360.85

Highest and Lowest Impact Templates (MJ)

Template	Initial Materials & Construction (A1-A5)	Use Stage Materials & Construction (B1-B5)	Integrated Energy Use (B6)	Plug Load Energy Use (B6+)	Water Supply & Treatment (B7)	End of Life (C1-C4)	Recycling & Energy Export (D)	Total
Top 10 Impact Templates								
Poured Concrete - Lowest Floor 35MPa (m3)	3563498.02	0	0	0	0	1560303.09	0	5123801.1
Roof Covering and Fiberglass Insulation, 50mm, 75 years (m2)	4573674.34	0	0	0	0	91415.78	0	4665090.12
200mm Hollow Concrete Block unfinished - Vedaçao	2482730.03	0	0	0	0	731042.3	0	3213772.33
Demolition - Large Scale (End-of-Life)	0	0	0	0	0	1414019.6	0	1414019.6
[BRAZIL] Reinforcement Bar - Superstructure - Gerdau EPD (kg)	833023.1	0	0	0	0	59302.13	0	892325.23
Poured Concrete - Foundations 30MPa (m3) - Radier	477543.22	0	0	0	0	236129.63	0	713672.85
External Works - Glass fibre reinforced polymer, Material Only, No Construction Waste Factors/Lost in transport/Assembly (tons)	697602.04	0	0	0	0	3630.8	0	701232.83
200mm Hollow Concrete Block unfinished - Estrutural	430503.97	0	0	0	0	153694.21	0	584198.18
External Finish - 13mm Render Cement (m2)	244565.39	305359.63	0	0	0	30927.16	0	580852.18
Prestressed alveolar concrete slab 25cm	417690.1	0	0	0	0	131641.43	0	549331.53
Bottom 5 Impact Templates								
[BRAZIL] Reinforcement Bar - Superstructure (kg) - Pilares e Vigas	9574.8	0	0	0	0	649.11	0	10223.91
[BRAZIL] Staircase. Steel frame and steel treads (lm)	6400.26	1301.99	0	0	0	461.37	0	8163.63
[BRAZIL] Reinforcement Bar - Substructure (kg) - Estaca Helice	6966.34	0	0	0	0	472.27	0	7438.61
Roof Covering - Spray on Waterproofing (External Use)	3041.28	3656.89	0	0	0	283.17	0	6981.34
[BRAZIL] Reinforcement Bar - Substructure (kg) - Lowest Floor	1838.52	0	0	0	0	124.64	0	1963.16

7 Scenarios Summary Tables

7.1 Final Design Scenarios Summary

Table 11: While modelling the Final Design the following scenarios were modelled.

	Scenario	GWP	ODP	AP	EP	POCP	ADPF
●	<Business as Usual>						
●	Steel Reinforcement - ArcelorMittal EPD	0.07%	0.09%	0.05%	0.26%	-0.04%	0.18%
●	Steel Reinforcement - Gerdau EPD	0.82%	0.88%	-0.23%	2.11%	-11.76%	0.49%
●	Cement with 13% FlyAsh in Superstructure	0.26%	0.00%	0.21%	0.06%	0.23%	0.08%
●	Replacement of Roof Insulation	0.13%	-0.21%	0.48%	0.30%	-1.13%	0.07%
●	Roof Covering - ArcelorMittal EPD	1.78%	-3.81%	-1.45%	-2.33%	2.60%	1.54%
●	Remove render finish	11.91%	11.60%	8.05%	8.55%	9.14%	11.58%
●	Ground floor construction optimisation	10.16%	7.40%	8.12%	5.10%	9.46%	7.61%
●	<Final Design>						

● Strategies included in Final Design ● Strategies not included in Final Design

8 Low Impact Strategies

The following low impact design strategies were modelled in the LCA study to determine the relative benefits and aid the design decision making process.

The relative saving of each progressed recommendation against the Business as Usual is provided in the following tables for each strategy. Further information regarding each strategy is also provided regarding motivation and logistical constraints.

8.1 Final Design Strategies

The following low impact strategies are included in the Final Design.

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPF
<Business as Usual>						
Steel Reinforcement - ArcelorMittal EPD	0.07 %	0.09 %	0.05 %	0.26 %	-0.04 %	0.18 %
Steel Reinforcement - Gerdau EPD	0.82 %	0.88 %	-0.23 %	2.11 %	-11.76 %	0.49 %
Cement with 13% FlyAsh in Superstructure	0.26 %	0.00 %	0.21 %	0.06 %	0.23 %	0.08 %
Replacement of Roof Insulation	0.13 %	-0.21 %	0.48 %	0.30 %	-1.13 %	0.07 %
Roof Covering - ArcelorMittal EPD	1.78 %	-3.81 %	-1.45 %	-2.33 %	2.60 %	1.54 %
Remove render finish	11.91 %	11.60 %	8.05 %	8.55 %	9.14 %	11.58 %
Ground floor construction optimisation	10.16 %	7.40 %	8.12 %	5.10 %	9.46 %	7.61 %
<Final Design>						

Table 12: Design Strategies in Final Design

8.1.1 Steel Reinforcement - ArcelorMittal EPD

% Changes Against the Business as Usual

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPF
Steel Reinforcement - ArcelorMittal EPD	0.07 %	0.09 %	0.05 %	0.26 %	-0.04 %	0.18 %

Table 13: Impact savings (or increases) associated with the Steel Reinforcement - ArcelorMittal EPD as a percentage of the Final Design.

Steel reinforcement has a significant impact, predominantly at the product stage (A1-A3). Available EPDs for steel reinforcement bars in Brazil have been reviewed and the baseline design considers the average performance product: EPD - Reinforcing Steel Bar Gerdau GG 50 GSP (Araçariguama) as per supporting documentation. The specific product used in this project is documented using the ARCELOR MITTAL - EPD Reinforcing Steel in Bars - Belo Horizonte, with 10324,00 Kg according documentation NF 001113122 - ARCELOR MITTAL - AÇO CA50 10, 16, 20MM, with improved performance due to higher recycled content and reduced impact at product stage.

This improvement was put forward to provide an incentive to manufactures that have higher recycled content and seek to reduce as much as possible the upfront emissions. Higher recycled content will provide impact savings at product stage only when module D (D2 - closed loop recycling) is not considered.

8.1.2 Steel Reinforcement - Gerdau EPD

% Changes Against the Business as Usual

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPF
Steel Reinforcement - Gerdau EPD	0.82 %	0.88 %	-0.23 %	2.11 %	-11.76 %	0.49 %

Table 14: Impact savings (or increases) associated with the Steel Reinforcement - Gerdau EPD as a percentage of the Final Design.

Available EPDs for steel reinforcement bars in Brazil have been reviewed and the baseline design considers the average performance product: EPD - Reinforcing Steel Bar Gerdau GG 50 GSP (Araçariguama) as per supporting documentation. The specific product used in this project is documented using the EPD Reinforcing Steel Bar Gerdau GG 50 URS (Sapucaia do Sul) with 83863,00 Kg according documentation NF 4390 - GERDAU - AÇO CA50 6.3, 8, 10, 12.5, 16, 20, 25 E 50mm, with improved performance due to higher recycled content and reduced impact at product stage.

This improvement was put forward to provide an incentive to manufactures that have higher recycled content and seek to reduce as much as possible the upfront emissions. Higher recycled content will provide impact savings at product stage only when module D (D2 - closed loop recycling) is not considered.

8.1.3 Cement with 13% FlyAsh in Superstructure

% Changes Against the Business as Usual

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPF
Cement with 13% FlyAsh in Superstructure	0.26 %	0.00 %	0.21 %	0.06 %	0.23 %	0.08 %

Table 15: Impact savings (or increases) associated with the Cement with 13% FlyAsh in Superstructure as a percentage of the Final Design.

Cement has high environmental impact incorporated mainly due to calcination and energy used during clinker production. The reduction of cement clinker content and efficiency of (kg of cement / m3 of concrete) have great potential to reduce impacts related to the project materials as a whole. The feasibility of using Fly Ash addition to replace the clinker should consider compliance with current technical standards and logistical limitations such as availability and curing time of concrete. Even though there is already 10% of BFS in concrete standard practice. In this project was used 13% Fly Ash as per documents *CIVIL - TERMO DE DECLARAÇÃO DOS PRODUTOS - GERAL, INTERCEMENT - DAP Cimento CP V ARI RS and NF - INTERCEMENT - CIMENTO CPV ARI.*

The table below show the quantity of concrete with cement that contains 13% of BFS:

Template	Quantity (m3)
Poured Concrete - Frames/Columns/Beams 25MPa (m3) - Pilares	24,07
Poured Concrete - Frames/Columns/Beams 25MPa (m3) - Vigas	36,08
TOTAL CONCRETE	**60,15**

8.1.4 Replacement of Roof Insulation

% Changes Against the Business as Usual

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPF
Replacement of Roof Insulation	0.13 %	-0.21 %	0.48 %	0.30 %	-1.13 %	0.07 %

Table 16: Impact savings (or increases) associated with the Replacement of Roof Insulation as a percentage of the Final Design.

Replacement of rockwool (63.5mm thick) with fiberglass (63.5mm thick) as insulation. The main goal of this scenario is to eliminated the second steel panel provided by the sandwich steel panel predicted in the baseline scenario and change the insulation.

For more see: ARTSERV- TERMO DE DECLARAÇÃO DOS PRODUTOS - TELHA ZIPADA COM ISOLAMENTO and NF 19457 - ISOPUR.

The table below shows quantities and specifications:

Template Baseline Design	Baseline Design Quantity (m2)	Template Improved Design	Improved Design Quantity (m2)
Roof Covering and rockwool Insulation, 50mm, 75 years (m2)	10977,84	Roof Covering and Fiberglass Insulation 50mm (m2)	10977,84

8.1.5 Roof Covering - ArcelorMittal EPD

% Changes Against the Business as Usual

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPF
Roof Covering - ArcelorMittal EPD	1.78 %	-3.81 %	-1.45 %	-2.33 %	2.60 %	1.54 %

Table 17: Impact savings (or increases) associated with the Roof Covering - ArcelorMittal EPD as a percentage of the Final Design.

Steel has a significant impact, predominantly at the product stage (A1-A3). The recycled content considered is the one informed in the material selected for this project, Arcelor Mittal Hot Dip Galvanized Steel with Pure Zinc Coating. According to the valid EPD, the material contains 88% of recycled content. In this project the roof area is 10977.84 m² and the area of the wall is 410.00 m².

For more see: ARTSERV- TERMO DE DECLARAÇÃO DOS PRODUTOS - TELHA ZIPADA COM ISOLAMENTO and ARCELOR MITTAL - DAP Bobinas de Aço Laminado Quente - Salvador.

8.1.6 Remove render finish

% Changes Against the Business as Usual

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPF
Remove render finish	11.91 %	11.60 %	8.05 %	8.55 %	9.14 %	11.58 %

Table 18: Impact savings (or increases) associated with the Remove render finish as a percentage of the Final Design.

The project team confirmed the improvement to remove plaster in internal finish and render in external finish walls, According to document BAY-PL-ARQ-001-DOC-R06 in the project baseline, the use of plaster was considered throughout the building, with 12432.36m² of total area and assumption of 1.3 centimeters thick, keeping only the painting in external walls, because of the great cement impact, removing this material can represent a great reduction of environmental impact.

8.1.7 Ground floor construction optimisation

% Changes Against the Business as Usual

Design Strategy Performance	GWP	ODP	AP	EP	POCP	ADPF
Ground floor construction optimisation	10.16 %	7.40 %	8.12 %	5.10 %	9.46 %	7.61 %

Table 19: Impact savings (or increases) associated with the Ground floor construction optimisation as a percentage of the Final Design.

Improvement made regarding the thickness of concrete slab with the introduction of Syntetic fibre, reducing from 20 cm to 17.5 cm, validated by the structural engineers. The use of this technology together with steel fiber helped to decrease the volume of concrete by 31%, besides to gains in greater resistence to natural wear, increasing the useful life and reducing the need for maintenance, reducing environmental impacts.

For more see: TR.8125-PIS-EX-001-PLA-R00, TR.8125-PIS-EX-002-DET-R00 and TR.8125-PIS-EX-003-QTD-R00.

Baseline Design Template	Baseline Design Quantity	UN	Improved Design Template	Improved Design Quantity	UN
Poured Concrete - Lowest Floor 25MPa (m3) - Piso - h=20cm - piso	1438,763	m3	Poured Concrete - Lowest Floor 25MPa (m3) - Piso - h=17.5cm - piso	1018	m3
			Reinforcement Bar - Lowest Floor (kg) - piso	161,78	kg
			Reinforcement bar superstructure (kg) - aço em tela	4803,56	kg
Reinforcement Bar - Lowest Floor (kg) - piso	143876,250	kg	Fibre reinforced polymer (tons) - Fibra sintética	5600	kg

9 Conclusion

The report shows that the Final Design has lower Global Warming Potential Total, GWP impact than the Business as Usual Design. The **Product Stage (A1A3)** GWP Impacts are the most dominant life cycle module in the Final Design Design followed by the **Transport of Waste Offsite (C2)** and then **Deconstruction / Demolition (C1)**.

Further analysis reveals:

- The **Super structure** is the highest impact construction category,
- **Concrete | Unreinforced | Blast Furnace Slag Blends | 40 MPa | 10% BFS** is the highest impact material category,
- **Excavator, 25t, Diesel** is the highest people and equipment impact

7 strategies were modelled in the Final Design, the **Remove render finish** strategy had the highest saving followed by **Ground floor construction optimisation** . See full LCA report for details of other environmental strategies.

In addition to GWP, other indicators were included in the study, the results of which are summerised below.

The Final Design shows an expected performance improvement against the Business as Usual Design for 5 indicators:

- 25.12% **saving** in GWP impacts
- NaN% **increase** in ODP impacts
- 15.22% **saving** in AP impacts
- 14.09% **saving** in EP impacts
- 8.06% **saving** in POCP impacts
- 21.55% **saving** in ADPF impacts

Appendix A: Environmental Indicators Description

Global Warming Potential Total, GWP

Anthropogenic global warming is caused by an increase of greenhouse gasses (GHG) in the earth's atmosphere. These gasses reflect some of the heat radiated from the earth's surface that would normally escape into space back to the surface of the earth. Overtime this warms the earth. Common GHGs include CO2, N2O, CH4 and volatile organic compounds (VOCs). Global Warming Potential Total (GWP) is expressed in equivalent GHGs released, usually in kgCO2e.
Global Warming Potential Total (GWP) = GWP Fossil + GWP Biogenic + GWP LULUC.

Ozone Depletion Potential, ODP

Ozone is formed and depleted naturally in the earth's stratosphere (between 15-40 km above the earth's surface). Halocarbon compounds are persistent synthetic halogen containing organic molecules that can reach the stratosphere leading to more rapid depletion of the ozone. As the ozone in the stratosphere is reduced more of the ultraviolet rays in sunlight can reach the earth's surface where they can cause skin cancer and reduced crop yields. Ozone Depletion Potential (ODP) is expressed in equivalent ozone depleting gasses (normally kgCFC11e).

Acidification Potential for Soil and Water, AP

Acidification is a consequence of acids (and other compounds which can be transformed into acids) being emitted to the atmosphere and subsequently deposited in surface soils and water. Increased acidity can result in negative consequences for flora and fauna in addition to increased corrosion of manmade structures (buildings vehicles etc.). Acidification Potential (AP) is an indicator of such damage and is usually measured in kgSO₂e

Eutrophication potential, EP

Over enrichment of aquatic ecosystems with nutrients leading to increased production of plankton, algae and higher aquatic plants leading to a deterioration of the water quality and a reduction in the value and/or the utilisation of the aquatic ecosystem. Eutrophication is primarily caused by surplus nitrogen and phosphorus. Sources of nutrients include agriculture (fertilisers and manure), aquaculture, municipal wastewater, and nitrogen oxide emissions from fossil fuel combustion.

Photochemical Ozone Creation Potential, POCP

Photochemical Ozone Creation Potential (POCP), commonly known as smog, is toxic to humans in high concentration. Although ozone is protective in the stratosphere at low levels it is problematic from both a health and nuisance perspective. Plant growth is also effected through damaged leaf surfaces and reduced photosynthesis. POCP is formed when sunlight and heat react with Volatile Organic Compounds (VOCs).

Abiotic Depletion Potential - Fossil Fuels, ADPF

Abiotic Resource Depletion of energy (ARDE) is a measure of the extraction and consumption of non-renewable energy sources (primarily fossil fuels, but also inclusive of other energy sources such as uranium). Primary energy content of non-renewable energy sources including the embodied energy to extract, process and deliver the non renewable fuels, or manufacture, transport and install the renewable generator. Hence there is usually and non-renewable energy content associated with renewable fuels also.