LCA Single Skin Roof and Wall Cladding

Environmental declarations for steel

Client

Metaalunie

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Table of Contents

Explanatory glossary and abbreviations 5

Sources 6

Standards 6
Bibliography 6

1 Introduction 7

1.1 Justification 7
1.2 Objective and Target Audience 7
1.3 Guide 8
1.4 Assessor's Judgment 8

2 Scope 9

2.1 Sector Wall and Roof Cladding and Liner trays 9
2.2 Product and/or Functional Unit 9
2.2.1 Product Units 9
2.2.2 Product Descriptions 9
2.2.3 Technical lifespan: 50 years 13
2.2.4 Calculation rules for averaging data 15
2.3 System Boundaries 16
2.3.1 Process tree 16
2.3.2 Product phase (module A1-3) 17
2.3.3 Quantification of Energy and Material Flows 19
2.4 Excluded Processes and Flows 19

3 Life Cycle Inventory (LCI) 20

3.1 Data Collection 20
3.1.1 Data Production Locations 20
3.1.2 Supplier Data 21
3.2 Qualitative / quantitative process data. 21
3.2.1 Production phase (A1-A3) 22
3.2.2 Construction Phase A4-A5 25
3.2.3 Operational Phase (B1-B5) 26
3.2.4 End-of-Life Phase (C1-4) 26
3.2.5 External Costs and Benefits (D) 27
3.3 Data validation 28
3.3.1 Generic Data 29
3.4 Biogenic Carbon 30

4 Life Cycle Analysis 31

4.1 Calculation of Environmental Profile 31
4.2 LCA Calculation Results and Shadow Prices 32
4.2.1 Wall cladding 33
4.2.2 Roof and Floor Cladding 37
4.2.3 Liner tray 41
4.3 Scaling 43
4.3.1 Sensitivity Analysis Scaling Wall Cladding 49
4.4 Sensitivity Analysis of Zinc and Coating Thickness 49

Appendices

Appendix Ia	LCI & Results for Wall Cladding
Appendix Ib	LCI & Results for Roof and Floor Cladding
Appendix Ic	LCI & Results for Liner tray
Appendix II	Data Quality Single Skin

Explanatory glossary and abbreviations

EPD:	Environmental Product Declaration
NMD:	Nationale Milieudatabase: the Dutch National Environmental Database
SBK-Assessment Method:	The Assessment Method for the Environmental Performance of Buildings, version 1.0 (July 2020 with Amendment 1 of October 2020, Amendment 2 of February 2021, and Amendment 3 of October 2021)
SBK	Stichting Bouwkwaliteit
EAF	Electric Arc Furnace
BF	Blast Furnace/Hoogoven
Worldsteel	World Steel Association
HDG	Hot Dip Galvanized
OC	Organic Coated
LD- steel slag	LD steel slag refers to steel slag that is generated during the LD (Linz-Donawitz) oxygen steelmaking process
MDG	Netwerk voor Metalen Daken en Gevels (Network for Metal Roofs and Walls)

Sources

Standards

EN15804	NEN-EN 15804:2012 + A2 (2019) *Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products.*
ISO 14025	ISO 14025:2010 Environmental labels and declarations - Type III environmental declarations - Principles and procedures.
ISO 14044	ISO 14044:2006 “Environmental management - Life cycle assessment - Requirements and guidelines”
SBK Assessment Method	Assessment Method for the Environmental Performance of Buildings, version 1.0, July 2020, with Amendment 1 of October 2020 and Amendment 2 of February 2021.

Bibliography

End-of-waste criteria for iron, steel and aluminium scrap	Council Regulation (EU) No 333/2011 of 31 March 2011 establishing criteria determining when certain types of scrap metal cease to be waste under Directive 2008/98/EC of the European Parliament and of the Council
World Steel LCI methodology report, 2017	World Steel Association – Life Cycle Inventory Methodology Report, 2017. ISBN 978-2-930069-89-0
World Steel LCI Study, 2018	World Steel Association – Life Cycle Inventory Study, 2018.
World Steel co-product methodology, 2014	A methodology to determine the LCI of steel industry co-products, 14th February 2014.
Terugwinning van zink bij de recycling van verzinkt staal(schroot), 2008	WMB Consultancy - Inventory of conducted studies regarding the recovery of zinc in the recycling of galvanized steel (scrap). No. 50040051303. March 31, 2008.
TNO, 2010	034-DTM-2010-02582, Beoordeling duurzame veiligheid van stalen gevels Fase III: Inspecties en levensduurvoorspelling.
Staalfederatie, 2019	‘LCA Staalfederatie, Basis Profielen Staalproducten’ (2019)
MDG, 2020	Kwaliteitsrichtlijn metalen gevels en daken 2020. Deel 1: Montage, verwerking en oplevering.

LBP|SIGHT

1 Introduction

On behalf of Metaalunie, LBP|SIGHT has conducted a life cycle analysis (LCA) for three common sheet steel building products intended for supply in the Dutch market.

The applications under consideration are as follows:
- Wall cladding including flashing;
- Roof and floor cladding including flashing;
- Liner Tray including flashing.

1.1 Justification

The LCA was carried out in accordance with the requirements and guidelines from the Environmental Performance Assessment Method for Buildings (version 1.0, July 2020 + Amendment 1, October 2020, Amendment 2, February 2021, Amendment 3, October 2021) and the SBK Verification Protocol (version 1, July 2020 + Amendment 1, February 2021).

The Assessment Method is based on ISO 14040 - ISO 14044 and NEN-EN 15804:2012 + A2 (2019) [1].. Additionally, the base profiles also comply with the requirements of NEN-EN-ISO 14025:2010 for EPD.

The LCA was conducted in collaboration between LBP|SIGHT, Bouwen met Staal, and various producers who were approached to provide production data. Data collection took place from May 2021 to September 2021, after which the calculations were performed and the LCA dossier was prepared. The LCA executors are Ir. René Kraaijenbrink, Ing. Jeannette Levels-Vermeer, and David van Nunen MSc.

The production data provided by the different production locations are confidential and are not published in this LCA report.

1.2 Objective and Target Audience

In this study, environmental profiles have been created for three steel products produced in Europe based on the weighted average in the Dutch market. The goal of the study is to include these environmental profiles as category 2 data (brand-independent and verified) in the NMD.

Only the summation of environmental impact scores into a single score (the MKI, see chapter 4.6) is outside the scope of ISO 14044.

The LCA dossier prepared for this study has been externally reviewed, substantiating that this study complies with the methodological requirements as mentioned in the preceding paragraph.

Additionally, the results of the LCA study can be used by the client to create an EPD, enabling the environmental performance of the product to be communicated externally (business-to-business).

The target audience for the results of this study is as follows:
- Metaalunie as the client of this LCA study.
- Users of the National Environmental Database (NMD) and the processes database.
- Manufacturers of the steel products.
- Consumers of the steel products.

1.3 Guide

Chapter 2 explains the scope of the study and includes the process tree with explanations. Chapter 3 provides the justification for the data inventory, and finally, the LCA results are presented and discussed in Chapter 4.

1.4 Assessor's Judgment

Toetsingsverklaring SGS INTRON

De getoetste LCA's van:

- *"1 m² stalen gevelbeplating inclusief zetwerk toegepast als onderdeel van een niet-constructieve buitenwand, in Europa geproduceerd en gebruikt in de Nederlandse markt"*
  MKI (A-D) € 1,65
- *"1 m² stalen binnendoos inclusief zetwerk als onderdeel van een niet-constructieve buitenwand, in Europa geproduceerd en gebruikt in de Nederlandse markt"*
  MKI (A-D) € 2,06
- *"1 m² stalen dak- en vloerbeplating inclusief zetwerk, in Europa geproduceerd en gebruikt in de Nederlandse markt"*
  MKI (A-D) € 1,93

zoals gerapporteerd in rapport LCA Single Skin dak- en gevelbekleding, Productkaarten staal. LBP Sight, R087398aa.2185CJ8.dvn, versie 01_003 13 juni 2022,

voldoen aan het gestelde in NMD Bepalingsmethode 'Milieuprestatie Bouwwerken', versie 1.0, juli 2020 en vigerende amendementen.

Sittard, 14 juni 2022,

drs. A. Schuurmans   dr. U. Hofstra

2 Scope

2.1 Sector Wall and Roof Cladding and Liner trays

Cold-rolled steel strip can be used for the liner tray, wall, roof, and floor cladding of a building. These claddings enclose the structure of the building, separating the indoor and outdoor climates. Insulation can be incorporated into the liner tray, which is sealed with wall cladding. The steel cladding types are partially galvanized and may have a coating layer. The thickness of galvanization and coating varies depending on the application.

2.2 Product and/or Functional Unit

2.2.1 Product Units

This study encompasses three steel products for which life cycle profiles have been developed (cradle-to-grave with module D).

The following product units are used as references in this LCA study:

- *"1 m^2 of steel wall cladding including flashing applied as part of a non-structural exterior wall, produced in Europe and used in the Dutch market"*
- *"1 m^2 of steel liner tray including flashing as part of a non-structural exterior wall, produced in Europe and used in the Dutch market"*
- *"1 m^2 of steel roof and floor cladding including flashing, produced in Europe and used in the Dutch market"*

2.2.2 Product Descriptions

Steel Wall Cladding (B&U 21.1 Exterior Walls; non-structural and B&U 41.1 Exterior Wall Finishes, see Table 2.1 and 2.2)

Steel wall cladding is a final product produced from cold-rolled steel strip, thermally galvanized, and usually organically coated. This product is representative of various geometries (seam, corrugated, profiled sheet, shiplap) and dimensions. The thickness of wall cladding ranges between 0.5-1 mm. Flashing and coating are integral parts of the production process. Steel wall cladding is commonly used in industrial, agricultural, and utility construction, sometimes in combination with insulation panels.

In this LCA, the reference unit is 1 m^2 of wall cladding with a thickness of 0.725 mm and a weight of 7.63 kg/m^2. The thickness of the reference profile is derived from an average of the most commonly used wall cladding types provided by suppliers. The mass is calculated from the product data using a scaling formula (see Chapter 4.3).

Steel liner tray (B&U 21.1 Exterior Walls; non-structural, see Table 2.1)
A steel liner tray is a profiled steel sheet produced from cold-rolled steel strip, thermally galvanized, and usually organically coated. This product represents various product dimensions and thicknesses ranging from 0.75-1.5 mm. Flashing and coating are included in the product profile. The liner tray can be equipped with insulation and sealed with wall cladding (e.g., steel wall cladding). The liner tray is then finished with the externally visible wall covering.

In this LCA, the reference unit is 1 m2 of liner tray with a thickness of 0.75 mm and a weight of 10.03 kg/m^2. The thickness of the reference profile is derived from an average of the most commonly used liner trays provided by suppliers. The mass is calculated from the product data using a scaling formula (see Chapter 4.3).

Table 2.1
B&U 21.1

	21.1 Exterior Walls; Non-structural
Code	Collection of non-structural exterior walls, forming the boundary of the building, measured from the top of the foundation structures to the top of the roof structures.
Description	Division of interior/exterior spaces.
Function	m^2
Functional unit	The entirety of non-structural exterior walls that form a separation between the building and the outdoor air or unheated spaces. Closed walls include all wall surfaces of a dwelling that do not consist of window frames, including: #(Basement) walls, composite walls, curtain walls, and system walls #Parapets, wall reinforcements, and recessed walls of galleries #Chimneys that are part of the wall; #Ventilation ducts that are part of the wall #Plaster layers in the cavities and edge connection provisions #Building insulation provisions #Finishes that form a single entity with the exterior wall (including the jointing of clean masonry) #Anchors, fasteners #Fascia boards #Expansion joint constructions #Masonry above 200 mm below ground level.
Composition	Non-structural exterior walls.
Construction	m^2
Functional unit	#Provisions for wall openings, roof edges, and roof finishes using small fascia boards and finishes.
Except	#Thermal insulation #Sun shading (Solar Shading Factor) #Sound insulation #Burglar resistance #Water and airtightness #Fire safety.

Table 2.2
B&U 41.1

Code	41.1 Exterior wall finishes
Description	Collection of finishes on the exterior of exterior walls, measured from the wall construction.
Function	Protection and embellishment.
Functional unit	m^2
Composition	The entirety of exterior wall finishes such as façade claddings and panelling, plastering, tiling, or painting finishes, including: #Finishes and preservation treatments #Sealing system, sealant/profiles #Ventilation grilles #Non-transparent filling.
Construction	Exterior finishes.
Functional unit	m^2
Except	#Finishes on the inside of exterior walls, finishes that form an integral part of the exterior wall, and cladding walls with an external cavity wall function.
Performance	#Thermal insulation #Soundproofing/sound insulation #Water and airtightness.

Steel roof and floor cladding (B&U 27.1, Roofs; non-structural, B&U 27.2 Roofs; structural, B&U 23.1 floors; non-structural, and B&U 23.2 floors; structural, tables 2.3 to 2.6)
Steel roof and floor cladding is a final product produced from cold-rolled strip steel, thermally galvanized, and organically coated. This product represents various geometries (seam, corrugated, sheet pile, shiplap) and dimensions.

The roof and floor plates are scalable in thickness from 0.5-1.25 mm. Flashing and coating are included in the product profile. Steel roof and floor cladding is used in industrial, agricultural, utility, and residential construction, among other applications. The steel roof and floor cladding can be insulated with an exterior finish such as bitumen.

In this Life Cycle Assessment (LCA), the reference unit is 1 m^2 of roof and floor cladding with a thickness of 0.815 mm and a weight of 10.75 kg/m^2. The thickness of the reference profile is derived from an average of the most commonly used types of roof and floor cladding provided by suppliers. The mass is calculated using the scaling formula (see Chapter 4.3).

Table 2.3
B&U 27.1

Code	27.1 Roofs; non-structural
Description	Collection of non-structural roofs, both sloping and flat, that form the upper boundary of the building, measured from the inside and from the top of the exterior walls.
Function	Separation of indoor and outdoor spaces
Functional unit	m^2
Composition	The entirety of non-structural roofs, including: #Roof decks, eaves, canopies #Small fascia boards as roof (edge) finish #Gutter constructions and roof edges, #Thermal insulation integrated with the roof structure or forming the slope as well, #Slope layers and mastic edges #Expansion joint constructions.
Construction	Non-structural roofs .
Functional unit	m^2
Except	#Roof coverings, provisions for roof openings, and battens.
Performance	#Thermal insulation #Soundproofing/sound insulation #Strength and stiffness #Water and airtightness.

Table 2.4
B&U 27.2

Code	27.2 Roofs; structural
Description	Collection of structural roofs, both sloping and flat, that form the upper boundary of the building, measured from the inside, including the support surfaces, and from the top of the exterior walls.
Function	Separation of indoor and outdoor spaces and the load-bearing structure of the building.
Functional unit	m^2
Composition	The entirety of non-structural roofs, including: #Roof decks, eaves, canopies #Small fascia boards as roof (edge) finish #Gutter constructions and roof edges, #Thermal insulation integrated with the roof structure or forming the slope as well, #Slope layers and mastic edges #Expansion joint constructions.
Construction	Non-structural roofs
Functional unit	m^2
Except	#Roof coverings, provisions for roof openings, and battens.
Performance	#Thermal insulation #Soundproofing/sound insulation #Strength and stiffness #Water and airtightness.

Table 2.5
B&U 23.1

Code	23.1 Floors; non-structural
Description	Collection of (non-structural) cantilevered floors, including gallery floors, balconies, and platforms, measured up to the inside of the exterior walls.
Function	Load-bearing structure for the useful load of the spaces above and limitation of spaces located one above the other.
Functional unit	m^2
Composition	The entirety of non-structural cantilevered floors, including: #Wall connection provisions, #Beams and reinforcements belonging to the floor, #Anchors #Fasteners #Finishes that form an integral part of the floor structure #Expansion joint constructions.
Construction	Non-structural cantilevered floors.
Functional unit	m^2
Except	#Stair landings, provisions for floor openings, screed floors, floor finishes, and coverings.
Performance	#Thermal insulation #Soundproofing/sound insulation #Strength and stiffness #Water and airtightness #Fire safety.

Table 2.6
B&U 23.2

Code	23.2 Floors; structural
Description	Collection of structural cantilevered floors, including gallery floors, balconies, and platforms, measured up to the inside of the exterior walls, including the support surfaces.
Function	Load-bearing structure for the useful load of the spaces above and the delimitation of spaces located one above the other.
Functional unit	m^2
Composition	The entirety of structural cantilevered floors, including: #Beams and reinforcements belonging to the floor, #Anchors #Fasteners #Finishes that form an integral part of the floor structure #Expansion joint constructions.
Construction	Non-structural cantilevered floors
Functional unit	m^2
Except	#Provisions for floor openings, screed floors, floor finishes, and coverings.
Performance	#Thermal insulation #Soundproofing/sound insulation #Strength and stiffness #Water and airtightness #Fire safety.

2.2.3 Technical lifespan: 50 years

The technical lifespan mentioned by suppliers for galvanized steel wall, roof, and floor cladding, as well as liner trays, ranges between 30 and 50 years, provided they are processed, assembled, and maintained correctly according to the supplier's specifications. A lifespan of 50 years is most commonly indicated.

Manufacturers provide warranties ranging from 5 to 25 years for cladding. Cladding with a thicker coating layer typically comes with a longer warranty and, consequently, a longer technical lifespan. Category 3 NMD environmental declaration 'coverings, steel-coated trapezium' and steel sandwich panels in the NMD both have a specified lifespan of 50 years.

According to the TNO report '034-DTM-2010-02582, assessment of the safety of steel walls; Phase III: Inspections and lifespan prediction' (2010), cladding with a standard zinc layer thickness of 20µm (per side) cannot be demonstrated to be suitable for the 50-year reference period in the Dutch climate. Depending on the simulation model, TNO estimates a lifespan of 22-32 years for the 20µm zinc layer, with degradation observed without coating. TNO suggests that a 20µm galvanization (possibly with coating) can be considered acceptable for a 50-year lifespan, as degradation would be visible from the outside in case of damage, allowing for repair or partial replacement if necessary. According to TNO (2020), liner trays with a 20µm galvanization achieve a 50-year lifespan if the insulation extends to the flanges. The standard zinc layer thickness of 20µm from the TNO study corresponds to the Z275 galvanization applied in this study.

MDG (Metal Roofs and Walls Network) states that a 50-year lifespan is representative for sendzimir-galvanized steel (Z275) in a dry environment, with the following conditions outlined:

1. The materials are produced and shaped correctly, taking into account their (limited) flexibility.
2. Contact corrosion is prevented.
3. Details are executed to be rain-tight so that no leakage water can flow into the cavity through connections.
4. The inside of the construction assembly is executed airtight and vapor-retarding to minimize condensation in the cavity.
5. Any moisture in the cavity due to subcooling condensation or some rain penetration can freely drain outward.
6. There is no additional burdened environment due to local conditions.
7. Accumulation of dirt and/or moisture in connections and details is prevented.
8. When using galvanized steel under moist conditions, the nominal thickness of the steel should be limited to a maximum of 1.5 mm.

The lifespan may be shorter if the wall and roof plates are not regularly cleaned (by rainwater), if the plates are applied near open water, and if stagnant water remains on the cladding[2]. Stagnant water should be avoided.

MDG (2020), https://mdg-net.nl/wp-content/uploads/2020/07/2020-05-12-Kwaliteitsrichtlijn-deel-2-2020.pdf

It is asserted that a **50-year lifespan is representative for steel liner trays and roof and floor cladding.** This aligns with TNO (2020) and the most frequently provided lifespan by suppliers. These products are intended for indoor applications. For **wall cladding, a 50-year lifespan is also assumed**, based on the assumption that the products are taken into use undamaged and are periodically inspected as recommended by TNO (2020). Additionally, the wall cladding must meet the requirements outlined by MDG. The 50-year lifespan is specified by suppliers and corresponds to existing environmental declarations for wall cladding in the NMD. Damages are not considered in the LCA, following the Assessment Method.

2.2.4 Calculation rules for averaging data

The environmental profiles are established as **weighted averages** based on the delivered **market share (in tonnage)** of various European suppliers to the Dutch market. If a manufacturer serves the Dutch market from different production locations, a weighted average is calculated for that manufacturer based on the **total production (in tonnage**) of individual production locations.

The weighted average environmental profiles are compiled based on the production data of **ten European production locations**. The product environmental declarations can be used for the products of the participating manufacturers in this study for the Dutch market.

For each product group, the market coverage (compared to the total market, including imports from outside Europe) is as follows:

Steel Wall Cladding.

- Nine manufacturers of steel wall cladding.
- Dutch market coverage of 90% in the reference year 2020. This market coverage is considered plausible by the suppliers due to the inclusion of major suppliers.

Steel Liner trays

- Five manufacturers of steel liner trays.
- Dutch market coverage of 90% in the reference year 2020. This market coverage is considered plausible by the suppliers due to the inclusion of major suppliers.

Steel roof and floor cladding

- Seven manufacturers of steel roof and floor cladding.
- Dutch market coverage of 90% in the reference year 2020. This market coverage is considered plausible by the suppliers due to the inclusion of major suppliers.

2.3 System Boundaries

The processes examined within the LCA are delineated by system boundaries. The system boundaries determine which phases and processes of the life cycle are considered in the LCA. Figure 2.3, derived from EN 15804 and the SBK Assessment Method, specifies the information that must be considered for each life cycle phase. In this LCA, the environmental impact across the entire life cycle is taken into account.

CONSTRUCTION WORKS ASSESSMENT INFORMATION																
Production stage			Construction stage		Use stage							End of life stage				Module D
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	
Raw materials supply	Transport	Manufacturing	Transport	Construction and installation process	Use	Maintenance	Replacement	Repair	Refurbishment	Operational energy use	Operational water use	De-construction	Transport	Waste processing	Disposal	Benefits and loads beyond the system boundary
X	X	X	X	X	X	X	X	X	X	ND	ND	X	X	X	X	X

X: module considered / ND: module not declared

Figure 2.1
Life cycle phases EPD for adopted product units.

2.3.1 Process tree

Figure 2.2 depicts the process tree with relevant processes and system boundaries, and these are further explained textually. This process tree is representative for both wall cladding, the liner tray, as well as roof and floor cladding. These products originate from a similar production process. Intentionally, no quantities are included in Figure 2.2; for these, reference is made to the tables included in Appendices I a, b, c in the 'LCI' section.

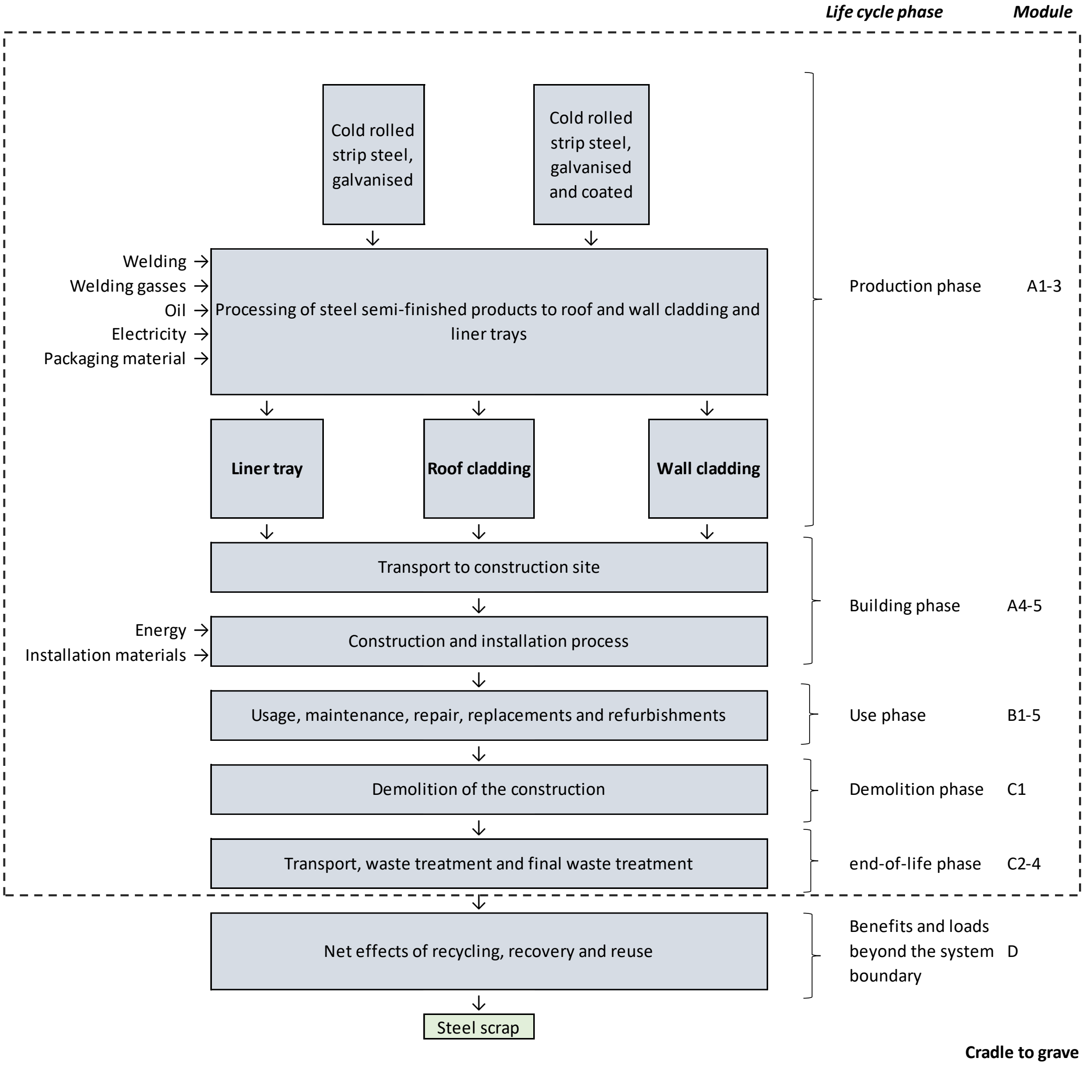

Figure 2.2
Process tree, liner tray, roof cladding & wall cladding

2.3.2 Product phase (module A1-3)

Roof, floor, and wall cladding, as well as the liner tray, are produced from cold-rolled sheet steel with thermal galvanization. Some of the cladding is also coated.

The thermally galvanized steel originates from the BOF (Basic Oxygen Furnace) route for steel production.

BOF Steel Production[3]

The BOF route is the primary production route for steel, where iron ore (in the form of pellets and sinter) is converted with limestone and coal (in the form of coke) in a blast furnace to produce pig iron and blast furnace slag (as a co-product). The pig iron is then processed in an oxygen steel converter to remove most of the carbon. Additives such as alloys are also introduced into the

[3] This description is from the verified report 'LCA Staalfederatie , Basic Profiles Steel Products' (2019).

converter. The granulated blast furnace slag, produced as a co-product of the blast furnace, is further processed by cement manufacturers. Granulation involves rapidly cooling the blast furnace slag (quenching), in contrast to natural cooling, resulting in a product with different properties.

Hot Rolling of Structural Profiles or Sheet/Strip Steel
Following the conversion of iron in an oxygen steel converter or electric arc furnace, the steel is cast into bars and slabs in a continuous process. In an integrated steel mill, this semi-finished product is further processed into sheet or strip material or into structural profiles in a hot rolling mill.

Cold Rolling of Sheet/Strip Steel
Hot-rolled steel is also further processed into cold-rolled steel in steel mills. Initially, the iron oxides on the surface of hot-rolled steel are removed by pickling. Subsequently, the sheet is rolled at a low temperature to reduce its thickness. Cold-rolled steel is thereby stronger but less deformable than hot-rolled steel.

Thermal Galvanization
Thermally galvanized cold-rolled sheet/strip steel is obtained by passing the cold-rolled steel through a bath of molten zinc. This results in a thin layer of zinc on the sheet, protecting the steel against corrosion.

Organic Coating
The thermally galvanized and cold-rolled sheet/strip steel is provided with a layer of paint or laminate in a coating line. The specific coating is tailored to various requirements such as aesthetic properties, corrosion resistance, wear resistance, etc. Commonly used coatings include PVC, polyester, and epoxy.

Processing Process
The galvanized sheet steel and the galvanized organically coated sheet steel are purchased as semi-finished products by the steel wall-roof panel and liner tray producer.

Then the following steps are followed:

1. *Slitting: If necessary, the coil is slit to the required width.*
2. *Profiling: The coil is unrolled and profiled. In this process, some suppliers use rolling oil to prevent steel from cracking during roll forming.*
    a. *The formed profiles can then be foamed to create a sandwich panel. This is beyond the scope of this analysis.*
3. *Cutting to length: The profiled sheet is cut to the correct length.*
4. *Packaging: The pieces of profiled sheet are stacked on wooden pallets and often wrapped in LDPE plastic film. This package is held together by metal or plastic straps.*
5. *Transport: The package is transported to a truck using a forklift.*

2.3.3 Quantification of Energy and Material Flows

- In accordance with EN 15804 and the supplement from the SBK Assessment Method, the following procedures have been followed:
- All input and output flows of a process for which information was available have been included in the calculation.
- When insufficient data is available, the criteria for excluding data are a maximum of 1% for (non)renewable primary energy consumption and 1% of the total mass input of the process. The condition is that excluding these flows does not exceed 5% in any of the environmental impacts per module.
- The total of excluded input flows is a maximum of 5% of energy use and mass.

In this LCA, within the system boundaries based on the above criteria, the following input or output flows have been excluded:

- Transport of auxiliary materials and packaging.

2.4 Excluded Processes and Flows

In accordance with EN 15804, the following processes have not been considered within the system boundaries of the LCA and have not been included in the calculations:

- Overhead processes such as office departments, staff transport, etc.
- Production, maintenance, and disposal of capital goods such as buildings, machinery, etc. [4]
- Transport processes of auxiliary materials to the production location.

It is also not expected that the above processes significantly contribute to the environmental profile of the products.

[4] The Assessment Method (2.6.3.6) states that capital goods may be excluded if they contribute no more than 5% to each individual environmental impact category in the production phase module (A1-A3). The capital goods have not been inventoried in this study. As a reference, comparing the capital goods from the Ecoinvent profile 'Sheet rolling, steel {RER}| processing | Cut-off, U' per kg with the production of wall cladding, these capital goods contribute less than 1% to each individual environmental impact category. With this, we can assume that we may exclude capital goods from consideration.

3 Life Cycle Inventory (LCI)

3.1 Data Collection

For the calculation of the life cycle analysis, data has been collected from various production processes that fall within the system boundaries of this LCA study, in accordance with the requirements set in ISO 14044 and EN 15804+A2. The elaboration pays attention to the precision, completeness, representativeness, consistency, and reproducibility of the data.

This section describes the methods used in the collection and selection of data. The data quality of the collected information is assessed in section 3.4.

3.1.1 Data Production Locations

Specific data has been applied for modelling the processes where the manufacturer has control. This involves products that are produced within the manufacturer's own factories/production locations.

For quantifying the production data, the following have been utilized:

- (Yearly) average data:
  - Production data derived from annual reports and purchasing information provided by the suppliers.
- Specific data:
  - Measurements, calculations, and expert estimates provided by the suppliers.
- Average inventory data to supplement missing information from some parties. Data quality is assessed in Chapter 3.3.

The production data were provided as a consolidated dataset for both wall, roof, floor, and liner tray cladding. The suppliers jointly asserted that all three product categories share the same production process. The difference lies in the applied plate thicknesses and the common profiles, thereby influencing the mass per square meter.

The annual production per product (roof/wall/floor/liner tray) was adjusted based on the share intended for the Dutch market. The percentage "intended for the Dutch market" was obtained from the suppliers.

To collect the relevant data, a standard inventory format was distributed to various steel sheet manufacturers producing steel wall, roof, and floor cladding, as well as liner trays. The production data originate from the locations as presented in Table 3.1.

Table 3.1
Production data originating from the locations

Suppliers	Wall profile	Roof profile	Liner tray	flashing surcharge
SAB	x	x	x	x
Werkcon	x			x
Joris Ide	x	x	x	x
Hardeman	x	x		x
SCH Holland	x	x		x
Allpro				x
Dutch Profiles Center	x	x		x
ArcelorMittal	x	x	x	x
Delft Profielen	x	x	x	x

3.1.2 Supplier Data

The primary procurement materials for the wall, roof, and floor cladding, as well as the liner tray, are 'cold-rolled strip steel, thermally galvanized' and 'cold-rolled strip steel, thermally galvanized and organically coated.' For these procurement materials, category 2 basic profiles from the Staalfederatie are used, as included in the NMD in 2020. These basic profiles are representative of the used cold-rolled strip steel (Dutch market and unalloyed). In these profiles, the zinc and coating layers are specified separately.

For modelling other materials and processes, category 3 data from the NMD process database, version 3.3 (based on Ecoinvent 3.6), or the Ecoinvent 3.6 process database, are used.

From this process database, the SBK Assessment Method also provides default values for the most important background processes that must be considered when specific data is not available. This mainly concerns processes for energy generation and transportation.

3.2 Qualitative / quantitative process data.

For the product and functional units considered, the input and output flows per life stage/module were inventoried. This section describes the assumptions used for this purpose for the LCI processing. The calculated weighted LCI is presented for the relevant product and functional units in Appendices Ia, Ib and Ic.

3.2.1 Production phase (A1-A3)

Steel sheets
Cold-rolled hot-dip galvanized strip and cold-rolled hot-dip galvanized and organically coated strip are the base materials for the products in this study.

For the steel, we assume a density of 7870kg/m^3 [5]. The category 2 base profiles of the Staalfederatie are the model basis for this. The calculated amount of steel scrap in these profiles (as a secondary material) is 9.1% for the hot-dip galvanized steel and 6.5% for the hot-dip galvanized steel with an organic coating. Table 3.2 shows the steel distribution. A total of 7.1% of the steel is of secondary origin.

Table 3.2
Steel distribution strip steel in product

Share	Type	Secundaire content
25%	Cold-rolled strip, hot-dip galvanized (9.1% secondary), excluding zinc coating, produced in Europe and for delivery to the Dutch market - Staalfederatie (A1-3)	9,1%
75%	Cold-rolled strip, hot-dip galvanized and organically coated (6.5% secondary), excluding zinc coating, produced in Europe and supplied to the Dutch market - Staalfederatie (A1-3)	6,5%

Galvanizing: Z275
Z275 galvanizing is most commonly specified for single skin cladding. This value has been applied in the model. In addition to Z275, Z225, and various ZM and ZA finishes are also specified. Z275 is the heaviest specified zinc coating, making it a conservative choice for application. With Z275, there is 275 grams of zinc per square meter on a flat sheet (without flashing).

Coating: 120µ façade cladding (scalable), 25µ roof and floor cladding & liner tray
Some manufacturers have specified specific coating types for the purchased strip steel with an organic coating. The specified coating thickness ranges from 25µ to 200µ with different coating types. According to Zink Info Benelux (2012), a coating layer thickness of 80µ is average for thermally galvanized coated steel when applied in an atmosphere with low pollution levels (rural areas). 120µ is common for a double coating layer, applied in an atmosphere with moderate pollution (urban and industrial areas) [6]. The involved steel manufacturers indicate that a coating of 120µ is common for wall cladding. However, wall cladding is often found with a thinner coating (25µ) or a thicker coating (200µ). Therefore, it has been decided to make the coating layer of wall cladding scalable with 120µ as the standard value, as outlined in chapter 4.3 on scaling.

[5] AISI 1020 Steel, cold rolled (matweb.com)

[6] This information is derived from the Gids voor bescherming van staal tegen corrosie Binnen- en buitenconstructies 1st edition: May 2012' (Zink Info Benelux) and from TECHNISCHE INFORMATIE POEDERCOATEN, Rotocoat.'

Roof and floor cladding and the liner tray are used for interior applications. For steel cladding intended for interior use, a thinner coating layer is common. The involved steel manufacturers indicate that a 25µ coating is typical for roof and floor cladding and the liner tray.

The base profile included in the NMD, 'Organic coating applied to thermally galvanized cold-rolled strip steel, produced in Europe and intended for delivery to the Dutch market - Staalfederatie (A1-3) cat.2,' encompasses the weighted average environmental profile of the organic coating. We assume that this profile is representative of the coating on the strip steel types addressed in this study. For the mass balance, we assume that the coating has a density of 1380 kg/m3 (density of polyester).

Mass balance steel composition

Suppliers with the largest market share have provided a reference product for wall cladding, roof and floor cladding, and the liner tray. From the provided reference cladding, we have chosen a market-average profile based on the two largest suppliers. This average profile provides the reference plate thickness and the reference cladding mass. The plate mass for scaling was calculated according to the scaling formula, as outlined in chapter 4.3.

Sheet metal flashing

In this LCA, we further calculate with the product mass including sheet metal flashing. The steel manufacturers have indicated that the sheet metal flashing mass is 10% of the cladding mass. In this analysis, we assume that the sheet metal flashing has the same material treatment and the same material thickness as the respective cladding. The functional units include the steel cladding, including sheet metal flashing. The cladding mass, including sheet metal flashing, is the cladding mass multiplied by 1.1.

Sheet shape correction factor

1m^2 of profile does not equate to a zinc or coating layer over 1 m^2 of material because the cladding is formed. The density of the profiles (kg/m^2/thickness (mm)) divided by the density of cold-rolled strip steel provides a correction factor that can be used to calculate how much m^2 of cold-rolled strip steel is needed for one m^2 of cladding. This is relevant since the coating is specified in thickness, and the zinc layer is specified in grams per square meter.

Table 3.3 shows the correction factors.

Table 3.3
Plate shape correction factor

	Correction factor
Wall cladding	1,21
Roof and floor cladding	1,61
Liner trays	1,50

Mass Balance

Table 3.4 provides the mass balance of the reference products. The mass is divided into steel, zinc, and the coating. All products have a Z275 galvanization. 75% of the cladding is galvanized and coated. The roofing and flooring cladding, as well as the liner tray, have a coating of 25µm, and the wall cladding has a coating of 120µm. In the calculation, we assume that the plate thickness and kg/m2 specified by the suppliers include the zinc and coating layers.

Calculation example wall cladding, galvanized and coated:

In this example, we explain how the correction factor and flashing are included in the mass balance.

- Zinc: for 1 m^2 of cladding you need 1.21 m^2 of unformed cladding (see correction factor). In addition, 10% flashing is added. There is a Z275 galvanization on the cladding. This makes the zinc mass: 0.275*1.21*1.1 = 0.37 kg.
- Coating: the cladding has a coating of 120µm, which is 0.000120m. The coating has a density of 1380 kg/m^3. This makes the mass of the coating: 0.000120*1380* 1.21*1.1 = 0.22 kg.
- Steel: the cladding has a product mass of 7.63 kg/m^2. When the mass of the zinc and coating is subtracted from this, the steel mass remains: 7.63 - 0.37 - 0.22 = 7.04 kg.

Table 3.4

Mass balance by functional unit (scrap excluded)

Mass balance plating including flashing, galvanized and coated (75% of total plating mass)						Galvanized, without coating (25% of the total cladding mass)	
Reference product	**Reference plate thickness (mm)**	**Product-mass (kg)**	**Steel (kg)**	**Zinc Z275 (kg)**	**Coating, 25µm (kg) Roof, floor & liner tray. 120µm, wall cladding**	**Steel (kg)**	**Zinc Z275 (kg)**
Wall cladding including flashing (per m^2)	0,73	7,63	7,04	0,37	0,22	7,26	0,37
Roof and floor cladding including flashing (per m^2)	0,82	10,75	10,20	0,49	0,06	10,26	0,49
liner tray including flashing (per m^2)	0,75	10,03	9,52	0,45	0,06	9,58	0,45

Closed-loop allocation, steel scrap.

The production processes release 3.47% steel scrap (0.035kg of scrap per kg of product). This scrap is galvanized and may have a coating. We declare the waste disposal of this steel scrap in accordance with the Assessment Method in A1-A3, the phase in which the waste is released. We state that 100% of the steel scrap is recycled. The zinc layer and coating also enter the recycling process.

The scrap metal reaches its end-of-waste status when it reaches the recycler. For this we declare transport. In accordance with the Assessment Method, there is a transport distance of 50 km for recycling.

We allocate the steel part of the production waste according to the closed-loop recycling calculation method. This is the method prescribed by EN15804. Based on the production waste, we make a correction to the secondary percentage of the material. This increases the net materials for recycling in Module D.

We calculate the corrected secondary content as:
'input materials per kg output * secondary content - scrap'
Or: corrected secondary steel content = 1.035 * 7.14% - 0.035 = 3.92%

We include the emissions from burning the coating in A1-A3. The zinc in the production waste cannot be processed according to the closed-loop method since zinc has no secondary content. To avoid allocation we assign no further processing to the zinc production waste (and thus no recycling benefits). The impact will be negligible due to its small mass.

Auxiliary materials
For the rolling process, one part of the suppliers specified rolling oil. The other part indicates they do not use rolling oil. Only one supplier indicates using CO_2 as a shielding gas for welding. Otherwise, no auxiliary materials are used.

Energy
The various production sites are located in several countries in Europe. The country-specific production mix was used to model electricity consumption. A proof or explanation was requested for the renewable electricity reported. This makes it plausible that the renewable electricity may be allocated to the production of the steel plating products.

Transportation to production site
The transport distances and methods for purchasing the cold rolled strip steel were inventoried by production location.

Emissions
None of the suppliers here provided information on emissions in the production process. We can state that emissions occur during primary strip production and not during processing. These emissions are included in the background processes of the single skin steel products.

3.2.2 Construction Phase A4-A5
The transportation distance is 150 km from the producer to the construction site. This standard value is set by the NMD.

The suppliers have only limited insights in the installation process of the cladding; therefore, we have outlined a general scenario. For each square meter of cladding, 1.5 screws are needed for attachment (3 grams of galvanized steel). This amounts to 217 screws per ton of cladding (with a profile of 6.92 kg/m^2, the reference mass of wall cladding without flashing). We assume that 75 m^2 of cladding is installed per hour using a cherry picker. The suppliers could not provide precise information about the installation time due to limited knowledge of the installation process.

For an average profile, this translates to approximately 1.45 hours of cherry picker crane usage per ton of steel [7]. In practice, the cherry picker will not be in use the entire time. We assume that the cherry picker is used for 1 hour per ton.

Although the masses per m^2 vary for each cladding method, both for wall, roof, and floor cladding, as well as liner trays, the above calculations and assumptions are applied. This is a conservative assumption, considering it involves the lightest profile.

3.2.3 Operational Phase (B1-B5)

In the operational phase, there are no emissions related to the steel products declared in this Life Cycle Assessment (LCA). Cladding exposed to the external environment always has both a galvanization and a coating layer. The coating ensures that there are no zinc emissions. Manufacturers indicate that no maintenance occurs on the steel cladding during the operational phase, and the cladding is not typically re-coated.

3.2.4 End-of-Life Phase (C1-4)

For the demolition/dismantling phase (C1), we assume that a cherry picker is used for the same duration as in A5. Regarding waste processing (C2-C3), we rely on standard scenarios as outlined in the Assessment Method.

We consider the four main material flows:

- Cold-rolled steel scrap;
- Zinc layer applied to steel scrap;
- Organic coating applied to steel scrap;
- Steel from the screws.

[7] 1.5 screws per m^2 is a rough estimate as mentioned by Qwinpro (https://www.qwinpro.nl/wat-is-een-sandwichpaneel/). This is a conservative estimate. One of the suppliers indicated expecting 1 screw per m^2. Balex Metal also estimates an average usage of 1 screw per m^2. Balex Metal also estimates an average usage of 1 screw per m^2 (https://balex.eu/en/knowledge-base/news/sandwich-panels-what-should-you-knowhttps://balex.eu/en/knowledge-base/news/sandwich-panels-what-should-you-know). Both sources provide an estimated installation time of 600 m^2/8 hours. This equates to approximately 0.7 tons of installation per hour, or 1.45 hours per ton. The mass of 3 grams per screw is an estimation.

For these three material flows, end-of-life phase processes are included as category 2 processes in the NMD. We incorporate these processes into the model.

Table 3.5
Applied standard end-of-life scenario

standard end-of-life scenario				
	Landfill	**Incineration**	**Recycling**	**Reuse**
Standard transport distances (km)	100	150	50	50
Steel, Single skin cladding (wall, roof, floor, liner tray)	5%	0%	95%	0%
Screws	5%	0%	95%	0%

Reuse
None of the suppliers identified in the inventory facilitate reuse. Reuse is not currently taking place. However, some suppliers suggest that reuse could be possible. Since there is currently no reuse occurring and no scenario is specified for anticipated reuse, we assert that the percentage of reuse is 0%.

3.2.5 External Costs and Benefits (D)

The use of secondary steel and the passing on of steel scrap (as material for recycling) is the most relevant flow for calculating module D. Table 3.6 outlines the assumptions made regarding steel for determining end-of-waste and the raw material equivalent.

For the remaining processes, default processes from the process database of the NMD are adopted. These processes are detailed in appendices Ia, Ib, and Ic and are therefore not explicitly mentioned again in this report.

Table 3.6
End-of-life scenario - Charges and benefits beyond system boundaries (D)

Scenario information	'1 kg Steel Scrap, per kg net output'
1. Material for Recycling	Steel Scrap
2. End-of-Waste	The point of end-of-waste is reached after the steel scrap has been sorted at a recycling facility in accordance with the criteria specified in Regulation (EU) No. 333/2011.[8].
3. Raw Material Equivalent (Point of Substitution)	Steel scrap is easily recyclable with a high degree of value retention. Secondary steel is generated in the form of post- or pre-consumer scrap. Pre-consumer steel scrap is primarily generated by manufacturing companies. In the BOF (Basic Oxygen Furnace) route of steel production, secondary steel can replace new steel on a 1-to-1 basis. To reach the point of substitution after the end-of-waste moment, it only needs to be transported to a BOF producer.
4. Net Passed-On Steel Scrap	Approximately 95% of steel products are recycled (default values). The steel content of the products consists of 3.92% secondary content per kg of steel (refer to Chapter 3.2.1, closed-loop allocation of steel scrap). In module D, 91.08% is passed on per kg of steel (1 * 95% - 1 * 3.92%).

The coating and the zinc layer are recycled along with the steel cladding. Both the coating and the galvanization are assigned to the Staalfederatie Module D processes for the recycling of zinc and coating. In these processes, zinc is recovered via the EAF (Electric Arc Furnace) route, and there are combustion emissions from the coating. Both the coating and zinc consist entirely of primary material. We have modelled Module D using the category 2 Module D processes provided by the Staalfederatie .

3.3 Data validation

Specific Data
The data provided by the manufacturer, used to quantify flows in various life phases, has been internally assessed by the LCA (Life Cycle Assessment) practitioner based on the data quality system from Annex D of the NMD (National Milieudatabase) evaluation protocol (version 1.0, July 2020) (see Table 3.7). The assessment covers all functional units considered in this LCA. In Annex II, the data quality assessment of horizontally aggregated processes is provided, along with the corresponding Pedigree score. The data quality assessment of the steel profiles is already part of the evaluated dossier of the respective profiles.

Regulation (EU) No. 333/2011 of the Council of 31 March 2011 laying down criteria determining when certain types of metal scrap cease to be waste in accordance with Directive 2008/98/EC of the European Parliament and of the Council.

Table 3.7
Assessment of data quality

Completeness	
1. Completeness of Environmental Interventions	*All environmental interventions that can reasonably be expected are assigned a value.*
2. Completeness of Economic Flows:	*All flows are inventoried and quantified. This includes all raw materials, materials, energy, emissions, and waste identified as input or output flows in the life phases..*
3. Mass Balance at the Process Level	*Closure >95%.* The quantity of materials used is directly derived from the Bill-Of-Materials and product-specific formulations of the specific substances..
4. Mass Balance at the Company Level	*Closure >95%.* The quantity of materials (and other inputs and outputs) has been inventoried for all three products within the company..
5. Energy Balance at the Company Level	*Closure >95%.* The energy flows have been inventoried for the three products per company..
Representativity	
1. Time-Based Representativity	*<2 years difference.* The production data were collected for the year 2020. These were the most recent production data available at the start of the life cycle inventory. The data are also representative of current production..
2. Geographical Representativity	We assume that the surveyed parties supply 90% of cladding products for the Dutch market..
3. Technological Representativity	*Data from the factory and the processes of the study.* The production data are representative of the same production process and type of product.
1. Uniformity and Consistency	*The category 2 base profiles of the Staalfederatie form the basis of this LCA study. The Staalfederatie 's profiles consist of aggregated data from steel supply to the Dutch market. These processes, like this study, are developed according to the Assessment Method and are thus consistent with the additions from this report.* *The environmental impact in the LCA is 96% derived from materialization. The reference profiles (coating thickness and galvanization type) are jointly developed by the manufacturers. Differences in scrap production vary from 2-10% per manufacturer. Variances in other flows (energy consumption, packaging, etc.) collectively contribute only 4% to the environmental profile. Therefore, we assume that the influence of the spread of LCI data per supplier deviates less than 20%.*
Reproduceerbaarheid	
1. Reproducibility by third parties	*The process description is fully quantitatively reproducible with the environmental interventions used.*

3.3.1 Generic Data

In accordance with the SBK Assessment Method, the NMD process database, version 3.3 (based on Ecoinvent 3.6), and the Ecoinvent 3.6 process database were used to model processes higher up in the supply chain and where the manufacturer has no influence. The data from both databases are not older than ten years or have been updated within this period.

The selection also took into account the technological and geographical representativity of the chosen background process. An overview of the representative background processes applied in this LCA is provided in Appendices Ia, Ib, and Ic.

3.4 Biogenic Carbon

Wall, roof, and floor cladding, as well as the liner tray, do not contain biogenic carbon. However, the wood in the packaging material does contain biogenic carbon. We calculate the biogenic carbon content based on the combustion of 1 kg of clean wood, using the NMD process '0262-avC&Verbranden hout, 'schoon' (13.99 MJ/kg) (based on Waste wood, untreated {CH}| treatment of municipal incineration | Cut-off, U.' This process has a biogenic CO_2 emission of 1.46 kg per kg of burned wood. One kg of biogenic carbon is equivalent to 44/12 kg of biogenic CO_2. The biogenic carbon in the products and packaging is shown in Table 3.8.

For biogenic carbon, we assume carbon neutrality. The biogenic carbon does not originate from indigenous forests.

Table 3.8

Biogenic Carbon	Weight per kg of cladding	Unit
Biogenic Carbon in the product	-	0 kg C
Biogenic Carbon in packaging	0.025 kg of wooden packaging per kg of cladding. (This is equivalent to 0.025 * 1.46 = 0.036 kg of CO_2 emission upon combustion)	0.01 kg C
Note: 1 kg of biogenic carbon is equivalent to 44/12 kg of CO_2.		

4 Life Cycle Analysis

4.1 Calculation of Environmental Profile

In this LCA, the following calculation procedures have been applied:

- The calculations in this LCA are made according to the requirements and guidelines of NEN-EN 15804+A2 and the SBK Assessment Method Environmental Performance of Buildings.
- Environmental interventions are calculated using the methods described in NEN-EN 15804+A2 supplemented with characterization factors from the Assessment Method (version 1.0, July 2020, NMD 3.4).
  - Indicators describing raw material consumption are derived from the calculated energy, including the use of secondary material and the use of primary energy as a material in the product.
  - For each reference product that has been calculated, the following calculation results are included in Appendices Ia, LCI & Results Cladding, Appendix Ib, LCI & Results Roof and Floor Cladding, and Appendix Ic, LCI & Results Liner tray:
    - Environmental Impact Assessment
    - Total substance list (aggregated LCI)
    - Checks
    - The contribution analysis for A1-A3
    - The complete LCI
    - The scaling formula and the environmental profiles
- Where applicable, the rules for allocation in multi-input, multi-output, recycling, and reuse processes from NEN-EN 15804+A2 have been followed, in accordance with NEN-EN-ISO 14044.
- The LCA calculations were performed using SimaPro 9.1.0.8
  - Ecoinvent processes were calculated, including infrastructure processes and capital goods.
  - Ecoinvent processes were calculated excluding long-term (>100 years) emissions.

Completeness of Environmental Interventions

The interventions considered in the LCA, such as the 'total substance list' and 'non-characterized interventions,' are included for each calculated process in the relevant appendix. For interventions from the used SBK calculation method, as specified in the SBK Assessment Method and in accordance with NEN-EN 15804, which are not included in Appendices I (a, b, and c) of this report, it is unknown whether the intervention occurs. We do not expect that interventions have been omitted that could reasonably occur in an amount that would influence the LCA results.

4.2 LCA Calculation Results and Shadow Prices

The weighing of results is a process where the results of different environmental impact categories are converted into a single-point score so that they can be considered integrally. In this study, we use the Environmental Cost Indicator (MKI), following the Environmental Performance of Buildings Assessment Method, to weigh the various impact categories into a single endpoint.

In the table below, the MKI results per module are presented per functional unit. The mass in kg per m^2 is also included in the table for reference.

Table 4.1
MKI values per functional unit per module

Functional unit	Kg per m^2	MKI Total	MKI A1-A3	MKI A4	MKI A5	MKI B1-B5	MKI C1	MKI C2	MKI C3	MKI C4	MKID
*1 m^2 of **steel cladding**, including flashing, used as part of a non-structural exterior wall, produced in Europe, and used in the Dutch market*	7,63	**€ 1,65**	€ 2,31	€ 0,02	€ 0,16	€ 0,00	€ 0,09	€ 0,01	€ 0,04	€ 0,00	€ -0,98
*1 m^2 of **steel roof and floor cladding**, including flashing, used as part of a non-structural exterior wall, produced in Europe, and used in the Dutch market.*	10,74	**€ 2,06**	€ 3,06	€ 0,03	€ 0,22	€ 0,00	€ 0,12	€ 0,01	€ 0,05	€ 0,00	€ -1,43
*1 m^2 of **steel liner tray**, including flashing, used as part of a non-structural exterior wall, produced in Europe, and used in the Dutch market*	10,03	**€ 1,93**	€ 2,85	€ 0,02	€ 0,21	€ 0,00	€ 0,12	€ 0,01	€ 0,05	€ 0,00	€ -1,33

The following sections contain the calculation results of the functional units in the declared life cycle phases. For each functional unit, there are contribution analyses.

4.2.1 Wall cladding

Table 4.2

Environmental profile of "1 m^2 of steel wall cladding, including flashing, used as part of a non-structural exterior wall, produced in Europe, and used in the Dutch market

"1 m^2 of steel wall cladding, including flashing, used as part of a non-structural exterior wall, produced in Europe, and used in the Dutch market."		Total	A1-A3 Single skin steel cladding (wall, roof, and floor cladding, and liner tray) Wall cladding	A4 Single skin steel cladding (wall, roof, and floor cladding, and liner tray)	A5 Single skin steel cladding (wall, roof, and floor cladding, and liner tray) Wall cladding	"Use Phase"	C1 Single skin steel cladding (wall, roof, and floor cladding, and liner tray)	C2 Single skin steel cladding (wall, roof, and floor cladding, and liner tray)	C3 Single skin steel cladding (wall, roof, and floor cladding, and liner tray)	C4 Single skin steel cladding (wall, roof, and floor cladding, and liner tray)	D Single skin steel cladding (wall, roof, and floor cladding, and liner tray) wall cladding
Indicators Set 1		Total	A1-A3	A4	A5	B1-B5	C1	C2	C3	C4	D
001. abiotic depletion, non fuel (AD)	kg Sb eq.	1,07E-03	2,70E-03	3,91E-06	1,04E-04	0,00E+00	1,01E-06	1,50E-07	3,34E-06	2,32E-09	-1,74E-03
002. abiotic depletion, fuel (AD)	kg Sb eq.	1,03E-01	1,57E-01	1,13E-03	9,24E-03	0,00E+00	4,32E-03	3,89E-04	1,26E-03	2,77E-05	-7,04E-02
004. global warming (GWP)	kg CO2 eq.	1,58E+01	2,59E+01	1,53E-01	1,47E+00	0,00E+00	6,54E-01	5,27E-02	1,92E-01	2,04E-03	-1,26E+01
005. ozone layer depletion (ODP)	kg CFK-11 eq.	1,20E-06	1,06E-06	2,72E-08	1,49E-07	0,00E+00	1,13E-07	9,72E-09	2,27E-08	6,74E-10	-1,82E-07
006. photochemical oxidation (POCP)	kg ethylene eq.	9,25E-03	1,39E-02	9,24E-05	1,11E-03	0,00E+00	6,66E-04	3,11E-05	1,51E-04	2,16E-06	-6,68E-03
007. acidification (AP)	kg SO2 eq.	6,14E-02	7,59E-02	6,73E-04	7,44E-03	0,00E+00	4,93E-03	2,29E-04	1,66E-03	1,51E-05	-2,94E-02
008. eutrophication (EP)	kg PO4- eq.	1,09E-02	1,24E-02	1,32E-04	1,54E-03	0,00E+00	1,12E-03	4,55E-05	3,56E-04	2,83E-06	-4,72E-03
009. human toxicity (HT)	kg 1,4-DCB eq.	4,70E+00	5,63E+00	6,44E-02	4,55E-01	0,00E+00	2,42E-01	2,11E-02	1,84E-01	8,30E-04	-1,90E+00
010. Ecotoxicity, fresh water (FAETP)	kg 1,4-DCB eq.	1,26E-01	1,29E-01	1,88E-03	7,85E-03	0,00E+00	3,37E-03	6,19E-04	2,57E-03	2,06E-05	-1,99E-02
012. Ecotoxicity, marine water (MAETP)	kg 1,4-DCB eq.	3,65E+02	3,70E+02	6,77E+00	2,44E+01	0,00E+00	1,17E+01	2,23E+00	1,54E+01	7,10E-02	-6,49E+01
014. Ecotoxicity, terrestric (TETP)	kg 1,4-DCB eq.	2,31E-01	8,14E-02	2,28E-04	3,11E-03	0,00E+00	3,99E-04	7,47E-05	5,98E-04	2,46E-06	1,46E-01
Indicators Set 2											
051. Climate change	kg CO2 eq.	1,59E+01	2,60E+01	1,54E-01	1,73E+00	0,00E+00	6,61E-01	5,32E-02	1,85E-01	2,05E-03	-1,28E+01
052. Climate change – Fossil	kg CO2 eq.	1,61E+01	2,65E+01	1,54E-01	1,50E+00	0,00E+00	6,61E-01	5,32E-02	1,95E-01	2,08E-03	-1,30E+01
053. Climate change - Biogenic	kg CO2 eq.	-2,53E-01	-6,32E-01	7,14E-05	2,30E-01	0,00E+00	1,84E-04	-1,93E-05	-9,94E-03	-2,70E-05	1,59E-01
054. Climate change - Land use and LU change	kg CO2 eq.	6,06E-02	5,45E-02	5,66E-05	1,75E-03	0,00E+00	5,21E-05	1,66E-05	2,22E-04	9,15E-07	4,02E-03
055. Ozone depletion	kg CFC11 eq.	1,21E-06	8,93E-07	3,41E-08	1,74E-07	0,00E+00	1,43E-07	1,22E-08	2,64E-08	8,49E-10	-6,79E-08
056. Acidification	mol H+ eq.	8,14E-02	1,01E-01	8,95E-04	1,03E-02	0,00E+00	6,91E-03	3,03E-04	2,08E-03	1,98E-05	-4,04E-02
057. Eutrophication, freshwater	kg P eq.	1,06E-03	1,60E-03	1,56E-06	5,32E-05	0,00E+00	2,41E-06	7,77E-07	5,69E-05	3,72E-08	-6,61E-04
058. Eutrophication, marine	kg N eq.	1,74E-02	1,77E-02	3,15E-04	3,66E-03	0,00E+00	3,05E-03	1,05E-04	4,66E-04	6,50E-06	-7,87E-03
059. Eutrophication, terrestrial	mol N eq.	2,26E-01	2,20E-01	3,48E-03	4,14E-02	0,00E+00	3,35E-02	1,17E-03	5,47E-03	7,19E-05	-7,85E-02
060. Photochemical ozone formation	kg NMVOC eq.	5,88E-02	6,43E-02	9,93E-04	1,14E-02	0,00E+00	9,21E-03	3,32E-04	1,47E-03	2,09E-05	-2,89E-02
061. Resource use, minerals and metals	kg Sb eq.	1,07E-03	2,70E-03	3,91E-06	1,04E-04	0,00E+00	1,01E-06	1,50E-07	3,34E-06	2,32E-09	-1,74E-03
062. Resource use, fossils	MJ	1,93E+02	2,44E+02	2,33E+00	1,68E+01	0,00E+00	9,10E+00	8,15E-01	2,65E+00	5,81E-02	-8,33E+01
063. Water use	m3 depriv.	3,08E+00	4,25E+00	8,33E-03	1,48E-01	0,00E+00	1,22E-02	4,79E-03	3,08E-02	2,69E-03	-1,38E+00
064. Particulate matter	disease inc.	8,59E-07	6,87E-07	1,39E-08	2,07E-07	0,00E+00	1,83E-07	4,78E-09	2,73E-08	3,73E-10	-2,64E-07
065. Ionising radiation	kBq U-235 eq.	5,84E-01	5,25E-01	9,75E-03	5,62E-02	0,00E+00	3,90E-02	3,49E-03	1,20E-02	2,38E-04	-6,11E-02
066. Ecotoxicity, freshwater	CTUe	2,64E+02	5,78E+02	2,08E+00	2,39E+01	0,00E+00	5,48E+00	5,26E-01	6,25E+00	3,24E-02	-3,52E+02
067. Human toxicity, cancer	CTUh	2,70E-08	5,10E-08	6,74E-11	1,87E-09	0,00E+00	1,92E-10	2,22E-11	1,93E-10	8,18E-13	-2,63E-08
068. Human toxicity, non-cancer	CTUh	1,18E-06	5,22E-07	2,27E-09	2,21E-08	0,00E+00	4,71E-09	7,47E-10	8,42E-09	2,58E-11	6,19E-07
069. Land use	Pt	1,06E+02	1,06E+02	2,02E+00	4,67E+00	0,00E+00	1,16E+00	6,92E-01	4,93E+00	1,23E-01	-1,37E+01
Information on raw material usage											
111. Energy, primary, renewable, excluding usage as material	MJ	2,20E+01	2,14E+01	2,91E-02	7,18E-01	0,00E+00	4,92E-02	1,12E-02	3,87E-01	1,49E-03	-5,84E-01
113. Energy, primary, renewable, used as material	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
101. Energy, primary, renewable (MJ)	MJ	2,20E+01	2,14E+01	2,91E-02	7,18E-01	0,00E+00	4,92E-02	1,12E-02	3,87E-01	1,49E-03	-5,84E-01
112. Energy, primary, non-renew., excl. usage as material	MJ	2,13E+02	2,84E+02	2,47E+00	1,86E+01	0,00E+00	9,66E+00	8,65E-01	2,80E+00	6,17E-02	-1,05E+02
114. Energy, primary, non-renewable, used as material	MJ	3,26E-03	1,05E-01	0,00E+00	3,26E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
102. Energy, primary, non-renewable (MJ)	MJ	2,13E+02	2,85E+02	2,47E+00	1,86E+01	0,00E+00	9,66E+00	8,65E-01	2,80E+00	6,17E-02	-1,05E+02
108. Secondary material (kg)	kg	5,42E-01	5,26E-01	0,00E+00	1,58E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
109. Secondary fuel, renewable (kg)	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
110. Secondary fuel, non-renewable (kg)	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
104. Water, fresh water use (m3)	m3	1,31E-01	2,10E-01	2,84E-04	7,09E-03	0,00E+00	4,68E-04	1,40E-04	1,20E-03	6,37E-05	-8,83E-02
Information on wast											
106. Waste, hazardous (kg)	kg	1,75E-03	2,12E-03	5,90E-06	9,20E-05	0,00E+00	2,48E-05	5,02E-07	3,20E-06	4,10E-08	-4,90E-04
105. Waste, non hazardous (kg)	kg	2,30E+00	2,37E+00	1,48E-01	1,21E-01	0,00E+00	1,08E-02	4,98E-02	7,70E-02	3,81E-01	-8,54E-01
107. Waste, radioactive (kg)	kg	7,09E-04	5,68E-04	1,53E-05	8,21E-05	0,00E+00	6,32E-05	5,49E-06	1,53E-05	3,80E-07	-4,14E-05
Information on output streams											
120. Components for re-use (kg)	kg	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
121. Materials for recycling (kg)	kg	7,45E+00	0,00E+00	0,00E+00	2,06E-01	0,00E+00	0,00E+00	0,00E+00	7,24E+00	0,00E+00	0,00E+00
122. Materials for energy recovery (kg)	kg	1,73E-04	0,00E+00	0,00E+00	1,73E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
123. Exported energy, electric (MJ)	MJ	4,45E-01	0,00E+00	0,00E+00	4,45E-01	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
124. Exported energy, thermal (MJ)	MJ	7,67E-01	0,00E+00	0,00E+00	7,67E-01	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Weighting (1-point score)											
Environmental cost indicator (MKI)	€	€ 1,65	€ 2,31	€ 0,02	€ 0,16	€ 0,00	€ 0,09	€ 0,01	€ 0,04	€ 0,00	-€ 0,98

Contribution Analysis of wall cladding

In the contribution analysis of Figure 4.1, it is evident that the production phase A1-A3 has the most significant impact on the environmental profile. Furthermore, there is a notable amount of benefits in module D. This is because 95% of the cladding will be recycled, while only 7% of the input consists of secondary material. Figure 4.2 shows that environmental costs mainly arise from global warming potential (CO2eq), acidification (SO2-eq), and human toxicity (kg 1,2-DBC-eq). Since most of the environmental impact occurs in A1-A3, another contribution analysis for this phase is shown in Figure 4.3. Here, it is evident that the cladding, including galvanizing and coating, accounts for 96% of the MKI. Figure 4.4 illustrates the sources of MKI for cold-rolled steel with a galvanizing and coating layer. It shows that galvanizing and coating contribute significantly with 16% and 12%, respectively.

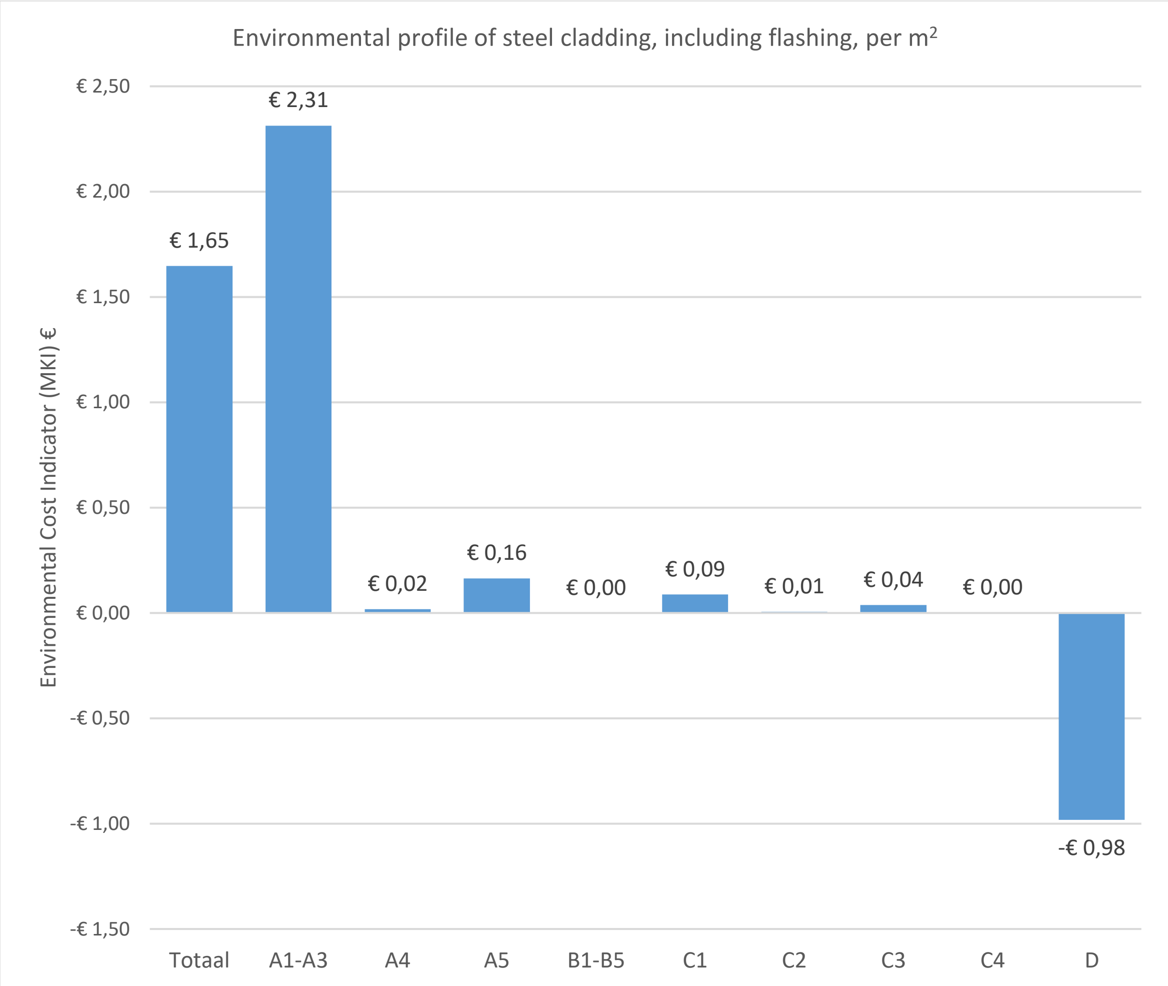

Figure 4.1

Contribution analysis of the environmental profile of 1 m^2 of steel cladding, including flashing, used as part of a non-structural exterior wall, produced in Europe, and used in the Dutch market

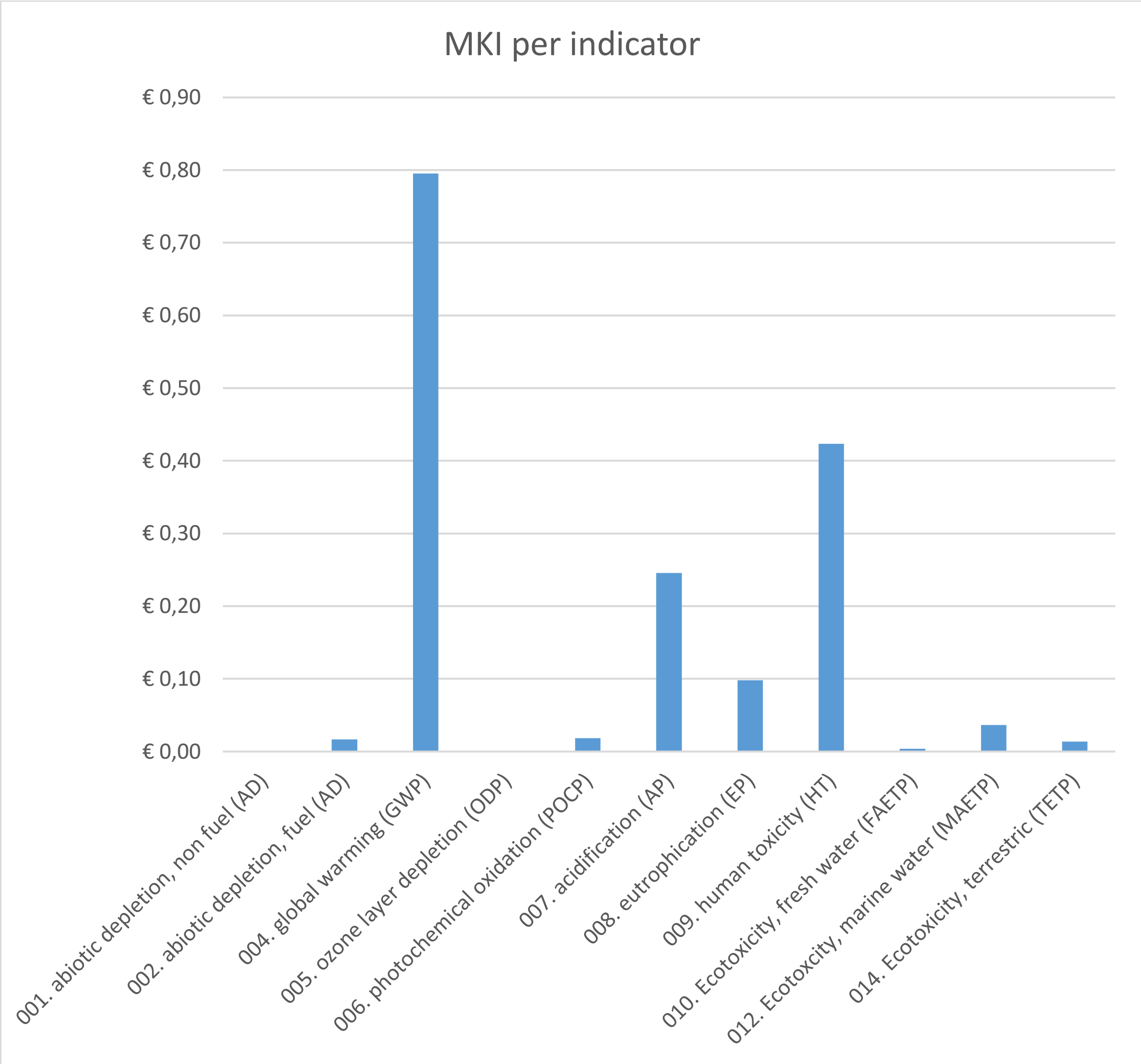

Figure 4.2

Contribution analysis per indicator of 1 m^2 of steel cladding, including flashing, used as part of a non-structural exterior wall, produced in Europe, and used in the Dutch market

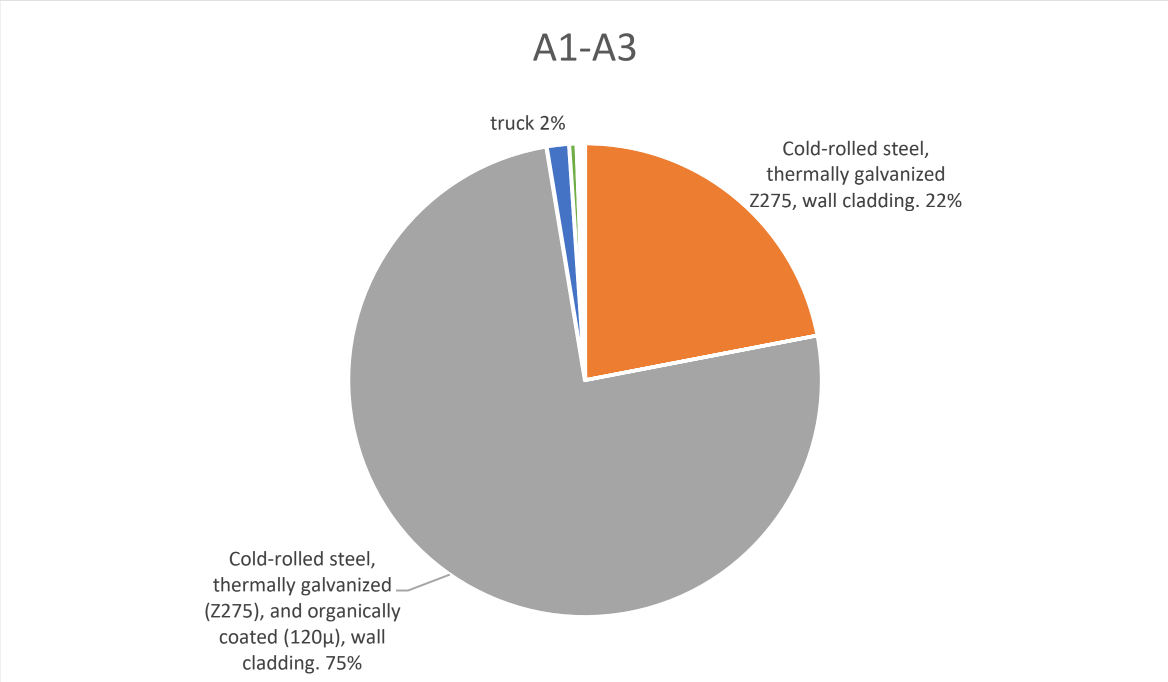

Figure 4.3

Contribution analysis within A1-A3 of 1 m^2 of steel wall cladding, including flashing, used as part of a non-structural exterior wall, produced in Europe, and used in the Dutch market

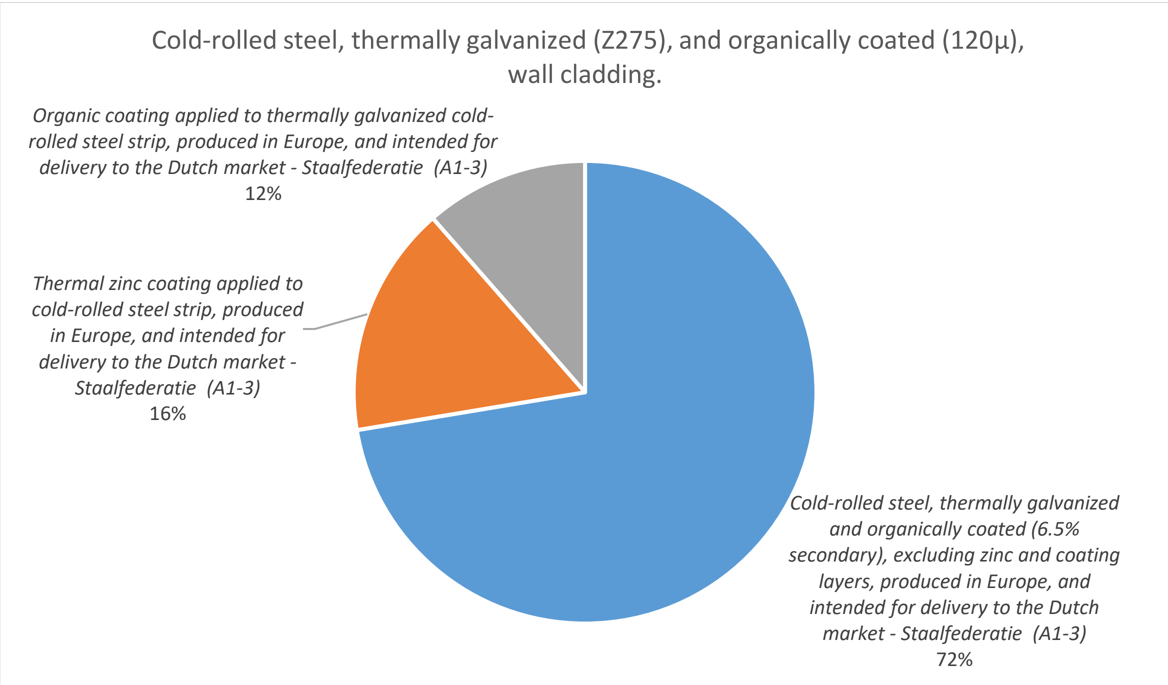

Figure 4.4

Contribution analysis within A1-A3 of Cold-rolled steel, thermally galvanized (Z275), and organically coated (120µ), wall cladding

4.2.2 Roof and Floor Cladding

Table 4.3
Environmental profile of "1 m^2 of steel roof and floor cladding, including flashing, used as part of a non-structural exterior wall, produced in Europe, and used in the Dutch market

		Total	A1-A3 Single-skin steel cladding (wall, roof and floor cladding, and liner tray) Roof and Floor Cladding	A4 Single-skin steel cladding (wall, roof and floor cladding, and liner tray)	A5 Single-skin steel cladding (wall, roof and floor cladding, and liner tray) Roof and Floor Cladding	Use Phase	C1 Single-skin steel cladding (wall, roof and floor cladding, and liner tray)	C2 Single-skin steel cladding (wall, roof and floor cladding, and liner tray)	C3 Single-skin steel cladding (wall, roof and floor cladding, and liner tray)	C4 Single-skin steel cladding (wall, roof and floor cladding, and liner tray)	D Single-skin steel cladding (wall, roof and floor cladding, and liner tray) Roof and Floor Cladding
Indicators Set 1		Total	A1-A3	A4	A5	B1-B5	C1	C2	C3	C4	D
001. abiotic depletion, non fuel (AD)	kg Sb eq.	1,41E-03	3,58E-03	5,51E-06	1,29E-04	0,00E+00	1,43E-06	2,11E-07	4,71E-06	3,28E-09	-2,31E-03
002. abiotic depletion, fuel (AD)	kg Sb eq.	1,30E-01	2,08E-01	1,59E-03	1,26E-02	0,00E+00	6,08E-03	5,48E-04	1,77E-03	3,91E-05	-1,01E-01
004. global warming (GWP)	kg CO2 eq.	1,99E+01	3,48E+01	2,16E-01	2,02E+00	0,00E+00	9,22E-01	7,43E-02	2,71E-01	2,87E-03	-1,84E+01
005. ozone layer depletion (ODP)	kg CFK-11 eq.	1,51E-06	1,33E-06	3,83E-08	2,04E-07	0,00E+00	1,60E-07	1,37E-08	3,20E-08	9,50E-10	-2,64E-07
006. photochemical oxidation (POCP)	kg ethylene eq.	9,51E-03	1,63E-02	1,30E-04	1,46E-03	0,00E+00	9,39E-04	4,39E-05	2,12E-04	3,04E-06	-9,58E-03
007. acidification (AP)	kg SO2 eq.	8,07E-02	1,02E-01	9,49E-04	1,03E-02	0,00E+00	6,95E-03	3,22E-04	2,34E-03	2,12E-05	-4,20E-02
008. eutrophication (EP)	kg PO4- eq.	1,42E-02	1,64E-02	1,86E-04	2,13E-03	0,00E+00	1,58E-03	6,42E-05	5,01E-04	3,99E-06	-6,63E-03
009. human toxicity (HT)	kg 1,4-DCB eq.	5,62E+00	7,03E+00	9,08E-02	6,00E-01	0,00E+00	3,41E-01	2,97E-02	2,59E-01	1,17E-03	-2,73E+00
010. Ecotoxicity, fresh water (FAETP)	kg 1,4-DCB eq.	1,36E-01	1,44E-01	2,65E-03	9,74E-03	0,00E+00	4,75E-03	8,72E-04	3,62E-03	2,91E-05	-2,95E-02
012. Ecotoxicity, marine water (MAETP)	kg 1,4-DCB eq.	4,77E+02	4,89E+02	9,54E+00	3,31E+01	0,00E+00	1,65E+01	3,15E+00	2,18E+01	1,00E-01	-9,64E+01
014. Ecotoxicity, terrestric (TETP)	kg 1,4-DCB eq.	3,18E-01	1,02E-01	3,21E-04	3,90E-03	0,00E+00	5,62E-04	1,05E-04	8,44E-04	3,47E-06	2,10E-01
Indicators Set 2											
051. Climate change	kg CO2 eq.	2,00E+01	3,50E+01	2,18E-01	2,38E+00	0,00E+00	9,32E-01	7,50E-02	2,61E-01	2,89E-03	-1,89E+01
052. Climate change - Fossil	kg CO2 eq.	2,03E+01	3,58E+01	2,18E-01	2,06E+00	0,00E+00	9,32E-01	7,50E-02	2,75E-01	2,93E-03	-1,91E+01
053. Climate change - Biogenic	kg CO2 eq.	-3,31E-01	-8,70E-01	1,01E-04	3,24E-01	0,00E+00	2,59E-04	-2,72E-05	-1,40E-02	-3,81E-05	2,28E-01
054. Climate change - Land use and LU change	kg CO2 eq.	3,68E-02	2,95E-02	7,97E-05	1,02E-03	0,00E+00	7,34E-05	2,34E-05	3,13E-04	1,29E-06	5,85E-03
055. Ozone depletion	kg CFC11 eq.	1,51E-06	1,07E-06	4,80E-08	2,39E-07	0,00E+00	2,01E-07	1,72E-08	3,72E-08	1,20E-09	-1,00E-07
056. Acidification	mol H+ eq.	1,08E-01	1,37E-01	1,26E-03	1,42E-02	0,00E+00	9,75E-03	4,28E-04	2,93E-03	2,78E-05	-5,77E-02
057. Eutrophication, freshwater	kg P eq.	1,42E-03	2,17E-03	2,19E-06	7,19E-05	0,00E+00	3,39E-06	1,10E-06	8,03E-05	5,25E-08	-9,08E-04
058. Eutrophication, marine	kg N eq.	2,31E-02	2,36E-02	4,45E-04	5,11E-03	0,00E+00	4,30E-03	1,49E-04	6,57E-04	9,17E-06	-1,12E-02
059. Eutrophication, terrestrial	mol N eq.	3,03E-01	2,96E-01	4,90E-03	5,76E-02	0,00E+00	4,72E-02	1,64E-03	7,71E-03	1,01E-04	-1,12E-01
060. Photochemical ozone formation	kg NMVOC eq.	7,35E-02	8,21E-02	1,40E-03	1,58E-02	0,00E+00	1,30E-02	4,68E-04	2,07E-03	2,95E-05	-4,13E-02
061. Resource use, minerals and metals	kg Sb eq.	1,41E-03	3,58E-03	5,51E-06	1,29E-04	0,00E+00	1,43E-06	2,11E-07	4,71E-06	3,28E-09	-2,31E-03
062. Resource use, fossils	MJ	2,40E+02	3,16E+02	3,28E+00	2,28E+01	0,00E+00	1,28E+01	1,15E+00	3,73E+00	8,19E-02	-1,20E+02
063. Water use	m3 depriv.	3,21E+00	5,12E+00	1,17E-02	1,80E-01	0,00E+00	1,72E-02	6,76E-03	4,34E-02	3,80E-03	-2,17E+00
064. Particulate matter	disease inc.	1,15E-06	9,17E-07	1,95E-08	2,90E-07	0,00E+00	2,58E-07	6,73E-09	3,85E-08	5,26E-10	-3,77E-07
065. Ionising radiation	kBq U-235 eq.	7,81E-01	7,00E-01	1,37E-02	7,78E-02	0,00E+00	5,50E-02	4,92E-03	1,68E-02	3,35E-04	-8,82E-02
066. Ecotoxicity, freshwater	CTUe	3,32E+02	7,75E+02	2,93E+00	3,22E+01	0,00E+00	7,73E+00	7,41E-01	8,80E+00	4,57E-02	-4,96E+02
067. Human toxicity, cancer	CTUh	3,63E-08	7,12E-08	9,49E-11	2,57E-09	0,00E+00	2,70E-10	3,13E-11	2,72E-10	1,15E-12	-3,82E-08
068. Human toxicity, non-cancer	CTUh	1,63E-06	6,84E-07	3,20E-09	2,90E-08	0,00E+00	6,64E-09	1,05E-09	1,19E-08	3,64E-11	8,94E-07
069. Land use	Pt	1,42E+02	1,43E+02	2,85E+00	6,37E+00	0,00E+00	1,64E+00	9,76E-01	6,95E+00	1,73E-01	-1,97E+01
Information on raw material usage											
111. Energy, primary, renewable, excluding usage as material	MJ	2,90E+01	2,82E+01	4,11E-02	9,48E-01	0,00E+00	6,94E-02	1,57E-02	5,46E-01	2,10E-03	-8,15E-01
113. Energy, primary, renewable, used as material	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
101. Energy, primary, renewable (MJ)	MJ	2,90E+01	2,82E+01	4,11E-02	9,48E-01	0,00E+00	6,94E-02	1,57E-02	5,46E-01	2,10E-03	-8,15E-01
112. Energy, primary, non-renew., excl. usage as material	MJ	2,67E+02	3,71E+02	3,48E+00	2,52E+01	0,00E+00	1,36E+01	1,22E+00	3,95E+00	8,70E-02	-1,51E+02
114. Energy, primary, non-renewable, used as material	MJ	4,46E-03	1,49E-01	0,00E+00	4,46E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
102. Energy, primary, non-renewable (MJ)	MJ	2,67E+02	3,71E+02	3,48E+00	2,53E+01	0,00E+00	1,36E+01	1,22E+00	3,95E+00	8,70E-02	-1,51E+02
108. Secondary material (kg)	kg	7,80E-01	7,57E-01	0,00E+00	2,27E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
109. Secondary fuel, renewable (kg)	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
110. Secondary fuel, non-renewable (kg)	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
104. Water, fresh water use (m3)	m3	1,50E-01	2,69E-01	4,00E-04	9,11E-03	0,00E+00	6,60E-04	1,97E-04	1,70E-03	8,97E-05	-1,31E-01
Information on waste											
106. Waste, hazardous (kg)	kg	2,36E-03	2,88E-03	8,32E-06	1,25E-04	0,00E+00	3,49E-05	7,08E-07	4,51E-06	5,78E-08	-6,90E-04
105. Waste, non hazardous (kg)	kg	3,12E+00	3,27E+00	2,08E-01	1,66E-01	0,00E+00	1,52E-02	7,02E-02	1,09E-01	5,37E-01	-1,26E+00
107. Waste, radioactive (kg)	kg	9,52E-04	7,58E-04	2,15E-05	1,14E-04	0,00E+00	8,90E-05	7,74E-06	2,15E-05	5,35E-07	-6,01E-05
Information on output streams											
120. Components for re-use (kg)	kg	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
121. Materials for recycling (kg)	kg	1,05E+01	0,00E+00	0,00E+00	2,91E-01	0,00E+00	0,00E+00	0,00E+00	1,02E+01	0,00E+00	0,00E+00
122. Materials for energy recovery (kg)	kg	2,44E-04	0,00E+00	0,00E+00	2,44E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
123. Exported energy, electric (MJ)	MJ	6,27E-01	0,00E+00	0,00E+00	6,27E-01	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
124. Exported energy, thermal (MJ)	MJ	1,08E+00	0,00E+00	0,00E+00	1,08E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Weighting (1-point score)											
Environmental cost indicator (MKI)	€	€ 2,06	€ 3,06	€ 0,03	€ 0,22	€ 0,00	€ 0,12	€ 0,01	€ 0,05	€ 0,00	-€ 1,43

Contribution analysis of roof and floor cladding

In the contribution analysis shown in figure 4.5, it is clear that the production phase A1-A3 has the largest impact on the environmental profile. It is also noticeable that there are relatively many benefits in module D. This is because 95% of the cladding will be recycled while only 7% of the input consists of secondary material. Figure 4.6 shows that the environmental costs mainly come from global warming potential (CO2eq), acidification (SO2-eq), and human toxicity (kg 1,2-DBC-eq). The contribution analysis within A1-A3 is shown in Figure 4.7. The cladding has a slightly lower share in the MKI compared to the wall cladding because less coating is applied.

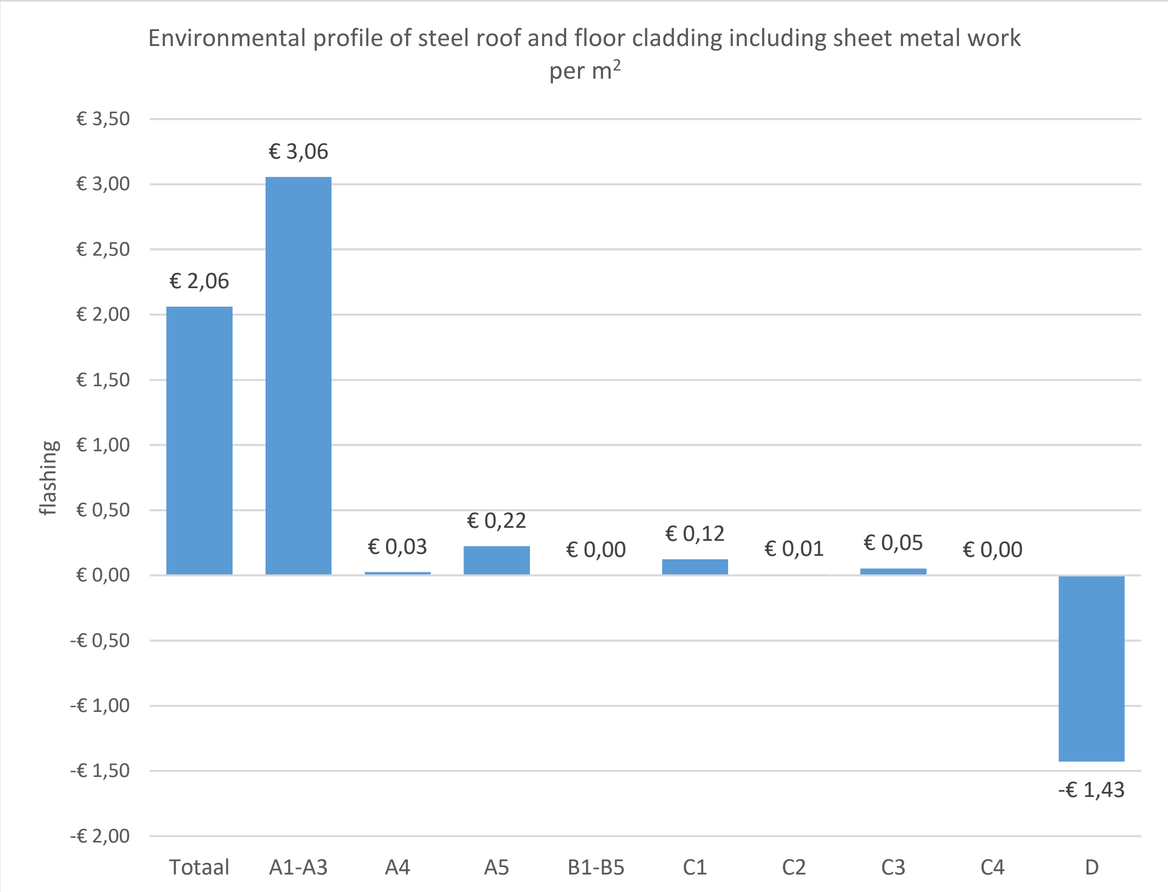

Figure 4.5

Weighted Environmental Profile of 1 m^2 steel roof and floor cladding including flashing applied as part of a non-structural exterior wall, produced in Europe and used in the Dutch market"

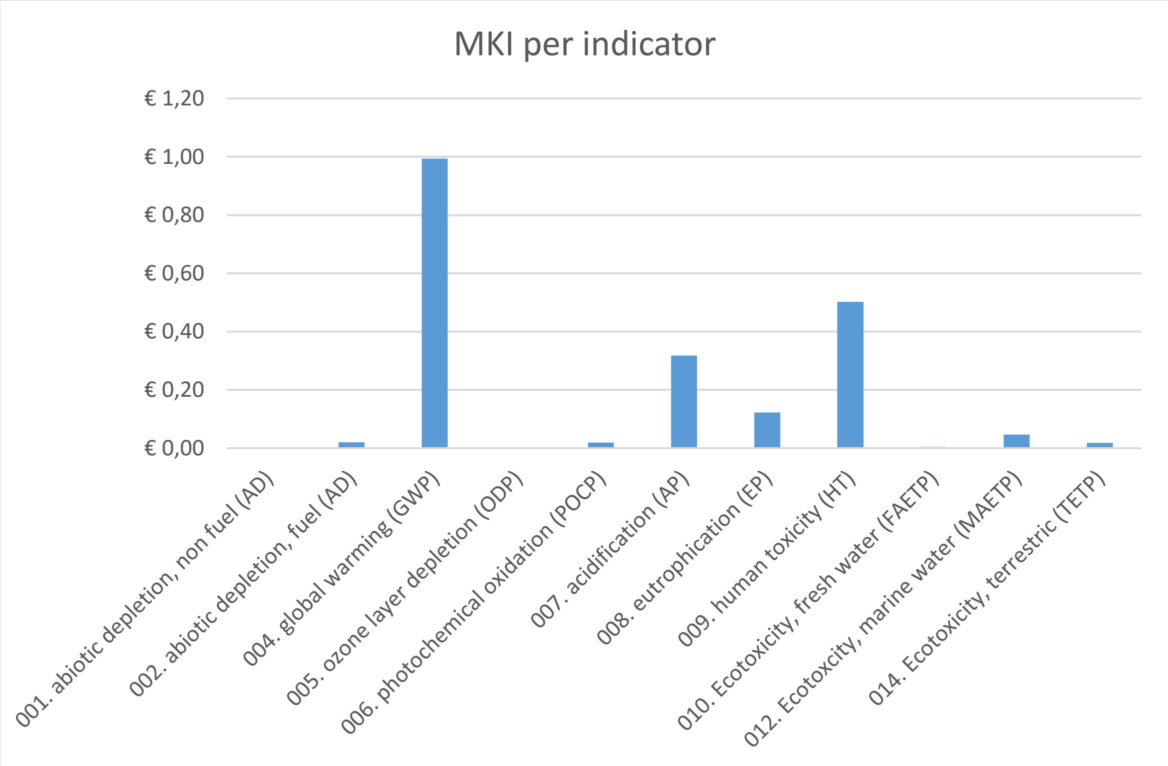

Figure 4.6
Weighted Environmental Profile per indicator of 1 m^2 steel roof and floor cladding including flashing applied as part of a non-structural exterior wall, produced in Europe and used in the Dutch market

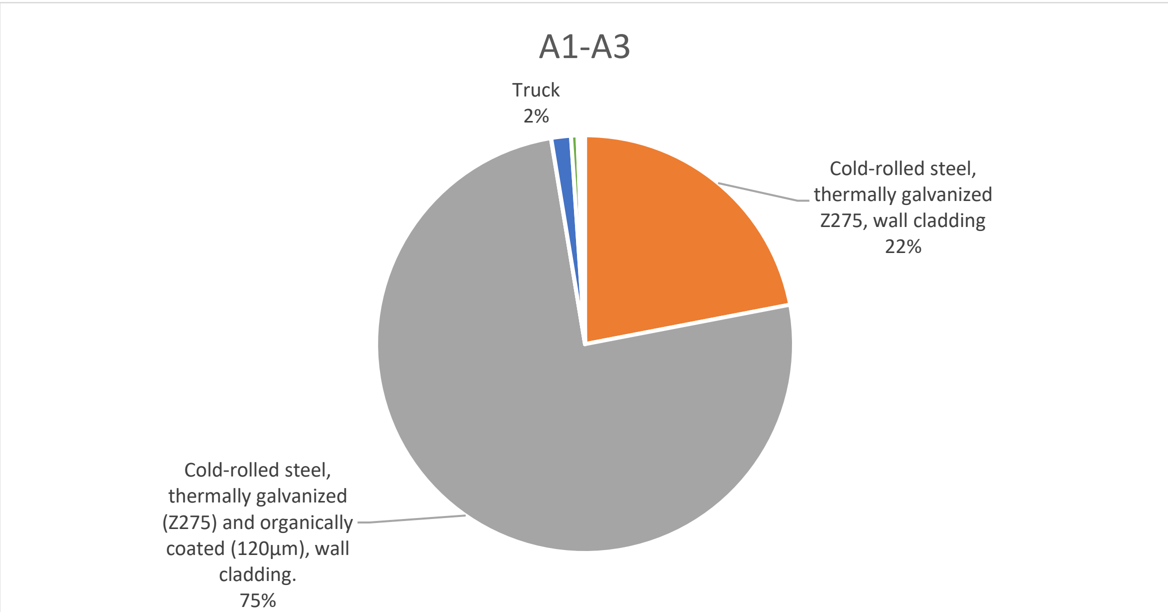

Figure 4.7
Weighted Environmental Profile within A1-A3 of 1 m^2 steel roof and floor cladding including flashing applied as part of a non-structural exterior wall, produced in Europe and used in the Dutch market

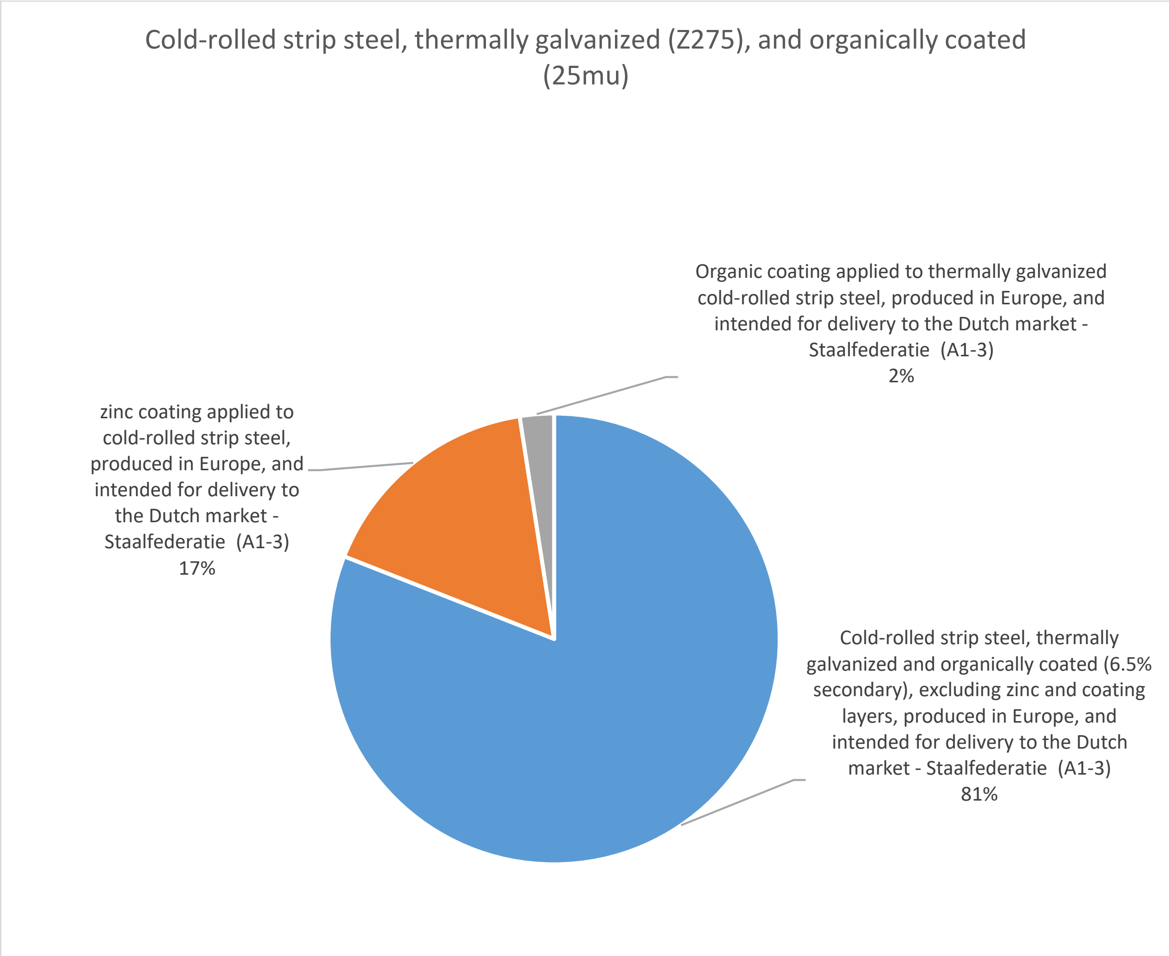

Figure 4.8
Contribution analysis within A1-A3 of Cold-rolled strip steel, thermally galvanized (Z275), and organically coated (120µ), for roof and floor cladding

4.2.3 Liner tray

Table 4.4

Environmental profile of '1 m^2 steel liner tray including flashing as part of a non-structural exterior wall, produced in Europe and used in the Dutch market

		Total	A1-A3 Single-skin steel cladding (wall, roof, and floor cladding, and liner tray) Liner tray	A4 Single-skin steel cladding (wall, roof, and floor cladding, and liner tray)	A5 Single-skin steel cladding (wall, roof, and floor cladding, and liner tray) Liner tray	Use phase	C1 Single-skin steel cladding (wall, roof, and floor cladding, and liner tray)	C2 Single-skin steel cladding (wall, roof, and floor cladding, and liner tray))	C3 Single-skin steel cladding (wall, roof, and floor cladding, and liner tray)	C4 Single-skin steel cladding (wall, roof, and floor cladding, and liner tray)	D Single-skin steel cladding (wall, roof, and floor cladding, and liner tray) Liner tray
Indicators Set 1		Total	A1-A3	A4	A5	B1-B5	C1	C2	C3	C4	D
001. abiotic depletion, non fuel (AD)	kg Sb eq.	1,33E-03	3,34E-03	5,15E-06	1,24E-04	0,00E+00	1,33E-06	1,97E-07	4,40E-06	3,06E-09	-2,15E-03
002. abiotic depletion, fuel (AD)	kg Sb eq.	1,21E-01	1,94E-01	1,48E-03	1,17E-02	0,00E+00	5,68E-03	5,12E-04	1,65E-03	3,65E-05	-9,44E-02
004. global warming (GWP)	kg CO2 eq.	1,86E+01	3,25E+01	2,01E-01	1,89E+00	0,00E+00	8,61E-01	6,94E-02	2,53E-01	2,68E-03	-1,72E+01
005. ozone layer depletion (ODP)	kg CFK-11 eq.	1,41E-06	1,24E-06	3,57E-08	1,91E-07	0,00E+00	1,49E-07	1,28E-08	2,99E-08	8,87E-10	-2,47E-07
006. photochemical oxidation (POCP)	kg ethylene eq.	8,88E-03	1,52E-02	1,22E-04	1,37E-03	0,00E+00	8,76E-04	4,09E-05	1,98E-04	2,84E-06	-8,94E-03
007. acidification (AP)	kg SO2 eq.	7,54E-02	9,51E-02	8,85E-04	9,62E-03	0,00E+00	6,49E-03	3,01E-04	2,18E-03	1,98E-05	-3,92E-02
008. eutrophication (EP)	kg PO4- eq.	1,33E-02	1,53E-02	1,74E-04	1,99E-03	0,00E+00	1,47E-03	5,99E-05	4,68E-04	3,73E-06	-6,18E-03
009. human toxicity (HT)	kg 1,4-DCB eq.	5,25E+00	6,56E+00	8,48E-02	5,65E-01	0,00E+00	3,19E-01	2,78E-02	2,42E-01	1,09E-03	-2,55E+00
010. Ecotoxicity, fresh water (FAETP)	kg 1,4-DCB eq.	1,27E-01	1,34E-01	2,48E-03	9,15E-03	0,00E+00	4,44E-03	8,14E-04	3,38E-03	2,72E-05	-2,75E-02
012. Ecotoxicity, marine water (MAETP)	kg 1,4-DCB eq.	4,45E+02	4,56E+02	8,90E+00	3,10E+01	0,00E+00	1,54E+01	2,94E+00	2,03E+01	9,34E-02	-8,99E+01
014. Ecotoxicity, terrestric (TETP)	kg 1,4-DCB eq.	2,97E-01	9,55E-02	3,00E-04	3,68E-03	0,00E+00	5,25E-04	9,83E-05	7,87E-04	3,24E-06	1,96E-01
Indicators Set 2											
051. Climate change	kg CO2 eq.	1,86E+01	3,26E+01	2,03E-01	2,22E+00	0,00E+00	8,70E-01	7,00E-02	2,44E-01	2,70E-03	-1,76E+01
052. Climate change - Fossil	kg CO2 eq.	1,89E+01	3,34E+01	2,03E-01	1,92E+00	0,00E+00	8,70E-01	7,00E-02	2,57E-01	2,73E-03	-1,78E+01
053. Climate change - Biogenic	kg CO2 eq.	-3,09E-01	-8,12E-01	9,39E-05	3,03E-01	0,00E+00	2,42E-04	-2,54E-05	-1,31E-02	-3,55E-05	2,13E-01
054. Climate change - Land use and LU change	kg CO2 eq.	3,44E-02	2,75E-02	7,44E-05	9,60E-04	0,00E+00	6,86E-05	2,19E-05	2,92E-04	1,20E-06	5,46E-03
055. Ozone depletion	kg CFC11 eq.	1,41E-06	9,98E-07	4,48E-08	2,23E-07	0,00E+00	1,88E-07	1,60E-08	3,48E-08	1,12E-09	-9,35E-08
056. Acidification	mol H+ eq.	1,01E-01	1,28E-01	1,18E-03	1,33E-02	0,00E+00	9,10E-03	3,99E-04	2,74E-03	2,60E-05	-5,38E-02
057. Eutrophication, freshwater	kg P eq.	1,33E-03	2,03E-03	2,05E-06	6,73E-05	0,00E+00	3,17E-06	1,02E-06	7,49E-05	4,90E-08	-8,47E-04
058. Eutrophication, marine	kg N eq.	2,15E-02	2,21E-02	4,15E-04	4,77E-03	0,00E+00	4,02E-03	1,39E-04	6,14E-04	8,56E-06	-1,05E-02
059. Eutrophication, terrestrial	mol N eq.	2,83E-01	2,76E-01	4,58E-03	5,38E-02	0,00E+00	4,41E-02	1,53E-03	7,19E-03	9,45E-05	-1,04E-01
060. Photochemical ozone formation	kg NMVOC eq.	6,86E-02	7,66E-02	1,31E-03	1,47E-02	0,00E+00	1,21E-02	4,37E-04	1,93E-03	2,75E-05	-3,86E-02
061. Resource use, minerals and metals	kg Sb eq.	1,33E-03	3,34E-03	5,15E-06	1,24E-04	0,00E+00	1,33E-06	1,97E-07	4,40E-06	3,06E-09	-2,15E-03
062. Resource use, fossils	MJ	2,24E+02	2,95E+02	3,06E+00	2,13E+01	0,00E+00	1,20E+01	1,07E+00	3,48E+00	7,65E-02	-1,12E+02
063. Water use	m3 depriv.	3,00E+00	4,78E+00	1,10E-02	1,69E-01	0,00E+00	1,60E-02	6,31E-03	4,05E-02	3,55E-03	-2,02E+00
064. Particulate matter	disease inc.	1,08E-06	8,56E-07	1,82E-08	2,71E-07	0,00E+00	2,41E-07	6,28E-09	3,59E-08	4,91E-10	-3,52E-07
065. Ionising radiation	kBq U-235 eq.	7,29E-01	6,53E-01	1,28E-02	7,27E-02	0,00E+00	5,13E-02	4,59E-03	1,57E-02	3,13E-04	-8,24E-02
066. Ecotoxicity, freshwater	CTUe	3,10E+02	7,24E+02	2,73E+00	3,02E+01	0,00E+00	7,22E+00	6,92E-01	8,22E+00	4,26E-02	-4,62E+02
067. Human toxicity, cancer	CTUh	3,39E-08	6,65E-08	8,86E-11	2,42E-09	0,00E+00	2,52E-10	2,92E-11	2,54E-10	1,08E-12	-3,57E-08
068. Human toxicity, non-cancer	CTUh	1,52E-06	6,39E-07	2,99E-09	2,73E-08	0,00E+00	6,19E-09	9,83E-10	1,11E-08	3,40E-11	8,35E-07
069. Land use	Pt	1,32E+02	1,33E+02	2,66E+00	5,96E+00	0,00E+00	1,53E+00	9,11E-01	6,49E+00	1,62E-01	-1,84E+01
Information on raw material usage											
111. Energy, primary, renewable, excluding usage as material	MJ	2,71E+01	2,63E+01	3,83E-02	8,87E-01	0,00E+00	6,48E-02	1,47E-02	5,10E-01	1,96E-03	-7,60E-01
113. Energy, primary, renewable, used as material	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
101. Energy, primary, renewable (MJ)	MJ	2,71E+01	2,63E+01	3,83E-02	8,87E-01	0,00E+00	6,48E-02	1,47E-02	5,10E-01	1,96E-03	-7,60E-01
112. Energy, primary, non-renew., excl. usage as material	MJ	2,49E+02	3,46E+02	3,25E+00	2,36E+01	0,00E+00	1,27E+01	1,14E+00	3,69E+00	8,12E-02	-1,41E+02
114. Energy, primary, non-renewable, used as material	MJ	4,17E-03	1,39E-01	0,00E+00	4,17E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
102. Energy, primary, non-renewable (MJ)	MJ	2,49E+02	3,46E+02	3,25E+00	2,36E+01	0,00E+00	1,27E+01	1,14E+00	3,69E+00	8,12E-02	-1,41E+02
108. Secondary material (kg)	kg	7,28E-01	7,07E-01	0,00E+00	2,12E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
109. Secondary fuel, renewable (kg)	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
110. Secondary fuel, non-renewable (kg)	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
104. Water, fresh water use (m3)	m3	1,40E-01	2,51E-01	3,73E-04	8,53E-03	0,00E+00	6,16E-04	1,84E-04	1,59E-03	8,38E-05	-1,22E-01
Information on waste											
106. Waste, hazardous (kg)	kg	2,20E-03	2,68E-03	7,76E-06	1,17E-04	0,00E+00	3,26E-05	6,61E-07	4,21E-06	5,39E-08	-6,44E-04
105. Waste, non hazardous (kg)	kg	2,91E+00	3,05E+00	1,94E-01	1,56E-01	0,00E+00	1,42E-02	6,56E-02	1,01E-01	5,01E-01	-1,17E+00
107. Waste, radioactive (kg)	kg	8,89E-04	7,07E-04	2,01E-05	1,07E-04	0,00E+00	8,31E-05	7,22E-06	2,01E-05	4,99E-07	-5,60E-05
Information on output streams											
120. Components for re-use (kg)	kg	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
121. Materials for recycling (kg)	kg	9,80E+00	0,00E+00	0,00E+00	2,72E-01	0,00E+00	0,00E+00	0,00E+00	9,53E+00	0,00E+00	0,00E+00
122. Materials for energy recovery (kg)	kg	2,27E-04	0,00E+00	0,00E+00	2,27E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
123. Exported energy, electric (MJ)	MJ	5,86E-01	0,00E+00	0,00E+00	5,86E-01	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
124. Exported energy, thermal (MJ)	MJ	1,01E+00	0,00E+00	0,00E+00	1,01E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Weighting (1-point score))											
Environmental cost indicator (MKI)	€	**€ 1,93**	**€ 2,85**	**€ 0,02**	**€ 0,21**	€ 0,00	**€ 0,12**	**€ 0,01**	**€ 0,05**	**€ 0,00**	**-€ 1,33**

Contribution analysis of the liner tray

The contribution analysis of the liner trays is substantively similar to the analysis of the roof and floor cladding.

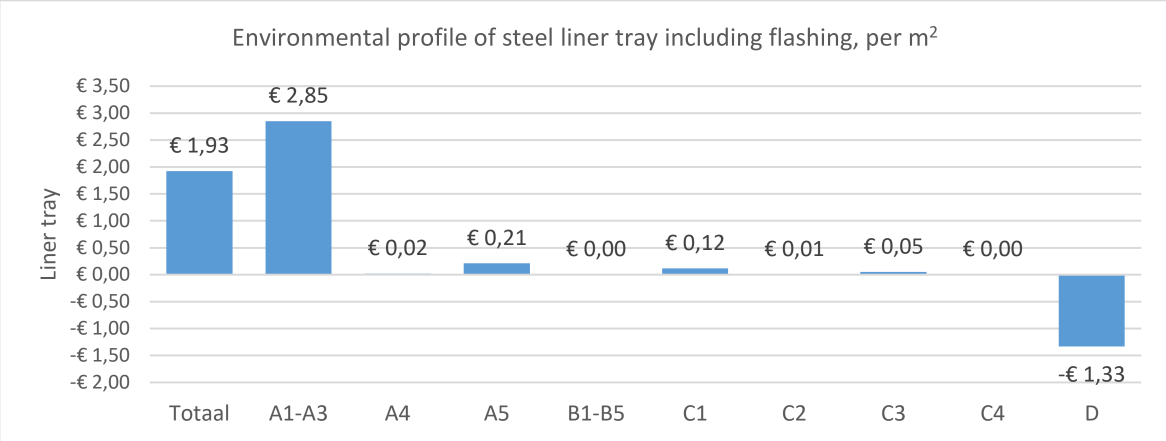

Figure 4.9

Contribution analysis environmental profile of 1 m^2 steel liner tray including flashing used as part of a non-structural exterior wall, produced and utilized in Europe and employed in the Dutch market

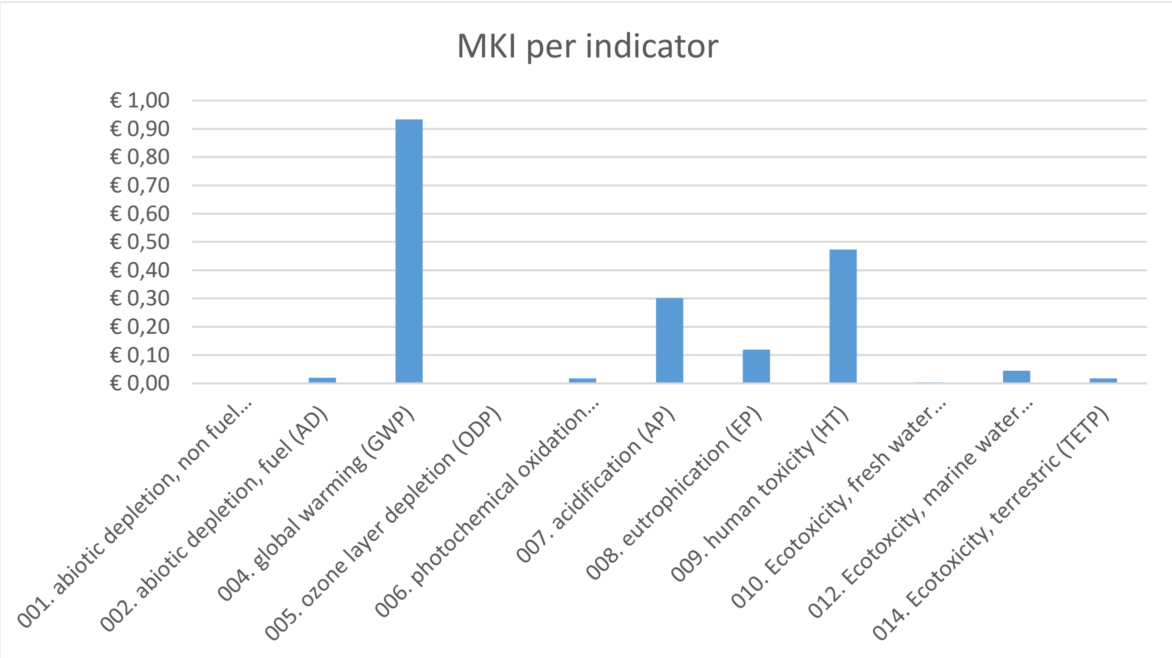

Figure 4.10

Contribution analysis per indicator for 1 m^2 steel liner tray including flashing used as part of a non-structural exterior wall, produced and utilized in Europe and employed in the Dutch market

4.3 Scaling

The environmental impact of the roof and floor cladding, including flashing and the liner tray with flashing, scales linearly with the plate thickness, except for the zinc and coating layer. For the wall cladding, including flashing, we also make the coating scalable because there can be a lot of variation in it.

Not scalable, zinc and coating
For the roof and floor cladding and the liner tray, the zinc and coating layers maintain the same mass when the thickness of the cladding changes. For the wall cladding, only the zinc layer has a fixed mass. The mass of zinc and coating per m^2 is provided in Table 4.5. The zinc and coating layer varies per product type due to the shaping of the reference product. For example, 1 m^2 of roof and floor cladding generally has more square meters of strip steel than 1 m^2 of wall cladding due to the profile shape.

Table 4.5
Masses of zinc and coating per m^2, non-scalable mass

	Reference plate thickness (mm)	Product mass (kg/m^2)	Zinc	Coating	Total mass, Non-scalable	Mass share compared to reference profile
Wall cladding including flashing	0,73	7,63	0,37	0,22	0,59 kg	7%
Roof and floor cladding including flashing	0,82	10,75	0,49	0,06	0,57 kg	5%
Liner tray including flashing	0,75	10,03	0,45	0,06	0,51 kg	5%

For the mass share of zinc and coating compared to the total reference profile, we have also included the other operations and processes as 'non-scalable.' This means that for the wall cladding, 7% of the operations, transport, waste treatment processes, etc., are allocated to the non-scalable part. The explicitly scalable processes (steel for all products and coating for the wall cladding, both in A1-3, A5, and D) are not included in the non-scalable part.

Scalable, steel
The claddings are available in various models and plate thicknesses. The plate thickness variation is provided by the suppliers, specifying the masses in kg/m2 for each model and plate thickness. This value has been adjusted by +10% for the flashing work. The scaling formula is based on the cladding type inventory from the three largest suppliers. The trendline of the plot resulting from the inventory represents the average mass per plate thickness. Figure 4.11 illustrates the scaling of the steel mass. This scaling has been adjusted for the non-scaling masses (zinc and coating). Figures 4.12 and 4.13 depict the cladding types used to formulate the scaling formulas. These figures have not been corrected for the non-scaling materials.

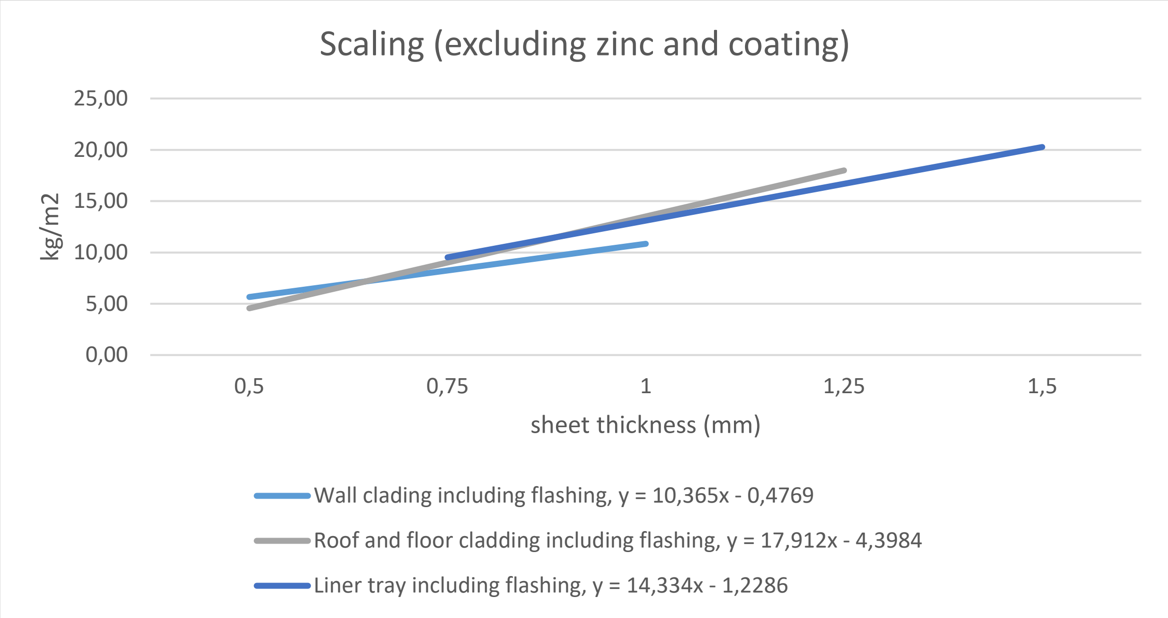

Figure 4.11
Scaling of steel. These scaling formulas have been adjusted for the non-scaling materials (zinc and coating)

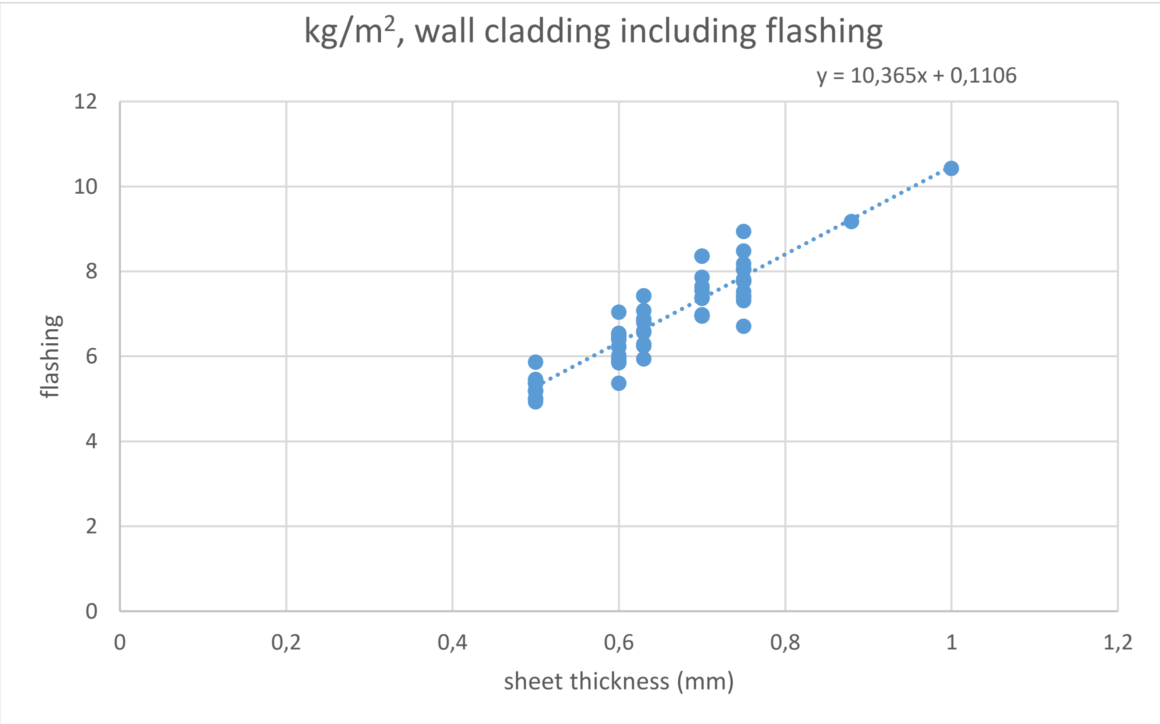

Figure 4.12
Scaling of wall cladding including flashing

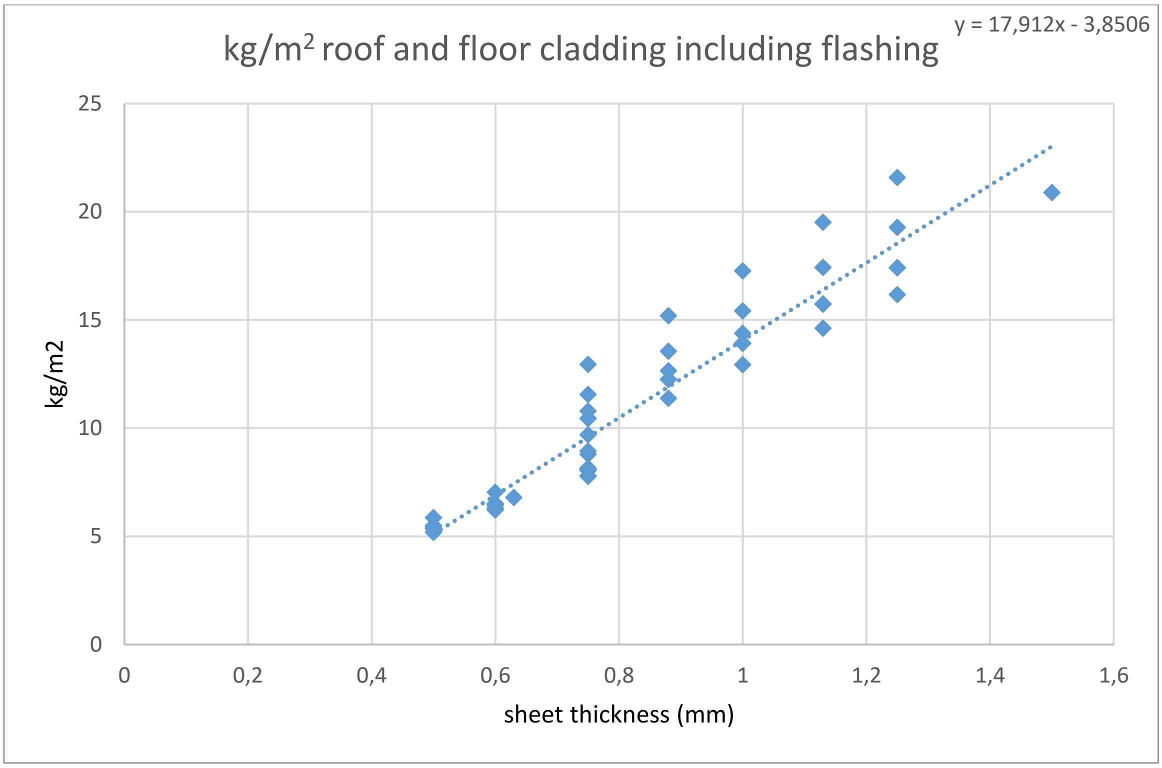

Figure 4.13
Scaling of roof and floor cladding including flashing

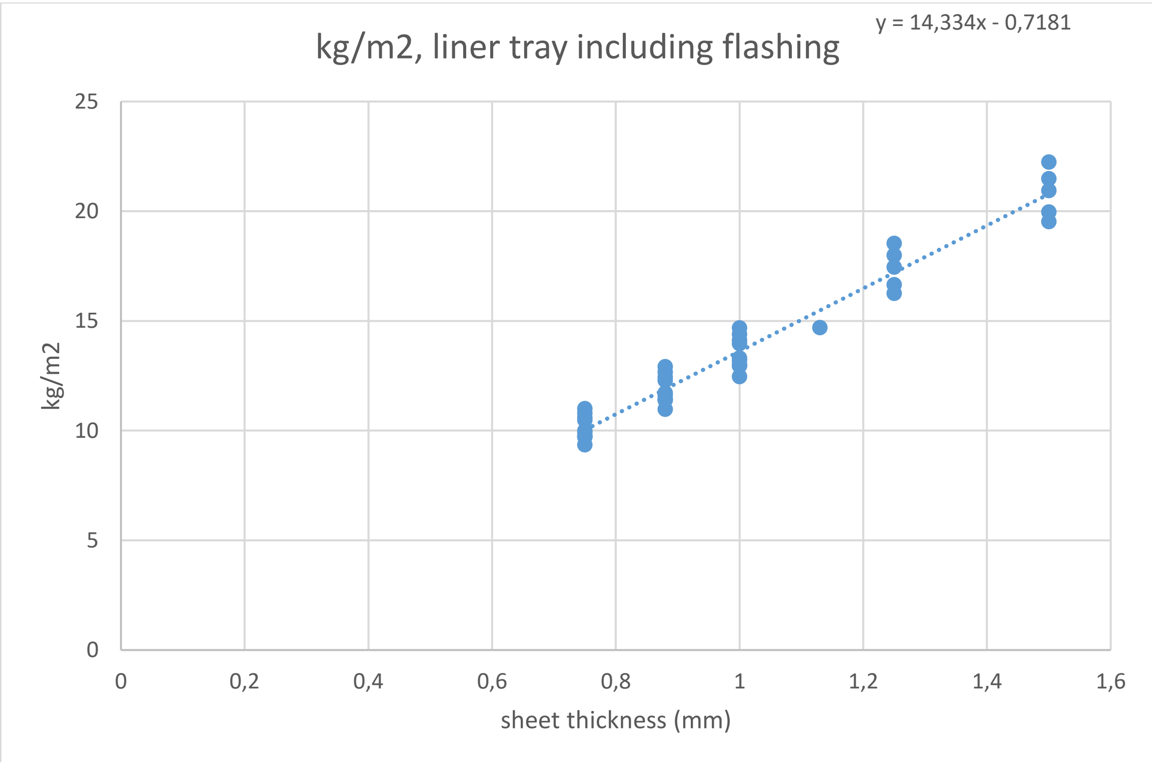

Figure 4.14
Scaling of liner tray including flashing

Scaling formula for steel and operations

The formulas of trendlines need to be corrected for the non-scalable zinc and coating layer. The total mass of the non-scalable part is subtracted from the trendline formulas to arrive at the scaling formula. Table 4.6 provides the scaling profile for each product type.

Table 4.6
Scaling formula for the variable part

	Wall cladding including flashing	Roof and floor cladding including flashing	Liner tray including flashing
Scaling range	0,50-1,00 mm	0,50-1,25 mm	0,75-1,50 mm
Scaling formula for the variable part (steel and operations): x = sheet thickness in mm. .	Kg/m^2 = 10,365x - 0,4769	Kg/m^2 = 17,912x - 4,3984	Kg/m^2 = 14,334x - 1,2286

In figures 4.15, 4.16, and 4.17, the total MKI per functional unit is depicted in relation to the scaling

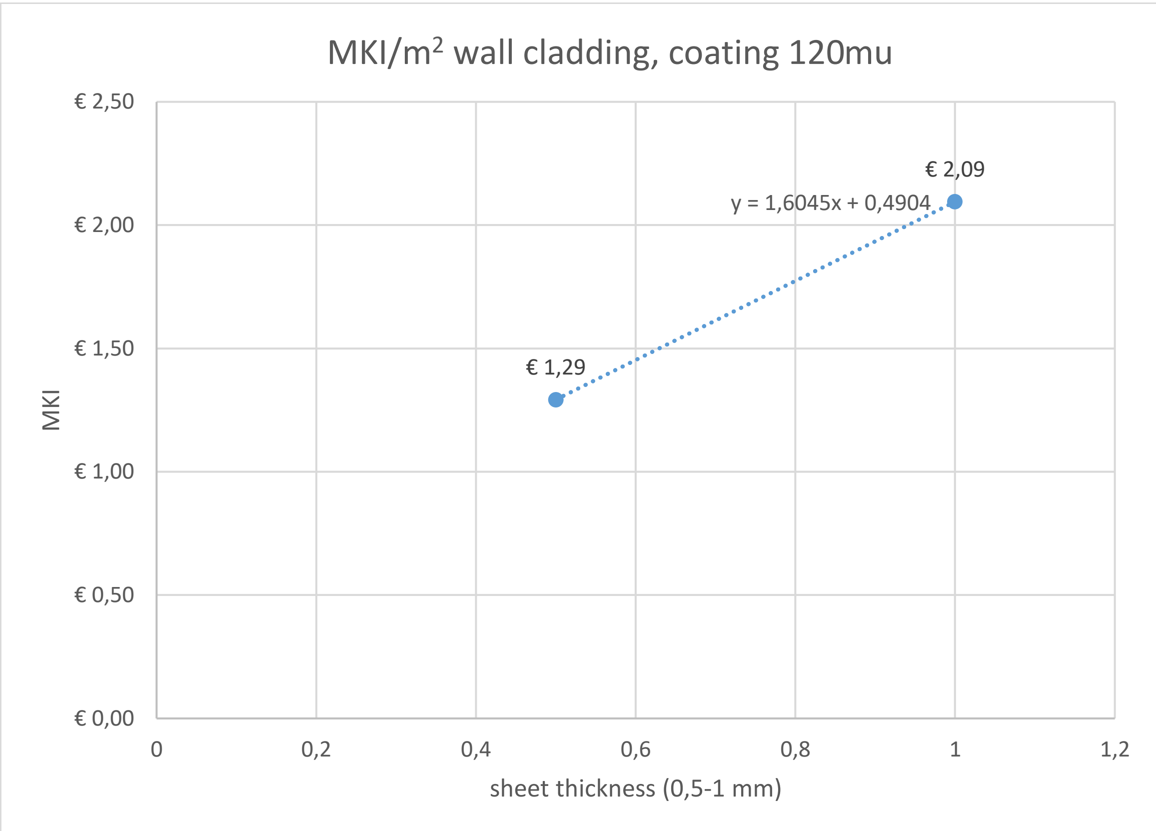

Figure 4.15
The effect of scaling on product MKI for wall cladding including flashing

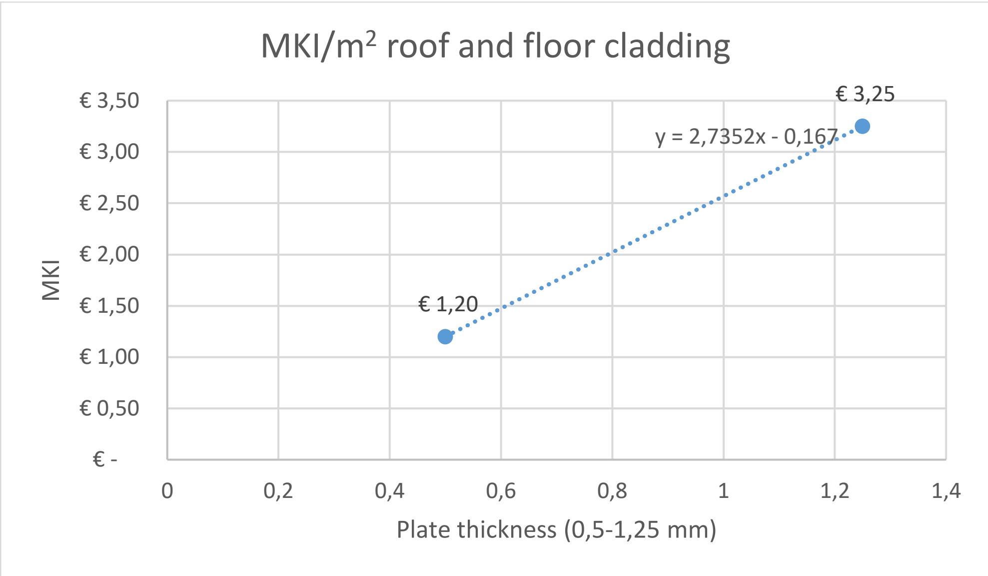

Figure 4.16
The effect of scaling on product MKI for roof and floor cladding including flashing

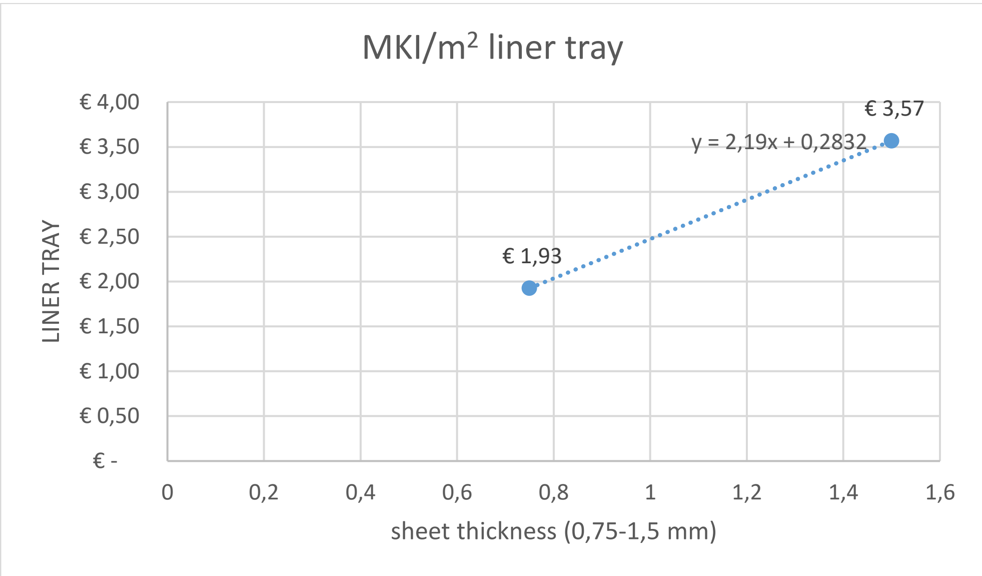

Figure 4.17
The effect of scaling on product MKI for liner trays including flashing

Scaling of wall cladding including flashing, coating

The coating layer thickness of wall cladding including flashing is set at a standard of 120µm. It is scalable from 0 to 200µm according to the formula:

*Coating mass = coating thickness (in μ) * 0,00184.*

The factor 0.00184 is derived from the density of the coating (1380 kg/m^3), the correction factor for the formation of wall cladding (1.21), the correction for including flashing work (1.1), and the correction for working with the coating thickness in µm instead of meters (1^{E-6}). The multiplication factor is calculated as follows = 1380 * 1,21 * 1,1 * 1^{E-6} = 0,00184.

Figure 4.18 illustrates the scaling of the coating in MKI per coating thickness.

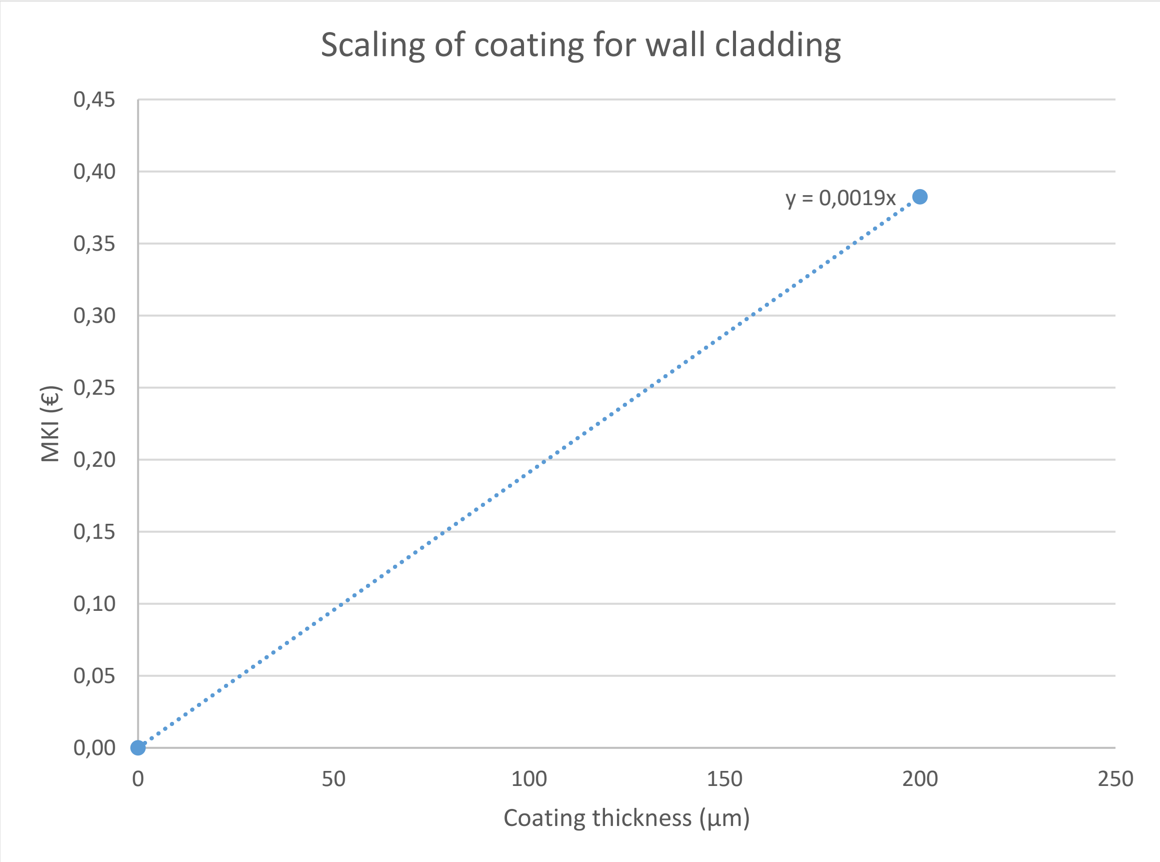

Figure 4.18
Scaling of the coating for wall cladding including flashing

For the reference profile with a coating thickness of 120 µm, the coating has an MKI of € 0.23. When no coating is applied, the MKI for the coating is also € 0. The thickest coating layer thickness of 200µm results in an MKI of € 0.38.

4.3.1 Sensitivity Analysis Scaling Wall Cladding

In the scaling formula for the steel and operations of the wall cladding, the reference zinc and coating mass has been subtracted from the total product mass. The reference mass of the coating (120µm) on the wall cladding is also scalable. However, this scalable coating mass does not scale within the formula of the scaling of the steel and the processing operations. This may create a slight deviation in the mass balance.

For the reference profile (thickness 0.725 mm), the scaling of the coating results in a mass underestimation of 3% when no coating is applied and a mass overestimation of 2% when a coating of 200µm is applied to a plate of 0.725 mm thickness.

Table 4.7
Scaling of wall cladding

Mass balance of wall cladding including flashing (scalable))			
Plate thickness (mm)	**0,725**	**0,725**	**0,725**
Coating thickness (µm)	**120**	**0**	**200**
Steel and operations (kg), scalable (according to plate thickness)	7,04	7,04	7,04
Zinc Z275, non-scalable (kg)	0,37	0,37	0,37
Coating, scalable	0,22	0,00	0,37
Total mass (kg)	7,63	7,40	7,77
Margin of error in mass balance	-	-3%	+2%

4.4 Sensitivity Analysis of Zinc and Coating Thickness

The MKI of zinc and coating per kg is higher than the MKI of steel. Zinc has an MKI of € 0.80 / kg, and coating has an MKI of € 1.29 / kg, while steel has an MKI per kg of € 0.10 for galvanized steel (excluding zinc) and € 0.11 for galvanized and coated steel (excluding zinc and coating). We determined these MKI values by considering both the A1-A3 and module D processes. Module D was calculated based on the net passed-on material, assuming 95% recycling.

Table 4.8
MKI

	MKI / kg, A1-A3 + D			
	Galvanized steel (excluding zinc)	**Steel, galvanized and coated (excluding zinc and coating)**	**Zinc**	**Coating**
MKI (€)	0,10	0,11	0,80	1,29

Zinc

The most commonly specified zinc layer in the LCIs, with a thickness of 275 g/m^2, is also the heaviest zinc layer, making this modelling choice a conservative one.

Coating

In the LCA model, an organic coating thickness of 120 µm is applied as the standard for wall cladding, and 25µm for roof and floor cladding and the liner tray. This coating is only applied to the 75% coated cladding; the remaining 25% of the cladding is only galvanized. In the LCIs, the specified coating thickness varies from 25 µm to 200 µm.

For the organic coating in the LCA model, a layer thickness of 120 µm is applied as the standard for wall cladding, and 25µm for roof and floor cladding and the liner tray. This coating is only applied to the 75% coated cladding; the remaining 25% is only galvanized. In the LCIs, the specified coating thickness ranges from 25 µm to 200 µm.

Table 4.9
Analysis of coating effects

Wall cladding, 6,92 kg/m^2, Z275			
Coating thickness	25mu	120mu	200mu
MKI	**1,48**	**1,65**	**1,79**
Difference	-10%	0%	9%

For the roof and floor cladding and the liner tray, the difference in MKI between different coating thicknesses is smaller. This is because the reference product has a higher mass. In this case, there is the same coating and zinc layer per m2 of cladding, but proportionally more steel..

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Appendix Ia

LCI & Results for Wall Cladding

Sent separately

Appendixx Ib

LCI & Results for Roof and Floor Cladding

Sent separately

Appendix Ic

LCI & Results for Liner tray

Sent separately

Appendix II

Data Quality Single Skin

Sent separately