



Life cycle assessment of a green wall within a small-scale project

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Green walls are an upcoming type of green infrastructure application. Due to the novelty of the green walls, there is still a lack of information about the life cycle assessment (LCA) of green walls. In this paper, a life cycle assessment of two types of green walls have been conducted to receive better insight of the environmental impact of current materials of green walls. The research has a focus on the Living Innovation Lab project, located on the campus of the University of Twente. Multiple companies located in The Netherlands have been contacted for information about their green walls. The results of the LCA of the two types of green walls are compared to one another. A clear difference can be seen between the environmental impact of the green walls.

Green walls; life cycle assessment; environmental impact; small-scale project.

1. Introduction

The increase of global climate change brings much more extreme weather, which means heavier rainfall and more drought. At the same time, the cities around the world keep expanding with impermeable surfaces. This means that the amount of stormwater keeps increasing to the point that cities are unable to handle the amount anymore [1]. With the help of green walls and other green infrastructure, this problem can be tackled. A green wall is a collective term for a system that enables greening a vertical surface (e.g., facades, walls, partition walls, etc.) with plant species. Green walls can be classified into two main systems, namely: green facades and living walls [2] [3]. At green facades, the plants usually will be climbing plants that grow and cover the wall. Living walls are the more recent green walls, where materials and technology are used to support the variety of plants and to create a uniform growth along the wall [4].

Green walls have multiple advantages when applied on buildings. Some of these advantages are: green walls attract heat and will longer hold the heat, the plants cause evaporation which helps cooling the city's climate, the plants capture fine particulate matter and aerosols, the green wall helps for energy saving because the K-value (isolation value) will go down when the outer wall is covered with vegetation and green walls cause noise absorption [5]. The main disadvantage of a green wall is that it could cause damage to the building if it has faults on the façade, inspection before installing a green wall can prevent this [5].

1.1. Research gap

During the literature review of green infrastructure, it was clear that the research gap lay with the life cycle assessment (LCA) of green walls, with mainly the end-of-life cycle. Since the end-of-life cycle of green walls is still a subject where little research is conducted, it is unknown what the environmental impact of these materials and therefore the green wall is. This can be researched with the help of a life cycle assessment of green walls.

1.2. Living Innovation Lab

This research is focussed on the environmental impact of the current materials of green walls at a real-life project called the Living Innovation Lab (LILa). LILa is a project from the University of Twente and the project location is within the Campus in Enschede, The Netherlands. Within LILa four different type of green walls will be researched. The four different types are: A normal wall (baseline measurement), free climbing soil bound plants, facade supported and wall forming modular vegetation system.

In this paper, only the facade supported and wall forming modular vegetation systems are considered since these are the only two types that use materials. The main question for this research is: "To what extent are the materials that are used in traditional green walls sustainable, according to a life cycle assessment and the end-of-life cycle of the materials?". This study attempts to compare the environmental impact of different green wall types and the used materials within a small-scale project. The hypothesis is that some of the used materials in traditional green walls already have a low environmental impact, but some components of the green wall have a larger environmental impact like the support construction.

2. Methodology

Since the scope of this research is the project LILa, only the facade supported and wall forming modular vegetation system are used for this research. To find out what materials are used for those two types of green walls, multiple companies located in the Netherlands that are specializes in green walls were contacted via email and telephone. The required information contained a decomposition of the parts, material characteristics, weight, service life, design information, and information about recycling possibilities. With the help of the companies that replied and were willing to supply information, a list of materials for the two different types of green walls were set up. These materials are also used as input for the LCA in Gabi Sphera.

2.1. LCA study

A life cycle assessment study consists of four main steps, namely: goal and scope definition, life cycle inventory, life cycle impact assessment, and interpretation. These steps are described in this paragraph.

Goal and scope of the study

This study aims to compare the environmental impact of different green wall types within a small-scale project. This information can be used for a choice of which green wall could be applied within the LLa project. The scope of this research is a 19m² façade of a building on the terrain of the University of Twente. This building was constructed in 1992 [6], this means that the building's age is approximately 30 years. Assuming the building's lifespan is 80 years, it still has 50 years before it will be dismantled. Therefore, the LCA study is calculated for 50 years. Only the support of the green wall will be considered in the LCA, so the bare wall and greening is not included. The LCA includes the production of the used materials, the production of components, transport of components, assembly of the green wall, the use phase of the green wall and the end of life of the green wall.

Life cycle inventory

The input data for the LCA study is collected from delivered documents and information from contractors and suppliers. When information was missing, public documents from suppliers were analysed and when information was not available, assumptions were made. The substantiation and assumptions for the input data can be found in Appendix 1. This study uses a student version of Gabi Sphera software version 9.2.1.

Analyse environmental impact

A life cycle assessment is performed to quantify the impact considering human health, the natural environment, and issues related to natural resource use. Within a LCA there are multiple impact indicators that could be considered [7]. For this study, the green walls will be compared on two relevant environmental impact categories, namely: Human Toxicity Potential (HTP, kg 1,4-dichlorobenzene (DB) equivalents), and Global Warming Potential (GWP, kg CO₂ equivalents). HTP concerns about the impact on humans of toxic substances emitted to human environment. GWP is associated with the amount of greenhouse gases that will be emitted to the open air. These two categories are most applicable to this study and are also used in similar studies [8] [9]. GWP relates to the general problem of global warming and climate change and HTP is relevant, because the green wall will be positioned in human environment.

Table 2: components of SemperGreenWall vertical system.

Component	Material	Amount (unit)	Weight (kg/unit)	Total weight (kg)	Service life (years)
Flexipanel	Rockwool, fabric	54 p	0,676	36,50	60+
	Poly-propylene fabric	54 p	0,068	3,67	60+
Bolts	Stainless steel	120 p	0,05	6,00	100+
Omega profile	Aluminium	8 p	4,57	36,54	60+
Gutter profile	Aluminium	2 p	12,66	25,32	60+
Top and edge profile	Aluminium	6 p	7,81	46,83	60+
Z-profile	Aluminium	4 p	3,55	14,20	60+
Chemical anchor	Mortar	120 p	0,03	3,6	100+

3. Results

The results from the life cycle assessment of the green walls within the small-scale project from Living Innovation Lab at the University of Twente are elaborated in the following paragraphs. These results are analysed to determine the relative environmental impact of the green walls and materials for the entire façade within this small-scale project. First the results of the inventory of the green wall materials from the companies are described, then the results of the life cycle assessment (LCA) of the separate green walls and materials are given.

3.1. Green wall input information

The assessed green walls within this study are described in the following paragraphs. The components, material, weight, and service life are listed per green wall type. This information is based on the façade of 19m².

Components supported façade Carl Stahl (type 1)

The façade supported green wall from Carl Stahl consists mainly out of stainless-steel components. The design of the facade supported green wall can be found in Appendix 4. On the outside of the façade and window, spacers are mounted into the wall with bolts and chemical anchors. A surrounding cable with a diameter of 6mm runs through the spacers. The surrounding cable forms the support for the cable network. The cable network is connected to the surrounding cables, which creates a wall covered with a cable network. The cable network forms a support for vegetation that grows from the ground. Overtime the vegetation will grow all over the cable network, which forms a green wall. Information about the components can be found in Table 1. The total weight of this type of green wall is 22,50 kg.

Carl Stahl also had a variant with aluminium spacers. This variant is not included in this research, because of lack in time. Also the assumption was made that it would not make a great difference in environmental impact compared to this variant.

Components SemperGreenWall vertical system (type 2)

The vertical greening system of SemperGreenWall is a modular vertical wall system consisting out of aluminium profiles and Flexipanel. An indication of the design of the vertical system can be found in Appendix 5. The aluminium profiles will function as a frame on which the Flexipanel are assembled. These Flexipanel consist mostly of Rockwool on which plants are pre-grown. The front side of the Flexipanel will be covered with polypropylene fabric functioning for UV-light protection. The system will be assembled on the wall with the use of bolts and chemical anchors. The plants in the Flexipanel will form the green wall. Information about the components can be found in Table 2. The total weight of this type of green wall is 172,66 kg.

Table 1: components of supported façade from Carl Stahl.

Component	Material	Amount (unit)	Weight (kg/unit)	Total weight (kg)	Service life (years)
Cable network	Stainless steel	19m ²	0,25	4,75	100+
Lacing cable	Stainless steel	29,81 m	0,0154	0,46	100+
Spacers	Stainless steel	28 p	0,23	6,44	100+
Tension housing	Stainless steel	28 p	0,225	6,30	100+
Surrounding cable	Stainless steel	27,10 m	0,138	3,74	100+
Chemical anchor	Mortar	28 p	0,03	0,84	100+

3.2. Supported façade Carl Stahl

The result from the life cycle assessment on the supported façade from Carl Stahl show that the total GWP is 230,8 kg CO₂ equivalents and that the HTP is 374,4 kg 1.4-DB equivalents. The total value and the main contributors to this value are schematized in Figure 1. A screenshot from the Gabi model of this green wall type can be seen in Appendix 2.

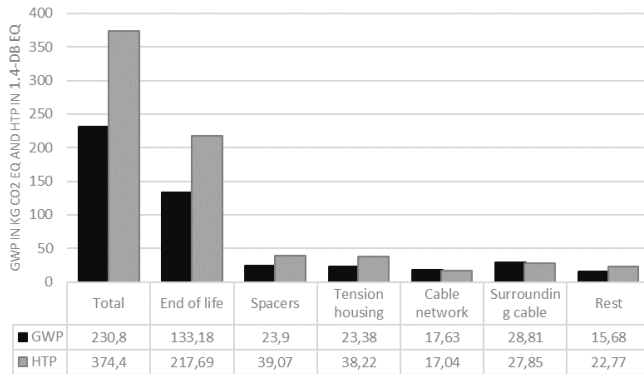


Figure 1: Environmental impact green wall Carl Stahl.

3.3. SemperGreenWall vertical system

The result from the life cycle assessment on the SemperGreenWall vertical system show that the total GWP is 1715,93 kg CO₂ equivalents and that the HTP is 2907,34 kg 1.4-DB equivalents. The total value and the main contributors to this value are schematized in Figure 2. A screenshot from the Gabi model of this green wall type can be seen in Appendix 3.

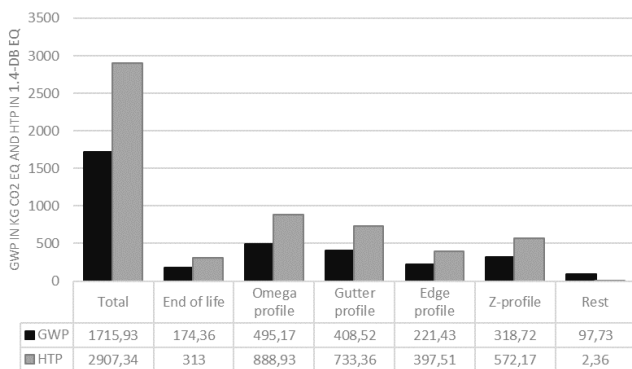


Figure 2: Environmental impact SemperGreenWall.

4. Discussion

The hypothesis for this research was that some of the used materials in traditional green walls already have a low environmental impact, but some components of the green wall have a larger environmental impact like the support construction. The results from the life cycle assessment show that the construction elements made from aluminium and stainless steel indeed have a relatively high environmental impact.

When the environmental impact from the green wall of Carl Stahl and from SemperGreenWall are compared, a huge difference can be seen. Carl Stahl has a GWP of 230,8 kg CO₂ equivalents compared to 1715,93 kg CO₂ equivalents from Sempergreenwall, which is 7,4 times higher. The HTP is from the green wall of Carl Stahl is 374,4 kg 1.4-DB equivalents compared to 2907,34 kg 1.4-DB equivalents from SemperGreenWall, which is 7,8 times higher. This difference can be explained by the total weight of the green wall types. SemperGreenWall weighs 7,5 times as much as the green wall from Carl Stahl.

When these two green walls are compared on environmental impact only, the green wall from Carl Stahl comes out the best. However, this study only focussed on environmental impacts of the materials of the green walls. Other aspects, like positive results for isolation and sound isolation for the building, costs, aesthetics, and impact on the environment of the green walls during the lifecycle by the plants were not considered. Furthermore, only two types of green walls were considered due to lack of responses from companies that are specialized in constructing green walls.

The component 'end of life' in Gabi Sphera model of the SemperGreenWall vertical system is due to a technical issue incomplete. It is expected this has no significant impact on the results of the research.

5. Conclusion

This paper shows the environmental impact of two types of green walls, namely a supported façade from Carl Stahl and a modular green wall from SemperGreenWall. This research contributes to the Living Innovation Lab (LiLa), which takes place at the University of Twente in the Netherlands, by gaining knowledge about the environmental impact of green walls and the used materials.

The green wall from Carl Stahl has a significant lower environmental impact than the green wall from SemperGreenWall, which can be explained by the significantly larger weight of the SemperGreenWall. Further research on the environmental impact of these and other types of green walls could expand knowledge on this topic and help to put the results from this research into perspective. Also, other aspects could be taken into count when comparing green walls, for example the influence of the green wall on the isolation value of the building or the influence on the living environment.

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Appendix

Appendix 1: substantiation and assumptions input LCA

Green wall type 1 – Carl Stahl

Materials frame

The materials used for the frame of the facade supported green wall are provided by the company Car Stahl. The frame is made completely of stainless steel (cold rolled coil 315). The following materials are within the frame:

- Spacers
- Threaded end
- Tension housing
- Cable network 2mm
- Surrounding cable 6 mm
- Lacing cables

Transportation

For the transportation trucks are used. The trucks use diesel as fuel. The assumption is made that the stainless-steel materials come from the nearest stainless-steel factory that can provide the required materials. This is from Van Merksteijn. The distance to LILa is 32 km.

Production Frame Green wall

The assumption is made that the production of the materials are done at the Van Merksteijn factory. To produce materials stainless steel, cold rolled coils are used. All stainless-steel materials are produced at the same location.

Chemical anchor production

According to Car Stahl, the frame is attached to the building with spacers and a chemical anchor. For the chemical anchor the type fischer Injectiemortel FIS V Plus 360 S is used. This mortar is entered as Portland cement into the Gabi software.

Electricity use

Based on insufficient information about the electricity use during the production process, this will not be considered.

End of life green wall

The green wall for the project LILa has a life cycle of 50 years. At the end of life of the green wall, the stainless-steel components will be recycled. Around 85% of the stainless-steel components can be recycled [10].

Commercial waste

The other materials that cannot be recycled, will be sent to the dumping ground.

Green wall type 2 – SemperGreenWall

Materials frame

The materials used for the frame of the green vertical wall are provided by the company SemperGreenWall. The frame is made mainly of aluminium. The following materials are made from aluminium sheet mix:

- Omega profile
- Gutter profile
- Top and edge profile
- Z-profile

The flexipanel are made from different products. The flexipanel are mounted in the wall by stainless steel bolts. In total 120 are used. The flexipanel consist of the following materials:

- Stone wool/ rockwool
- Water buffering fleece cloth (made from old clothes)
- UV resistant fibre (polypropylene)

Transportation

For the transportation trucks are used. The trucks use diesel as fuel. The assumption is made that aluminium materials come from the nearest aluminium factory that can provide the required materials. This will be Nedal Aluminium BV. The distance is 150 km from LILa.

production green wall

The assumption is made that the production of the materials are done at the Nedal Aluminium BV. For the production of materials aluminium sheets are used. All the aluminium materials will come from this company. The main components of the flexipanel are stone wool and the polypropylene fibre. For the other two components the exact type and weight could not be found. For this reason, these two materials are not taken in the LCA. Since these are small components, it is assumed that it will not influence the outcome.

Production chemical anchor

The frame is attached to the building with bolts and a chemical anchor. Based on the facade supported green wall the chemical anchor the type fischer Injectiemortel FIS V Plus 360 S is used as chemical anchor. This mortar is entered as Portland cement into the Gabi software.

Electricity use

Due to insufficient information about the electricity use during the production process, this will not be considered.

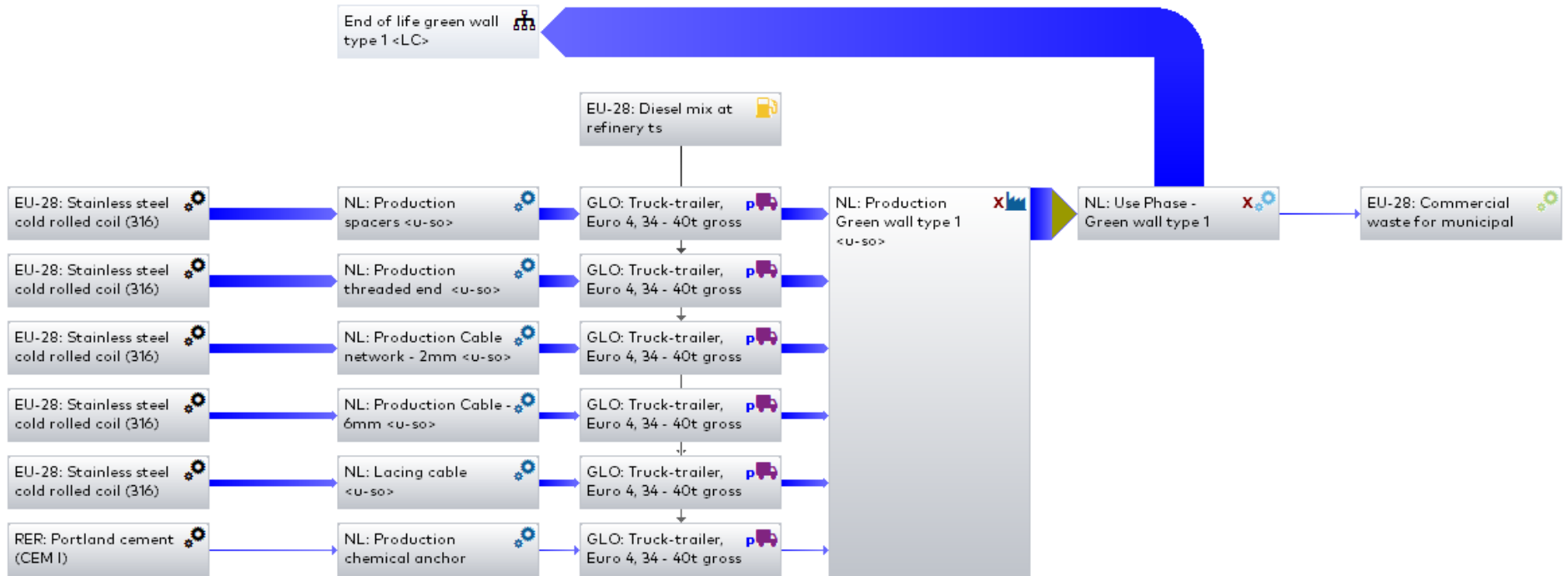
End of life green wall

The green wall for the project LILa has a life cycle of 50 years. At the end of life of the green wall, the aluminium components will be recycled. Around 95 % of the aluminium components can be recycled [11].

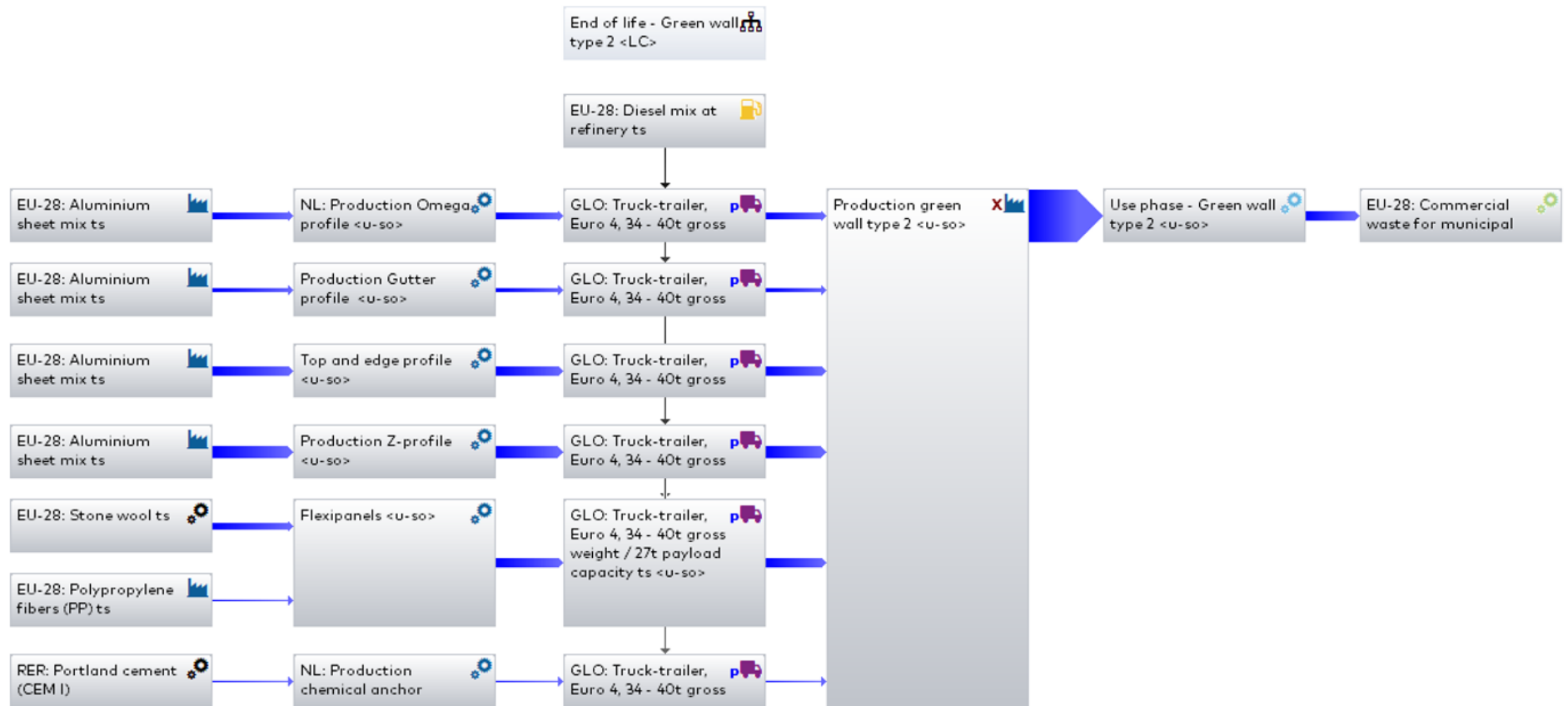
Commercial waste

The other materials that cannot be recycled, will be sent to the dumping ground.

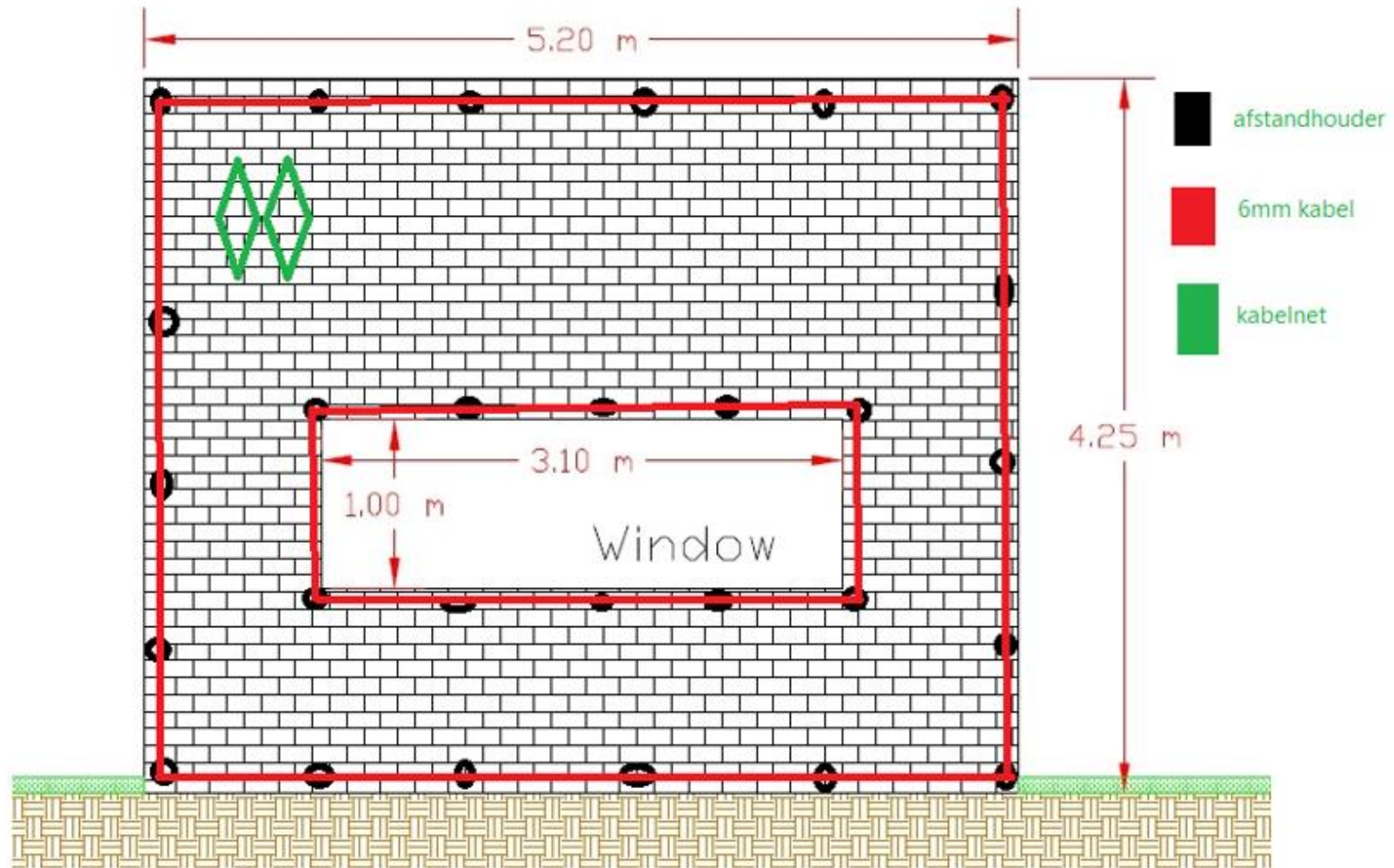
Appendix 2: screenshot Gabi model Carl Stahl



Appendix 3: screenshot Gabi model SemperGreenWall



Appendix 4: Facade supported green wall from Carl Stahl



Appendix 5: Vertical system from SemperGreenWall

