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# Screening Life Cycle Assessment (LCA) of Halo 11 kW and Aura 22 kW

**Commissioned by** Charge Amps

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# 1 Introduction

This report presents a life cycle assessment (LCA) on two charging stations from Charge Amps. The report was prepared by IVL Swedish Environmental Institute on behalf of Charge Amps. The study was conducted with the aim of gaining an understanding of the environmental impact along the entire value chain for the products and being able to use the report as a basis for decision-making and communication. The two charging stations included in the study have been selected by Charge Amps and have the following product names: Halo 11 kW and Aura 22 kW. The function is the same for the two products, but something that distinguishes them is that the Aura 22 kW offers double charging capacity and two sockets compared to Halo 11 kW which has one socket.

# 2 What is LCA?

Life cycle assessment (LCA) is the calculation and evaluation of the environmentally relevant inputs and outputs and the potential environmental impacts of the life cycle of a product, material or service (ISO 14040:2006 and 14044:2006).

Environmental inputs and outputs refer to demand for natural resources and to emissions and solid waste. The life cycle consists of the technical system of processes and transports used at/needed for raw material extraction, production, use and after use (waste management or recycling). LCA is sometimes called a "cradle-to-grave" assessment, see Figure 1.

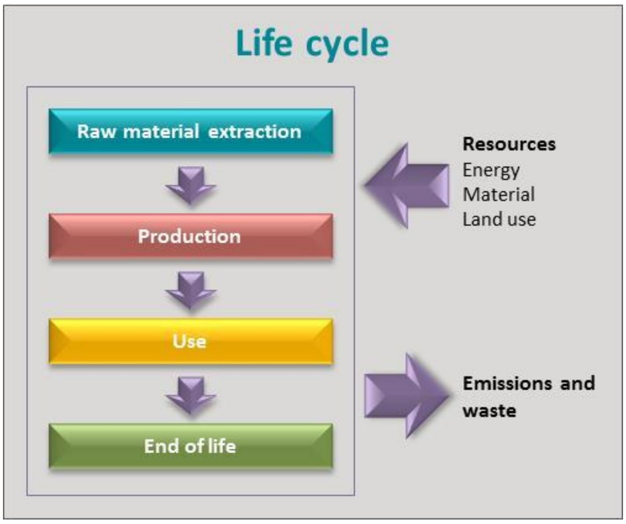

Figure 1. Illustration of the LCA system.

An LCA is divided into four phases. In accordance with the current terminology of the International Organization for Standardization (ISO), the phases are called goal and scope definition, inventory analysis, impact assessment, and interpretation, see Figure 2.

An LCA can be used in many different ways, depending on how the goal and scope are defined. Product development, decision making, indicator identification and marketing are examples of areas where the information retrieved from an LCA may be valuable.

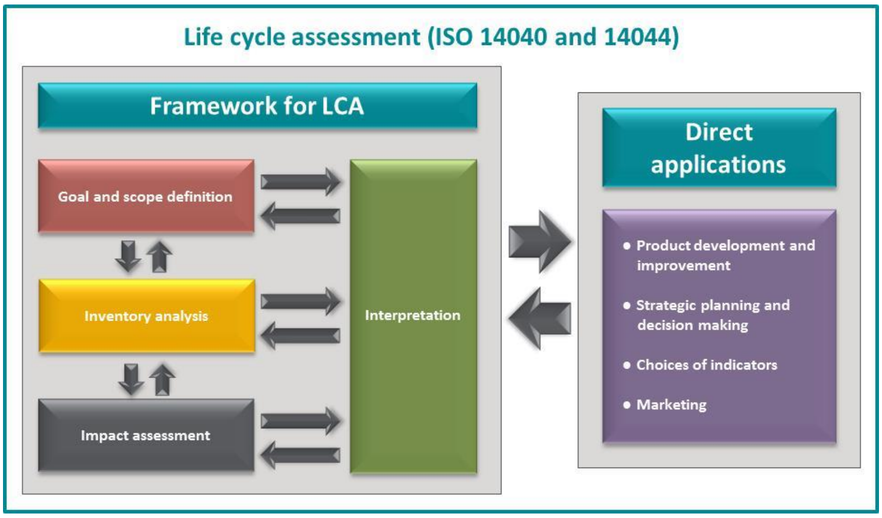

Figure 2. Illustration of the phases of an LCA.

# 3 Goal and scope

The goal and scope of the study are described below, which include the purpose of the study, a description of the studied product alternatives, functional unit, and system boundaries for the study.

## 3.1 Goal

The goal of the study is to investigate the environmental impact of two different charging stations from Charge Amps. In addition, the study will highlight the steps in the life cycle and components/materials that have the greatest impact on the total environmental impact that can be used as a basis for future improvements.

## 3.2 Studied product systems

The following section describes the types of charging stations that have been included in studies and the functional unit that has been used in the calculation of studies.

The charging stations studied in this study are:

1. Halo 11 kW
2. Aura 22 kW

Table 1 describes the two charging stations. Service life is assumed by Charge Amps.

**Table 1. Charging stations included in the study.**

| Charging stations | Weight (incl. packaging) | Assumed service life | Standby consumption |
|---|---|---|---|
| Halo 11 kW | 4.7 kg | 15 year | 44 kWh/year |
| Aura 22 kW | 11.2 kg | 15 year | 42 kWh/year |

### 3.2.1 Functional unit

The functional unit serves as a calculation basis for the study and is the unit to which the result refers. In the study, the following functional unit was chosen:

- *one charging station unit in operation for 15 years*.

### 3.2.2 Type of LCA

There are two different types of LCA studies that differ in the sense that they answer different questions. An LCA study can be either an *attributional LCA* or a *consequence LCA*. An attributional LCA focuses on examining the environmental impact of one system, while an impact LCA examines the environmental consequences of the transition from one system to another.

This study is an attributional LCA and focuses on examining the environmental impact of each charging station.

## 3.3 System boundaries

This section describes the system boundaries of the LCA models and which processors are included and excluded for all product systems studied.

Figure 3 below shows the flowchart on the life cycle of the charging stations. The flowchart shows which processors are included and excluded. Installation as well as disassembly and maintenance are not included in the study. The study only takes into account the charging stations and no capital goods/infrastructure that may be needed during production and use. The use phase only covers standby consumption.

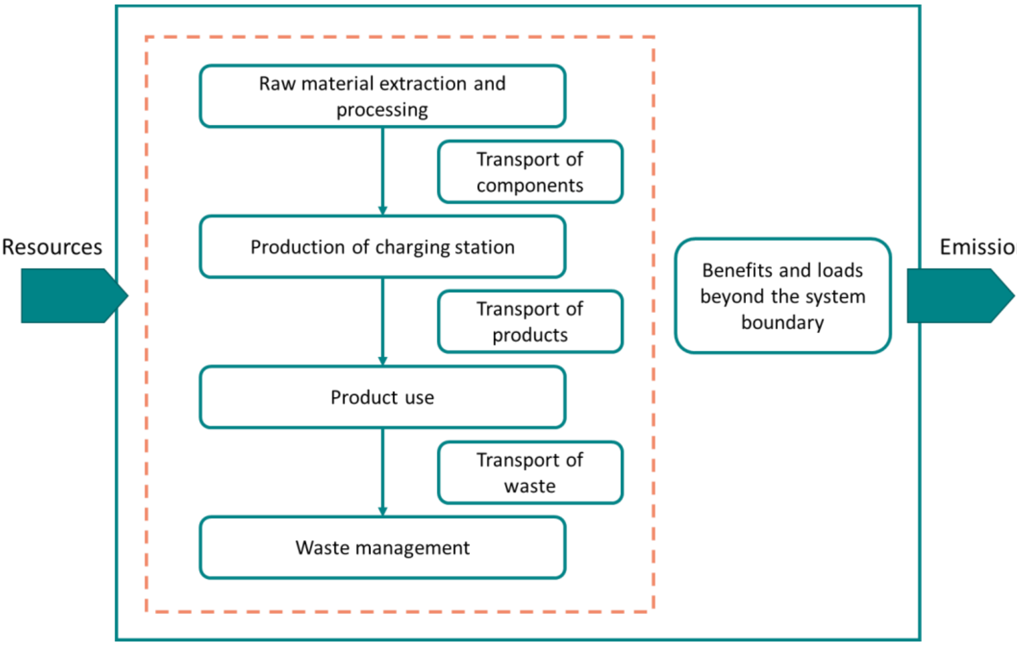

Figure 3. Flowchart on the life cycle of the charging stations.

## 3.3.1 Boundaries towards nature

The inventory flows are mapped from the "cradle" where the natural resources are extracted until the "grave" where the product are sent to waste management. In all steps, natural resources are used and emissions to air, water and soil are emitted. The boundary between nature and the product life cycle is crossed when the natural resources (e.g. crude oil or uranium) are extracted from the ground. The "grave" of the life cycle is the soil (after human activity has ceased, and landfill gas emissions and leakage production are minimal), the air (e.g. emissions from combustion of fuels) or water (e.g. water emissions from wastewater treatment). At incineration of waste, the emissions to air and the ashes or waste generated from the incineration process are included. The landfilling of the ashes however is not included, *i.e.* the ashes are a non-elementary outflow from the system, *i.e.* an outflow not followed to the boundary between technosphere and nature (stated as non-elementary waste).

## 3.3.2 Geographical boundaries

The production of the charging stations is based in Sweden and all waste generated from the process is sent to waste facilities within the same country. The use and waste management of the charging stations are assumed to take place in Sweden.

The components are manufactured in different countries. Data for raw material extraction and processing are based on generic data with a high level of aggregation, which are primarily country-specific. If country-specific data are not available, European or global averages are used as a second option, as last resort, data from other countries are used.

### 3.3.3 Time boundaries

The study takes into account the rule on data quality according to EN 15804: 2012+A2:2019/AC:2021 (CEN, 2021), which requires that specific and generic data must not be more than 5 and 10 years old, respectively.

Data on the production of the Swedish residual mix presented in chapter 4.6 is based on the year 2020.

### 3.3.4 Boundaries to other technical systems

Since there is an exchange of flows between this system and other technical systems, e.g. inflow of recycled aluminum, there is a need to define the boundaries between these systems. How this is done depends on the chosen allocation method, which is described in chapter 3.5.

## 3.4 Other important assumptions and limitations

In addition to the above assumptions about the modeling, the following key assumptions are made, some of which constitute limitations for the study.

- Interpretation of results has been excluded in the study, which means that, for example, underlying resource flows for processes with a relatively large environmental impact are not investigated and described in this report.
- The collection rate of the product for waste management is assumed to be 100%
- For the calculation of credits, material recycling has been excluded.
- Information about the contents of the circuit boards in Halo 11 kW has a smaller level of detail than Aura 22 kW, which can affect the comparability between the two products. In general, the data collected for the Aura 22 kW was more detailed than the Halo 11 kW.

## 3.5 Allocation

The following two allocation methods are applied:

1. Allocation of co-products, i.e. allocation of the environmental burden from processes that produces several products.
2. Allocation of waste, i.e. allocation of environmental burden from waste management processes such as landfilling, recycling and reuse.

### 3.5.1 Allocation of co-products

In this study, it was not possible to exclude allocation, which should be done primarily according to the standard ISO 14044:2020 by dividing the process into several sub-processes. Another option is system expansion but it is not recommended for attributional LCA. What is recommended by the standard if you cannot avoid allocation is to allocate with regard to physical properties between the products that produce in the same process.

The charging stations are manufactured in the same plant together with other products. This process cannot be divided into several ones and thus allocation of in- and outflows has been carried out with regard to the share of the total production volume for each charging station under one year. Inflows that have been allocated are the energy consumption in the production plant, which includes electricity and district heating. Outflows that have been allocated are all waste generated in the production plant. Table 2 presents the production volume for the two charging stations.

**Table 2. Collected data for production of the charging stations.**

| Parameters | Halo 11 kW | Aura 22 kW |
|---|---:|---:|
| Production year | 2019 | 2021 |
| Weight, including packaging (kg/piece) | 4.7 | 11.2 |
| Production volume (pieces/year) | 4 229 | 14 894 |
| Production volume (kg/year) | 19 876 | 166 494 |
| **Share of total production volume** | **4.60%** | **14.7%** |

### 3.5.2 Allocation of waste

The chosen method for allocation of waste is according to EN 15804:2012+A2:2019/AC:2021 (CEN, 2021) and complies with the attributional-LCA approach but also includes the effect of reuse and recycling. The method is most often characterized by the name *Cut-off plus credit* and is similar to ISO 14044+A2:2020 to some extent. However, there is a significant difference regarding the allocation of recycled materials that go into the studied product system:

- EN 15804: Recycled material does not carry any environmental impact to product systems that utilize these resources.
- ISO 14044: Recycled material carries the same environmental impact as a virgin material.

The reason why recycled material has the same environmental impact as virgin material according to ISO 14044 is to avoid double counting. This is because the standard suggests using system expansion and taking into account credits (environmental benefits) as well as any environmental burden when recycling the product. In short, there is no advantage to using recycled materials according to ISO 14044 because previous product systems have already included credits in their studies for having created the conditions for the material from their product to be recycled. In the same way, but on the contrary, there is no incentive to recycle materials according to EN 15804 because credits cannot be considered due to the fact that recycled materials do not carry any environmental impact to the next product system. Nevertheless, EN 15804 has chosen to include credits for recycling to be able to provide information about the consequences that arise when materials leave the product system and replaces other materials or energy. However, the result for credits must always be reported separately and never summed up with other results as this would cause double counting.

#### 3.5.2.1 Allocation of incoming flows of recycled material

For both charging stations, recycled aluminum is used and this material is assumed to have been recycled from products that have been used in a previous product system, which is characterized as *post-consumer material*. Table 5 presents the components in more detail for each product.

**Table 3. Recycled material used in charging stations.**

| Product | Components | Weight (kg/fu) | Content |
|---|---|---|---|
| Halo 11 kW | Aluminium front cover | 0.43 | 86% recycled aluminium & 14% alloy |
| | Aluminium rear housing | 0.67 | 86% recycled aluminium & 14% alloy |
| Aura 22 kW | Housing outer | 1.55 | 86% recycled aluminium & 14% alloy |
| | Housing middle | 2.52 | 86% recycled aluminium & 14% alloy |

For these components, the aluminum scrap has been modeled without any environmental impact to comply with the allocation method *Cut-off plus credit*. Note that no environmental impact is only applicable to post-consumer materials and not materials that come directly from the factory, pre-consumer materials. Processes for converting aluminum scrap to an aluminum profile are, however, included in the LCA and have been modeled with a melting and extrusion process.

The melting process[1] is modeled with generic data representing the European average. This process includes both the recycling of aluminum scrap that comes directly from the factory and those from products that have been used in previous product systems, ie pre-consumer material and post-consumer material. The result of the process is an aluminum alloy with typical alloying elements such as silicon, copper and magnesium. What should be noted is that this process may to some extent deviate from the actual case as it includes the recycling of aluminum scrap from the factory and considers a material composition of the aluminum alloy that does not necessarily represent what is in the components of the charging stations. Finally, these components are produced in China, but the process is based on a European average, however, it is a common problem with LCA not to find country-specific data for all processes. In terms of data availability this process was the most representative and at the same time has acceptable quality.

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[1] More information on the process: http://gabi-documentation-2022.gabi-software.com/xml-data/processes/a9aa87f8-2daa-4634-83a4-51659ebfb3d5.xml

### 3.5.2.2 Allocation of outgoing flows of recycled materials and energy

According to EN15804:2012+A2:2019/AC:2021, the environmental burden from recycling processes must be allocated to the studied product system if the processes are before the point when material ceases to be waste, which is often referred to as *end-of-waste state*[2]. This rule has been applied as follows:

- **Transport of waste** is allocated to this product system
- **For waste incineration with energy recovery**, the environmental burden from the incineration, including previous recycling processes, is allocated to this product system with the reason that the recycling companies are paid in Sweden to take care of the waste. Environmental burden and credits that occur after the end-of-waste state are declared separately because it is beyond the system boundary. Electricity and heat produced from the combustion process are assumed to replace the production of the Swedish average residual mix and the Swedish average district heating mix, respectively.
- **For waste that is reused or recycled into a new material**, the environmental burden from the recycling processes before the end-of-waste state is allocated to this product system. In this study, end-of-waste state is assumed to occur after the waste has been transported to a possible collection point or recycling facility. Environmental burden and credits that occur after the end-of-waste state are declared separately because it is beyond the system boundary. In this study, environmental burdens and credits beyond the system boundary have been excluded.
- **For waste that goes to landfill,** all environmental burdens are allocated to this product system.

## 3.6 Environmental impact categories

The results from the study are presented for several environmental impact categories. The environmental impact categories included in the study, as well as the method used, are presented in Table 4 below. Selection of environmental impact categories and methods are based on requirements from EN 15804:2012+A2:2019/AC:2021 (CEN, 2021). These are also the ones used as a default for non-construction products at EPD International AB (2022).

**Table 4. Environmental impact categories included in the study.**

| Environmental impact categories | | Unit | Method | Source |
|---|---|---|---|---|
| Global warming potential (GWP) | Fossil | kg $CO_2$ eq. | GWP100, EN 15804. Version: August 2021 | IPCC (2013) |
| | Biogenic | kg $CO_2$ eq. | GWP100, EN 15804. Version: August 2021 | IPCC (2013) |
| | Land use and land transformation | kg $CO_2$ eq. | GWP100, EN 15804. Version: August 2021 | IPCC (2013) |
| | TOTAL | kg $CO_2$ eq. | GWP100, EN 15804. Version: August 2021 | IPCC (2013) |
| Acidification potential (AP) | | kg mol $H^+$ | AP, accumulated exceedence, | Seppälä et al. 2006, Posch et al. |

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[2] The term end-of-waste state is used in the standard EN 15804+A2 and describes the point when materials cease to be waste.

| | | | | |
|---|---|---|---|---|
| | | eq. | EN 15804. Version: August 2021. | 2008 |
| Eutrophication potential (EP) | Aquatic freshwater | kg P eq. | EP, aquatic freshwater, EUTREND model, EN 15804. Version: August 2021. | Struijs et al. 2009 as implemented in ReCiPe |
| | Aquatic marine | kg N eq. | EP, terrestrial, accumulated exceedance, EN 15804. Version: August 2021. | Struijs et al. 2009 as implemented in ReCiPe |
| | Aquatic terrestrial | mol N eq. | | Seppälä et al. 2006, Posch et al. 2008 |
| Photochemical oxidant creation potential (POCP) | | kg NMVOC eq. | POCP, LOTOS-EUROS as applied in ReCiPe, EN 15804. Version: August 2021. | Van Zelm et al. 2008, ReCiPe 2008 |
| Ozone layer depletion (ODP) | | kg CFC 11 eq.- | ODP, EN 15804. Version: August 202 | WMO 2014 |
| Abiotic depletion potential (ADP) | Metals and minerals | kg Sb eq. | ADP minerals & metals, EN 15804. Version: August 2021. | Guinée et al. 2002, van Oers et al. 2002, CML 2001 baseline (Version: January 2016) |
| | Fossil resources | MJ, net calorific value | ADP fossil resources, EN 15804. Version: August 2021. | Guinée et al. 2002, van Oers et al. 2002, CML 2001 baseline (Version: January 2016) |
| Water deprivation potential (WDP) | | $m^3$ world eq. | Available water remaining (AWARE) method | Boulay et al (2017) |

In Table 5, the LCI indicators included in this study are presented.

Table 5. LCI indicators included in the study.

| LCI indicators | Unit |
|---|---|
| Total use of renewable primary energy resources (PERT) | MJ |
| Total use of non-renewable primary energy resources (PENRT) | MJ |

## 3.7 Software and databases

The LCA has been modeled in GaBi version 10.5 from Sphera Solutions GmbH. The databases that have been used are from IVL (version 2022), GaBi Professional Database (version 2022.1) and Ecoinvent (version 3.7.1).

# 4 Life cycle inventory

The following chapter describe how the products have been modeled and which assumptions have been made.

## 4.1 Manufacturing of components

Data with regard to which raw materials and quantities per manufactured charging station were collected by Charge Amps. In addition, the company collected information on which manufacturing processes are used for each component. A significant difference between the collected data on the charging stations Halo 11 kW and Aura 22 kW is the level of detail. For Aura 22 kW, data is collected for 109 components, while for Halo 11 kW, data is collected for 30 components. The total weight of the components corresponds to the weight of the products and thus no data is missing.

In Table 6, manufacturing processes are presented for each type of material that is included in the study, as well as assumed material loss.

**Table 6. Manufacturing processes and material losses for each type of material.**

| Type of material | Manufacturing process | Loss of material |
|---|---|---|
| Polymer and rubber | Injection moulding | 1% |
| Metal | Die casting<br>Laser cutting<br>Bending<br>Punching | 5% |
| Wood | Production of corrugated cardboard box | 10% |

The table above presents the manufacturing processes that have been used to produce all components, but there are also other manufacturing processes that are embedded in the upstream data that has been used in the LCA.

### 4.1.1 Manufacture of electronic components

The charging stations contain electronic components that are mounted on the circuit boards, also known as printed circuit board assembly (PCBA). The components have been modeled either as passive or active components using generic data from the Ecoinvent database. Generic data on passive components is an average output of the following components: connectors, capacitors, inductors and resistors. Generic data on active components is an output of the following components: diodes, transistors and integrated circuits datasets. The relay components have been modelled as inductors in consultation with Charge Amps. SMPS (Switching Mode Power Supply) components have also been modeled with generic data representing those who are used in a desktop computer. Table 7 and Table 8 present how the electronic components in the circuit boards have been modeled.

Table 7. PCBA for Halo 11 kW

| Components | Weight (kg/fu) | Share | Modeled as |
|---|---|---|---|
| Relays | 0.21 | 46% | Inductors |
| Passive components | 0.01 | 1% | Passive components |
| Active components | 0.12 | 25% | Active components |
| Other (non-electronic components) | 0.13 | 28% | Cabling, screws, printed circuit boards, etc. |
| **TOTAL** | **0.46** | **100%** | |

Information about the contents of the PCBA for the Halo 11 kW was less detailed than the Aura 22 kW and the proportion of the various electronic components was determined in consultation with Charge Amps.

Table 8. PCBA for Aura 22 kW

| Components | Weight (kg/fu) | Share | Modeled as |
|---|---|---|---|
| Transformers | 0.11 | 12% | Passive components |
| Relays | 0.42 | 46% | Inductors |
| SMPS | 0.04 | 4% | SMPS |
| Capacitors | 0.02 | 2% | Passive components |
| Connectors | 0.01 | 1% | Passive components |
| Coils | 0.02 | 2% | Passive components |
| Other (non-electronic components) | 0.31 | 33% | Cabling, screws, printed circuit boards, etc. |
| **TOTALT** | **0.92** | **100%** | |

## 4.2 Manufacturing of product

Manufacturing of the charging stations takes place in Sweden and in the same manufacturing facility. Reported energy during manufacturing is electricity and district heating. Electricity comes mainly from the grid but also from the manufacturing plant's own solar panels. Production of electricity and district heating is based on the Swedish residual mix and Swedish average, respectively. More info about the share of energy sources is found in chapter 4.6. Due to the fact that the production volume is greater for Aura 22 kW, as reported in chapter 3.5.1, the environmental burden will be greater than for Halo 11 kW. Manufacturing of the charging stations has been modeled in the same way and more information can be found in the Excel file.

## 4.3 Use

The environmental burden of using the charging stations is based on the standby consumption and any electricity losses. The time horizon is 15 years, which is the technical lifespan that has been assumed. Standby consumption was measured by Charge Amps to be 44 and 42 kWh/year for Halo 11 kW and Aura 22 kW respectively. The electricity is assumed to come from the grid and is based on the residualmix in Sweden reported in chapter 4.6.

## 4.4 Transports

### 4.4.1 Transport of components

Information on transport distance and transport mode for components has been collected from Charge Amps. The majority of components come from China where transport by truck and ship is included

All truck transport uses the same fuel, which is diesel with 6% RME (biofuel). For the modeling of Halo 11 kW, the same truck model has been assumed. This truck model has a load capacity of 27 tons and a load utilization rate of 85%. For the Aura 22 kW, Charge Amps has collected data for different truck models for each component being transported. Note that load utilization rate correlates with load capacity. In other words, a small truck generally has a lower load utilization rate than a large truck. More information about truck models and distances can be found in the Excel file.

All ship transports use the same fuel, which is HFO (Heavy fuel oil). The same ship model has been used for all transports for both Halo 11 kW and Aura 22 kW. This ship model has a dead weight of 27500 tons (DWT) and a cargo utilization rate of 70%. More information about distances for all ship transports can be found in the Excel file.

### 4.4.2 Transport of product

Information on transport distance and mode for the products has been collected by Charge Amps. Both charging stations are assumed to be transported first to a supplier and then to the end-customer. The fuel for both transports is assumed to be diesel with 6% RME. The following transport mode has been assumed for these two transports:

- **From manufacturing site to supplier**
    - Distance 500 km
    - Load capacity 22 ton
    - Utilization rate 85%
- **From supplier to end-customer**
    - Distance 150 km
    - Load capacity 1.5 ton
    - Utilization rate 53%

### 4.4.3 Transport of waste

Information on transport distance and transport type for waste has been collected by Charge Amps. The waste refers to both waste from the manufacture of the products as well as the products after use. All waste is transported by truck and the conditions are the same for both charging stations. The fuel for all transport is assumed to be diesel with 6% RME. Table 9 presents the transport of waste from manufacturing.

**Table 9. Transport of waste from the manufacture of the product.**

| Waste | Distance | Load capacity | Utilization rate |
|---|---|---|---|
| Combustible waste | 183 km | 22 ton | 85% |
| Hazardous waste | 183 km | 22 ton | 85% |
| Paper waste | 163 km | 22 ton | 85% |

For transport of the charging stations to waste management, a transport distance of 50 km is assumed. The truck is assumed to have a load capacity of 22 tons and a load utilization rate of 85%.

## 4.5 Waste management

### 4.5.1 Disposal

As mentioned in chapter 3.5.2.2, all environmental burdens from landfilling are allocated to this product system. The only material that is assumed to end up in landfill is a relatively small share of metals that are not recycled. The landfill process is based on European conditions and includes landfill gas treatment, leachate treatment, sludge treatment and deposition. The emissions from the landfill are considered over a time horizon of 100 years.

### 4.5.2 Recycling

The recycling in this study refers to waste from manufacturing and recycling of the charging stations after use.

When recycling into a new material, all process steps are included until the waste has been transported to a collection point or waste facility. Calculation of credits and environmental burden beyond the system limit has been excluded.

When recycling into energy, all process steps are included until the point when energy is produced, which means that the environmental burden from incineration is allocated to this product system with the reason that waste facilities charge for taking care of the waste that goes to incineration (EPD International AB, 2021). Calculation of credits for electricity and district heating produced from the combustion process is included but reported separately.

If waste is not recycled, it is assumed to go to landfill where all the environmental burden is allocated to this product system.

#### 4.5.2.1 Recycling of waste from manufacturing

From the manufacturing of the charging stations, waste is collected in three fractions: combustible waste, hazardous waste and paper waste. Table 10 presents the assumed waste management scenario for the three waste types.

**Table 10. Waste management scenario for waste from manufacturing.**

| Waste | Waste management scenario |
|---|---|
| Combustible waste | 100% incineration |
| Hazardous waste | 100% incineration |
| Paper waste | 85% material recycling and 15% incineration |

Generic data for the incineration process is specific for the type of waste that is handled.

#### 4.5.2.2 Recycling of the charging stations

For the charging stations, their recyclability has been calculated with regard to standard EN 45555:2020 as well as a preliminary study on the recyclability of electronic products by the Commission's Joint Research Center (Chancerel et al. 2016). Table 11 and Table 12 present the recyclability and recycling scenario on each material type for Halo 11 kW and Aura 22 kW respectively, including packaging.

**Table 11. Recyclability and waste management scenario on each type of material per functional unit (fu) for Halo 11 kW.**

| | Weight (kg/fu) | Recyclability | Waste management scenario |
|---|---|---|---|
| Metal | 2.90 | 98% | 98% material recycling, 2% landfill |
| Polymer & rubber | 0.82 | 88% | 88% material recycling, 12% incineration |
| Paper | 0.45 | 85% | 85% material recycling, 15% incineration |
| PCBA | 0.53 | 24% | 24% material recycling, 76% incineration |
| Other | 0.001 | 0% | 100% incineration |
| **Total** | 4.71 | 87% | |

**Table 12. Recyclability and waste management scenario on each type of material per functional unit (fu) for Aura 22 kW.**

| | Weight (kg/fu) | Recyclability | Waste management scenario |
|---|---|---|---|
| Metal | 6.65 | 98% | 98% material recycling, 2% landfill |
| Polymer & rubber | 2.85 | 90% | 90% material recycling, 10% incineration |
| Paper | 0.71 | 85% | 85% material recycling, 15% incineration |
| PCBA | 0.92 | 24% | 24% material recycling, 76% incineration |
| Other | 0.01 | 0% | 100% incineration |
| **Total** | 11.1 | 89% | |

## 4.6 Energy

For the entire life cycle, cradle-to-grave, country-specific residual mix is primarily used, which is a requirement according to GPI 4.0 (EPD International AB, 2021). Residual mix is the electricity that remains after deducting contract-specific electricity, such as Guarantees of Origin, from the total consumption mix. If the market allows guarantees of origin or the like, residual mix should be used to avoid double counting. Figure 4 presents the share of energy sources used to produce the Swedish residual mix. Production of one kWh corresponds approximately to the emission of 0.04 kg $CO_2$-eq.

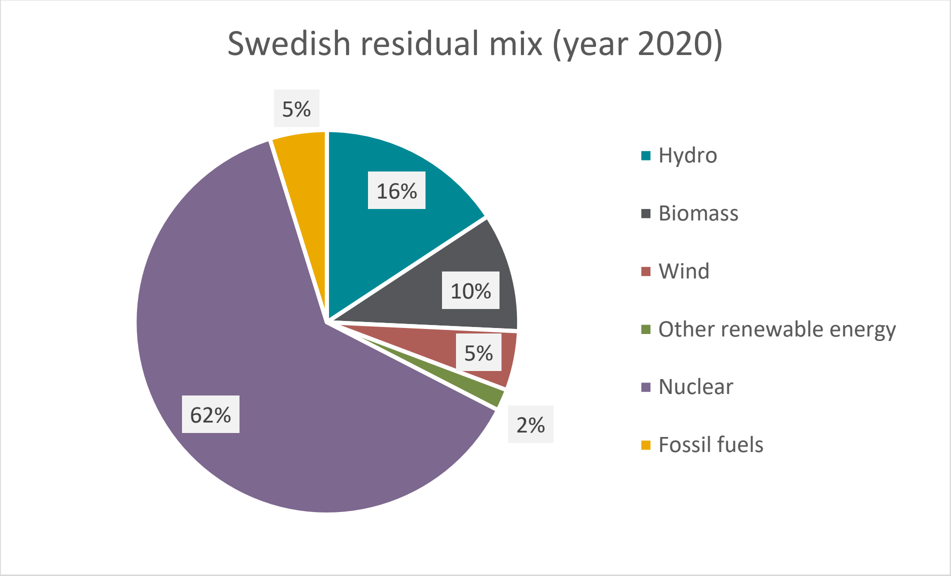

Figure 4. Share of energy sources used for production of Swedish residual mix.

In this study, only residual mix has been used for processes in Sweden and includes electricity for the manufacture of components and final product, use phase and waste management. However, it happens that the electricity is baked into processes used for the modeling and there is no guarantee that residual mix has been used. This was most common for the manufacture of components, which was the reason why residual mix could not be used for processes in the countries of Italy and Germany. For processes in China, there was no data on residual mix.

The district heating is modeled based on previous work by IVL. According to the model, more than 44% of the fuel mix consists of wood biomass, while 25% comes from waste. Production of one kWh corresponds approximately to the emission of 0.05 kg $CO_2$-eq (fossil).

# 5 Result

The result has been reported in three life cycle stages as well as a separate division for credits. Table 13 describes the three life cycle stages. Credits include environmental benefits as well as any environmental burden from the recycling processes that are beyond the system boundary.

**Table 13. Description of the three life cycle stages.**

| Life cycle stages | Inclusion |
|---|---|
| Upstream | Extraction and processing of raw materials<br>Recycling processes of secondary materials from other life cycles<br>Production of input components<br>Transportation of raw materials and components<br>Production of packaging<br>Production of electricity, fuels and other energy carriers used in upstream processes |
| Core | Transportation of materials and components to manufacturing<br>Manufacturing of the product<br>Waste management of manufacturing waste, including transportation<br>Production of electricity, fuels and other energy carriers used in core processes |
| Downstream | Transportation of the product to retailer and end-consumer<br>Product use<br>Waste management of the used product and its packaging, including transportation<br>Production of electricity, fuels and other energy carriers used in downstream processes |

LCA results are also presented in more detail in an Excel file supplied to Charge Amps along with this report.

## 5.1 Halo 11 kW

Table 14. Result on environmental impact categories for Halo 11 kW.

| Environmental impact categories | | Unit | Upstream | Core | Downstream | Credit |
|---|---|---|---|---|---|---|
| Global warming potential (GWP) | Fossil | kg $CO_2$ eq. | 4.00E+01 | 1.52E+00 | 3.01E+01 | -6.59E-02 |
| | Biogenic | kg $CO_2$ eq. | 1.06E-01 | 1.55E+00 | 1.26E-01 | -6.51E-04 |
| | Land use and land transformation | kg $CO_2$ eq. | 4.68E-02 | 8.11E-04 | 1.52E-02 | -7.40E-05 |
| | TOTAL | kg $CO_2$ eq. | 4.01E+01 | 1.55E+00 | 3.02E+01 | -6.66E-02 |
| Acidification potential (AP) | | kg mol $H^+$ eq. | 2.94E-01 | 2.99E-02 | 1.01E-01 | -3.72E-04 |
| Eutrophication potential (EP) | Aquatic freshwater | kg P eq. | 2.96E-02 | 1.85E-05 | 3.75E-04 | -3.02E-06 |
| | Aquatic marine | kg N eq. | 4.79E-02 | 7.84E-03 | 2.85E-02 | -1.35E-04 |
| | Aquatic terrestrial | mol N eq. | 5.10E-01 | 8.34E-02 | 2.42E-01 | -1.09E-03 |
| Photochemical oxidant creation potential (POCP) | | kg NMVOC eq. | 1.87E-01 | 2.14E-02 | 6.64E-02 | -2.89E-04 |
| Ozone layer depletion (ODP) | | kg CFC 11 eq. | 1.67E-06 | 2.47E-11 | 4.10E-12 | -3.96E-14 |
| Abiotic depletion potential (ADP) | Metals and minerals | kg Sb eq. | 1.42E-02 | 2.64E-07 | 1.19E-05 | -2.20E-08 |
| | Fossil resources | MJ, net calorific value | 5.70E+02 | 7.77E+01 | 5.77E+03 | -3.44E+00 |
| Water deprivation potential (WDP) | | $m^3$ world eq. | 2.03E+01 | 2.36E-01 | 9.94E+00 | -2.40E-02 |

Table 15. Result on LCI indicators for Halo 11 kW.

| LCI indicators | Unit | Upstream | Core | Downstream | Credit |
|---|---|---|---|---|---|
| Total use of renewable primary energy resources (PERT) | MJ | 5.20E+01 | 2.37E+01 | 7.98E+02 | -2.68E+00 |
| Total use of non-renewable primary energy resources (PENRT) | MJ | 5.71E+02 | 7.77E+01 | 5.77E+03 | -3.44E+00 |

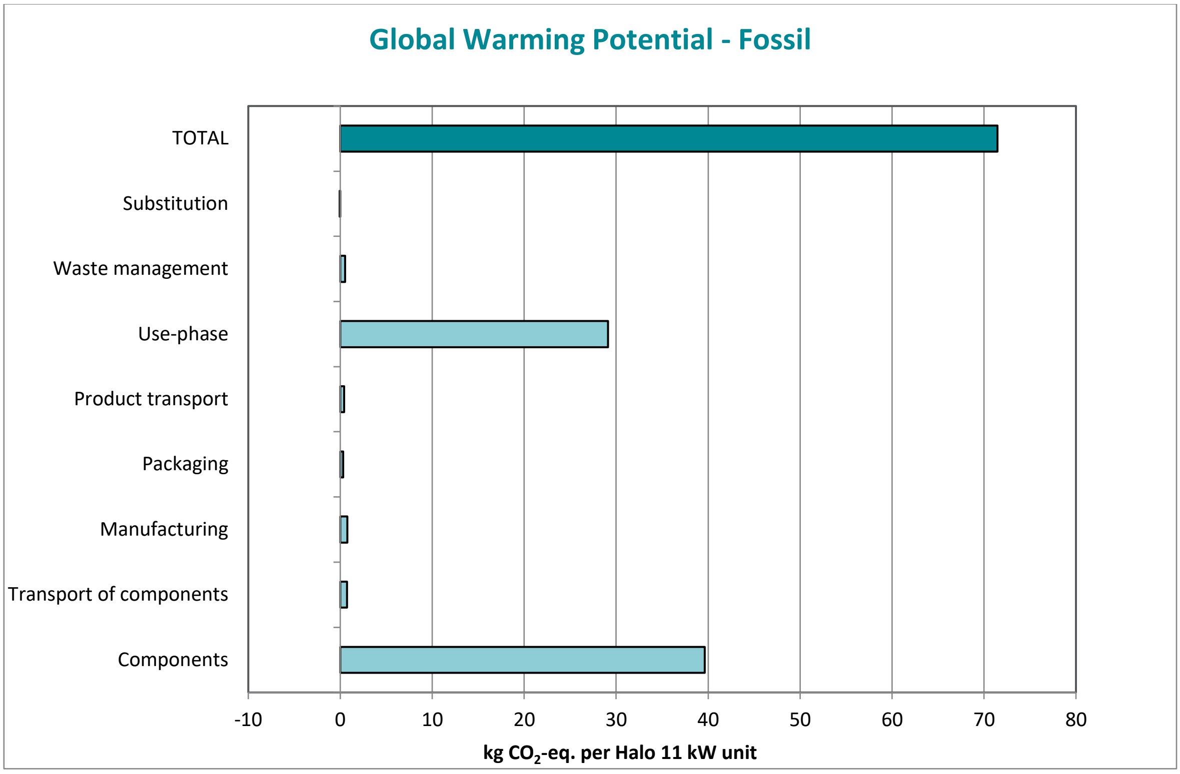

Figure 5. Result on GWP-fossil for Halo 11 kW

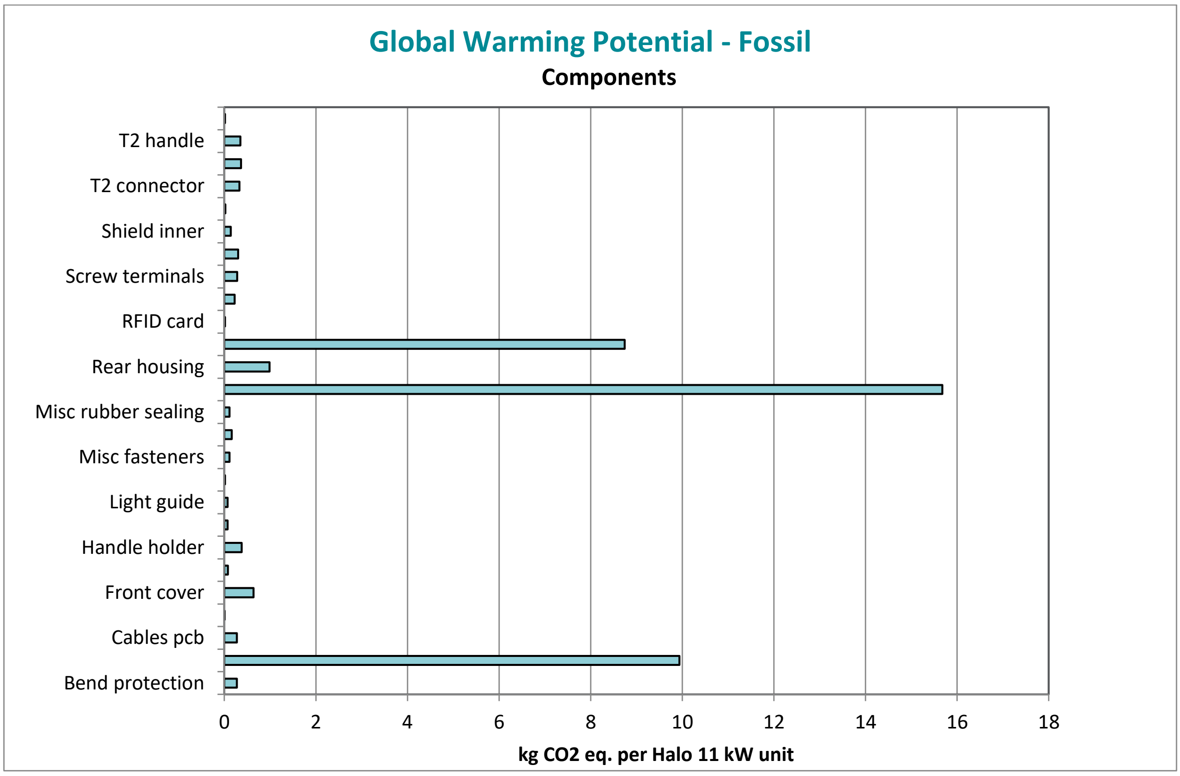

Figure 6. Result on GWP-fossil for components of Halo 11 kW

## 5.2 Aura 22 kW

Table 16. Result on environmental impact categories for Aura 22 kW

| Environmental impact categories | | Unit | Upstream | Core | Downstream | Credit |
|---|---|---|---|---|---|---|
| Global warming potential (GWP) | Fossil | kg $CO_2$ eq. | 7.03E+01 | 2.89E+00 | 2.99E+01 | -1.69E-01 |
| | Biogenic | kg $CO_2$ eq. | 1.57E-01 | 3.43E-02 | 2.68E-01 | -1.73E-03 |
| | Land use and land transformation | kg $CO_2$ eq. | 6.84E-02 | 8.76E-03 | 2.13E-02 | -1.97E-04 |
| | TOTAL | kg $CO_2$ eq. | 7.05E+01 | 2.93E+00 | 3.01E+01 | -1.71E-01 |
| Acidification potential (AP) | | kg mol $H^+$ eq. | 4.12E-01 | 6.01E-02 | 9.72E-02 | -9.74E-04 |
| Eutrophication potential (EP) | Aquatic freshwater | kg P eq. | 3.13E-02 | 2.01E-05 | 3.60E-04 | -8.05E-06 |
| | Aquatic marine | kg N eq. | 7.01E-02 | 1.55E-02 | 2.75E-02 | -3.57E-04 |
| | Aquatic terrestrial | mol N eq. | 7.34E-01 | 1.68E-01 | 2.35E-01 | -2.87E-03 |
| Photochemical oxidant creation potential (POCP) | | kg NMVOC eq. | 3.00E-01 | 4.30E-02 | 6.40E-02 | -7.62E-04 |
| Ozone layer depletion (ODP) | | kg CFC 11 eq.- | 1.96E-06 | 1.91E-11 | 4.01E-12 | -1.06E-13 |
| Abiotic depletion potential (ADP) | Metals and minerals | kg Sb eq. | 1.23E-02 | 3.12E-07 | 1.13E-05 | -5.57E-08 |
| | Fossil resources | MJ, net calorific value | 1.12E+03 | 8.13E+01 | 5.47E+03 | -7.47E+00 |
| Water deprivation potential (WDP) | | $m^3$ world eq. | 2.33E+01 | 1.95E-01 | 9.54E+00 | -6.19E-02 |

Table 17. Result on LCI indicators for Aura 22 kW

| LCI indicators | Unit | Upstream | Core | Downstream | Credit |
|---|---|---|---|---|---|
| Total use of renewable primary energy resources (PERT) | MJ | 1.28E+02 | 1.94E+01 | 7.55E+02 | -7.00E+00 |
| Total use of non-renewable primary energy resources (PENRT) | MJ | 1.12E+03 | 8.13E+01 | 5.47E+03 | -7.47E+00 |

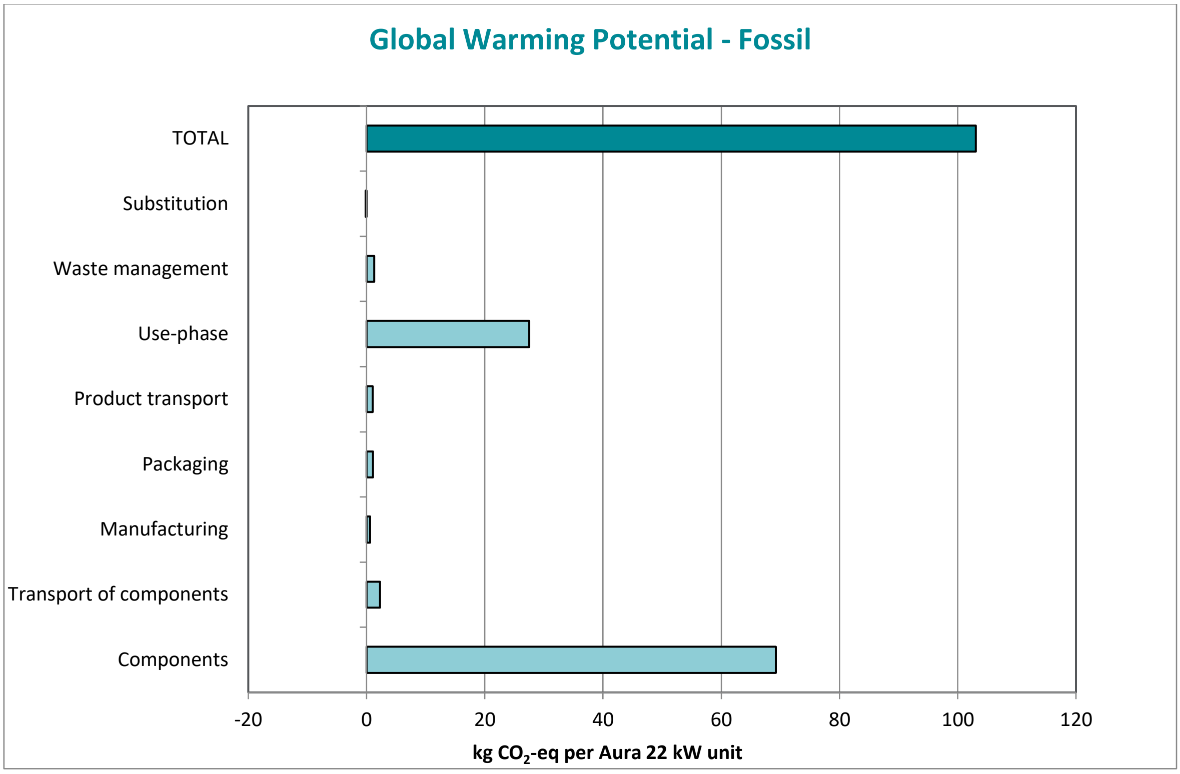

Figure 7. Result on GWP-fossil for Aura 22 kW.

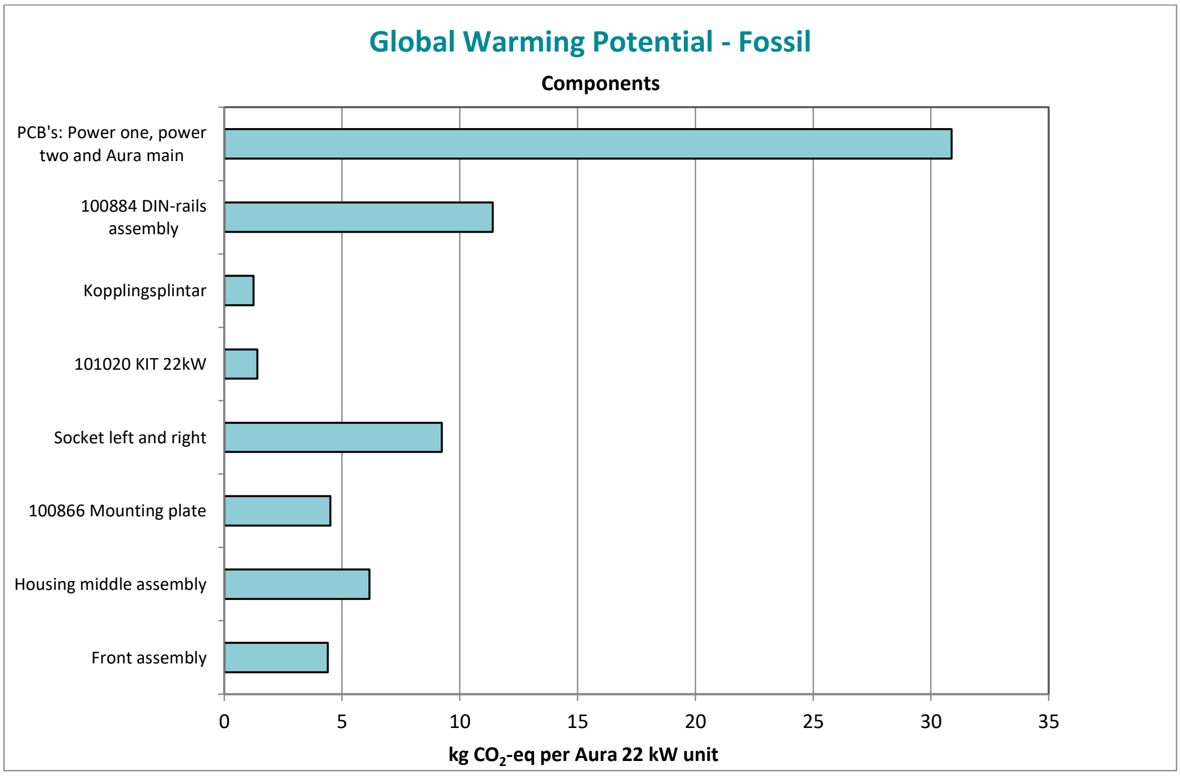

Figure 8. Result on GWP-fossil for components of Aura 22 kW.

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