Project: LCA 009/2023

LCA ANALYSIS WITH COMMENTS FOR THE ELECTRIC VEHICLE CHARGER "RDC CHARGER"

Client: Robotina d.o.o. – OIC Hrpelje 38, Hrpelje, SI-6240 Kozina

Contractor: M projekti in inovacije d.o.o.., prepared by LCA expert EDIN LAKIĆ

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STUDY SUMMARY

Robotina d.o.o. manufactures charging lines for EV "RDC Charger". The production of components, their assembly, the use of the charging station, its disassembly, and the recycling of components contribute 82.8 kg CO_2(eq) to greenhouse gas emissions and 32.202 mPt of total environmental impacts globally. The main source of environmental and human health impacts is the use of electronic printed circuit boards and electronic components. To potentially improve the environmental footprint, it is necessary to consider the most complete disassembly and recycling of electronic components, with the most critical aspect being the recovery of rare metals and minerals.

Keywords: LCA, electric vehicle charger, recycling of electronic components.

DISCLAIMER:

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1. INTRODUCTION

1.1. COMPANY OVERVIEW

Robotina d.o.o. is a high-tech company that develops and manufactures advanced electronic controllers based on machine learning and the use of artificial intelligence. On a European and global scale, the company is establishing itself as a leading provider of "smart and connected" solutions, components, and platforms that enable the development and implementation of new models of a connected society, which is the foundation of digital transformation. To this end, they develop and implement proprietary solutions comprising knowledge, hardware and software, as well as organizational structure and processes.

1.2. BASIS AND DEFINITION OF THE PROBLEM

The electric vehicle charger market was valued at EUR 24.4 billion in 2022 and is growing at an annual CAGR of 24.7%. This trend is expected to continue until 2032. An EV charging station is a point where an electric vehicle is charged via an appropriate converter [1]. Charging electric vehicles is the process of using "EV chargers" to deliver electrical energy to the car's battery, whereby the charger connects to the electrical grid. EV drivers can charge their vehicles at a home charging station, a public charging station, or a workplace charging station. Charging EVs at a home charging station is done with chargers that operate at "Level 2." Charging at commercial and workplace electric charging stations is done at both "Level 2" and "Level 3." An electric vehicle charger draws electrical current from the grid and supplies it to the electric vehicle through a connector or plug. The electric vehicle stores this electrical energy in the battery and uses it as needed to power the electric motor. Special cables are used for charging the electric vehicle, connecting the EV plug to the connector at the charging station. EV batteries can only accept direct current (DC).

There are three main types of electric vehicle charging: Level 1, Level 2, and Level 3, commonly known as DC fast charging or simply fast charging.

Level 1 charging can be done through a standard 120-volt wall outlet, commonly found in homes and garages in the USA. Level 1 charging is extremely slow and is typically reserved for home charging, where it occurs overnight. Fully charging an EV battery with Level 1 charging can take more than 24 hours.

Level 2 chargers use 240 volts and are typically found in homes across Europe and at public charging stations. A Level 2 charger is much faster than a Level 1 charger (up to 15 times faster). Level 2 EV charging stations require a dedicated 208-/240-volt outlet. Most homes do not have an extra outlet of this type, so a dedicated circuit, installed by an electrician, is necessary for charging.

DC fast chargers, or fast chargers, use 480+ volts and are currently the fastest way to charge an electric vehicle.

Level 1 and Level 2 chargers supply alternating current (AC) to the electric vehicle, which is then converted to direct current (DC) by the EV's system. The EV battery can only accept direct current. Fast charging stations supply direct current directly to the EV, eliminating the need for conversion. As a result, Level 1 and Level 2 chargers charge electric vehicles much more slowly due to the AC/DC conversion process.

There are three types of Level 3 or DC fast charging: Combined Charging System (CCS), CHAdeMO ("CHArge de MOve"), and Tesla Supercharger. CCS allows for both AC and DC charging through the same port, while cars with CHAdeMO have separate ports for AC charging.

Not all EVs can charge via a DC fast charger. DC fast chargers are used only in commercial applications and cannot be installed in homes for several reasons: homes do not have the electrical capacity for a DC fast charger, EV drivers do not require such fast charging for overnight home charging, and the installation of DC fast charging is much more expensive than Level 2 due to the necessary upgrades to the electrical infrastructure. On the other hand, a DC fast charging station can be an ideal solution for commercial applications for charging electric vehicles for businesses. For example, DC fast chargers are perfect for charging fleets and for public charging stations on highways.

There are a limited number of LCA studies available to both professionals and the general public, primarily defining the impacts of using EV charging stations [2,3], making it difficult to isolate the direct impacts of charger production. The only available LCA analysis that more precisely defines the impacts of the production of an EV charging station was provided by GARO in July 2021 [4], but this analysis is marked as internal. In it, the authors found that 47% of all harmful emissions are attributed to the aluminium used for the casing and the embedded electronics.

Robotina d.o.o. is entering the electric vehicle charger market with its EV charging station (RDC Charger), which differs in design from the GARO LS4 charger, particularly in the casing design where steel and plastic are used instead of aluminium. For this type of charger, data is not readily available to the general public.

1.3. TECHNICAL SOLUTIONS - RDC CHARGER

The EV charging system "RDC Charger" by Robotina d.o.o. is a charging station that enables fast charging of electric vehicles. It meets all the technical criteria required for the efficient and safe operation of a fast charger:

- The rated charging power of 22 kWh is sufficient to charge an electric vehicle for a distance of 100 km in 45 minutes (calculated based on consumption of 16 kWh per 100 km).
- Modern and simple design. It complies with the IP54 & IK10 standards and is suitable for both indoor and outdoor use. Customizable charger housing colours.

- Button with coloured LED light for charging status. Different colours or colour combinations have different meanings. The charging station's status can be easily checked by the colour of the LED light.
- RFID, MIFARE card, or QR code for access and usage control. The RFID/MIFARE card or QR code is used to unlock and start the charging process. Easy management, addition, and removal of charging station users.
- The vehicle can be charged with excess renewable energy. Suitable for systems where a solar/wind inverter is connected to the home grid.
- With proper planning, charging (eco-charging) can be optimized during times of cheap electricity.
- The station prioritizes charging at the highest possible power.
- Fully autonomous operation, automatic restart after an error.
- The system allows the control of up to 8 RDC chargers and is also suitable for multi-apartment buildings, hotels, etc. The chargers communicate with each other and enable optimal operation within the building.
- HEMS – Home Energy Management System allows remote control of key consumers (heat pump, battery storage...). The dynamic current limiter keeps energy consumption below network fuses.
- Wireless power meters and long-range relays for cable-free installation enable easy installation and optimization of energy consumption in the building.

1.3.1. Dynamic charging/operation

Impact Indicator: Potential Water Scarcity (water consumption, weighted by scarcity). Relative remaining available water (AWARE) is the amount of water in a given area after the needs of people and water ecosystems have been met. This indicator is recommended only for characterization.

The RDC Charger allows all high-energy consumers to adapt to the RDC charger and its energy needs. Since the RDC Charger operates as a HEMS system, it can manage, control, and regulate other loads, enabling the optimization of energy flow throughout the building. It includes a dynamic current limiter that prevents the circuit breaker from tripping (overload) caused by high-energy-consuming devices operating simultaneously. The DCL monitors the current consumption of devices and allocates available capacity in real-time, allowing them to operate without overloading. Various high-energy-consuming devices in the building can be prioritized differently with a single button press. The same applies if there are multiple (up to 8) RDC chargers in the building. Priorities can be set among them. If one charger quickly needs a lot of energy, another charger will reduce its charging power.

1.3.2. Technical specifications

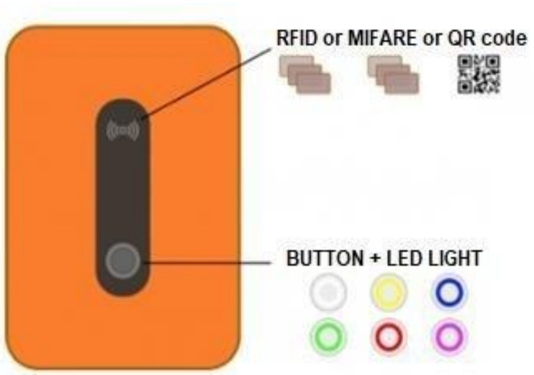


Figure 1.1 displays the control panel of the "RDC Charger" EV charger

Basic features

- Charging starts automatically as soon as the vehicle is connected with a cable.
- A short press of the button enables/temporarily stops charging.
- A long press of the button switches between priority/economy charging modes.
- LED indicator for charging status.
- Swipe the RFID/MIFARE/QR card to unlock the RDC charger.

Table 1.1. Technical Specifications of the "RDC Charger" by Robotina d.o.o.

Specification	Details
Nominal Voltage	1x230Vac 50/60Hz, 3×230/400Vac 50/60Hz
Maximum Current	1x32A, 3x32A
Maximum Charging Power	Single-phase connection → 7.4kW Three-phase connection → 22kW
Charging Cable Network Connection	Type 2, length 5m
	Ethernet 100M RJ45 4G LTE (optional)
Wireless Range	300m open / 50m indoor *Range varies depending on actual installation conditions
Frequency Band	868Mhz
Enclosure Protection Level	IP54
Impact resistance	IK10
Operating temperature	-20°C to +60°C
Insulation	1200Vac

Mounting Options

The charging cable holder can be mounted directly on the RDC charger or independently on the wall.

Figure 1.2 displays the option for mounting the charging cable.

2. OBJECTIVES OF THE LCA STUDY

2.1. REASONS FOR CONDUCTING THE STUDY - PROBLEM IDENTIFICAITON

Robotina d.o.o. operates in accordance with the ISO 9001 quality standards and the ISO 14000 environmental management standards. The company's business policy is based on implementing business practices that adhere to circular economy models. For this purpose, the company's management has decided to identify and define the global impact of their production processes and products on the environment. They have chosen to create Environmental Product Declarations (EPD) for individual products, which will continuously inform users of their products about the global impact of purchasing and using each product. By creating this document, they will enable direct users to compare their product with competing products from other manufacturers in terms of product sustainability and provide business users with easier evaluation of their own production processes. The basis for creating an EPD is a consistent and accurate LCA analysis of each product.

2.2. STRUCTURE AND TYPE OF STUDY

Based on ISO standards ISO 14040:2006 and ISO 14044:2006, the structure of LCA is divided into four phases: goal and scope definition, inventory analysis, life cycle impact assessment, and interpretation through iterative processes [5-10]. In this study, the structure of the LCA analysis is adapted for evaluating the environmental impacts of manufacturing an electric vehicle charging station. The scope of the analysis is defined from the goal and intended use definitions, requiring precise definition of the functional unit and clear boundaries of the calculation regarding the product or system to be analysed.

The goal definition determines the scope of the analysis, which can be divided into several life stages. The cradle-to-gate analysis considers the impact of the processes for manufacturing the equipment. This phase is followed by the gate-to-gate analysis, focusing on the maintenance and management processes to consider the pre-production life stages. The final life stage is the gate-to-grave phase, which includes the method of its disposal. All three phases can be combined in a cradle-to-grave LCA, which holistically describes the entire life cycle of the equipment (charging station). The functional unit is one charging station. A comprehensive (absolute) study of the production, use, and disposal of the EV charger "RDC Charger" was carried out. The LCA is done on a cradle-to-grave basis. The boundaries of the study will be defined in more detail later, and the charger is described in section 1.3 of this document.

The study is presented for the European region for the year 2023, but with critical review, it can be applied to different territorial areas and various time periods.

By creating this document, direct users will be able to compare their product with competing products from other manufacturers in terms of product sustainability, and business users will be able to more easily evaluate their own production processes.

The study is intended for interested users (customers) to assess their environmental footprint when using the device.

3. SCOPE OF THE STUDY

3.1. FUNCTIONAL UNIT (FU)

The functional unit (FU) is one electric vehicle charging unit "RDC Charger" by Robotina d.o.o. with the corresponding charging cable and mounting stand.

Table 3.1 The weight of the main components and the total weight of the "RDC Charger", which is defined as one functional unit (FU).

Component	**Mass in g**
Charging module	6250
Charging cable	2800
Stand	850
Total	**9900**

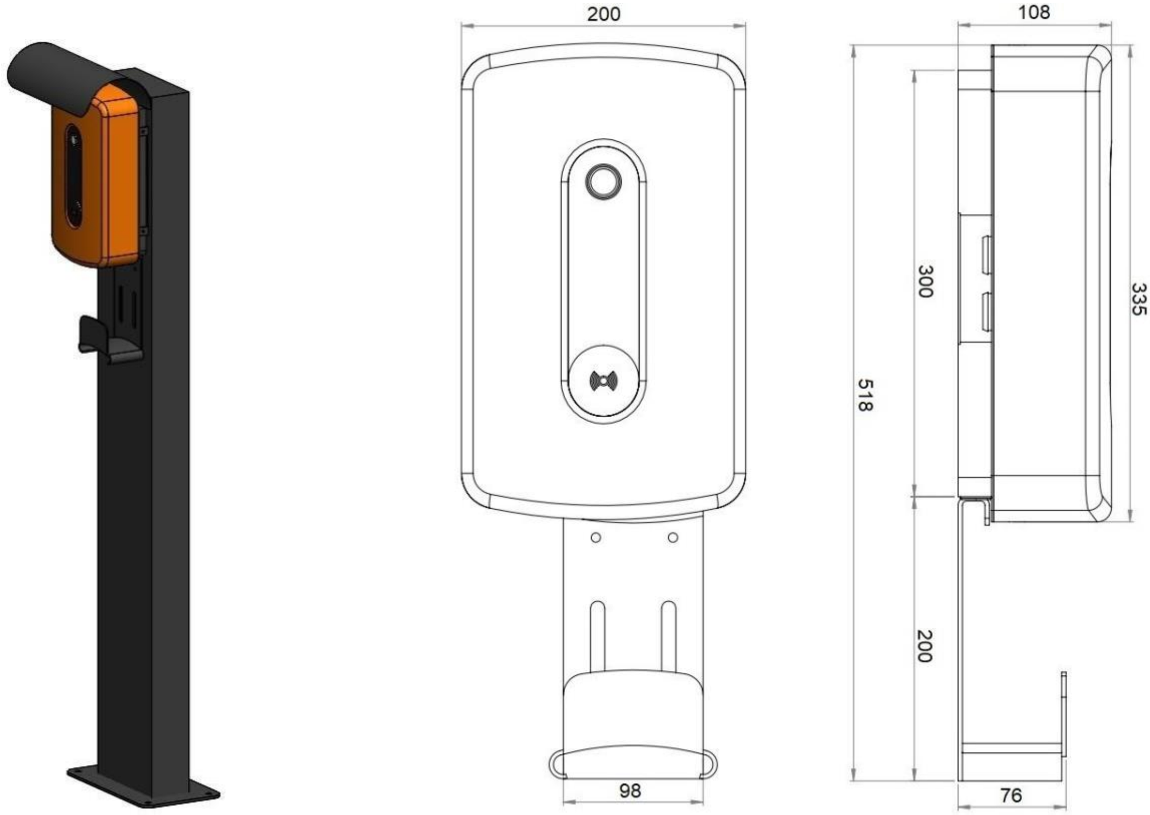


Figure 3.1 displays the charging station and the dimensional measurements of the "RDC Charger", which is defined as one functional unit (FU)

3.2. BOUNDARIES OF THE CALCULATED MODEL

The LCA is intended to assess the environmental and human health impacts of manufacturing the "RDC Charger" charging station by Robotina d.o.o. A holistic cradle-to-grave approach was used for the calculation, which included the manufacturing of basic components, their assembly, the disassembly of the whole back into components, and the recycling or disposal of the components. The calculation considered the consumption of electricity for production and disassembly, as well as assembly and recycling (disposal) of the components. The impact of transporting the components to the assembly site of the charging station, the transport of the charging station to the place of use, the transport of the used charging station to the disassembly site, and the transport of the worn-out components to the recycling or disposal site were also considered. The calculation is based on the cut-off approach, where the boundaries for individual materials and processes are set in the EcoInvent 3.8 database. For accuracy, we used unit libraries.

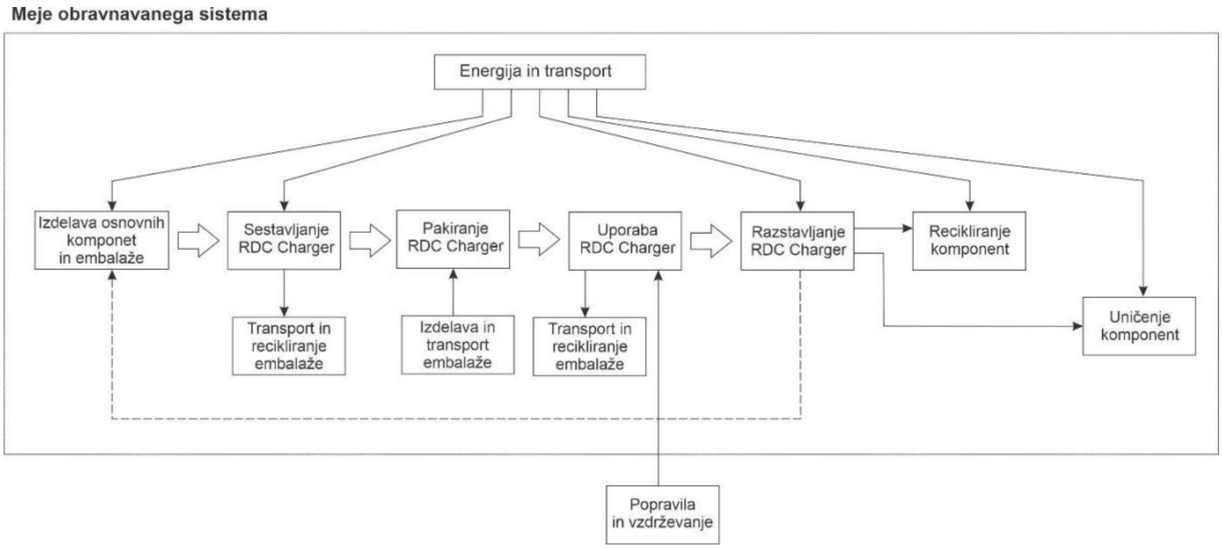


Figure 3.1 displays the calculation boundaries.

3.1.1. Geographical Boundaries of the LCA Analysis

The determination of LCI was made at the headquarters of Robotina d.o.o. in Hrpelje pri Kozini. Most of the components were procured within the EU. The energy embedded in the production of 1 FU was obtained from the Slovenian electric grid. Although individual electronic assemblies are procured within the EU, most electronic components are manufactured outside the EU, and often the manufacturer of these electronic components is unknown. The data obtained for the processes of assembly, use, disassembly, recycling of the RDC Charger, use and recycling of packaging, and disposal of individual components apply to the EU, while the data to produce basic components are estimated based on global data and are less reliable. The analysis is essentially valid for the EU.

3.1.2. Time Limitations of the LCA Analysis

All data were measured in June 2023. The mass balance for the assembly of 1 FU does not change, and based on the mass balance, the LCA study is valid until the technological design of the functional unit changes. The energy balance is based on the basket of electricity sources as specified in the EcoInvent 3.8 database. The data are valid until the basket of electricity sources changes in the RS region. The production of electronic components includes global data as specified in the EcoInvent 3.8 database. The LCA study remains valid until the composition of the data mentioned above changes. Based on experience, the author of the study estimates that the LCA study is valid for at least 5 years.

3.1.3. Cut-off Criterion

In accordance with the European standard EN 14044:2006, a simplification of the calculation was performed using the cut-off rule, where only impacts exceedingly more than 1% of the total impacts were considered in the calculation, as shown in Figure 3.9.

4. USED PARAMETERS (INVENTORY - LCI)

The life cycle inventory (LCI) combines the energy and material flows involved within the boundaries of the studied system. Typical information in the life cycle assessment of the production of a charging station includes the amount of material and energy for manufacturing the equipment (e.g., raw materials, auxiliary materials, energy, transport), maintenance processes, and processes for the disassembly and recycling of materials (transport and energy) or waste disposal. Once the inventory of various ideas about potential impacts is collected, the inventory indicators are converted into a series of environmental and human health and animal impact categories using standardized methods and tools for environmental impact assessment (e.g., EF3.0, ReCiPe, CML, TRACI) [11,12]. A typical list of impact categories in LCA includes acidification potential, climate change, eutrophication potential, freshwater sediment ecotoxicity potential, marine sediment ecotoxicity potential, terrestrial ecotoxicity potential, human toxicity potential, ionizing radiation impact, photochemical oxidant formation, abiotic depletion potential, and ozone layer depletion potential. Once the impacts are determined, the last step of the LCA analysis is to interpret the results, followed by an explanation and conclusion.

4.1. Assumptions and limitations

All data in the LCA were obtained by directly weighing individual components. The energy for product assembly was measured across the entire production and distributed per product unit. Transport distances were estimated. The transport distance for delivering the components was estimated to average 500 ± 50 km, the delivery of the final product to the user at 250 ± 25 km, transport of the used product to the disassembly site at 250 ± 25 km, and transport of components to the recycling and/or disposal site at 250 ± 25 km. Data used in the study were measured by weighing individual components from which the product is composed, and they are determined by the accuracy limit of the scale. The energy used for assembling one unit is difficult to determine due to the complexity of operations and other factors (maintenance of workplace microclimate); therefore, the energy was measured across the entire production and distributed per product unit. Transport distances were estimated, as the exact location of the device is difficult to determine, and distances needed to be reasonably averaged.

4.2. Allocation of Material and Energy Flows

A comprehensive LCA study was conducted. The scope and methodology of the study are set in accordance with the recommendations of EN ISO 14044:2006 to ensure that the calculation is direct and pertains specifically to the production of one charging unit. Allocations for individual materials, components, transport, and energy are already considered in the data obtained from the EcoInvent 3.8.1 database. There were no direct allocations in the production of the charging station since all materials, components, transport, and energy were used for the assembly of the charging station. Economic allocations were not anticipated because the study does not address the economic parameters of the project.

4.3. Tabular Presentation of LCI

Table 3.1 and Figures 3.2 to 3.8 show the inventory for the production of one FU (RDC Charger).

Table 3.1 Bill of Materials for the »RDC Charger« charging station.

ID	Description	Qty.	Copper	Galvanized Sheet	Plastic insulation	PCB	Paper
			[g]	[g]	[g]	[g]	[g]
F-0001	EPDM seal	1			2		
F-0002	Screws	1		53			
F-0003	Wires and cables	1	75		27		
F-0004	Packaging				112		1150
F-0519	DIN-Rail	0,4		86			
F-0671	WAP 2.5-10 plate	1			3		
F-0997	WDU 6 terminal	1	3	5	12		
F-0998	WDU 6 terminal	3	9	15	18		
F-0999	WDU 6 terminal	1	3	5	6		
F-1362	Stepped collar (cable gland)	2			8		
F-1434	3-phase power meter, DIN rail	1	45	49	136	106	
F-1809	Installation Contactor	1	82	116	61		
F-1810	Bottom housing of the charging station	1		1500			
F-1811	Cable hanger	1		850			
F-1812	Top housing of the charging station	1			450		
F-1813	PCB EVC-charging station mockup/P	1	4	12	22	92	
F-1815	Rubber grommet	1			5		
F-1818	Protective metal sheet	1		550			
F-1819	Sealing cap	1			4		
F-1822	RGB Pushbutton Switch	1	6	20	4		
F-1823	Residual Current sensor	1	25		7		
F-1825	RFID Reader Wireless Module Uart	1	2			3	
F-1839	Cable 3 phase, opened end, type2	1	1500		1300		
F-1854	EW 35 vscrew clamp	2		5	12		
F-1855	Mounting plate, decap.sheet	1		550			

Figure 3.2 Charging unit »RDC Charger«.

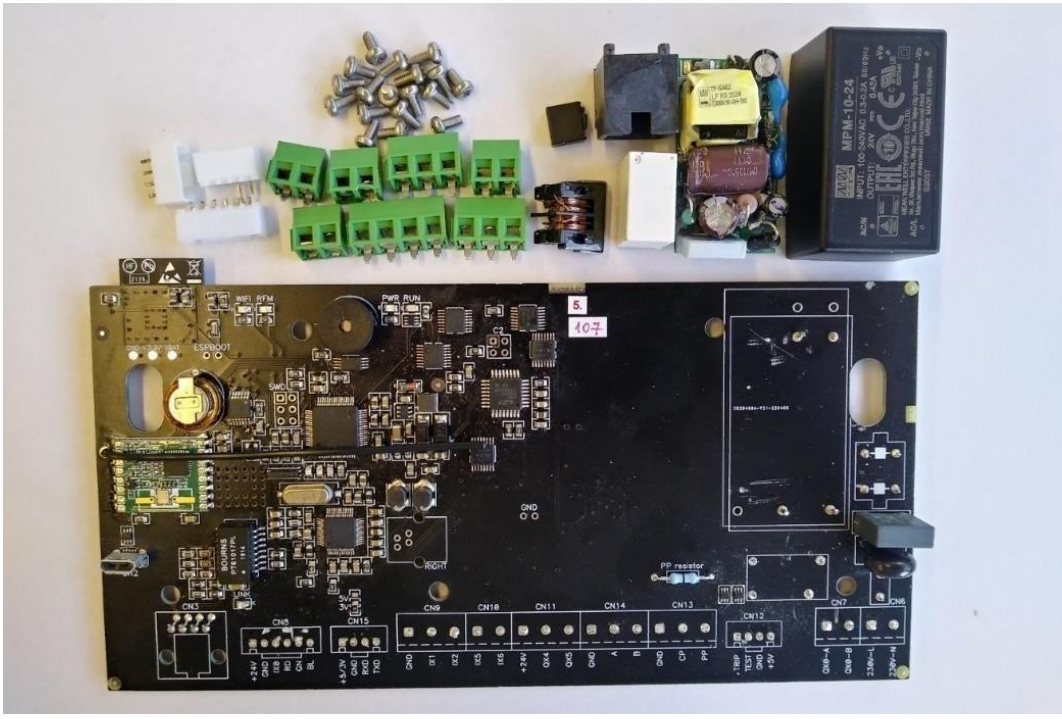


Figure 3.3 Printed circuit board with electronic components F-1813 PCB EVC-charging station mockup/P.

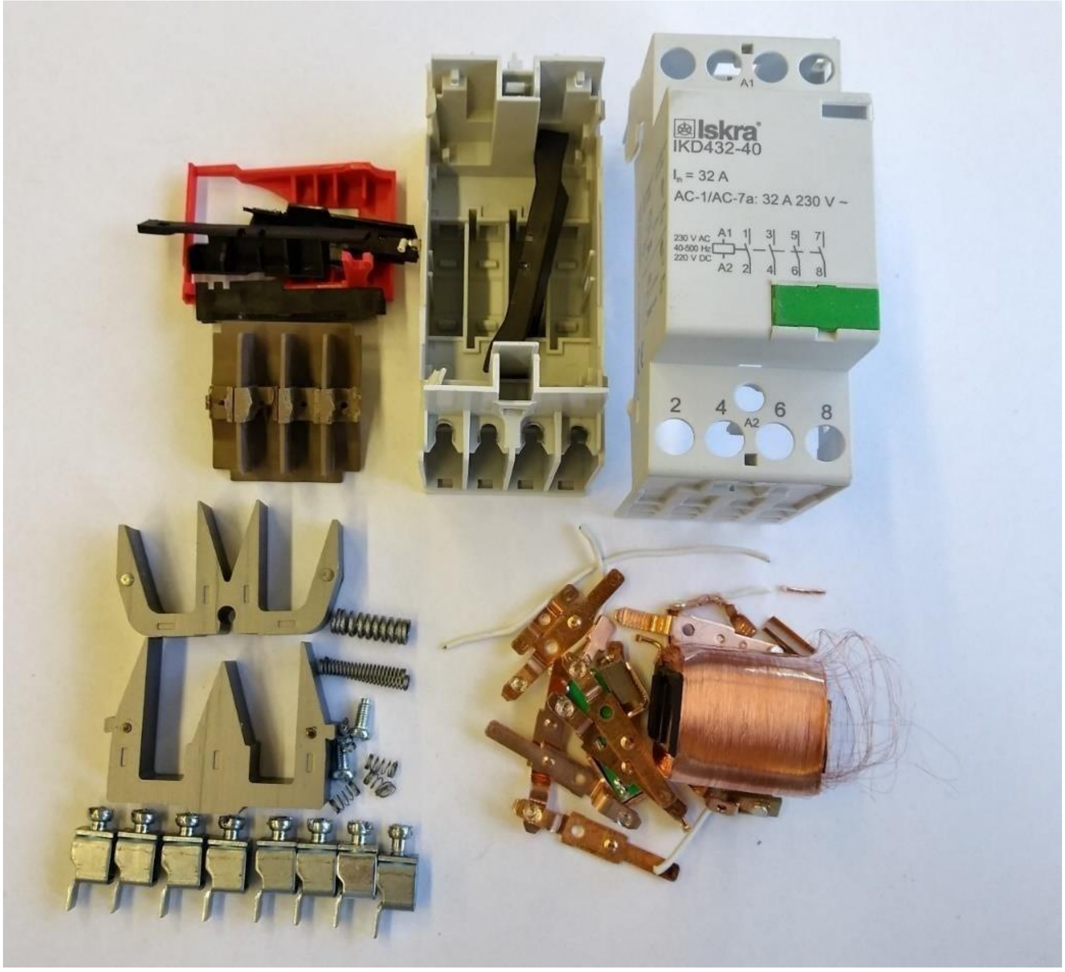


Figure 3.4 Installation contactor F-1809 Installation Contactor IKD432-40.

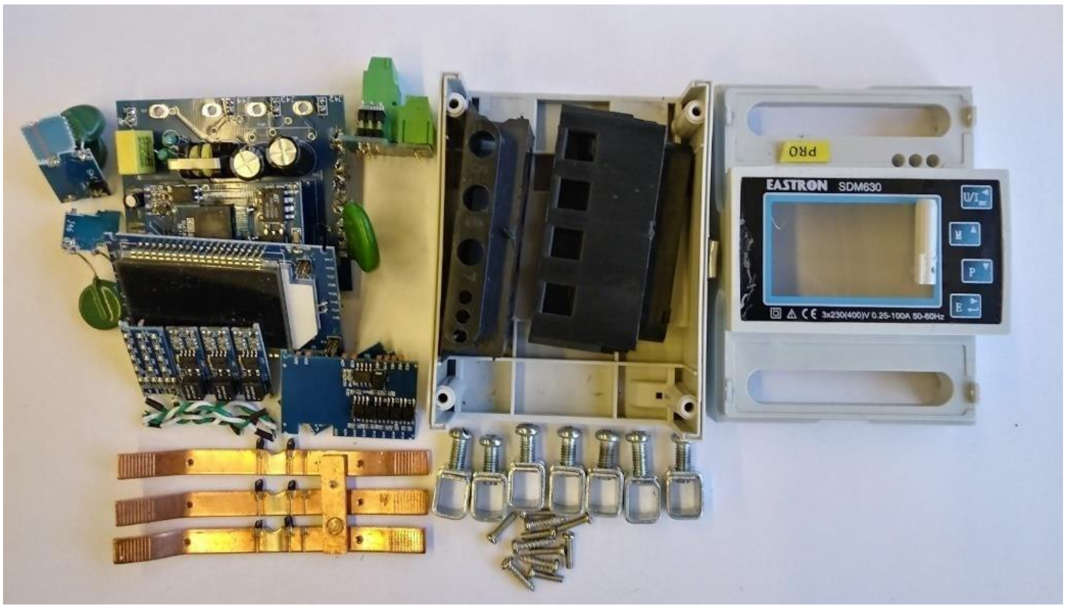


Figure 3.5 3 F-1434 3 Phase Power Meter.

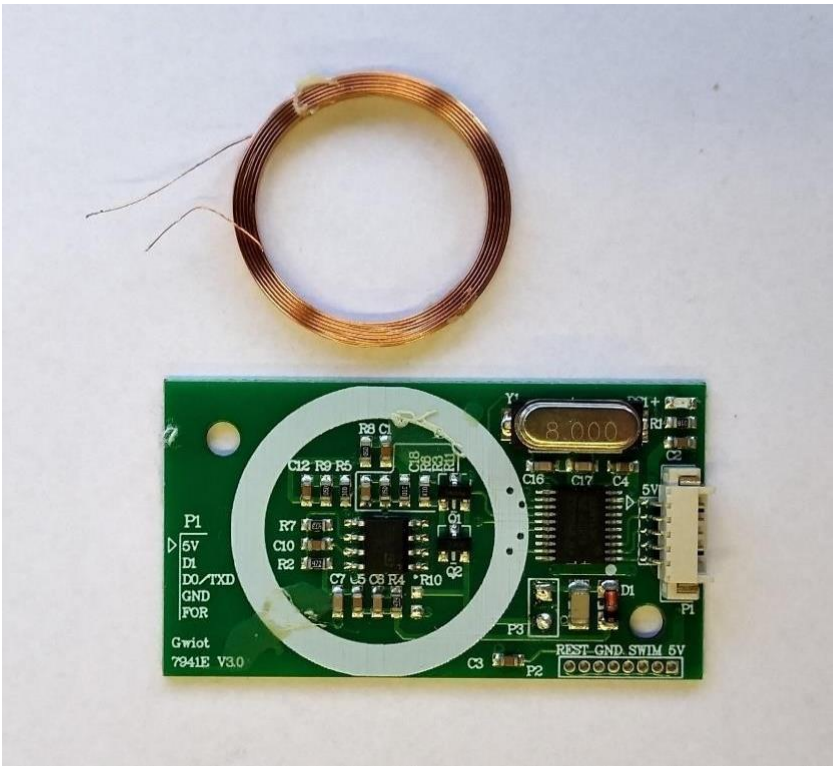


Figure 3.6 3-phase power meter F-1434 3 Phase Power Meter.

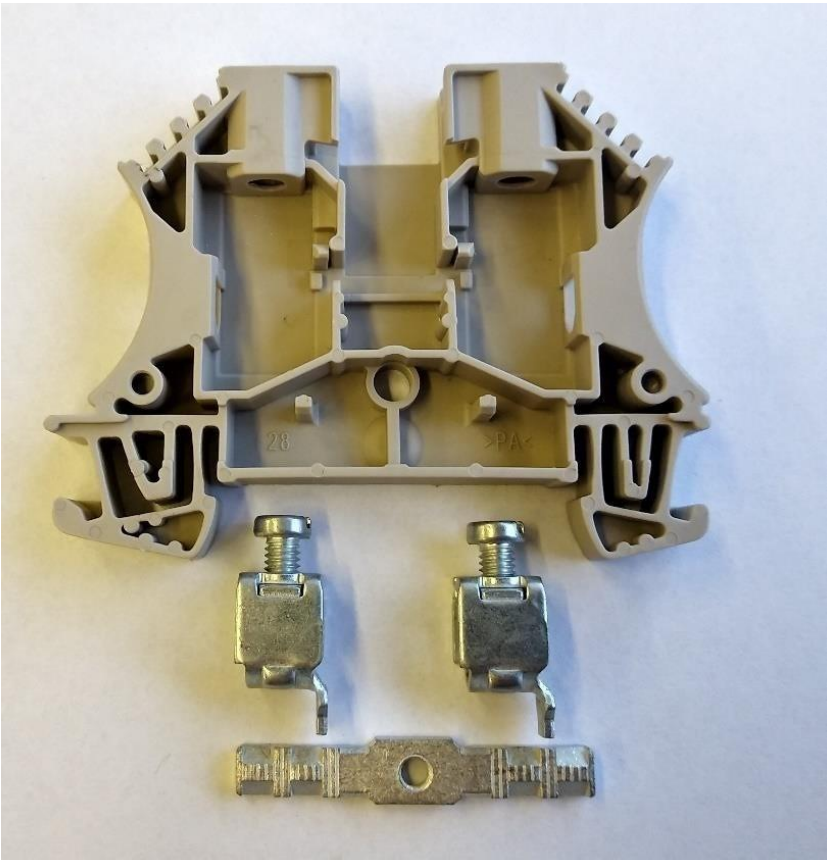


Figure 3.7 Terminal F-0998 Terminal WDU 6.

Figure 3.8 Associated wires and cables.

Table 3.2 Displays the inventory (LCI) used in the calculations from the Ecoinvent database for the assembly of the charging station.

Materials/assemblies – RDC Charger		
F-0001 EPDM Plastic Foam	1	p
F-0002 Screws	1	p
F-0003 Wires and Cables	1	p
F-0004 Package	1	p
F-0519 DIN Rail	1	p
F-0671 WAP Plate	1	p
F-0997 Clamp WDU 6	1	p
F-0998 Clamp WDU 6	3	p
F-0999 Clamp WDU 6	1	p
F-1362 Stepped Collar	2	p
F-1434 3 phase power meter, DIN rail	1	p
F-1809 Installation contactor IKD432-40	1	p
F-1810 Housing Bottom	1	p
F-1811 Cable Hanger	1	p
F-1812 Cover	1	p

F-1813 PCB EVC mockup/P	1	p
F-1815 Rubber Gland	1	p
F-1818 Protection Metal	1	p
F-1819 Closing Plug	1	p
F-1822 RGB Push Button	1	p
F-1823 Residual Current Sensor	1	p
F-1825 RFID Reader WiFi Module Uart 3PIN 125 KHZ	1	p
F-1839 Cable 3 Phase, 22 kW, 32 A, opened end, Typ	1	p
F-1854 Streme EW 35, screw	2	p
F-1855 Mounting Plate	1	p
Transport of input materials	1	p
Transport of RDC Charger	1	p

Processes		
Electricity, low voltage {SI}| market for | Cut-off, U	4,625	kWh
Transport, freight, lorry 7.5-16 metric ton, euro6 {RER}| market for transport, freight, lorry 7.5-16 metric ton, EURO6 | Cut-off, U	2475	kgkm

Inputs from Technosphere: materials/fuels F-0001 EPDM Plastic Foam		
Polymer foaming {RER}| processing | Cut-off, U	2	g
Fleece, polyethylene {RER}| production | Cut-off, U	2	g

Inputs from Technosphere: materials/fuels F-0002 Screws		
Cast iron {RER}| production | Cut-off, U	48	g
Zinc coat, pieces {RER}| zinc coating, pieces | Cut-off, U	5	cm2

Inputs from Technosphere: materials/fuels F-0003 Wires and Cables		
_57 Copper basic, virgin, EU27	75	g
Wire drawing, copper {RER}| processing | Cut-off, U	75	g
PVC injection moulding E	27	g

Inputs from Technosphere: materials/fuels F-0004 Package		
Fleece, polyethylene {RER}| production | Cut-off, U	112	g
Polymer foaming {RER}| processing | Cut-off, U	112	g
_35 Paper and paper products, EU27	1150	g

Inputs from Technosphere: materials/fuels F-0004 Package		
Polymer foaming {RER}| processing | Cut-off, U	170	g

Fleece, polyethylene {RER}| production | Cut-off, U	170	g
_35 Paper and paper products, EU27	620	g

Inputs from Technosphere: materials/fuels F-0005 Energy for production		
Electricity, low voltage {SI}| market for | Cut-off, U	4,625	kWh

Inputs from Technosphere: materials/fuels F-0519 DIN Rail		
Cast iron {RER}| production | Cut-off, U	81	g
Zinc coat, pieces {RER}| zinc coating, pieces | Cut-off, U	5	cm2

Inputs from Technosphere: materials/fuels F-0005 Energy for production		
Polypropylene injection moulding E	3	g
Inputs from Technosphere: materials/fuels F-0997 Clamp WDU 6		
_57 Copper basic, virgin, EU27	3	g
Polypropylene injection moulding E	12	g
Cast iron {RER}| production | Cut-off, U	4	g
Zinc coat, pieces {RER}| zinc coating, pieces | Cut-off, U	1	cm2

Inputs from Technosphere: materials/fuels F-0998 Clamp WDU 6		
_57 Copper basic, virgin, EU27	3	g
Polypropylene injection moulding E	6	g
Cast iron {RER}| production | Cut-off, U	4	g
Zinc coat, pieces {RER}| zinc coating, pieces | Cut-off, U	1	cm2

Inputs from Technosphere: materials/fuels F-0999 Clamp WDU 6		
_57 Copper basic, virgin, EU27	3	g
Polypropylene injection moulding E	6	g
Cast iron {RER}| production | Cut-off, U	4	g
Zinc coat, pieces {RER}| zinc coating, pieces | Cut-off, U	1	cm2

Inputs from Technosphere: materials/fuels F-1362 Stepped Collar		
Polypropylene injection moulding E	4	g

Inputs from Technosphere: materials/fuels F-1434 3 Phase Power Meter		
Capacitor, electrolyte type, < 2cm height {GLO}| market for | Cut-off, U	25	g
Polypropylene injection moulding ECapacitor, for surface-mounting {GLO}| market for | Cut-off, U	5	g
Liquid crystal display, unmounted {GLO}| production | Cut-off, U	20	g

Integrated circuit, logic type {GLO}| market for | Cut-off, U	6	g
Printed wiring board, surface mounted, unspecified, Pb free {GLO}| market for | Cut-off, U	50	g
_57 Copper basic, virgin, EU27	45	g
PVC injection moulding E	136	g
Cast iron {RER}| production | Cut-off, U	45	g
Zinc coat, pieces {RER}| zinc coating, pieces | Cut-off, U	4	cm2

Inputs from Technosphere: materials/fuels F-1809 Installation Contact. IKD32-40		
_57 Copper basic, virgin, EU27	85	g
Wire drawing, copper {RER}| processing | Cut-off, U	82	g
PVC injection moulding E	61	g
Cast iron {RER}| production | Cut-off, U	115	g
Zinc coat, pieces {RER}| zinc coating, pieces | Cut-off, U	3	cm2

Inputs from Technosphere: materials/fuels F-1810 Housing Bottom		
Cast iron {RER}| production | Cut-off, U	1400	g
Zinc coat, pieces {RER}| zinc coating, pieces | Cut-off, U	1982	cm2
Inputs from Technosphere: materials/fuels F-1811 Cable Hanger		
Cast iron {RER}| production | Cut-off, U	840	g
Zinc coat, pieces {RER}| zinc coating, pieces | Cut-off, U	896	cm2

Inputs from Technosphere: materials/fuels F-1812 Cover		
Polypropylene injection moulding E	450	g

Inputs from Technosphere: materials/fuels F-1813 PCB EVC mockup/P		
Resistor, wirewound, through-hole mounting {GLO}| production | Cut-off, U	20	g
Capacitor, electrolyte type, > 2cm height {GLO}| market for | Cut-off, U	10	g
Capacitor, electrolyte type, < 2cm height {GLO}| market for | Cut-off, U	20	g
Transistor, wired, small size, through-hole mounting {GLO}| market for | Cut-off, U	4	g
Printed wiring board, surface mounted, unspecified, Pb free {GLO}| market for | Cut-off, U	5	g
Integrated circuit, logic type {GLO}| market for | Cut-off, U	5	g
Printed wiring board, surface mounted, unspecified, Pb free {GLO}| market for | Cut-off, U	87	g
Electric connector, wire clamp {GLO}| market for | Cut-off, U	22	g
Cast iron {RER}| production | Cut-off, U	21	g
Zinc coat, pieces {RER}| zinc coating, pieces | Cut-off, U	4	cm2

Inputs from technosphere: materials/fuels F-1815 Rubber Gland		
Synthetic rubber {RER}| production | Cut-off, U	5	g

Inputs from technosphere: materials/fuels F-1818 Protection Metal		
Cast iron {RER}| production | Cut-off, U	500	g
Zinc coat, pieces {RER}| zinc coating, pieces | Cut-off, U	1530	cm2

Inputs from technosphere: materials/fuels F-1819 Closing PLug		
Synthetic rubber {RER}| production | Cut-off, U	4	g

Inputs from technosphere: materials/fuels F-1822 RGB Push Button		
_57 Copper basic, virgin, EU27	6	g
Polypropylene injection moulding E	4	g
Cast iron {RER}| production | Cut-off, U	19	g
Zinc coat, pieces {RER}| zinc coating, pieces | Cut-off, U	1	cm2

Inputs from technosphere: materials/fuels F-1823 Residual Current Sensor		
_57 Copper basic, virgin, EU27	25	g
Polypropylene injection moulding E	7	g

Inputs from technosphere: materials/fuels F-1825 RFID Reader WiFi Module		
Capacitor, electrolyte type, < 2cm height {GLO}| market for | Cut-off, U	0,25	g
Resistor, wirewound, through-hole mounting {GLO}| production | Cut-off, U	0,25	g
Integrated circuit, logic type {GLO}| market for | Cut-off, U	0,25	g
Printed wiring board, surface mounted, unspecified, Pb free {GLO}| market for | Cut-off, U	2,25	g
_57 Copper basic, virgin, EU27	2	g

Inputs from technosphere: materials/fuels F-1839 Cable 3 Phase, 22 kW, 32 A		
_57 Copper basic, virgin, EU27	1500	g
Wire drawing, copper {RER}| processing | Cut-off, U	1500	g
PVC injection moulding E	1300	g

Inputs from technosphere: materials/fuels F-1854 Streme EW 35, screw		
PVC injection moulding E	12	g
Cast iron {RER}| production | Cut-off, U	5	g
Zinc coat, pieces {RER}| zinc coating, pieces | Cut-off, U	1	cm2

Inputs from technosphere: materials/fuels F-1855 Mounting Plate		

Cast iron {RER}| production | Cut-off, U	540	g
Zinc coat, pieces {RER}| zinc coating, pieces | Cut-off, U	650	cm2

Table 3.3 Displays the inventory (LCI) used in the calculations from the Ecoinvent database for the disassembly of the charging station.

Disposal scenarios	**Reuse**	**Waste**	**Transport**	**Energy**
	%	%	kgkm	Wh
F-0001 EPDM Rubber	0	100	1	0
F-0002 Screws	100	0	26,5	0,01
F-0003 Wires and Cables	73	27	64,77	0,2
F-0004 Package	10	90	200	0
F-0519 DIN-Rail	100	0	43	0,02
F-0671 WAP Plate	0	100	1,5	0
F-0997 Clamp WDU 6	40	60	11,2	0,01
F-0998 Clamp WDU 6	40	60	11,2	0,01
F-0999 Clamp WDU 6	40	60	11,2	0,01
F-1362 Stepped Collar	0	100	2	0
F-1434 3 Phase Power Meter, DIN Rail	30	70	336	0,2
F-1809 Installation Contactor IKD432-40	75	25	260	0,4
F-1810 Housing Bottom	100	0	750	3
F-1811 Cable Hanger	100	0	425	1,75
F-1812 Cover	0	100	225	0
F-1813 PCB EVC mockup/P	50	50	195	5
F-1815 Rubber Gland	0	100	2,5	0
F-1818 Protection Metal	100	0	275	1
F-1819 Closing Plug	0	100	2	0
F-1822 RGB Push Button	25	75	40	3,8
F-1823 Residual Current Senzor	80	20	19,2	0,05
F- 1825 RFID Reader Wifi Module Uart 3 p	0	100	2,5	0
F-1839 Cable 3 Phas, 22 kW, 32 A, open	55	45	2030	3
F-1839 Streme EW 35m screw	30	70	9	3
F-1855 Mounting Plate	100	0	275	1

Transport - Transport, freight, lorry 7.5-16 metric ton, euro6 {RER}| market for transport, freight, lorry 7.5-16 metric ton, EURO6 | Cut-off, U,
Energy - Electricity, low voltage {SI}| market for | Cut-off, U.

4.4. Process Description

The process of manufacturing, using, and disassembling 1 FU (RDC Charger) is shown in Figure 3.9.

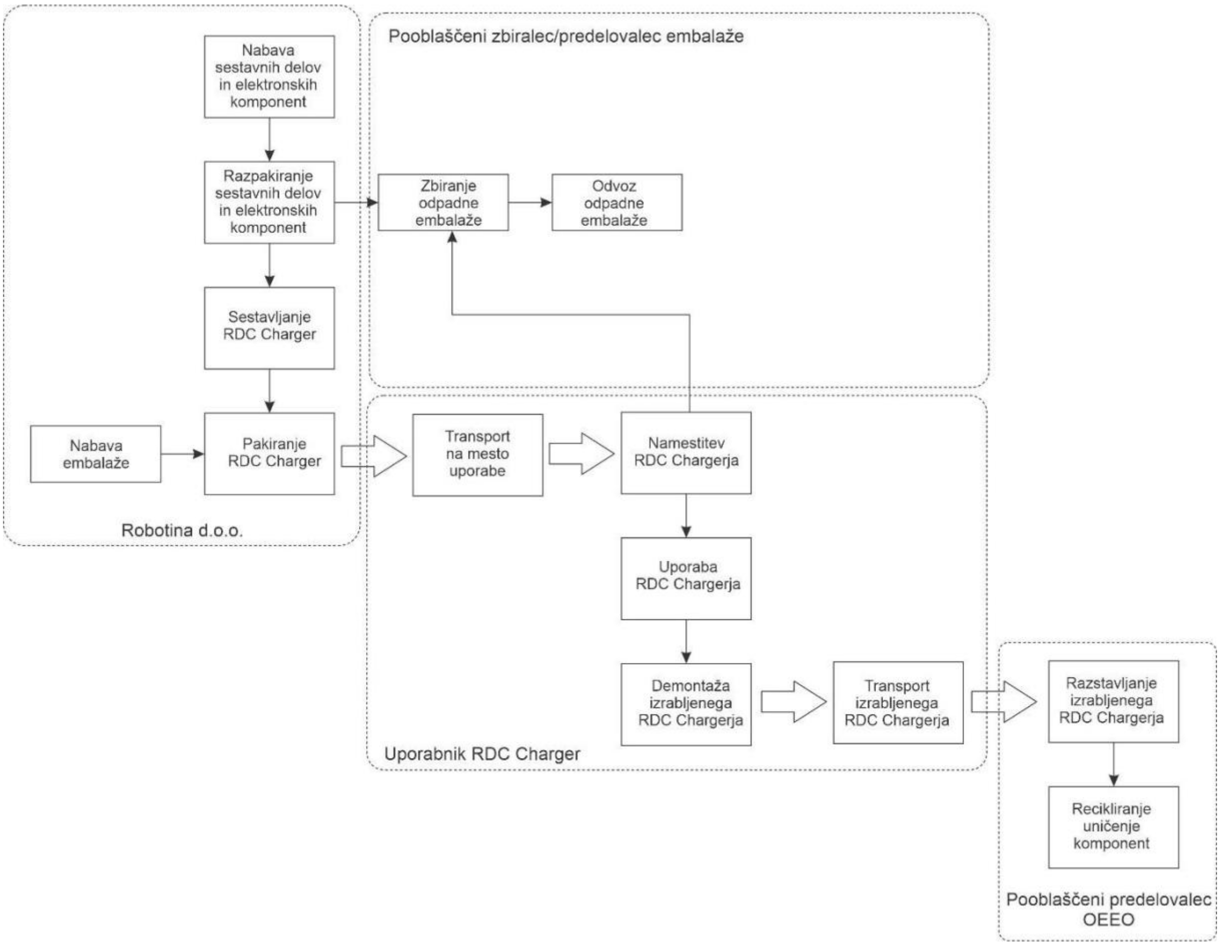


Figure 3.9 It displays the process of manufacturing, using, and disassembling the RDC Charger charging station.

Robotina d.o.o. purchases electronic components and parts from electronic component suppliers, while steel and plastic parts are bought directly from manufacturers. The electronic components and parts are stored in a dedicated warehouse until they are needed. Before assembly, the electronic components and parts are gathered and transferred to the workbench, where a worker unpacks and sorts them. The primary and secondary packaging used for the electronic components and parts is collected and handed over to an external contractor who collects and recycles waste packaging. The worker/assembler manually combines and assembles the electronic components into a functional unit (charging station). Once the charging station is assembled, it is tested and packed in packaging. The packed charging station is stored in a dedicated warehouse until it is dispatched to the dispatch centre or the end user. The end user, with the help of an electrical specialist, installs the charging station at the place of use. After use, a qualified electrical specialist dismantles the equipment, which is then handed over to an OEEO processor who organizes the disassembly, separation of useful electronic components, recycling, or disposal of used electronic components and parts.

4.5. Data Collection Timeframe

All data were measured and obtained in June 2023. The mass balance for the assembly of 1 FU does not change, and based on the mass balance, the LCA study is valid until the technological design of the functional unit changes. The energy balance is based on the basket of electricity sources as specified in the EcoInvent 3.8 database. The data are valid until the basket of electricity sources changes in the RS region. The production of electronic components includes global data as specified in the EcoInvent 3.8 database. The LCA study remains valid until the composition of the data mentioned above changes. Based on the author's experience, the LCA study is estimated to be valid for at least 5 years.

4.6. Limitations of data usage

All data in the LCA were obtained by directly weighing individual components. The energy for product assembly was measured for the entire production and distributed per product unit. Transport distances were estimated. The transport distance for delivering components was estimated to average 500 ± 50 km, the delivery of the final product to the user at 250 ± 25 km, the transport of the used product to the disassembly site at 250 ± 25 km, and the transport of components to the recycling and/or disposal site at 250 ± 25 km.

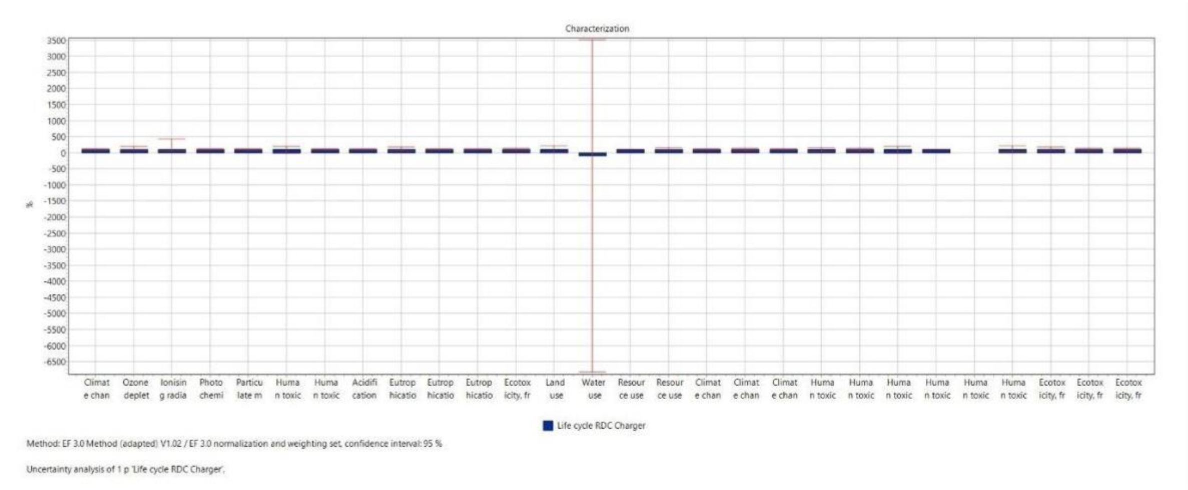
The data used in the study were measured by weighing individual components from which the product is composed, and they are determined by the accuracy limit of the scale. The energy used for assembling one unit is difficult to determine due to the complexity of operations and other factors (maintenance of workplace microclimate); therefore, the energy was measured for the entire production and distributed per product unit. Transport distances were estimated because the exact location of the device is difficult to determine, and distances needed to be reasonably averaged.

4.7. Data quality validation

For data validation, the software package SimaPro 9.3.0.3 was used – specifically the “Uncertainty Analysis” function. The data considered has a triangular distribution, as the lower and upper bounds of the distribution are statistically determinable, while the data from EcoInvent has a continuous probability distribution of the random variable (lognormal). The global warming potential was determined based on a 100-year horizon. For the purposes of verification and definition of the methodology to determine the confidence level for the scenarios used, the pedigree matrix from the Ecoinvent 3.8.1 database was used. The dispersion of results was evaluated using the “Monte Carlo” simulation method, where 5000 sample points were considered. The results are shown in Tables 3.6, 3.7, and 3.8.

Table 3.6 The level of confidence in the LCA results for the case of producing 30 capsules, their packaging in blister packs of 10 capsules per pack, and packaging 3 blister packs in a cardboard box.

Impact category	Unit	Mean	**Median**	**SD**	**CV**	**2,5%**	**97,5%**	**SEM**
Acidification	mol H+ eq	5,274E-01	5,107E-01	3,581E-02	6,790E+00	4,703E-01	5,820E-01	7,162E-03
Climate change	kg CO2 eq	8,430E+01	8,295E+01	4,831E+00	5,731E+00	7,645E+01	9,423E+01	9,662E-01
Climate change - biogenic	kg CO2 eq	1,402E-01	1,398E-01	1,594E-02	1,137E+01	1,127E-01	1,915E-01	3,189E-03
Climate change – fossil	kg CO2 eq	8,408E+01	8,272E+01	4,813E+00	5,725E+00	7,623E+01	9,397E+01	9,627E-01
Climate change – resource use	kg CO2 eq	8,747E-02	8,532E-02	7,301E-03	8,347E+00	7,651E-02	1,039E-01	1,460E-03
Ecotoxicity, freshwater	CTUe	4,518E+03	4,363E+03	6,679E+02	1,478E+01	3,335E+03	6,340E+03	1,336E+02
Ecotoxicity, inorganic	CTUe	6,310E+02	6,347E+02	1,175E+02	1,863E+01	4,556E+02	8,774E+02	2,351E+01
Ecotoxicity, metals	CTUe	3,861E+03	3,734E+03	6,242E+02	1,617E+01	2,660E+03	5,644E+03	1,248E+02
Ecotoxicity, organic substances	CTUe	2,688E+01	2,421E+01	7,029E+00	2,615E+01	1,670E+01	4,294E+01	1,406E+00
Eutrophication, freshwater	kg P eq	7,168E-02	7,021E-02	1,638E-02	2,285E+01	5,031E-02	1,144E-01	3,275E-03
Eutrophication, marine	kg N eq	1,000E-01	9,662E-02	1,061E-02	1,060E+01	8,182E-02	1,202E-01	2,122E-03
Eutrophication, soil	mol N eq	1,053E+00	1,015E+00	1,173E-01	1,113E+01	8,564E-01	1,262E+00	2,346E-02
Human toxicity, carcinogenic	CTUh	6,942E-07	6,850E-07	5,624E-08	8,101E+00	6,005E-07	8,265E-07	1,125E-08
Human toxicity, carc.-inorganic	CTUh	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
Human toxicity, carc.-metals	CTUh	1,225E-07	1,151E-07	5,715E-08	4,666E+01	3,469E-08	2,582E-07	1,143E-08
Human toxicity, carc.-organic	CTUh	5,717E-07	5,726E-07	9,773E-09	1,709E+00	5,599E-07	5,999E-07	1,955E-09
Human toxicity, non-carcinogenic	CTUh	3,327E-06	3,560E-06	1,818E-06	5,465E+01	-6,197E-07	6,519E-06	3,636E-07
Human toxicity, non carc.-inorganic	CTUh	2,586E-07	2,475E-07	3,949E-08	1,527E+01	1,951E-07	3,344E-07	7,899E-09
Human toxicity, non carc.-metals	CTUh	2,911E-06	3,189E-06	1,791E-06	6,152E+01	-1,075E-06	6,024E-06	3,582E-07
Human toxicity, non carc.-organic	CTUh	1,640E-07	1,549E-07	4,266E-08	2,602E+01	9,341E-08	2,474E-07	8,532E-09
Ionizing radiation	kBq U-235 eq	7,683E+00	5,640E+00	4,938E+00	6,427E+01	3,737E+00	2,394E+01	9,876E-01
Land use	Pt	3,993E+02	4,193E+02	2,258E+02	5,655E+01	-4,513E+01	8,353E+02	4,516E+01
Ozone depletion	kg CFC11 eq	9,354E-06	8,684E-06	2,480E-06	2,651E+01	6,587E-06	1,683E-05	4,959E-07
Particulate matter emissions	disease inc.	4,616E-06	4,636E-06	5,071E-07	1,099E+01	3,657E-06	5,797E-06	1,014E-07
Photochemical ozone formation	kg NMVOC eq	3,106E-01	3,125E-01	3,060E-02	9,851E+00	2,506E-01	3,653E-01	6,119E-03
Fossil resource depletion	MJ	1,167E+03	1,179E+03	6,293E+01	5,391E+00	1,037E+03	1,243E+03	1,259E+01
Mineral and metal depletion	kg Sb eq	1,842E-02	1,746E-02	2,875E-03	1,561E+01	1,467E-02	2,702E-02	5,750E-04
Water resource depletion	m3 depriv.	-8,945E+01	-3,962E+01	8,899E+02	-9,949E+02	-2,703E+03	1,391E+03	1,780E+02
Confidence interval	95 %							



Graph 3.1 shows the confidence level in the LCA results for the case of production, use, and disposal of 1 FU.

The confidence level in the results is satisfactorily high in all calculated categories except for water resource depletion. The reason likely lies in the difficulty of obtaining data for the local area, necessitating reliance on global sources, where there is significant variance both in the data itself and in data quality. The uncertainty was calculated using the EF 3.0 method and the pedigree matrix from the Ecoinvent 3.8.1 database.

5. LCIA CALCULATION

For the purposes of conducting the LCA study for the "RDC Charger" charging station, the **"Environmental Footprint" EF 3.0 methodology** was used. This is the latest version of the EF method and complies with ISO 14040 and 14044 standards. The EF method is an impact assessment method adopted during the transition phase for determining the environmental footprint, as prescribed by the European Commission. It includes normalization and weighting factors, published in November 2019 in the Official Journal of the EU. The normalization and weighting sets are summarized from Annex 2 of the Product Environmental Footprint Category Rules Guidance by the European Commission [13]. For the calculation of normalized results (NF), the global population (6,895,889,018 people) [14] was considered, and for weighting the results, the guidelines by Sala et al. [15] were followed.

The calculation considered 15 prescribed criteria:

2.3.1 Climate change

Impact Indicator: Emissions as Global Warming Potential (GWP100);

The basic IPCC 2013 model was used, considering certain factors adapted from the EF guidelines:

- A factor of 1 was used for carbon dioxide emissions to air (as fossil carbon dioxide according to the original method).
- A factor of -1 was used for carbon dioxide emissions to soil or biomass stock (this flow is necessary for proper modeling of land use according to Ecoinvent 3.0).
- A factor of 0 was used for carbon dioxide that was consumed as a raw material (both fossil and biogenic carbon dioxide).

2.3.2. Ozone depletion

Impact Indicator: Impact on ozone depletion (ODP) through the evaluation of destructive effects on the stratospheric ozone layer over a 100-year time.

2.2.3. Ionizing radiation

Impact Indicator: Impact of ionizing radiation through the evaluation of the effects of ionizing radiation on the population compared to uranium-235.

2.2.4. Photochemical ozone formation

Impact Indicator: Displays the photochemical ozone creation potential (POCP) or the impact of potential contribution to photochemical ozone formation. It includes spatial differentiation. Considering the marginal increase in ozone formation, the spatially differentiated LOTOS-EUROS model was used, which on average includes more than 14,000 grid cells to define European factors.

2.2.5. Particulate matter

Impact Indicator: Displays the incidence of diseases due to particulate matter emissions, normalized to 1kg of emitted PM2.5. The indicator is calculated using the average slope between the working point of the emission response function (ERF) and the theoretical minimum risk level. The exposure model is based on archetypes that include urban environments, rural environments, and indoor environments in urban and rural areas.

2.1.6. Human Toxicity – Non-Carcinogenic

Impact Indicator: Comparative unit of human toxicity (CTUh) calculated based on the harmonized multimedia USEtox model. It encompasses two spatial scales: a continental scale consisting of six zones (urban air, rural air, agricultural natural soil, freshwater, coastal seawater), and a global scale with the same structure, but without considering urban air. Specific groups of chemicals have not yet been accounted for and require further evaluation.

2.1.7. Human Toxicity – Carcinogenic

Impact Indicator: Comparative unit of human toxicity (CTUh) calculated based on the harmonized multimedia USEtox model. It encompasses two spatial scales: a continental scale consisting of six compartments (urban air, rural air, agricultural natural soil, freshwater, coastal seawater), and a global scale with the same structure but without urban air. Specific groups of chemicals have not yet been accounted for and require further evaluation.

2.1.8. Acidification

Impact Indicator: Accumulated exceedance (AE) values, which indicate changes in critical load exceedances in sensitive areas of terrestrial and freshwater ecosystems where acidifying substances are deposited.

2.1.9. Eutrophication of Water Resources

Impact Indicator: Phosphorus equivalents, which indicate the rate at which discharged nutrients reach the threshold in freshwater, causing changes in the natural nutrient cycling (phosphorus is considered the limiting factor in water).

2.1.10. Eutrophication of Freshwater Resources

Impact Indicator: Phosphorus equivalents, which indicate the rate at which discharged nutrients reach the threshold in freshwater, causing changes in the natural nutrient cycling (phosphorus is considered the limiting factor in surface waters).

2.1.11. Marine Eutrophication

Impact Indicator: Phosphorus equivalents, which indicate the rate at which discharged nutrients reach the threshold in marine waters, causing changes in the natural nutrient cycling (phosphorus is considered the limiting factor in marine environments).

2.1.12. Soil Eutrophication

Impact Indicator: Accumulated Exceedance (AE), which indicates changes in the critical load exceedance of sensitive areas where eutrophying substances are deposited.

2.1.13. Freshwater Ecotoxicity

Impact Indicator: Comparative Toxic Unit for ecosystems (CTUe), calculated based on the harmonized multimedia USEtox model. It encompasses two spatial scales: a continental scale consisting of six compartments (urban air, rural air, agricultural natural soil, freshwater, coastal seawater), and a global scale with the same structure but without urban air. Specific groups of chemicals require further evaluation.

2.1.14. Land use

Impact Indicator: Soil quality index, calculated from a set of CFs based on the LANCA® model version 2.2. Of the 5 original indicators, only 4 were included in the aggregation (physical-chemical filtration was excluded due to high correlation with mechanical filtration).

2.1.15. Water use

Impact Indicator: Drinking water scarcity potential (water consumption weighted by scarcity). The Available Water Remaining (AWARE) is the amount of water available in a given area after the needs of people and aquatic ecosystems have been met. This indicator is recommended only for characterizing blue water consumption, where consumption is defined as the difference between the withdrawal and release of blue water. This set of indicators cannot properly characterize green water, fossil water, seawater, and rainwater. AWARE100 does not include: differentiation between agricultural and non-agricultural water use at the country level, temporal (monthly) specification, and characterization factors at the watershed level.

2.1.16. Resource Use, Energy Carriers

Impact Indicator: Fossil fuel depletion due to the use of abiotic resources (ADP-fossil), considering the lower heating values for energy carriers as calculated by van Oers et al. in 2002, included in CML 4.8 (2016). The depletion model is based on the ratio between use and availability. It assumes the possibility of complete substitution among fossil energy carriers.

2.1.17. Resource Use, Minerals and Metals

Impact Indicator: Abiotic resource depletion (ultimate reserve ADP), calculated based on correlations by van Oers et al. in 2002, included in CML version 4.8 (2016). The depletion model is based on the ratio between use and availability. It assumes the possibility of complete substitution among fossil energy carriers. Each region is assigned a national characterization factor. Connected regions (e.g., energy-related) encompassing more than one country (e.g., WECC) are assigned a GLO characterization factor.

To assess the effectiveness of implementing a remote monitoring system for beehive status, we conducted a comparative life cycle analysis (LCA) comparing the reference state, where hive management is performed manually according to generally accepted "Good Beekeeping Practices" [96], with the state after the implementation of the remote beehive monitoring system. The LCA was calculated using the EF3.0 methodology with the SimaPro 9.5.0 software package, considering reference data from the EcoInvent 3.8 database.

5.1. INTERDEPENDENCE NETWORK

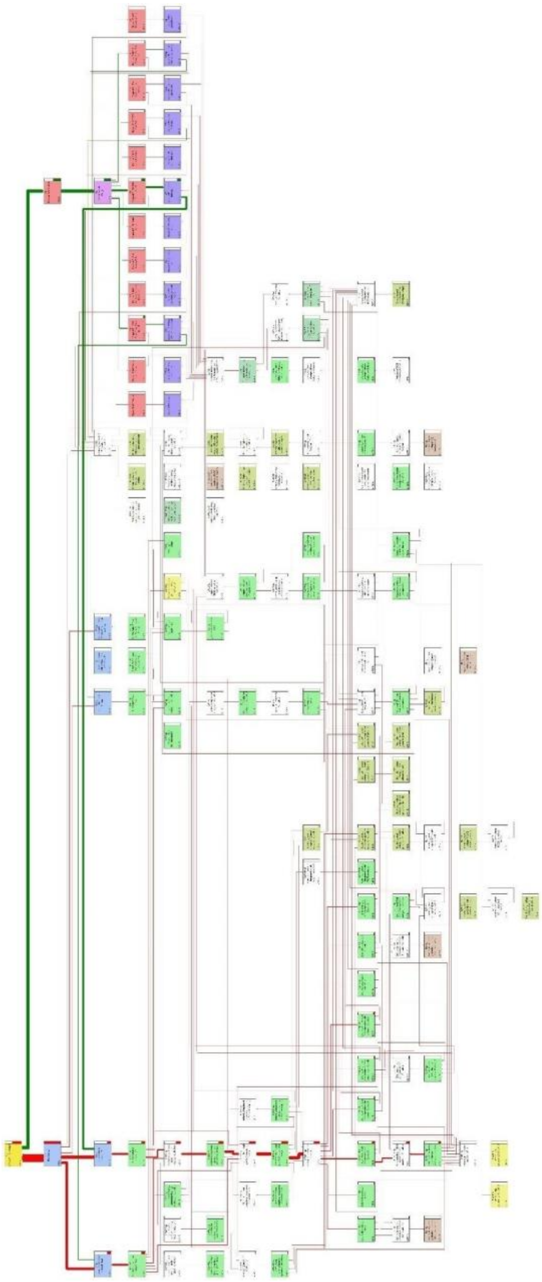


Figure 3.10 The interdependence network of processes that have more than 1% impact on the LCA results.

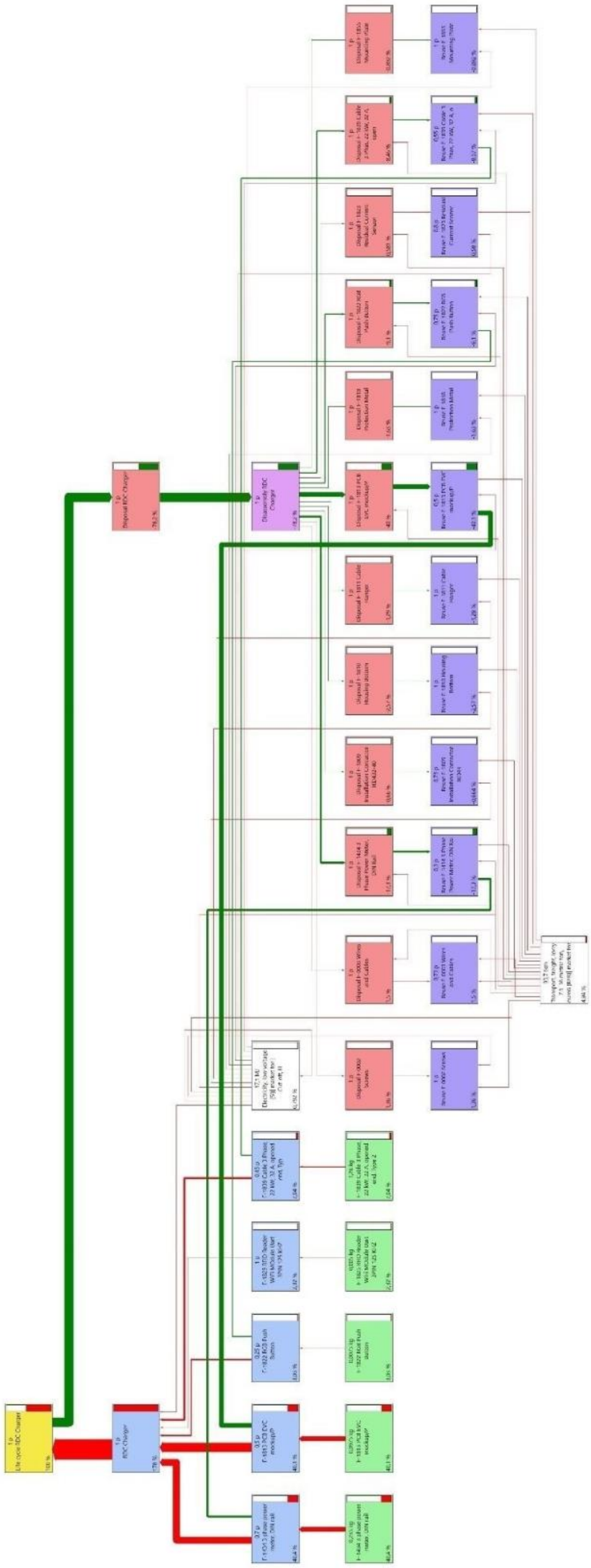


FIgure 3.11 The simplified interdependence network of processes that have more than 1% impact on the LCA results.

5.2. IMPACT ANALYSIS

An LCA study was conducted to determine the environmental and human health impacts associated with the production of the »RDC Charger«.

Table 3.4 Overall LCA Study Results for the Production of the »RDC Charger«.

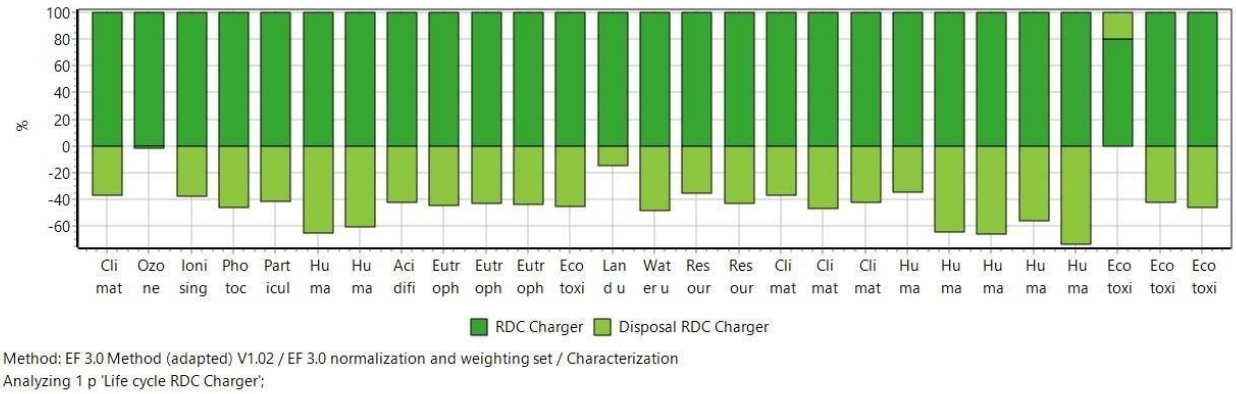
Impact category	Unit	Assembly	Disassembly	Total
Climate Change	kg CO2 eq	1,31E+02	-4,84E+01	8,28E+01
Ozone Depletion Ionizing	kg CFC11 eq	8,78E-06	-1,36E-07	8,65E-06
Radiation	kBq U-235 eq	1,36E+01	-5,19E+00	8,45E+00
Photochemical Ozone Formation	kg NMVOC eq	5,32E-01	-2,44E-01	2,88E-01
Particulate Matter Emissions	disease inc.	7,97E-06	-3,30E-06	4,67E-06
Human Toxicity, Non-Carcinogenic	CTUh	1,14E-05	-7,42E-06	3,94E-06
Human Toxicity, Carcinogenic	CTUh	1,77E-06	-1,07E-06	6,94E-07
Acidification	mol H+ eq	8,71E-01	-3,68E-01	5,03E-01
Eutrophication, Freshwater	kg P eq	1,26E-01	-5,66E-02	6,92E-02
Eutrophication, Marine	kg N eq	1,60E-01	-6,92E-02	9,09E-02
Eutrophication, Terrestrial	mol N eq	1,69E+00	-7,36E-01	9,50E-01
Ecotoxicity, Freshwater	CTUe	8,56E+03	-3,87E+03	4,68E+03
Land use	Pt	4,73E+02	-7,06E+01	4,03E+02
Water use	m3 depriv.	3,29E+01	-1,60E+01	1,69E+01
Fossil Resource Depletion	MJ	1,75E+03	-6,15E+02	1,13E+03
Mineral and Metal Resource Depletion	kg Sb eq	3,26E-02	-1,42E-02	1,84E-02
Climate Change – Fossil	kg CO2 eq	1,31E+02	-4,83E+01	8,26E+01
Climate Change – Biogenic	kg CO2 eq	2,56E-01	-1,20E-01	1,36E-01
Climate Change – Resource Use	kg CO2 eq	1,48E-01	-6,28E-02	8,54E-02
Human Toxicity, Non-Carcinogenic, Organic	CTUh	2,33E-07	-7,99E-08	1,53E-07
Human Toxicity, Non-Carcinogenic, Inorganic	CTUh	7,56E-07	-4,89E-07	2,67E-07
Human Toxicity, Non-Carcinogenic, metals	CTUh	1,04E-05	-6,86E-06	3,53E-06
Human Toxicity, Carcinogenic, organic	CTUh	1,30E-06	-7,26E-07	5,70E-07
Human Toxicity, Carcinogenic, inorganic.	CTUh	4,74E-07	-3,49E-07	1,24E-07
Human Toxicity, Carcinogenic, metals	CTUh	2,26E+01	5,61E+00	2,82E+01
Water Resource Toxicity, Organic Substances	CTUe	1,15E+03	-4,89E+02	6,66E+02
Water Resource Toxicity, Inorganic Substances	CTUe	7,38E+03	-3,39E+03	3,99E+03
Water Resource Toxicity, Metals	CTUe	1,31E+02	-4,84E+01	8,28E+01

Table 3.5 Overall Normalized and Weighted Results of the LCA Study for the EV Charger "RDC Charger" by Robotina d.o.o.

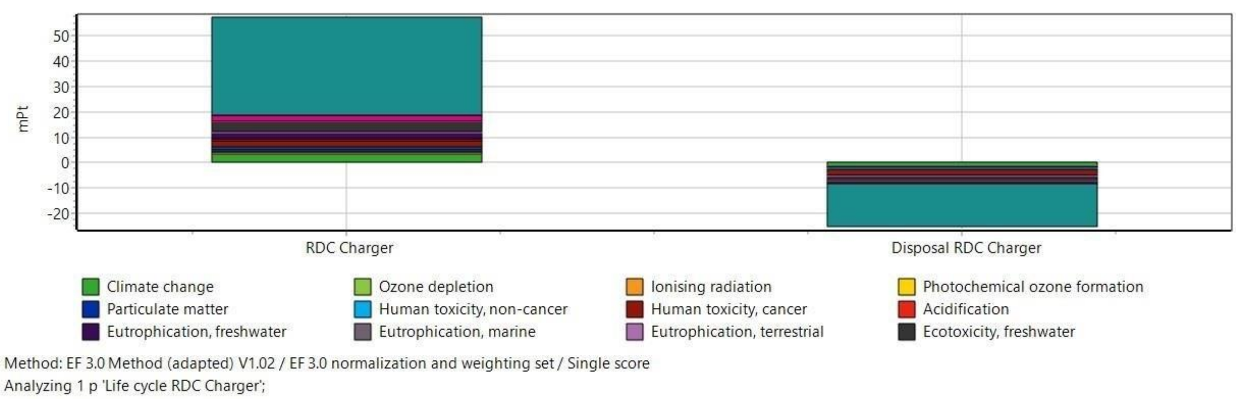
Impact Category	Unit	Assembly	Disassembly	Total
Overall Impact	mPt	57.384	-25.182	32.202

Climate Change	mPt	3.413	-1.260	2.153
Ozone Depletion	mPt	0.010	0.000	0.010
Ionizing Radiation	mPt	0.162	-0.062	0.100
Photochemical Ozone Formation	mPt	0.626	-0.287	0.339
Particulate Matter Emissions	mPt	1.200	-0.497	0.703
Human Toxicity, Non-Carcinogenic	mPt	0.910	-0.595	0.316
Human Toxicity, Carcinogenic	mPt	2.230	-1.355	0.875

Impact Category	**Unit**	**Assembly**	**Disassembly**	**Total**
Overall Impact	mPt	57.384	-25.182	32.202
Climate Change	mPt	3.413	-1.260	2.153
Ozone Depletion	mPt	0.010	0.000	0.010
Ionizing Radiation	mPt	0.162	-0.062	0.100
Photochemical Ozone Formation	mPt	0.626	-0.287	0.339
Particulate Matter Emissions	mPt	1.200	-0.497	0.703
Human Toxicity, Non-Carcinogenic	mPt	0.910	-0.595	0.316
Human Toxicity, Carcinogenic	mPt	2.230	-1.355	0.875



Graph 3.2 shows the overall results of environmental and human health impacts by individual parameters in the LCA calculation for the EV charger "RDC Charger" by Robotina d.o.o.



Graph 3.3 shows the normalized results of the LCA study for the EV charger "RDC Charger" by Robotina d.o.o.

5.3. LCA ANALYSIS – EXPLANATION OF RESULTS

The LCA showed that the production of the "RDC Charger" charging line, its delivery to the place of use, its disassembly, and recycling contribute a total of 32.202 mPt, with the largest share of environmental burden arising from the use of minerals and metals (67.9%), followed by impacts on climate change (6.67%), impacts on drinking water sources (6.54%), etc. (see Table 3.5). Figures 3.10 and 3.11 show that most of the environmental impact is contributed by elements containing PCB and electronic components. This is due to the extraction of rare metals, primarily gold. In the LCA, we considered that 50% of the motherboard (F-1813 PCB EVC mockup/P), 30% of the power meter (F-1434 3 Phase Power Meter), and 25% of the contactor (Installation Contactor IKD432-40) are successfully recycled. The simulation showed that the production and use of the "RDC Charger" contributes to a 36.73% reduction in the overall impact on the environment and human health. If we were able to fully recycle components containing PCB and electronic components, the environmental impact could be reduced to only 6.26 mPt, which is a reduction of 80.56% compared to the current state and 87.70% compared to the baseline state (no recycling of electronic equipment and PCB).

Based on the LCA, it is necessary to consider ways of optimally recycling individual components, especially the optimal and environmentally friendly extraction of rare minerals and metals from electronic printed circuit boards and electronic components.

6. CONCLUSION

The company Robotina d.o.o. manufactures EV charging lines "RDC Charger". The production of components, their assembly into the final product, the use of the charger, its disassembly, and the recycling of components contribute 82.8 kg CO_2 (eq) to greenhouse gas emissions and 32.202 mPt of total environmental impacts on a global level. The main source of environmental and human health impacts is the use of electronic printed circuit boards and electronic components. To potentially improve the environmental footprint, it is necessary to consider the complete disassembly of electronic components and their recycling, with a focus on the extraction of rare metals and minerals.

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8. LEGAL BASIS

The analysis was based on technical data provided by experts from Robotina d.o.o., which manufactures EV charging lines "RDC Charger". The calculations were made using the SimaPro 9.3.0.3 Analyst software package and the corresponding Ecoinvent 3.8 and Industry Data 2.0 databases. The study is owned by Robotina d.o.o. Permission from Robotina d.o.o. is required for any third-party inspection, copying, or any other use of the study.