Life Cycle Assessment Report

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Prepared with the support of

Ollum S.r.l.

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Scope and goal of the study

Sustainability lies at the heart of Zucchetti Centro Sistemi's operations, especially when it comes to the environmental impact of its products. For this reason, the company has conducted a Life Cycle Assessment (LCA) on its main products. This study is pivotal in the development of innovative products that support a fair and sustainable energy transition.

Conducting a product LCA is crucial to assessing the environmental impact of products throughout their life cycle and communicating it in a transparent manner. Zucchetti Centro Sistemi's decision to provide customers, partners and stakeholders with reliable and verifiable data on the environmental performance of inverters, storage systems and charging stations underscores its tangible commitment to sustainability.

Reference standards

A life-cycle assessment has been conducted on all the products listed here to calculate their environmental impacts throughout their life cycle. However, for certain products, only greenhouse gas (GHG) emissions have been certified, whereas for others, multiple environmental impact parameters have been calculated or certified.

The following norms and standards were used for the calculations:

- ISO 14040:2006, Life cycle assessment — Principles and framework
- ISO 14044:2006, Life cycle assessment — Requirements and guidelines
- ISO 14067:2018, Carbon footprint of products — Requirements and guidelines for quantification
- PAS 2050:2011, Specification for Life Cycle Greenhouse Gas Emission Assessment of Goods and Services
- ISO 14025, Environmental labels and declarations — Type III environmental declarations — Principles and procedures
- GHG Protocol 2011, Quantification of Uncertainty of Carbon Emissions
- 2006 IPCC Guidelines for National Greenhouse Gas Inventories
- EPD International C-PCR-024：PV components: inverters, battery energy storage systems, combiner boxes and tracker systems, Version 2023-01-02

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- Other relevant laws and regulations, national industry standards and norms

In particular, the main assumptions of the studies were based on the three Product Category Rules (PCRs) established by EPD Italy and developed by Enel S.p.A.:

- EPD Italy
    - PCR Core 007 – Electronic and electrical products and systems
    - Sub PCR 017 – Charging stations
    - Sub PCR 021 – Energy storage
    - Sub PCR 032 – Power inverters

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AZZURRO 3PH 100K-125KTL-V4 Inverter

Functional Unit

The product chosen for the assessment is a large three-phase inverter. In this case, the AZZURRO 3PH HYD TL-V4 three-phase range of inverters, ranging from 100kW to 125kW was considered. The following specific products are included in this study: AZZURRO 3PH 100KTL-V4, AZZURRO 3PH 110KTL-V4, AZZURRO 3PH 125KTL-V4-A, AZZURRO 3PH 100KTL-V4-ST, AZZURRO 3PH 110KTL-V4-ST and AZZURRO 3PH 125KTL-V4-ST. For the inverters, the emissions of the median product, specifically the 110k Watt size, were assessed.

The study was conducted using a functional unit of 1 kWh of electrical energy transformed into AC, irrespective of its use.

Although the functional unit is defined as 1 kWh of electrical energy transformed into AC and stored in the battery, the greenhouse gas emissions for the product's entire life-cycle was also calculated using a product-centred approach.

Type of study

This study adopts the “cradle-to-grave” principle to analyse the carbon footprint according to ISO 14067:2018. This means that the system boundary should include all greenhouse gas emissions that occur from the raw material input to the final disposal of the product outside the reporting entity. Specifically, the study includes GHG emissions generated in the following processes:

1) Formation, extraction or conversion of raw materials, including energy consumption and direct GHG emissions related to the formation of raw materials;
2) Production processes, including consumables used;
3) Company infrastructure, comprising factories, office buildings, warehouses, etc.;
4) Transportation by road, air, water, rail or other means;
5) Energy supply and consumption throughout the product's life cycle, including the phase of use;
6) Disposal of the product at end-of-life.

The study has been certified according to ISO 14067:2018 by DNV GL.

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Assumptions

The main assumptions of this study were based on PCR Core 007 – Electronic and electrical products and systems and Sub PCR 032 – Power inverters.

The photovoltaic system supplying power to the inverter is assumed to be 143 kWp, with a production factor of 1,100 hours per year. Considering the decay factor of the solar panels, the inverter is estimated to convert a total of 3,619,235 kWh of electrical energy into AC over its lifetime. Furthermore, the service life of the inverter was assumed to be 25 years, in accordance with Sub PCR 032 – Power inverters. The efficiency of the inverter is assumed to be 98%, resulting in a power consumption of 72,385 kWh during use.

Due to challenges in monitoring the end-of-life disposal and recycling phases, no reliable projections are available. Consequently, it is assumed that 100% of the metal in the battery cell and structural parts will be recycled during the end-in-life phase, while the remaining parts will be disposed of in landfills.

Impacts

Stage	$kgCO_2eq$ per kWh	$kgCO_2eq$ per individual product	Percentage
Raw materials	0.00034899	1,263	18%
Transport of raw materials	0.00000295	11	0%
Product assemblage	0.00000472	17	0%
Transport to customer	0.00000395	14	0%
Use	0.00167044	6,046	86%
Disposal	-0.00008194	(297)	-4%
Total	**0.00194911**	**7,054**	**100%**

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Integrated system: AZZURRO 1PH HYD 3000~6000 ZP1 Inverter series and AZZURRO HV ZBT 5K Battery

Functional Unit

The product chosen for the assessment is an integrated inverter plus battery system. In this case, the AZZURRO 1PH HYD series of single-phase hybrid inverters, ranging from 3000 to 6000 Watts and an AZZURRO HV ZBT 5K battery, were considered. For the inverters, the average emissions of the batteries were also assessed.

The study was conducted using a functional unit of 1 kWh of electrical energy transformed into AC and stored in the battery. This means that the energy transformed by the inverter that is self-consumed without being stored in the battery is not considered. Consequently, the LCA study does not include the energy consumed by the inverter when it transforms electrical energy into AC that is immediately self-consumed.

Although the functional unit is defined as 1 kWh of electrical energy transformed into AC and stored in the battery, the greenhouse gas emissions generated by the product over its entire life cycle was also calculated using a product-centred approach.

Type of study

This study adopts the "cradle-to-grave" principle to analyse the carbon footprint according to ISO 14067:2018. This means that the system boundary should include all greenhouse gas emissions that occur from the raw material input to final disposal of the product outside the reporting entity. Specifically, the study includes GHG emissions generated in the following processes:

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2) Production processes, including consumables used;
3) Company infrastructure, including factories, office buildings, warehouses, etc.;
4) Transportation by road, air, water, rail or other means;
5) Energy supply and consumption throughout the product's life cycle, including the phase of use;
6) Disposal of the product at end-of-life.

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Assumptions

The main assumptions of this study were based on PCR Core 007 – Electronic and electrical products and systems and Sub PCR 021 – Energy storage.

The battery has a nominal capacity of 5120 Wh and its capacity before disposal is considered to be 66% of the nominal capacity. A total of 7,000 charge and discharge cycles are considered in the service life. The charging and discharging efficiency of the battery is approximately 96%, while the efficiency of the inverter is approximately 98%. The total amount of kilowatts inverted and stored per hour is 29,750

Due to challenges in monitoring the end-of-life disposal and recycling phases, no reliable projections are available. Consequently, it is assumed that 100% of the metal in the battery cell and structural parts will be recycled during the end-in-life phase, while the remaining parts will be disposed of in landfills.

Impacts

Stage	$kgCO_2eq$ per kWh	$kgCO_2eq$ per individual product	Percentage
Raw materials	0.03923	1,167	73%
Transport of raw materials	0.00074	22	1%
Product assemblage	0.00057	17	1%
Transport to customer	0.00047	14	1%
Use	0.01573	468	29%
Disposal	-0.00334	(99)	-6%
Total	**0.05341**	**1,589**	**100%**

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Integrated system: AZZURRO 3PH HYD5000~20000 ZSS Inverters and AZZURRO HV ZBT ES5, AZZURRO HV ZBT ES10, AZZURRO HV ZBT ES15 and AZZURRO HV ZBT ES20 Batteries

Functional Unit

The product chosen for the assessment is an integrated inverter plus battery system. In this case, the AZZURRO 3PH HYD three-phase hybrid inverters ranging from 5000 to 20000 Watts, and two AZZURRO HV ZBT ES 5~20 batteries, were considered. The AZZURRO HV ZBT ES5~20 series is composed of four products, AZZURRO HV ZBT ES5, AZZURRO HV ZBT ES10, AZZURRO HV ZBT ES15 and AZZURRO HV ZBT ES20, and consists of an AZZURRO BDU ZBT5K base and a variable number of AZZURRO HV ZBT 5K batteries (stacked 1, 2, 3 and 4 respectively). For the inverters and batteries, the average emissions of the included products were also assessed.

The study was conducted using a functional unit of 1 kWh of electrical energy transformed into AC and stored in the battery. This means that the energy transformed by the inverter that is self-consumed without being stored in the battery is not considered. Consequently, the LCA study does not include the energy consumed by the inverter when it transforms electrical energy into AC that is immediately self-consumed.

Although the functional unit is defined as 1 kWh of electrical energy transformed into AC and stored in the battery, the greenhouse gas emissions generated by the product over its entire life cycle was also calculated using a product-centred approach.

Type of study

This study adopts the “cradle-to-grave” principle to analyse the carbon footprint according to ISO 14067:2018. This means that the system boundary should include all greenhouse gas emissions that occur from the raw material input to final disposal of the product outside the reporting entity. Specifically, the study includes GHG emissions generated in the following processes:

1) Formation, extraction or conversion of raw materials, including energy consumption and direct GHG emissions related to the formation of raw materials;
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5) Energy supply and consumption during the life cycle of the product, including the phase of use;
6) Disposal of the product at end-of-life.

The study has been certified according to ISO 14067:2018 by DNV GL.

Assumptions

The main assumptions of this study were based on PCR Core 007 – Electronic and electrical products and systems and Sub PCR 021 – Energy storage.

The battery has a nominal capacity of 5120 Wh and its capacity before disposal is considered to be 66% of the nominal capacity. Two batteries with a nominal capacity of 5120 Wh each were considered in this study. A total of 7,000 charge and discharge cycles are considered in the service life. The charging and discharging efficiency of the battery is approximately 96%, while the efficiency of the inverter is approximately 98%. The total amount of kilowatts inverted and stored per hour is 59,500

Due to challenges in monitoring the end-of-life disposal and recycling phases, no reliable projections are available. Consequently, it is assumed that 100% of the metal in the battery cell and structural parts will be recycled during the end-in-life phase, while the remaining parts will be disposed of in landfills.

Impacts

Stage	$kgCO_2eq$ per kWh	$kgCO_2eq$ per individual product	Percentage
Raw materials	0.03002	1,786	68%
Transport of raw materials	0.00063	37	1%
Product assemblage	0.00057	34	1%
Transport to customer	0.00048	29	1%
Use	0.01573	936	36%
Disposal	-0.00332	(198)	-8%

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Total	**0.04411**	**2,625**	**100%**

7kW Caro Series charging station

Functional Unit

The product chosen for the assessment is a 7kW Caro Series single-phase AC charging station.

The study was conducted by considering the entire product, including the cable and charging gun, as the functional unit.

Type of study

This study adopts the "cradle-to-gate” principle to analyse the carbon footprint according to the standards issued by EPD Italy, namely the PCR Core 007 – Electronic and electrical products and systems and Sub PCR 017 – Charging stations. This means that the system boundary should include all greenhouse gas emissions that occur from the raw material input to the delivery of the product at the ZCS plant. Specifically, the study includes GHG emissions generated in the following processes:

1) Formation, extraction or conversion of raw materials, including energy consumption and direct GHG emissions related to the formation of raw materials;
2) Production processes, including consumables used;
3) Company infrastructure, comprising factories, office buildings, warehouses, etc.;
4) Transportation by road, air, water, rail or other means;

The study has not yet been certified by third-party entities, but will be verified by EPD Italy.

Assumptions

The main assumptions of this study were based on PCR Core 007 – Electronic and electrical products and systems and Sub PCR 017 – Charging stations.

Due to challenges in monitoring the end-of-life disposal and recycling phases, no reliable projections are available. Considering also the uncertainty surrounding the actual use of the products by customers, it was decided not to include the phases of product use and end-of-life disposal in the study.

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The following materials were used for the construction of the charging station:

Material	Kg	Percentage
Electronic components	0.124	3%
PCB	0.192	4%
Polycarbonate	1.023	24%
Polyurethane	1.239	29%
Other plastic	0.220	12%
Steel and other metals	0.077	9%
Paper and wood	0.831	19%

Impacts

As the table below shows, the greatest impacts for the production and transport of the 7 kW Caro Series are not related to greenhouse gas emissions, but rather to water pollution. The highest values were recorded for marine and freshwater eco-toxicity parameters, as well as human carcinogenic toxicity. In particular, most of the product's impact stems from the extraction and refining of the metals used, while a significant portion still depends on the energy consumed to produce the semi-finished products, as a considerable amount of this energy is still derived from fossil fuels.

Impact	Unit of measurement	Value
Global warming	kg CO2 eq	120
Ozone depletion	kg CFC11 eq	6.81E-5
Ionising radiation	kBq Co-60 eq	10.7

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Ozone formation, human	kg Nox eq	0.374
Fine particulate matter	kg PM2.5 eq	0.261
Ozone formation, terrestrial	kg Nox eq	0.385
Terrestrial acidification	kg SO2 eq	0.535
Freshwater eutrophication	kg P eq	0.129
Marine water eutrophication	kg N eq	0.00591
Terrestrial eco-toxicity	kg 1.4-DCB	886
Freshwater eco-toxicity	kg 1.4-DCB	55.6
Marine water eco-toxicity	kg 1.4-DCB	73.4
Human carcinogenic toxicity	kg 1.4-DCB	8.3
Non-carcinogenic human toxicity	kg 1.4-DCB	875
Soil consumption	m2a crop eq	4.66
Use of mineral resources	kg Cu eq	2.94
Use of fossil resources	kg oil eq	31.8
Water consumption	m3	3.34

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22kW Corebox charging station

Functional Unit

The product for the assessment is a DC three-phase charging station from the 22kW Corebox Series.

The study was conducted by considering the entire product, including the cable and charging gun, as the functional unit.

Type of study

This study adopts the "cradle-to-gate" principle to analyse the carbon footprint according to the standards issued by EPD Italy, namely the PCR Core 007 – Electronic and electrical products and systems and Sub PCR 017 – Charging stations. This means that the system boundary should include all greenhouse gas emissions that occur from the raw material input to the delivery of the product at the ZCS plant. Specifically, the study includes GHG emissions generated in the following processes:

1) Formation, extraction or conversion of raw materials, including energy consumption and direct GHG emissions related to the formation of raw materials;
2) Production processes, including consumables used;
3) Company infrastructure, comprising factories, office buildings, warehouses, etc.;
4) Transportation by road, air, water, rail or other means;

The study has not yet been certified by third-party entities, but will be verified by EPD Italy.

Assumptions

The main assumptions of this study were based on PCR Core 007 – Electronic and electrical products and systems and Sub PCR 017 – Charging stations.

Due to challenges in monitoring the end-of-life disposal and recycling phases, no reliable projections are available. Considering also the uncertainty surrounding the actual use of the products by customers, it was decided not to include the phases of product use and end-of-life disposal.

The following materials were used for the construction of the charging station:

Material	Kg	Percentage
Electronic components	12.179	27%
Plastic	2.467	5%
Polycarbonate and polyurethane	0.636	1%
Glass	0.286	1%
Steel and other metals	25.103	56%
Paper and wood	4.555	10%
Electronic components	12.179	27%
Plastic	2.467	5%

Impacts

As the table below shows, the greatest impacts for the production and transport of the 22 kW Corebox are not related to greenhouse gas emissions, but rather to water pollution. The highest values are recorded for marine and freshwater eco-toxicity parameters, as well as human carcinogenic toxicity. In particular, most of the product's impact stems from the extraction and refining of the metals used, while a significant portion still depends on the energy consumed to produce the semi-finished products, as a considerable amount of this energy is still derived from fossil fuels.

Impact	Unit of measurement	Value
Global warming	kg CO2 eq	1,150
Ozone depletion	kg CFC11 eq	0.000521
Ionising radiation	kBq Co-60 eq	107

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Ozone formation, human	kg Nox eq	3.58
Fine particulate matter	kg PM2.5 eq	3.08
Ozone formation, terrestrial	kg Nox eq	3.71
Terrestrial acidification	kg SO2 eq	6.84
Freshwater eutrophication	kg P eq	1.17
Marine water eutrophication	kg N eq	0.0595
Terrestrial eco-toxicity	kg 1.4-DCB	2,0600
Freshwater eco-toxicity	kg 1.4-DCB	496
Marine water eco-toxicity	kg 1.4-DCB	654
Human carcinogenic toxicity	kg 1.4-DCB	137
Non-carcinogenic human toxicity	kg 1.4-DCB	8,020
Soil consumption	m2a crop eq	49.4
Use of mineral resources	kg Cu eq	31.7
Use of fossil resources	kg oil eq	289
Water consumption	m3	10.2

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