LIFE CYCLE ASSESSMENT OF PORTABLE POWER SUPPLIES

White paper Instagrid ONE

Instagrid

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Life Cycle Assessment – A Quantitative Approach to Sustainability

Companies are increasingly adopting more sustainable practices, while the global regulatory environment continues to push for stricter requirements, particularly around emission reductions. Since a large share of emissions is linked to products themselves, it is essential to focus on the entire product life cycle and move beyond vague sustainability claims. This calls for a quantitative, data-driven approach.

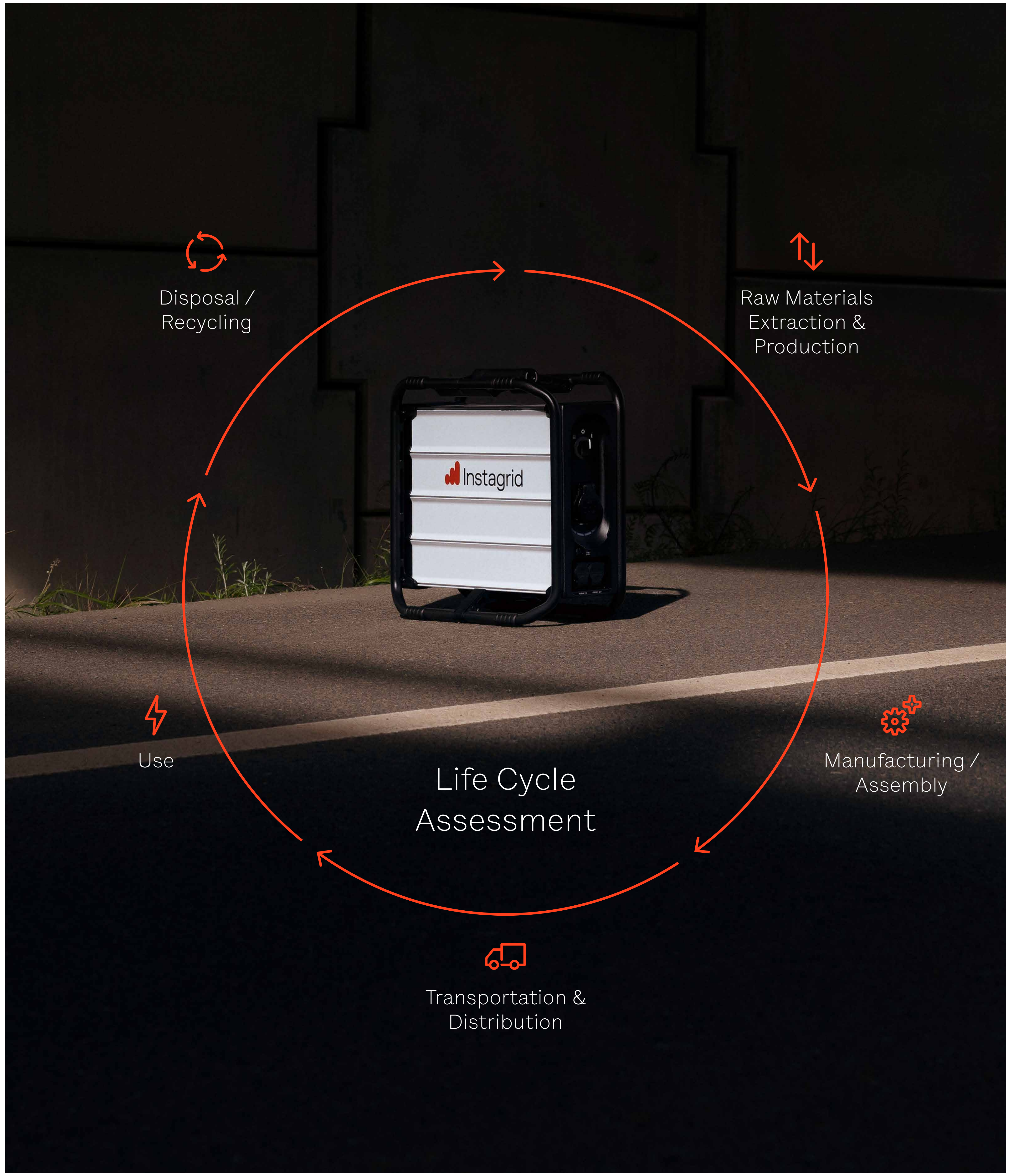
Quantifying Impact

Life Cycle Assessment (LCA) is a widely recognised methodology for quantifying the environmental impacts of a product across its entire life cycle - from **production** (raw material extraction & production and manufacturing), **transportation** & **distribution**, **use**, and **end-of-life**.By accounting for the impacts of these factors in the Life Cycle Inventory and then the Impact Assessment stages, an LCA forms the foundation of a credible and transparent approach to product sustainability.
By providing visibility into the most impactful life cycle stages, LCA helps prioritise actions, inform design choices, and guide greener manufacturing and product development with quantifiable data outputs.

Why share our approach?

Tackling climate change requires more data and more LCAs. Yet, getting started and knowing where to focus can be challenging. That's why we're sharing our quantitative approach to sustainability: because we believe in the power of shared knowledge and open dialogue. We hope it inspires you to take action too.

LET'S TALK?
sustainability@instagrid.co



Scope and Methodology

Our product LCA started as part of the European Union co-financed EU LIFE project (June 2019–June 2022) focused on clean air. Building on this foundation, the LCA study was first certified in early 2023 by TÜV NORD[1], in accordance with ISO 14040 and ISO 14044 standards. In early 2025, we received an updated certification, reflecting the most recent version of our study and reaffirming its methodological robustness and transparency.

The primary goal of the LCA was to analyse the environmental impacts of Instagrid's portable power supply (Instagrid ONE) over its entire life cycle, support sustainable product development, and establish a robust baseline for benchmarking against small combustion generators.

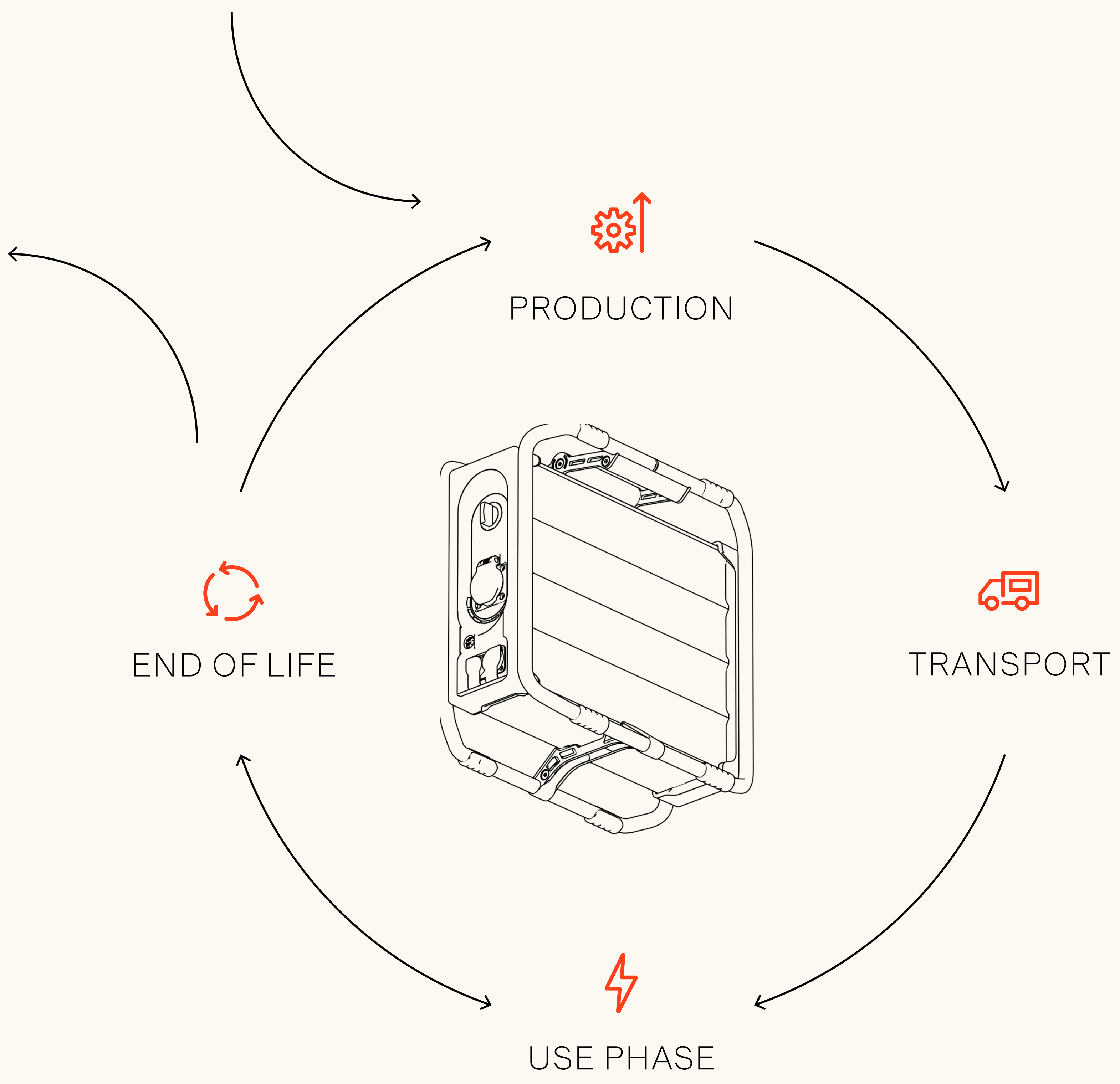
The system boundaries cover all activities from extraction of raw materials through processing, manufacturing, distribution, use, and end-of-life (cradle-to-grave). The product life cycle is divided in four main phases:

- production
- transport
- use-phase
- end-of-life

The functional unit is defined as 1 kWh of total energy delivered by the product over its entire service life.

Emission measurements for representative gasoline and diesel generators based on equivalent load profiles were conducted in collaboration with the external partner HLNUG[2] in 2023. Additionally, TÜV NORD measured fuel consumption and verified selected emission results to ensure data robustness and consistency.

The FIT Umwelttechnik GmbH conducted **a product recycling and dismantling study**, and its findings were incorporated into the LCA model.



[1] TÜV NORD - A German based global technical certification service provider
[2] HLNUG - Hessisches Landesamt für Naturschutz, Umwelt und Geologie

Life Cycle Inventory

For a Life Cycle Inventory (LCI), we collected data on all inputs and outputs across various stages of the product's life cycle. The LCI included a Dismantling Analysis and a Composition Analysis. We analysed the data using SimaPro LCA software and the Ecoinvent database, supplemented by primary data from Instagrid's case.

Our **primary data** sources:

- **Manufacturing data:** We have access to annual average data regarding key material inputs, including energy and water and core waste outputs used during the manufacturing of our products.
- **Dismantling Analysis**: We have our battery-based portable power supply dismantled into sub-assemblies, which were further disassembled and analysed into base materials.
- **Composition Analysis**: We assessed a battery cell LCI dataset by gathering information from product material safety data sheets obtained from suppliers and similar product LCAs.
- **Product IoT Data:** We collected IoT data from a broad range of customers (mainly construction companies) to analyse real-world user behaviour.

Examples of our **secondary data** sources:

- We tracked all materials back to **resource extraction**, mainly using the Ecoinvent database.
- We analysed the environmental impact of **product disposal** using Ecoinvent waste treatment data.
- For **lithium-ion batteries**, we adopted a 50:50 mix of hydrometallurgical and pyrometallurgical methods – which are the two key methods for recycling and recovery of valuable metals – based on consultations with battery recycling experts.

Material distribution of Instagrid ONE.[3]

46.1 %
Battery cells

5.0 %
Electronics

0.4 %
Copper

19.6 %
Plastics

1.6 %
Steel & Iron

0.1 %
Others

8.0 %
Paper

20.2 %
Aluminium

[3] Based on product recycling and dismantling study by FIT Institute

Impact Assessment

For the Impact Assessment, we applied the Product Environmental Footprint (PEF) methodology. PEF emphasises region-specific impacts by incorporating spatially differentiated data where available. It is also the recommended method under the EU Battery Regulation.

From the 16 available PEF impact categories, we focused on eight that are most relevant to the application and context of our product. These selected categories are considered the most significant for evaluating the environmental performance of energy systems and portable power supplies.

1

Climate change (kg CO_2e)
Total global warming potential, a measure used to quantify the impact of greenhouse gas (GHG) emissions on global warming over a 100-year timeframe.

2

Acidification (mol H+ eq)
This measures the release of acidic substances (e.g., SO_2, NOx, NH_3) into the environment, leading to acid rain and acid deposition.

3

Eutrophication, freshwater (kg P eq)
This assesses nutrient overloading in freshwater due to excess phosphorus (P), leading to algae blooms and oxygen depletion.

4

Photochemical ozone formation, human health (kg NMVOC eq)
This assesses emissions of non-methane volatile organic compounds (NMVOCs) that react with nitrogen oxides (NOx) under sunlight, forming ground-level ozone (O_3).

5

Ozone depletion (kg CFC_{11} eq)
This evaluates emissions of ozone-depleting substances (e.g., CFCs, HCFCs, halons) that break down stratospheric ozone, increasing UV radiation reaching Earth.

6

Particular matter (disease incidence)
This assesses the effect of airborne particulate matter (PM_{10}, $PM_{2.5}$) on human health, linked to respiratory and cardiovascular diseases.

7

Resource depletion (kg Sb eq)
This assesses the depletion of non-renewable mineral and metal resources.

8

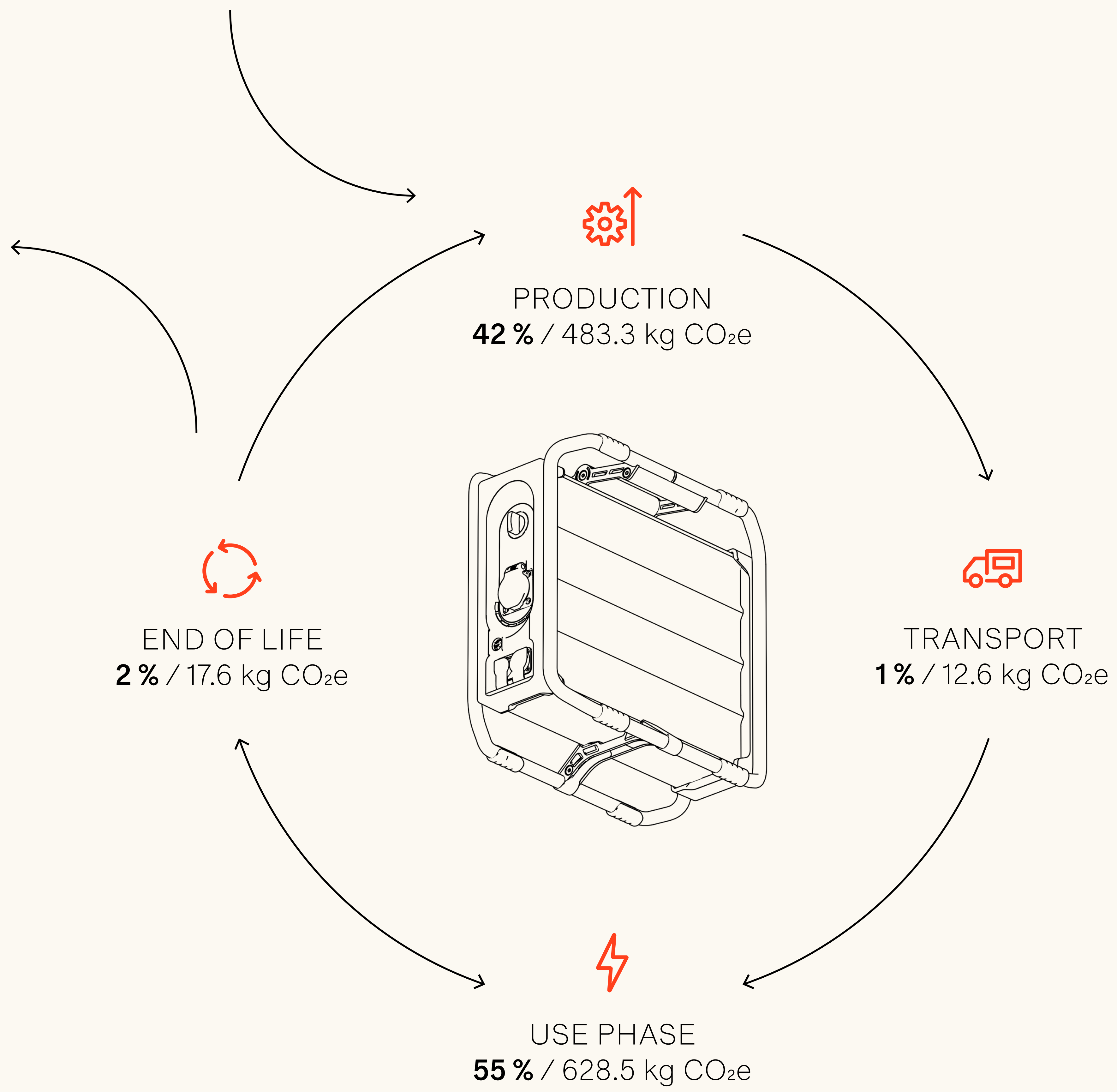
Water use (m^3 world eq)
This quantifies the impact of freshwater consumption on water scarcity and environmental stress.

Instagrid ONE

Our LCA yielded the following results: Over its full product life cycle, Instagrid ONE emits **1,142 kg CO_2e**[4], of which the **use phase contributes 55 %**.

The 'use phase' represents how the product is typically operated after purchase. In our study, we examined real-world usage data collected from a range of professional users across European countries to reflect representative operating conditions.

Instagrid ONE's CO_2e emissions divided into life cycle phases.



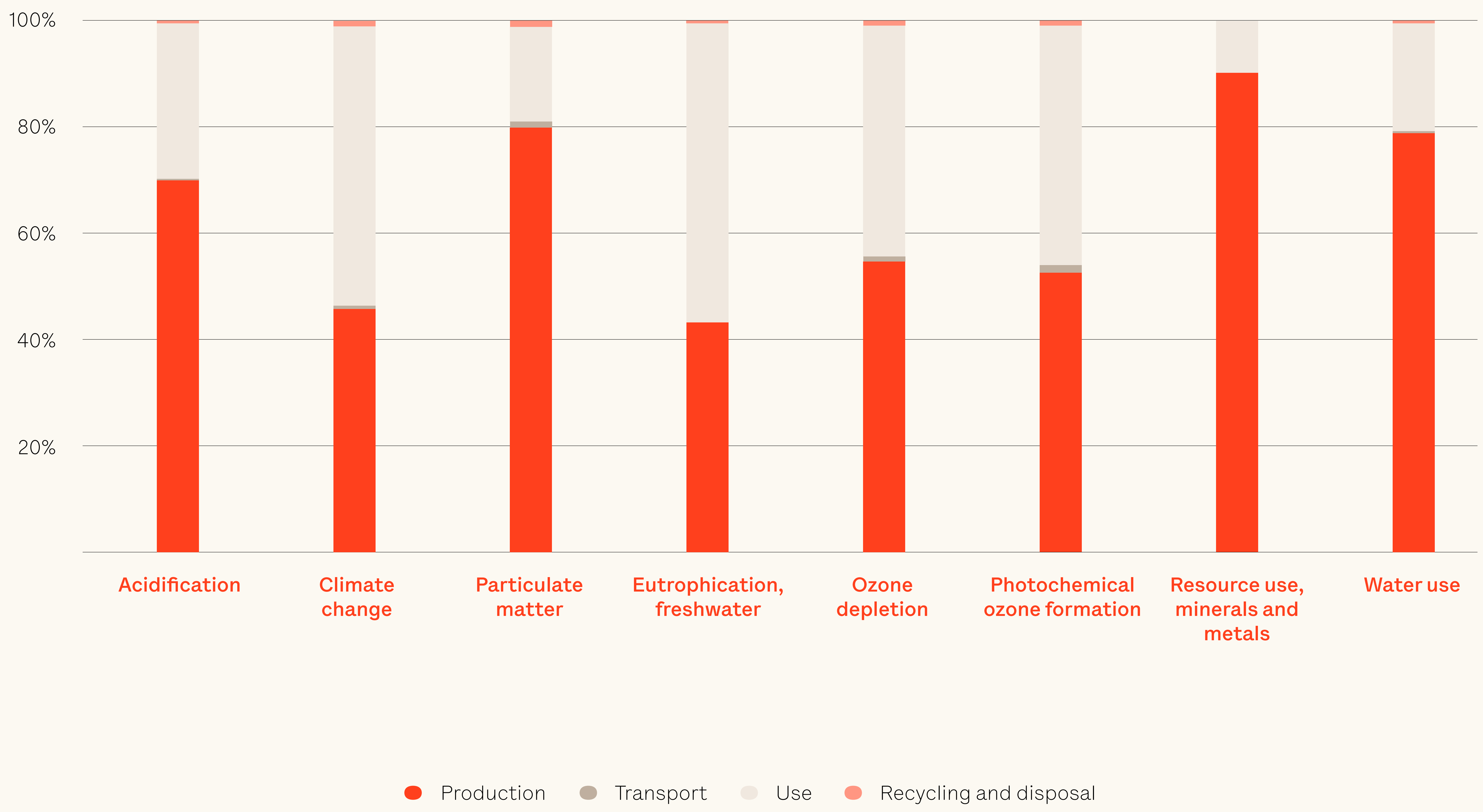
[4] Total life cycle emissions and emissions per life cycle phase are rounded.

Instagrid ONE

By expanding our focus beyond greenhouse gas (GHG) emissions to include selected impact categories, we gained a more holistic understanding of the environmental impacts associated with the life cycle of Instagrid ONE.

The analysis shows that the **production** and **use** phases are the main drivers of environmental impact across the selected categories.

Environmental impacts of life cycle phases of Instagrid ONE assessed with the PEF characterisation method.



Benchmarking: Instagrid ONE vs Diesel and Gasoline Generators

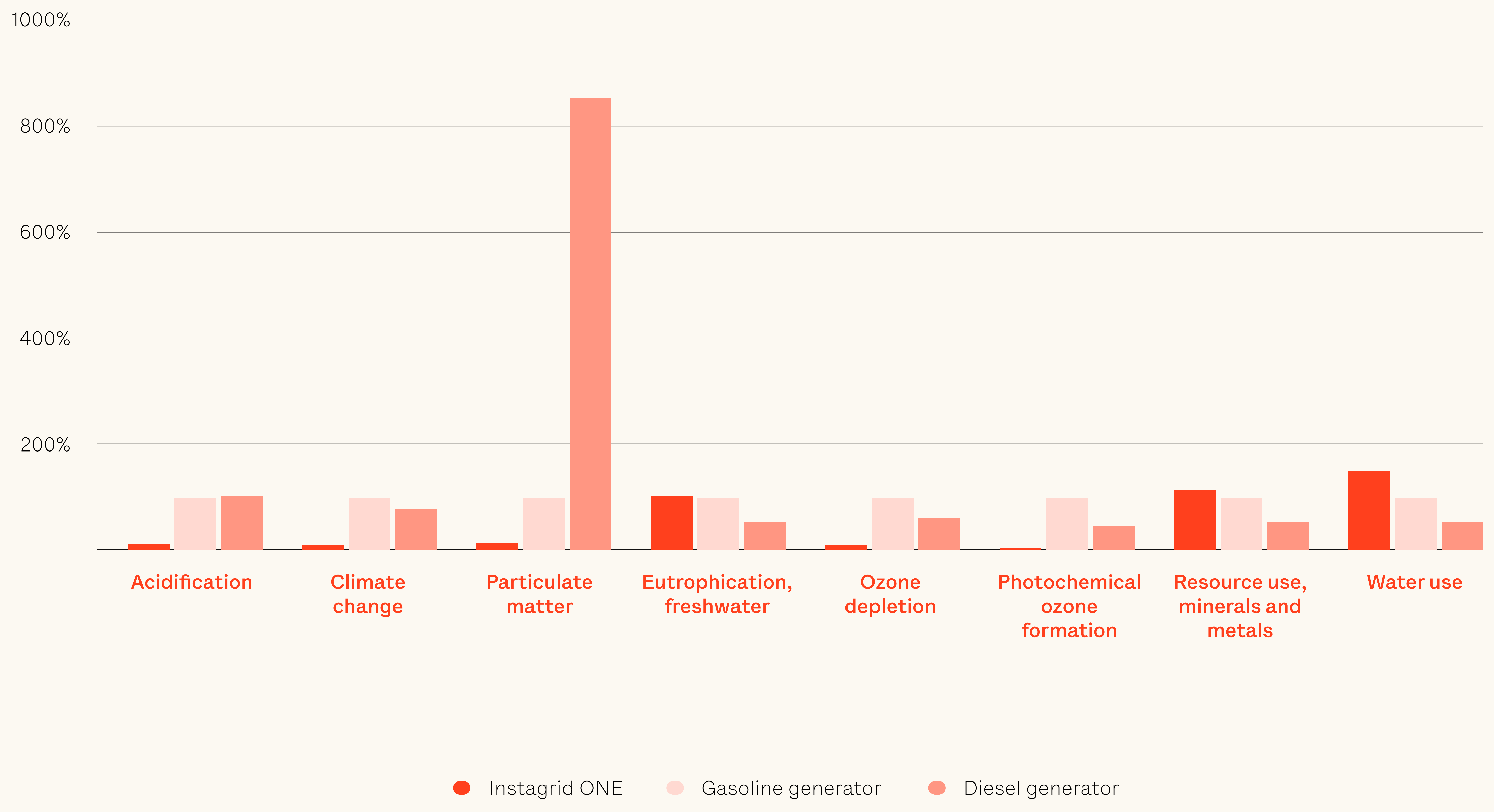
After analysing the life cycle of Instagrid ONE and gathering environmental data for conventional generators, we conducted a benchmarking exercise. To ensure a fair comparison, despite differences in product lifespan and usage patterns, we normalised all results using the measurement of energy delivered (per kWh). This enabled a transparent evaluation across multiple environmental impact categories.

The environmental impact results for diesel and gasoline generators were modelled applying the same methodology. Primary energy consumption and emission measurements were conducted in collaboration with external partners, including HLNUG and TÜV Nord. These were combined with LCA modelling using SimaPro and the Ecoinvent database, applying consistent system boundaries.

According to the LCA model, Instagrid ONE achieves a remarkable **94 %** reduction in total GHG emissions.[5]

Battery-based portable power supplies therefore generally show significantly lower environmental impact across assessed impact categories.[6]

The overall results on all impact categories across the life cycle of the product scope.



[5] Relative environmental impact across the lifecycle of battery-based portable power supplies compared to gasoline and diesel generators when values are normalised by kWh under the assumption of high profile users.
[6] Water usage is a regional topic and impacts areas with scarcity challenges. For the LCA study, there was no primary data available to get a clear picture. Instagrid's supply chain choices aim to minimise this impact and we continue to further investigate it.

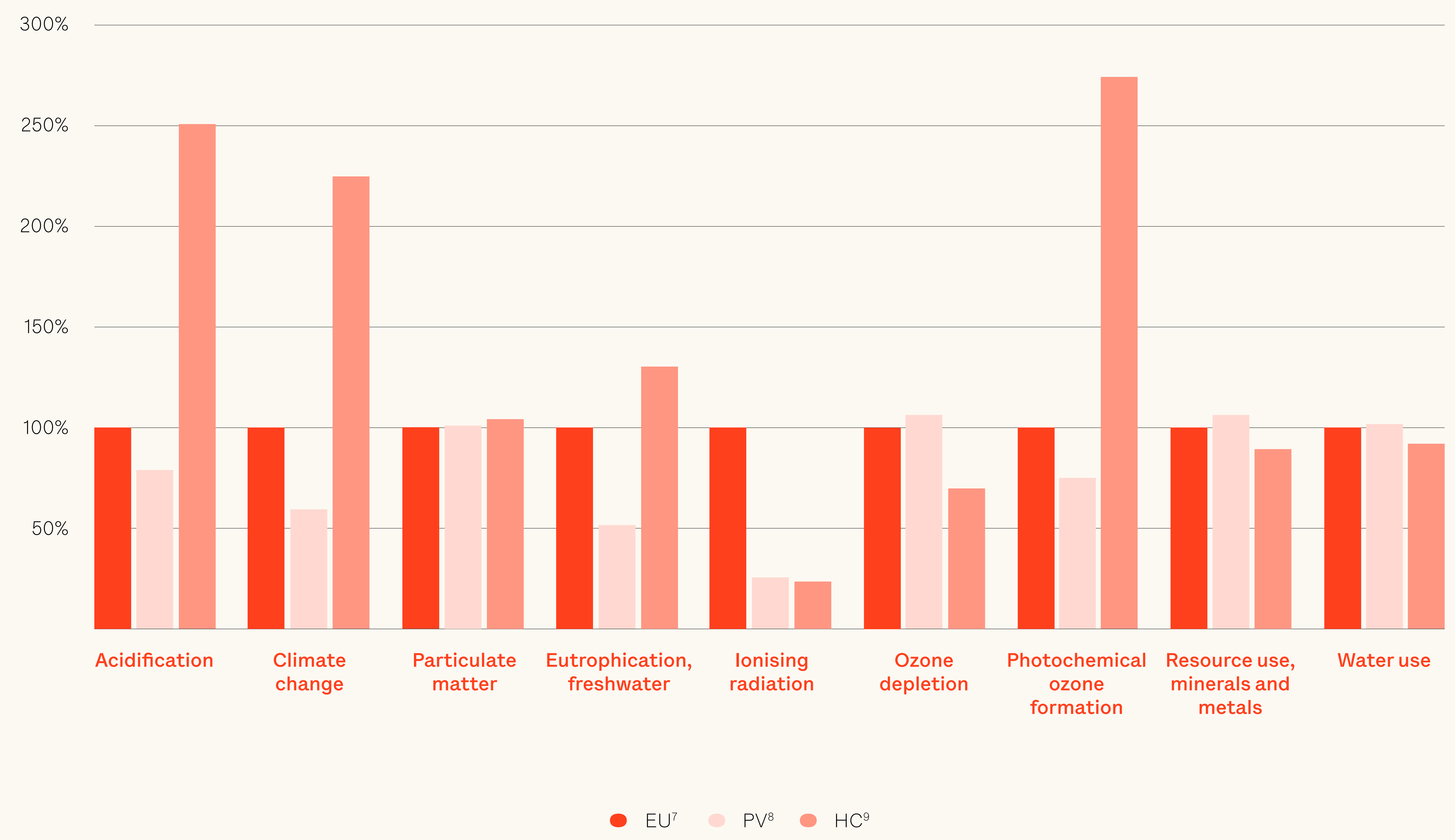
Sensitivity Analysis

To ensure the reliability of our results, we conducted a sensitivity analysis, systematically varying key parameters such as user profiles (high vs. average profile users), battery life cycle, and charging scenarios. Among these, the charging scenario has the strongest influence on overall results.

Charging Instagrid ONE with renewable electricity, such as solar power, significantly reduces its environmental footprint. Our sensitivity analysis shows that solar charging (PV) lowers climate change impacts by 38 % compared to using the EU electricity mix, while charging with hard coal (HC) increases emissions by 25 %. This pattern holds true across multiple impact categories, including acidification and photochemical ozone formation.

In total, using solar energy reduces the life cycle impact in five out of nine assessed categories. Notably, electricity source also influences impacts like eutrophication and ionising radiation, the latter due to nuclear power in the EU grid mix (EU). In contrast, impacts on water use and resource depletion remain mostly unaffected by the charging scenario, as these are dominated by the product's production phase.

Environmental impact of Instagrid ONE charged with different electricity sources.



[7] EU grid mix (EU)
[8] Photovoltaic/solar charging (PV)
[9] Hard coal (HC)

Limitations and Challenges

Understanding the limitations and challenges of LCA is essential, given its data-intensive nature and the complexity of product life cycles. In our study, several aspects required particularly careful consideration.

- **Primary data:** Collecting primary data requires targeted measurements or surveys involving suppliers, customers, or monitoring equipment at production facilities. Although it offers high relevance and accuracy, the process is resource-intensive and time-consuming.

- **Secondary data:** The quality and credibility of the entire assessment often depends on selecting appropriate data from LCA databases. This demands a deep understanding of material composition and production processes to ensure a representative and meaningful model.

- **Impact categories in practice:** Some categories, like water use, are highly regional in nature. Although crucial for strategy development, obtaining accurate, site-specific data, especially from suppliers, can be difficult. The environmental impact may vary significantly depending on sourcing locations.

- **Feedback effect and lack of comparability:** Specific recycling methods might increase CO_2 intensity but contribute positively to circularity. Therefore, it's hard to compare the impacts of different recycling methods solely based on CO_2 intensity, but differentiated indicators are needed.

What we have learned: Prioritising high-impact initiatives

Based on the LCA findings, here are our key takeaways for the near future.

As our product portfolio grows, we will expand LCA coverage to include new products and adapt our methodology to align with the evolving requirements of the EU Battery Regulation.

In parallel, we aim to scale up the use of IoT technologies to enhance the scope and precision of our primary data collection.

Biggest Impact Projects

Our commitment to sustainability means tackling what matters most. Through the LCA, we've pinpointed plastic components as major contributors to our carbon footprint. That's why we're investing in circular alternatives – such as bioattributed and recycled plastics – to drive meaningful change in our product design.

Emission Saving Model

We developed an Emission Saving Model to demonstrate the environmental benefits of switching to battery-based portable power supply. Built on key insights from our LCA, such as lifetime GHG savings and real-world usage data, the model provides customers with tangible figures. It clearly shows how charging behaviour can significantly influence emission reductions.

Sustainable Product Development Plan

We have developed a Sustainable Product Development Plan to review designs with product owners, engineers, and designers. The plan helps us identify ways to reduce the product's overall environmental impact throughout its lifecycle. For example, using recycled aluminium for the housing of Instagrid ONE reduces its carbon footprint by 48% compared with using virgin aluminium.

Second Life Strategy

We focus on making our products last longer, as indicated by our sensitivity analysis, which demonstrated a notable reduction in life cycle emissions. Accordingly, we are actively developing a reuse strategy for our batteries to maximise lifespan.

Supplier Data

We collaborate with key suppliers to collect environmental data for LCA and impact assessments. This enables us to identify and implement measures to reduce the environmental footprint during the production phase.

Iterative Improvement

We are continuously refining our LCA modelling by improving data collection methods and ensuring methodological consistency. We aim to make our product assessments more transparent, comparable, and aligned with evolving regulatory requirements across the product life cycle.

Want to know more? Download our latest impact report or send us a message.
We like to answer all your questions – including the tough ones! sustainability@instagrid.co

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