Life Cycle Analysis

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Introduction

Ampler Bikes is an electric bike company with focus on clean design and durability. This is our first Life Cycle Analysis (LCA) report. We calculated the carbon footprint of our bike “Stellar” with the support of GreenDelta. The aim is to give an overview of the climate impact of our bikes. We’ll use the results to identify “hot-spots” and set goals for emission reductions for the year 2025.

But our action is not enough - to limit global warming to 1.5 degrees, we need to change the whole cycling & mobility industry. That’s why we aim to be as transparent as possible about how we calculate the impact and what we learn along the way. We hope this helps to scale up climate action with the speed we need.

Contents

About the Life Cycle of Bikes

All products come from somewhere and go somewhere when we throw them out. This "life cycle" is usually broken down into five different phases: raw materials are extracted and refined into parts, products are manufactured, transported, used, and thrown out. We'd like to start from the beginning though – design that is behind all of this.

Product Life Cycle

Design

Design is where you make choices about everything related to the product – what materials to use, who can make those materials, how long will it last, and more. Best designers think about the whole life cycle of the product. They ask: "What kind of environmental and social impacts will my design create?" At Ampler, we want to make high-quality bikes that last long and can be easily modified to fit your life. We keep it simple and leave out all unnecessary things – no big frames to keep the bike light, no oversized tires that don't serve a purpose on city streets.

Materials extraction & refining

Our bikes' production starts where most of the stuff starts – in mines and factories. Various raw materials are extracted from the ground (or cultivated in the case of natural rubber for the wheels) and refined into materials that can be used in the production of components.

Manufacturing

Supply chain is where things can get complex. We have 40+ supply chain partners for Stellar components. Some of them are fairly new suppliers to us as we changed our parts this year to improve the biking experience even more. While we don't know (yet) exactly how the components are made by some of the suppliers, we're always trying to see if the supplier aligns with our values (including caring and sustainable). Most of the components are transported from Taiwan by air freight to our assembly plant. We always need to balance between securing the supply of components and offering reasonable bike delivery times to our customers.

Assembly

We assemble and package our bikes in Estonia, Northern Europe. This gives us control over assembly quality and creates jobs at our homebase. At our factory, we use powder coating to paint our bikes – this gives durability for the frame.

Product use

After a test ride and careful inspection, the bike gets shipped to the customer. All of our customers are encouraged to take care of their bikes and the battery to prolong their lifetime. We hope you love your bike and use it as much as possible for your daily trips! Our workshops offer regular checks and repair services to keep you on the road.

End of life

When the bike cannot be repaired anymore, it is sent out for final disposal (the "end of life" phase). This can be recycling, burning or landfilling. When disposed responsibly, the material is sent to recycling and becomes a part of a new product. While we cannot control how our customers dispose their bikes, we take responsibility over the end of our bikes' life by supporting third party partners (such as GRS in Germany) to collectively take care of recycling of the materials. When the bikes are sent to a recycling centre, the parts are dismantled and sorted out for further processing. And so, the material finds a new purpose.

What is an LCA?

LCA stands for Life Cycle Assessment or Life Cycle Analysis – it's a method to calculate and assess the environmental footprint of products in a quantitative way. Guided by the numbers, companies can identify where to focus their efforts, find ways to reduce emissions and be more efficient. After all, we cannot do everything at once. This way, we know what to do first to have a higher impact.

To make sure that no negative impacts are missed or shifted to other life cycle stages, it's best to do a comprehensive assessment. Meaning all the life cycle stages are investigated in the LCA. Likewise, if we know the positive impacts, we can focus on harnessing those if they are big enough. This is why we focus on cradle to grave for our bikes. This means calculating the impact from metals and other materials all the way to the final disposal of the bike.

We've also included scenarios at the end that depict the impact that customers have, depending on how they use their bikes.

At Ampler, we decided to do an LCA with the following objectives in mind:

- Understand the environmental impact and hotspots of our bike production (we focus mainly on global warming potential, resource scarcity and ecotoxicity)
- Support us in making decisions on even better ecodesign
- Provide transparent and credible information to report our product carbon footprint, and invite our peers to use our analysis as a steppingstone for industry improvement

How is Stellar’s impact calculated?

The full lists of materials covered in this LCA can be found in Annex 2. We assume that the lifespan of the bike is 40 000 km (this is also the “functional unit” in LCA terms).

This LCA covers all stages of the value chain, from metal to pedal and final disposal! Aluminium is assumed to be wrought aluminium, and go through sheet rolling and extrusion. Steel processing is represented by hot rolling and wire drawing. Plastic parts go through injection moulding. All the undefined plastics are modelled with nylon 6.

There are various methods for impact assessments. For our bikes, we use ReCiPe 2016 Midpoint (cut-off). While we have results for all impact categories that this method provides (Annex 4 provides an overview for the curious), the results below focus on climate change, resource scarcity and marine eco-toxicity. To get a full overview of the methodology, you can look over Annex 1.

The LCA does not contain supplier specific data as the purpose is to have the first overview of impact hotspots. We hope to update the LCA with more specific data for the hotspots in the coming years and expand the analysis to all of our bike models.

It is also notable that the methodology chosen (cut-off) accounts only for the “first life” of the product and cuts off the second life, i.e. recycling of materials into new products. So in the case of secondary materials, the one who uses the recycled content in their product does not have to carry the burdens from its first life.

Bike model	Stellar
Weight	17,8 kg
Range	70 km avarage
Battery	336 Wh Li-ion battery

Data details & limitations

The hard part of understanding the product's impact is often finding the data. It's about asking: "Can I get accurate information?" and "Is my model comprehensive enough to see the big picture?" For Ampler, we decided to do a basic model with industry average data from pre-existing databases (ecoinvent v. 3.8 cut-off) and get enough information to guide our further focus.

We chose to report the transport to customer as a separate category, and use the distribution from Estonia to a Berlin-based customer as a case study. However, distribution to an overseas customers by air freight would naturally cause higher emissions.

This LCA does not represent the full impact of running our business, such as Ampler Bikes showrooms and offices impact. More specifically, the data does not include:

- Processes at Ampler Bikes such as business travels, R&D activities or other indirect emissions
- Ampler Bikes infrastructure e.g., the use of buildings or equipment used in the production
- Emissions associated with showrooms, workshops and offices. Ampler started as an online retailer and ecommerce is still the main channel for sales. Nonetheless, we are expanding our physical stores and will re-evaluate our methodology in the future.
- Emissions associated with the electricity use of personal computers and the online shopping platform are not currently included in the product carbon footprint.

The reader should note that comparing the carbon footprints of similar products is challenging at the moment as companies use different methodologies. For example, this LCA calculates the impact of various factors in the use phase that we have not seen in LCAs by other bike companies: these include construction and maintenance of roads, emissions from tyres and road wear, as well as maintenance of the bikes. However, the LCA does not cover the potential changes in the wider system (i.e. it's not consequential) and neither the rebound effects such as increased electricity use.

Life cycle assessment (LCA) results for the Stellar

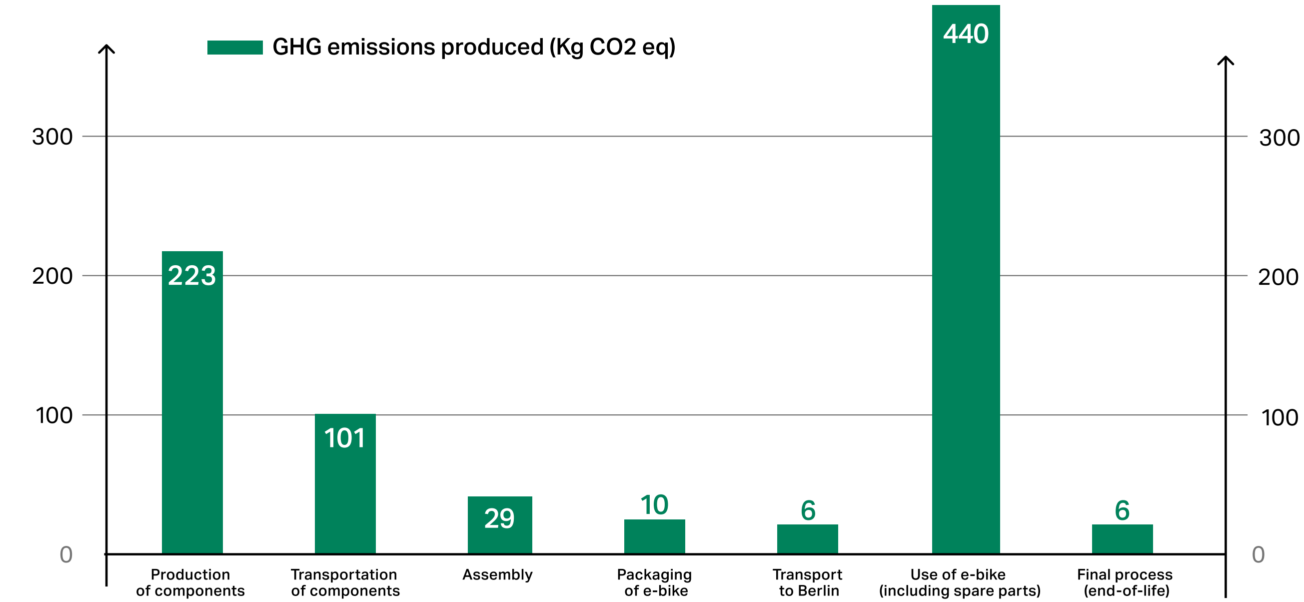
Starting with the Stellar, we aim to measure how much greenhouse gas emissions we cause when making our bikes. With this data, we can identify the “hotspots”, improve our product design and focus our efforts for emission reductions.

Climate change

Based on our analysis, the Ampler Stellar produces 815 kg of CO_2 eq* emissions. This is mainly caused by two lifecycle stages: production of components and use of the bike. Within the production phase, the frame causes the highest impact from all parts. Most of the impacts come from the use phase though: the major share is caused by the production of the spare parts, followed by electricity use (German energy mix).

The transportation phase causes smaller emissions; most of the climate impact in this phase is due to air freight from suppliers to final assembly in our factory. Assembly at Ampler factory and the end-of-life treatment have a smaller impact in comparison to the total carbon footprint.

**CO2-eq stands for carbon dioxide equivalents. This is a measure that is used to compare the emissions from various greenhouse gases based on their potential to warm the climate globally. Different greenhouse gases cause a different kind of greenhouse effect; some can warm the climate more than others. That’s why the amounts of other gases are converted to the equivalent amount of carbon dioxide with the same global warming potential.*

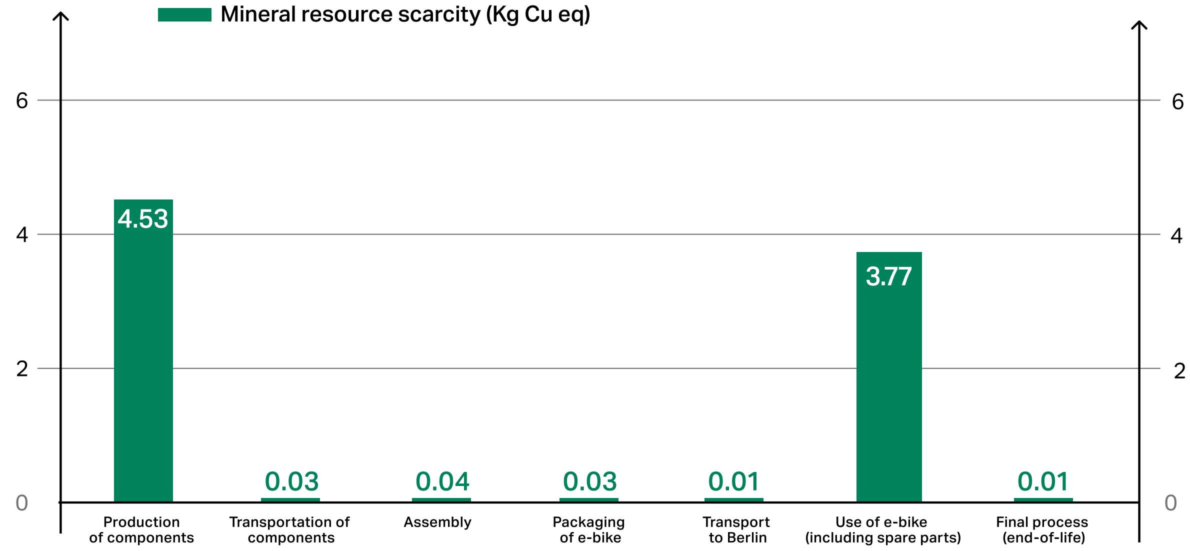


Contribution to GHGs (%)	27%	12%	4%	1%	>1%	54%	>1%

Resource scarcity

Looking into the materials use, the Stellar causes most of the mineral resource scarcity in the production of parts, including original parts and spare parts. The parts that deplete the resources the most are battery, motor and charger. The main impact drivers are bauxite, ferronickel and iron ore – these are used to make aluminium and steel. The impact is measured in copper equivalents (8.4 kg Cu eq*) so the data has limitations and the impact is likely even higher.

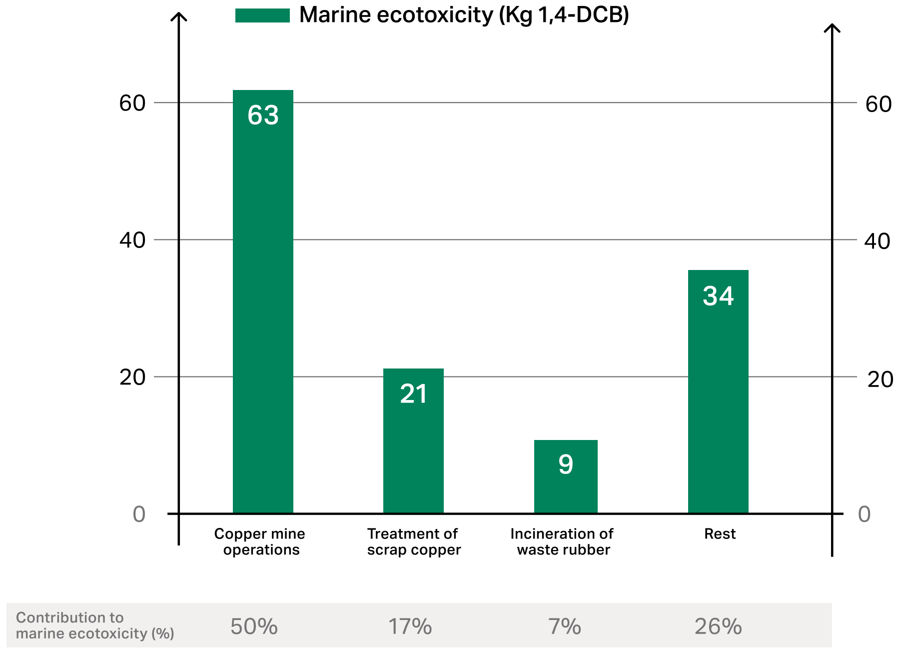
**Similar to CO2 equivalents, mineral resource scarcity is also calculated by converting the impact of various minerals to the impact of copper. However, rare earth minerals are not well represented in the chosen dataset and need further exploration.*



Contribution to resource scarcity (%)	54%	>1%	>1%	>1%	>1%	45%	>1%

Marine ecotoxicity

This may come as a surprise. Turns out that when we normalise all the impact categories (i.e., put all the different impact categories and their metrics “on the same level”), ecotoxicity of marine waters comes out as the highest impact category causing harm. It measures the toxic effects to marine ecosystems by the impact caused by chemicals. This is mainly due to three processes along the life cycle: production of battery (copper mining is the culprit here), incinera-tion of scrap copper as well as incineration of tires at the end of their life (especially zinc in the tires). These processes together make up a whopping 74 % of the impact to marine ecosystems.



Closer Look at the Carbon Footprint

Looking deeper into the production processes, most of the carbon footprint comes from aluminium extraction and processing. Depending on the energy source used, this has more or less higher impact than the rest of the material production. We've modelled the impact with average industry data, which assumes that the use of non-renewable energy is high.

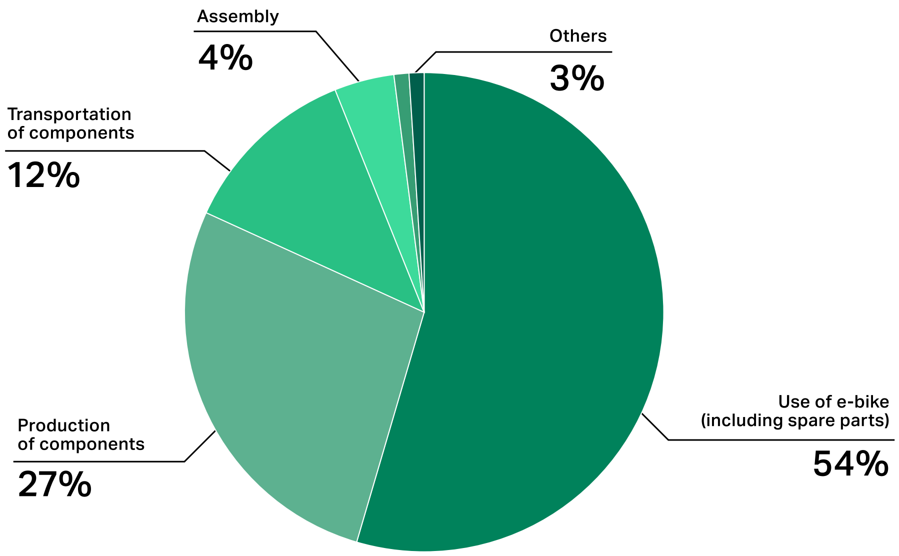
Life cycle stage analysis

Impacts generated at the production stage are mainly caused by electricity consumption with fossil fuels, especially related to the production of aluminium and steel components. Overall, production of components causes 27% of the global warming impact.

Transportation emissions from the suppliers to Ampler factory add up to 101 kgCO2-eq, which is equivalent to 12% of total potential global warming potential emissions, mainly due to air freight. On the other hand, the assembly of the bike in Estonia contributes about 4% of the climate impact, with the main causes being electricity consumption for painting and heating with natural gas. Packaging adds only a small contribution (1%), as does transport to customer (also approximately 1%), depending on the location of the customer.

The bike use causes 54 % of the global warming potential emissions. The biggest impact comes from repair and spare parts (36%) and electricity use (13%), assuming average grid energy in Germany. The main causes in the repair phase are the substitution of aluminium and steel components (such as rim, chain and cassette), and production and disposal of materials for tire substitution. Finally, the road use causes about 4% of the impacts. Resources used for the care of the bike (cleaning agents, lubrication oils, etc) have minor impact.

Greenhouse gas emissions at the end-of-life add up 1% of total global warming potential emissions, due to waste treatment of rubber, battery and plastics.



Material analysis

The main climate impact is caused by the frame, followed by the charger and the wheels (more specifically the rims in the wheels). After these, fork, battery and crankset also have high greenhouse gas (GHG) impacts.

Global warming potential	How much (kg CO2 eq)?	Why this much?
Frame	33	Aluminium production and related energy use
Charger	25	Inductor and capacitor production and their related electricity demand
Rims	16	Aluminium production and related energy use
Fork	14	Aluminium production and related energy use
Battery	13	Cathode production; related aluminium use and energy use; anode production; related copper use and particularly smelting processes
Crankset	13	Aluminium production and related energy use

The production of frame leads to a total consumption of 33 kg of CO2e, mainly due to the use of much electricity in aluminium production. Likewise, rims contribute 16 kg and fork 14 kg of GHG emissions due to aluminium. Given that aluminium is easily recyclable, it's important to see this at a system level, where other companies would be using recycled aluminium. Thus, most of this impact could potentially be recovered through recycling.

Charger and battery also contribute to some of the biggest negative impacts on global warming out of the whole bike, leading to 25 and 13 kg of GHG emissions respectively. The production of battery also requires aluminium, along with copper and lithium, which cause the most emissions. The production stage of the charger, which includes the inductors and capacitors, also require high amounts of electricity.

Crankset contributes a little over 1 % of the whole carbon footprint, respectively, also due to aluminium extraction and processing.

Light-weight design

From the start of Ampler, we focused on making the bikes light. It made sense since riders could carry their bikes up the stairs and over other obstacles, and gain access to more places. From the material point of view, this kept the need for material minimal while offering a kilometre-range that's well-suited for moving around in cities.

From the scenario we built, we estimate that the Ampler Stellar G2 has an approximately 10% lower carbon footprint than the average e-bike of 25 kg, mainly due to using less materials and having a lighter weight.

Impact category	Light-weight: Ampler Stellar	Heavier weight: 25 kg	Difference %
Climate Change (kg CO2 eq)	815	894	10%
Mineral resource depletion (kg Cu eq)	8.44	10.08	19%
Marine ecotoxicity (kg 1,4-DCB)	127	150	18%

Sharing responsibility with our customers

This LCA illustrates our impact, but it also shows how our customers can make a positive impact. Although we can't know for sure how our customers take care of the bikes and what energy source they use to charge them, we can help to guide them to make better choices.

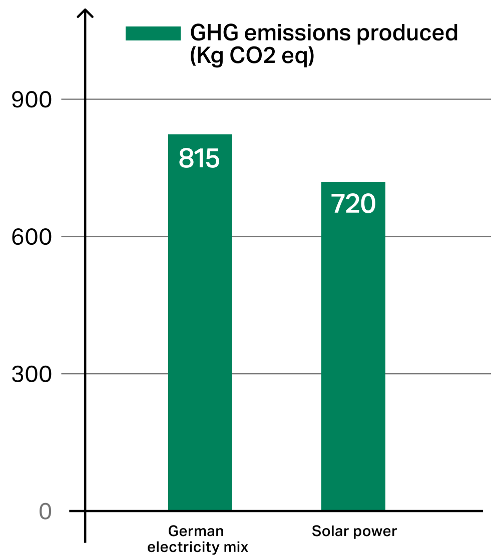
Clean energy

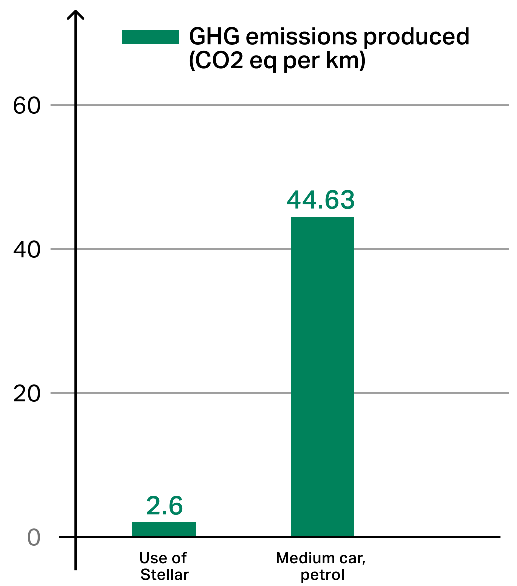
Charging your bike with clean energy is a high-impact choice. In the lifespan of 40 000 km of Ampler bike, each customer can have approximately 95 kg less CO2 impact, if they charge with solar power instead of the average energy mix in Germany.* This might sound small, but it's a drop of 12% in the bike's carbon footprint.

Conscious travel

Using the bike instead of a car is the best positive impact you can make. While we're not expecting every person to get rid of their car completely, electric bikes can replace short trips for most of the time - at least up to 10 km. It's about the small choices you make every day. How do I go to work today? How do I go to the super-market? We put the following comparison together to show how you help the planet if you choose a bike instead of a car for your next trip. Stellar's impact is calculated with the average German electricity mix.

**We used Germany as a case study as most of our customers are based in Germa-ny.*





Sensitivity analysis

How confident are we about the results? Let's face it, we don't have all the data to get to 100% accuracy. The point was to dig deep enough to understand our biggest hotspots. Then we checked how alternative choices in the model would change the results (a.k.a. we did a sensitivity analysis).

Using solar power rather than the average German electricity grid to charge the bike would decrease global warming potential by 12%, to 720 kgCO2-eq. This would shift hotspots more towards component production and transportation. This is due to the use of fossil fuels in the German electricity grid across the country. Most likely the share of renewables will increase in Germany during the lifetime of the bike, so this is a conservative modelling approach.

Likewise, using renewable energy rather than the average Estonian electricity grid in the assembly would decrease global warming potential by approximately 21 kgCO2-eq, reducing the carbon footprint by 2-3%. Estonia has one of the most fossil fuel intensive grids in Europe, which is why this would produce notable changes for climate change results.

An alternative production model of aluminium ("average metal working for aluminium") was tested with the heaviest part (the frame) and it does not produce significant changes to any impact categories. Particularly for climate change, this causes an increase of 4 kgCO2eq compared to the baseline assumptions (i.e. extrusion and sheet rolling). Since the difference is insignificant, the reasons are not elaborated further.

Alternative scenarios were also examined in the case of production location. Assuming the aluminium for the frames would be produced in Europe compared to global, the results show the environmental impacts reduce for almost all of the impact categories. For the main three indicators, global warming potential would be reduced by 30 kg CO2-eq, marine ecotoxicity by 3 kg 1,4-DCB, and mineral resource scarcity by 0.38 kg Cu eq. The impact for global warming reduction by 3-4% is mainly due to the lower intensity of greenhouse gas emissions in the EU energy mix in comparison to global mix and particularly China.

In the case of changing the inbound logistics of the frame, motor and battery (the heaviest parts) from air freight to a combination of air and train, global warming decreases by 3-4%, or by 30 kgCO2eq. Thus, transport choices from supplier to Ampler, especially if scaled up to all parts, have the potential to significantly change the carbon footprint results.

Changing transportation distances for outbound logistics (i.e. bike sent to customer) does not significantly change the results. This was tested by changing the transport from Estonia to Portugal (instead of to Berlin, Germany). The global warming contribution from customer transport increases from 1% to 2%, adding 12 kg CO2 eq more. However, it remains as one of the three smallest contributors of all life cycle phases to the carbon footprint.

Given that bikes have parts that need maintenance and some parts eventually wear out, different care and repair scenarios were also analysed here. The parts that are assumed to be replaced if care is neglected are chain (replaced 2 additional times), tires, tubes, cassette and brake disc (replaced 1 additional time). The environmental impact increases slightly mainly due to increased use of rubber and its associated waste (tires), increased use of steel (chain, cassette and brake disc) and transport of components from suppliers to customers. For global warming potential, the increase would be approximately 2% with less bike care and more repair.

Looking ahead

To wrap it up, our top impact hotspots are the use of virgin aluminium, air freight, carbon intensive energy (for manufacturing and bike charging) as well as waste disposal (burning of tires particularly). These are the main areas we need to improve to reduce our impact. However, some improvements will need collaborations, as the issues are not in our direct control.

Currently we have only estimates with industry average data – we'll be crunching more numbers as we learn more from our suppliers and customers. We also see more regulation being discussed, such as the new Lithium-ion battery regulation, which would require battery "passports". This would push more companies to trace their supply chains – as more companies start asking these questions, it will make it easier for also smaller companies to gain access to this information.

Looking at the big picture, our bikes are on the road for a purpose – allow people to get where they need to, faster and with more joy. While there's no doubt that we also have things to improve, we have a product with lots of potential to do good. The biggest positive impact is in the hands of our riders, but also cities to design our places for walking and biking.

We hope to inspire the rest of the industry by sharing these results. More and more companies are starting to publish carbon footprints, but only a few show their methods. This makes it confusing and almost impossible for customers to compare the results. It also makes it difficult to scale the climate action with the speed needed. Our hope is that we can move towards collaborative advantage in climate action. One way is to show what we learn along the way. This report is our first step to that direction.

Annexes

Annex 1 – Methodology

Annex 2 – Data and assumptions

Annex 3 – Case studies

Annex 4 – Complete list of impact assessment results

Annex 1 - Methodology

LCA results are affected by the chosen system boundaries (i.e., what is included in the study and what not). The table below gives an overview of the choices we've made. Overall, the aim has been to identify the major hotspots for environmental impact.

LCA objectives	LCA over the life cycle of the Stellar (Generation 2 or "G2") to: Identify hotpots Support ecodesign Quantify product carbon footprint
LCA scope	
Functional unit	Move one person for 40 000 km
System boundaries	LCA for bike production, use and recycling (cradle to grave)
Data basis	Weight of the bike: part list (as in 2022), BoM documentation and weightings
	Ampler-specific data (paintwork, energy and water use in assembly): Ampler product and facility teams
	Location-specific energy supply: ecoinvent
	Use (km): Ampler assumption
	Use (spare parts): Ampler assumption
Allocations	No specific allocations.
Cut-off criteria	ecoinvent database and its cut-off criteria
	No explicit cut-off criteria. All available weight information is processed.
	No credits are given for recycling or creating recycled material. Only transport to the waste facility is accounted for.
Assessment	Lifecycle, following the ISO 14040 and 14044 (LCA) standards.
	Impact assessment: the assessment is carried out with the ReCiPe 2016 Midpoint (H) method including 18 impact categories.
	Analysis of lifecycle results according to phases (which phases are responsible for the highest impacts) and components.
	Interpretation: sensitivity analyses of different modelling choices.
Software support	openLCA. This is an open source software for sustainability assessments and modelling LCAs, provided by GreenDelta.

Annex 2 – Data and assumptions

To make the analysis easier, we grouped the materials in our components by group. These material groups were then used to build up the model.

The materials also need to be processed. Since we did not have specific data from our suppliers, we used assumptions to include the processing steps of components for the manufacturing stage. Scrap rates are included and based on ecoinvent datasets, assumptions and Ampler factory data.

For materials sent to recycling, only transportation to recycling facility is included, due to the cut-off approach. Transport to waste treatment is modelled with 50 km. Pre-existing datasets from ecoinvent were used for the modelling.

Material	Assumption on processing	Assumption on end-of-life
Aluminium, wrought	Rolling and extrusion	Recycling
Brass	No extra manufacturing processes	Recycling
Copper	No extra manufacturing processes	Recycling
Electronics	No extra manufacturing processes	Recycling
Fluids (lubricants, washing agents,…)	No extra manufacturing processes	Incineration and landfill
Lithium-ion battery	No extra manufacturing processes	According to ecoinvent dataset "used Li-ion battery"
Packaging and printed materials	No extra manufacturing processes	Recycling
Polymers (ABS, TPR, nylon,…)	Injection moulding	Incineration and landfill
Steel	Wire drawing	Recycling
Steel, stainless	Wire drawing	Recycling
Tires (latex, carbon black, steel, synthetic rubber, textile fibres)	No extra manufacturing processes	According to ecoinvent dataset "used tire"
Other materials	No extra manufacturing processes	According to datasets

Annex 3 – Case studies and use phase assumptions

The latest ecoinvent datasets from the database v. 3.8 are used. All other cases are based on modelling assumptions.

Care and repair

Assumptions of the substitutions of components over the life time of Stellar (40 000km).

Components	Assumption on number of replacements
Battery	+1
Bearings, bottom bracket	+2
Bearings, others	+1
Bell	+1
Brake pads	+16
Cassette	+8
Chain	+16
Crankset, front sprocket	+4
Grips	+2
Pedals	+1
Rim	+2
Saddle	+1
Shifter cable	+4
Spokes	+2
Tires and tubes	+5

Energy choices

This scenario was calculated using the following datasets:

- German average electricity mix, as in the ecoinvent dataset “market for electricity, low voltage I cutoff, U - DE”
- Solar power, as in the ecoinvent datasets “electricity production, photovoltaic, 3kWp slanted-roof installation, multi-Si, panel, mounted | electricity, low voltage | Cutoff, U - DE” and “electricity production, photovoltaic, 3kWp slanted-roof installation, single-Si, panel, mounted | electricity, low voltage | Cutoff, U - DE”. The scenario was calculated with 50% of the former, and 50% of the latter.

It is expected that the emissions from the German electricity grid are going to be reduced in the coming years as the Government of Germany has a plan to run at least 80% on renewable energy by 2030. Over the lifetime of Stellar, the negative impact from charging would then be reduced.

Transportation modes

The emission comparison between electric bikes (Stellar) and cars were calculated using the following information:

- Electric bikes: GHG emissions 2.6 g CO2 eq/km (market for electricity, low voltage I cutoff, U - DE)
- Cars: GHG emissions 44.63 g CO2 eq/km (transport, passenger car, medium size, petrol, EURO 3 | transport, passenger car, medium size, petrol, EURO 3 | Cutoff, U; only fuel use)

Annex 4 – Complete list of impact assessment results

The latest ecoinvent database (v. 3.8) is used as a source for the environmental impact.

Impact Category	Units	Impact
Climate change	kg CO2 eq	814.86552
Fossil resource scarcity	kg oil eq	232.57875
Freshwater ecotoxicity	kg 1,4-DCB	97.75491
Freshwater eutrophication	kg P eq	0.36874
Human carcinogenic toxicity	kg 1,4-DCB	135.07883
Human non-carcinogenic toxicity	kg 1,4-DCB	1670.78310
Ionizing radiation	kBq Co-60 eq	48.09472
Land use	m2a crop eq	33.70185
Marine ecotoxicity	kg 1,4-DCB	127.31306
Marine eutrophication	kg N eq	0.03588
Mineral resource scarcity	kg Cu eq	8.44078
Ozone formation, human health	kg NOx eq	2.54184
Ozone formation, terrestrial ecosystems	kg NOx eq	2.60931
Particulate matter formation	kg PM2.5 eq	1.34654
Stratospheric ozone depletion	kg CFC11 eq	0.00036
Terrestrial acidification	kg SO2 eq	3.17946
Terrestrial ecotoxicity	kg 1,4-DCB	6697.31528
Water consumption	m3	5.79340

The drivers of the impact categories for human toxicity (carcinogenic and non-carcinogenic) are mining and processing of raw materials, mainly copper, as well as waste treatment.

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