CEORA™ 546 EPOS™

Rider P525DX

Husqvarna Group

LCA of CEORA™ 546 EPOS™ & Rider P525DX

Electrical & diesel driven

2022-06-07

LCA of CEORA™ 546 EPOS™ & Rider P525DX

Electrical & diesel driven

Date	2022-06-07
Project No.	1320057468
Version/Status	Version 1.3

Agnes Rönnblom
Project Manager

Axel Cullberg
Project Engineer(s)

Yevgeniya Arushanyan
Internal Reviewer

Ramboll Sweden AB
Box 17009, Krukmakargatan 21
104 62 Stockholm

Phone: +46-10-615 60 00
VAT Registration No. 556133-0506

Table of Contents

LCA of CEORA 546 EPOS & Rider P525DX
Electrical & diesel driven

1. Background

As part of the development of Husqvarna Group 2025 Sustainability strategy, the company identified the need to better understand the environmental impact of their products along the value chain and highlight the main levers to reduce these environmental impacts. Even more importantly Husqvarna Group wanted to build a reliable comparison between selected electrical and fossil fuel products. Today Husqvarna Group is monitoring the differences between several products in the use phase, and several full life cycle assessments have been performed.

This assessment is not classified as a comparative assertion as defined in ISO 14044:2006. Ramboll's interpretation of the definition therein is that it does not apply on comparisons between products within the same company, i.e. that it does not affect other parties. Hence is review performed by a third party expert rather than a third party panel of experts. This study has been third party reviewed by Mats Zackrisson at RISE based on the ISO 14040 and ISO 14044 standards, and the LCA and report was assessed to comply with the standards. The review report can be found attached to this document.

1.1 Introduction to the assessment

The products compared in this study are two different product types which both can provide the service under study in this assessment, but with different technology solutions based on different energy supplies. The products are one electrical robotic lawn mower and one diesel driven rider, which are used to provide the service of cutting grass.

The products are used at a football club with two pitches, which are assumed to cover a combined area of approximately 16 000 m^2. The electrical robotic lawn mower is of the model CEORA™ 546 EPOS™ which consists of the CEORA drive unit and cutting deck, an EPOS™ position reference station, the cutting deck Razor 43M and the charging station CS4 (hereafter all together referred to as only CEORA). The diesel rider is of the model P525DX and includes the cutting deck Combi 155.

The life cycle assessment addresses the entire life span of the products, from extraction of raw materials, through manufacturing, usage and finally waste treatment. Included are as well transports throughout the entire value chain. For easier understanding and division of the life cycle impacts, the life cycle has been divided into three major modules;

1. Production: raw material extraction, processing, manufacturing and assembly. Transports are included from suppliers to manufacturing site;
2. Use: Transports to end user, electricity for CEORA, fuel for P525DX, and manufacturing and waste treatment of consumables (i.e. oils, blades and filters), and;
3. End-of-Life: transport to waste treatment plant and waste treatment.

Modelling and environmental impact calculations are performed with the LCA software GaBi 2021.2, using life cycle inventory data from Sphera [1] and Ecoinvent 3.7.1 [2], and is conducted in accordance with ISO 14040 and ISO 14044.

A description of the Husqvarna parties involved in the process of this project, along with short description of the time frame, is made available in Appendix A.

2. Goal and scope

The goal of the Life Cycle Assessment is to:

- Generate insight on environmental impact of the products along the value chain for Husqvarna Group's Sustainability Strategy
- Create a fundament for ideas on how Husqvarna Group can improve electrical driven products
- Generate a reliable statement for the public on comparison between electrical and fossil-driven products with a focus on the climate impact of the products

The result of the comparative assessment between electrical and fossil-driven products are intended to be used in public communication, while the insight on the environmental impacts along the value chain and ideas to improve the electrical driven products are intended for internal Husqvarna Group communication.

2.1 Functional unit

The functional unit is *cutting two football pitches owned by a football club, 16 000 m^2 of average pitch grass lawn, in country X*[1] *during one cutting season*.

The mode of cutting is different between the two products, as described below.

- the CEORA cuts two pitches in 9 hours. Daily for 18 weeks and every other day during the remaining 12 weeks.
- The rider cuts two pitches in approximately 1,5 hours. Three times a week for 18 weeks, and two times a week during the remaining 12 weeks.

The difference in cutting frequency per week is due to the rider's ability to cut higher grass compared to CEORA. A functional difference for the two mowers is that the CEORA is dedicated to one club of this size during the entire season, while the Rider could be used for several clubs, as it has a faster cutting speed and is transportable. This will be tested in a sensitivity analysis. An operative difference is that you need a person to drive the rider, while the CEORA operates autonomously. Thus, the CEORA is not limited to regular working hours, and can cut during night-time.

Both products leave the cut grass on the lawn. The rider mulches cut grass, thus converting longer grass straws into shorter ones, while the CEORA leaves short straws as a result of its high cutting frequency. The difference in bioavailability in cut grass left by the products is deemed to be negligible[2]. There is also a difference in noise, as an electrical motor operates more silently compared to a combustion engine. Additionally, the rider causes local emissions through its combustion of fossil fuel, while the CEORA is emission free during use.

2.2 System boundaries

The studied system includes the production, packaging, distribution, use and disposal of the mowers during its lifetime - in other words, the entire life cycle of the product.

[1] See section 2.2.3 for further details on different countries/markets.

[2] According to Daniel Mannerström, Husqvarna

The study does not include the operator for the rider. Potential grass and soil quality changes driven by the different cutting frequencies during one season is also not included within the system boundary, neither is noise.

Pallets used for packaging and transport of the mowers are assumed to be circulated 10 times during its life cycle, thus 10% of the impacts associated with the pallets are allocated to the products under study.

No data could be retrieved on the amount of packaging materials arriving at Husqvarna Group site from suppliers. These materials are mainly plastics and corrugated paper, which usually are recycled. The conclusion from the chainsaw assessment [3] was that these materials do not add up to a significant mass[3] and the environmental impact related to these materials do not have a significant contribution to the assessed environmental impact categories. These packaging materials have consequently been excluded from the assessment.

2.2.1 Time

The comparison is made for one football club with two pitches, with a need to cut a total of 16 000 m^2 of grass. The comparison is made on a scenario of a 30-week cutting season[4] per year, during the lifetime of the products. See Table 1 and text below for more details.

Table 1 Lifetime, charging, cutting and fuel consumption. All data is provided by Husqvarna.

	Lifetime [h]	Charging time [min]	Cutting time /charge [min]	Fuel consumption [l/h]	Rated power [kW]	Efficiency factor
CEORA	33 600*	150	255	N/A	0,272	0,85
P525DX	3 000	N/A	N/A	4,36	**	N/A

* Full use lifetime

** Has not been provided for rider as fuel consumption [l/h] is applied in calculations

The CEORA cuts two football pitches (about 16 000 m^2) in about 9 hours. The cutting time is 3,75 h per charge, leading to 2,4 charging cycles per day. CEORA typically has a lifetime expectancy of 10 years when used intensively, as it is designed for uninterrupted use. In this scenario, the CEORA is running on halftime[5] why the lifetime expectancy is increased to 20 years. During the lifetime of 33 600 hours, the CEORA has about 1 680 hours of cutting per 30-week season.

The cutting time of 16 000 m^2 for the rider varies depending on the number of turns and the applied speed. During the lifetime of 3 000 hours, the rider has about 122 hours of cutting during a 30-week season, giving it a lifetime of about 24,6 years.

The country electricity mixes during the use phase have not been altered throughout the years of usage, as this assumption would be connected to a large uncertainty.

---

[3] With reference to data received for a chainsaw; 1 weight-% corrugated paper and 0,2 weight-% vinyl in relation to total weight of the product.

[4] Assumption based on an April-October season in North Europe. A longer season (August-May) is common in other parts of Europe as well as globally, but this is not covered by this study.

[5] Due to it not running continuously but rather at halftime, due to daytime use of the pitch.

Characterization factors for the global warming potential represent a 100-year perspective.

2.2.2 **Nature**
All known use of resources and emissions to air, water and soil are included.

2.2.3 **Geography**
Four (4) market areas, in which both the CEORA and Rider are sold, have been addressed in this assessment, see Table 2 below. Europe is chosen as the baseline market.

Table 2 Market areas agreed upon with Husqvarna project group

	France	Germany	United States	Europe*	Europe: Wind*	Europe: Future
CEORA	✓	✓	✓	✓	✓	✓
P525DX	✓	✓	✓	✓	-	-

* EU-28

The environmental impacts of all activities in the life cycle are included regardless of geographic location. The sensitivity of the recipient environment in question has not been considered.

Regarding market energy mixes, the *Europe: Wind* and *Europe: Future* scenarios are only applied to CEORA, as the electricity mix would not affect P525DX. The Europe-Future scenario is based a report from IEA [4] where cases for the future global energy sector for 2050 is presented. The Announced Pledges Case (APC) is applied herein, where it is assumed that all announced national net zero pledges are achieved in full and on time, whether or not they are currently underpinned by specific policies. The APC case is not solemnly developed for Europe and includes the United States as well. It has however been applied assuming it applicable for a future European scenario.

2.3 **Allocation and assumptions**
The allocation method used for recycled materials is the so-called polluter pays principle. This means that the scrap metal used as a resource in Husqvarna Group's products carries no burden from before the point it enters the recycling process. In the end-of-life where the metal enters the metal recycling process, the mowers carry the environmental burden up to the point where the metals reach a recycling facility.

2.4 **Environmental impact categories**
Within the scope of the project, the environmental impacts and indicators considered are:

- Resource use[6]
    - Abiotic Depletion Potential (elements)
    - Abiotic Depletion Potential (primary energy)
- Global Warming Potential, excluding biogenic carbon
- Acidification Potential
- Eutrophication Potential, and

[6] The results of these environmental impact indicators shall be used with care as the uncertainties of these results are high or as there is limited experience with the indicator

- Photochemical Oxidant Creation Potential[5].

These are the latest baseline characterization factors from the Institute of Environmental Sciences of Leiden University (CML) [5] for all but acidification where the non-baseline characterization from CML is used (in line with previous recommendations[7] for EPDs in the International EPD system [6]).

The resource use is presented as a characterized result:

- Abiotic Depletion Potential (elements) is a measurement of the non-renewable abiotic depletion of elements, as metals, minerals etc. The impact category takes into account the size of the reserves and rate of extraction, so a metal or mineral that is rare is rated higher. The material use is accounted as a depletion even if the metal is recycled and used in another life cycle in the end of life, as the impact category measured the depletion of reserves.
- Abiotic Depletion Potential (primary energy) is a measurement of non-renewable abiotic depletion of fossil fuels. The impact category takes into account the size of the reserves and rate of extraction, so a fossil fuel that is rare is rated higher.

In addition, the toxicity potential and the health risks related to the battery cells are addressed qualitatively in Appendix B.

2.5 Interpretation

The comparison is made for the countries that represent a selection of the markets for the two products, in addition to two additional electricity scenarios (see 2.2.3).

The following sensitivity analyses have been conducted:

- If the rider would use 100% HVO instead of market-specific diesel
- If the mowers would be used by four football clubs (8 pitches)
- Alternative datasets for Li-ion battery cells
- A Net-Zero Emissions by 2050 Scenario (NZE) provided by IEA [4]
- If the rider would have a doubled lifetime expectancy
- If the rider would cut faster than in the baseline scenario

A dominance analysis is made to identify key contributors to emissions contributing to Global Warming Potential. The reason why the impact category Global Warming Potential was chosen is that the carbon footprint, or climate impact, is one of the key focus areas in Husqvarna group Sustainability strategy.

[7] During the course of this assessment, the recommended impact indicators in the International EPD system have changed. The decision is however to keep the initial impact categories, in order to keep consistency with previously conducted LCAs a Husqvarna.

3. Life cycle inventory

Below follows a general description of the choices made in the life cycle inventory phase for both the robotic lawn mower and the rider. The following sub-chapters present product-specific information and assumptions. Regarding specific material and transportation choices for each individual part, it is referred to the underlying Bill of Materials – which have been modified to contain this information.

3.1 In general

All known processes within the system boundaries are included in the assessment. Infrastructure, buildings, manufacturing of machines and production equipment is excluded from the assessment.[8]

A simplified process tree with the system boundaries for the assessment is available in Figure 1.

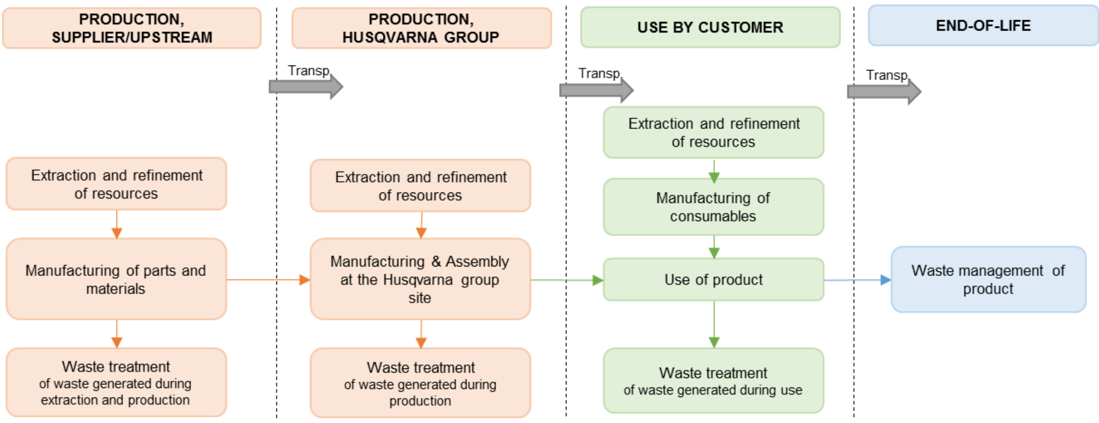

Figure 1 Simplified process tree. Orange marks the Production phase, green the Use phase, and blue the End-of-Life phase

3.1.1 Material and production data

Specific data has been collected for the material composition of the two products as well as the assessed cutting deck for the rider. Husqvarna Group does not always have information on the exact material specification for each part in the products. Assumptions have therefore been made based on similar parts.

Depending on production locations for materials and components, different production country data is used, see Table 3-Table 5 below. For some regions, there is no available LCA-data. Hence, another region's LCA data has been applied and, if possible, modified to fit the current region.

Regarding the datasets used from Plastics Europe, these are not always updated within the last 10 years. But as these still are the most accurate LCA-data on some plastic production there is – they are considered valid.

---

[8] An exception is that some data sets from Ecoinvent include infrastructure, buildings etc. This does however not have a significant impact on the result.

Table 3 Raw material processes

	Process name	Source
Aluminium		
EU	EU-28: Aluminium ingot mix (53% scrap) <u-so> EU-28: Aluminium ingot mix Sphera EU28+EFTA+Turkey: Aluminium remelting: wrought alloys ingot from scrap (2015) European Aluminium EU28+EFTA: Aluminium refining: casting alloy ingot from scrap (2010) European Aluminium	[7] [1] [1, 8] [1, 8]
CN	GLO: Aluminium ingot mix (32% scrap) <u-so> CN: Aluminium ingot mix IAI 2015 IAI/Sphera RoW: treatment of aluminium scrap, new, at remelter ecoinvent 3.7.1 RoW: treatment of aluminium scrap, new, at refiner ecoinvent 3.7.1	[9] [1, 10] [2] [2]
Other	GLO: Aluminium ingot mix (32% scrap) <u-so> GLO: Aluminium ingot mix IAI 2015 IAI/Sphera RoW: treatment of aluminium scrap, new, at remelter ecoinvent 3.7.1 RoW: treatment of aluminium scrap, new, at refiner ecoinvent 3.7.1	[9] [1, 9] [2] [2]
Stainless steel		
EU	EU: Steel hot dip galvanized worldsteel	[1, 11]
RAS	RAS: Steel hot dip galvanized worldsteel	[1, 11]
Screw	EU-28: Fixing material screws stainless steel (EN15804 A1-A3) Sphera	[1]
Steel – hot rolled		
EU	EU: Steel hot rolled coil worldsteel	[1, 11]
RAS	RAS: Steel hot rolled coil worldsteel	[1, 11]
Other	GLO: Steel hot rolled coil worldsteel	[1, 11]
Steel – cold rolled		
EU	EU: Steel cold rolled coil worldsteel	[1, 11]
RAS	RAS: Steel cold rolled coil worldsteel	[1, 11]
Steel – wire		
EU	EU: Steel wire rod worldsteel	[1, 11]
RAS	RAS: Steel wire rod worldsteel	[1, 11]
Other	GLO: Steel wire rod worldsteel	[1, 11]
Steel – screw		
All	EU-28: Fixing material screws galvanized (EN15804 A1-A3) Sphera	[1]
Copper		
All	EU-28: Copper Wire Mix (Europe 2015) DKI/ECI	[1, 12]
Other metals		
Brass	DE: Red brass part (EN15804 A1-A3) Sphera	[1]
Neodymium magnet	(32%) GLO: market for neodymium oxide ecoinvent 3.7.1 (1,2%) GLO: boron carbide production ecoinvent 3.7.1 (66,8%) GLO: ferrite production ecoinvent 3.7.1	[2, 13] [2, 13] [2, 13]
Plastics		
ASA/ABS	DE: Acrylonitrile-Butadiene-Styrene Granulate (ABS) Mix Sphera[9]	[1]

[9] Proxy for ASA

	Process name	Source
EPDM	DE: Polypropylene / Ethylene Propylene Diene Elastomer Granulate (PP/EPDM, TPE-O) Mix Sphera	[1]
PA, PA-GF	RER/RoW: nylon 6 production ecoinvent 3.7.1 RER/RoW: nylon 6 production, glass-filled ecoinvent 3.7.1 RER/RoW: nylon 6-6 production ecoinvent 3.7.1 RER/RoW: nylon 6-6 production, glass-filled ecoinvent 3.7.1	[2] [2] [2] [2]
PC	EU-28: Polycarbonate granulate (PC) Sphera	[1]
PE (LD-, HD-), PET	DE: Polyethylene High Density Granulate (HDPE/PE-HD) Mix Sphera DE: Polyethylene Low Density Granulate (LDPE/PE-LD) Sphera DE: Polyethylene terephthalate granulate (PET via DMT) Sphera	[1] [1] [1, 14]
PP	DE: Polypropylene granulate (PP) mix Sphera	[1, 14]
PVC	DE: Polyvinyl chloride granulate (Suspension; S-PVC) mix Sphera	[1, 14]
TPE/TPU	DE: Thermoplastic polyurethane (TPU, TPE-U) Sphera	[1]
Elastomers		
NBR	DE: Nitrile butadiene rubber (NBR, 33% acrylonitrile) Sphera	[1]
Electronics		
PWB	GLO: printed wiring board production, through-hole mounted, unspecified, Pb free ecoinvent 3.7.1	[2]
Wiring (unspec.)	*See Table 5*	
Battery cells	*See section 12*	
Other		
Oil	EU-28: Lubricants at refinery Sphera	[1]
Paper	RER: graphic paper production, 100% recycled ecoinvent 3.7.1	[2]
EUR-pallet	EUR-Pallet from literature	[15, 16]
Cardboard boxes	EPD S-P-00981, Flute E	[17]

Specific production data has been collected for processes owned by Husqvarna Group. Generic data has been used for processes conducted by suppliers, which mainly concerns metal working and plastic injection moulding, see Table 4.

Table 4 Further material production processes

	Process name	Source
Metal working (+ the metal that is machined, creating 22,7% waste)		
EU	RER: metal working, average for XX* product manufacturing ecoinvent 3.7.1 <u-so> RER: metal working factory construction ecoinvent 3.7.1 RER: metal working machine production, unspecified ecoinvent 3.7.1 GLO: market for energy and auxiliary inputs, metal working factory ecoinvent 3.7.1 RER: market for energy and auxiliary inputs, metal working machine ecoinvent 3.7-1	[2] [2] [2] [2] [2]
Other	RoW: metal working, average for XX* product manufacturing ecoinvent 3.7.1 <u-so> RoW: metal working factory construction ecoinvent 3.7.1 RoW: metal working machine production, unspecified ecoinvent 3.7.1 GLO: market for energy and auxiliary inputs, metal working factory ecoinvent 3.7.1 RoW: market for energy and auxiliary inputs, metal working machine ecoinvent 3.7.1	[2] [2] [2] [2] [2]
Plastic injection moulding, grid mix depends on production country (+ the plastic that is moulded)		

-	GLO: Plastic injection moulding (parameterized) Sphera <u-so> XX**: Electricity grid mix Sphera	[1] [1]

* Aluminium/steel/stainless steel/copper/average metal working
** Region

Due to lack of information on several copper wiring assemblies used in both rider and robotic lawn mower, a model of an average wiring assembly was modelled with data from Husqvarna. The model was used to represent all such assemblies in both mowers and includes the copper wire, connector, grommet, jacket and insulation as well as material forming processes to account for cable production. See Table 5 for process and material mass share in the average wiring assembly. The selected data was deemed to be representative for other wiring assemblies in the products as well.

Table 5 Average wiring assembly based on data from Husqvarna

	(mass share) Process name	Source
Wiring assembly (unspec.)	(67,6%) DE: Polyvinyl chloride granulate (Suspension; S-PVC) mix Sphera	[1]
	(25,9%) EU-28: Copper Wire Mix (Europe 2015) DKI/ECI	[1, 12]
	(3,2%) RER/ROW: nylon 6 production ecoinvent 3.7.1	[2]
	(3,2%) DE: Polypropylene / Ethylene Propylene Diene Elastomer Granulate (PP/EPDM, TPE-O) Mix Sphera	[1]
	(1,6%) RoW: tin production ecoinvent 3.7.1	[2]
	(1,5%) RER/ROW: nylon 6-6 production ecoinvent 3.7.1	[2]

3.1.2 **Waste management**

Regarding the assessed end user markets, scenarios for waste management has been set up; one scenario for all European markets and one for the United States, as presented in Table 6 below. The European waste scenario represents the EU, France and Germany, as waste management in these markets is assumed to be similar. Allocation procedure is the polluter pays principle, which means that Husqvarna Group accounts for the environmental burden to the grave for landfill – or, as for recycling, until the point the material enters the recycling process. All PWB and WEEE is sent to waste treatment for conservative measures, as it is uncertain if, and at what point, it reaches the end-of-waste state.

Reuse of batteries is something that currently is under study worldwide. However, as the reuse is a potential future scenario and difficult to estimate, it is not included in this assessment. Battery cells are currently recycled in a copper smelter, where copper, manganese, cobalt, nickel and iron are recycled. Aluminium within the cells, lithium, graphite and electrolytes are oxidized and lost in the current recycling process.

51,3% of batteries are assessed as being recycled at End-of-Life, which corresponds to the recycling rate of portable batteries in the EU in 2019 [18]. This is well in line with the EU directive *on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC* [19]. It is assumed that this recycling rate is applicable for the US market as well. The remaining share of battery cells are assumed to be landfilled.

RAMBOLL

Table 6 Waste management

	EU	US	Process name	Source
Metals				
90% recycled	X	X	N/A (only transport to recycling plant)	-
10% landfilled	X	X	EU-28: Ferro metals on landfill Sphera	[1]
Plastics				
Incinerated	X		EU-28: Polypropylene (PP) in waste incineration plant Sphera (EU)	[1]
Landfilled		X	EU-28: Plastic waste on landfill Sphera (US)	[1]
Battery cell li-ion				
51,3% recycled	X	X	N/A (only transport to recycling plant)	-
48,7% landfilled	X	X	EU-28: Ferro metals on landfill Sphera	[1]
PWB	X	X	RoW: treatment of scrap printed wiring boards, shredding and separation ecoinvent 3.7.1	[2]
WEEE	X	X	GLO: treatment of waste electric and electronic equipment, shredding ecoinvent 3.7.1	[2]
Wood	X	X	EU-28: Wood (natural) in municipal waste incineration plant Sphera	[1]
Recycling waste	X	X	N/A (only transport to recycling plant)	-

3.1.3 **Transports**

All transports from suppliers to the manufacturing sites are estimated based on supplier location. If supplier location is not known, China is assumed as point of origin. From the manufacturing site to the assessed market locations, the centre of the country is applied as destination.

The vehicles used for transportation are global averages, while the fuels needed is applied based on region of departure. See Table 7 for details on applied processes.

Table 7 Transportation processes

	Process name	Source
Vehicles		
Truck	GLO: Truck, Euro 6, 28 - 32t gross weight / 22t payload capacity Sphera (US & EU) GLO: Truck, Euro 4, 28 - 32t gross weight / 22t payload capacity Sphera (other)	[1] [1]
Container ship	GLO: Container ship, 5,000 to 200,000 dwt payload capacity, ocean going Sphera	[1]
Fuels		
Diesel	XX*: Diesel mix at filling station Sphera	[1]
Heavy fuel oil	XX*: Heavy fuel oil at refinery (1.0 wt.% S) Sphera	[1]

* Region

3.2 CEORA™ 546 EPOS™

Below follows descriptions and assumptions related to CEORA divided into the life cycle stages Production, Use and End-of-Life.

3.2.1 Production

CEORA is assembled and partly manufactured at the Husqvarna Group factory in Aycliffe, in the United Kingdom. All raw materials for manufacturing and parts for assembly are therefore transported to this site.

CEORA weighs a total of about 165 kg when delivered to end user (including all accessories and packaging materials). During the mapping of materials however, a surplus of nearly 13 kg where reached (mostly due to packaging), giving a total of about 178 kg. The decision was made to include the surplus weight in the modelling, to not underestimate the environmental impact of the product. See Table 8 below for material/part division.

Table 8 Parts, materials and weights per one CEORA. Note that the values presented are calculated from bill of material, why they may not correspond entirely to the actual weight. Due to rounding, the values may not add up.

Material/Part	Amount	Unit
CEORA™ 546 EPOS™ including cutting deck Razor 43M	**73 890***	**g**
Steel	13 666	g
Stainless steel	2 317	g
Aluminium	12 386	g
Copper	774	g
Electronics and PWB	1 385	g
Battery pack	8 970	g
Plastics (including elastomers)	31 841	g
Other (other metals)	11	g
Accessories	**18 800**	**g**
CEORA™ CS4 Charging station	14 354	g
EPOS™ Reference Station	2 831	g
Loose part kit	202	g
Manuals + guide	**4 200**	**g**
Packaging	**85 600****	**g**
TOTAL	**178 345**	**g**

* Product weight is actually 72 300 grams

** Mainly pallets

The manufacturing that takes place at the Husqvarna Group site in Aycliffe is injection moulding of several plastic details, which requires energy and gives rise to waste. A total of 40 kWh wind electricity and 1,2 kWh liquefied petroleum gas is used for plastic moulding at the Husqvarna Group factory. The electricity is modelled with wind power from Spain as the electricity used is wind power from Haven Power, see Appendix C. The manufacturing gives rise to plastic waste of 600 g, divided into 458 g mixed plastic and 142 g plastic purging, which is sent for recycling.

Pigments and additives are mixed in with the plastic granulate to give the product its desired colour. Specific data was collected from the supplier of the largest plastic components in CEORA, the ASA[10] and ASA+PC[11] Luran polymers [20], see Table 9 below. The same mass share of pigments and additives was also assumed to be representative for ABS and ABS+PC components. As there is no publicly available dataset for ASA, ABS is used as proxy. To model the additive, phenol was assumed based on SpecialChem who states that "*The majority of primary antioxidants for polymers are sterically hindered phenols*" [21].

Table 9 Pigments and additives in Luran polymers used in CEORA

Polymer	(mass share) Process name	Source
ASA/ABS	(94%) DE: Acrylonitrile-Butadiene-Styrene Granulate (ABS) Mix Sphera*	[1]
	(0,7%) RER: titanium dioxide production, sulfate process ecoinvent 3.7.1	[2]
	(0,7%) RER: titanium dioxide production, chloride process ecoinvent 3.7.1	[2]
	(0,035%) GLO: ferrite production ecoinvent 3.7.1	[2]
	(0,375%) RER: chromium oxide production, flakes ecoinvent 3.7.1**	[2]
	(0,375%) GLO: carbon black production ecoinvent 3.7.1	[2]
	(2,5%) EU-28: Phenol Sphera	[1]
ASA+PC/ ABS+PC	(48%) DE: Acrylonitrile-Butadiene-Styrene Granulate (ABS) Mix Sphera*	[1]
	(48%) DE: Polycarbonate Granulate (PC) Sphera	[1]
	(0,75%) RER: titanium dioxide production, sulfate process ecoinvent 3.7.1	[2]
	(0,75%) RER: titanium dioxide production, chloride process ecoinvent 3.7.1	[2]
	(0,75%) GLO: ferrite production ecoinvent 3.7.1	[2]
	(0,375%) RER: chromium oxide production, flakes ecoinvent 3.7.1**	[2]
	(0,375%) GLO: carbon black production ecoinvent 3.7.1	[2]
	(1%) EU-28: Phenol Sphera EU-28: Phenol Sphera	[1]

*Proxy for ASA

** Proxy for chromium nitrate

Battery pack

The battery pack is produced and assembled in Poland and the battery cells are manufactured by Samsung in South Korea. One battery pack weighs a total of about 9 kg with a material/part distribution according to Table 10 below. Husqvarna provided information related to the material content of the battery pack and product specifications for the battery cells. However, since specific production data could not be provided, generic data was consequently used. The battery pack is installed in CEORA, and has a lifetime expectancy of 7,6 years in the intended application.

Table 10 Part weights of one battery pack. Note that the values presented are calculated from bill of material, why they may not correspond entirely to the actual weight. Due to rounding, the values may not add up.

Material/Part	Amount	Unit
Battery pack	**8 970**	**g**
Cell - NMC (LiNiMnCoO2), INR21700-50E; 4900mAh; 3,6V	6 923	g
Housing (PC+ABS)	1 427	g
Steel plates	205	g
PWB	75	g
Screws	13	g
Wiring (copper)	1,4	g

[10] Luran S 757G UV GY37447

[11] Luran S KR2868C UV GY700025

Pallet*	175	g
PE film*	6,9	g
Steel holder*	156	g

* Weight related to the packaging share for 1 battery system, which are shipped in units of 72 per pallet according to Husqvarna

The specific battery cells used in the battery pack of the CEORA are NMC batteries, Lithium Nickel Manganese Cobalt Oxide, 4,9 Ah. There does not exist any publicly available LCA-data for this type of batteries cells, why a literature study has been performed in order to access the most representative data. The data found is representative for a lithium-ion battery vehicle pack, lithium-ion nickel-cobalt-manganese battery, 26,6 kWh [22]. The cell energy density for the two battery types is 175 Wh/g cell for the vehicle pack, while it is 255 Wh/g cell in the battery type used by Husqvarna. The underlying assumption is that the size of the battery will not impact the environmental impacts per kg battery cell significantly.

3.2.2 **Use**

Depending on end user market, the CEORA is assumed to be transported by truck and ship (container carrier). Distances are estimated through google maps.

The energy needed for the CEORA relates to the rated power of 0,272 kW and efficiency factor of 85%, see Table 1 earlier. The charge/discharge efficiency is assumed to be 0,9, meaning that an extra 10% kWh is added, which is supported by Majeau-Bettez et. al [23]. Per season this amounts to 591 kWh[12]. The electricity used for operating CEORA is assumed to be the regional/country consumption mixes, with EU-28 wind power and a future energy mix as an addition, see Table 11 below. The resulting Global Warming Potential related to these electricity mixes are presented for reference in Figure 2 below.

Table 11 Electricity processes

Market	Process	Source
France	FR: Electricity grid mix Sphera	[1]
Germany	DE: Electricity grid mix Sphera	[1]
United States	US: Electricity grid mix Sphera	[1]
Europe	EU-28: Electricity grid mix Sphera	[1]
Europe: wind	EU-28: Electricity from wind power Sphera	[1]
Europe: future	APC-2050: Electricity mix IEA	[1, 4]

[12] Energy needed [kWh] = (season [h] * Rated power [kW]) / Efficiency factor * charge/discharge factor

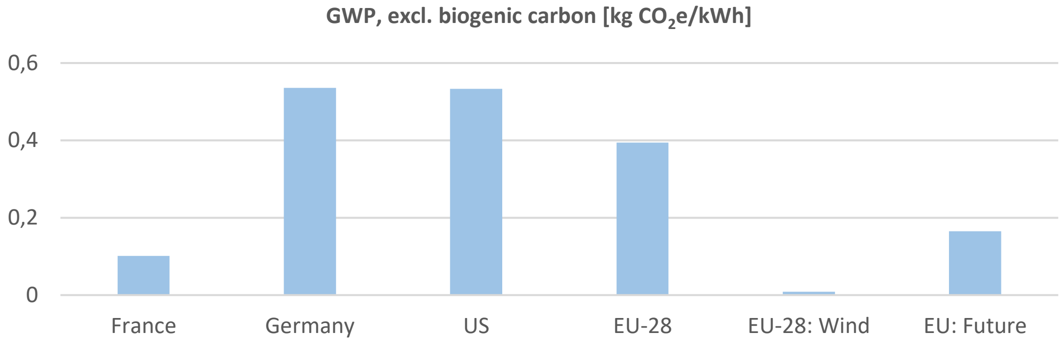

Figure 2 Global Warming Potential related to the electricity mixes used in the assessment.

The battery pack in CEORA needs to be exchanged 1,64 times during its lifetime due to the difference in lifetime expectancy between the battery pack and the mower. However, Husqvarna believes it to be unlikely that the battery pack would be removed from the robotic mower to be further used after the CEORA lifetime has passed. Hence has 2 full battery exchanges been accounted for. Additionally, 225 steel blades are exchanged yearly, meaning a total weight of 12 kg blades for the full lifetime of 20 years (0,6 kg per cutting season).

3.2.3 **End-of-Life**

At the end-of-life, when the product is no longer in use, the product is waste managed. Disassembly and/or shredding occurs in accordance with description in chapter 3.1.2. Transport distances are estimated.

3.3 **Rider P525DX**

Below follows descriptions and assumptions related to P525DX divided into the life cycle stages Production, Use and End-of-Life.

3.3.1 **Production**

Rider P525DX is assembled and partly manufactured at the Husqvarna Group factory in Mielec, Poland. All raw materials for manufacturing and parts for assembly are therefore transported to this site.

P525DX weighs a total of 943 kg when delivered to end user (all included). During the mapping of materials however, a shortfall of about 37 kg (4%) was reached (all within the rider, which should weigh 847 kg including cutting deck). The decision was therefore made to account for this shortfall in the modelling by approximating it with what was declared for the rider, to not underestimate the environmental impact of the product. See Table 12 below for material/part division in the declared part of the rider, along with manual and packaging.

Table 12 Parts, declared materials and weights per one rider P525DX. Note that the values presented are calculated from bill of material, and scaled where needed due to shortfalls, why they may not correspond entirely to the actual weight. Due to rounding, the values may not add up.

Material/Part	**Amount**	**Unit**
Rider	**684 000**	**g**
Steel	467 853	g
Stainless steel	146	g
Aluminium	39 506	g
Copper	2 925	g
Electronics	3 556	g
Starter battery	14 000	g
Plastics (including elastomers)	68 438	g
Other (oil, glycol, other metals)	21 394	g
Cutting deck C155	**163 000**	**g**
Manual	**2 300**	**g**
Packaging	**93 700**	g
Pallet, lid, walls	70 000	g
Cardboard	23 000	g
Other	700	**g**
TOTAL	**943 000**	**g**

The manufacturing and assembly that takes place at the Husqvarna Group site in Mielec requires 123 kWh natural gas, 0,03 GJ heat[13] and 110 kWh electricity for each rider. At the site, metal components are spray painted using 2 kg of coating powder, which is the only colouring process included in the rider. The spray painting has a loss share of 3%, giving rise to 0,06 kg waste, which is assumed to be sent for waste paint incineration. The Mielec production site purchases 100% renewable electricity (by certificate), which is being accounted for with Polish solid biomass power, see Appendix D. The operations on site give rise to 53 kg unspecified waste per rider, which is assumed as plastic and incinerated. When finished, the rider is tested on site, which requires approximately 0,4 litres of diesel, which is accounted for with European diesel and combustion.

Cutting deck Combi 155

As can be seen in Table 12 above, a cutting deck is included when delivered to an end user in this assessment. The cutting deck Combi 155 (C155) is as well produced at the Husqvarna Group site in Mielec and is compatible with several Husqvarna riders. See Table 13 below for the cutting deck's material division.

Table 13 Parts, declared materials and weights per one cutting deck C155

Material/Part	**Amount**	**Unit**
Cutting deck C155	**163 000**	**g**
Steel	156 004	g
Plastics (including elastomers)	6 996	g

[13] Assumed to be produced from coal. Poland's share of coal generated heat in 2020 was ~80% [42]

Since the rider and cutting deck is manufactured at the same site, the energy sources are identical to those presented for Mielec above. To produce and assemble one C155 cutting deck at Husqvarna's site, 20 kWh natural gas, 0,05 GJ heat and 18 kWh electricity is used. The cutting deck generates 9 kg of unspecified waste, assumed to be plastic sent for incineration.

Lead-acid starter battery

The starter battery within the rider is a closed lead-acid battery, 12V and 62Ah, manufactured in Spain. According to a supplier safety data sheet for a similar battery (although 24Ah), it consists of about 7% PP while the remaining weight is the lead-acid battery. The same material mass share is assumed to be representative for this battery. The lead-acid battery has been modelled based on a life cycle assessment of starting-lighting-ignition lead-acid batteries in China [24], which presents its impact assessment for lead-acid batteries in relation to 1 kWh. As the battery in P525DX is of 0,744 kWh[14], the impact has been scaled accordingly.

3.3.2 **Use**

Depending on end user market, the Rider is assumed to be transported by truck and ship (container carrier). Distance to customer in the respective market is estimated through google maps.

The fuel needed for the rider amounts to 4,36 litres per hour. Per season this amounts to about 532 litres. The diesel used is assessed with country/region specific data, see Table 14 below.

Table 14 Fuel processes

Market	Process name	Source
EU	EU-28: Diesel mix at filling station Sphera (6,35 wt% biogenic content)	[1]
FR	FR: Diesel mix at filling station Sphera (10,14 wt% biogenic content)	[1]
DE	DE: Diesel mix at filling station Sphera (6,19 wt% biogenic content)	[1]
US	US: Diesel mix at filling station Sphera (4,87 wt% biogenic content)	[1]

The exhaust emission from the diesel driven Rider is measured by Husqvarna Group to ensure conformity to European, US and other emission standards. These emission data are provided in g/kWh. To match these emissions to the fuel use above, the data has been recalculated based on the fact that the CO_2 emissions are directly linked to the fuel consumption. In other words, the other emissions to air are set in relation to the CO_2 emission per kg fuel used. The emissions per kg fuel correspond well to emission data for these types of engines provided by the European Environment Agency report (EEA) [25]. In the report from EEA the emission data is provided for two ways of calculating: tier 1 and tier 2, both are presented in Table 15. Exhaust emission to air of emission impacting the climate is based on the Greenhouse Gas Protocol's emission factors for motor fuel [26], and the sulphur content has been set to 10 mg/kg.

[14] (12 [V] * 62 [Ah])/1000 = 0,744 [kWh]

Table 15 Emission data provided by Husqvarna Group[15] and Greenhouse Gas Protocol [26] for Rider P525DX, compared to Tier 1 and 2 in European Environment Agency report [25]

Emission to air	Rider P525DX	Rider P525DX	Tier 1, diesel* (EEA)	Tier 2, diesel*, stage V (EEA)
	g/kWh	g/kg fuel	g/kg fuel	g/kg fuel
CO	1,0	3,04	10,8	7,4
CO_2	1 047	3 186**	3 160	3 160
HC	0,25	0,76	3,38	0,93
NOx	4,80	14,6	32,6	7,7

* Diesel 1.A.4.a.ii/b.ii ; Commercial/institutional: Mobile / Residential: Household and gardening (mobile)

** Only data from GHG Protocol. The emissions of CO_2 are adjusted according to the biogenic content of the fuel for each region.

During usage, lubricating oil needs to be exchanged in both engine, hydraulics and transmission. 3,3 litres engine oil, 0,9 litres transmission oil and 2 litres hydraulic oil is exchanged every 100 hours of use.

According to a maintenance schedule for P525DX, oil- air- and fuel filters are needed to be exchanged as well. During the rider lifetime, 30 oil-, 7,5 air- and 30 fuel filters are exchanged. For the same duration, 7,5 PTO rubber belts and 36 blades are exchanged.

The lead-acid battery has an expected lifetime exceeding 1 500 hours[16] although potentially less than the full lifetime of the rider. Thus, one starter battery exchange is included together with its transport to the user and its end-of-life management. Potential remaining battery service life is allocated to the rider.

3.3.3 End-of-Life

At end-of-life, when the product is no longer in use, the product is waste managed. Disassembly and/or shredding occurs in accordance with description in chapter 3.1.2. Transport distances are estimated.

3.4 The comparison of robotic lawn mower and rider

To make the comparison of the electrical CEORA and the diesel rider fair, they have to be able to provide the same function during the same period of time. The two products are chosen as they are judged to be able to perform the same task, which is cutting one football club's two pitches (16 000 m^2) during a 30-week long cutting season for 20 years.

Since the Rider has a somewhat longer lifetime expectancy (24,6 years), its impact related to the Production and End-of-life phases is divided based on its actual lifetime expectancy. This based on the assumption that the rider will be used to its full lifetime.

[15] Husqvarna personell, email 2021-12-02

[16] According to Husqvarna's product lab

4. Results

The following presents the comparison between the electrical CEORA™ 546 EPOS™ and the diesel Rider P525DX with regards to their environmental impact throughout their entire life cycle. As mentioned in chapter 2 earlier, four markets are assessed. EU, a region which both products are sold in, is chosen as the baseline market. Hence will the coming chapters address EU in detail, while the details of the remaining countries can be found in the excel spread sheet containing all results (the "Output file"). However, the results for the other markets will be commented here.

4.1 Comparison electrical CEORA vs. diesel driven rider (in the EU)

Table 16 below presents the total life cycle impacts from the robotic lawn mower and the rider, regarding resource depletion as well as the four addressed impact categories. The colour codes green-red clarifies which of the mowers that has the lowest-highest input/output in each category. Where differences may be less than 10% between alternatives, they are colour coded yellow.

Quantities are expressed per functional unit; *Cutting of one football club's grass lawn (16 000 m²) during one cutting season* in the EU.

Table 16 Usage in the EU: Total life cycle impact per cutting season - resource depletion and potential environmental impacts

INPUT			
Resource depletion	**Unit/season**	**CEORA**	**P525DX**
Abiotic Depletion Potential (elements)	kg Sb-eq	0,0028	0,58
Abiotic Depletion Potential (primary energy)	MJ	3 429	23 668
OUTPUT			
Environmental impact categories	**Unit/season**	**CEORA**	**P525DX**
Global Warming Potential	kg CO_2-eq*	297	1 770
Acidification Potential	kg SO_2-eq	0,85	5,8
Eutrophication Potential	kg Phosphate-eq	0,12	1,2
Photochem. Ozone Creation Potential	kg Ethene-eq	0,048	0,44

* 100 years (GWP100)

In regards to all assessed indicators, the electrical CEORA requires a smaller amount of resources as well as gives rise to a smaller amount of environmental impact. CEORA gives rise to about 83% less Global Warming Potential, 85% less Acidification Potential, and has about 90% lower Eutrophication Potential and Photochemical Ozone Creation Potential, in comparison to the rider.

4.1.1 Hot-spot analysis on Global Warming Potential

To gain a better understanding of where the impacts on the Global Warming Potential arises in both CEORA and P525DX, hot-spot analysis is performed on the use scenario in the EU. In Figure 3 below, which presents the distribution within Rider P525DX, it is made clear that it is the Use phase that stands for the largest share of the impact, this mainly due to the production and combustion of the diesel (13+75%). The consumables such as blades, battery and oil changes during use includes production, transport and end-of-life management, and have a minor contribution. When looking at the production of the rider, the chassis is the largest contributor, which is mainly due to the steel use.

The analysis also shows that transports from Husqvarna Group out to market accounts for about 0,2% of the total Global Warming Potential.

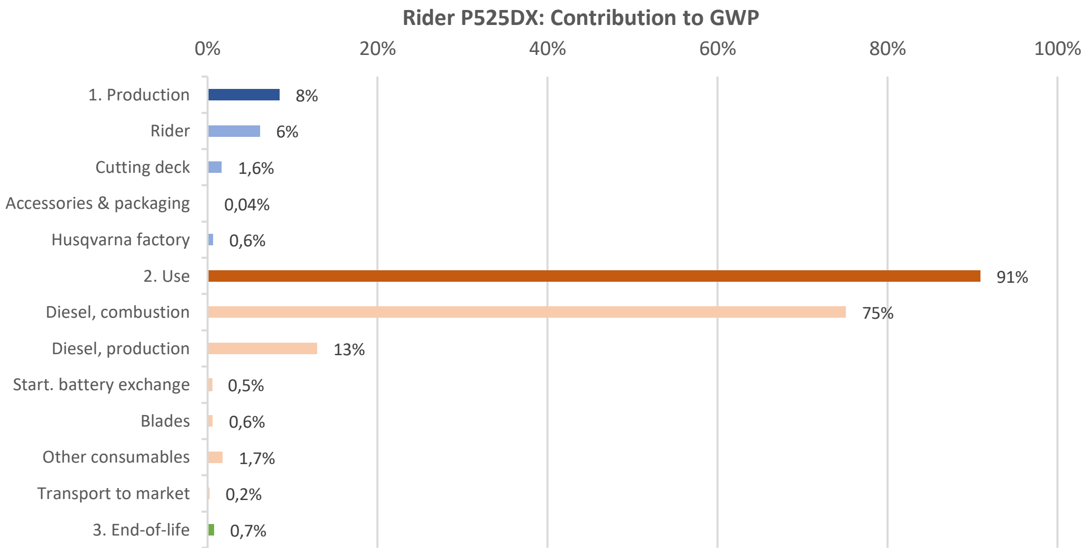

Figure 3 Rider P525DX contribution distribution to Global Warming Potential during its lifetime. The blue bars present the Production phase, the orange the Use phase and the green the End-of-Life phase. The bars with the life cycle stages names and the numbers 1-3 present the total for this phase, while the remaining present their shares.

When performing the same type of hot-spot analysis on the CEORA, a similar distribution between life cycle stages is presented, see Figure 4. Note that the contribution from electricity varies between the studied markets – please see the next chapter for more information on this.

Compared to Rider P525DX, the production phase contributes somewhat more significantly for CEORA, with 12% compared to the riders 8%. Within the production of CEORA, the battery pack stands out the most, with over a fifth of the CEORA production impact but only 12% of the weight. The impact is mainly caused by the battery cells. Apart from the mower itself, the charging station contributes with about 2%, and the reference station only by about 0,2%. The exchange of batteries during the use phase has an impact of 6%, which is about half as much as the total impact of the production phase, which is 12%. Battery exchanges, seen in Figure 4, include their production, transport to market and waste management. For an installed battery, production, transport to market and end-of-life waste management is included in each respective life cycle stage, as it is mounted in the CEORA. In contrast to P525DX, the End-of-Life phase accounts for a larger share of the life cycle impact. This is due to the high share of plastic in CEORA which is assumed to be incinerated at end of life in the baseline scenario. As for the rider, transports to market account for an insignificant share (about 0,5%).

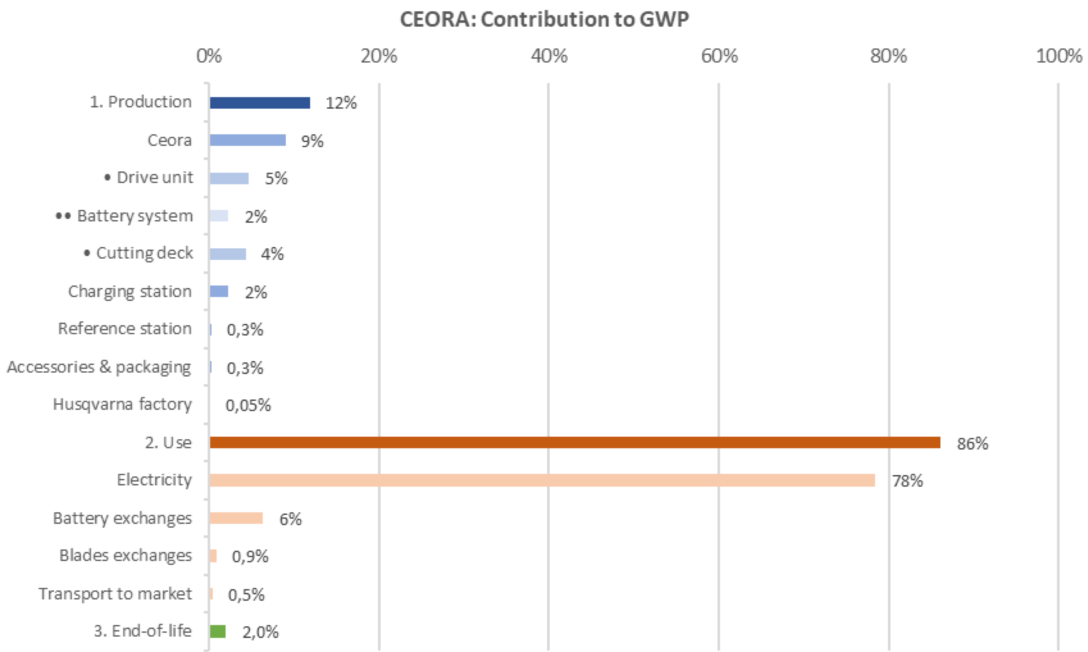

Figure 4 CEORA contribution distribution to Global Warming Potential during typical usage in the EU market. The blue bars present the Production phase, the orange the Use phase and the green the End-of-Life phase. The bars with the life cycle stages names and the numbers 1-3 present the total for this phase, while the remaining present their shares. The symbol "•" indicates that this part/process is underlying the closest part/process above.

4.1.2 **Results analysis**

The results for the Rider P525DX in the other countries show for more or less identical results as for the baseline scenario – Europe. Due to this, P525DX is herein addressed in regards to an average for "all markets" (as can be seen in Figure 5 below). There is however a slight difference detectable due to the different amount of biogenic carbon content in the different market's diesel mixes, as well as differences in end-of-life management between the US and Europe. The total impact differences between the average European market and Germany towards the average "all market" value for the Rider is around -0,7%, France around -2,4% and the US around +3,8%.

In regard to the electrical CEORA on the other hand, the results vary significantly between the different countries and electricity scenarios, see Table 17 below. See also Figure 5 for illustrative comparison with the rider. The difference between the markets for the CEORA depends heavily on the countries' different electricity consumption mixes. The contribution distribution between the different life cycle stages in Figure 4 previously only applies for the EU average, but as can be seen in both Table 17 and Figure 5 below, the difference towards the remaining markets is visible, but does not affect the comparison with the rider.

Table 17 Global Warming Potential for CEORA per average cutting season at each market, total and life cycle distribution.

GWP/season	FR	DE	US	EU	EU: Wind	EU: Future
Total	123	380	373	297	69	162
Production	29%	9%	9%	12%	51%	22%
Use	67%	89%	90%	86%	41%	75%
End-of-Life	5%	2%	0%	2%	9%	4%

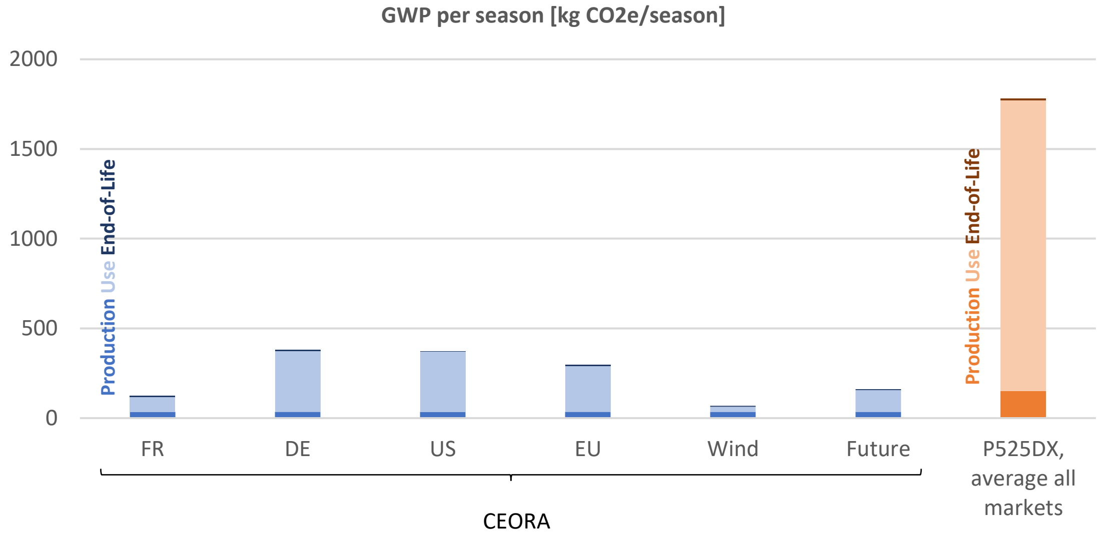

Figure 5 Global Warming Potential per one average cutting season at each market for CEORA, and on all markets for P525DX.

As is made clear in Figure 5 as well, the use of CEORA is preferable in regard to Global Warming Potential in all markets, causing about 79-96% less impact per average cutting season as the rider. It is worth pointing out that only the production of the rider is higher than the full life cycle emissions for CEORA's French and EU-wind scenarios, and comparable to the future European scenario.

Per cutting season, the production of one P525DX is four times higher in the Global Warming Potential which does not correlate to it being about ten times heavier. Since CEORA has a somewhat shorter lifetime expectancy than the rider, the production impact per season is also more compressed. This means that per kg product produced, the CEORA has a higher Global Warming Potential compared to the rider.

When it comes to the use phase it is clear that the Global Warming Potential connected to the rider is significantly larger, even when including the exchanges of the battery system in CEORA. To maintain two football pitches, CEORA spends much more time cutting compared to the rider. However, the energy consumption per hour is very low for CEORA. Comparing the energy need in kWh per season, the energy need of the rider is almost 9 times higher than for the robotic lawn mower, see Table 18.

Table 18 Energy use per season

	Diesel [l]	Diesel [kWh]	Electricity [kWh]
Rider P525DX	532	5 298	-
CEORA™ 546 EPOS™	-	-	591*

* Including 10% charge/discharge

In regard to the other environmental impact categories, the large difference between electrical and diesel mowers in Photochemical Ozone Creation Potential is similar in all studied markets and is heavily dependent on the diesel combustion, making the electrical product preferable. The Eutrophication and Acidification Potential is largely the same in all markets, with significantly lower impact for the CEORA.

When it comes to the use of element resources, reflected in the Abiotic Depletion Potential (elements) indicator, the antimony additive used in the lead-acid battery in the Rider is the main driver (>99%) of its impact. It should be noted that the battery is modelled with secondary data as specific data have not been collected from the supplier. Thus, there is uncertainty regarding the antimony content and the results presented. In fact, if this element was excluded, the rider would perform better in this indicator than CEORA.

For the Abiotic Depletion Potential (fossil) indicator, covering the use of fossil resources, diesel production is the dominant driver for the rider (90%), mainly from the use phase. For CEORA, electricity consumption during cutting makes out the majority of the impact (76%) which originates from the use of fossil resources in the market electricity mixes.

4.2 Husqvarna Group’s VS Other parties’ contributions

To further illustrate what contributions to Global Warming Potential that are directly linked to Husqvarna Group’s production sites and what is connected to other parties, Figure 6 below presents what shares that are related to the below listed segments.

- Supplier production: Impact from material production that lies with the suppliers
- Transports, inbound: Transports from suppliers to Husqvarna Group manufacturing/assembly site
- Husqvarna Group production: Impacts occurring within the manufacturing/assembly site
- Transports, outbound: Transports from Husqvarna Group manufacturing/assembly site to the assessed market/customer
- Customer use: Impact from fuel/electricity use and impact connected to spare parts and other auxiliaries consumed during use
- End-of-Life: Impact from transport to waste management, and from the waste management itself

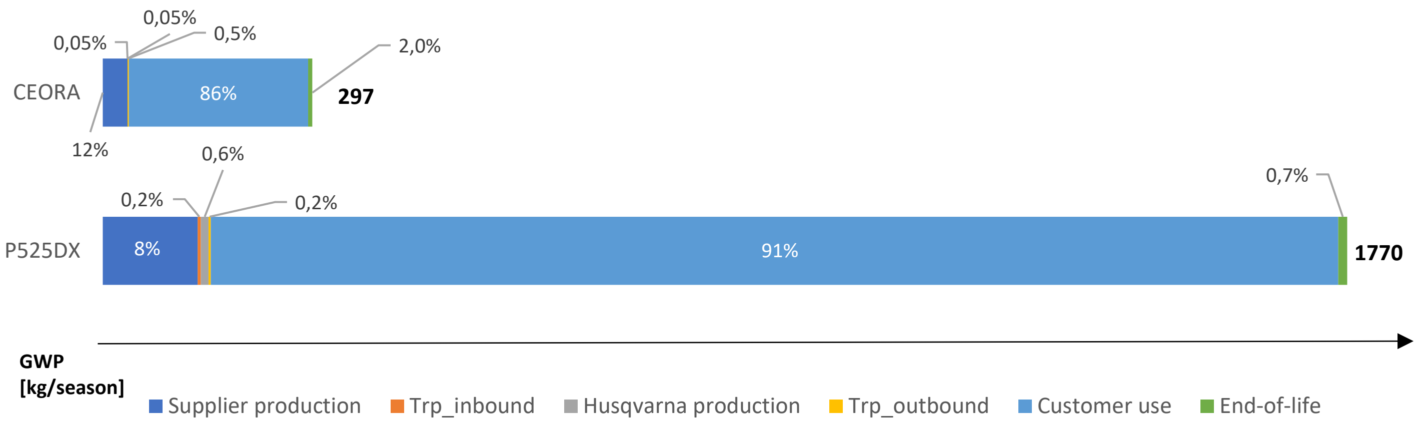

Figure 6 Contributions to GWP during usage in the EU. Values given at the far right of each column represents the GWP per cutting season.

4.3 Data quality

In the result presentation of the environmental performance, values are given with three significant numbers. As more values are used in the underlying calculations at times, the numbers might not always add up in this report due to rounding errors.

Specific data is aimed at being used if available. If specific data is lacking, then *Generic data* is used. There are two types of generic data, namely *Selected generic data* and *Proxy data*. Selected generic data are data that can be used if they are representative for the geographical area in question, that there is a technological equivalence, that there is a completeness of data regarding inputs and outputs and the boundaries are equivalent. Proxy data are data that do not fulfil mentioned data quality rules, for instance regarding geographical area.

Data originating from Sphera and Ecoinvent databases are considered to fulfil the requirements of selected generic data, if it covers the technology in question. When it comes to geographical scope the aim has been to find representative data for the region in question. For some regions, there is no available LCA-data. Hence, another region's LCA data has been applied and, if possible, modified electricity inputs to fit the current region.

Most of the selected generic datasets are not older than 10 years. However, datasets from Plastics Europe are in some cases older than 10 years. But as these still are the most accurate LCA-data on plastic production there is – they are considered valid.

For both assessed mowers, there is no use of proxy data that contributes by more than 10% in the results, in any environmental impact category. At most, CEORA reaches about 9,8% proxy content in Abiotic Depletion Potential (primary energy) for the European scenario with electricity from wind. This depends almost mainly on ABS being assumed as a proxy for ASA, in combination with the lower electricity emission factor for the scenario in comparison to baseline – making production phase a larger contribution to the total impact. Would ABS though not be considered as proxy for ASA, the impact from proxy data would not be as noticeable even in the European scenario with electricity from wind.

4.4 **Sensitivity analysis**

Below follow descriptions of the sensitivity analysis performed for CEORA and P525DX together with results in short. Focus of the sensitivity analysis is on the aspect of Global Warming Potential. All analysis performed are on the usage in Europe, although the other scenarios are commented. For further details on calculations, please see the Output file containing all results.

4.4.1 **HVO instead of diesel**

The use of diesel stands for the largest share in all impact categories in P525DX, with the exception of Abiotic Depletion Potential of elements. In the base case, the emissions to air mainly originates from combustion of the market diesel mix. By using 100% Hydrotreated Vegetable Oil (HVO) instead, the fossil emissions to air can be reduced.

An LCI of HVO developed by f3centre [27] is applied to exchange diesel. The production uses slaughterhouse waste as residue and aims at reflecting the Swedish HVO market.

The origin of combustion emission flows for CO, CO_2 and CH_4 was altered to 100% biotic from the baseline model. Note that the Global Warming Potential indicator used in this assessment excludes emissions of biogenic origin, as the sum of the full life cycle biogenic emissions is zero. Producing HVO dominates the use phase fuel impact, where approximately 99% comes from its production and the remaining 1% originates from its combustion.

Global Warming Potential decreases by about 58% in the use phase, and about 53% in total. Approximately 99% of the impact from HVO derives from the production of it, while the remaining 1% originates from its combustion. The Abiotic Depletion Potential of fossil fuels decreases by a similar share as Global Warming Potential, with about 58% in the use phase and 54% for the full life cycle. Remaining emissions to air do not change drastically when moving to HVO.

In comparison to CEORA, the difference between the two alternatives is reduced substantially in regards to Global Warming Potential, see Figure 7 below for illustrative presentation of the results. CEORA is however still performing significantly better in this indicator, and continues to pe preferable on all remaining impact categories as well.

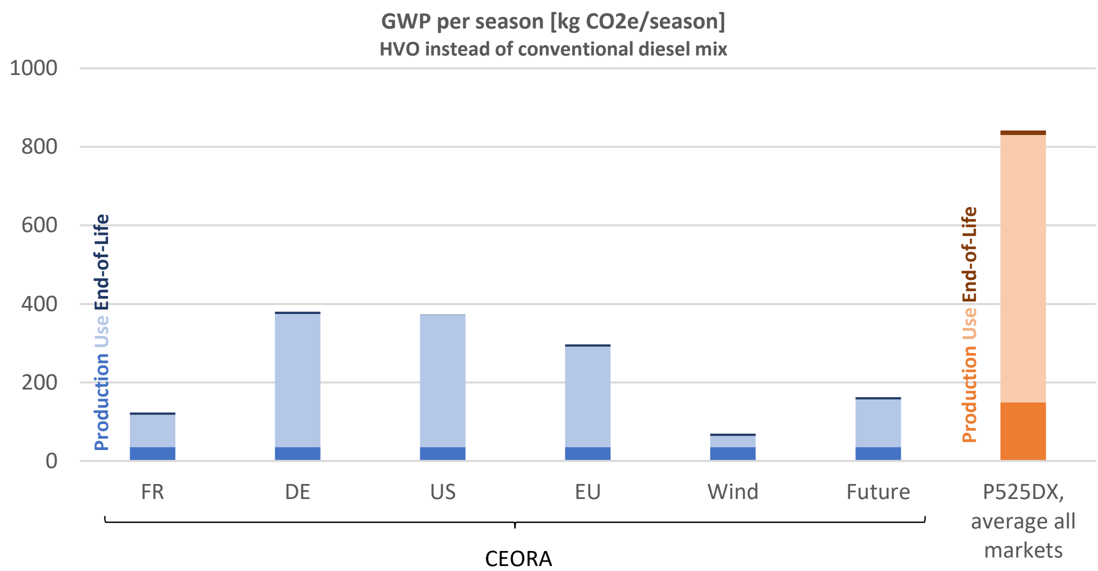

Figure 7 Sensitivity analysis for using 100% HVO in P525DX instead of conventional diesel

Worth noting is that HVO can be produced from several different raw material sources, why the impact related to its production also varies. Raw material access also varies depending on availability and region. The values presented herein are with slaughterhouse waste residue as raw material, with 32 gCO_2e/MJ. The Swedish Energy Agency reports an impact for HVO of 20,4 gCO_2e/MJ with an unspecified raw material source [28]. Since the Swedish Energy Agency does not specify other environmental impacts, the LCI used for HVO in this sensitivity analysis is applied as it is the only publicly available LCI. The impact of using different raw materials gives a large impact variation, from 7 gCO_2e/MJ for tall oil to 32 gCO_2e/MJ for slaughterhouse waste according to the f3centre's study [27]. These use the cut-off method as they are regarded as a waste rather than a co-product, meaning that no environmental impacts are allocated to the raw material. Increasing biofuel use increases the demand for, and value of, raw materials which can justify an economical allocation instead. It would then include a share of the impacts of generating the raw material, such as forestry for tall oil. With an economical allocation, the impact of tall oil increases from 7 CO_2e/MJ to 34 CO_2e/MJ [27]. There is no data for an economical allocation with slaughterhouse waste as raw material available.

4.4.2 **Four football clubs**

The baseline use scenario in this study means that the rider is used infrequently, since it has a much faster cutting time compared to the CEORA. A scenario where the rider would be used more intensively was therefore examined in regard to Global Warming Potential per season. In this scenario, one rider is shared by four football clubs and hence cuts a total of eight pitches.

For the rider, transports between clubs are included in this scenario, with an assumed additional transportation time of about 14 minutes. The time spent for cutting the two pitches owned by one club is increased from 95 to 110 minutes when including transportation. During transportation, which is performed by the rider itself, the fuel consumption is lower than while cutting. The riders average fuel consumption per hour is reduced to 4,24 litres diesel, since the share of transportation time per working hour increases. In total, the rider works for 566 hours per 30-week season, which means a lifetime of about 5,3 years. This means that the rider needs to be exchanged about 4 times in order to maintain all eight football fields during the assessed 20 years.

For the CEORA however, each football club owns one unit each since one CEORA would not have the capacity to maintain four football club's pitches properly and that transportation between clubs would be inefficient since it would have to be reprogrammed to a new reference station between every iteration. That means that the environmental impact in terms of Global Warming Potential of the CEORA is quadrupled and that no transportation time is added.

The results from this assessment, presented in Figure 8, shows a similar distribution compared to if the rider would be used by one football club, with a slightly larger difference compared to the baseline scenario of one football club, with 1-3% higher Global Warming Potential for P525DX. The increase of emissions in relation to CEORA is a result of the rider's increased fuel consumption used for moving between football clubs, which the CEORA does not have to do.

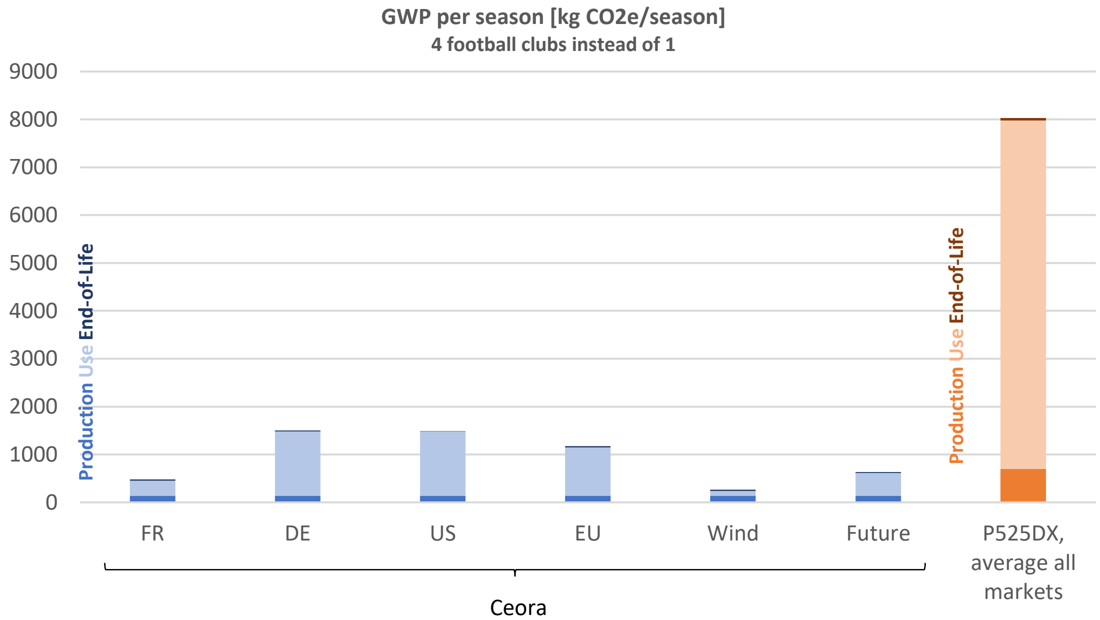

Figure 8 Sensitivity analysis: Using one Rider P525DX for four football clubs, and one CEORA each per club. Global Warming Potential per one average cutting season at each market for CEORA, and on all markets for P525DX.

4.4.3 **Other battery datasets**

For the sensitivity analysis of the battery cells, six other datasets are used for comparison. One of them is from Ecoinvent [2], for unspecified Li-ion battery cell production. The second data is on NCA batteries (Lithium Nickel Cobalt Aluminium Oxide), type 18650. The dataset used for NCA batteries in this assessment is provided by Mats Zackrisson at RISE in 2019 and the data was prepared for the study comparing different types of battery cells for vehicles [29]. The underlying assumption is that the size of the battery will not impact the environmental impacts per kg battery cell significantly. The remaining four batteries are from Sony of the US18650 type, models VT2B, VC3, V3 and VTC4, which was provided by Husqvarna personnel.

The battery cells alone account for about 9% of the total impact on Global Warming Potential during typical usage of CEORA in the EU, and up to 36% for the EU Wind scenario, as the production phase and the battery exchanges during usage there stands for a larger share than if the average EU grid mix is used (due to the electricity from wind is less carbon intensive). When applying the six other datasets on the battery cell, the total results for CEORA is changed between -5,6% to +0,2%, which is not considered significant, and does not affect the comparison towards the rider.

A report published by IVL in 2019 [30], where the production of lithium-ion vehicle battery packs (not only the battery cell) is addressed, a Global Warming Potential of 61-106 kg CO_2e/kWh is presented. The dataset for the battery cell applied in this assessment of CEORA, along with the rest of the battery pack, has the equivalent Global Warming Potential of about 104 kg CO_2e/kWh (battery cell accounting for nearly 92%), which is roughly in line with the values presented by IVL, although in the higher range. This sensitivity analyses hence also suggests that the base case dataset applied is representative and it does not impact the result significantly in the base case comparison.

4.4.4 **Net Zero Emissions by 2050**

To contrast the electricity mix for the future based on the "Announced Pledges Case" (APC) from IEA, a sensitivity analysis was conducted using the "Net Zero Emissions by 2050" (NZE) scenario from the same report [4]. NZE describes how energy demand and the energy mix will need to evolve if the world is to achieve net-zero emissions by 2050, in contrast to the APC which is based on governmental pledges. The scenario is in line with limiting the global temperature increase to 1,5°C with 50% probability, given that corresponding action outside of the energy sector takes place.

The sensitivity analysis scenario is applied as the use phase electricity mix for CEORA, with the rest of the market-based parameters is based on the baseline (EU) market, such as transport to customer. The Global Warming Potential for the NZE scenario is 67% lower compared to the baseline EU scenario. Compared to the rider, a reduction in Global Warming Potential of about 95% could be reached with this future NZE electricity mix, see Figure 9.

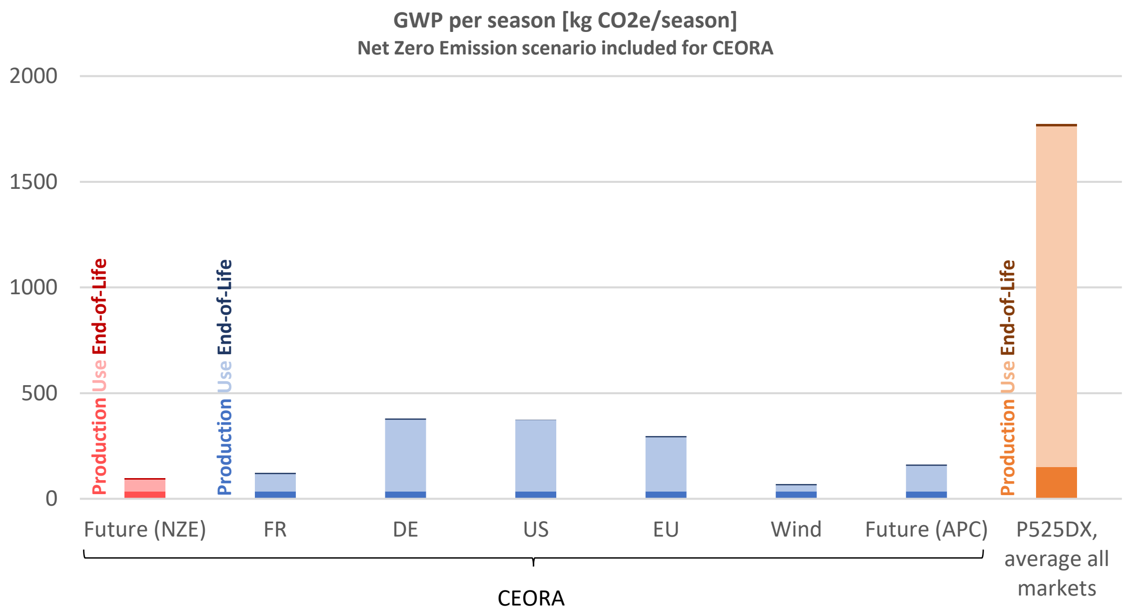

Figure 9 Sensitivity analysis with NZE scenario as energy source in the use phase for CEORA

4.4.5 Double lifetime in Rider P525DX

A sensitivity analysis where the rider's lifetime is doubled, to 6 000 hours, was conducted. Since the rider is capable of cutting grass in more challenging terrain than football fields, where steep hills, higher grass and more turns are present, the lifetime applied in the baseline is based on the wear and tear from its average use. Cutting football pitches presents a much more forgiving topography, with flat surfaces and relatively low grass growth between cutting occasions. Thus, the rider may have a longer lifetime due to lower wear per hour of use according to Husqvarna personnel. As the consumables are exchanged based on use hours, they are assumed to be exchanged accordingly, thus twice the amount is required for the full lifetime compared to the baseline scenario.

Compared to the baseline scenario, the Global Warming Potential is reduced by about 5% per season, see Figure 10. As the dominating impact originates from the use of fuel, the use phase is not significantly affected. However, the production and end of life impact per season is halved, a direct consequence of a doubled lifetime expectancy.

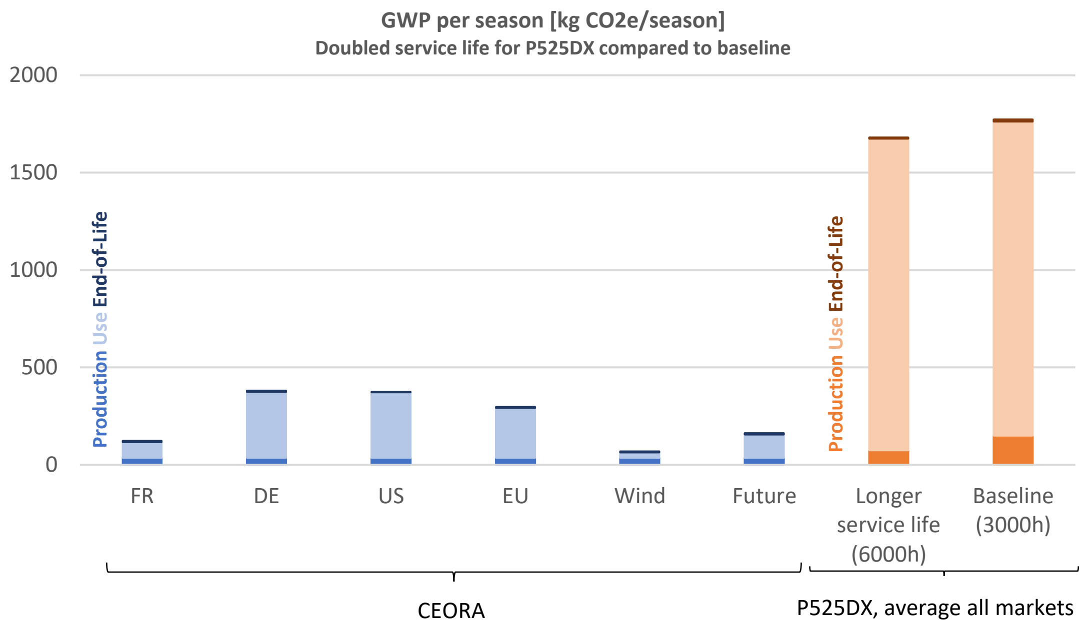

Figure 10 Sensitivity analysis with 6 000h rider lifetime, compared to baseline results

4.4.6 **Shorter cutting time for Rider P525DX**

As was described in the sensitivity analysis in section 4.4.5, the rider's cutting scenario is based on average use. Since a football pitch is flat, has relatively short grass on an average cutting occasion and that there are few turns, the rider could potentially drive at max speed except for when it is turning. A scenario analysis has therefore been conducted where the cutting time for two pitches was reduced from 95 minutes to 65 minutes. That results in about 83 cutting hours per season, corresponding to a lifetime expectancy of approximately 36 years.

The shorter cutting time reduces the Global Warming Potential per season by approximately 32% in each life cycle phase as well as in total, as can be seen in Figure 11. Although the baseline cutting time is regarded as most common, an increased driving speed is preferable in terms of Global Warming Potential, as it leads to a noticeable reduction in impact per season. As the rider requires a driver, it also leads to a more efficient use of the operator's working hours.

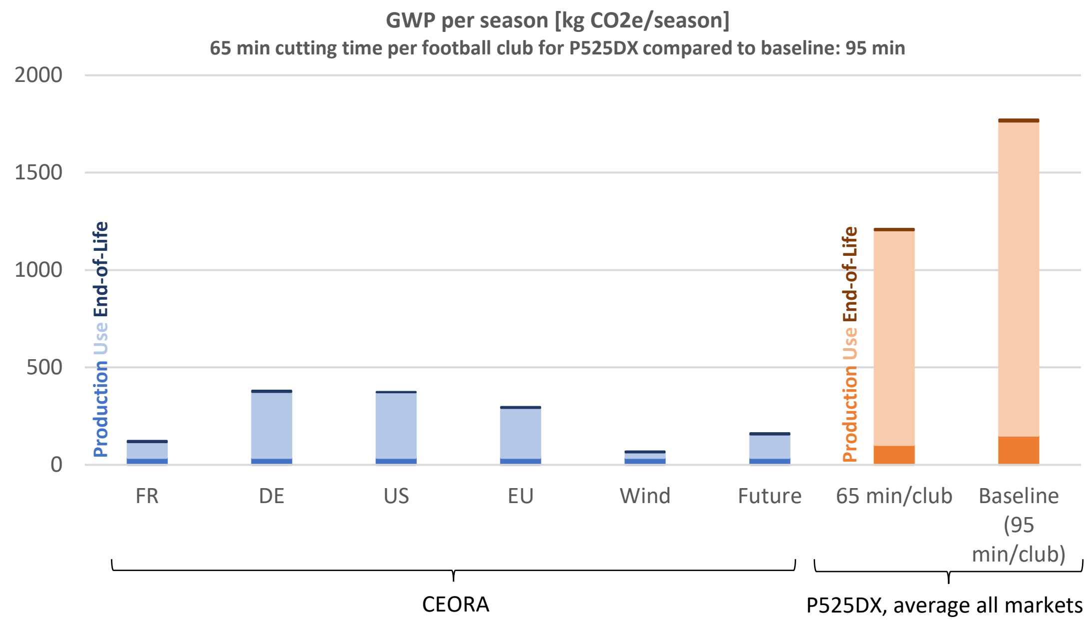

Figure 11 Sensitivity analysis with reduced rider cutting time compared to baseline results

4.4.7 **Combined scenarios for P525DX**

A combination of baseline and sensitivity analysis results is herein presented in regards to the rider, to obtain minimum and maximum Global Warming Potential scenarios, presented in Figure 12. The minimum scenario combines double service life (6 000 hours) for the production and end of life phase, with HVO in the use phase. The maximum scenario is identical to the baseline results.

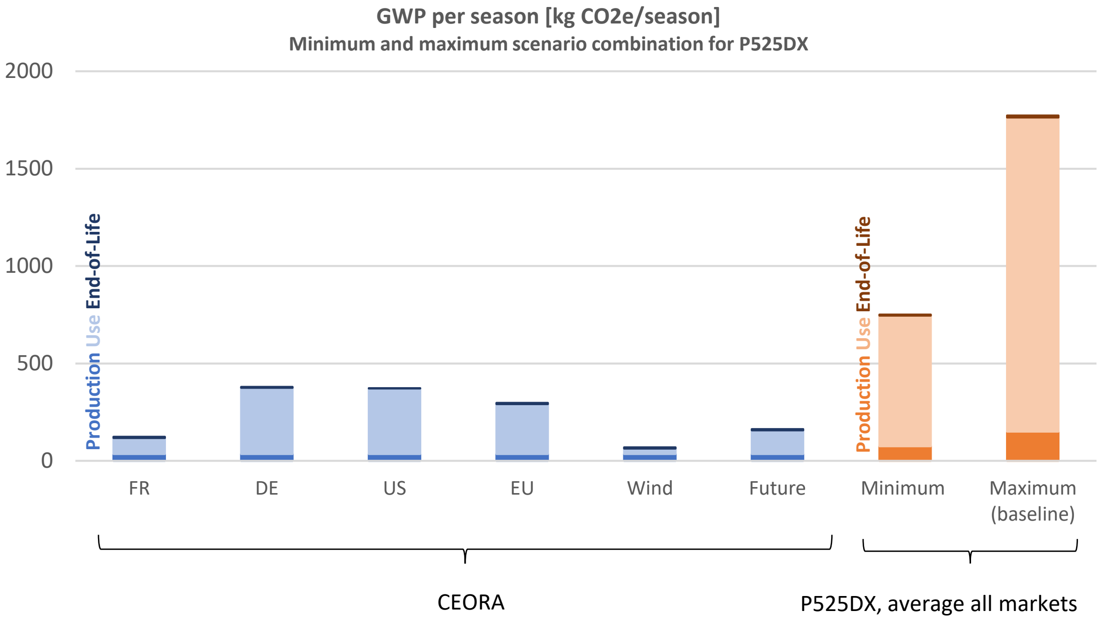

Figure 12 Sensitivity analysis with combined scenarios for P525DX compared to baseline

RAMBOLL

5. Conclusions & discussion

Regardless of the studied market, the electrical driven CEORA performs significantly better in all environmental impact categories assessed compared to the rider. In regard to Global Warming Potential, the robotic lawn mower gives rise to about 79-96% less impact per cutting season. The assessment therefore clearly shows that the CEORA is preferable to the rider on all studied markets.

When it comes to the production of the mowers, the Rider gives rise to about 4 times as much Global Warming Potential than the production of CEORA in the base case, which does not correlate to it being about 10 times as heavy. CEORA hence has a higher impact per kg product compared to P525DX, due much to the battery pack and other electronics.

The Global Warming Potential connected to the rider P525DX in the use phase is significantly larger, even when including 2 battery exchanges (i.e. 3 batteries in total) during the CEORA's life time. To maintain a football clubs two pitches of 16 000m^2 grass lawn in total, the CEORA spends significantly more time cutting - 9h - while the rider can cut the same area in less than a fifth of that time. However, the energy consumption per hour is very low for the robotic lawn mower compared to the rider. Comparing the energy need in kWh per season, the energy need of the rider is almost nine times higher.

Noteworthy from the sensitivity analyses performed is that when the rider uses 100% HVO instead, the difference between the two alternative mowers is reduced. CEORA is however continuously preferable on all markets and environmental impact categories.

An important aspect to keep in mind is that the CEORA is somewhat limited in its use. Both since it cannot manage an equally large area as the rider due to its cutting time, and cannot be driven to a neighbouring football club. Moreover, for it to be used for several football clubs, it would have to be reprogrammed to a new reference station between every iteration, which would lower the efficiency and hence make the task time consuming. However, it does not require an operator and thus is not limited to working hours, and does not produce local emissions during use. It also cuts the grass more frequently, which gives a more consistent grass length. The rider on the other hand, allows for a more flexible usage pattern as it can maintain more than two pitches during one cutting season since it is more time effective, and is easier to transport.

Ways to improve the environmental performance of both the CEORA and the P525DX are to:

- Produce more energy efficient products to reduce the usage of diesel and electricity
- Increase the use of recycled copper, in cooperation with suppliers, to reduce the resource depletion and toxicity potential
- Increase the use of recycled plastics, in cooperation with suppliers, to reduce the resource depletion and environmental impact.
- Increase the use of recycled content in both aluminium and steel, to decrease the Global Warming Potential during production and reduce the resource depletion
- Work with supplier of electrical components to increase the use of recycled metals and reduce the environmental impact from the production

- Secure that the plastic in the CEORA is easy to recycle, which would reduce the end-of-life impact
- Start a dialogue with the battery cell and pack suppliers to receive specific LCA data for the batteries and address measures to reduce the environmental impact related to the battery cell and pack production.
- Choose a supplier of battery cells that can provide proof of a work environment where the health risks related to battery cell production are minimized.
- Installing solar panels on the charging station can be beneficial, as the CEORA most likely would not be used during the day in this scenario.
- Recommend an increased driving speed for the rider, in accordance with the sensitivity analysis, when safe and possible.

There are few examples of reuse of batteries and trials for larger battery cells used in electric vehicles; this is however something that is not a reality today and will not be for the smaller type of batteries used in these battery packs in the coming years. However, if and when this becomes reality - this will improve the environmental performance of the battery cells (by allocating part of the battery production and End-of-life impacts to additional life cycles).

Working towards the reduction requirements related to the Paris agreement, the electricity mixes of the compared countries will most likely improve during the years, as highlighted by the EU-future scenario. This will improve the performance of the electrical robotic lawn mower even further; while this will not impact the diesel driven rider to the same degree as the main environmental burden lays in the use of, and combustion of, a fossil fuel. If the customer actively purchases renewable electricity with certificate, the environmental burden related to the electricity consumption is reduced substantially already today, which the European wind scenario presents. To address the use-phase impact of the rider, the use of HVO significantly reduces fossil greenhouse gas emissions, along with other environmental impacts.

References

[1] Sphera, *GaBi Professional database,* version 10.6.0.119, incl. databases 2021.2 Edition..

[2] Ecoinvent Centre, *Ecoinvent data v3.7.1 Ecoinvent,* Swiss centre for life cycle inventories, 2007.

[3] Ramboll SE, "Husqvarna_LCA_Chainsaw 20191101," 2019.

[4] International Energy Agency, "Net Zero by 2050: A Roadmap for the Global Energy Sector.," 2021. [Online]. Available: https://iea.blob.core.windows.net/assets/deebef5d-0c34-4539-9d0c-10b13d840027/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf. [Accessed 07 04 2022].

[5] Institute of Environmental Sciences - Universiteit Leiden, "CML-IA Characterisation Factors," 2016. [Online]. Available: http://cml.leiden.edu/software/data-cmlia.html. [Accessed 14 03 2022].

[6] the International EPD® System, "Impact Indicators," enviorndec, [Online]. Available: https://www.environdec.com/resources/indicators. [Accessed 14 03 2022].

[7] European Aluminium, "Environmental Profile Report: Life-Cycle inventory data for aluminium production and transformation processes in Europe," 2018.

[8] European Aluminium, 2015.

[9] International Aluminium Institute, "Global Aluminium Recyling: A Cornerstone of Sustainable Development," 2009.

[10] International Aluminium Institute, 2015.

[11] World Steel Association, 2017.

[12] Deutsches Kupferinstitut/European Copper Institute, 2015.

[13] Bunting Magnetics, "How magnets are made," [Online]. Available: https://e-magnetsuk.com/introduction-to-neodymium-magnets/how-neodymium-magnets-are-made/. [Accessed 02 03 2022].

[14] PlasticsEurope, *Eco-Profiles,* https://www.plasticseurope.org/en/resources/eco-profiles.

[15] Deviatkin, I., Khan, M., Ernst, E., & Horttanainen, M., "Wooden and Plastic Pallets: A Review of Life Cycle Assessment (LCA) Studies," *Sustainability,* p. 11(20)., 2019.

[16] European Pallet Association, *EPAL,* 2020.

[17] ICO s.r.l., "EPD Corrugated Paperboard boxes (E flute). Registration number S-P-00981. Valid unitl 2019-09-21," EPD International AB, Italy, 2016.

[18] Eurostat, "Waste statistics - recycling of batteries and accumulators," 2021.

[19] DIRECTIVE 2006/66/EC, "Batteries and accumulators and waste batteries and accumulators," 2006.

[20] Ineos Styrolution, *LURAN S 757G,* 2022.

[21] SpecialChem, *BASF Antioxidant.*

[22] L. A.-W. Ellingsen, G. Majeau-Bettez, B. Singh, A. K. Srivastava, L. O. Valøen and A. H. Strømman, "Life Cycle Assessment of a Lithium-Ion Battery Vehicle Pack (supporting information)," *Journal of Industrial Ecology,* vol. 18, no. 1, pp. 113-124, 2013.

[23] Majeau-Bettez, "Life Cycle Environmental Assessment of Lithium-Ionand Nickel Metal Hydride Batteries for Plug-in Hybridand Battery Electric Vehicles. Supporting Information," *Environmental Science & Technology,* 2011.

[24] Y. Ma, S. Yu, J. Wang and W. Yu, "LCA/LCC analysis of starting-lighting-ignition lead-acid battery in China," *PeerJ,* vol. 6:e5238 https://doi.org/10.7717/peerj.5238, 2018.

[25] EEA, "1.A4. Non road mobile machinery 2016 update May 2017," European Environment Agency, 2016.

[26] Greenhouse Gas Protocol, "Emissions Factors from Cross-Sector Tools - GHG Protocol," 2017. [Online]. Available: https://ghgprotocol.org/sites/default/files/Emission_Factors_from_Cross_Sector_Tools_March_2017.xlsx. [Accessed 23 04 2019].

[27] f3centre, "Well-to-wheel LCI data for HVO fuels on the Swedish market," 2019.

[28] Energimyndigheten, Västhusgasutsläpp, 2021.

[29] M. Zackrisson, "Life cycle assessment of long life lithium electrode for electric vehicle batteries," Swerea IVF AB, Mölndal, 2018.

[30] E. Emilsson and L. Dahllöf, "Lithium-Ion Vehicle Battery Production. ISBN 978-91-7883-112-8," IVL Swedish Environmental Research Institute, In cooperation with the Swedish Energy Agency, Stockholm, 2019.

[31] e. a. Ellingsen, "Life Cycle Assessment of a Lithium-Ion Battery Vehicle Pack," Journal of Industrial Ecology, 2014.

[32] e. a. Majeau-Bettez, "Life Cycle Environmental Assessment of Lithium-Ionand Nickel Metal Hydride Batteries for Plug-in Hybridand Battery Electric Vehicles.," Norwegian University of Science and Technology (NTNU), Trondheim, 2017.

[33] S. Posner, "Riskanalys av kemikalier vid tillverkning av litiumjonbatterier," Swerea IVF, Mölndal, 2009.

[34] Science Daily, "Production of batteries made cheaper and safer, thanks to Finnish researchers," 2012. [Online]. Available: http://www.sciencedaily.com/releases/2012/11/121113083548.htm. [Accessed 07 12 2015].

[35] International Energy Agency, *Poland.*

Appendix A – Project interaction with Husqvarna

The study was conducted together with employees at Husqvarna between October 2021 until June 2022. The project held goal and scope meeting on October 14th 2021, where the products and scenarios were discussed, together with data collection practicalities and project timeframe.

The data collection phase lasted between November 2021 and March 2022 and involved several meetings for clarification and quality assurance with the teams responsible for their respective product.

For the CEORA, Pär Forsman was the main project contact and data provider, with assistance from Stefan Toppe who provided the bill of materials.

For the rider P525DX, Daniel Mannerström and Fredrik Edholm were the main project contacts and data providers, with assistance mainly from Christoffer Romfors who provided the bill of materials.

Jonas Willaredt and Sara Tollin were also involved in study discussions, such as the ones regarding aim, scenarios and scope. The CEORA and rider teams, Jonas Willaredt and Sara Tollin performed Husqvarna's internal quality review of the report during April and May 2022.

Additional Husqvarna staff assisted in collecting data for e.g. emissions tests, Husqvarna manufacturing data and component details.

Appendix B – Qualitative assessment of toxicity & health risks related to batteries

An issue related to batteries that are discussed are toxicity and health risks. These are not assessed quantitatively in this study but discussed qualitatively here below.

Toxicity
A study of lithium batteries, NMC, show that the negative current collector stands for the largest potential impact related to toxicity related to the copper mining and refining (Freshwater Toxicity Potential, Marine Toxicity Potential, Terrestrial Toxicity Potential, Human Toxicity Potential). [31] Another study supports the importance of the negative copper electrode on the toxicity potential, even though it shows a more even distribution between the negative copper electrode and the BMS (Battery Management System). The positive electrode paste (lithium-nickel-cobalt-manganese oxide) is a hotspot for terrestrial toxicity potential where it stands for 30% [32].

It is important to emphasize that the toxicity potential is heavily dependent on the detail level and assumptions of the data provider, as it is connected to smaller emissions to air and water that is not always consistently mapped and reported between different data providers.

The toxicity potential can be reduced by using recycled copper and other metals instead of mined metals and increasing the lifetime of the product.

Health risks
Studies have been made on primarily health risks by Posner [33] for some of the common materials and substances included in Lithium batteries. These risks are primarily for employees in production of battery cells and battery packs and possibly in recycling facilities.

The solvent N-methyl-2-pyrrolidone is volatile, flammable, easily absorbed by the skin and suspected to cause genetic and reproductive damage [33]. The solvent is used in production of electrodes and poses an exposure risk to employees in the production. Studies by e.g. Swerea and Aalto University are trying to find a substitute for this solvent. Aalto University has created a replacement which is said to be cheaper which should increase the possibility of a switch in production, but whether this has already happened could not be confirmed [34].

Polyvinylidene fluoride PVDF might have serious impacts on the environment and may be carcinogenic, but research is lacking. Substances known to have these effects are used in the production of PVDF [33]. PVDF is used as a binder in the cathode (positive electrode paste) in the batteries and little is known of its impacts.

Carbon black might contain PAHs and then be carcinogenic. It can also pose a risk if particles are inhaled [33]. It is used together with PVDF in the cathode (positive electrode paste) in the batteries.

The significance of the above-described risks is highly dependent on the specific producer of the battery cells and battery packs. Husqvarna Group can reduce these risks by choosing a supplier that can provide proof of a work environment where these risks are minimized.

Appendix C – Guarantee of origin, Aycliffe

havenpower
A Drax Group company

Haven Power
The Havens
Ransomes Europark
Ipswich
IP3 9SJ

+44(0)1473 725943
www.havenpower.com
enquiries@havenpower.com

Husqvarna UK Limited
Preston Road
Aycliffe Business Park
Newton Aycliffe
Durham
DL5 6UP

13-Sep-2021

Dear Sir/Madam,

Supply of Renewable Power

In accordance with our agreement that 100% of the electricity supplied under the contract will be from Renewable Source generation, please find enclosed the certificate statement for CP19 (April 2020 to March 2021). This statement details the guarantee of origin certificates specifically attributed to your consumption over this period.

Kind Regards,

Tom Stebbings
Sustainable Commodities Trader
M: 07719 902062
E: thomas.stebbings@drax.com

Renewable Certificate Schedule
Husqvarna UK Limited

Generating Station / Agent Group	Scheme	Country	Technology Group	Output Period	Certificates	Start Certificate No.	End Certificate No.
P.E. MOTILLA DEL PALANCAR	GOO	Spain	Wind / Unspecified / Onshore	Oct-2020	8981	84370190150000000000747026188	84370190150000000000747035168

Appendix D – Guarantee of origin, Mielec

RGP
Rejestr Gwarancji Pochodzenia

CERTYFIKAT

DLA

Husqvarna Poland Sp. z o.o.

Poświadczający, że
1 037 MWh
energii elektrycznej wprowadzonej do sieci dystrybucyjnej lub sieci przesyłowej zostało wytworzonych
w źródłach biomasowych
w instalacji odnawialnego źródła energii, co zostało potwierdzone na dokumencie
RGP_DALKIA_2021-10-28_1139, gwarancjami pochodzenia przysługującymi firmie
Veolia Energia Łódź S.A.
Warszawa, dnia 28.10.2021

Prezes Zarządu Towarowej Giełdy Energii S.A.

TGE

RGP
Rejestr Gwarancji Pochodzenia

CERTYFIKAT

DLA

Husqvarna Poland Sp. z o.o.

Poświadczający, że
2 789 MWh
energii elektrycznej wprowadzonej do sieci dystrybucyjnej lub sieci przesyłowej zostało wytworzonych
w źródłach biomasowych
w instalacji odnawialnego źródła energii, co zostało potwierdzone na dokumencie
RGP_DALKIA_2021-10-28_1140, gwarancjami pochodzenia przysługującymi firmie
Veolia Energia Łódź S.A.
Warszawa, dnia 28.10.2021

Prezes Zarządu Towarowej Giełdy Energii S.A.

TGE

CRITICAL REVIEW STATEMENT

Contact person RISE
Mats Zackrisson
Division Materials and Production
+46 10 228 46 88
mats.zackrisson@ri.se

Date
2022-06-07

Reference

Critical review of LCA of Husqvarna lawn mowers CEORA™ 546 EPOS & Rider P525DX

Background

The LCA (life cycle assessment) study of CEORA™ 546 EPOS™ & Rider P525DX was commissioned by Husqvarna AB and carried out by Axel Cullberg and Agnes Rönnblom at Ramboll. Critical review was carried out by an independent expert, Mats Zackrisson at RISE Research Institutes of Sweden.

The aim of the review was to ensure that:

- the methods and process used to carry out the LCA are consistent with the ISO 14040:2006 and ISO 14044:2006 standards
- the methods used to carry out the LCA are scientifically and technically valid;
- the data used are appropriate and reasonable in relation to the goal of the study;
- the interpretations reflect the limitations identified and the goal of the study;
- the study report is transparent and consistent.

It was decided in the scope phase that this LCA should not be considered as a comparative assertion as defined in ISO 14044:2006, since it only involves comparisons between products manufactured and sold by the same company, i.e., it does not affect external parties. Hence this critical review is performed by a third party expert rather than a panel of interested parties.

The critical review process involved the following:

- Reading and reviewing the draft LCA report by the third party expert; submitting comments and suggestions for improvements and clarifications 20 May 2022 by e-mail
- Discussing comments and suggestions in a telephone meeting 31 May between Axel Cullberg and Agnes Rönnblom Rambol and Mats Zackrisson RISE.
- Submission of final version of LCA report 7 June 2022 by e-mail
- Dispatching Critical review statement 7 June 2022, by e-mail

The critical review did not encompass review of the LCA numerical model as such, only the results of the model and the description of it in the LCA report. Though some input data was discussed during the review.

Conclusion of the critical review

The independent expert Mats Zackrisson confirms that this LCA study follows the guidance and is consistent with ISO 14040 and ISO 14044. The data used seem appropriate and the interpretations reasonable and well explained in relation to the goal and limitations of the study.

Communication of the study results

In all communication of results relating to comparisons between the electric mower and the diesel mower, it is important to point out that the fulfilment of the functional unit of cutting football fields differs also concerning aspects such as: noise, need of driver, ability to be used at other locations, speed of cutting and local emissions.

RISE Research Institutes of Sweden AB
Environment and Sustainable Chemistry

Mats Zackrisson

Stockholm 2022-06-07