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Carbon footprint screening of Toucan Active Plus

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1. Introduction

Increasingly, more political and consumer focus is being placed on environmentally responsible products and systems to assist with reducing the impact of global warming through the reduction of emissions of greenhouse gasses. There is now a far higher level of awareness of the environmental consequences of inaction or minimum action on reducing greenhouse gasses with countries setting political-driven reduction targets which are cascaded down to companies and organisations to fulfil. However, there is still many actions that are needed to prevent the worst effects that global climate change is, and will, be causing.

All companies and organisations purchase products to be used in cleaning and disinfecting their offices, workplaces and facilities, and their production processes. Most still purchase synthetically manufactured chemicals which should be questioned in terms carbon footprint levels, due to the manufacturing process, transport/distribution, and use of plastic containers. Centrego Ltd is an industry leader in the development and production of ElectroChemical Activation (ECA) technology which generates powerful but safe disinfectant and cleaning solutions (liquids) on-site from water and salt. One of their products is the Toucan Active Plus.

The Toucan Active Plus is one of the ECA systems that Centrego has developed and is implemented in many countries. The solutions generated by the Toucan Active Plus product contain the active substances of hypochlorous acid (HOCl) and sodium hypochlorite (NaOCl) which are deployed for general cleaning and disinfectant purposes as well as for more specialist application in food production, water treatment and healthcare. The inputs to generate the activated solutions are water (H_2O) and salt (NaCl), natural compounds, passed across specialist cells through which electricity is passed. The electrolysis of the water and salt generates hypochlorous acid and sodium hypochlorite. Hypochlorous acid is also naturally produced in humans and animals and is an effective disinfectant that is 80-200 times more efficient than standard disinfecting procedures (Nguyen et. al, 2021). This study aims to address this, and more specifically calculate the carbon footprint, through Life Cycle Assessment (LCA), of the Toucan Active Plus production and use. The considered product is already on the market but needs documentation of its carbon footprint performance.

LCA is an ISO 14040 and 14044 standardised method and is considered a comprehensive exercise that can quantify a broad range of potential environmental impacts, from global to local/regional (ISO, 2006). The way this is done in LCA is firstly by accounting the input/outputs from the life cycle of a product or system. Secondly these are related to the potential implications each of these have to different environmental impact categories, when substances are released to air, water, and soil. In this way, and depending on scope, environmental impacts during a product or system life cycle can be quantified and assessed. However, this study focusses on one impact category, the greenhouse gas emissions (global warming contribution), and is a carbon footprint assessment. The study is based on the general principles of LCA, described in the ISO 14040 series, but only quantifies the contribution to global warming (ISO, 2006). The assessment is a cradle-to-gate type (incl. use stage), and includes production, use and upstream activities, including the transport of final product to a specific use stage destination (specific amount of km).

1.1. Aim of study

The LCA carbon footprint is performed by FORCE Technology, an independent engineering consultancy company, and commissioned by Centrego Ltd, through Food Diagnostics A/S, with the aim of quantifying the carbon footprint of the Toucan Active Plus production and use. The carbon footprint study has not been subject to a review process, as it on a screening level.
NB. comma is used as a decimal separator.

2. Method

2.1. Definition of goal, scope and functional unit

The goal of the cradle-to-gate (incl. use) assessment is to quantify and document the carbon footprint of the Toucan Active Plus from Centrego Ltd. The approach will yield a hotspot carbon footprint analysis of the product, and the solution generated, and show where the main impacts arise, and where there can be set in to reduce these. Further, this assessment can be used in the future to benchmark the carbon footprint of the Toucan Active product with alternative and competing products. For this, detailed and comparable production data is needed, along with carbon footprint calculations. This will allow users of disinfectants and cleaning solutions to compare the carbon footprint of using different systems and chemicals.

The functional unit (reference flow only) is 1 litre of non-diluted cleaning solution produced with the Toucan Active Plus, to be used by humans for cleaning and disinfection after dilution. Hence, if in the future wanting to compare this product with other alternatives, the functional unit and use phase must be described in more detail (i.e. how efficiently does the solution disinfect and clean compared to other solutions and how much non-diluted solution is used per task). The place of delivery (the use stage) is set to be a specific distance from the final product assembly plant of the Toucan Active Plus in Frome (Somerset, UK) (600 km away, e.g. Brussels).

The geographical scope of the study is global, as main production occurs in the UK and the use phase is set to be in the EU. Parts for the Toucan Active Plus are produced in UK, USA and China. The secondary process data is thus aimed at being according to the actual occurrence, but is commonly based on European conditions, due to LCA data providers focus being mainly on Europe. The technology applied, in this relation, is considered best available. The temporal scope is several years, as products are used for a long time (enquire Centrego Ltd for further information). However, the disposal stage is not considered in this study due to lack of information about the end-of-life.

Table 1. Overview of considered Toucan Active Plus Scenarios, included in the carbon footprint LCA study (1 litre of solution produced, incl. hardware).

Scenario	Disinfectant (L of non-diluted solution)	Toucan Active Plus production and use stages									
		Production & transport							Use & transport		Reference
		Parts (incl. upstream)	**Transport** (parts to XED or Centrego)*	**XED assembly** (sub-product)	**Transport** (XED to Centrego)	**Centrego assembly** (final product)	**Packaging** (final product)	**Transport** (final product & packaging)	**Utilities**	**Chemical**	
#1 **EU use 2022 – Toucan Active Plus**	1	X (UK, USA & China)	Lorry (UK, USA or CN diesel); Airplane (USA or CN kerosene)	Electricity (UK grid mix)	Lorry (40,7 km) (UK diesel)	Electricity (UK grid mix); Water (EU-28)	Cardboard + Paper + PP	Lorry (600 km) (UK diesel)	Electricity (EU-28 grid mix - **2022**); Water (EU-28)	Sodium chloride (NaCl) (lorry, UK diesel)	Centrego/ Food Diagnostics (2022)
#2 **EU use 2030 – Toucan Active Plus**	1	X (UK, USA & China)	Lorry (UK, USA or CN diesel); Airplane (USA or CN kerosene)	Electricity (UK grid mix)	Lorry (40,7 km) (UK diesel)	Electricity (UK grid mix); Water (EU-28)	Cardboard + Paper + PP	Lorry (600 km) (UK diesel)	Electricity (EU-28 grid mix – **2030****); Water (EU-28)	Sodium chloride (NaCl) (lorry, UK diesel)	Centrego/ Food Diagnostics (2022)

* Parts are either delivered to XED (Bristol) or Centrego (Frome, Somerset) – distances to these are considered from UK, USA, and China, depending on actual part production.

** The 2030 use scenario is based on EU energy trends report, accessed through Sphera (2022). The 2030 scenario has a greener energy profile – see reference.

2.2. System boundaries

The considered system is from cradle-to-gate and includes upstream activities from the factory gate where the final Toucan Active Plus hardware is produced and packaged. The use stage is considered, up to and including the production of non-diluted (scaled to 1 litre of non-diluted solution produced locally, e.g. in a company where the hardware is setup. The disposal of the hardware and packaging is not considered, while the use of solution is not relevant due to it is applied on surfaces and in solution and is subject to evaporation and other removal processes. The transport of parts for construction of the Toucan Active Plus, packaging, NaCl and final product happens via lorry or airplane.

The waste treatment is not considered in this study but may be considered in future expansions of the study. Then, the hardware lifetime and waste treatments in a specific region should be considered, alongside the potential reuse (refurbishment) of hardware components.

This carbon footprint assessment is based on primary production and use data collected by Centrego Ltd and Food Diagnostics A/S (Centrego/Food Diagnostics, 2022).

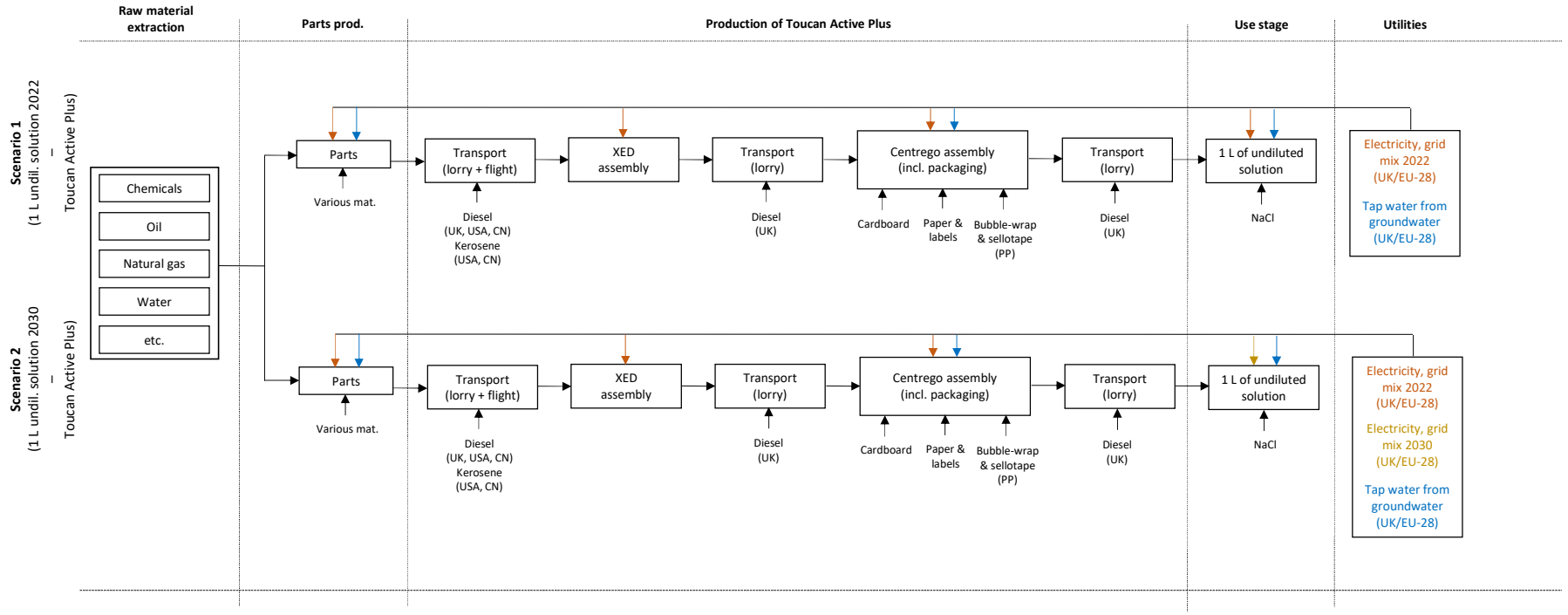

Figure 1. System boundaries of the two Toucan Active Plus scenarios (2022 vs. 2030 use), considered in the LCA carbon footprint assessment.

2.3. Life cycle stages

In relation to the LCA stages and specific processes, some of the main aspects of these are described as follows. It needs to be underlined that the study has a focus on the construction of Toucan Active Plus and the operational aspect of processes (until non-diluted solution), thus the construction of e.g. buildings and other equipment is excluded. The geographical, temporal, and technological retrospectivity is as representative as possible, but certain assumptions were made, as production information or processes are not always available in the desired format. Disposal stage is excluded, regarding the hardware and packaging (end-of-life) – this will depend on the actual lifetime of the hardware, potential reuse of parts, and available waste treatment infrastructure in a specific region/country.

2.3.1. Raw materials and parts production

Different raw materials and parts are used to produce the Toucan Active Plus hardware (see table 2). These have been modelled accordingly in the LCA software, but in certain cases some assumptions are made due to the specific production processes (inventories) are not available. However, the initial consideration is that the assumptions are reasonable.

In relation to the composition, of the Toucan Active Plus, one of the main parts used (according to mass) are the stainless steel (SS) shelf with screws (304 stainless steel) and Ecomix duo (PP plastic). Due to lack of production data on specific shapes of a material, a general approach is used – e.g. the SS steel shelf manufacturing is solely modelled with a stainless steel sheet manufacturing process and the electrolysis cell manufacturing with a titanium production process. Also, the pelican pump is simplified with modelling injection moulded polypropylene plastic (generic) and stainless steel (cold rolled coil). Hence, the assembly of the pelican pump is not modelled, but is likely to be of less importance for the results.

The energy used in the production of materials and parts is commonly included in the processes, as they cover the upstream occurrence. However, if this was included via chosen processes, e.g. for injection moulding, the corresponding geographical representation is obtained. Here UK (mainly), US, and CN electricity grid mix is modelled. In terms of water, tap water from groundwater for UK (Sphera, 2022) was used, as such productions occurred in the UK.

2.3.2. Transport

In all scenarios transport is included. Parts are transported from producers to the Toucan Active Plus assembly facilities – either to the XED plant or the Centrego plant where the final product assembly and packaging occurs. Truck and airplane transport is applied – airplane is used from USA/China for PCB, power supply, fan, main socket, and electrolysis cell. Transport of final product from Centrego (Frome, Somerset) to use stage is considered, where 600 km lorry transport is assumed as the final destination (endpoint of assessment, e.g. Brussels). Transport of waste from production is not modelled, as none was reported by the company – however, this should be investigated further e.g. in future updates of the study.

The road transport process applied is an average non-aggregated global truck (Euro VI) transport process, with 20-26t gross weight and maximum payload of 17.3t from GaBi-Sphera v. 10.5 database (Sphera, 2022). The diesel supplied to the truck is diesel at filling station from UK, USA, or China, also from GaBi-Sphera v. 10.5 database (Sphera, 2022). This depends on the part production. Otherwise, most parts are produced in the UK and the XED and Centrego plants are in the UK, so diesel from UK filling station is commonly applied. The cargo airplane transport from USA and China is based a global process for cargo plane transport (113t payload, technology mix and kerosene driven), plus kerosene jet fuel at refinery (A1 quality), from GaBi-Sphera v. 10.5 database (Sphera, 2022).

Production of transport technologies, and the related aids (e.g. containers), are not included. These are considered of insignificant importance, as operation of these during its lifetime leads to main environmental emissions.

2.3.3. Utilities (production of final product and use)

Production of final product and use requires use of electricity and water. The primary data, covering quantities and sources, is based on Centrego/Food Diagnostics (2022). Electricity is based on average national grid mix, from either UK, USA, or China, depending on part and operation. The water for parts production is based on GB water production (from groundwater), while use stage water usage is set to EU-28 water production (from groundwater). Processes have its origin from the GaBi-Sphera v. 10.5 database (Sphera, 2022).

The first assembly occurs at the XED facility in Bristol, where UK grid mix electricity is modelled used, and the final assembly occurs at Centrego (Frome, Somerset). At Centrego both UK electricity and water is reported used by Centrego/Food Diagnostics (2022).

2.3.4. Packaging

Packaging of final products at Centrego is done with paper and small amounts of plastic. The used packaging materials, in both scenarios, include corrugated cardboard (300 g), paper (3 g), and PP (11,5 g). No waste or end-of-life is considered for packaging, besides the one included in the aggregated secondary production processes. The collected information on materials and weights of packaging is based on Centrego/Food Diagnostics (2022).

The modelling of packaging is based on the corresponding secondary data for production of materials, along with production processes of the packaging (e.g. injection moulding of PP plastic).

2.3.5. Solution production (undiluted)

The use stage is considered to occur in the EU and covers the production of the undiluted solution for, with the use of the Toucan Active Plus hardware. The production requires electricity, water and salt (NaCl). The salt can be sourced locally to where the system is installed and used, but for the purposes of this exercise NaCl is modelled as being sent 600 km from Centrego (UK) to the use stage – as the Toucan Active plus hardware.

The solution production inventory is originally based on 5 L of solution production with a concentration of 500 parts per million (ppm) of the active substance, over an activation cycle of 45 min with the Toucan Active Plus. The Toucan Active Plus solution production is calculated according to a ca. 8-year service time, 5 days a week for a year, and with 2

activations per day of 5 litre each. This leads to 4172 activations during a year, and 2860 L of undiluted solution produced during 8 years. Lower or higher activation numbers can be used, depending on the user demand.

For the spray bottle dispenser, a 3:1 dilution ratio is used and, the 20 860 l of undiluted solution becomes 62 400 l of diluted and ready-to-use solution. For the bucket dispenser: 6:1 dilution ratio is used. Ordinary use is likely a combination of the two.

2.4. Carbon footprint method

The modelling of the 2 scenarios is performed with GaBi 10.5 LCA software. Here the applied Life Cycle Impact Assessment (LCIA) method is PEF 3.0 (2020). In the LCA software the primary data from table 2 and secondary data from appendix 1 is related with the PEF v.3.0 (2020) characterization factors. This carbon footprint study is an LCA, where focus is only on one impact category – more specifically the contribution to global warming (midpoint), presented in characterized result form (expressed in kg CO_2-equivalents). The applied approach to the global warming potential quantification is based on IPPCC (2007), where the considered time horizon of the greenhouse gasses is 100 years.

3. Life cycle data

Data used in this study is based on primary data delivered by Centrego/Food Diagnostics (2022), and on secondary data (upstream process data) mainly from GaBi-Sphera v. 10.5. LCA database (Sphera, 2022). Otherwise, in general, if secondary data could not be found in the common and professional LCA databases, data from literature and reasonable assumptions were used. This is specifically described in section 2.3, and in the overview of used data in appendix 1.

3.1. Resource consumption

The scenarios that consider the production of Toucan Active Plus and undiluted solution during use, are modelled to quantify a carbon footprint hotspot analysis of the two different options. Also, if possible, they can be compared. But caution must be applied as in the second scenario only the electricity production is changed (according to a EU 2030 forecast). The functional unit in this study is in fact a reference unit, that is set to 1 L of undiluted solution and with a share of the produced equipment according to a 8 year operation cycle (incl. packaging). End-of-life or waste is not considered.

The considered life cycle stages are within cradle-to-gate, with the use stage and transport to and from the facilities and to the user (600 km transport distance set from Frome Somerset – e.g. to Brussels, Belgium).

Table 2. Primary data for the included scenarios, where 1 L solution is produced (incl. hardware and packaging).

Data inputs		Reference	Scenarios	
			#1 (2022) (1 L undil. solution – Toucan Active Plus)	**#2 (2030) (1 L undil. solution – Toucan Active Plus)**
Product	Production of	Centrego/Food Diagnostics (2022)	Undiluted solution (disinfectant) + Toucan Active Plus equipment	Undiluted solution (disinfectant) + Toucan Active Plus equipment
	Production place (final product)	Centrego/Food Diagnostics (2022)	UK (Centrego)	UK (Centrego)
	Weight (reference flow)	Centrego/Food Diagnostics (2022)	1 L *Undiluted disinfectant/sanitizer*	1 L *Undiluted disinfectant/sanitizer*
Transport (Euro V, 20-26t)	Transport of parts to Toucan Active Plus manufacturing	Centrego/Food Diagnostics (2022)	to UK *(Truck/Airplane)*	to UK *(Truck/Airplane)*
Manufacturing of Toucan Active Plus **(parts for one whole Toucan Active Plus – if according to one L solution it is 1/20860 of each part)**	PCB (Fibreglass FR 4 material with copper traces)	Centrego/Food Diagnostics (2022)	50 g *(Truck: 49 km)*	50 g *(Truck: 49 km)*
	Power supply part	Centrego/Food Diagnostics (2022)	150 g *(Truck: 20 km) (Airplane: 5600 km)*	150 g *(Truck: 20 km) (Airplane: 5600 km)*
	Fan (PBT, glass reinforced)	Centrego/Food Diagnostics (2022)	27 g *(Truck: 20 km) (Airplane: 5600 km)*	27 g *(Truck: 20 km) (Airplane: 5600 km)*
	Switch (PDM)	Centrego/Food Diagnostics (2022)	16 g *(Truck: 49 km)*	16 g *(Truck: 49 km)*
	Main socket (Thermoplastic – tin plated brass contacts)	Centrego/Food Diagnostics (2022)	20 g *(Truck: 20 km) (Airplane: 5600 km)*	20 g *(Truck: 20 km) (Airplane: 5600 km)*
	Mechanical parts	Centrego/Food Diagnostics (2022)	20 g *(Truck: 0 km)*	20 g *(Truck: 0 km)*
	Cables (PVC coated copper)	Centrego/Food Diagnostics (2022)	50 g *(Truck: 0 km)*	50 g *(Truck: 0 km)*
	Case (ABS)	Centrego/Food Diagnostics (2022)	305 g *(Truck: 321 km)*	305 g *(Truck: 321 km)*
	Electrolysis cell (titanium)	Centrego/Food Diagnostics (2022)	200 g *(Truck: 284 km) (Airplane: 8000 km)*	200 g *(Truck: 284 km) (Airplane: 8000 km)*
	Acrylic 3 mm white cell cover	Centrego/Food Diagnostics (2022)	180 g *(Truck: 39 km)*	180 g *(Truck: 39 km)*
	Enclosure (ABS)	Centrego/Food Diagnostics (2022)	310 g *(Truck: 321 km)*	310 g *(Truck: 321 km)*
	Illuminated switch (POM)	Centrego/Food Diagnostics (2022)	23 g *(Truck: 321 km)*	23 g *(Truck: 321 km)*

	Enclosure 2000 series (ABS)	Centrego/Food Diagnostics (2022)	38 g *(Truck: 321 km)*	38 g *(Truck: 321 km)*
	Ecomix duo (PP)	Centrego/Food Diagnostics (2022)	1200 g *(Truck: 282 km)*	1200 g *(Truck: 282 km)*
	SS shelf (4 screws) (304 Stainless steel)	Centrego/Food Diagnostics (2022)	1460 g *(Truck: 285 km)*	1460 g *(Truck: 285 km)*
	5 L tank (PE)	Centrego/Food Diagnostics (2022)	714 g *(Truck: 77 km)*	714 g *(Truck: 77 km)*
	300 ml Long pushfit 15 ml (Polybutylene))	Centrego/Food Diagnostics (2022)	137 g *(Truck: 0 km)*	137 g *(Truck: 0 km)*
	15-10 mm reducer (Polybutylene)	Centrego/Food Diagnostics (2022)	19 g *(Truck: 0 km)*	19 g *(Truck: 0 km)*
	UK/EU power cable	Centrego/Food Diagnostics (2022)	200 g *(Truck: 175 km)*	200 g *(Truck: 175 km)*
	Male comp gland black (20 mm) (Nylon 66)	Centrego/Food Diagnostics (2022)	14 g *(Truck: 0 km)*	14 g *(Truck: 0 km)*
	Jerry Can (HDPE)	Centrego/Food Diagnostics (2022)	81 g *(Truck: 255 km)*	81 g *(Truck: 255 km)*
	Pelican pump (PP+stainless steel)	Centrego/Food Diagnostics (2022)	68 g *(Truck: 285 km)*	68 g *(Truck: 285 km)*
	10 mm piping (LDPE)	Centrego/Food Diagnostics (2022)	12 g *(Truck: 64 km)*	12 g *(Truck: 64 km)*
Transport (Euro VI, 20-26t)	Transport from XED to Centrego (subpart)	Centrego/Food Diagnostics (2022)	From Bristol to Frome (Somerset) *(Truck: 41 km)*	From Bristol to Frome (Somerset) *(Truck: 41 km)*
Utilities (XED & Centrego) **(for one whole Toucan Active Plus – if according to one L solution it is 1/20860 of each part)**	XED electricity (UK grid mix)	Centrego/Food Diagnostics (2022)	0,18 MJ	0,18 MJ
	Centrego electricity (UK grid mix)	Centrego/Food Diagnostics (2022)	0,045 MJ	0,045 MJ
	Tap water (UK)	Centrego/Food Diagnostics (2022)	5 L	5 L
Packaging **(for one whole Toucan Active Plus – if according to one L solution it is 1/20860 of each part)**	Cardboard	Centrego/Food Diagnostics (2022)	300 g *(Ship: 100 km)*	300 g *(Ship: 100 km)*
	Paper	Centrego/Food Diagnostics (2022)	2 g *(Ship: 100 km)*	2 g *(Ship: 100 km)*
	Labels (paper)	Centrego/Food Diagnostics (2022)	1 g *(Ship: 100 km)*	1 g *(Ship: 100 km)*
	Bubble wrap (PP)	Centrego/Food Diagnostics (2022)	10 g *(Ship: 100 km)*	10 g *(Ship: 100 km)*
	Sellotape (PP)	Centrego/Food Diagnostics (2022)	1,5 g *(Ship: 100 km)*	1,5 g *(Ship: 100 km)*
Transport (Euro VI, 20-26t)	Transport of final product to use stage	Centrego/Food Diagnostics (2022)	From Frome (Somerset) to unspecified *(Truck: 600 km)*	From Frome (Somerset) to unspecified *(Truck: 600 km)*
Use stage **1 L solution production**	Electricity (EU-28 grid mix or EU-28 2030 grid mix)	Centrego/Food Diagnostics (2022)	0,081 MJ	0,081 MJ

(undiluted)	Tap water (EU-28)	Centrego/Food Diagnostics (2022)	1 L	1 L
	Sodium chloride (NaCl) (EU-28)	Centrego/Food Diagnostics (2022)	1,2 g	1,2 g

The collected primary data contains all the flows that are identified by Centrego/Food Diagnostics (2022). However, improvement to processes may occur in the future and thus new data shall be collected. In potential follow up studies the primary data, and secondary data, will have to be improved and verified, to further substantiate the LCA results. This will improve and minimize the applied assumptions, which are described in section 2.3.

4. Results

The carbon footprint results are presented in characterized form, i.e. in kg CO_2-equivalents. The results are at first presented as cumulated for the two product scenarios. And thereafter as grouped for the hardware, then it can be seen which processes that contribute the most to the greenhouse gas emissions. The results are also shown in tables, in appendix 2.

4.1. Scenario comparison (1 litre of undiluted solution only, today and in 2030)

The results in figure 2 illustrate a clear difference in the carbon footprint of production of 1 l of solution today and in 2030 (EU trend for electricity), where only the use phase electricity supply is altered. This underlines the potential lowering of greenhouse gasses related to electricity production and use. The carbon footprint results show that the production of 1 l of undiluted Toucan Active Plus solution currently, incl. hardware and packaging, is responsible for 9,21E-03 kg CO_2-eq (equal to 9,21 g CO_2-eq). If looking at the future scenario, where the use phase electricity is adjusted to the EU 2030 trend (forecast) (Sphera, 2022) – the greenhouse gas emissions are 7,15E-03 kg CO_2-eq (7,15 g CO_2-eq) pr l of undiluted solution. Hence, a 22 % reduction is observed when including the 2030 scenario.

A greenhouse gas emission saving of 1000 kg CO_2-eq. corresponds to ca. 400 l fuel combusted in an average car engine, or ca. 1/10 part of a person's average yearly contribution (WHO, 2008; Benini et al., 2014).

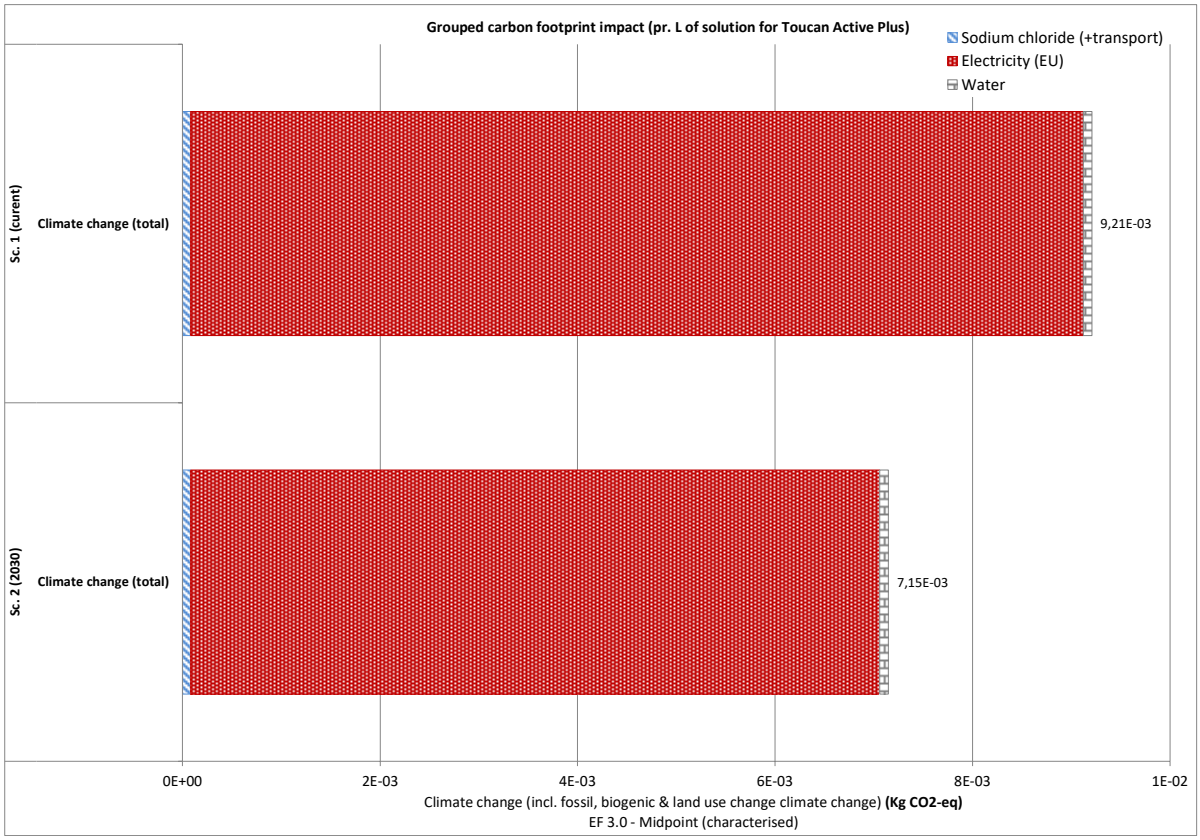

Figure 2. Characterized carbon footprint results for the two scenarios, where 1 litre of undiluted solution is produced (incl. hardware and packaging).

The electricity use in the use phase is of main importance for the Toucan Active Plus, as it accounts for 98 % of the greenhouse gas profile in the use stage. Thus, if wanting to redesign to a global warming friendlier product, the energy use is key.

This screening level carbon footprint shows the results for the two scenarios, and the conclusion is that future, and more sustainable ways to produce electricity, could lower the carbon footprint of Toucan Active Plus substantially. Thus, it could be more interesting for companies that attain more environmentally friendly electricity, e.g. with green certificates.

4.2. Contributions to carbon footprint (equipment + solution)

In figure 3 it can be seen what contributes to the carbon footprint during an 8-year service time of the Toucan Active Plus – it is the solution production. However, the hardware is also responsible for a smaller part and is the second largest contributor after the solution production.

It shows that 2030 scenario is better, but more importantly it provides the result that by using the Toucan Active Plus for 8 years, with current electricity grid mix in the use stage, the greenhouse gas emissions are 219 kg CO_2-eq. While for the 2030 it is 176 kg CO_2-eq.

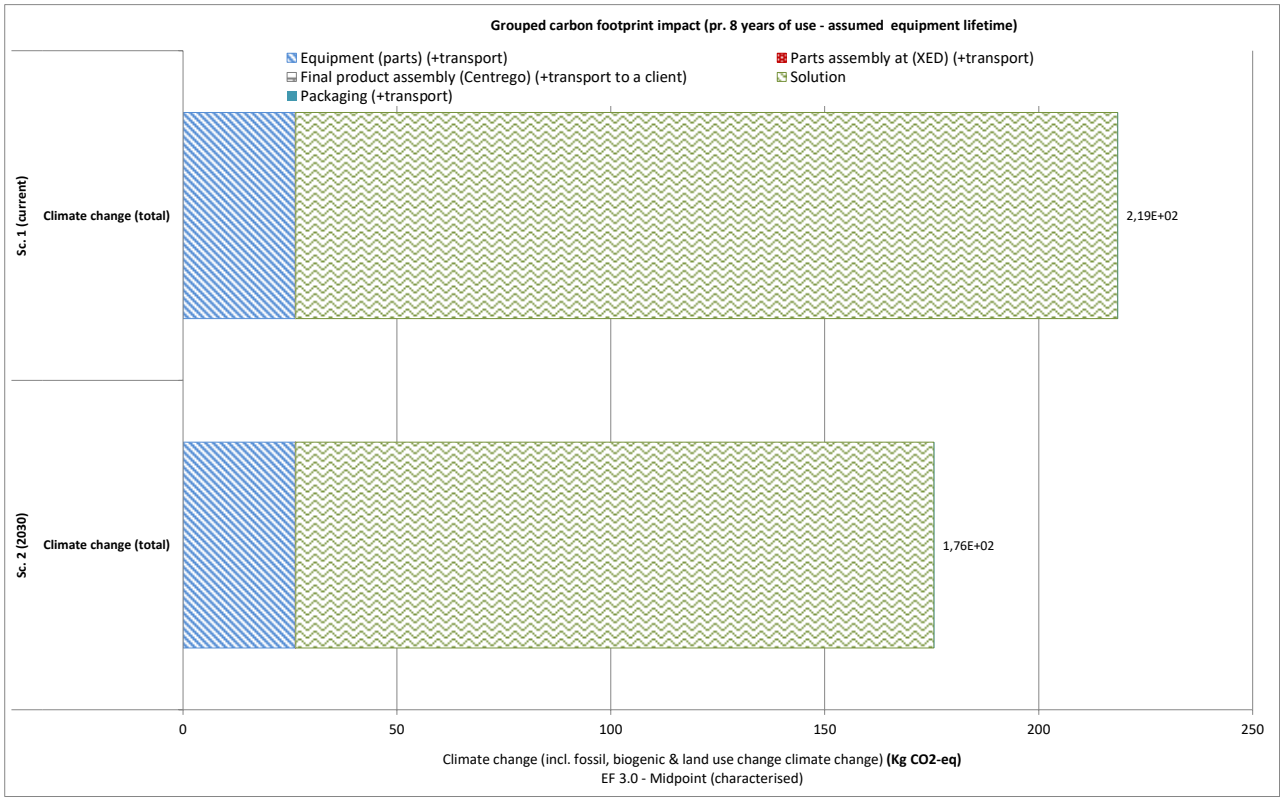

Figure 3. Process grouped and characterized carbon footprint results for the current (2022) and 2030 scenario – where it is presented for an 8-year period of the equipment lifetime (incl. hardware production, packaging).

As we know that the use stage is dominated by the electricity use, it is for the hardware production somewhat different. The production of the Toucan Active Plus shows a carbon footprint profile where the Ecomix Duo (PP), Electrolysis cell (Titanium), and shelf (stainless steel) are responsible for 64 % of the emissions. These parts are also the ones that weigh the most – in total these three materials weigh 2,86 kg out of the total 5,1 kg (excl. packaging).

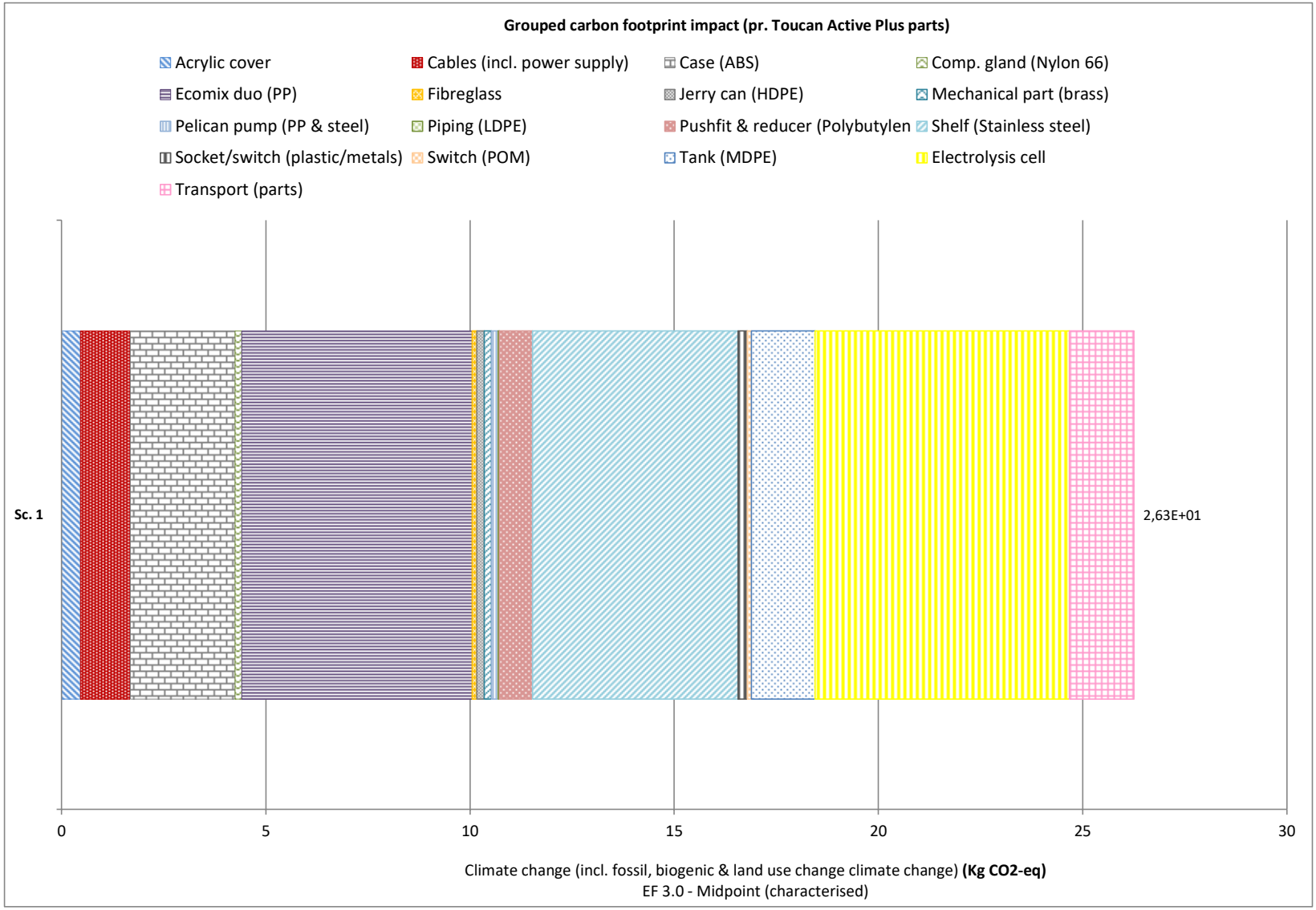

Figure 3. Process grouped and characterized results of the hardware/equipment, produced, and packaged, without solution production (Toucan Active Plus).

In terms of production of the Toucan Active Plus it is important to underline that the production inventory was supplied by Centrego/Food Diagnostics and is based on novel collected data, which is needed to calculate an LCA based carbon footprint. Certain aspects should be highlighted, as mainly the electricity use during solution production contributes most in the carbon footprint profile. Secondly, the hardware (Toucan Active Plus) is of importance, and there ecomix duo (PP), shelf (stainless steel), and electrolysis cell (titanium) are identified as main contributors.

Thus, the contribution is primarily due to energy use in use stage, which can lead to consideration of more energy efficient hardware and in general more sustainable energy production. The latter is also a challenge that is actively worked on, by governments and even by companies that are on their own securing more sustainable energy production. If follow up studies are performed, e.g. if production paths change, there should be a verification of the inventory of the flows related to this study. In this way a more in-depth approach would be used, from which the certainty of the results would improve. Also, other LCA environmental impacts could be quantified, along with greenhouse gas emissions.

5. Conclusion

This study quantifies the potential carbon footprint of the Toucan Active Plus disinfectant solution (according to 1 l of undiluted solution), which includes production, packaging, transport and use stage. Due to electricity consumption during use, the use stage and solution production is central in the carbon footprint profile. This means that use of alternative energy sources, or more energy efficiency, could substantially lower the carbon footprint - hence the future 2030 scenario with more renewable electricity sources.

SYSTEM INCLUDED	SCENARIO	IMPACT CATEGORY (UNIT)	EQUIPMENT (PARTS) (+TRANSPORT)	PARTS ASSEMBLY AT (XED) (+TRANSPORT)	FINAL PRODUCT ASSEMBLY (CENTREGO) (+TRANSPORT TO A CLIENT)	SOLUTION			PACKAGING (+TRANSPORT)	TOTAL
						Sodium chloride (EU)	Electricity (EU)	Water (EU)		
EQUIPMENT AND SOLUTION (8 YEARS – 4172 ACTIVATIONS OF 5 L)	**Sc. 1 (current)**	Climate change (total) (kg CO_2-eq.)	2,63E+01	1,79E-02	3,13E-02	1,92E+02			1,34E-01	2,19E+02
	Sc. 2 (2030)	Climate change (total) (kg CO_2-eq.)	2,63E+01	1,79E-02	3,13E-02	1,49E+02			1,34E-01	1,76E+02
SOLUTION (8 YEARS – 4172 ACTIVATIONS OF 5 L)	**Sc. 1 (current)**	Climate change (total) (kg CO_2-eq.)	-	-	-	1,72E+00	1,89E+02	1,80E+00	-	1,92E+02
	Sc. 2 (2030)	Climate change (total) (kg CO_2-eq.)	-	-	-	1,72E+00	1,46E+02	1,80E+00	-	1,49E+02
SOLUTION, PR. LITER	**Sc. 1 (current)**	Climate change (total) (kg CO_2-eq.)	-	-	-	8,23E-05	9,04E-03	8,64E-05	-	9,21E-03
	Sc. 2 (2030)	Climate change (total) (kg CO_2-eq.)	-	-	-	8,23E-05	6,98E-03	8,64E-05	-	7,15E-03

The results show that the greenhouse gas emissions related to 1 l of undiluted disinfectant solution is 9,21E-03 kg CO_2-eq (9,21 g CO_2-eq). From that 98 % is due to the electricity consumption during use, for on-site solution production. If looking towards 2030, and the EU energy trend projection with a greener electricity production, a 22 % would occur for 1 l of solution production – to 7,15E-03 kg CO_2-eq (7,15 g CO_2-eq) pr l of undiluted solution. If looking solely on the hardware, the Toucan Active Plus, the Ecomix Duo (PP), Electrolysis cell (Titanium), and shelf (stainless steel) are responsible for 64 % of the greenhouse gas emissions.

The application and functionality of the solution is not defined in this study, meaning that the solution cannot directly be compared to other solutions. The efficiency of the solutions, among other use phase issues, must first be defined.

This should be defined, before potential comparison occurs. Hence, further investigation may be needed and more detailed data, so the basis for the results can be strengthened. A future follow-up study could also quantify more LCA environmental impact categories and thereby unveil more benefits and/or burdens.

6. References

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7. Appendices

7.1. Appendix 1: Secondary process data, used in the study.

Material / action modelled		Process in tool	Source	Geographical coverage	Year (validity)	Comment
Transport (parts to manufacturing)	Transport of parts and packaging to Toucan Active Plus manufacturing sites	Truck, Euro 6, up to 20-26t gross weight / 17,3 payload capacity Cargo plane 113t payload	GaBi-Sphera v.10.5	Global	2020-2023	Fuel in truck: Diesel mix at filling station (GB, CN, US) (2020-2023) (GaBi-Sphera v.10.5) Fuel in airplane: Kerosene/Jet A1 at refinery (CN, US) (2020-2023) (GaBi-Sphera v.10.5)
Manufacturing of Toucan Active Plus (parts prod.)	PCB (Fibreglass FR 4 material with copper traces)	Fiberglass Kraft Faced NAIMA	GaBi-Sphera v.10.5 (NAIMA)	US	2016	Approximated, due to missing exact process data. Also, US data is used instead of GB.
	Power supply part	Cable 3 wire (EN15804 A1-A3)	GaBi-Sphera v.10.5	EU-28	2020-2023	Approximated, due to missing exact process data. Also, EU data is used instead of US.
	Fan (PBT, glass reinforced)	Polybutylene Terephthalate Granulate (PBT) Mix Plastic injection moulding part (unspecific)	GaBi-Sphera v.10.5	DE	2020-2023 2017-2020	The processes are approximated and used to model a simplified US production, due to lack of specific production data for the part. Also, due to missing US process data the data for Germany was used. However, US electricity and water (surface) was used as input to injection moulding process.
	Switch (PDM)	Dip-switch (light switch) (EN15804 A1-A3)	GaBi-Sphera v.10.5	EU-28	2020-2023	Approximated, due to missing exact process data.
	Main socket (Thermoplastic – tin plated brass contacts)	Fluorescent lamp socket T8-18W LFL (EN15804 A1-A3)	GaBi-Sphera v.10.5	EU-28	2020-2023	Approximated, due to missing exact process data.
	Mechanical parts (nylon with chrome plated brass)	Fitting brass - FSB	GaBi-Sphera v.10.5	DE	2020-2023	Approximated, due to missing exact process data.
	Cables (PVC coated copper)	Cable 3 wire (EN15804 A1-A3)	GaBi-Sphera v.10.5	EU-28	2020-2023	
	Case (ABS)	Acrylonitrile-Butadiene – styrene granulate (ABS) mix Plastic injection moulding part (unspecific)	GaBi-Sphera v.10.5	DE	2020-2023 2017-2020	Geographical specification is set to DE, instead of GB, due to missing data. Electricity and water for injection moulding is GB specific.
	Electrolysis cell (titanium)	Titanium production, primary	Ecoinvent 3.6	Global	2018	Assumed as being titanium, due to missing exact process data. Also, main environmental impacts are associated to the resource. Geographical specification used is global and China (diesel and kerosene use for road and air transport).
	Acrylic 3 mm white cell cover	Acrylate sealing mass (EN15804 A1-A3)	GaBi-Sphera v.10.5	EU-28	2020-2023	Geographical specification is set to EU-28, instead of GB, due to missing data.
	Enclosure (ABS)	Acrylonitrile-Butadiene – styrene granulate (ABS) mix Plastic injection moulding part (unspecific)	GaBi-Sphera v.10.5	DE	2020-2023 2017-2020	Geographical specification is set to DE, instead of GB, due to missing data. Electricity and water for injection moulding is GB specific.
	Illuminated switch (POM)	Polyoxymethylene granulate (POM)	GaBi-Sphera v.10.5	DE	2020-2023 2017-2020	Geographical specification is set to DE, instead of GB, due to missing data. Electricity for injection moulding is from GB grid mix.

	Plastic injection moulding part (unspecific)				
Enclosure 2000 series (ABS)	Acrylonitrile-Butadiene – styrene granulate (ABS) mix Plastic injection moulding part (unspecific)	GaBi-Sphera v.10.5	DE	2020-2023 2017-2020	Geographical specification is set to DE, instead of GB, due to missing data. Electricity and water for injection moulding is GB specific.
Ecomix duo (PP)	Polypropylene injection moulding part (PP)	GaBi-Sphera v.10.5	Europe	2012	Geographical specification is set to Europe, instead of GB, due to missing data.
SS shelf (4 screws) (304 Stainless steel)	Stainless steel sheet (EN15804 A1-A3)	GaBi-Sphera v.10.5	EU-28	2020-2023	Simplified to stainless steel sheet, due to data availability. Also, geographical specification is set to EU-28, instead of GB, due to missing data.
5 L tank (PE)	Polyethylene high density granulate (HDPE/PE-HD) Plastic injection moulding part (unspecific)	GaBi-Sphera v.10.5	DE	2020-2023 2017-2020	Geographical specification is set to DE, instead of GB, due to missing data. Electricity and water for injection moulding is GB specific.
300 ml Long pushfit 15 ml (Polybutylene)	Polybutylene terephthalate granulate (PBT) Plastic injection moulding part (unspecific)	GaBi-Sphera v.10.5	DE	2020-2023 2017-2020	Simplified to PBT material, incl. injection moulding. Geographical specification is set to DE, instead of GB, due to missing data. Electricity and water for injection moulding is GB specific.
15-10 mm reducer (Polybutylene)	Polybutylene terephthalate granulate (PBT) Plastic injection moulding part (unspecific)	GaBi-Sphera v.10.5	DE	2020-2023 2017-2020	Simplified to PBT material, incl. injection moulding. Geographical specification is set to DE, instead of GB, due to missing data. Electricity and water for injection moulding is GB specific.
UK/EU power cable	Cable 3 wire (EN15804 A1-A3)	GaBi-Sphera v.10.5	EU-28	2020-2023	
Male comp gland black (20 mm) (Nylon 66)	Nylon (PA 6.6) – yarn Plastic injection moulding part (unspecific)	GaBi-Sphera v.10.5	US DE	2020-2023 2017-2020	Simplified to nylon 6.6 yarn, due to data availability. Geographical specification is set to US/DE, instead of GB, due to missing data. Electricity and water for injection moulding is GB specific.
Jerry Can (HDPE)	Polyethylene high density granulate (HDPE/PE-HD) Plastic injection moulding part (unspecific)	GaBi-Sphera v.10.5	DE	2020-2023 2017-2020	Geographical specification is set to DE, instead of GB, due to missing data. Electricity and water for injection moulding is GB specific.
Pelican pump (PP+stainless steel)	Polypropylene granulate (PP) Plastic injection moulding part (unspecific) Stainless steel cold rolled coil	GaBi-Sphera v.10.5	DE DE Europe	2020-2023 2017-2020 2016	Geographical specification is set to DE/EU, instead of GB, due to missing data. Electricity and water for injection moulding is GB specific.
10 mm piping (LDPE)	Polyethylene low density granulate	GaBi-Sphera v.10.5	DE	2020-2023 2017-2020	Geographical specification is set to DE, instead of GB, due to missing data. Electricity and water for injection moulding is GB specific.
Electricity used in injection moulding	Electricity grid mix	GaBi-Sphera v.10.5	GB or US	2020-2023	Used for injection moulding of plastics, depending on where it occurs. Along with water from the specific country.

Transport (XED to Centrego)	Transport from XED to Centrego (subpart)	Truck, Euro 6, up to 20-26t gross weight / 17,3 payload capacity	GaBi-Sphera v.10.5	Global	2020-2023	Fuel in truck: Diesel mix at filling station (GB) (2020-2023) (GaBi-Sphera v.10.5)
Utilities (XED & Centrego) (final product prod.)	XED electricity (UK grid mix)	Electricity grid mix	GaBi-Sphera v.10.5	GB	2017-2023	
	Centrego electricity (UK grid mix)	Electricity grid mix	GaBi-Sphera v.10.5	GB	2017-2023	
	Tap water (UK)	Tap water from groundwater	GaBi-Sphera v.10.5	GB	2020-2023	
Packaging	Cardboard	Corrugated box, uncoated	GaBi-Sphera v.10.5	EU-28+EFTA	2012-2020	
	Paper	Paper production, woodcontaining, lightweight coated	Ecoinvent 3.6	Europe	2018	
	Labels (paper)	Paper production, woodcontaining, lightweight coated	Ecoinvent 3.6	Europe	2018	
	Bubble wrap (PP)	Polypropylene granulate (PP) Plastic injection moulding part (unspecific)	GaBi-Sphera v.10.5	DE DE	2020-2023 2017-2020	Geographical specification is set to DE, instead of GB, due to missing data. Electricity and water for injection moulding is GB specific.
	Sellotape (PP)	Polypropylene granulate (PP) Plastic injection moulding part (unspecific)	GaBi-Sphera v.10.5	DE DE	2020-2023 2017-2020	Geographical specification is set to DE, instead of GB, due to missing data. Electricity and water for injection moulding is GB specific.
Transport (Centrego to client – assumed 600 km distance)	Transport of final product to use stage	Truck, Euro 6, up to 20-26t gross weight / 17,3 payload capacity	GaBi-Sphera v.10.5	Global	2020-2023	Fuel in truck: Diesel mix at filling station (GB) (2020-2023) (GaBi-Sphera v.10.5)
Use stage (Solution prod.)	Electricity (EU-28 grid mix or EU-28 2030 grid mix)	Electricity grid mix	GaBi-Sphera v.10.5	GB	2017-2023	
	Tap water (EU-28)	Tap water from groundwater	GaBi-Sphera v.10.5	EU-28	2020-2023	
	Sodium chloride (NaCl) (EU-28)	Sodium chloride (rock salt)	GaBi-Sphera v.10.5	EU-28	2020-2023	

7.2. *Appendix 2: Characterised carbon footprint results.*

SOLUTION FOR 8 YEARS (4172 ACTIVATIONS OF 5 L EACH):

		SODIUM CHLORIDE (+TRANSPORT)	ELECTRICITY (EU)	WATER	TOTAL
SC. 1 (CURRENT)	Climate change (total) (kg CO_2-eq.)	1,72E+00	1,89E+02	1,80E+00	1,92E+02
SC. 2 (2030)	Climate change (total) (kg CO_2-eq.)	1,72E+00	1,46E+02	1,80E+00	1,49E+02

SOLUTION PR. L:

		SODIUM CHLORIDE (+TRANSPORT)	ELECTRICITY (EU)	WATER	TOTAL
SC. 1 (CURRENT)	Climate change (total) (kg CO_2-eq.)	8,23E-05	9,04E-03	8,64E-05	9,21E-03
SC. 2 (2030)	Climate change (total) (kg CO_2-eq.)	8,23E-05	6,98E-03	8,64E-05	7,15E-03

EQUIPMENT & SOLUTION (FOR 8 YEARS USE):

		EQUIPMENT (PARTS) (+TRANSPORT)	PARTS ASSEMBLY AT (XED) (+TRANSPORT)	FINAL PRODUCT ASSEMBLY (CENTREGO) (+TRANSPORT TO A CLIENT)	SOLUTION	PACKAGING (+TRANSPORT)	TOTAL
SC. 1 (CURRENT)	Climate change (total) (kg CO_2-eq.)	2,63E+01	1,79E-02	3,13E-02	1,92E+02	1,34E-01	2,19E+02
SC. 2 (2030)	Climate change (total) (kg CO_2-eq.)	2,63E+01	1,79E-02	3,13E-02	1,49E+02	1,34E-01	1,76E+02

EQUIPMENT:

		ACRYLIC COVER	CABLES (INCL. POWER SUPPLY)	CASE (ABS)	COMP. GLAND (NYLON 66)	ECOMIX DUO (PP)	FIBRE GLASS	JERRY CAN (HDPE)	MECHANICAL PART (BRASS)	PELICAN PUMP (PP & STEEL)	PIPING (LDPE)	PUSHFIT & REDUCER (POLYBUTYLEN	SHELF (STAINLESS STEEL)	SOCKET/SWITCH (PLASTIC/METALS)	SWITCH (POM)	TANK (MDPE)	ELECTROLYSIS CELL	TRANSPORT (PARTS)	TOTAL
SC. 1 (CURRENT)	Climate change (total) (kg CO_2-eq.)	4,61E-01	1,22E+00	2,57E+00	1,59E-01	5,64E+00	1,20E-01	1,77E-01	1,76E-01	1,65E-01	3,03E-02	8,15E-01	5,03E+00	2,27E-01	9,69E-02	1,56E+00	6,23E+00	1,58E+00	2,63E+01