0.1 LCA DETAILED CALCULATIONS

In this supplementary section all the detailed calculations used to obtain the results presented into the paper are collected. The impact evaluation data considered are those in Table S1 and Table S2.

Table S1. *Impact evaluation data of a diesel powered IVECO ECOSTRALIS Active AS truck considering a payload of* 10200 *kg.*

	Unit	Value
Emissions	$[kg_{CO_2}/l]$	2.65
Fuel consumption	[l/km]	0.3
Fuel calorific value	[MJ/kg]	45
Fuel density	[kg/l]	0.83

Table S2. *Impact evaluation data of a HFO powered MAN S90ME-C9.2-GI cargo ship considering an average speed* $\tilde{v}_{cargo} = 23.5\ kn = 43.6\ km/h$ *[**ecta2011guidelines**] .*

	Unit	Value
Emissions	$[g_{CO_2}/\text{km t}]$	12.5
Fuel consumption	[t/d]	206.8
Fuel calorific value	[MJ/kg]	42.7

0.1.1 *Cell support: material transportation*

Aluminum 6065 Choosing the Al6065 it is necessary to use both the cargo ship and the truck to import the material from China. The cargo covers a distance $s_{\text{cargo}} = 19535\ km$ at an average speed $\tilde{v}_{\text{cargo}} = 43.6\ km/h$, meaning that the time it takes to travel the whole path is $t_{\text{cargo}} = 448.05\ h = 18.669\ d$. As the daily fuel consumption is $F_{\text{day, cargo}} = 206.8\ t/d$ (Table S2), the total fuel consumption results $F_{\text{TOT, cargo}} = 3860.7\ t$. Knowing that the emission factor for cargo ships related to the grams of CO_2 emitted per ton and kilometer is $f_{\text{CO}_2\text{, cargo}} = 12.5\ g_{\text{CO}_2}/km\ t$ [**ecta2011guidelines**], the specific emission (GWP_{s}) can be calculated as $GWP_{\text{s, cargo}} = f_{\text{CO}_2\text{, cargo}} \cdot s_{\text{cargo}}$ which, in numbers, becomes $GWP_{\text{s, cargo}} = 12.5\ g_{\text{CO}_2}/km\ t_{\text{Al}} \cdot 19535\ km \cdot 10^{-3}\ kg_{\text{CO}_2}/g_{\text{CO}_2} \cdot 10^{-3}\ t_{\text{Al}}/kg_{\text{Al}} = 0.244\ kg_{\text{CO}_2}/kg_{\text{Al}}$. As the chosen cargo ship is a 8000 TEU and the maximum payload for each container is $Pl_{\text{cargo}} = 24000\ kg$, the total emission value is $GWP_{\text{TOT, cargo}} = GWP_{\text{s, cargo}} \cdot Pl_{\text{cargo}} = 5856\ kg_{\text{CO}_2}$. The transport ED takes into consideration the fuel calorific value for HFO (H_{HFO}, Table S2) so that the cumulative energy demand is

$CED_{\text{cargo}} = F_{\text{TOT, cargo}} \cdot H_{\text{HFO}} = 164851890\ MJ = 164851.89\ GJ$. Finally, it is possible to calculate the specific energy demand as $ED_{\text{s, cargo}} = CED_{\text{cargo}}/(8000 \cdot Pl) = 0.859\ MJ/kg_{\text{Al}}$.

Talking about the Al6065 road transportation, the calculations are easier. The truck covers a distance $s_{\text{truck}} = 1565\ km$ with a total fuel consumption $F_{\text{TOT, truck}} = 469.5\ l$ (see the average fuel consumption of the truck in Table S1). Considering the emission factor for trucks $f_{CO_2,\text{ truck}}$ (Table S1), the total emissions are $GWP_{\text{TOT, truck}} = F_{\text{TOT, truck}} \cdot f_{CO_2,\text{ truck}} = 1244.18\ kg_{CO_2}$ and the specific emissions are $GWP_{\text{s, truck}} = GWP_{\text{TOT, truck}}/Pl_{\text{truck}} = 0.122\ kg_{CO_2}/kg_{\text{Al}}$. As the diesel density is $\rho_{\text{d}} = 0.83\ kg/l$, converting the fuel consumption $F_{\text{TOT, truck}} = 469.5\ l = 389.685\ kg$ and considering the diesel calorific value (Table S1) it is possible to calculate $CED_{\text{truck}} = F_{\text{TOT, truck}} \cdot H_{\text{d}} = 17535.825\ MJ = 17.54\ GJ$. Dividing this value by the truck payload the result is $ED_{\text{s, truck}} = CED_{\text{truck}}/Pl_{\text{truck}} = 1.72\ MJ/kg_{\text{Al}}$.

The overall ED and GWP specific values for the Al6065 are the sum of the cargo and the truck contributions: $GWP_{\text{s, Al6065}} = 0.366\ kg_{CO_2}/kg_{\text{Al}}$, $ED_{\text{s, Al6065}} = 2.579\ MJ/kg_{\text{Al}}$.

0.1.2 *Li-ion cells: material processing*

Copper anode current collector After the extraction of sulphide ores, a beneficiation phase ($GWP_{\text{s, Cu}} = 2.40\ kg_{CO_2}/kg_{\text{Cu}}$ [**manjong2021life**]) is necessary to transform the ores into a slurry from which skimming the copper minerals. These minerals are then dried and sent to the smelter ($GWP_{\text{s, Cu}} = 1.8 \div 7.4\ kg_{CO_2}/kg_{\text{Cu}}$ [**manjong2021life**]). For the copper anode collector a refining phase is needed to process the metal, obtaining $4 \div 12\ \mu m$ thick foils [**high_targay**]. First, an aqueous solution of copper(II) sulfate ($CuSO_4$) has to be prepared, dissolving electrolytic copper or waste copper in sulfuric acid (H_2SO_4). Then, the metallic copper is electrodeposited on a cathodic roller surface thanks to an electrolytic reaction. At the same time, one side of the resulting copper foil is peeled to achieve the desired thickness, so that the final product is a foil having one rough side and one smooth side [**evoqua2022electrolytic**, **international2022copper**]. In general, two main methods can be followed for the copper processing: a pyrometallurgical technique ($ED_{\text{s, Cu}} = 33\ MJ/kg_{\text{Cu}}$) or a hydrometallurgical one ($ED_{\text{s, Cu}} = 64\ MJ/kg_{\text{Cu}}$) [**norgate2000life**, **international2022copper**]. For this LCA study, pyrometallurgy is chosen as more related literature data are available. For the copper current collector processing it is found: $GWP_{\text{s, Cu}_{\text{anod}}} = 4.1\ kg_{CO_2}/kg_{\text{Cu}_{\text{anod}}}$; $ED_{\text{s, Cu}_{\text{anod}}} = 47\ MJ/kg_{\text{Cu}_{\text{anod}}}$ [**international2022copper**].

Cathode Ni–Mn–Co powders The cathode powders production begins with a reaction among nickel(II) sulfate ($NiSO_4$), manganese(II) sulfate ($MnSO_4$) and cobalt(II) sulfate ($CoSO_4$), all mixed together in a co-precipitate with sodium hydroxide ($NaOH$) and an ammonia aqueous solution ($NH_{3(aq)}$) [**yoke1989ammonium**], obtaining $Ni_{1/3}Mn_{1/3}Co_{1/3}(OH)_2$. Then, this compound reacts with lithium carbonate (Li_2CO_3) during a multi-stage process carried out at high temperature and called calcination. The results of the overall production process are the desired oxide $LiNi_{1/3}Mn_{1/3}Co_{1/3}O_2$ and CO_2. For the *Ni-Mn-Co* cathode powders processing it is $GWP_{\text{s, Ni–Mn–Co}} = 16.11\ kg_{CO_2}/kg_{\text{Ni–Mn–Co}}$; $ED_{\text{s, Ni–Mn–Co}} = 231.28\ MJ/kg_{\text{Ni–Mn–Co}}$ [**dai2019life**].

Aluminum cathode current collector The aluminum rolling operations start with a hot rolling phase during which ingots are pre-heated at 500 °C. The process ED is strictly related to the ingot temperature which, in turn, influences the time process: the higher the ingot temperature, the lower the energy needed to deform the aluminum block, as well as the processing time. The partial results for the hot rolling operations are the following: $GWP_{\text{s, Al}_{\text{hot}}} = 0.41\ kg_{CO_2}/kg_{\text{Al}_{\text{hot}}}$; $ED_{\text{s, Al}_{\text{hot}}} = 7.06\ MJ/kg_{\text{Al}_{\text{hot}}}$. After the hot rolling, a cold rolling follows: the product thickness continues to decrease and the environmental temperature is kept around 80 °C. The partial results for the cold rolling operations are: $GWP_{\text{s, Al}_{\text{cold}}} = 0.41\ kg_{CO_2}/kg_{\text{Al}_{\text{cold}}}$; $ED_{\text{s, Al}_{\text{cold}}} = 7.92\ MJ/kg_{\text{Al}_{\text{cold}}}$.

0.1.3 *Li-ion cells: product transportation*

For the first truck stage Santiago de Compostela–Rio Grande do Sul (2435 *km*): $GWP_{\text{s, cells, T1}} = 2.108\ kg_{CO_2}/kg_{\text{cells}}$; $ED_{\text{s, cells, T1}} = 29.721\ MJ/kg_{\text{cells}}$. For the cargo stage Rio Grande do Sul–Antwerp (7289 *km* and 167.18 *h* of sailing): $GWP_{\text{s, cells, C}} = 0.091\ kg_{CO_2}/kg_{\text{cells}}$; $ED_{\text{s, cells, C}} = 0.320\ MJ/kg_{\text{cells}}$. For the second truck stage Antwerp–Bologna (1259 *km*): $GWP_{\text{s, cells, T2}} = 1.090\ kg_{CO_2}/kg_{\text{cells}}$; $ED_{\text{s, cells, T2}} = 15.367\ MJ/kg_{\text{cells}}$. The overall results for the transportation of the entire cells are the following: $GWP_{\text{s, cells}} = 3.289\ kg_{CO_2}/kg_{\text{cells}}$; $ED_{\text{s, cells}} = 45.408\ MJ/kg_{\text{cells}}$.

0.1.4 *BTMS: raw material extraction and processing*

The silicon metallurgical production is based on the silicon(IV) oxide (SiO_2) reduction that occurs in a submerged arc furnace (SAF) fed with carbonaceous raw materials as quartz, coke, coal, charcoal, and woodchips [**takla2013energy**]. In the SAF body all the raw materials (the charge) are put together with a continuous addition of carbon (inserted into the furnace when the SAF Söderberg electrodes are too much consumed) and small quantities of limestone. The overall process is modelled at a glance with the following reaction: $SiO_2(s) + 2C(s) \rightarrow Si(l) + 2CO(g)$. However, a more detailed and exhaustive description provided by the literature [**vangskaasen2012metal**, **broggi2019characterization**, **andersson2009reaction**], revealing that this process is characterized by various simultaneous reactions, associated to different SAF temperatures. Finally, some of the most relevant transformations are reported below (note that *s* = solid, *l* = liquid):

$$2SiO(g) \rightarrow Si(s,l) + SiO_2(s,l)\ (1)$$
$$3SiO(g) + CO(g) \rightarrow 2SiO_2(s,l) + SiC(s)\ (2)$$
$$SiO(g) + 2C(s) \rightarrow SiC(s) + CO(g)\ (3)$$
$$SiO(g) + SiC(s) \rightarrow 2Si(l) + CO(g)\ (4)$$

The product of the SAF reactions is the metal silicon which then undergoes a grinding phase, several other chemical reactions, a distillation phase and other chemical processes such as the hydrolysis and the stripping [**ces_silicon**]. The resulting product is a silicone rubber which becomes the raw material for the next extrusion phase during which the rubber is forced through a die, finally obtaining the desired shape.