Life cycle assessment of lithium ion battery recycling - The ReLion process

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Preface

This report contains a life cycle assessment, LCA, of recycling of battery cells. It was performed in the context of the Swedish ReLion project, financed by Energimyndigheten. The life cycle assessment, LCA, has been carried out by Mats Zackrisson at RISE IVF. Members of the ReLion project have delivered detailed data about recycling related to lithium battery cells. A list of acronyms and abbreviations used is provided below.

CFCs  Chlorofluorocarbons
CO₂  Carbon dioxide
CO₂-eq  Carbon dioxide equivalents
CH₄  Methane
C₂H₄  Ethene
CTU  Comparative Toxic Unit
EPD  Environmental Product Declaration
EEA  European Environment Agency
HFCs  Hydrofluorocarbons
ISO  International Organization for Standardization
Kg  Kilogram
KW  Kilowatt
KWh  Kilowatt-hour, 1 kWh = 3.6 MJ
LCA  Life Cycle Assessment
LFP  Lithium iron phosphate, LiFePO₄, battery cell
Li  Lithium
LMO  Lithium manganese oxide, LiMn₂O₄, battery cell
MJ  Megajoule
MWh  Megawatt-hour
NCA  Lithium nickel cobalt aluminium oxide battery cell
NMC  Lithium nickel manganese cobalt oxide battery cell
NMP  N-Methyl-2-pyrrolidone
NOₓ  Nitrogen oxides
PEFCR  Product Environmental Footprint Category Rules
PHEV  Plug-in hybrid electric vehicle
PO₄  Phosphorus
PS  Polystyrene
PVDF  Polyvinylidenfluoride
PP  Polypropylene
RER S  RER = Region Europe, S = system process
Sb  Antimony
SO₂  Sulphur dioxide
SF₆  Sulphur hexafluoride
## Contents

Preface .......................................................... 3
Figures .......................................................... 4
Summary .......................................................... 6

### Introduction

**Method in general** ........................................ 7
Functional unit .................................................. 7
System boundary ............................................... 8
Environmental impact assessment ......................... 9

### Modelling

Sorting, crushing and separating ............................. 10
About the LithoRec process .................................. 11
De-coking black mass ......................................... 12
Smelting and lithium separation ............................ 14
Model parameters ............................................. 16
Avoided products .............................................. 17

### Results

ReLion .......................................................... 18
Alternative de-coking ......................................... 21
Comparing with PEFCR ........................................ 22

### Discussion and conclusions

Comparison with other battery LCAs ....................... 24
Decoking .......................................................... 26
Electricity mix .................................................. 26
Abiotic depletion ............................................... 26
Conclusions ..................................................... 26

### Referenser

.......................................................... 27

## Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>System boundary for lithium-ion study .................................................. 9</td>
</tr>
<tr>
<td>Figure 2</td>
<td>The Lithorec process from (Kwade and Diekman 2016). ..................... 10</td>
</tr>
<tr>
<td>Figure 3</td>
<td>LCA model of sorting, crushing and separating waste lithium cells 11</td>
</tr>
<tr>
<td>Figure 4</td>
<td>Step 1: de-coke, separation of C from cathode material ....................... 12</td>
</tr>
<tr>
<td>Figure 5</td>
<td>Model of 1 ton of de-coked lithium ion black mass ............................ 13</td>
</tr>
</tbody>
</table>
Figure 6 Alternative model of 1 ton of de-coked lithium ion black mass

Figure 7 Relationships between amounts of traction battery, NMC cells, wet black mass and de-coked black mass

Figure 8 Step 2: Smelting reduction for Ni-Co-Mn recovery and Li-separation

Figure 9 Model of reduction for Ni-Co-Mn recovery and Li-separation

Figure 10 Avoided product from LIB recycling

Figure 11 SimaPro model parameters

Figure 12 Avoided products

Figure 13 Climate impact of end-of-life recycling of lithium ion cells according to ReLion, sorting, crushing and separating, base case conditions

Figure 14 Climate impact of end-of-life recycling of lithium ion cells according to ReLion, decoking, base case conditions

Figure 15 Climate impact of end-of-life recycling of lithium ion cells according to ReLion, smelting and Li-separation, base case conditions

Figure 16 Abiotic depletion of end-of-life recycling of lithium ion cells according to ReLion, base case conditions, 5.3% cut-off

Figure 17 Climate impact of end-of-life recycling of lithium ion cells according to ReLion, decoking with air and water

Figure 18 Climate impact of end-of-life recycling of lithium ion cells according to ReLion, European electricity mix

Figure 19 Climate impact of end-of-life recycling of lithium ion cells. ReLion process compared with PEFCR data, European electricity mix

Figure 20 Abiotic depletion of end-of-life recycling of lithium ion cells. ReLion process compared with PEFCR data, European electricity mix. 3.5% cut-off

Figure 21 Climate impact of end-of-life recycling of lithium ion cells, PEFCR data, Swedish electricity mix

Figure 22 Nissan LEAF with 24 kWh NMC battery, life cycle climate impacts compared to ReLion process

Tables
Table 1 Electricity mixes
Summary

This report contains a life cycle assessment, LCA, of recycling of lithium ion battery cells. It was performed in the context of the Swedish ReLion project. The study aims to highlight environmental hotspots with LIB recycling and show the potential of LIB recycling. In short, the results indicate that the ReLion process:

- replicated in full scale, can potentially recover at least 10% of the climate impacts of producing an NMC traction battery, the currently most common traction battery chemistry
- decoking with air and water instead of liquid oxygen gives a bit more climate avoidance, 0.2 kg CO\textsubscript{2}/kg cell and a bit more abiotic depletion avoidance. If it can be done easily and without much extra cost this option should be utilized.
- The ReLion process is not dependant on carbon-lean electricity to potentially avoid at least 10% of the climate impacts of producing an NMC traction battery
Introduction

This report contains a life cycle assessment, LCA, of recycling of lithium ion batteries. It was performed in the context of the Swedish ReLion project, financed by Energimyndigheten.

The purpose of the LCA is to highlight environmental hotspots with battery cell recycling in order to improve it as well as to verify environmental benefits with battery cell recycling. LCA is generally considered very useful in the product development stage in order to identify environmental hot-spots and aid in directing development efforts in relevant areas (Rebitzer et al. 2004) (Mats Zackrisson et al. 2008). Battery design needs to consider the recyclability of the batteries at end-of-life as well as the possibility to use recycled materials in the original design, i.e. aim for a circular material usage.

Method in general

The LCA was performed in the context of the Swedish ReLion project. The LCA has been carried out by Mats Zackrisson in close cooperation with Guozhu Ye at Swerim and Pekka Väänänen at uRecycle Oy and reviewed by Patrik William-Olsson at RISE IVF. Material and energy needs were determined by experience, theoretical calculations and pilot scale smelting tests. Associated resources and emissions were found in existing databases for LCA and represent in general European or global averages. Data has mainly been drawn from the database Ecoinvent 3.5 (Wernet, G., Bauer, C., Steubing, B., Reinhard, J., Moreno-Ruiz, E., and Weidema, B. 2016). PEFCR- Product Environmental Footprint Category Rules for High Specific Energy Rechargeable Batteries for Mobile Applications, was also used as a data source as well as general guidance for the study (The Advanced Rechargeable & Lithium Batteries Association 2018).

SimaPro 9.0.0.48 was used for the calculations. The software includes several databases and is thus a source of generic data. It was also used to store the collected site-specific data, see project ReLion and EBaR. The study is protected in the software. Only the author of this study has access to the project specific data.

Functional unit

The PEFCR-guide (The Advanced Rechargeable & Lithium Batteries Association 2018) defines the functional unit as 1 kWh of the total energy provided over the service life of the battery system, and the associated reference flow, Rf, as kg of battery per kWh of the total energy provided. It prescribes calculation of the reference flow with consideration to both the application need and the battery capacity according to the formula:

1. \( Rf = \) Reference flow=\( Nb \times mass/AS \), where,
   a) \( Nb \) is number of batteries per application, known or calculated as \( Nb = AS/QuA \)
   b) \( mass \) = mass of battery
c) $AS = \text{Total kWh needed by application}$

d) $QuA = \text{Total kWh delivered by battery, thus}$

e) $Rf = \text{Reference flow} = \text{mass/QuA} = \text{mass/Total kWh delivered by battery, if the application is unknown or of less interest}$

For a 24 kWh Nissan Leaf battery (Mats Zackrisson 2018) weighing 294 kg and using 0,186 kWh/km, assuming 80% depth of discharge\(^1\) and 200000 km design service life: equation 1 would yield $1 \times 294 \text{ kg} / (200000 \text{ km} \times 0,186 \text{ kWh/km}) = 0,0079 \text{ kg battery/kWh}$ and equation d) would yield $294 \text{ kg} / (2000 \text{ cycles} \times 0,8 \text{ depth of discharge} \times 24 \text{ kWh}) = 0,0077 \text{ kg battery/kWh}$, so around 8 g battery is needed per delivered kWh. However, maximum service life according to (Burzio and Parena 2012) is 226716 km. Equation 1 then yields $294 \text{ kg} / (226716 \text{ km} \times 0,186 \text{ kWh/km}) = 0,0070 \text{ kg battery/kWh}$.

The PEFCR-guide deviates from earlier guidelines to put traction batteries in an application context (Del Duce et al 2013), which recommend presenting LCA results as environmental impact per vehicle kilometre. The vehicle context is realized via data about vehicle weight and electricity consumption from tests or assumptions. Calculating impacts per km facilitates comparisons with vehicle emission targets, e.g. the European passenger car standards 95 g CO\(_2\)-eq/km fleet average to be reached by 2021 by all manufacturers (EC 2000).

Some studies of traction batteries report environmental impacts per kg of battery or per kWh of battery nominal capacity. Thus, there is an obvious risk of misunderstanding data when comparing between studies, since so many different reference flows are used: mass/Total kWh delivered; vehicle kilometre; mass of battery; and nominal capacity of battery.

Since this study concerns mostly the end-of-life part of traction battery cells, the application is not obvious. Input data was given per ton or kilogram of battery black mass (BM). **Environmental impact results are mainly given as environmental impact per kg of battery cell and per kg battery (assuming 0.5 kg cell in 1 kg battery pack).**

**System boundary**

The system boundary for the lithium-ion study is shown below. Note that only the End-of-life stage is inside the system boundary, i.e. included in the study. However, the environmental impact of the end-of-life stage is compared to the production related environmental impacts from other studies in the discussion.

\(^1\) 80% depth of discharge means that maximum 80% of the nominal battery capacity is used each charge cycle, so a 24 kWh battery would actually only deliver 19.2 kWh before it is recharged.
Environmental impact assessment

LCA of traction batteries inevitably leads to comparisons of electric vehicles, EV, with internal combustion engine vehicles, ICEV. Such LCAs should therefore be able to assess trade-offs between tailpipe emissions, material resource use and toxicological impacts. Thus, relevant environmental impact categories for LCA of vehicles and traction batteries in particular are climate impact, resource depletion and toxicity.

Climate impacts in accordance with the Intergovernmental Panel on Climate Change (IPPC 2013). The unit is climate impact in grams or kilograms of carbon dioxide equivalents, CO2-eq. Europe’s emissions in 2005 corresponded to 11200 kg CO2 equivalents per person (EEA 2005). To avoid unwanted climate impact requires global yearly emissions to be reduced by between 50 to 85% by 2050 on current levels, according to (Barker 2007). This would translate to a sustainable emission level at approximately 1000 kg CO2-eq per capita world average.

Resource depletion, or abiotic resource depletion is calculated with the method CML-IA baseline\(^2\), version 3.02 as recommended by the ILCD handbook (Wolf and Pant 2012). Only depletion of mineral reserves is reported since the climate impact indicator, above, is considered to cover environmental impacts and depletion of fossil fuels. Abiotic depletion is measured in kilogram Antimony equivalents, abbreviated kg Sb-eq. It should be mentioned that there is no universal consensus within the LCA community on methodology and on the relative ranking of resource depletion impacts (Klinglmair, Sala, and Brandão 2014). (Peters and Weil 2016) cautions against far-reaching conclusions regarding abiotic depletion while confirming that the recommended CML method is the best available today.

Earlier studies have shown that current methods for toxicity evaluation have considerable inadequacies related to metals and lithium in particular; among other

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\(^2\) This CML baseline method contained in SimaPro is also used to calculate the climate impacts.
there is a lack of data concerning lithium emissions during the life cycle and a lack of characterization factors to translate such emissions into toxic impacts (M. Zackrisson et al. 2016). Toxicity has therefore not been assessed in this study.

**Modelling**

*Sorting, crushing and separating*

The modelling of sorting, crushing and separating is based on ecoinvent process "Iron scrap, sorted, pressed {RER}| sorting and pressing of iron scrap | Alloc Rec, U. (Kwade and Diekmann 2018) presents a value of 58.3 kWh for disassembly, crushing, drying, air-separation and sieving for a 346 kg battery pack in connection to the LithoRec recycling process. The processes used are similar to those envisioned in the ReLion project to produce a black mass. See figure below.

![Figure 2 - The Lithorec process from (Kwade and Diekman 2018).](image)

**Fig. 16.7** Modeled energy and material flows from the LithoRec process

Considering that the discharged energy (0-13 kWh) can be credited, only 50 kWh would be needed per 346 kg battery system which is equal to 0.14 kWh/kg battery or 0.28 kWh/kg cell if we assume that the battery contains 50% cells (Ellingsen et al. 2013). See figure below. This figure is assumed in the calculations.

For the diesel, the same value, 0.1 MJ/kg, as in the original process Iron scrap, sorted, pressed {RER}| sorting and pressing of iron scrap | Alloc Rec, U was assumed. Other additions to the original process include:

- avoided products (0.232 kg copper per kg cell and 0.418 kg aluminium per kg cell) based on Leaf NMC battery BOM-list (according to Ellingsen et al 2013) minus what is left in black mass as measured by Swerim in pilot scale tests. Note that most of the aluminium stem not from the cell but from the rest of the pack (which is 50% of the battery). Note that recovered steel, electronics and plastics have not been considered to avoid any virgin materials in the calculations.
Transports from bilskrot to sorting facility assumed 300 km according to (Cullbrand, Fråne, and Jensen 2015), see details below.

Since the Lithorec process includes separation of the electrolyte, no hydrocarbon emissions were assumed.

Figure 3  LCA model of sorting, crushing and separating waste lithium cells

About the LithoRec process

The LithoRec Process (Kwade and Diekman 2018) combines mechanical, mild thermal and hydrometallurgical treatment to regain nearly all materials of a battery system. One of the main results of the first Lithorec project was a concept for the mechanical separation of the components of a battery system in different fractions including the coating materials. Therefore, manual and automated processes for the disassembly of battery systems as well as different classifying and sorting processes for the material separation were investigated in laboratory scale. The recovered coating materials were treated hydrometallurgically afterwards. The project partner Chemetall GmbH realized a pilot plant for this part of the process in Langelsheim; combining leaching, filtration and different precipitation steps. This kind of hydrometallurgical treatment regains the valuable materials nickel, cobalt, manganese, and lithium hydroxide or lithium carbonate. It was found that small impurities of aluminum have no negative impact on the electrochemical performance of battery test cells with lithium nickel cobalt manganese oxide (NCM) as a cathode material. Furthermore, the project partners investigated new ways for the recovery of electrolyte solvents and the conducting salt. Processes like vacuum condensation and extraction via supercritical carbon dioxide showed positive results. Ecologic and economic assessments were carried out for the investigated concept. While the ecological impact was high, the process is only economically feasible at high throughputs and as such, very sensitive to the market for electric driving systems. The follow-on project
LithoRec II started July 2012 and focused on the detailing of the scientific and technical results, and the realization of the optimized process steps in a pilot plant.

**De-coking black mass**

De-coking black mass is based on data from the ReLion project run by Swerim. Input output data for de-coking based on pilot scale tests by Swerim described in ReLion flowsheets, see figure below. Transports based on data from Urecycle on recycling of ZnC/Alkaline big block batteries (distance between Karlskoga and Skellefteå 880 km).

**De-coking by partial combustion**

![Diagram](image)

**Figure 4  Step 1: decoke, separation of C from cathode material**

The outputs and inputs related to 1 ton of de-coked LIB black mass (BM) are shown in Figure 4 and modeled in Simapro as shown below. The output hydrogen and CO gas is estimated to replace 590 m³ natural gas based on heating value. 880 km transport equal to the distance between Karlskoga and Skellefteå assumed.
An alternative decoking process is also possible using air and water instead of liquid oxygen. This would give the same output gases, plus 2597 Nm$^3$ of nitrogen which is modelled as an emission. See Figure 6 below.

Figure 5  Model of 1 ton of de-cooked lithium ion black mass

Figure 6  Alternative model of 1 ton of de-cooked lithium ion black mass

Figure 7 shows the relationships between the amount of traction batteries, NMC cells, wet black mass and de-cooked black mass. Since the batteries only contain 50% cells, 2 kg traction battery is needed for 1 kg of cells. 1.8 kg wet BM give 1 kg de-cooked BM, see Figure 4. From Figure 2 it can be deduced that wet BM is 31.8% of battery content (BM plus Volatile components). 2 kg battery containing 31.8% wet BM, then gives $2 \times 0.314/1.8 = 0.349$ decoked BM. The parameter ALT1 gives possibility to switch between decoking with air instead of oxygen, see above.
Smelting and lithium separation

Smelting and lithium separation is based on data from the ReLion project run by Swerim. Input output data based on pilot scale tests by Swerim as shown in the figures below.

Figure 7  Relationships between amounts of traction battery, NMC cells, wet black mass and de-coked black mass

Figure 8  Step 2: Smelting reduction for Ni-Co-Mn recovery and Li-separation

The outputs and inputs related to smelting and lithium separation of 1 ton of de-coked LIB BM are shown in Figure 8 and modelled in Simapro as shown below. The process gas contains 21% CO$_2$, 12% H$_2$O, 67% N$_2$ and 0.2% SO$_2$ and is modelled as emissions of those gases. The model allows for calculation with different electricity mixes (Swedish or European).
Avoided products are modelled as in Figure 10. Since the slag contains 41% manganese, that amount is assumed to replace manganese and the rest is slag for deposit. 95% lithium carbonate purity was obtained in pilot tests. With additionally 100 kWh electricity, 99.9% lithium carbonate purity is assumed to be obtained, see Figure 10 below.
Model parameters

In order to calculate the results using, e.g., different electricity mixes, the model parameters in SimaPro are manipulated according to the figure below. Base case conditions assume Swedish average electricity for all recycling operations, decoking according to lab test and transporting between Karlskoga and Skellefteå between, shredding and metallurgical treatment. Parameters EL and GAS has no meaning for LIB recycling.

Electricity

It is possible to do the calculations with different electricity mixes. The alternatives used in the calculations are given in the table below.

<table>
<thead>
<tr>
<th>Name of data set</th>
<th>Gram CO₂e eq/kWh</th>
<th>Comment</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity, high voltage (SE)</td>
<td>41.5</td>
<td>Simulates current smelting in Sweden and future European conditions.</td>
<td>Prodel=0</td>
</tr>
<tr>
<td>Name of data set</td>
<td>Gram CO\textsubscript{2}-eq/kWh</td>
<td>Comment</td>
<td>Parameter</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------------</td>
<td>---------------------------------</td>
<td>-------------------------------------------------------------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Electricity, medium voltage (SE) market for Alloc Rec, S</td>
<td>44</td>
<td>Simulates current sorting/crushing in Sweden and future European conditions.</td>
<td>Prodel=1</td>
</tr>
<tr>
<td>Electricity, medium voltage (ENTSO-E) market group for Cut-off, S</td>
<td>417</td>
<td>Simulates current sorting/crushing in western Europe and average global conditions.</td>
<td>Prodel=0</td>
</tr>
<tr>
<td>Electricity, high voltage (ENTSO-E) market group for Cut-off, S</td>
<td>414</td>
<td>Simulates recycling in western Europe and average global conditions.</td>
<td>Prodel=0</td>
</tr>
</tbody>
</table>

**Avoided products**

Recycling avoids using other material resources. Thereby recycling is often calculated as having a net benefit to the environmental impact. However, it is not evident which material should be considered as being avoided or replaced, because the quality of the material output from the recycling is not obvious. The figure below shows some of the replacement choices used in this project.

![Figure 12 - Avoided products](image)

**Figure 12  Avoided products**

It was assumed that the recycling output of copper, aluminium and steel needed transport and remelting in order to replace virgin copper, aluminium and steel respectively. On the other hand, it was assumed that the recycling output of manganese, cobalt, nickel and lithium carbonate could replace virgin manganese, cobalt, nickel and lithium carbonate respectively without further treatment. In Figure 12 the calculation is done with European average electricity for remelting but that could be changed to Swedish average electricity production with parameter Prodel, see Table 1.

**Results**

In the figures below, the thickness of the arrows corresponds to the global warming impact measured in carbon dioxide equivalents from respective process. The amount of CO\textsubscript{2}-eq in gram is shown in the lower left corner of each box. Green arrows or minus in the box means avoided emissions in the Sankey diagram. Some Sankey diagrams show abiotic depletion.
ReLion

Recycling lithium ion cells with the ReLion method avoids potentially around 4.5 kg CO₂ per kg cell in total. However, most of this avoided burden stem from the rest of the battery pack, not from the cells. Since roughly half of a traction battery pack consist of cells and the other half is packaging, cooling and battery management system, BMS, 2 kg of battery pack is needed for 1 kg of cells.

Sorting, crushing and separating a LIB pack avoids 2.9 kg CO₂ per kg LIB cell due to avoided burdens associated with copper and aluminium recycling from the pack (packaging, cooling, BMS)³, see figure below. Base case conditions are assumed (Swedish average electricity for all recycling operations, de-cooking according to lab test and transportation between Karlskoga and Skellefteå between shredding and metallurgical treatment.) Transportation of batteries from car scrap yards is included and give a climate impact at the same level as internal energy needs.

Figure 13  Climate impact of end-of-life recycling of lithium ion cells according to ReLion, sorting, crushing and separating, base case conditions

De-cooking, smelting including lithium separation avoids the balance, i.e. 1.6 kg CO₂/kg cell, see Figure 14 and Figure 15.

³ So it would in a way be more correct to say that sorting, crushing and separation 2 kg och lithium ion traction battery pack avoids 2.9 kg CO₂
Figure 14 Climate impact of end-of-life recycling of lithium ion cells according to ReLion, decoking, base case conditions

Nickel, cobalt and lithium carbonate recovery and recycling save substantive climate impact, as can be seen in the figure below.

Figure 15 Climate impact of end-of-life recycling of lithium ion cells according to ReLion, smelting and Li-separation, base case conditions
The figure below shows abiotic depletion. The main trend that copper, aluminium and nickel give substantive contributions is the same as for climate impact. However, copper has changed place with aluminium as the most important contributor to the impact category. Processes contributing with less than 5.3% of the total are not shown (5.3% cut-off).

Figure 16  Abiotic depletion of end-of-life recycling of lithium ion cells according to ReLion, base case conditions, 5.3% cut-off
Alternative decoking

An alternative decoking process is possible using air and water instead of liquid oxygen. The total climate impact of using this alternative is avoidance of 4.67 kg CO₂/kg cell, see figure below.

![Diagram](image)

**Figure 17** Climate impact of end-of-life recycling of lithium ion cells according to ReLion, decoking with air and water

In the figure below the calculations are done with European average electricity mix. Otherwise base conditions apply. The climate impact avoidance decreases to 3.9 kg CO₂/kg cell.
Comparing with PEFCR

For comparison, recycling with the data given in PEFCR is calculated below. The model is based on the information given in Annex 4 of the PEFCR-guide (RECHARGE 2018). It should be emphasized that the PEFCR only consider LIB cells while ReLion consider LIB packs. Thus, the avoided 2.9 kg CO₂ burdens associated with copper and aluminium recycling from the pack is not included in the PEFCR model. So it is more fair to compare the PEFCR avoided 0.1 kg CO₂/kg cell burden with the 3.9-2.7=1.2 kg CO₂/kg cell balance in Figure 18.

Figure 18  Climate impact of end-of-life recycling of lithium ion cells according to ReLion, European electricity mix
Figure 19 Climate impact of end-of-life recycling of lithium ion cells. ReLion process compared with PEFCR data, European electricity mix

Figure 20 Abiotic depletion of end-of-life recycling of lithium ion cells. ReLion process compared with PEFCR data, European electricity mix. 3.5% cut-off
From a resource perspective, the ReLion process is much more similar to the PEFCR, as can be seen in the figure above. Savings are around 0.003 kg Sb/kg cell for both processes.

Recalculation with Swedish electricity does not give drastically improved results for the PEFCR data (0.3 kg CO\textsubscript{2}/kg cell avoidance compared to 0.1), see figure below.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure21.png}
\caption{Climate impact of end-of-life recycling of lithium ion cells, PEFCR data, Swedish electricity mix}
\end{figure}

Discussion and conclusions

Comparison with other battery LCAs

As mentioned above, comparisons with PEFCR is halting due to that the PEFCR only consider LIB cells while ReLion consider LIB packs. Thus, the avoided 2.9 kg CO\textsubscript{2} burdens associated with copper and aluminium recycling from the pack is not included in the PEFCR model and it is therefore more relevant to compare the PEFCR avoided 0.1 kg CO\textsubscript{2}/kg cell burden with the 3.9-2.7=1.2 kg CO\textsubscript{2}/kg cell balance see Figure 17. But what does around 0.1-1.2 kg of CO\textsubscript{2}/kg cell mean in the life cycle of a traction battery? In the figure below, life cycle climate impact for a 24 kWh NMC traction battery used in Nissan LEAF is shown (Mats Zackrisson 2018) compared to the ReLion process.
In Zackrisson 2018, the recycling phase was estimated based on the assumption that 80% of metal content could be recycled at an environmental cost equal to half the avoided burden of the recycled materials. Recycling climate avoidance thus estimated amount to 9.5% of production phase impacts. The ReLion recycling process avoids 12% of the production phase impacts as modelled in Zackrisson 2018 (Cusenza et al. 2019) reports 8% climate impact recycling credits of total life cycle climate impact (for a LMO-NMC battery) but since the end-of-life burdens (approx. 4%) are included in the total, the total end-of-life climate avoidance should amount to around 5% of production impacts in that study. (Tagliaferri et al. 2016) reports around 20% climate impact recycling credits of production impacts, but here the whole vehicle (a Nissan LEAF with an NMC battery) is included.

In conclusion, the figures achieved by the ReLion process is somewhere in between figures received by other studies incorporating end-of-life of traction batteries. It seems therefore reasonable to assume that if the ReLion process can be replicated in full scale, it should be possible to recover at least 10% of the climate impacts of producing an NMC traction battery.

It should be mentioned that the climate impact of producing an NMC traction battery calculated by Zackrisson 2018 is at the higher end of those reported. Transformed to climate impact per delivered kWh it corresponds to 229 kg CO₂/kWh nominal battery capacity. (Emilsson and Dahllöf 2019) claim production of NMC traction batteries have a climate impact in the range 61-106 kg/kWh nominal battery capacity, where the range mainly is claimed to depend on electricity mix. If Emilsson and Dahllöf are correct, then recycling with the ReLion process could potentially avoid around 20% of production climate impacts.

**Figure 22**  *Nissan LEAF with 24 kWh NMC battery, life cycle climate impacts compared to ReLion process*
**Decoking**
Decoking with air and water instead of liquid oxygen gives a bit more climate avoidance, 0.2 kg CO₂/kg cell. If it can be done easily and without much extra cost this option should be utilized.

**Electricity mix**
Using average European electricity mix instead of Swedish electricity mix only decrease the climate impact avoidance from 4.5 to 3.9 kg CO₂/kg cell. This shows that the ReLion process is not dependant on carbon-lean electricity.

**Abiotic depletion**
The abiotic depletion gains of the ReLion process follows the same trend as the climate impact gains.

**Conclusions**
The results indicate that the ReLion process:

- replicated in full scale, can potentially recover at least 10% of the climate impacts of producing an NMC traction battery, the currently most common traction battery chemistry
- decoking with air and water instead of liquid oxygen gives a bit more climate avoidance, 0.2 kg CO₂/kg cell and a bit more abiotic depletion avoidance. If it can be done easily and without much extra cost this option should be utilized.
- The ReLion process is not dependant on carbon-lean electricity to potentially avoid at least 10% of the climate impacts of producing an NMC traction battery
Referenser

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