LCA of Electric Vehicles Recycling
Comparison of three business lines of dismantling

CHEMICAL ENGINEERING

Processes and Sustainable Development
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1. Life Cycle Assessment

1.1. Methodology

- ISO Standards 14040/44
- Comprises all stages:
  - Extraction
  - Manufacturing
  - Transportation
  - Packaging
  - Distribution
  - Product / Use
  - End-of-Life
- "Cradle to grave"
1. Life Cycle Assessment

1.2. Steps

Goal and scope definition

Life Cycle Inventory (LCI)

Impact Assessment (LCIA)

Interpretation
1. Life Cycle Assessment

1.3. Inventory
1. Life Cycle Assessment

1.4. Impact assessment

*Impact categories*

- Climate change
- Acidification
- Eutrophication
- Non-renewable resources
- Ozone layer depletion
- Photochemical oxidation
- Etc.

<table>
<thead>
<tr>
<th>Impact Category</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>10 kg</td>
</tr>
<tr>
<td>CH₄</td>
<td>12 m³</td>
</tr>
<tr>
<td>SO₂</td>
<td>150 g</td>
</tr>
<tr>
<td>As, Cd, HAP</td>
<td>...</td>
</tr>
</tbody>
</table>

\[ \text{CO}_2, \text{CH}_4, \text{N}_2\text{O} \Rightarrow \text{Climate change} \]
\[ \text{SO}_2, \text{NO}_x \Rightarrow \text{Acidification} \]
\[ \text{As, Cd, HAP} \Rightarrow \text{Carcinogens effects} \]
1. Life Cycle Assessment

1.4. Impact assessment

- No universal methodology

- ISO standards refer to international methods
- EC → Joint Research Center (JRC) → International Reference Life Cycle Data System (ILCD) Handbooks

- Examples
  - Eco-Indicator 99
  - CML 2001
  - ReCiPe 2008
  - EPD 2008
2. Context of the study

**European directive : 2000/53/EC**

- By 2015: global recovery of End of Live Vehicle (ELV) = 95% wt

- Possibilities:
  - Removal of metal components before shredding (Cu, Al, Mg)
  - Removal of large plastic components (bumpers, dashboards, fluid containers,...)

- BE: no removal of Engine Control Unit (ECU) and plastics → recovering after shredding

- ⇒ selective dismantling

- Life Cycle Assessment of both possibilities to get the environmental performance of these scenarios
3. Goal and Scope

Goal definition

Environmental impact of 2 recycling routes of ELV and comparison with current recycling scenario ("business as usual")

• Dismantling of ECU and recycling before shredding

• Dismantling of large plastics components and recycling before shredding
3. Goal and Scope

Scope: Main stages in scenarios ("gate to grave")

DEPOLLUTION DISMANTLING → SHREDDING → PST METALS

ELV

(P1) ECU

(2) Plastics

Fe scraps

Cu scraps

Al, Cu, Fe scraps

PCB

PST PHOENIX

PST PLASTICS

PST MINERALS

Ashes

Carbon black

Electricity/Heat

Plastics (PP, PE, ABS, PS)

Fe scraps

Minerals (sand)

Functional Unit: Treatment and recycling of a depolluted ELV (with or without selective dismantling before shredding)
4. Main assumptions and results

Belgian electricity mix:

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Belgium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>6.0%</td>
</tr>
<tr>
<td>Natural gas</td>
<td>28.2%</td>
</tr>
<tr>
<td>Hydroelectricity</td>
<td>1.6%</td>
</tr>
<tr>
<td>Nuclear energy</td>
<td>53.5%</td>
</tr>
<tr>
<td>Wind</td>
<td>2.6%</td>
</tr>
<tr>
<td>Waste</td>
<td>2.2%</td>
</tr>
<tr>
<td>Biomass</td>
<td>4.3%</td>
</tr>
<tr>
<td>Solar PV</td>
<td>1.3%</td>
</tr>
<tr>
<td>Oil</td>
<td>0.3%</td>
</tr>
</tbody>
</table>
4. Main assumptions and results

First route: classical vehicles
4. Main assumptions and results

First route: classical vehicles
5. Second route

Dismantling of plastics

• Same steps than before
  • Dismantling
  • Shredding
  • PST Metals
  • PST Minerals
  • PST Plastics
  • PST Phoenix

• Recovery of plastics during the dismantling phase
• Main assumption: yield of valorisation for plastic before or after shredding is the same = 97% ⇒ sensitivity analysis
5. Second route

Dismantling of plastics
## 5. Second route

### Dismantling of plastics

<table>
<thead>
<tr>
<th>Impact category</th>
<th>Unit</th>
<th>Classical route</th>
<th>Dismantling of plastics</th>
<th>Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate change</td>
<td>kg CO(_2) eq</td>
<td>-2015.50</td>
<td>-2021.07</td>
<td>0.3%</td>
</tr>
<tr>
<td>Terrestrial acidification</td>
<td>kg SO(_2) eq</td>
<td>-7.99</td>
<td>-8.03</td>
<td>0.5%</td>
</tr>
<tr>
<td>Freshwater eutrophication</td>
<td>kg P(_{eq})</td>
<td>-1.75</td>
<td>-1.76</td>
<td>0.6%</td>
</tr>
<tr>
<td>Human toxicity</td>
<td>kg 1.4-DB(_{eq})</td>
<td>-140.06</td>
<td>-144.32</td>
<td>3.0%</td>
</tr>
<tr>
<td>Particulate matter formation</td>
<td>kg PM(_{10}) eq</td>
<td>-5.78</td>
<td>-5.80</td>
<td>0.3%</td>
</tr>
<tr>
<td>Metal depletion</td>
<td>kg Fe(_{eq})</td>
<td>-1527.12</td>
<td>-1534.52</td>
<td>0.5%</td>
</tr>
<tr>
<td>Fossil depletion</td>
<td>kg oil(_{eq})</td>
<td>-721.04</td>
<td>-722.73</td>
<td>0.2%</td>
</tr>
</tbody>
</table>
5. Second route

Dismantling of plastics – climate change

![Graph showing climate change impact comparison between Business as usual and Plastics dismantling from 2016 to 2021. The graph indicates a significant reduction in kg CO₂ for the dismantling option.]
5. Second route

Dismantling of plastics – metal depletion
5. Second route

Dismantling of plastics – fossil fuel depletion

![Chart showing comparison between Business as usual and Plastics dismantling for fossil fuel depletion. The chart indicates a decrease in fossil fuel depletion for both scenarios, with a slightly higher impact for Plastics dismantling.](chart.png)
5. Second route – Sensitivity analysis

Yield of Plastics recovery and valorisation

[Graph showing the yield of plastics recovery and valorisation with and without plastics removal, comparing various environmental impacts such as climate change, terrestrial acidification, freshwater eutrophication, human toxicity, particulate matter formation, metal depletion, and fossil depletion.]
5. Second route – Sensitivity analysis

Yield of Plastics recovery and valorisation

Max. 3% gain = 50 kg$_{eq}$ CO$_2$

Max. 6% gain
6. Third route

Dismantling of ECU

- PCB and Aluminium (+ plastics: incinerated → heat)
- Same steps than before
  - Dismantling
  - Shredding
  - PST Metals
  - PST Minerals
  - PST Plastics
  - PST Phoenix
- Recovery of ECU during the dismantling phase
- Main assumption: 1 kg of PCB scrap replaces 1 kg of primary PCB ⇒ sensitivity
6. Third route

Dismantling of ECU

![Graph showing the impact of ECU dismantling on various environmental factors. The x-axis represents different environmental categories, and the y-axis represents the percentage change. The graph compares 'Business as usual' (orange bars) with 'With ECU Dismantling' (blue bars).]
## 6. Third route

### Dismantling of ECU

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<thead>
<tr>
<th>Impact category</th>
<th>Unit</th>
<th>Classical route</th>
<th>Dismantling of ECU</th>
<th>Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate change</td>
<td>kg CO$_2$ eq</td>
<td>-2015.50</td>
<td>-2031.89</td>
<td>0.8%</td>
</tr>
<tr>
<td>Terrestrial acidification</td>
<td>kg SO$_2$ eq</td>
<td>-7.99</td>
<td>-8.18</td>
<td>2.4%</td>
</tr>
<tr>
<td>Freshwater eutrophication</td>
<td>kg P$_{eq}$</td>
<td>-1.75</td>
<td>-1.78</td>
<td>1.7%</td>
</tr>
<tr>
<td>Human toxicity</td>
<td>kg 1.4-DB$_{eq}$</td>
<td>-140.06</td>
<td>-148.46</td>
<td>6.0%</td>
</tr>
<tr>
<td>Particulate matter formation</td>
<td>kg PM$_{10}$ eq</td>
<td>-5.78</td>
<td>-5.83</td>
<td>0.9%</td>
</tr>
<tr>
<td>Metal depletion</td>
<td>kg Fe$_{eq}$</td>
<td>-1527.12</td>
<td>-1539.93</td>
<td>0.8%</td>
</tr>
<tr>
<td>Fossil depletion</td>
<td>kg oil$_{eq}$</td>
<td>-721.04</td>
<td>-712.05</td>
<td>-1.2%</td>
</tr>
</tbody>
</table>
6. Third route

Dismantling of ECU – climate change

![Graph showing climate change with two scenarios: Business as usual and ECU dismantling. The y-axis represents kg CO₂ eq, and the x-axis shows years from 2016 to 2032. The graph compares the environmental impact of different processes such as dismantling, shredding, PST Metals, PST Minerals, PST Plastics, PST Phoenix, and the total impact.]
6. Third route

Dismantling of ECU – metal depletion

Metal depletion

-1527

-1540

kg_{eq, iron}

Business as usual

ECU dismantling

Dismantling  Shredding  PST Metals  PST Minerals  PST Plastics  PST Phoenix  Total
6. Third route

Dismantling of ECU – fossil fuel depletion

Fossil fuel depletion

-721
-712
6. Third route - Sensitivity analysis

Yield of PCB recovery and valorisation

![Graph showing sensitivity analysis of PCB recovery and valorisation]
6. Third route - Sensitivity analysis

Yield of PCB recovery and valorisation

- Climate change
- Terrestrial acidification
- Freshwater eutrophication
- Human toxicity
- Particulate matter formation
- Metal depletion
- Fossil depletion

Max. 17% gain = 283 kg eq CO₂

Max. 10% gain

With ECU dismantling
Business as usual
Business as usual - without PCB
7. Conclusions

Classical route
- Shredding step is the most important
- All processes obtain a negative score ⇒ positive environmental impacts
- All results are dependent to the market

Dismantling of plastics
- Small gain relative to the classical route
- Depends on the plastics valorisation
- In the worst case for the classical scenario:
  - Climate change gain = 3%
  - Fossil fuel depletion gain = 6%
7. Conclusions

Dismantling of ECU

- Small gain relative to the classical route
- Few changes in all valorisation units
- In the worst case for the classical scenario:
  - Climate change gain = 17%
  - Fossil fuel depletion gain = 10%

ECU and Plastics recovery before shredding is not significant in an environmental point of view.