VALOMAG project

From the recovery of scrap magnets to the production of new magnets and rare earth oxides

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This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation
EIT Raw Materials

**EIT RawMaterials**, initiated and funded by the EIT, a body of the European Union, is the largest consortium in the raw materials sector worldwide. Its vision is to develop raw materials into a major strength for Europe. Its mission is to enable sustainable competitiveness of the European minerals, metals, and materials sector along the value chain by driving innovation, education, and entrepreneurship.
General description – Main features

**VALOMAG – Value of Magnets from Waste**

*Project number: 19049*

*Project budget: 2 526 102 €*

*Start date: February 2020*

*Project duration: 36 months*

*Area: D2 Acceleration*

*Activity: D2.2 Upscaling*

*Strategic objective: Designing materials solutions*

*Thematic fields:*

4- Recycling and material chain optimization for End-of-Life products
Outline

General description of VALOMAG project
- Background on Critical Raw Materials
- Process chart considered in VALOMAG project

Some results on magnets from wind turbines
- Market study on EoL wind turbines
- Sourcing of wind turbine magnets
- Dismantling process => demagnetization
- Recycling and Recovery Routes
- LCA - Process integration and value chain analysis

Wind turbine dismantling
- SUEZ activity in France

Perspectives
General description: Background

**Market’s trends**

**Context on Critical Raw Materials (CRM)**

- Increasing demand of CRM like Rare Earth Elements (REE) for clean energy applications (wind turbine)
- Increasing use of new technologies (today’s technology-driven society)
- Development of cleaner ways of transport ⇒ electric vehicles, e-mobility

**Position of Europe**

- China has 95% of global REE-production (Strategic forum/ EC Input 2018) ⇒ 85 – 90% supply of Rare Earth (RE) in Europe
- REE considered as “strategic” materials by EU ⇒ recycling of CRM as a secondary supply to decrease the import dependence
- European Union support Innovation and Research (Strategic Forum / EC 2018) through funding of projects – Prioritization of actions in EU for innovative applications
  ⇒ Foundation of European Raw Materials Alliance – **ERMA** with 2 clusters focusing on Rare Earth Magnets & Motors + Materials for Energy Storage and Conversion
General description:
Process chart considered in VALOMAG project
Market Study: Data and Hypotheses used for forecasts calculation

<table>
<thead>
<tr>
<th>Wind Turbines</th>
<th>Weight PM (g/unit)</th>
<th>NdFeB/PM (%)</th>
<th>Lifespan (years)</th>
<th>Rate collection (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct drive</td>
<td>650 kg/MW</td>
<td>30</td>
<td>25</td>
<td>100%</td>
</tr>
<tr>
<td>- mid &amp; high speed</td>
<td>160 &amp; 80kg/MW</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sources:
- Ademe, 2020. Avis Technique - Terres rares, énergies renouvelables et stockage d’énergie
Estimation of EoL Permanent Magnets used in on & offshore WT in Europe from 2025 to 2044 – from already installed capacities (GW)

<table>
<thead>
<tr>
<th>Year</th>
<th>Offshore (GW)</th>
<th>Onshore (GW)</th>
<th>Total usable (GW)</th>
</tr>
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<tbody>
<tr>
<td>2000</td>
<td>0.004</td>
<td>33.5</td>
<td>0.004</td>
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<tr>
<td>2001</td>
<td>0.05</td>
<td>6.5</td>
<td>0.05</td>
</tr>
<tr>
<td>2002</td>
<td>0.17</td>
<td>7.1</td>
<td>0.17</td>
</tr>
<tr>
<td>2003</td>
<td>0.25</td>
<td>8.6</td>
<td>0.25</td>
</tr>
<tr>
<td>2004</td>
<td>0.1</td>
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<td>0.1</td>
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<tr>
<td>2005</td>
<td>0.08</td>
<td>10</td>
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<td>2006</td>
<td>0.9</td>
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<td>0.9</td>
</tr>
<tr>
<td>2007</td>
<td>0.32</td>
<td></td>
<td>0.32</td>
</tr>
<tr>
<td>2008</td>
<td>0.35</td>
<td></td>
<td>0.35</td>
</tr>
<tr>
<td>2009</td>
<td>0.6</td>
<td></td>
<td>0.6</td>
</tr>
</tbody>
</table>

Typology of permanent magnet generators:

- Low speed or direct drive (DD): 19% in 2015, 29% in 2020, 44% in 2030
- Mid speed: 4% in 2015, 12% in 2020, 28% in 2030
- High speed: 4% in 2015, 12% in 2020, 28% in 2030

Mass of permanent magnets:

- Low speed or direct drive (DD): 650 kg/MW
- Mid speed: 160 kg/MW
- High speed: 80 kg/MW

Direct drive wind turbine testing at the world’s largest wind turbine drive chain testing facility at Clemson University (Image courtesy of the Clemson University)
Estimation of EoL Permanent Magnets used in on & offshore WT in Europe from 2045 to 2055

Additional wind power capacities (GW) expected to be installed between 2020 and 2030


Direct drive wind turbine testing at the world’s largest wind turbine drive chain testing facility at Clemson University (Image courtesy of the Clemson University)
Forecasts of return flows from 2020 to 2040 in Europe

Sourcing of EoL products => magnets from wind turbines

Sourcing: SUEZ / BRGM

Thermal treatment: CRM Group

Fragmentation / Classification: BRGM

Recovery: BRGM, CEA, Kolektor

980kg Wind Turbines’ magnets sourced by BRGM and provided by Net Wind company in France

2 types: with and without Zn coating
Thermal treatment of Wind Turbine magnets

Sourcing: SUEZ / BRGM

Thermal treatment: CRM Group

Fragmentation / Classification: BRGM

Recovery: BRGM, CEA, Kolektor

Zinc coating magnets

N38 magnets

Before heating

After heating

After cleaning
Recovery and Recycling Routes

Sourcing: SUEZ / BRGM

Thermal treatment: CRM Group

Fragmentation / Classification: BRGM

Recovery: BRGM, CEA, Kolektor

From raw materials to functional magnets

- Alloy manufacturing
- Crushing (hydrogen decrepitation)
- Milling
- Aligning and pressing
- Sintering and annealing
- Machining and surface finishing
- Magnetizing

Short Loop Recycling with CEA and Kolektor
Connecting different unit operations: whole value chain approach

- Mass and energy balance
- Process efficiency analysis
- Process cost/economic analysis
- Environmental analysis (support to LCA)
Assessing impact on critical material supply dependency

- **Sourcing:** SUEZ / BRGM
- **Thermal treatment:** CRM Group
- **Fragmentation / Classification:** BRGM
- **Recovery:** BRGM, CEA, Kolektor
- **Simulation:** Leiden Univ. / TU Delft
Perspectives

• Characterization of the scrap magnets from the different sources to assess their quality and their variability

• Implementation of:
  ✓ the 2 short loop recycling routes at CEA and KOLEKTOR for sintered and bonded magnets
  ✓ the hydrometallurgical route at BRGM for recovery of REE oxides

• Set up of the LCA and Process integration for the 3 routes
Wind Turbines Dismantling activities in SUEZ

Objectives:

- To maintain and increase the recovery and the recycling of materials from Wind Turbines
- To choose the most valuable recycling routes
- To answer the needs of different recycling value chains in EU

https://www.youtube.com/watch?v=6gfoylf6C_4I
Thank you for your attention

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation.
To follow VALOMAG project

- Project Website

https://valomag.tudelft.nl/

- LinkedIn Group

https://www.linkedin.com/groups/12500202/