VALOMAG project

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

Virginie Decottignies – SUEZ Group

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.

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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

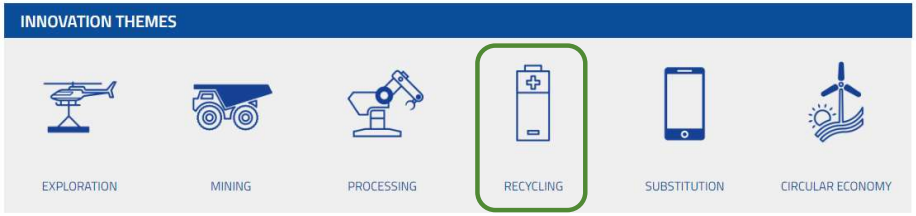
Area: D2 Acceleration

Activity: D2.2 Upscaling

Strategic objective: Designing materials solutions

Thematic fields:

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



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RECYCLING
TURNING WASTE
INTO VALUABLE RESOURCES
Re-Thinking Recycling: New Processes,
New Business Models, Attracting Talents

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Outline

General description of VALOMAG project

- *Background on Critical Raw Materials*
- *Process chart considered in VALOMAG project*

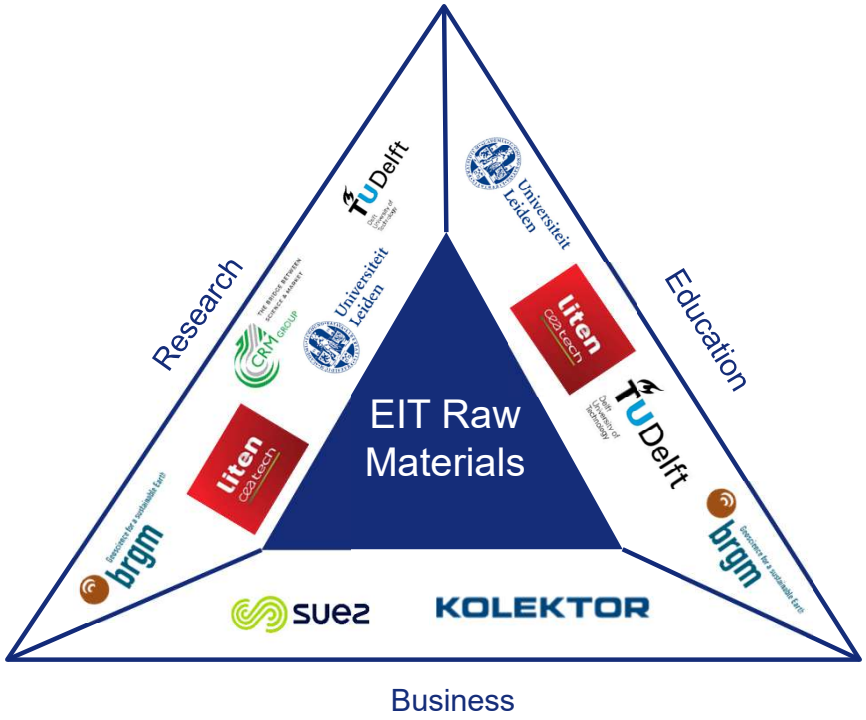
Some results on magnets from wind turbines

- *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



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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*

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EUROPEAN RAW MATERIALS ALLIANCE ERMA

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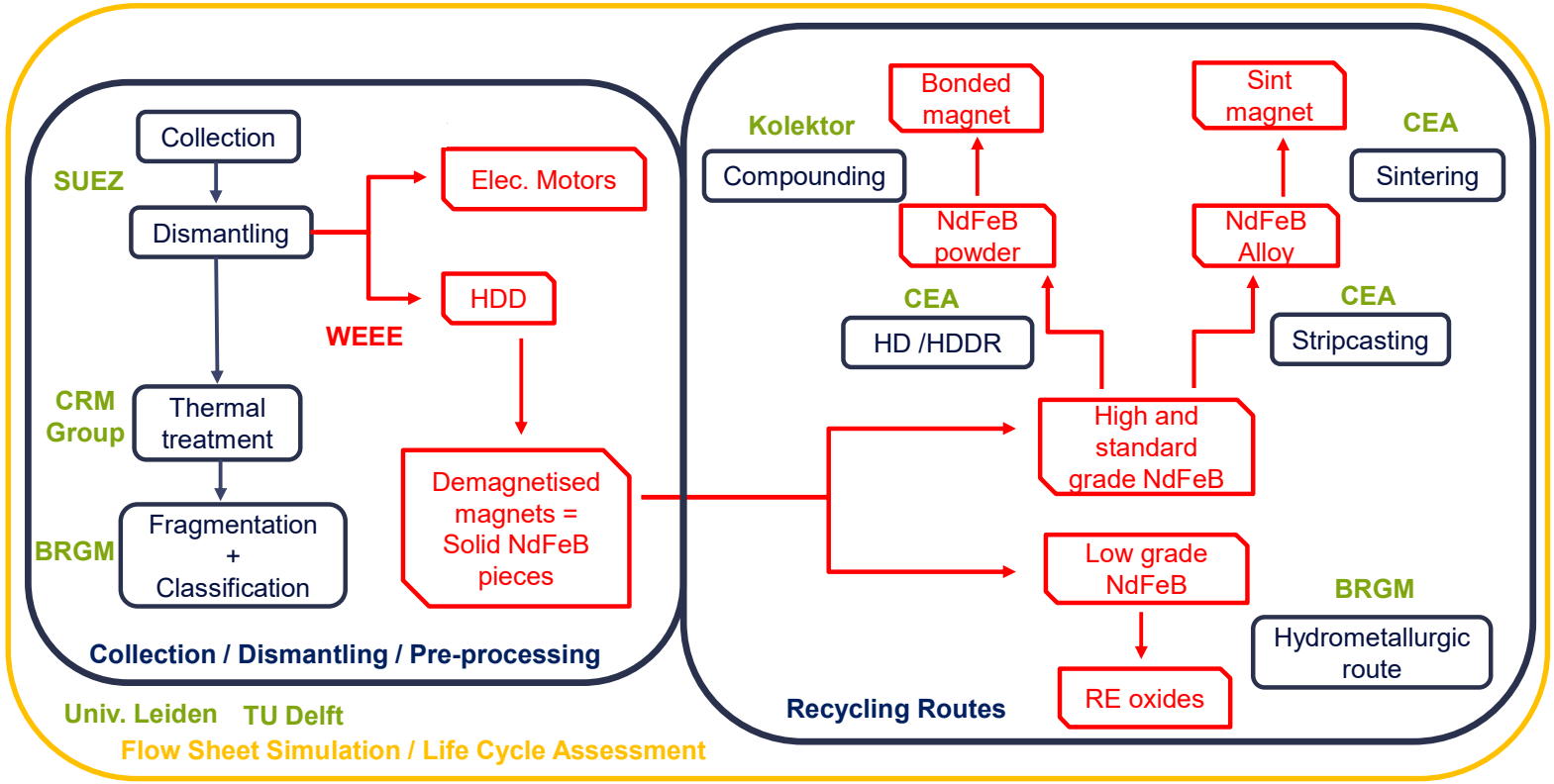
General description:
Process chart considered in VALOMAG project



Legend: Partner involved | Materials | Process step

Market Study: Data and Hypotheses used for forecasts calculation

	Weight PM (g/unit)	NdFeB/PM (%)	Lifespan (years)	Rate collection (%)
Wind Turbines Direct drive - mid & high speed	650 kg/MW 160 & 80kg/MW	30	25	100%

- *Sources:*
  - ✓ *Ademe, 2020. Avis Technique - Terres rares, énergies renouvelables et stockage d'énergie*
  - ✓ *JRC, 2017. Wind Energy Status Report 2016. Market, technology and regulatory aspects of wind energy*
  - ✓ *Pavel C., Lacal-Arántegui R., Marmier A., Schüler D., Tzimas E., Buchert M., Jenseit W., Blagoeva D., 2017, Substitution strategies for reducing the use of rare earths in wind turbines. 52 (2017) 349-357*
  - ✓ *Reimer M.V., Schenk-Mathes H.Y., Hoffmann M.F. and Elwert T., 2018 Recycling Decisions in 2020, 2030, and 2040—When Can Substantial NdFeB Extraction be Expected in the EU? Metals 2018, 8, 867 (doi:10.3390/met8110867)*

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Estimation of EoL Permanent Magnets used in on & offshore WT in Europe from 2025 to 2044 – from already installed capacities (GW)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Offshore (*GW*)	0,004	0,05	0,17	0,25	0,1	0,08	0,9	0,32	0,35	0,60
Onshore (*GW*)				33,5		6,5	7,1	8,6	8,1	10
Total usable (*GW*)	**0,004**	**0,05**	**0,17**	**0,25**	**0,10**	**0,08**	**0,90**	**8,92**	**8,45**	**10,6**

Single data available.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Offshore (*GW*)	0,9	0,8	1,2	1,5	1,5	3,0	1,6	3,2	2,7	3,6
Onshore (*GW*)	9,6	9,5	11,7	11	11	10	12,3	13,9	9,4	11,7
Total usable (*GW*)	**10,5**	**10,3**	**12,9**	**12,5**	**12,5**	**13,0**	**13,9**	**17,1**	**12,1**	**15,3**

Typology of permanent magnet generators	2015	2020	2030	Mass of permanent magnets
Low speed or direct drive (*DD*)	19%	29%	44%	**650** kg/MW
Mid speed	4%	12%	28%	**160** kg/MW
High speed				**80** kg/MW

	By 2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Total usable (*GW*)	0,005	0,05	0,17	0,25	0,10	0,08	0,9	8,9	8,5	10,6

	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044
Total usable (*GW*)	10,5	10,3	12,9	12,5	12,5	13,0	13,9	17,1	12,1	15,3

X 128,3 kg PM/MW

	By 2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
PM Mass (*Tons*)	1	6	22	32	13	10	115	1 144	1 084	1 360

	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044
PM Mass (*Tons*)	1 347	1 321	1 655	1 604	1 604	1 668	1 783	2 194	1 552	1 963

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https://www.engineering.com/story/the-future-of-wind-turbines-comparing-direct-drive-and-gearbox

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

Expectations	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Total usable (*GW*)	48GW (*offshore*) + 70GW (*onshore*) (*i.e. 10.72 GW per year on average*)										

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

Typology of permanent magnet generators	2015	2020	2030	Mass of permanent magnets
Low speed or direct drive (*DD*)	19%	29%	44%	**650** kg/MW
Mid speed	4%	12%	28%	**160** kg/MW
High speed				**80** kg/MW

Expectations	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2045-2055
Total usable (*GW*)	48GW (*offshore*) + 70GW (*onshore*) (*i.e. 10.72 GW per year on average*)											***118***

X 202,9 kg/MW

Expectations	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2045-2055
PM Mass (*Tons*)	2 177	2 177	2 177	2 177	2 177	2 177	2 177	2 177	2 177	2 177	2 177	***23 942***

https://www.engineering.com/story/the-future-of-wind-turbines-comparing-direct-drive-and-gearbox

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)

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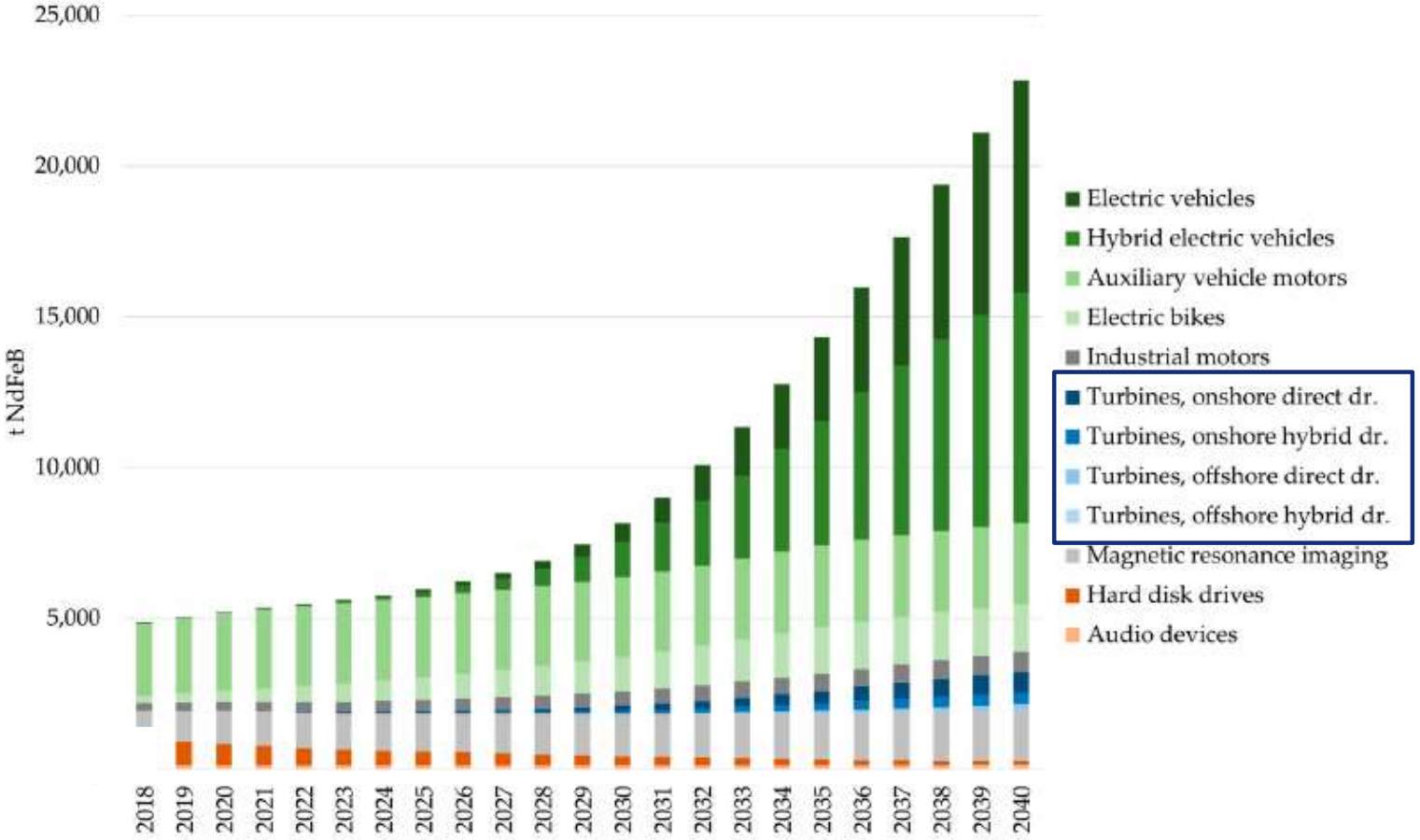
Forecasts of return flows from 2020 to 2040 in Europe



- *Source: Reimer M.V., Schenk-Mathes H.Y., Hoffmann M.F. and Elwert T., 2018 Recycling Decisions in 2020, 2030, and 2040—When Can Substantial NdFeB Extraction be Expected in the EU? Metals 2018, 8, 867 (doi:10.3390/met8110867)*

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Sourcing of EoL products => magnets from wind turbines

Sourcing: SUEZ / BRGM

↓

Thermal treatment: CRM Group

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Fragmentation / Classification: BRGM

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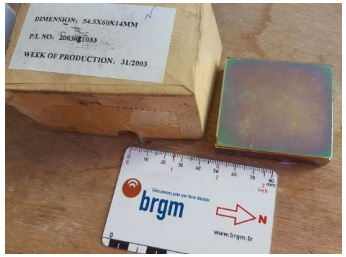
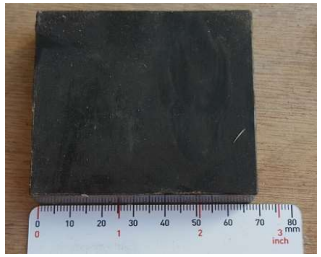
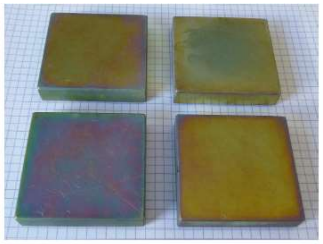
Recovery: BRGM, CEA, Kolektor

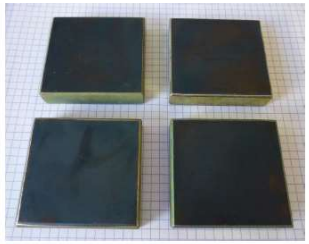
980kg Wind Turbines' magnets sourced by BRGM and provided by Net Wind company in France





2 types: with and without Zn coating





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Thermal treatment of Wind Turbine magnets

Sourcing: SUEZ / BRGM

↓

Thermal treatment: CRM Group

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Fragmentation / Classification: BRGM

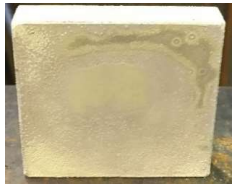
↓

Recovery: BRGM, CEA, Kolektor

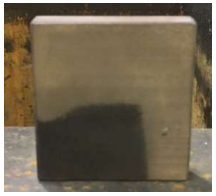
Zinc coating magnets

N38 magnets

Before heating



After heating



After cleaning

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Recovery and Recycling Routes

Sourcing: SUEZ / BRGM

↓

Thermal treatment: CRM Group

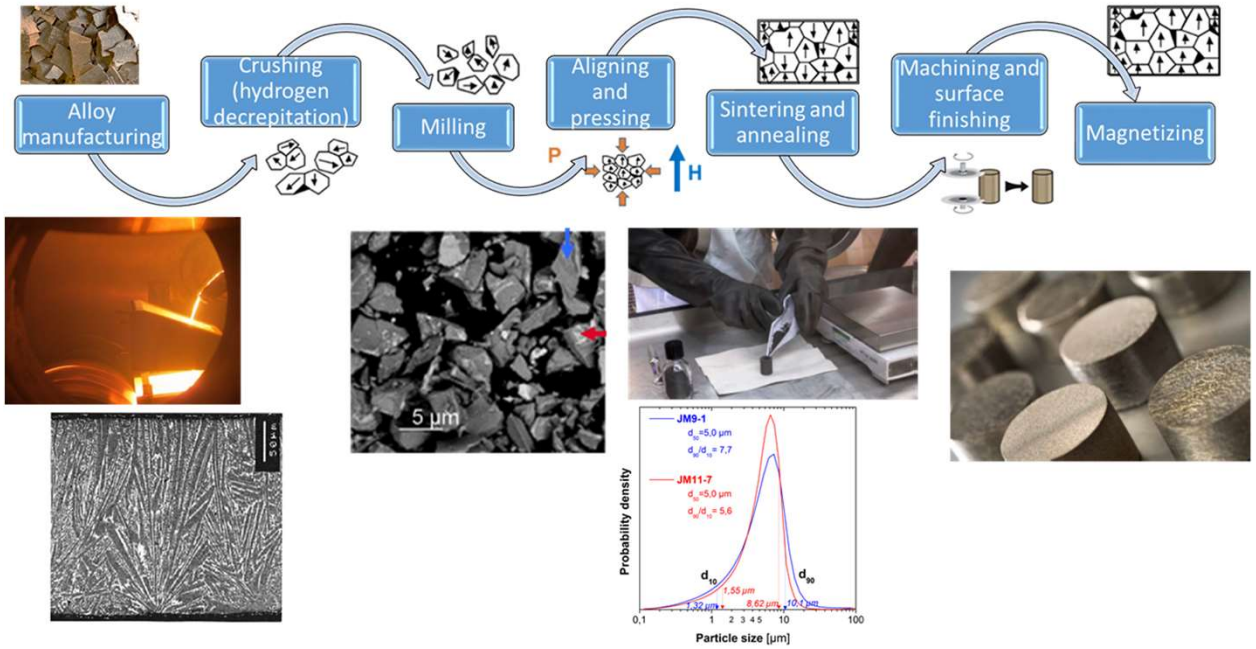
↓

Fragmentation / Classification: BRGM

↓

Recovery: BRGM, CEA, Kolektor

From raw materials to functional magnets



Short Loop Recycling with CEA and Kolektor

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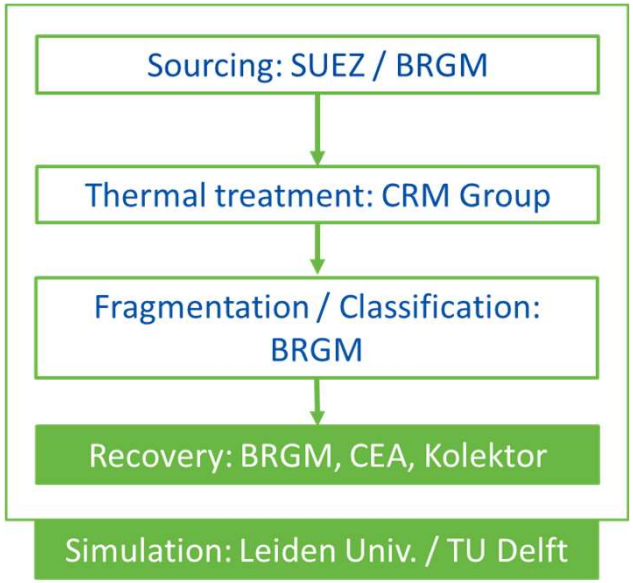
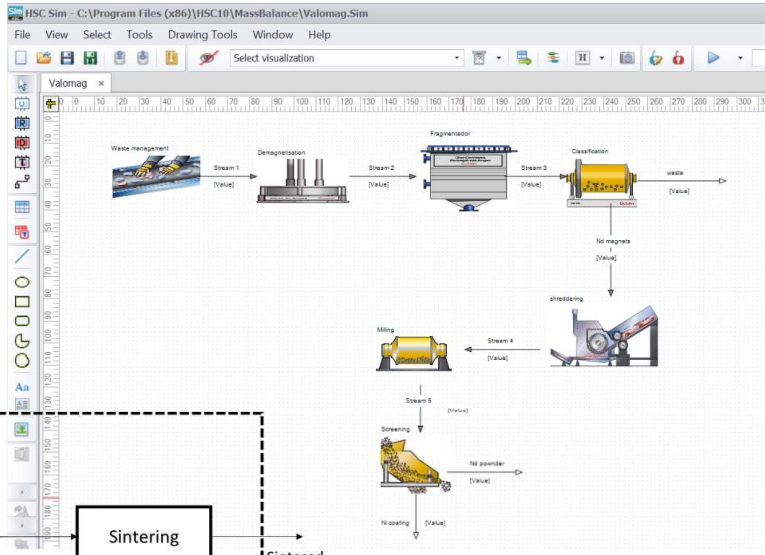
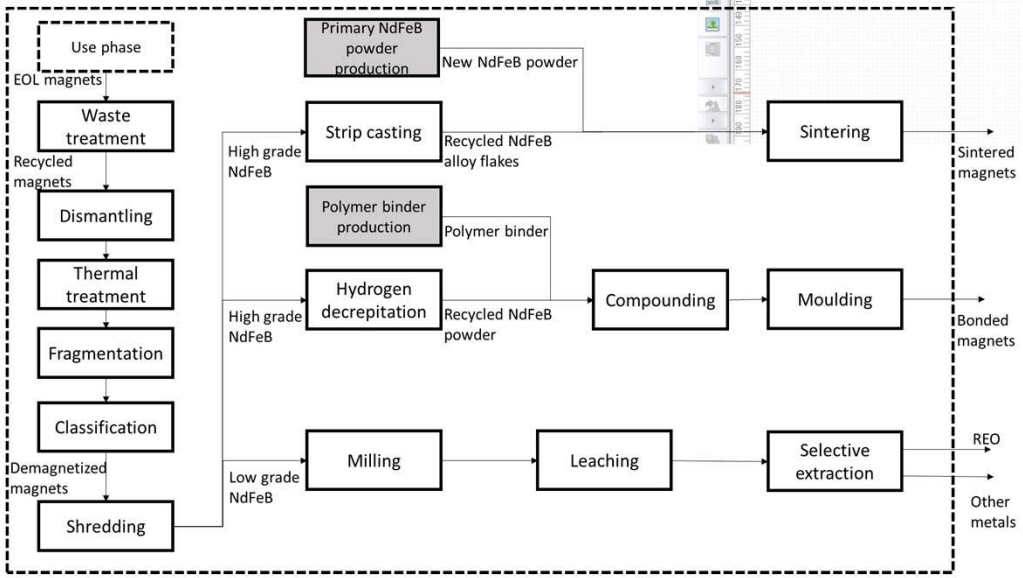
LCA - Process integration and value chain analysis

- Connecting different unit operations: whole value chain approach
- Mass and energy balance
- Process efficiency analysis
- Process cost/economic analysis
- Environmental analysis (support to LCA)







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Assessing impact on critical material supply dependency

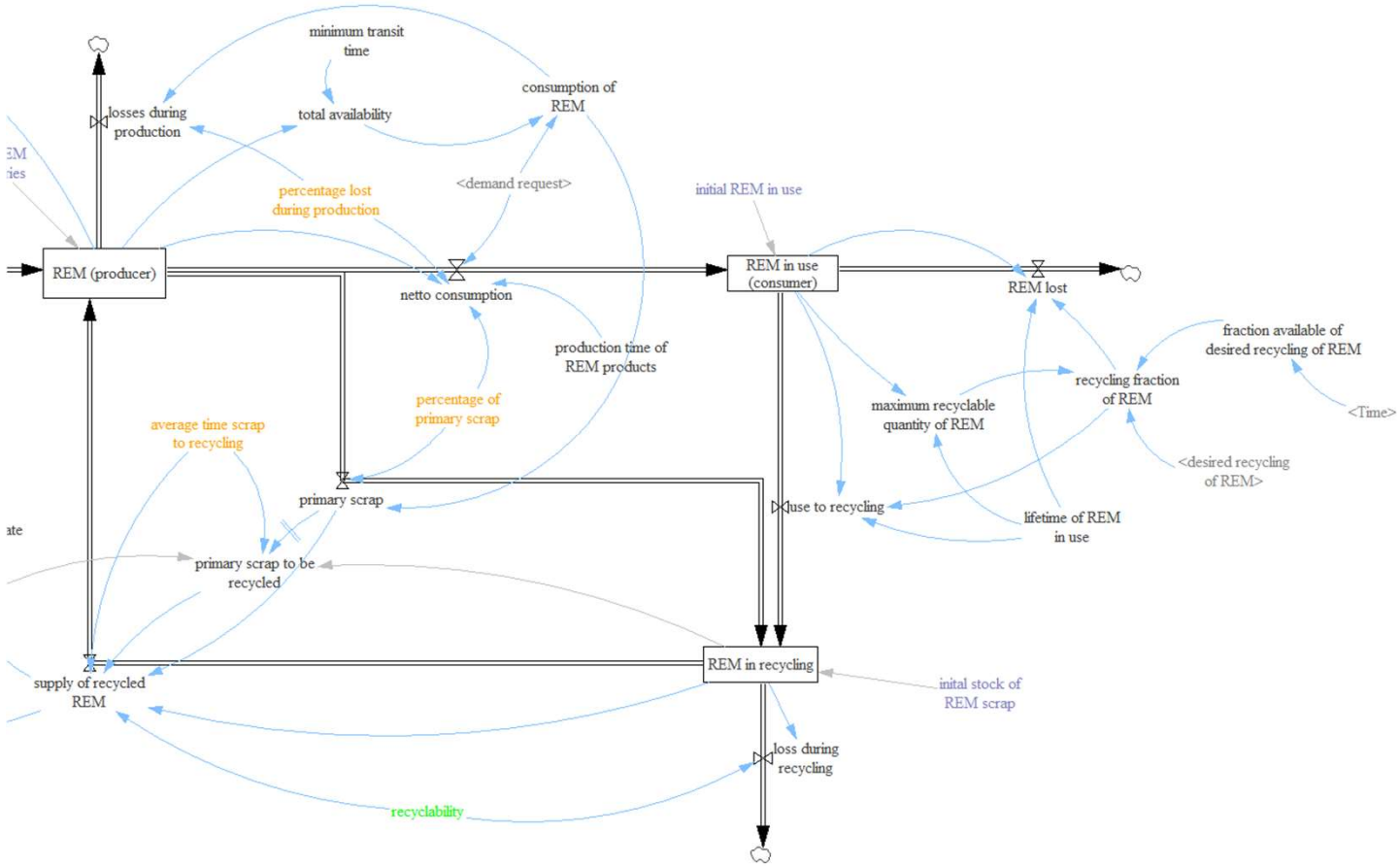
Sourcing: SUEZ / BRGM

Thermal treatment: CRM Group

Fragmentation / Classification: BRGM

Recovery: BRGM, CEA, Kolektor

Simulation: Leiden Univ. / TU Delft



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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=6gfoyf6C_4I

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RECYCLING
TURNING WASTE INTO VALUABLE RESOURCES

Re-Thinking Recycling: New Processes, New Business Models, Attracting Talents

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Thank you for your attention

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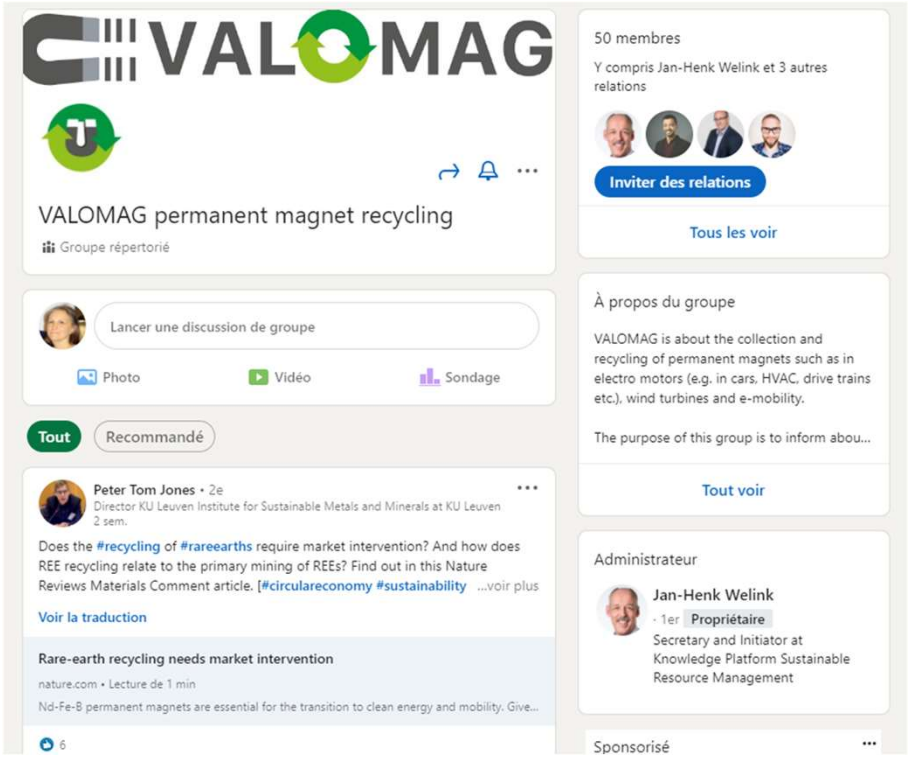
To follow VALOMAG project

- Project Website

https://valomag.tudelft.nl/

- LinkedIn Group



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

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