cea liten

New challenges for high performance permanent magnets

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OUTLINE

1. **Permanent magnets in emerging wind energy and automotive markets**

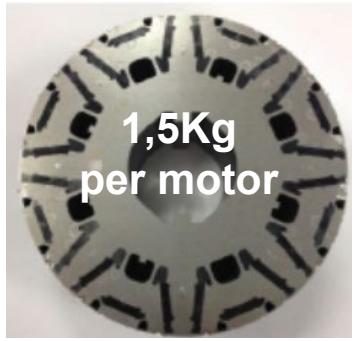
2. **Key technologies developed at CEA-Liten**

3. **Implementation of Circular Economy: the Magnolia Project**

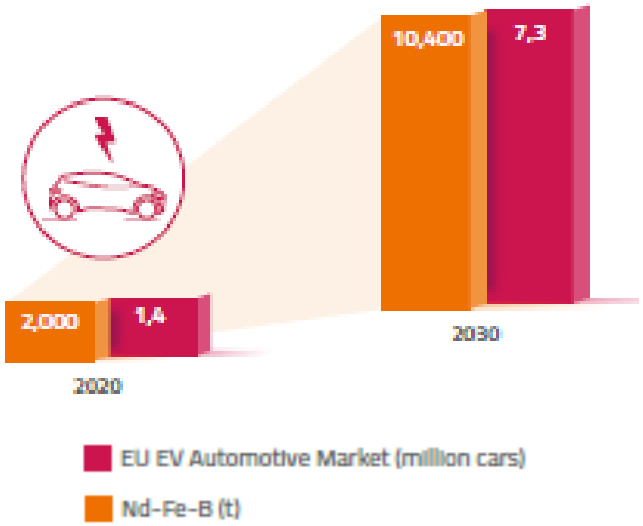
Permanent magnets in emerging wind energy and automotive markets:

1 - STRONG DEMAND

Automotive

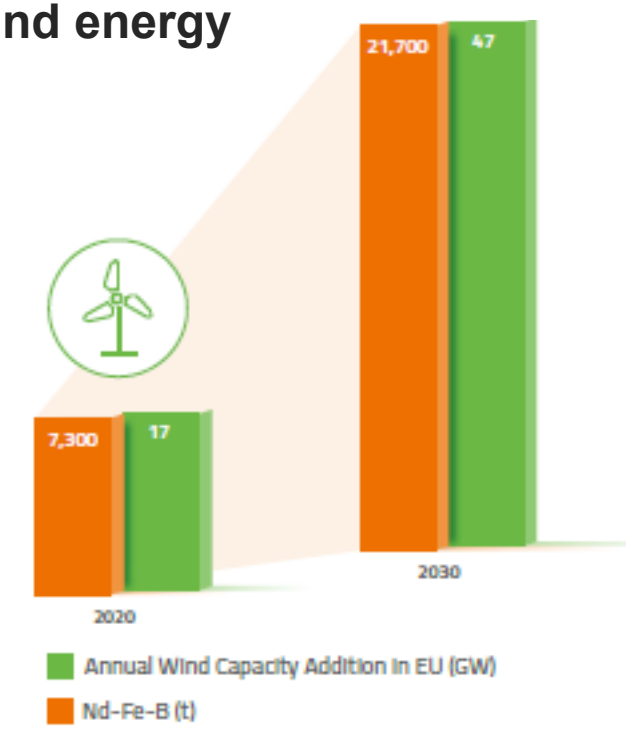


- Efficiency
- Compactness



Wind energy

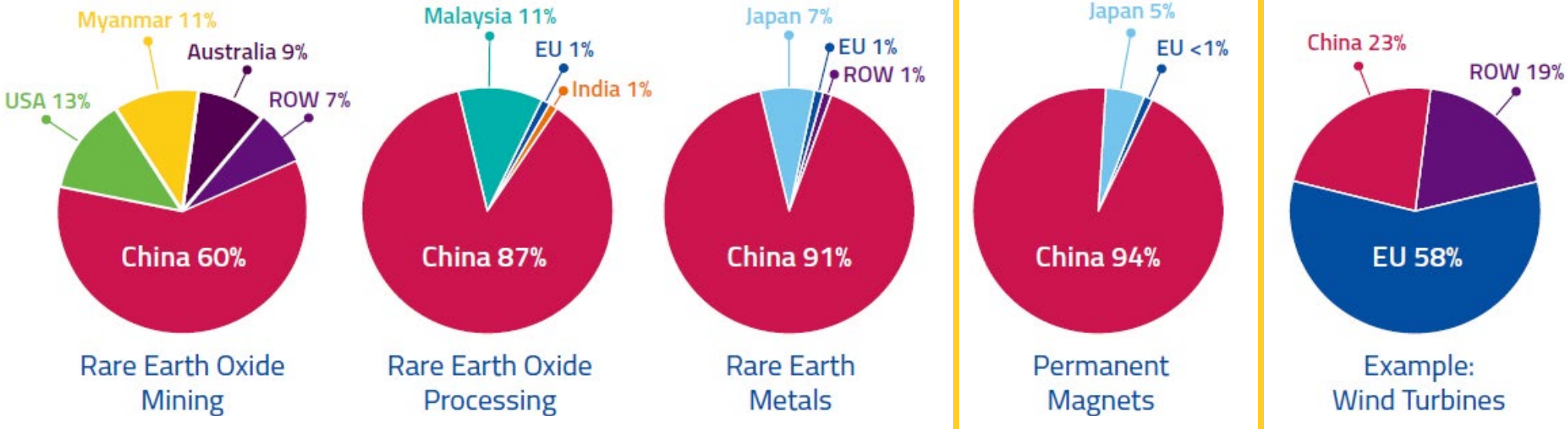
- Reliability
- Compactness



Increase in the EU demand x5 for automotive and x3 for wind turbines by 2030

Permanent magnets in emerging wind energy and automotive markets:

2 – EU DEPENDANCE

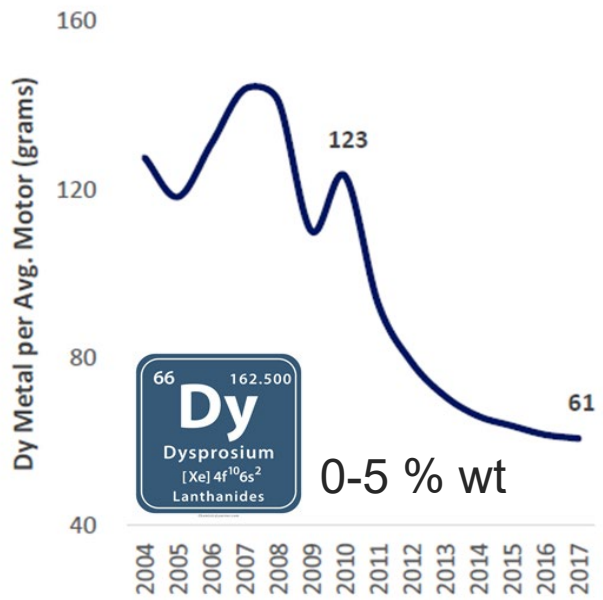


From rare earths mining to wind turbine manufacturing: estimated market shares in 2019.
Sources: Team analysis and Roskill 2018; Adamas Intelligence 2019; Peteves 2017; Carrara et al. 2020; IEA 2021; USGS 2021.

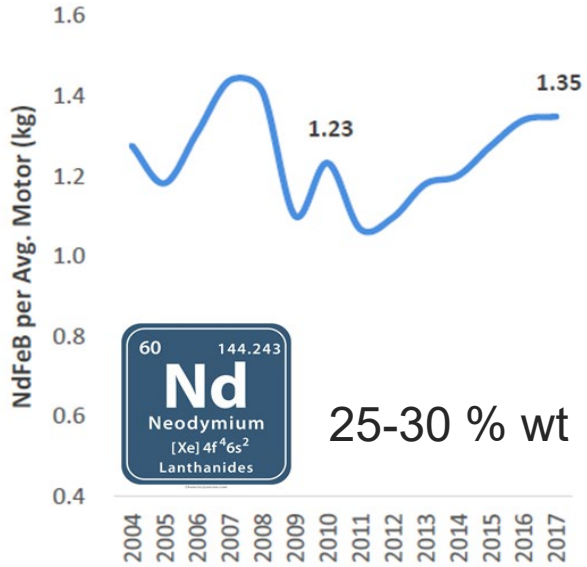
25-30 % Nd, Pr
0-5 % Dy,Tb
PM route

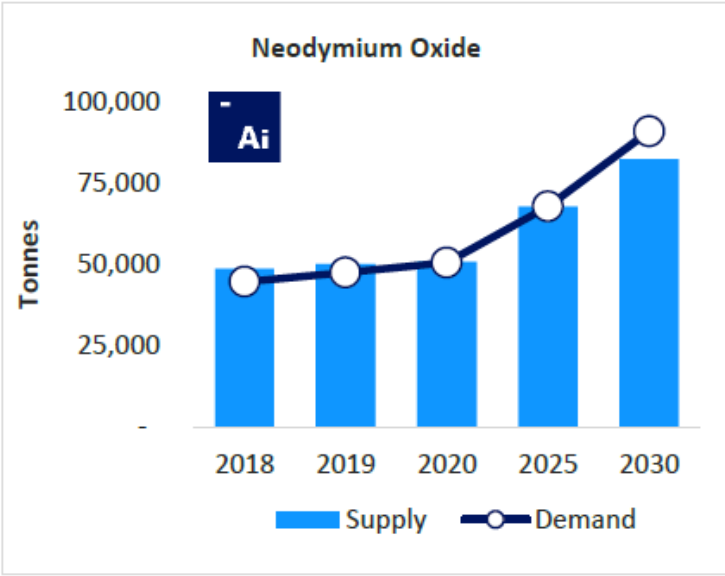
Permanent magnets in emerging wind energy and automotive markets:

3 – SUPPLY RISK



More efficient use of HREE (Dy, Tb) implemented in magnet industry during the last decade





Source: Adamas Intelligence

Strong rise in the LREE (Nd, Pr) demand that may excess the production capabilities by 2030

How to maintain high performances with less raw materials ?

How to maintain high performances with less raw materials ?

1. REDUCTION & SUBSTITUTION

- Heavy rare earth reduction
- Light rare earth substitution in current materials
- Lean rare earth materials (NEW MAGNETS)

2. 3D DESIGN

- Netshape process (PIM, Additive manufacturing)
- Ecodesign (in collaboration with IFPEN)

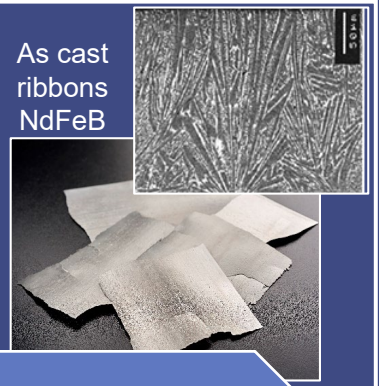
3. RECYCLING

Recovery of critical materials from EOL magnets and magnet remanufacturing by short loops with LCA

Powder Metallurgy process overview

Strip casting

As cast ribbons NdFeB



Alloy synthesis

Milling

Embrittled ribbons

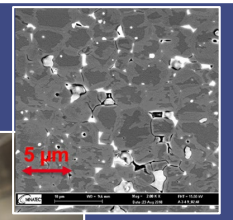
Micron sized powder

Hydrogen Decrepitating

Jet-milling

Sintering

dense magnets



Pressing + Sintering

1. Reduction of critical materials

UPGRADE's goal:
Development of a strip-cast process with improved casting conditions and alloy composition for a Dy-reduction of up to 2.5 wt.% in a fine-grained magnet

- Horizon2020 project
- Timeline: 01/2019 – 12/2021
- Budget: 1.9 M€

Pilot scale strip casting
15 Kg per batch

Implementable at industrial scale

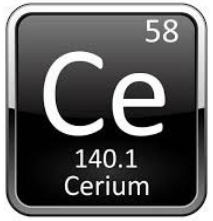
no need for additional equipment costs

Industrial strip casting
600 Kg per batch

KEY RESULT

Reduction of 2.5 wt.% of Dy demonstrated

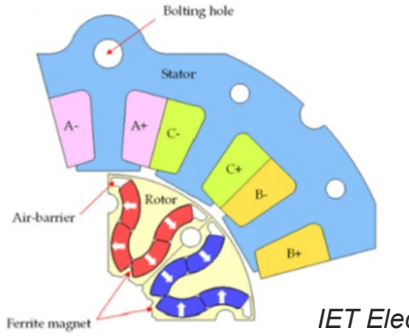
1. Substitution of critical materials



- Abundancy: more than 50% part of the rare earth in some deposit
- Large amount of unused Ce
- Price ratio favorable for Ce (5$/Kg) / Nd (53$/Kg) (2018)
- Lower magnetic properties

Level of substitution 	Reference **0%** Ce	Results **20%** Ce	Target **30%** Ce
Merit Factor BH_{max} [MGOe] + H_{cJ}[kOe]	61.7	54.3	51
Performance penalty		-12%	-17,5%
Material cost gain		+17.5%	+26,5%

➔ Full performances restored by machine redesign with non-standard magnet shapes

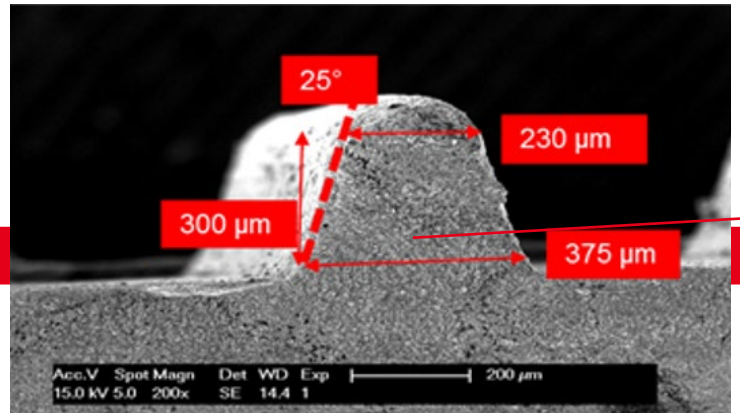


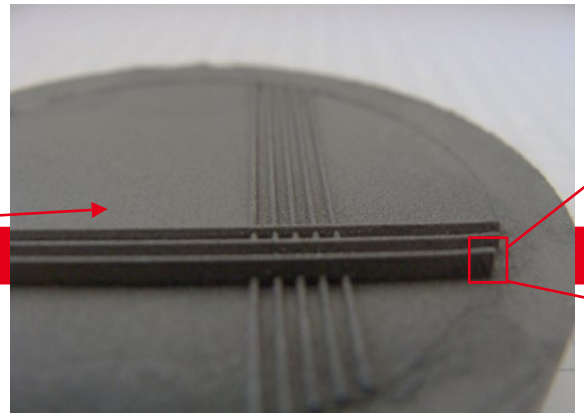
IET Electr. Syst. Transp., 2017

2. 3D Design

NdFeb Ribbons	Powder (NdFeB) millig	Powder (NdFeB) coating	Feedstock manufacturing	Injection	Chemical debinding	Thermal debinding	Sintering	Characterization

PIM PROCESS



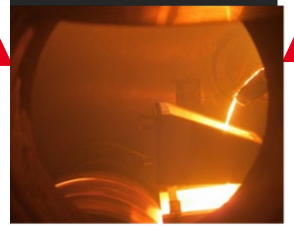


Geometrical details for cooling, assembly,…

Up to 30 % material saving (cutting, grinding)

3. Recycling

Raw metals → Strip casting → H2 crushing → Jet milling → Sintering



Collect Dismantling Recovery

Scrap magnets

Melting route

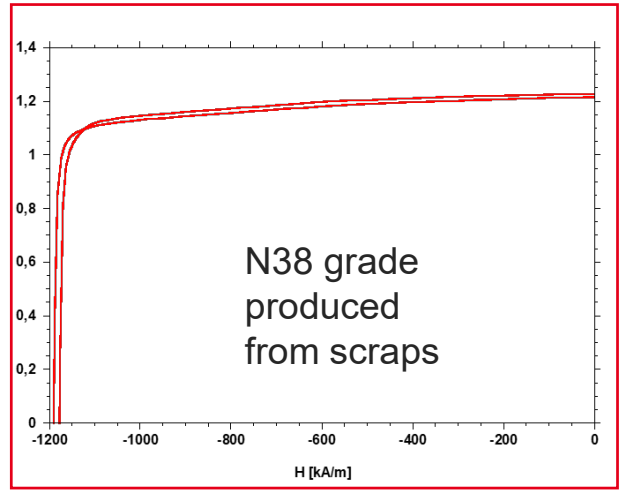
Powder route

Rare Earth extraction

VALOMAG

CRM GROUP — SUEZ — brgm — Universiteit Leiden

cea liten — KOLEKTOR — TU Delft



- **Commercial grade properties achievable**
- **Chemical heterogeneity of collected magnets addressed**
- **Magnet factory equipment**

Implementation of Circular Economy: the Magnolia Project

Objectives

1. Organize an industrial value chain in France for manufacturing rare earth permanent magnets ($Nd_2Fe_{14}B$)
2. Secure raw materials sources in order to mitigate the Chinese monopoly
3. Implement the circular economy paradigm

5 partners, leaders in their own activity

Recovery	Technologies	Production	Use
PAPREC GROUP	Daimantel	cea	orano	Valeo

Support from end users

12.3 M€ Overall budget

Timeline

MAGNOLIA

2021 — Platform POUDR'INNOV 2.0
R&D Sintered $Nd_2Fe_{14}B$ magnets

2023 2024 — Pilot line R&D (4T)
Upscaling

2024 — Small scale factory (20 T)
Implementation on an industrial pilot line

2025 — Magnet Factory in France (500-2000T)
High competiveness

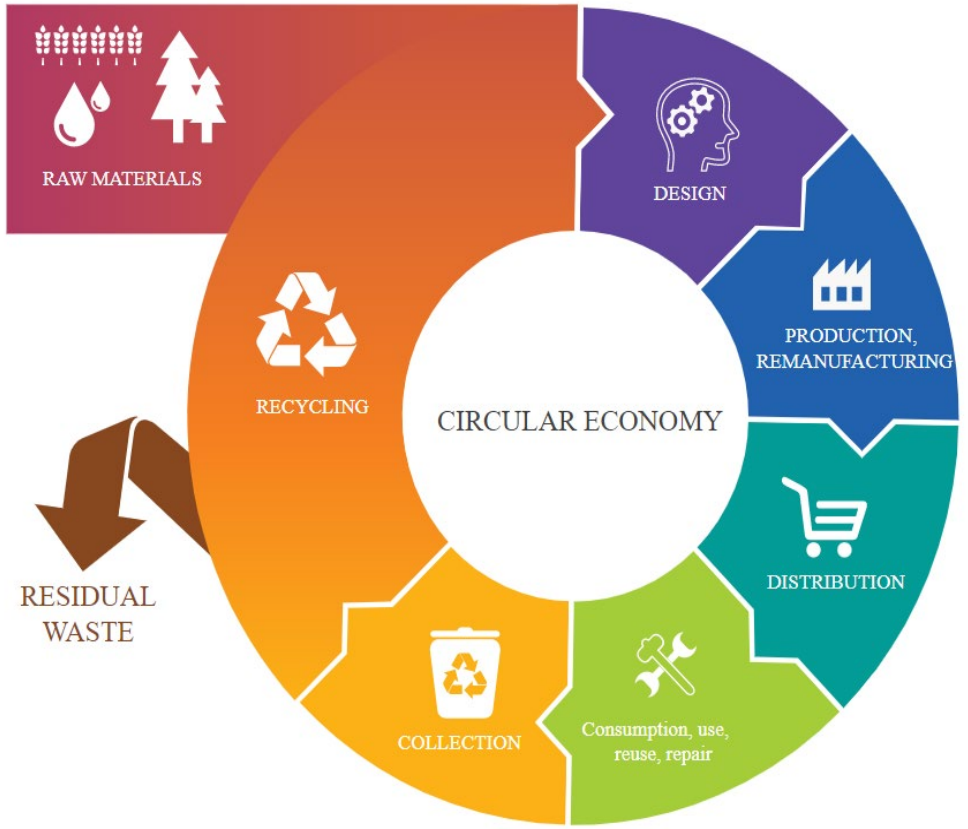
MINISTÈRE CHARGÉ DE L'INDUSTRIE
Liberté Égalité Fraternité
FRANCE RELANCE
bpifrance

Conclusion

1. **More circular economy in the magnets supply chain to face to the current challenges**

2. **Innovation activities of CEA-LITEN aim at producing high performance magnets with less critical (primary) raw materials**

3. **CEA-LITEN positioning enables advising, expertise and partnerships with industrial players**



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