MinFuture

Demonstration of the MinFuture framework

Learning outcomes from material specific workshops on

P, Co, Al, Aggregates, Nd and Pt

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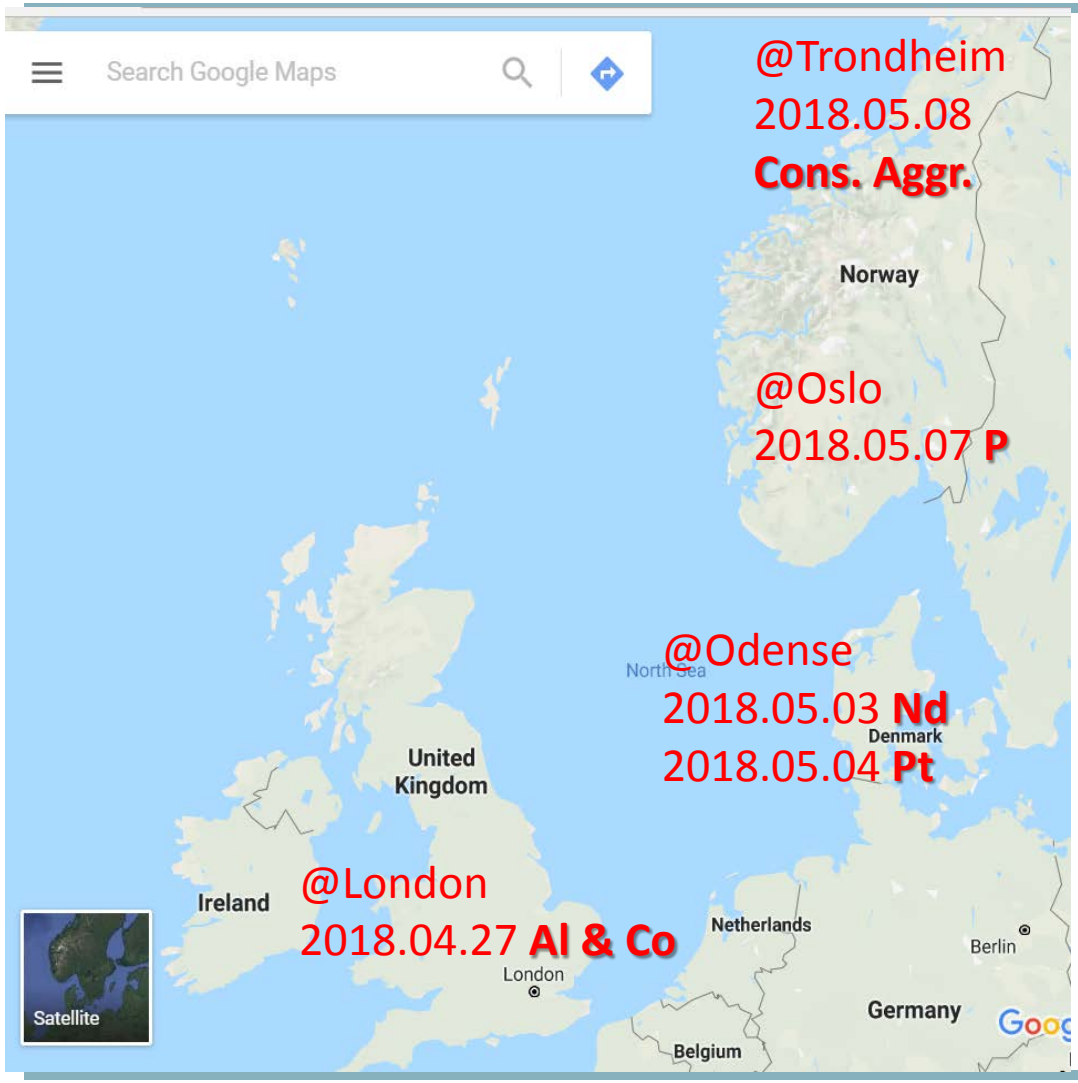
Material specific workshops



Workshop programme based on the MinFuture pyramid

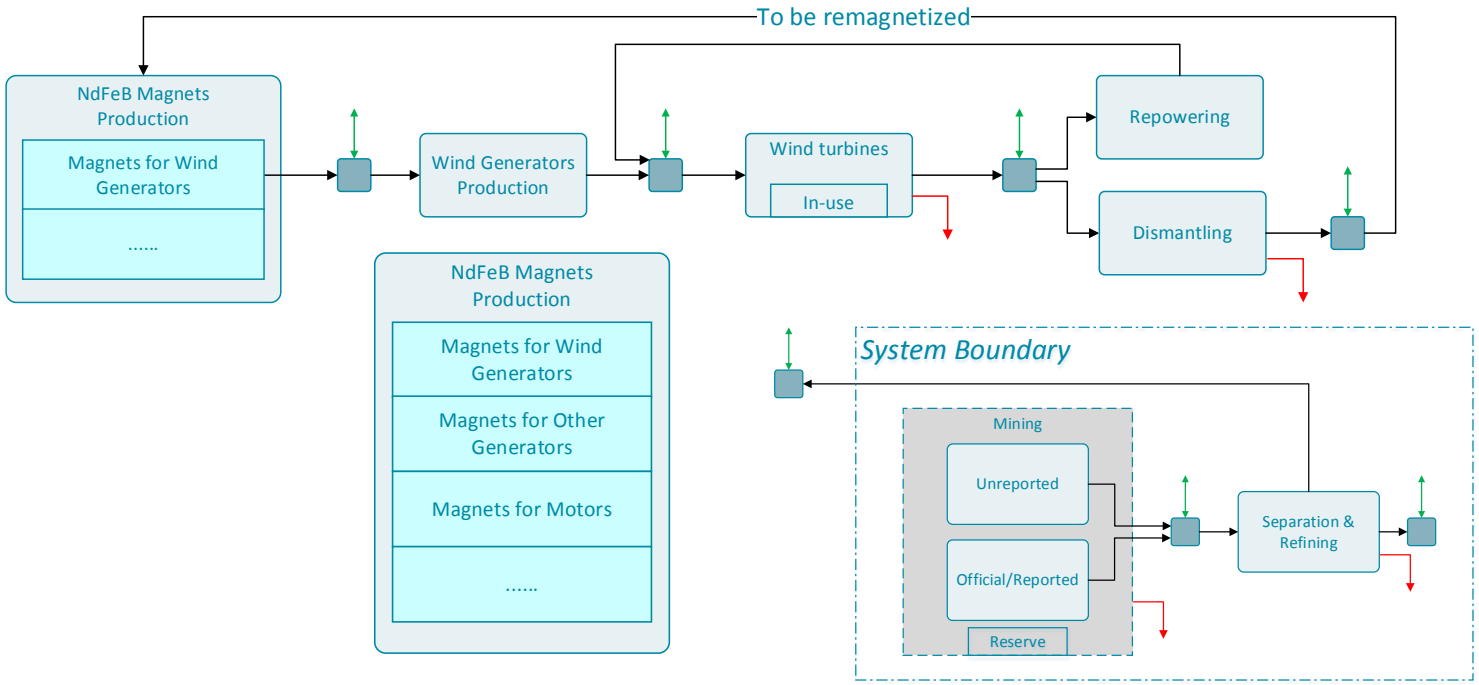
- Introduction/status
- Challenges/Issues
- System
- Data

- Introduction/status
- Trends/opportunities
- Vision and gaps
- Addressing the gaps

Common challenges from the workshops

1. System definition does not correspond to all challenges yet:

- Resolution of life cycle stages not always high (e.g., semi-products, stocks);
- EoL routes not clear (e.g., magnets repowering; Pt recycling via hydrometallurgy);
- Linkage of material cycles not included (e.g., co-products and shredded waste).



Common challenges from the workshops

2. Spatial resolution is usually missing:

- For critical metals (Nd, Pt, and Co), existing studies mostly on the global level

- P: A Norwegian model looking with spatial resolution is being developed.

- Al: Future models to look at regions within countries will be important.

- Construction Aggregates: Regions needs to be better understood in order to make better use of the materials

- Where can we go to find scrap in the future?

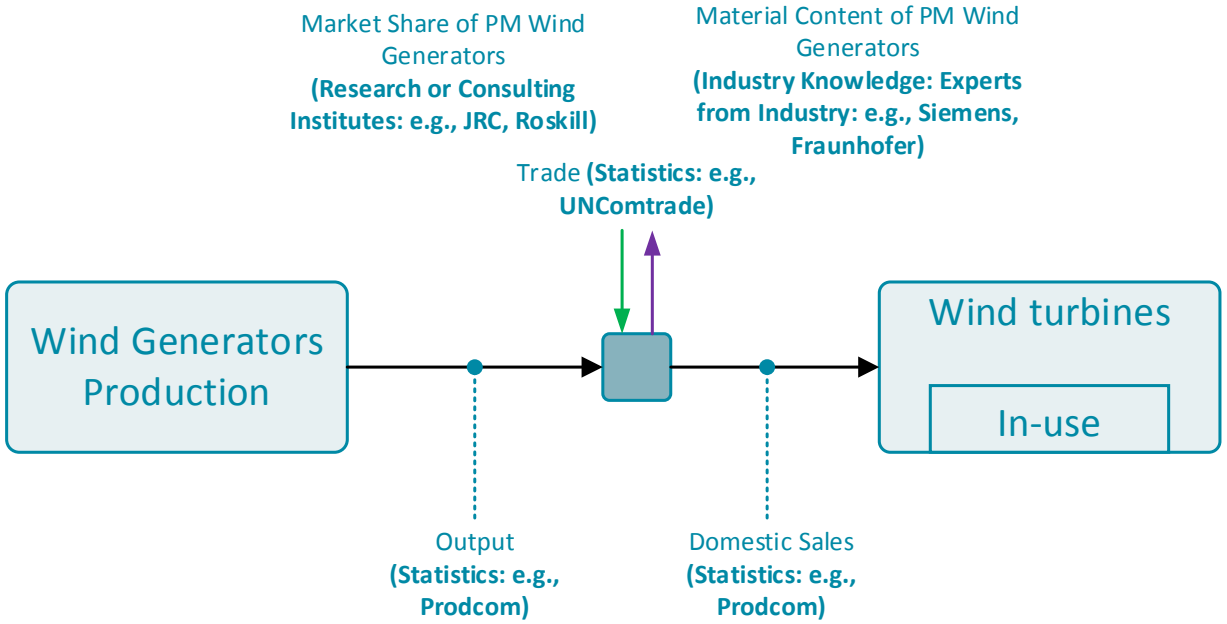
- Security of supply (criticality) at a regional level

→ Requires an understanding of international trade along the value chain (not trivial!)

Common challenges from the workshops

3. Data gaps and harmonization needs:

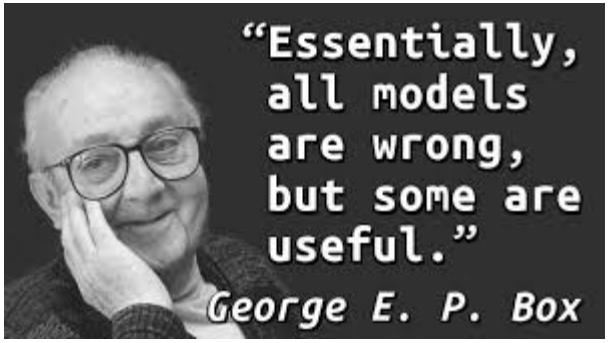
- Data gaps in output/shipment, market share, and material content per product;
- Inconsistent commodity code systems for shipment and trade data;
- Reported data vs real data (e.g., non-Chinese magnets production data).



Common challenges from Nd and Pt workshops

4. Better demand-supply forecasting models needed:

- Based mainly on indicator-based criticality assessment and LCA; dynamics and feedbacks were rarely included (→ requires understanding of stocks);
- Lifetime is key here but poorly understood/characterized;
- Low technology resolution (design, substitution, market share…);
- Largely on the global level and low country/region resolution;
- Supply forecasting is very difficult (if not impossible?)

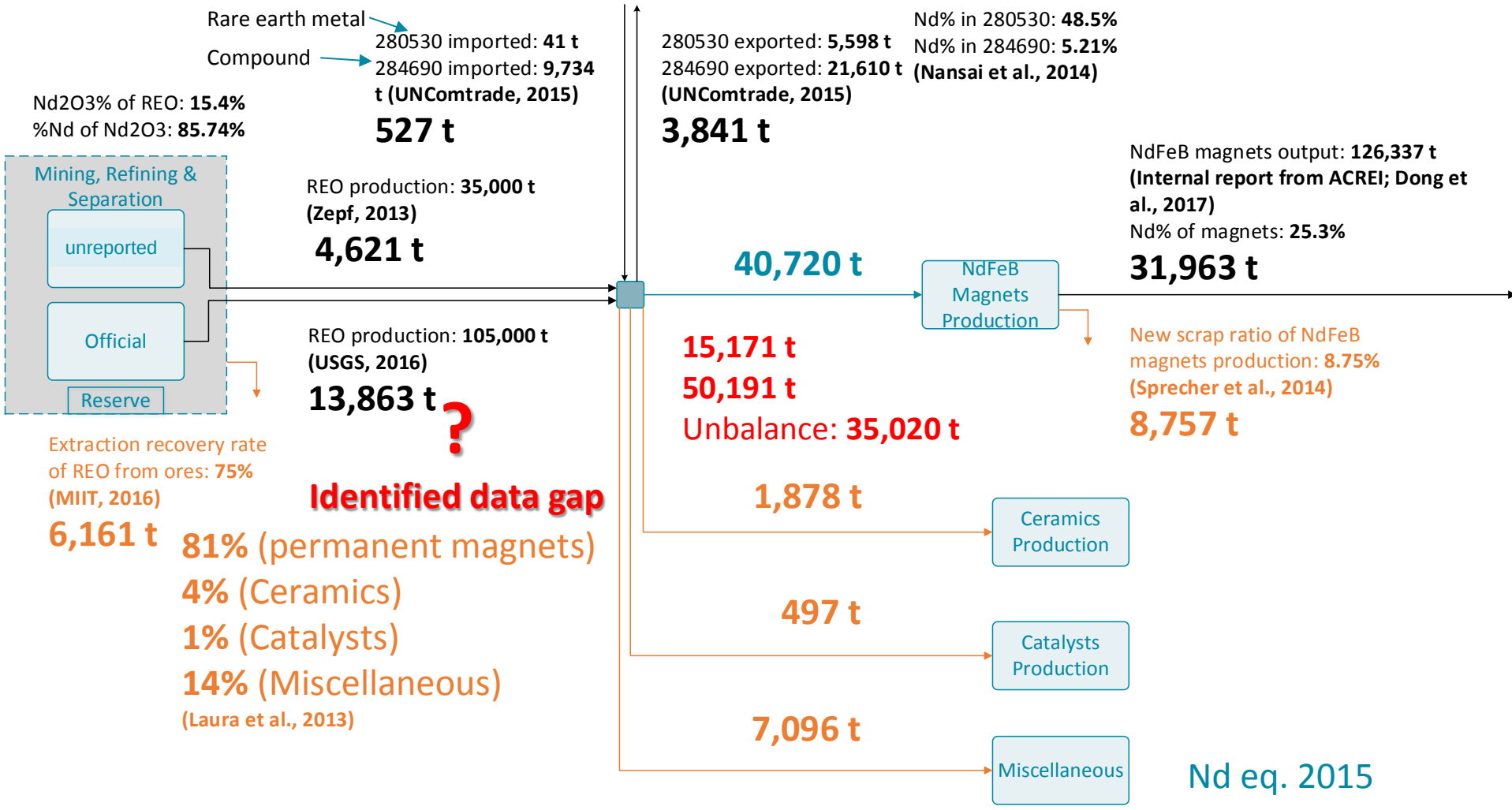


Common challenges from the workshops

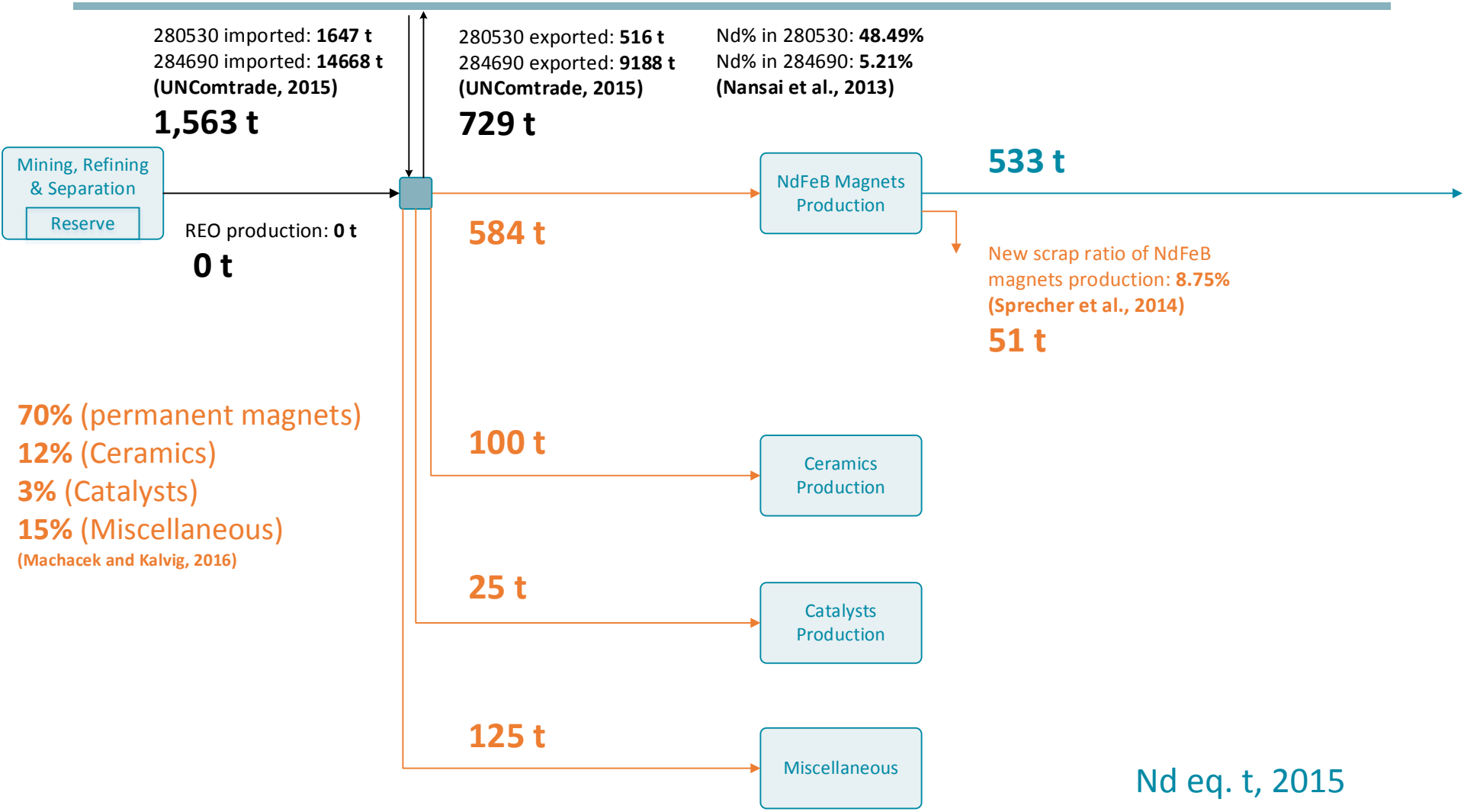
5. Untapped potentials to inform / link to other sustainability challenges (circular economy, climate target, SDGs…)

- Link to other layers (value, emission) needed but only seen in a few examples (e.g., Al cycle, recycling, energy, and emissions)
- To inform the yet-to-come end-of-life management challenges (currently expanding markets, incompatibility between multiple producers, changes in quality requirements, development pathways and window of opportunity…)
- Traceability of material quality and embodied impacts

Neodymium flows from primary products to permanent magnets production in China



Neodymium flows from primary products to permanent magnets production in EU28



Neodymium flows from permanent magnets to wind turbines in EU28

Nd content: **0.196 t/MW**
Weight of wind power generators: **39 t/MW**
Market share of NdFeB wind power generators: **15%**
Nd% of genrators: **0.076%**
(Habib et al., 2014; The Wind Power, 2017; JRC, 2016; UNComtrade, 2015)

Permanent magnets

850511 imported: **26,927 t**
(UNComtrade, 2015)
Nd% of magnets: **25.3%**
6,813 t

850511 exported: **3,022 t**
(UNComtrade, 2015)
Nd% of magnets: **25.3%**
765 t

Generating sets for wind power

850231 imported: **469,551 t**
(UNComtrade, 2015)
357 t

850231 exported: **241,497 t**
(UNComtrade, 2015)
184 t

533 t

Generators Production

300 t

Wind turbines
In-use

474 t

No information

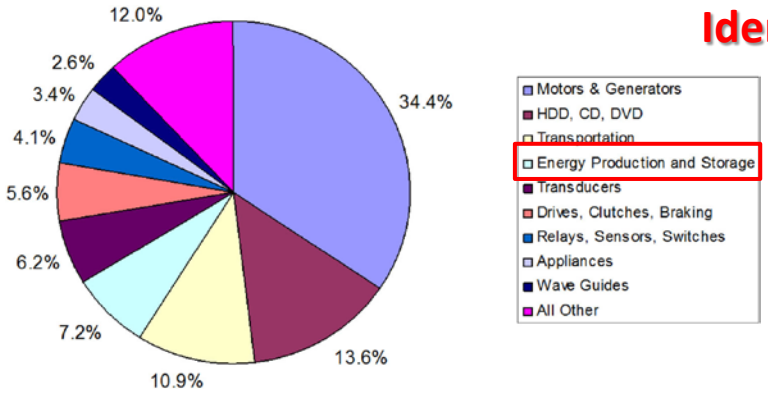
No information

Motors Production

No information

Other turbines
In-use

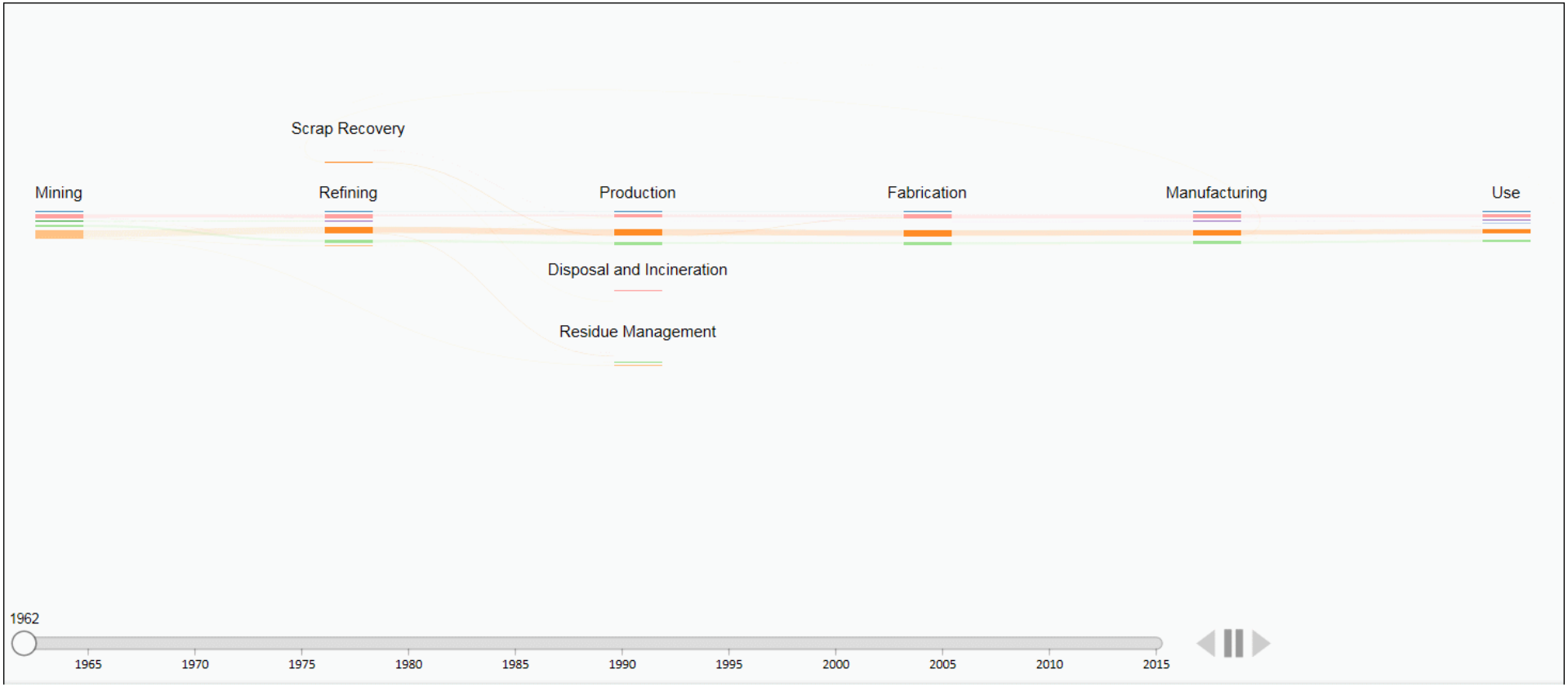
Identified data gap



% of NdFeB magnets enter into wind turbines: **7.2%**
(Roskill, 2012)

Nd eq. t, 2015

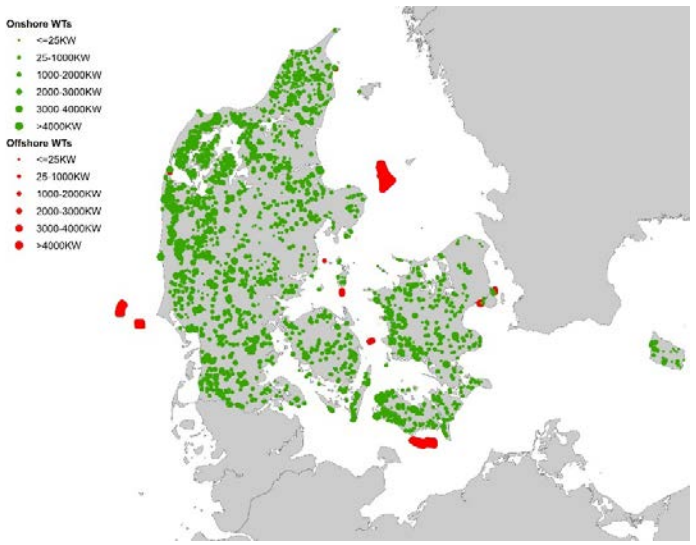
Monitoring the global physical Al economy

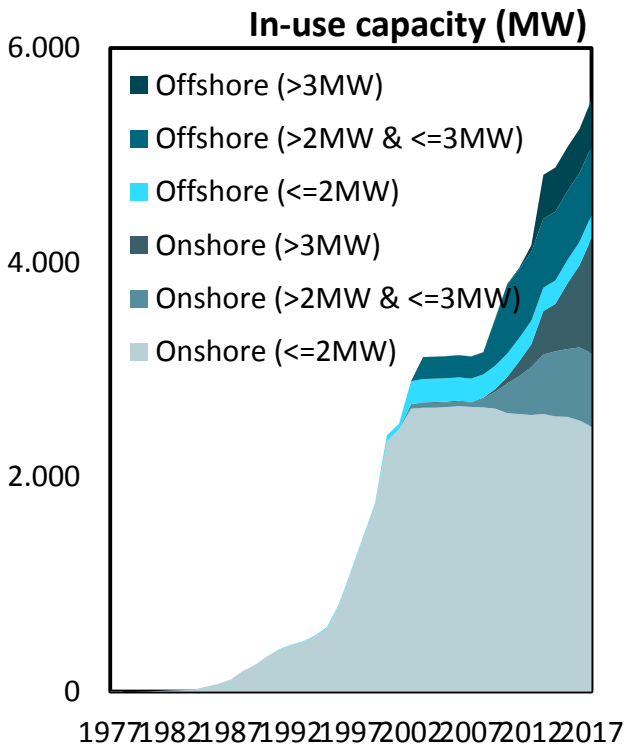


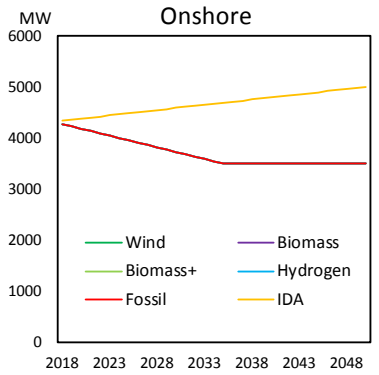
The temporal-spatial dynamics of global physical Al economy

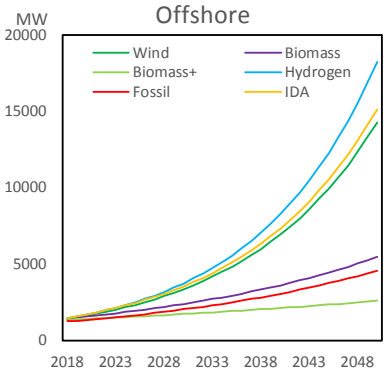
http://www.world-aluminium.org/statistics/massflow/

Stock-driven & bottom-up demand forecasting - Danish wind energy case







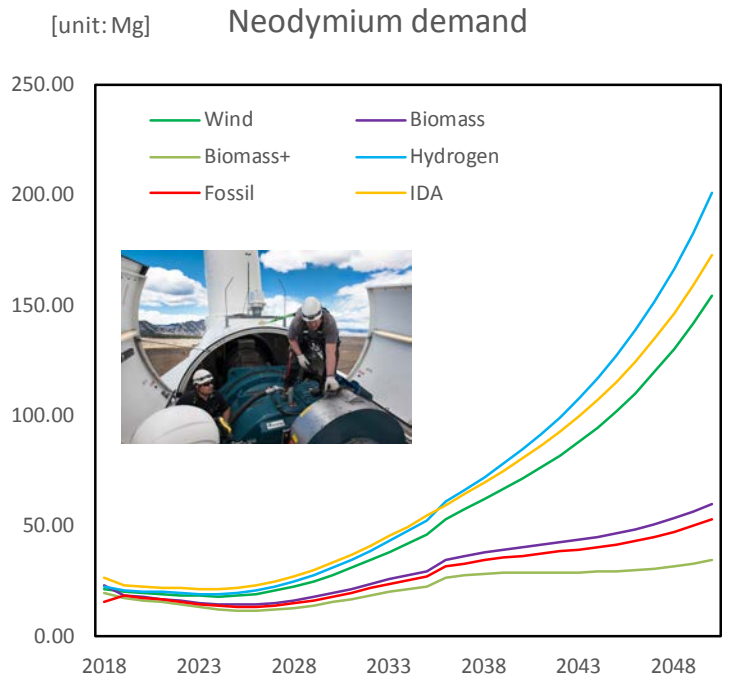


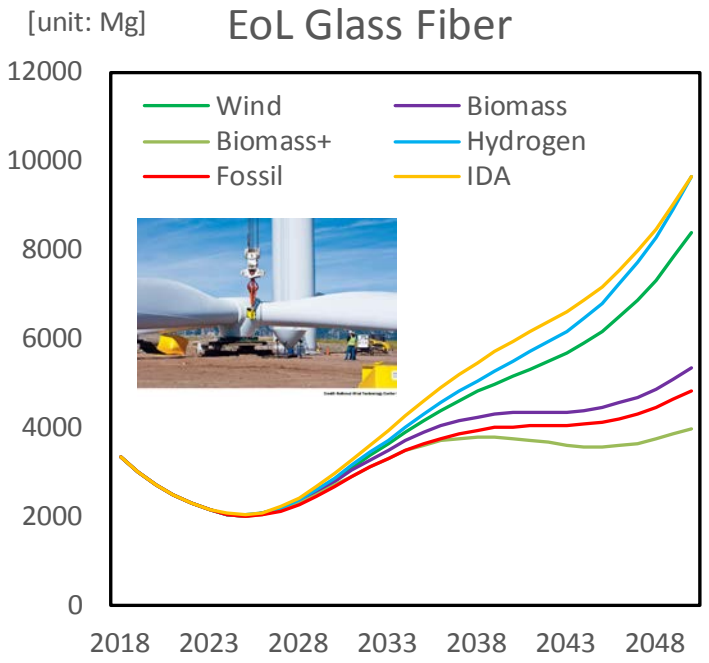
Current wind turbine distribution map and future wind energy scenarios

Material composition	Total mass	Rotor Nacelle Tower Elec & Ca.	Rotor diameter Hub height	Capacity categories	Direct-drive Gearbox	Offshore newly-installed capacity	Offshore in-use capacity

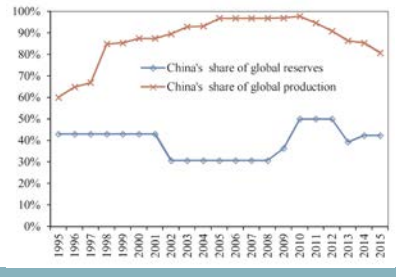
A stock-driven and bottom-up demand forecasting

Stock-driven & bottom-up demand forecasting - Danish wind energy case (cont.)





Do we have enough materials and secure supply?



Can we handle the (yet to come) waste issues?