Accelerating the Electrification in the Process Industry

Reducing the Demand for Critical Raw Materials

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TU Delft

A sustainable energy system

Battery storage

Seasonal Storage >10 TWh

Heat storage

Mechanical storage

Storage in chemical bonds

Hydrogen

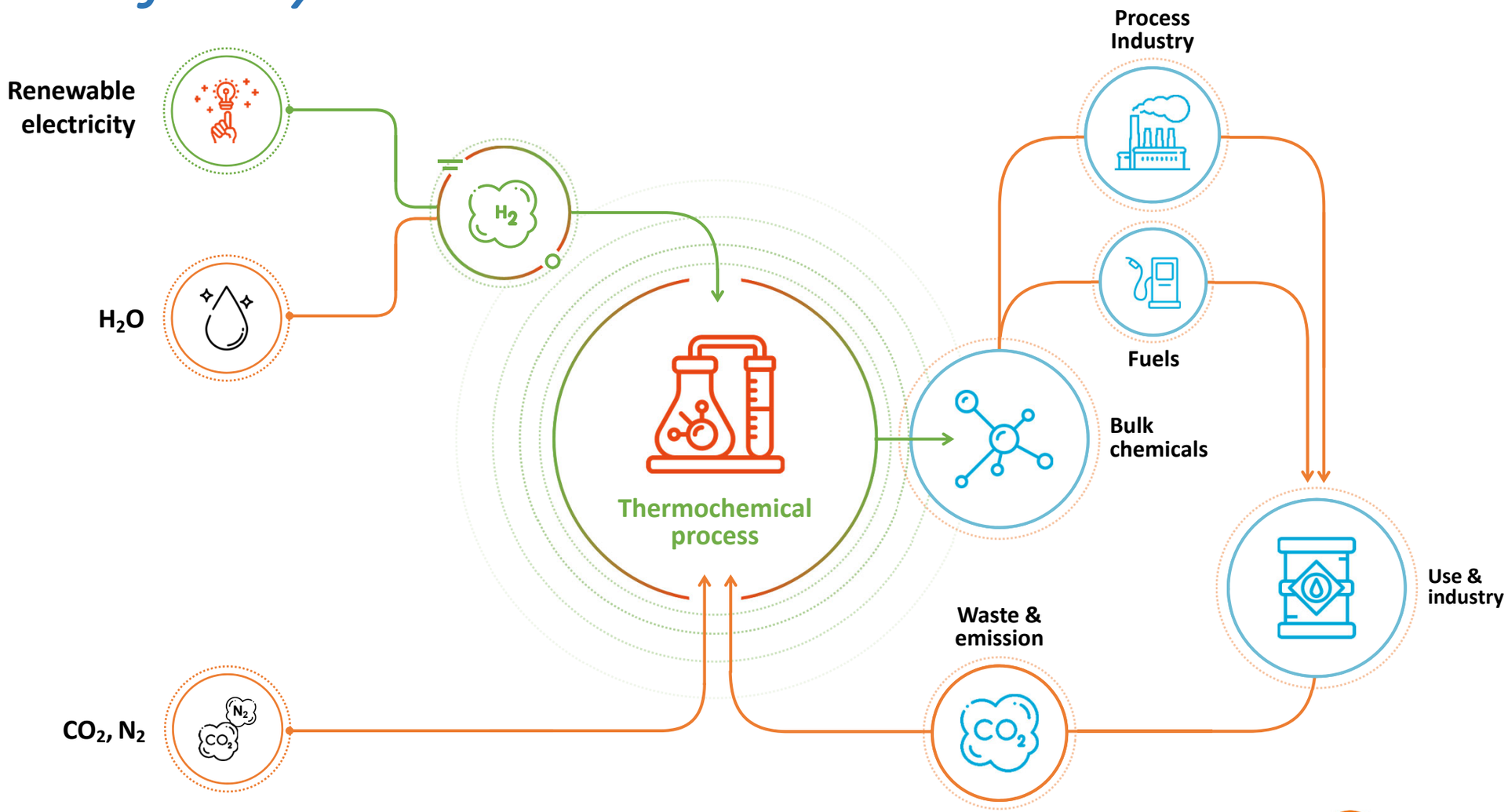
Fuel

Ammonia

Feedstock

Hydrocarbons

e-Refinery: Indirect route



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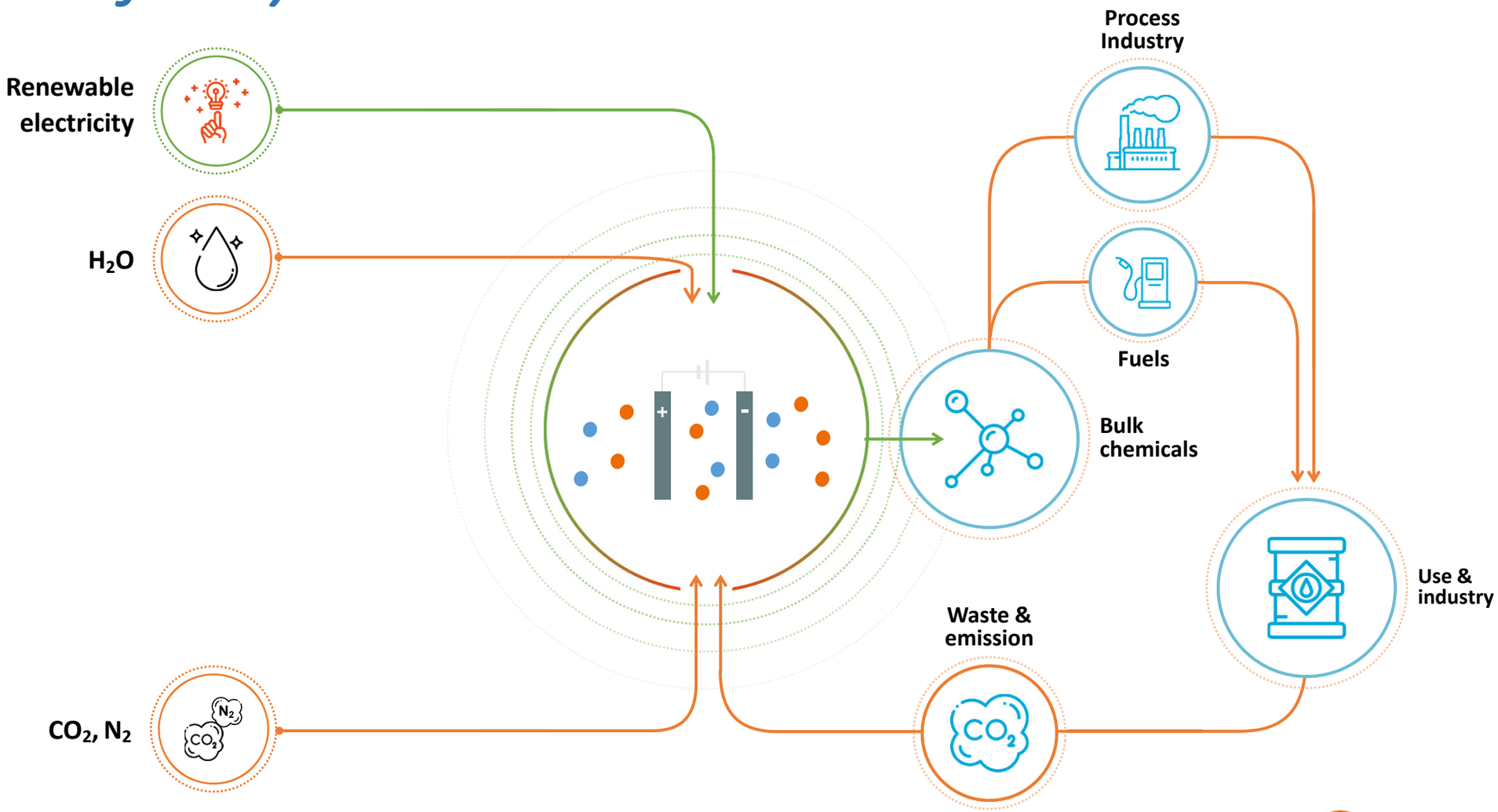
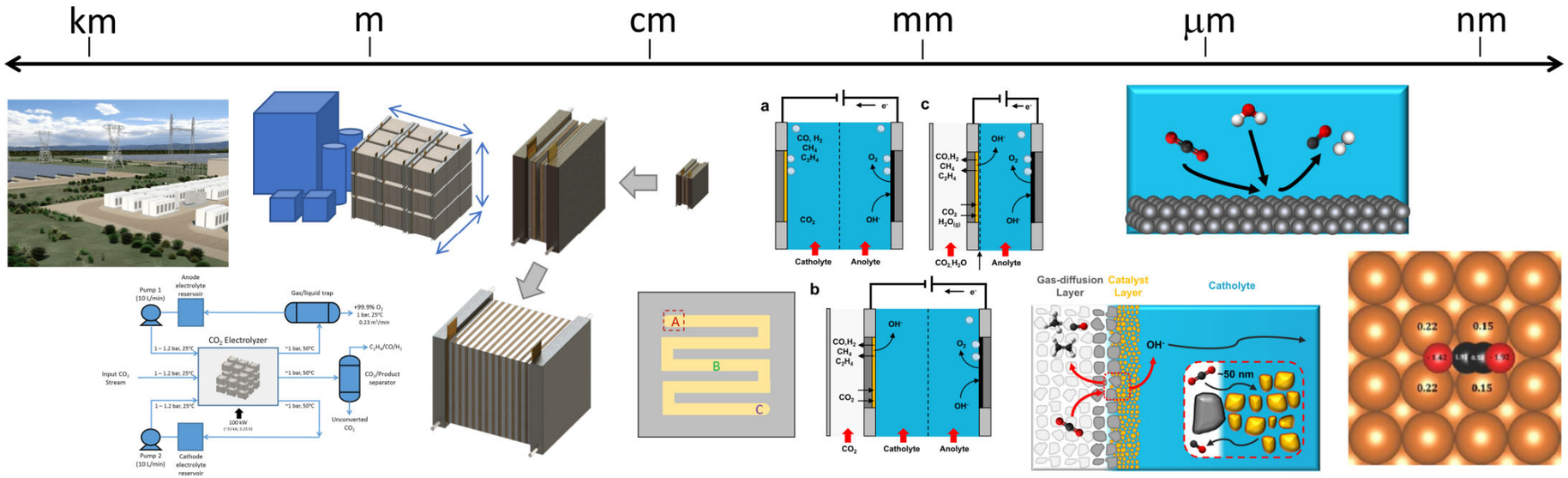
e-Refinery: Direct route



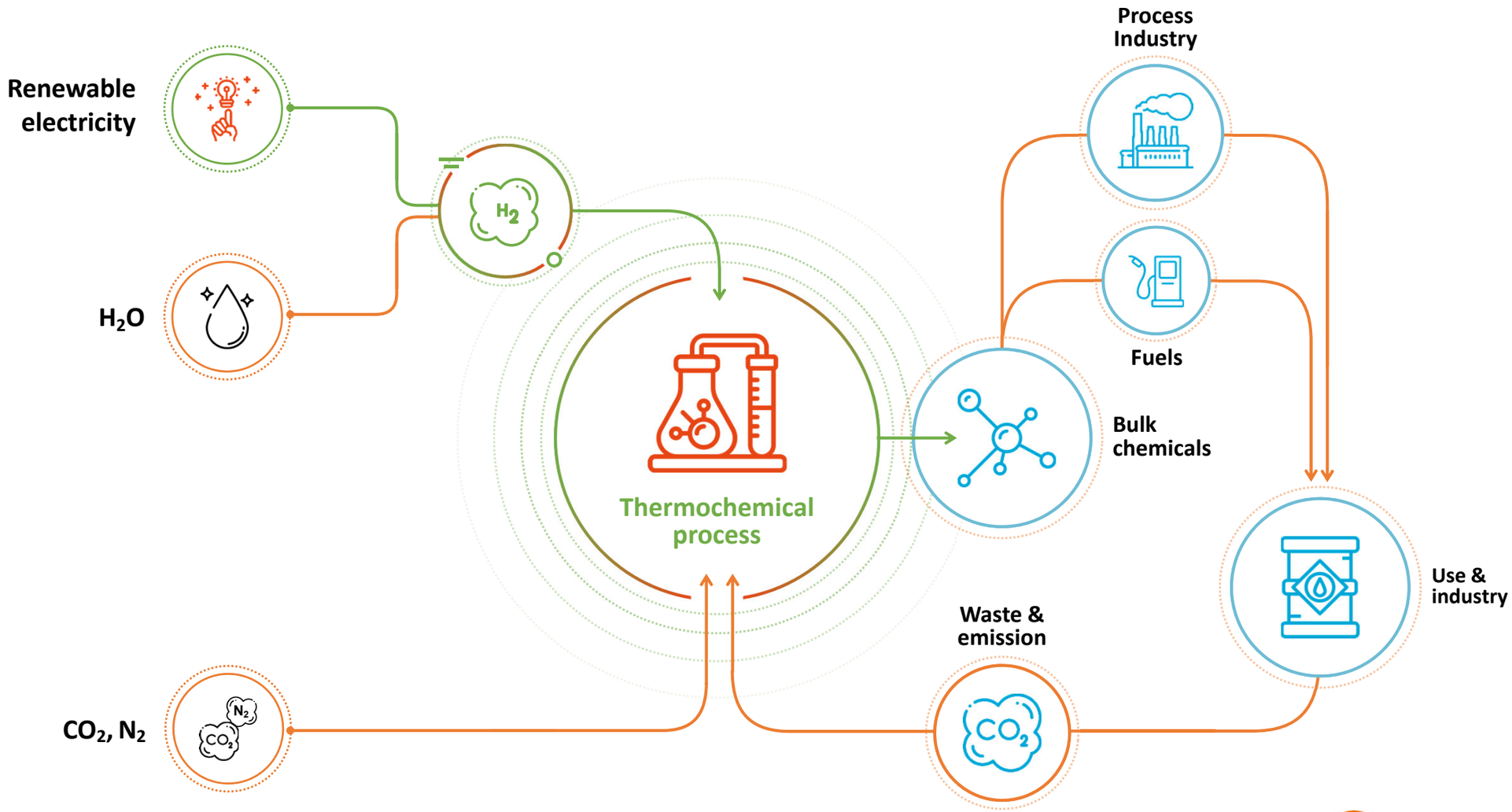
Electro-conversion: from atoms to factories



Most research up to now…

Large scale: high current density, considering materials availability, …

Indirect route



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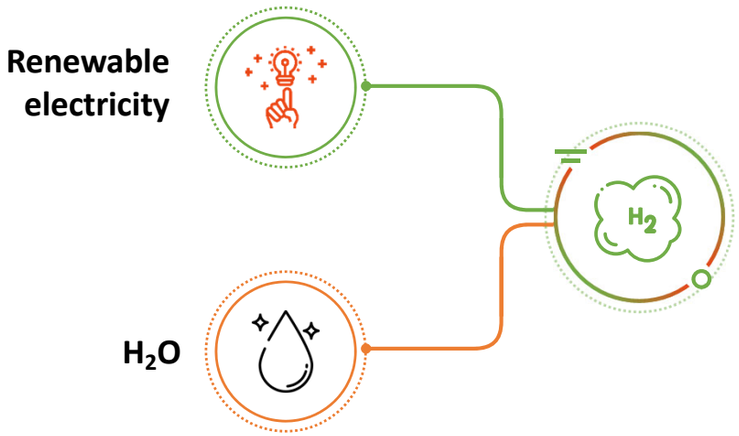
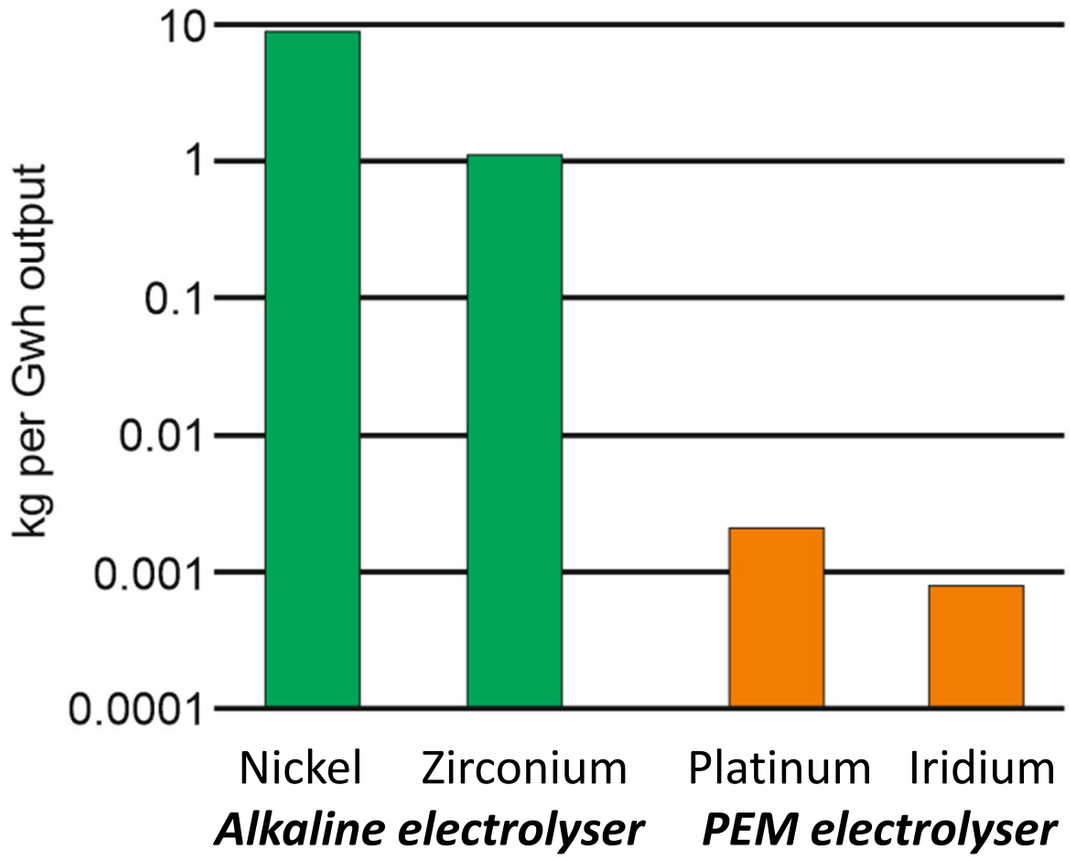
Indirect route





PEM = polymer electrolyte membrane

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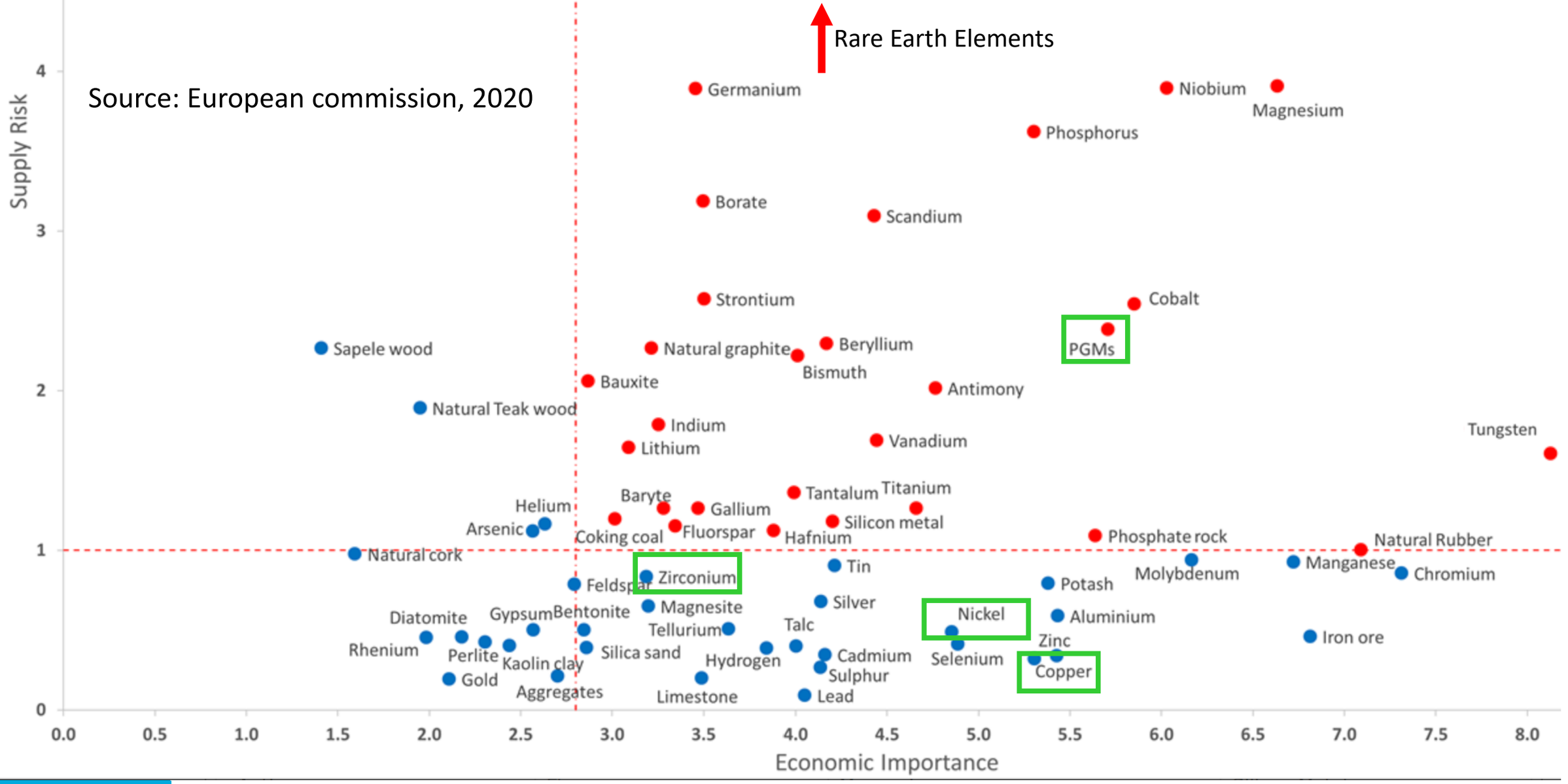
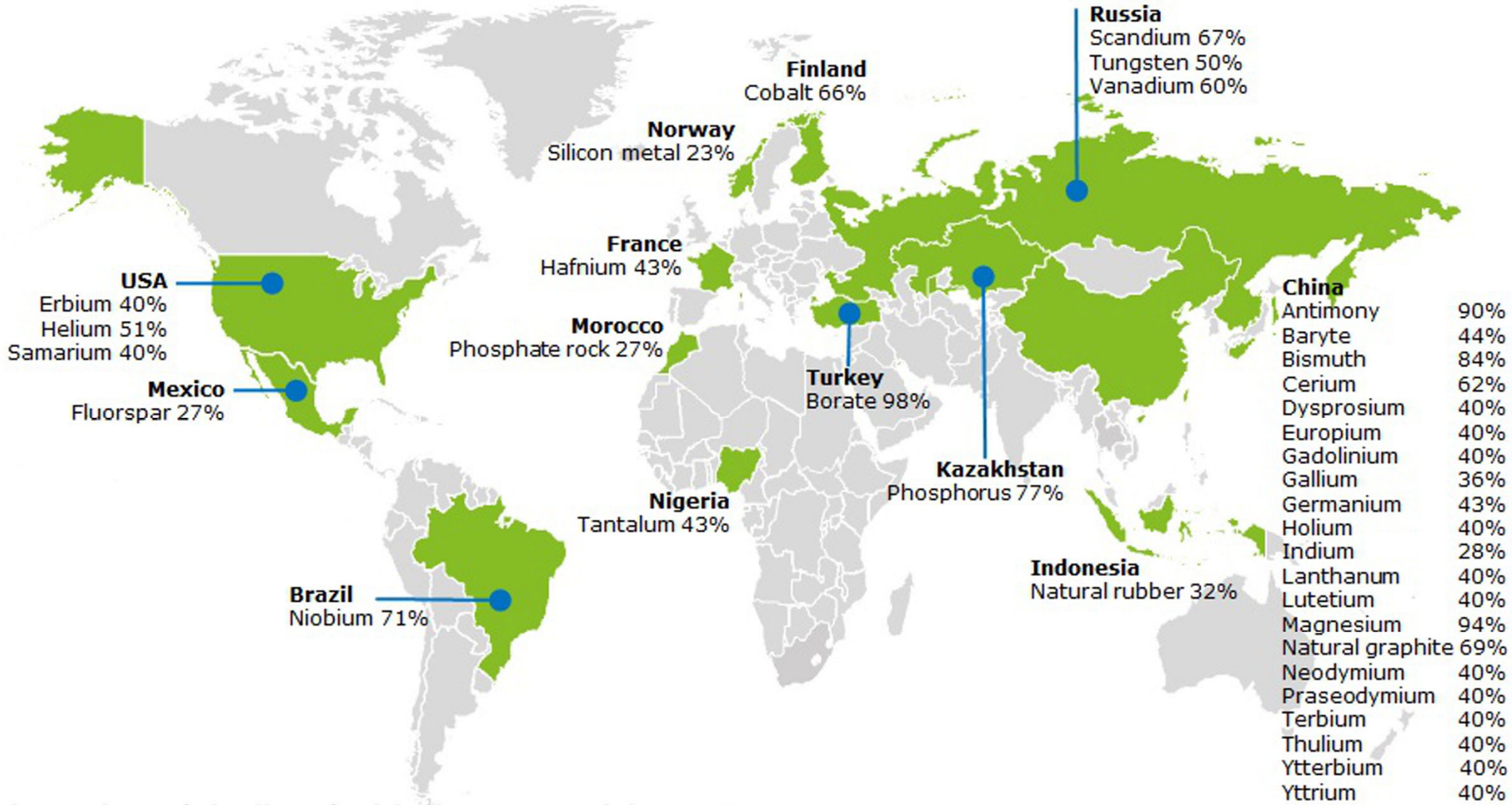
Critical raw materials

Source: European commission, 2020



Critical raw materials



Study on the review of the list of critical raw materials 2017

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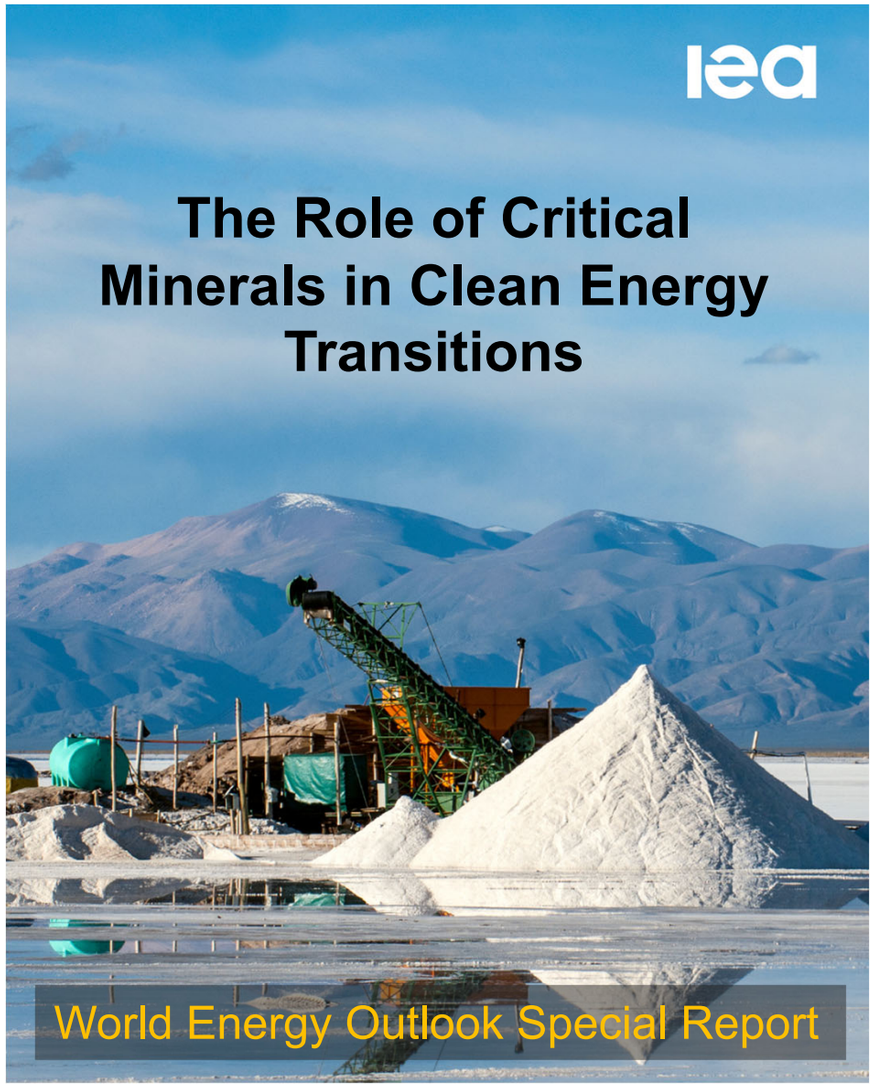
Energy Transition will Strongly Change Demands



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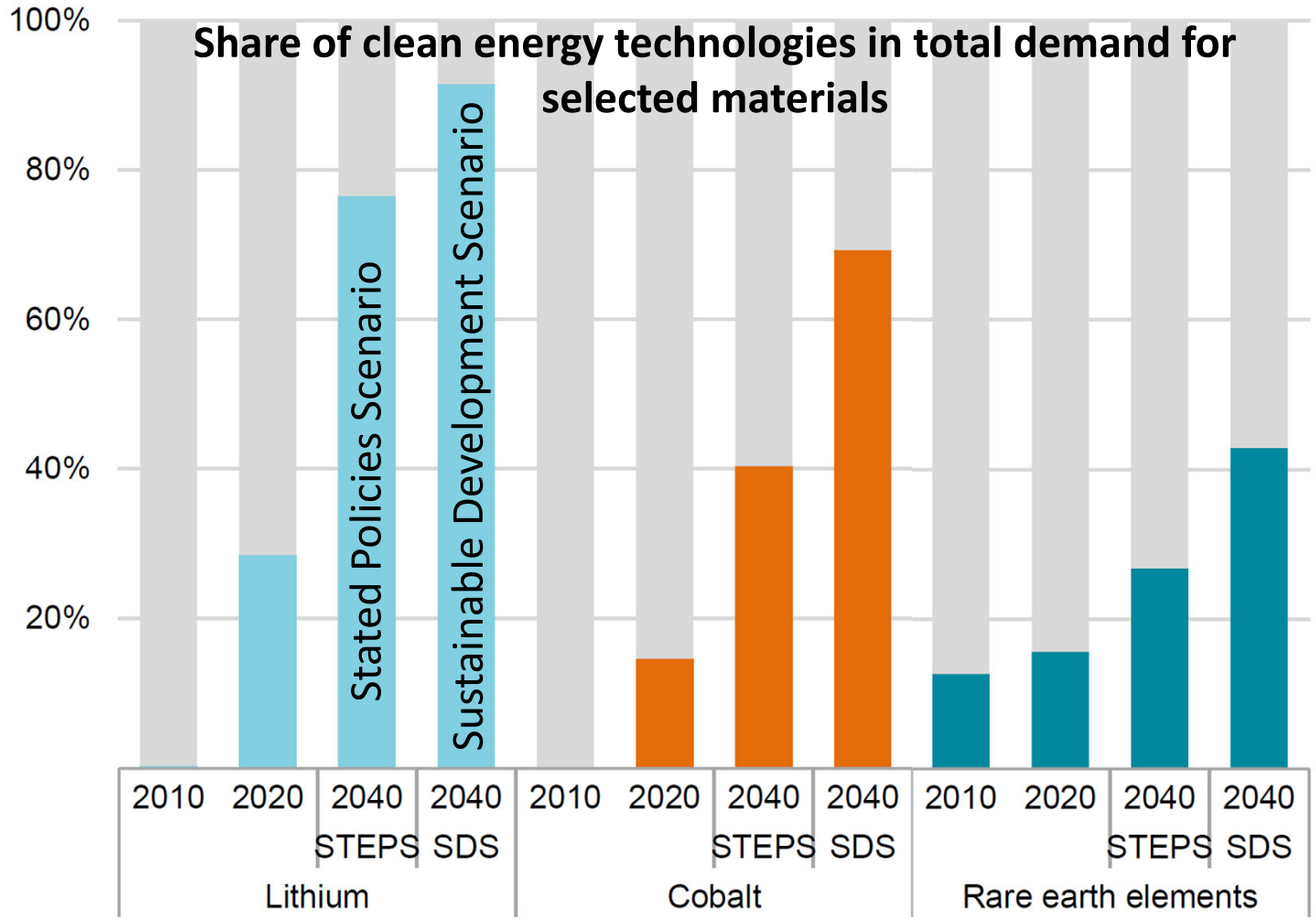
Critical materials: IEA



Source: The Role of Critical Minerals in Clean Energy Transitions, IEA 2021

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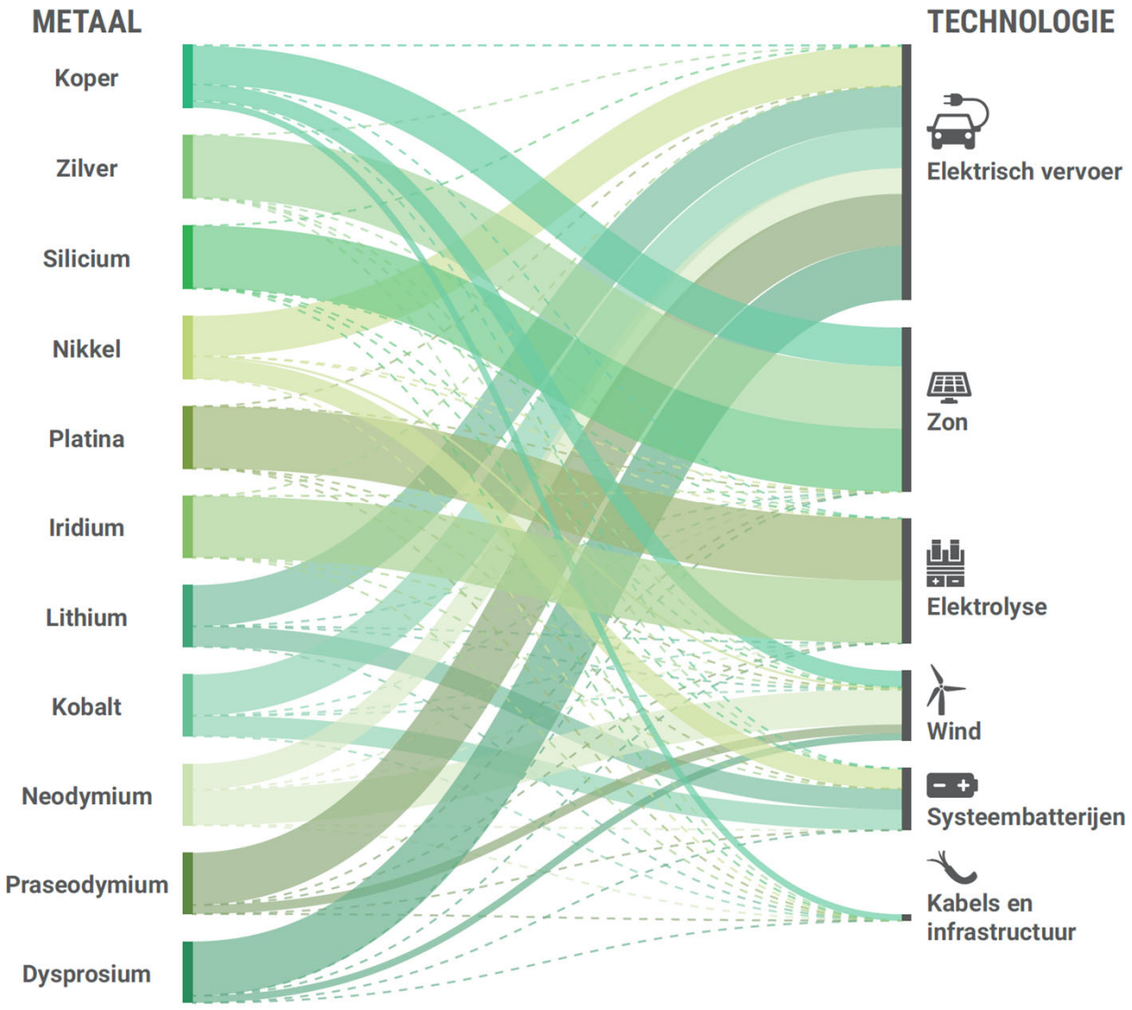
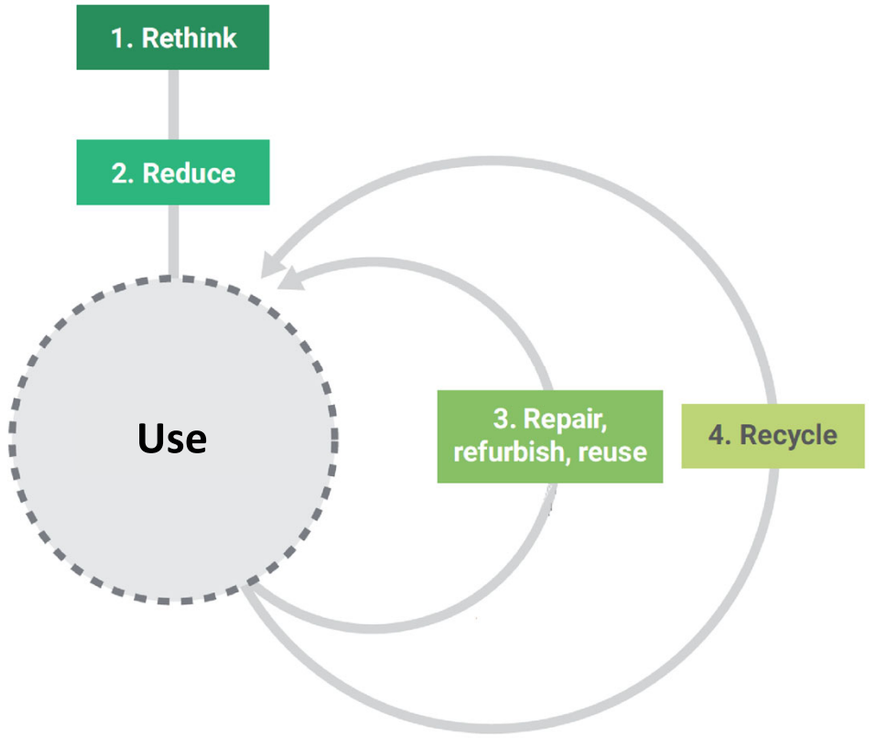
Critical materials: “Dutch report”





Source: Een circulaire energietransistie, 2021

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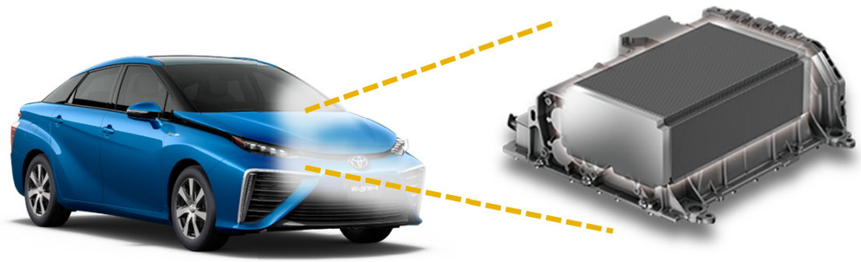
Reduce amount of platinum in fuel cells

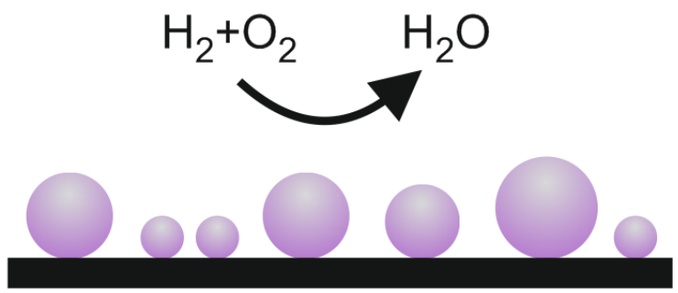
Hydrogen car



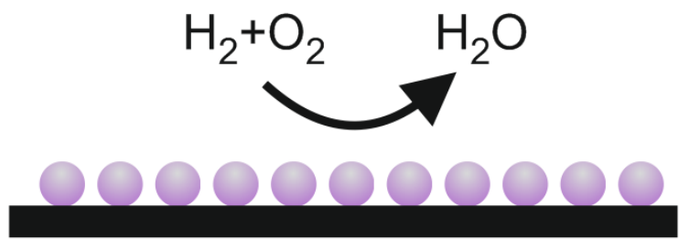
Fuel cell in person car: **~10 g platinum**

Global Pt production: **180 ton/year**

Max. **18 mln cars/year** can be supplied



10 g Pt



<1 g Pt?

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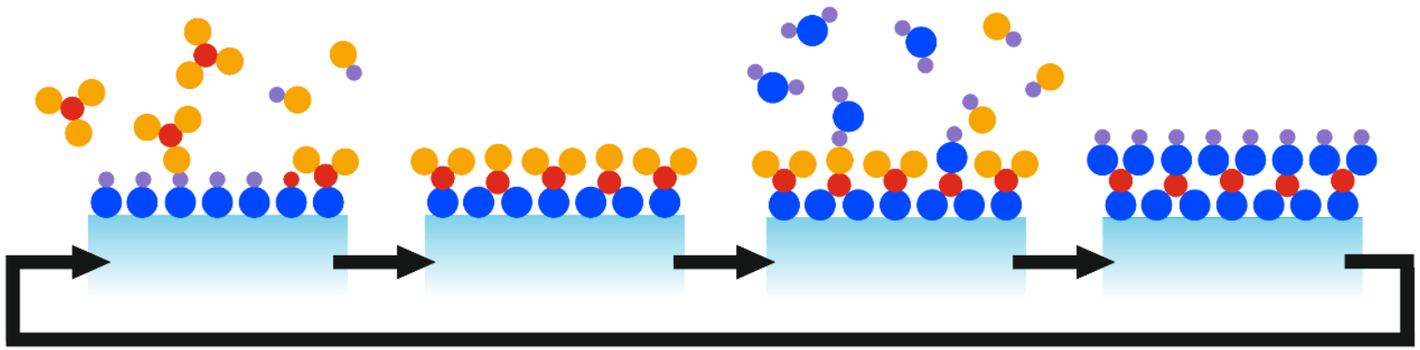
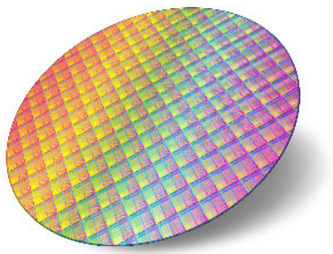
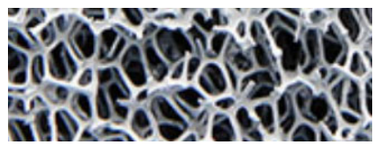
Atomic Layer Deposition (ALD)



Wafer



Powder



Porous support

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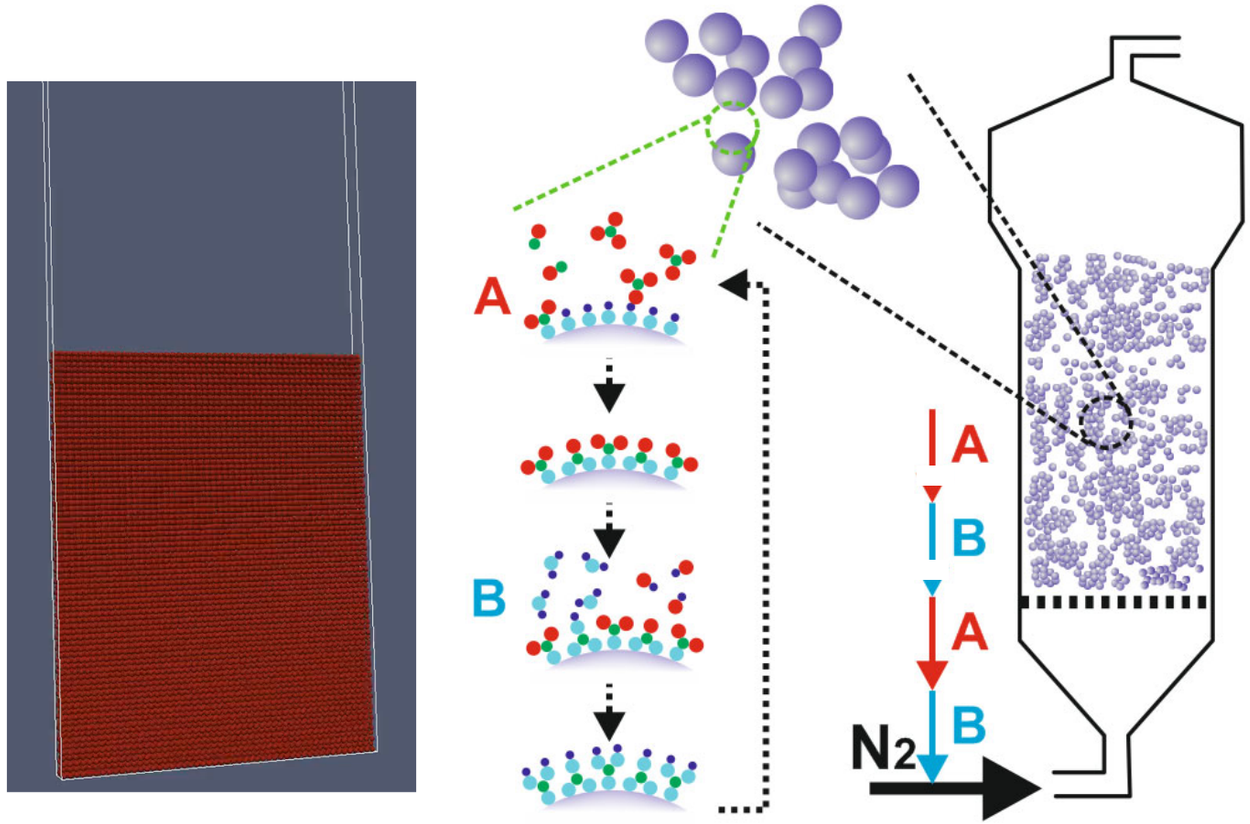
van Ommen & Goulas, Mat Today Chem 14 (2019) 100183

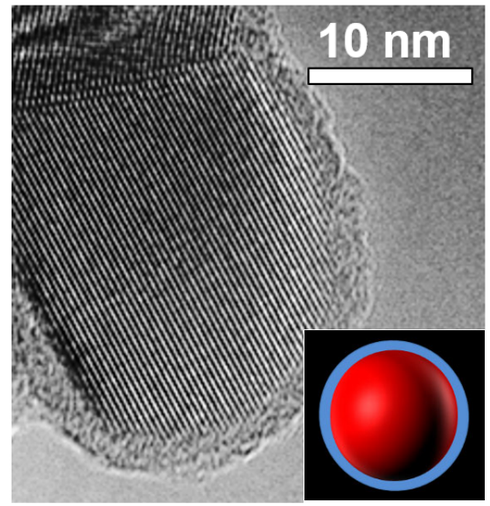
Fluidized Bed ALD Reactor

ALD = Atomic Layer Deposition

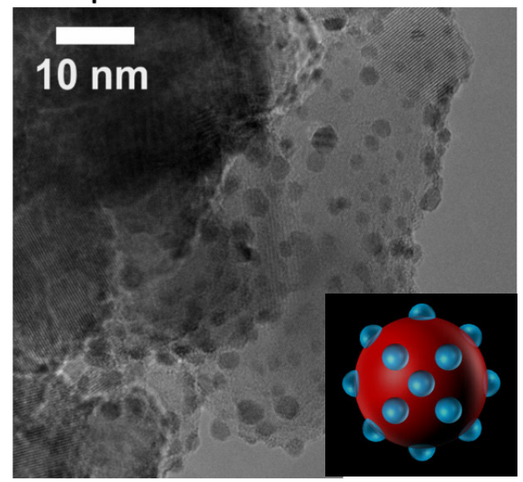


Technology from semi-conductor industry, applied to energy materials

Titanium oxide nanoparticle
with aluminum oxide film ~ 3 nm



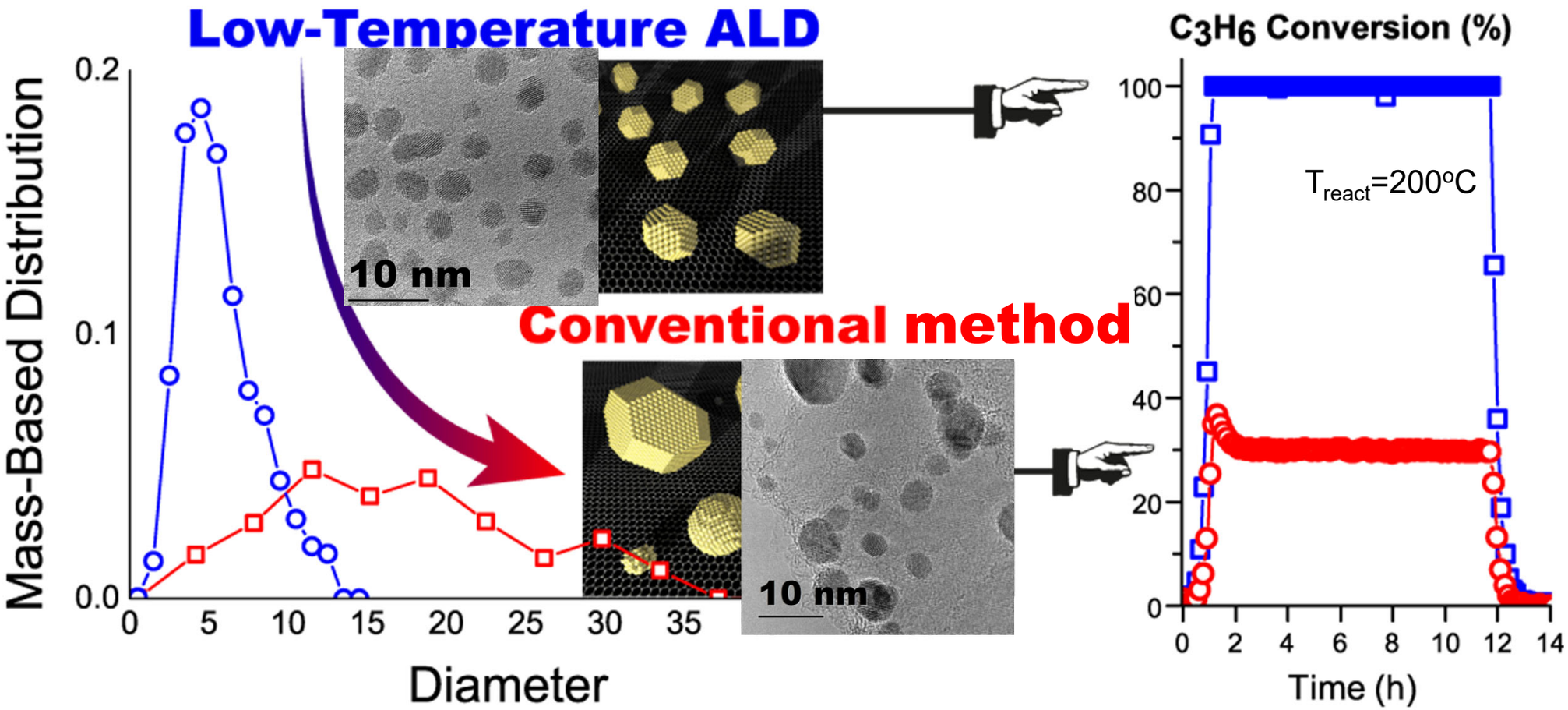
Titanium oxide nanoparticle
with platinum clusters ~ 2 nm



van Ommen & Goulas, *Mat. Today Chem. 14* (2019) 100183.

Efficient platinum usage via ALD

Pt on graphene powder: catalyst activity in propene oxidation



Bui et al., Nanoscale 9 (2017) 10802

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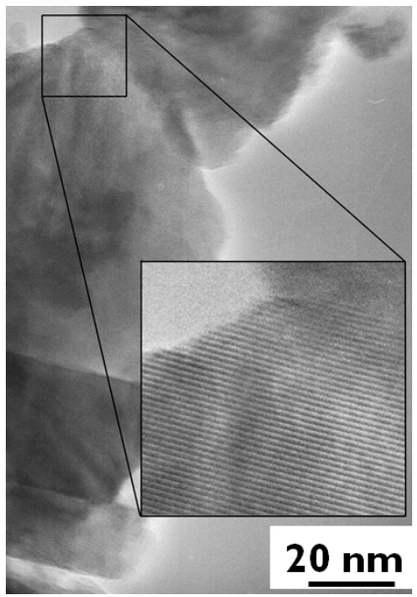
Cathode Particles for Li-ion Batteries

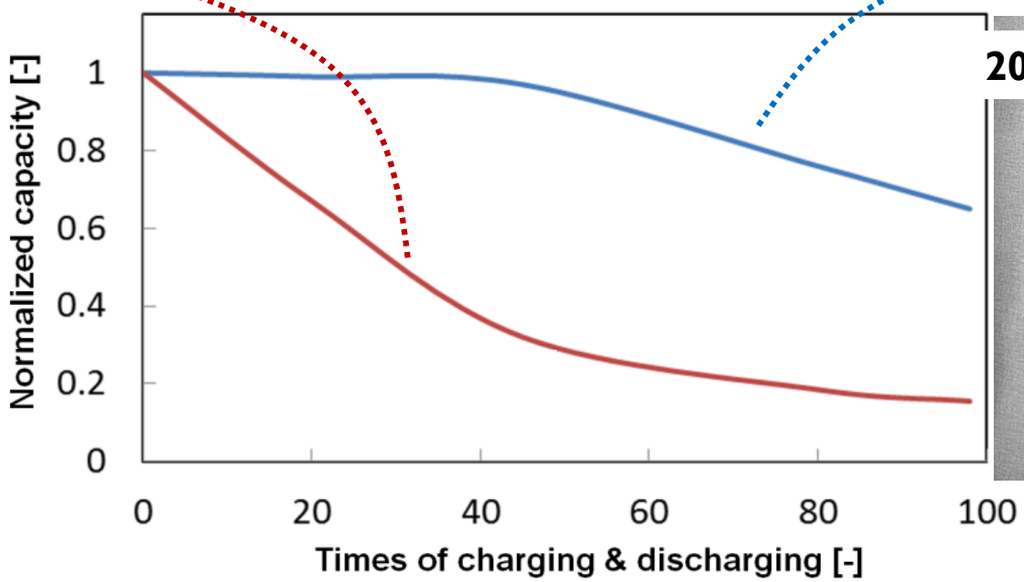
200-500 nm particles: faster charging, but increased aging
Ultrathin coating needed to improve the lifetime

120 g powder, coated at 160°C & 1 bar

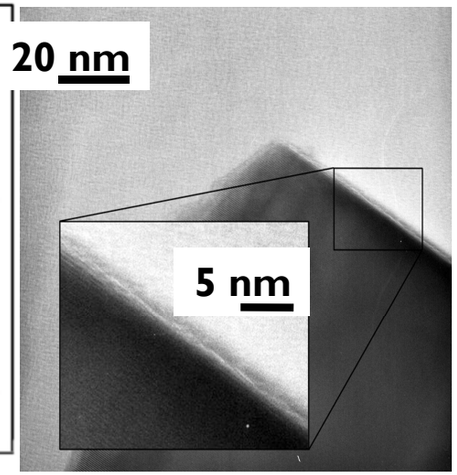
Uncoated $LiMnO_2$ particles



Battery test at 60°C



$LiMnO_2$ particles with Al_2O_3 film



Beetstra et al. *Chem. Vap. Dep.* 15 (2009) 227
Beestra et al., EuroCVD (2007)

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INTENSIFIED MATERIALS PRODUCTION

Summary

TU Delft's e-Refinery develops conversion of electricity into chemicals (fuels & feedstock)

Critical raw materials need to be considered when accelerating electrification

Rethink, reduce, reuse, recycle

Making nanostructured materials using ALD is an example of "reduce"

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