



WELCOME TO

THE NEW IRON AGE

ENABLING THE GREEN ENERGY
REVOLUTION WITH IRON POWDER

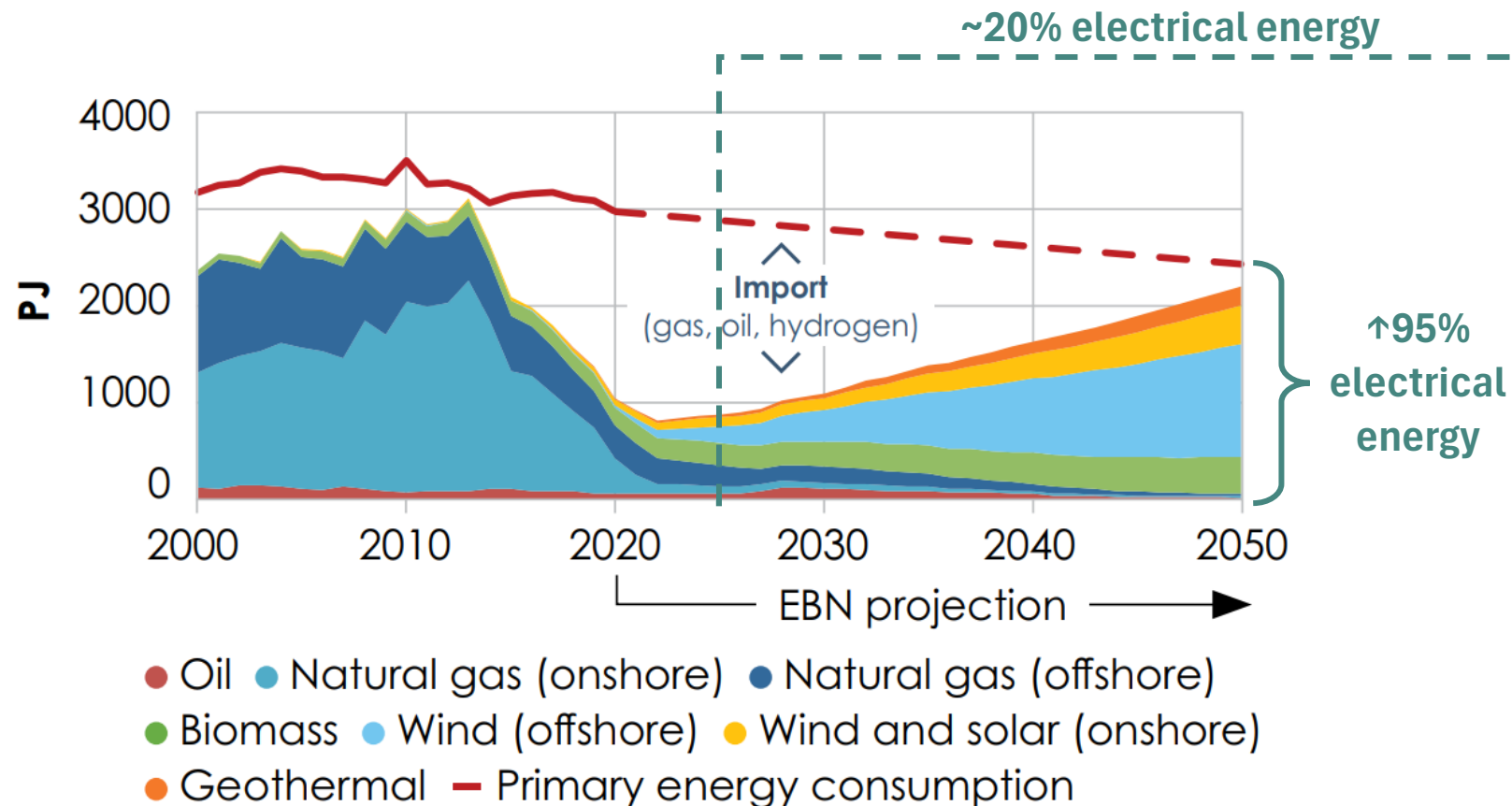


A sustainable energy mix

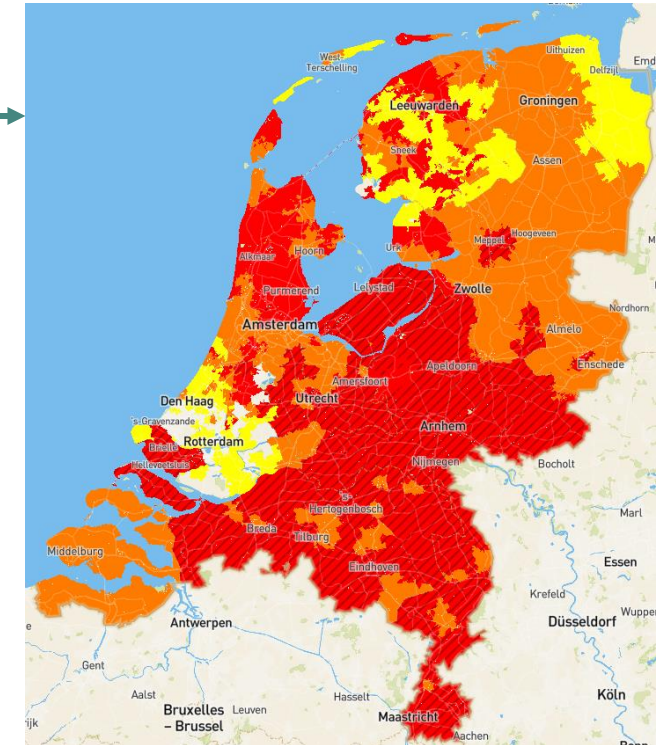
And challenges along the way

Dutch energy mix

Facing out fossil fuels and forecasted increase of green energy



Source: EBN Infographic 2022



Grid capacity: 600 PJ
Total demand: 3000 PJ

Source: Netbeheer Nederland

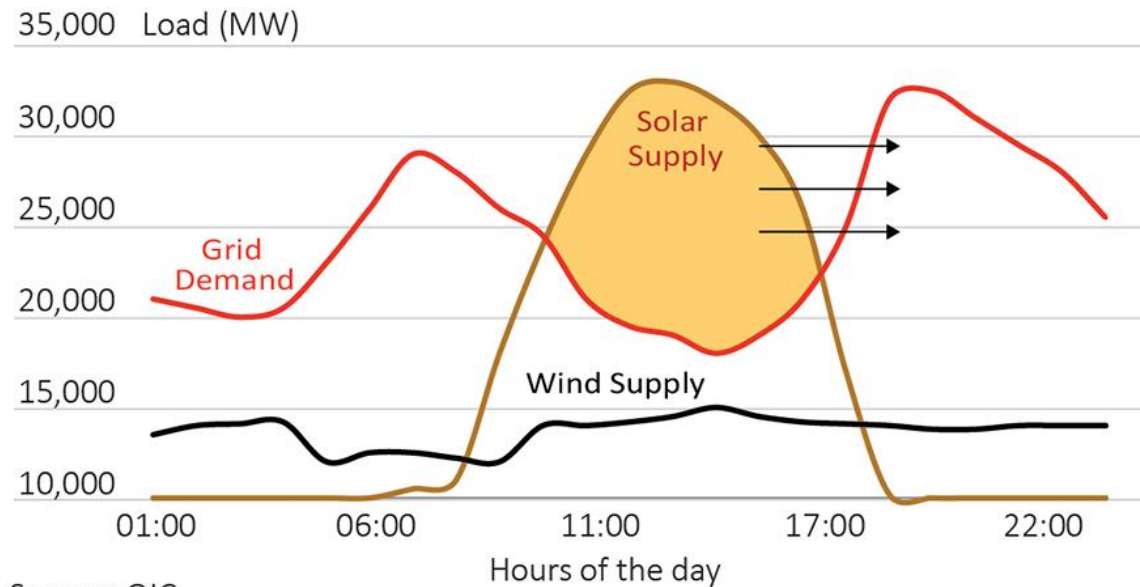
06/05/2024

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Mismatch in green energy supply and demand

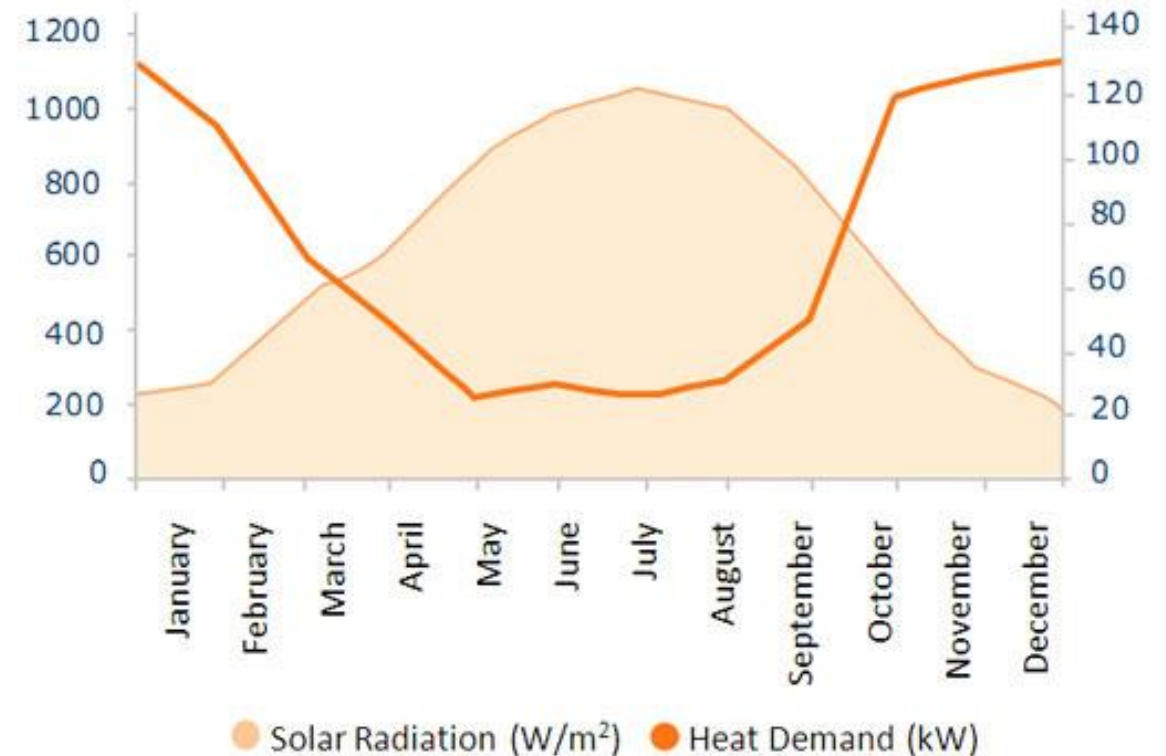
Both **temporal** and spatial

Hourly



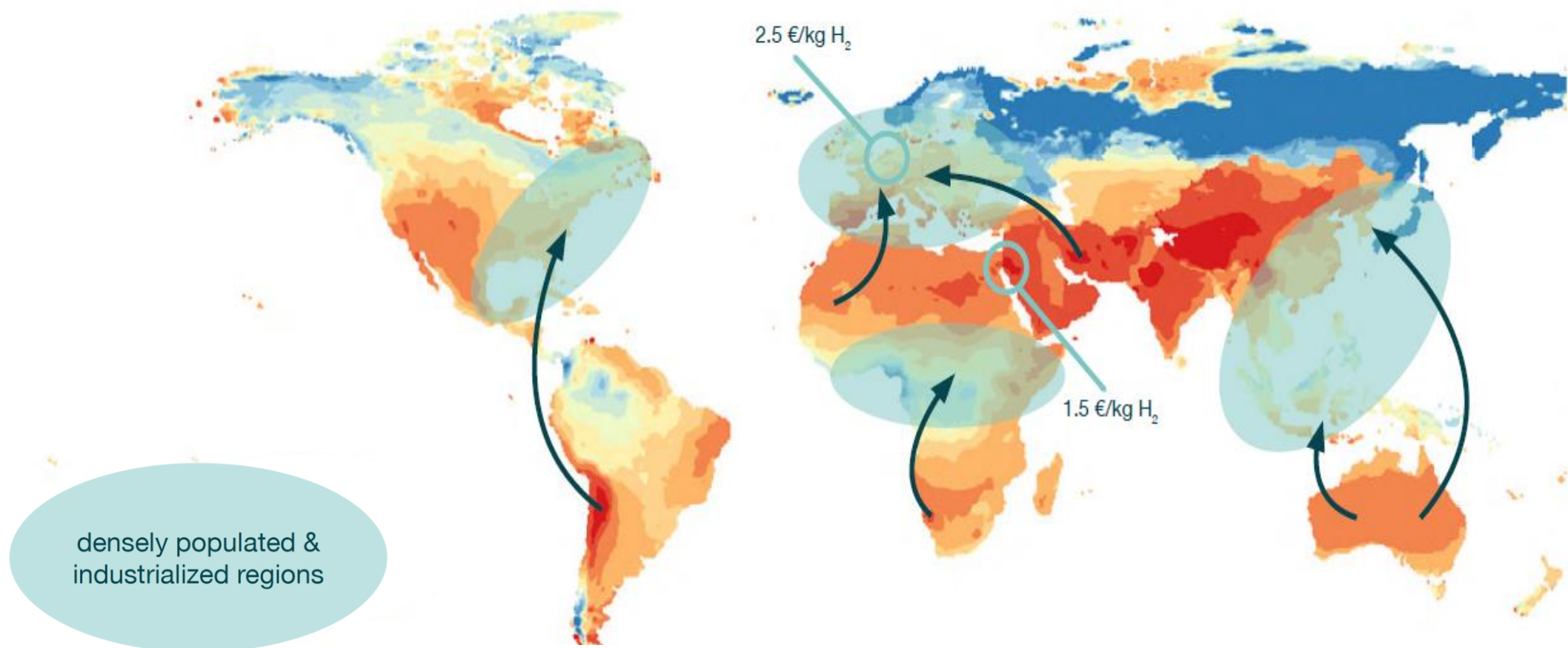
Source: QIC

Monthly



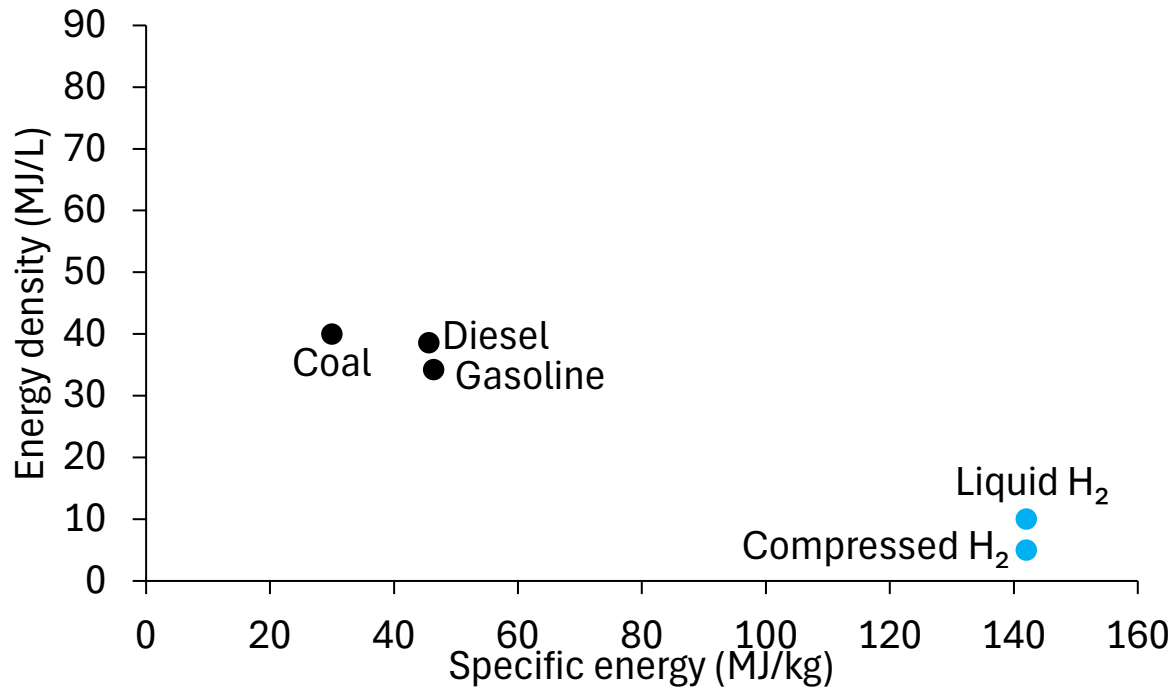
Mismatch in green energy supply and demand

Both temporal and spatial



Long-term energy storage becomes more important

What options do we have?



To carry the same amount of energy



Liquified hydrogen

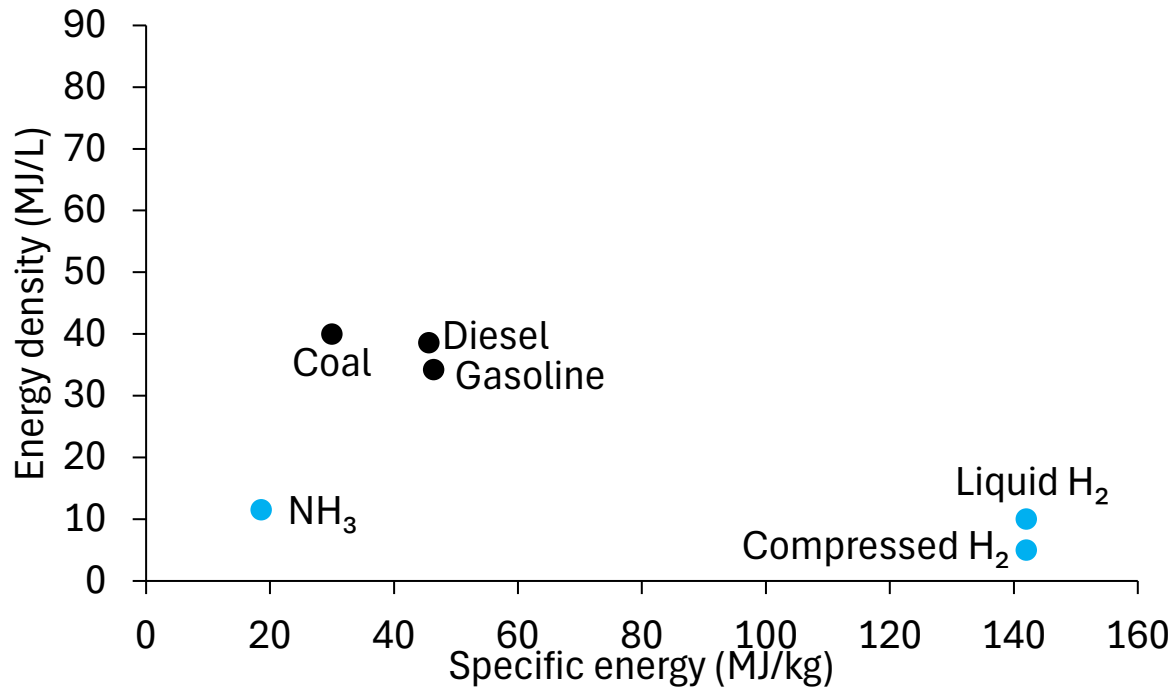
Hydrogen

- Low volumetric energy density
- Highly volatile



Long-term energy storage becomes more important

What options do we have?



To carry the same amount of energy



Liquid ammonia

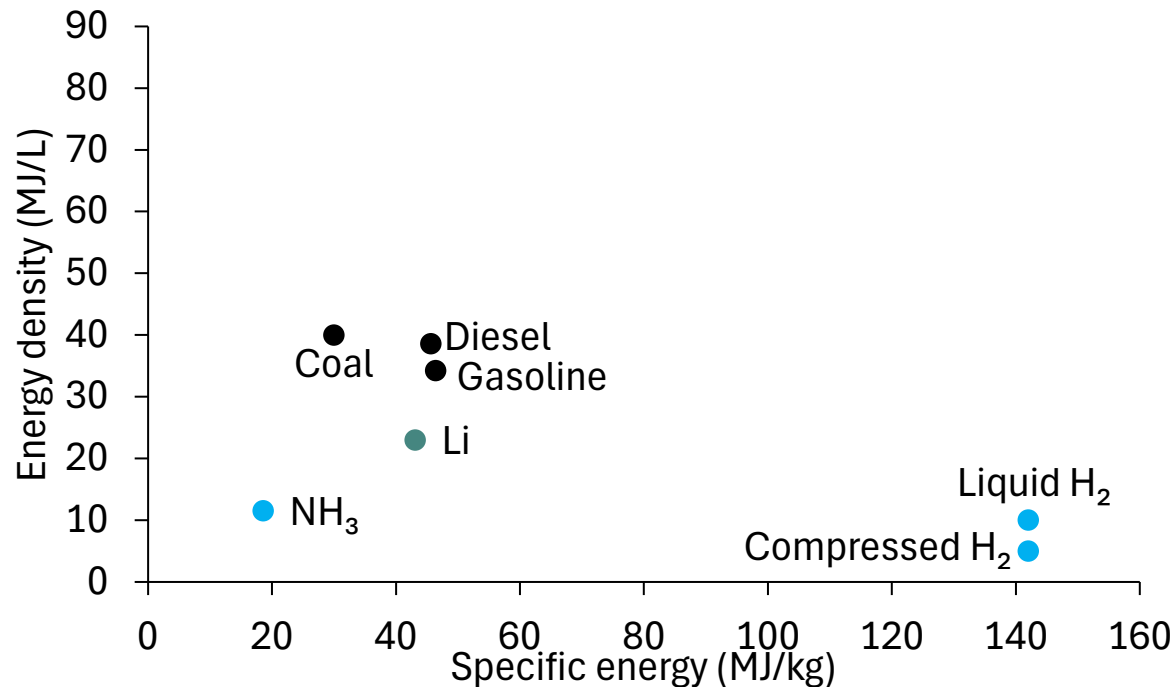
Ammonia

- Slightly higher energy density
- Easier to store



Long-term energy storage becomes more important

What options do we have?



To carry the same
amount of energy



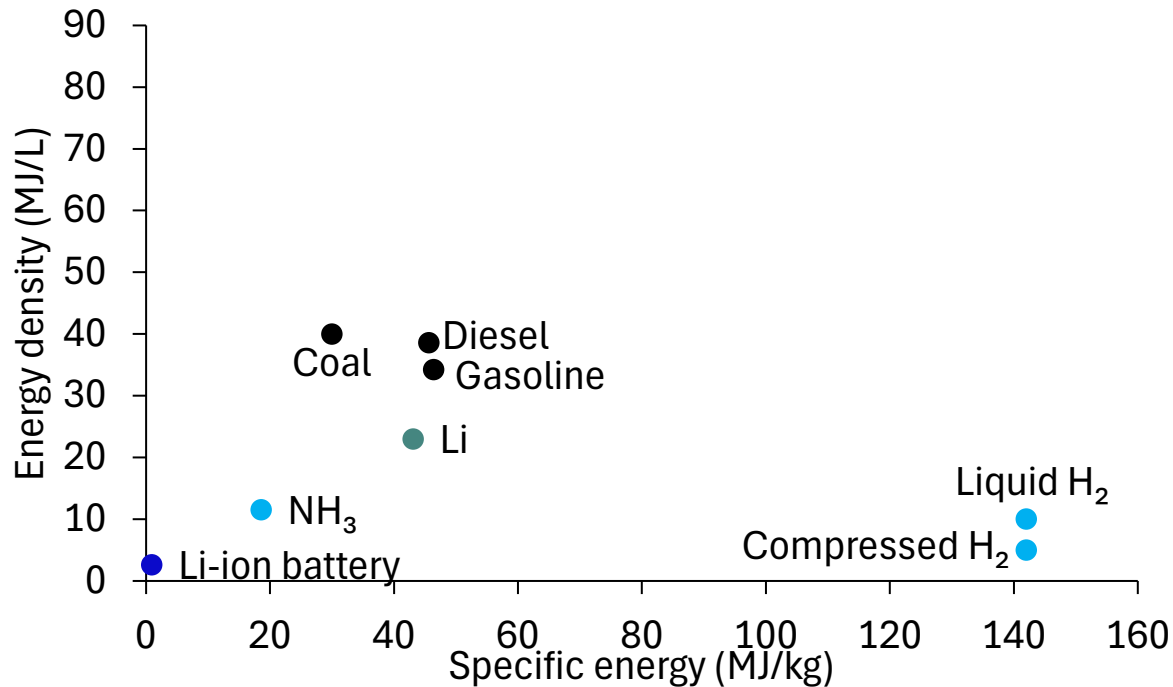
Lithium-ion battery

- Lithium cannot easily burn with air
- Li-ion battery carries both fuel (Li) and oxidizer (CoO₂)



Long-term energy storage becomes more important

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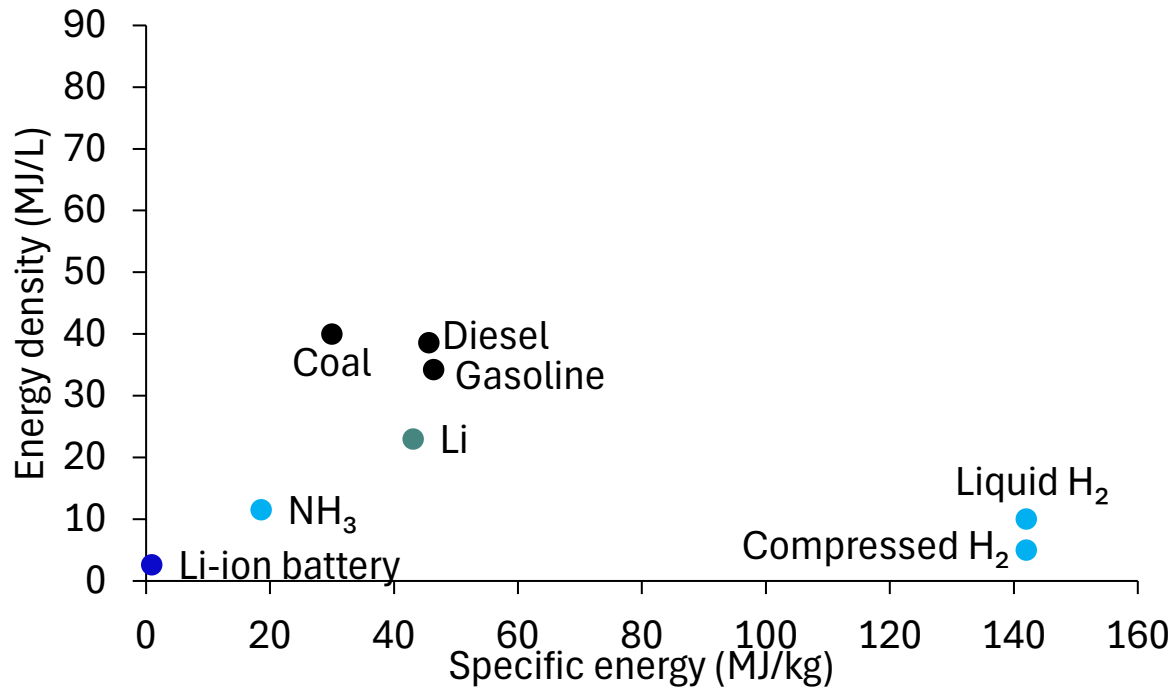
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Lithium-ion battery

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Approximately 3% discharge rate per month

To carry the same amount of energy

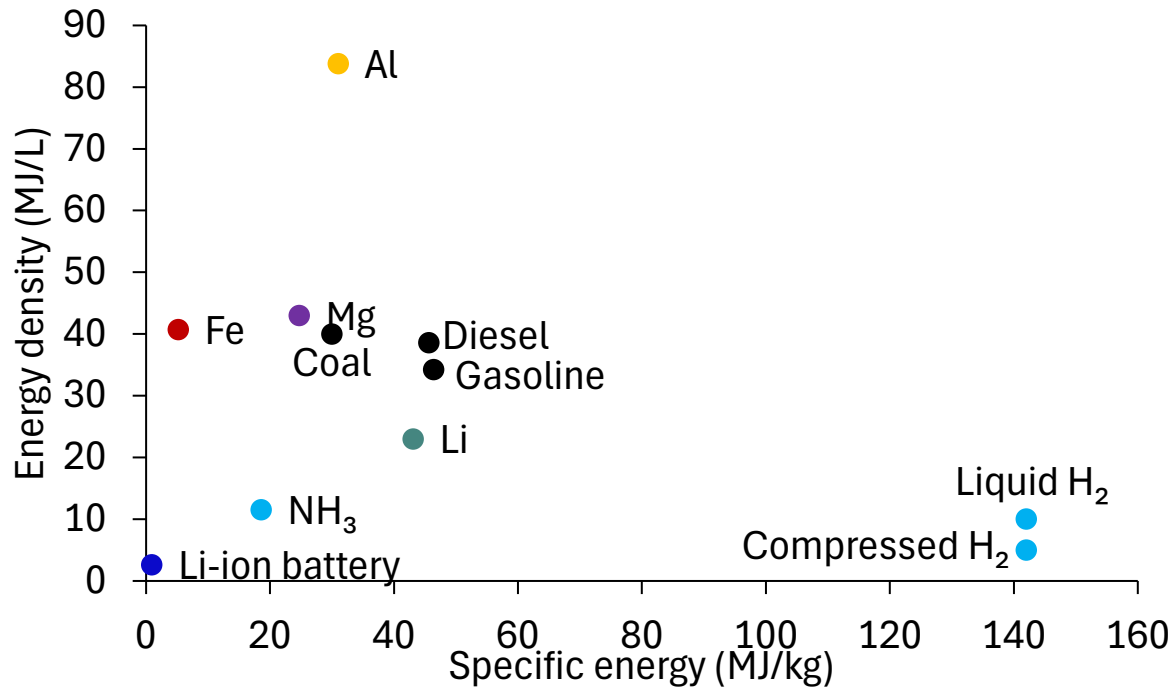


Li-ion battery



Long-term energy storage becomes more important

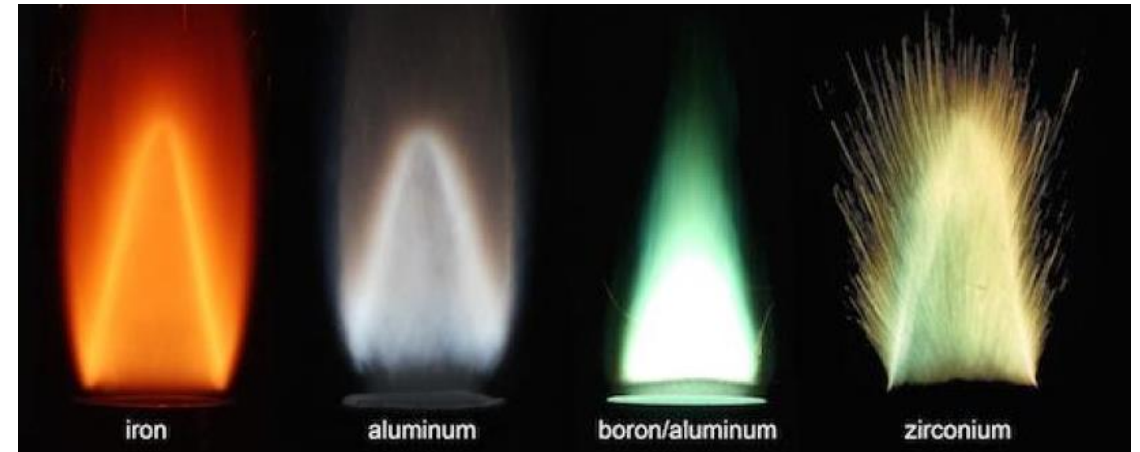
What options do we have?

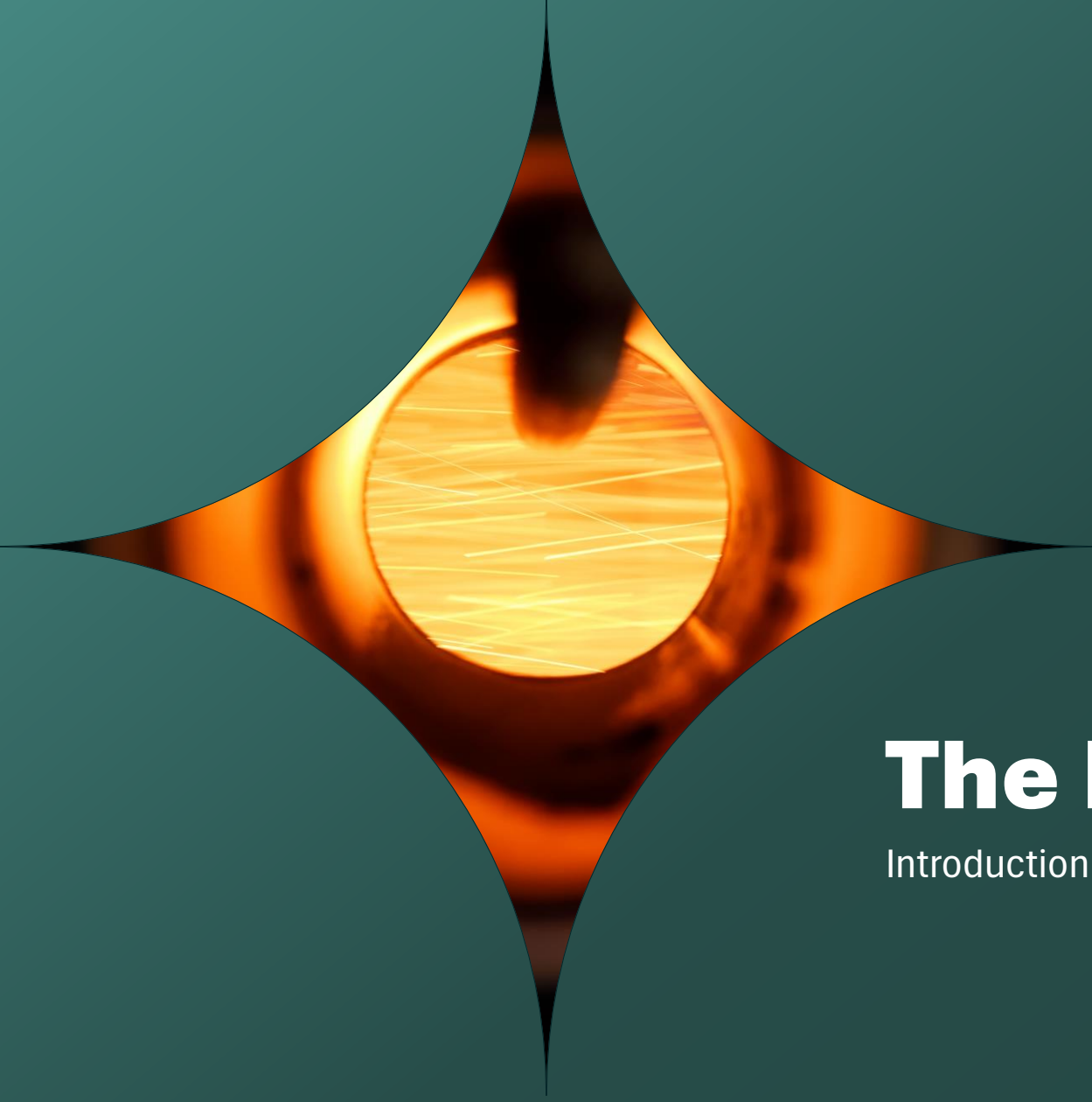


To carry the same amount of energy



Metals



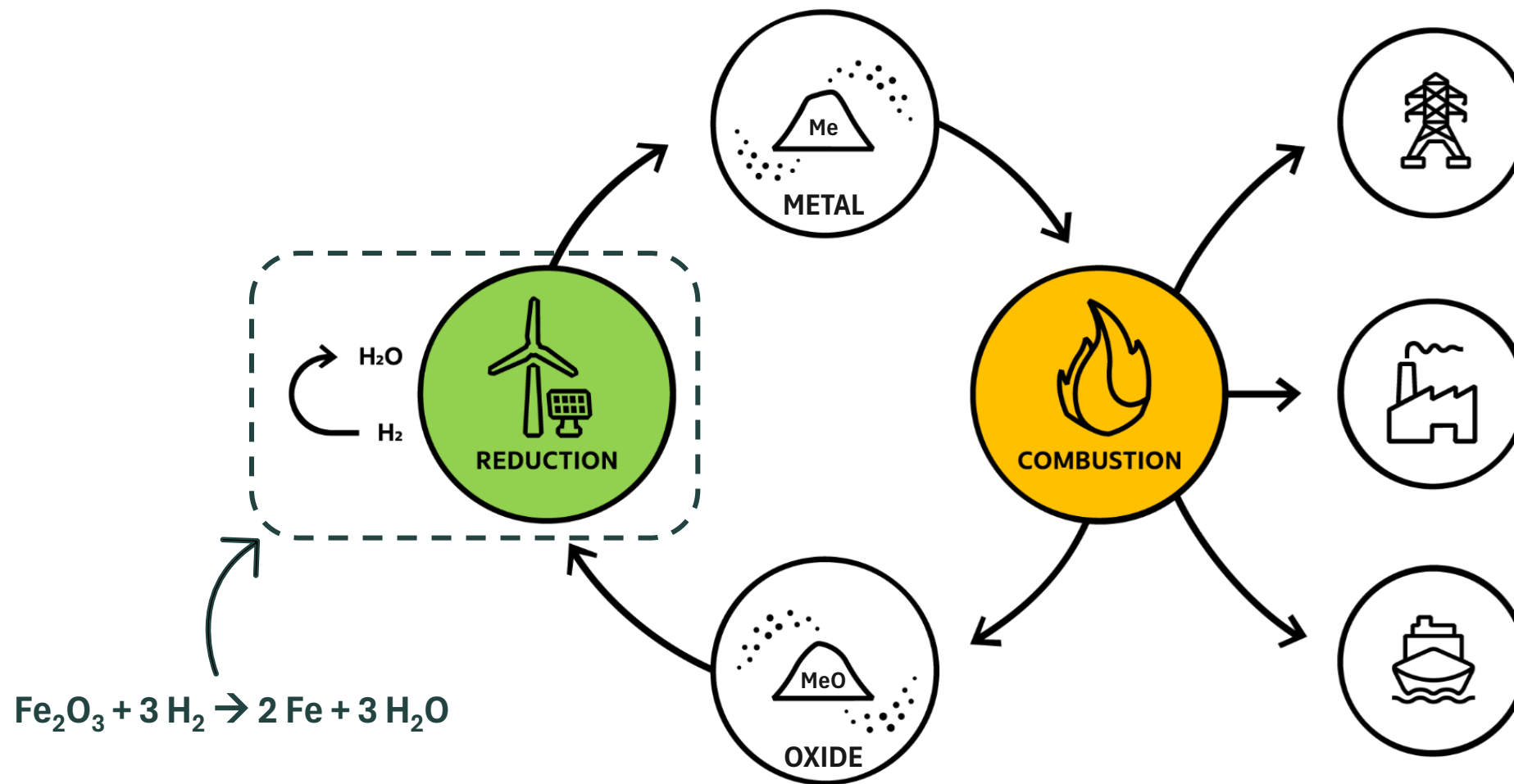


The Metal Power Cycle

Introduction to the Metal Power Cycle and its key benefits

Metals as sustainable energy carrier

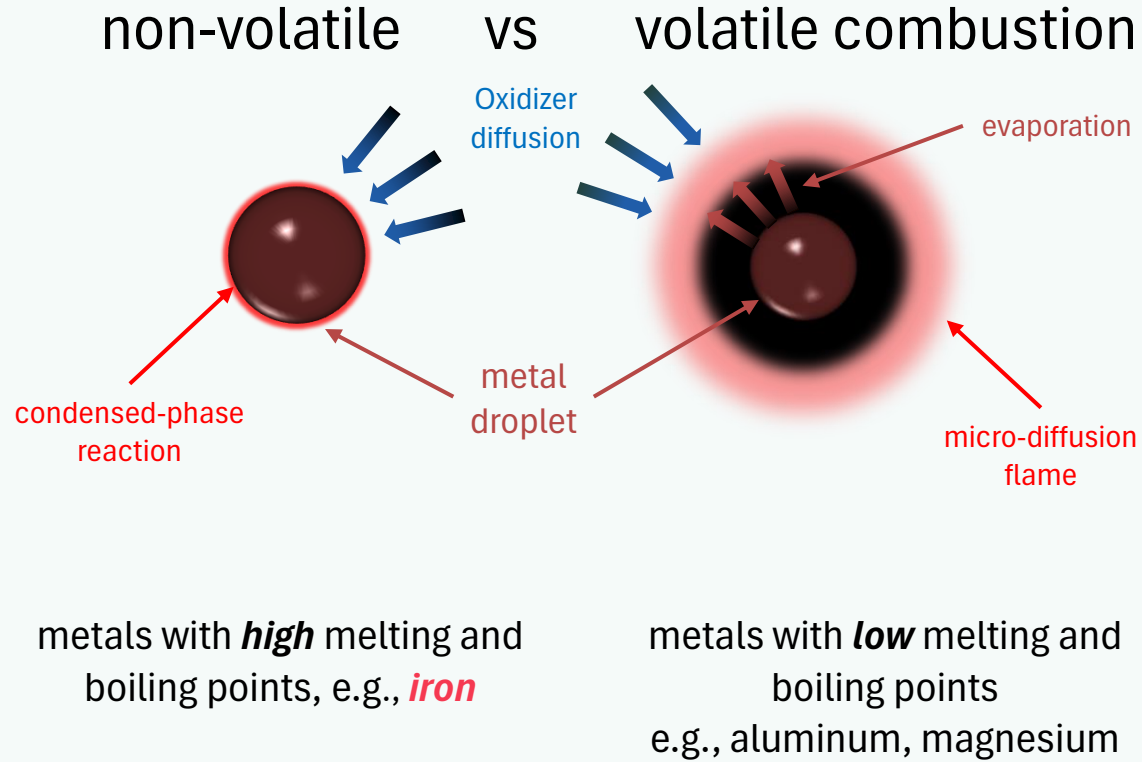
Sustainable energy storage and transportation in a circular value chain



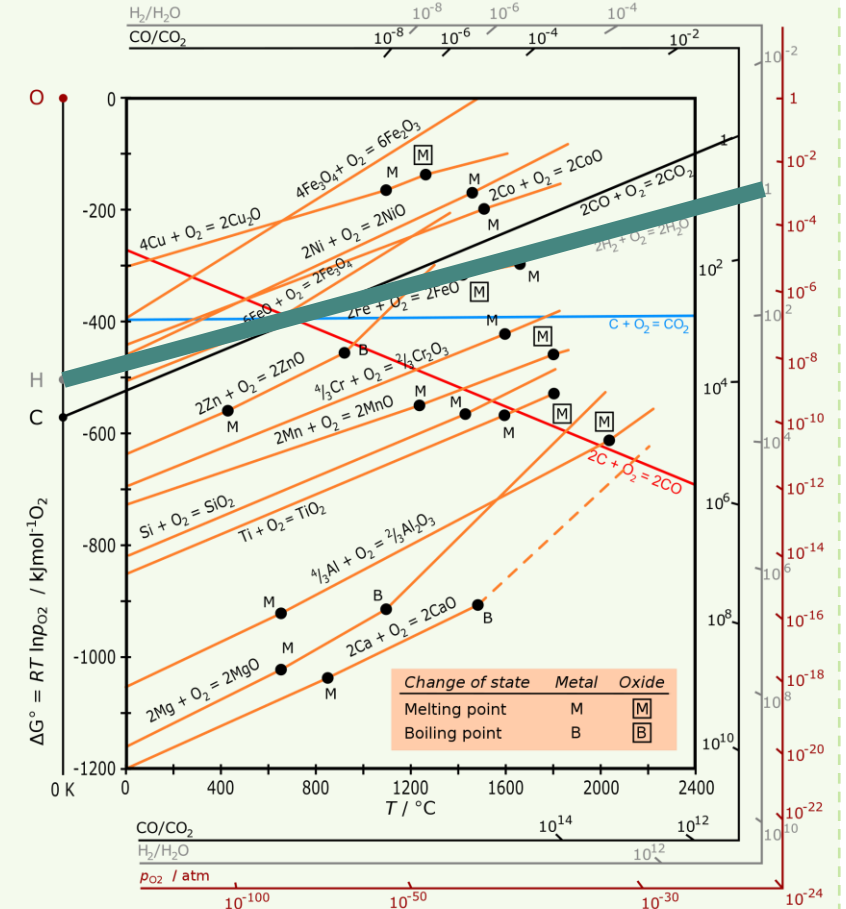
Iron as the perfect candidate

For both oxidation and reduction

Oxidation



Reduction



Key advantages of Iron Power

Clean

Circular

Safe

Compact

Cheap

Key advantages of Iron Power

No gaseous reaction products

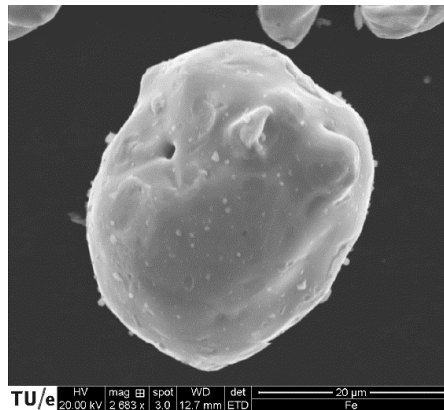
Clean

Circular

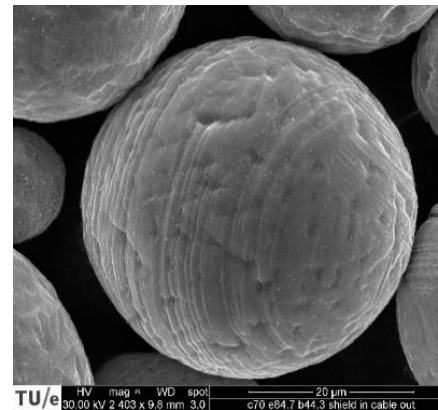
Safe

Compact

Cheap



Iron



Iron oxide

- No CO₂ emissions
- Very low NOx emissions

Key advantages of Iron Power

Iron powder can be recycled many times

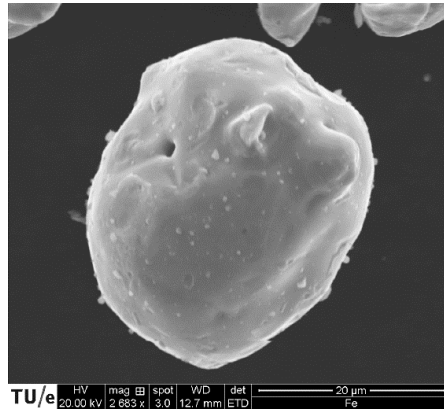
Clean

Circular

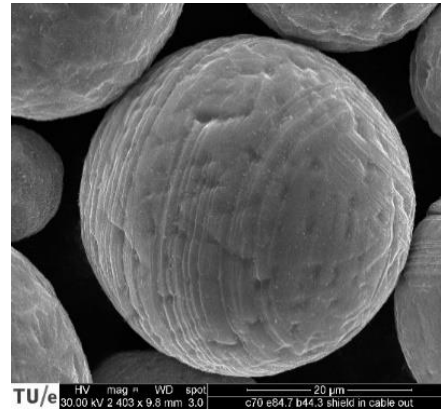
Safe

Compact

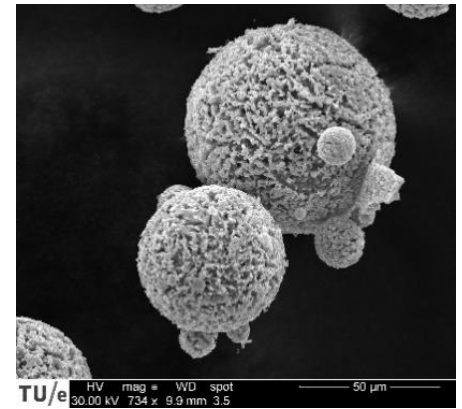
Cheap



Iron



Iron oxide



Iron

- Circular use of iron

- Water usage also circular!

Key advantages of Iron Power

Iron powder is very safe to work with compared to other energy carriers







Clean

Circular

Safe

Compact

Cheap

	Flammable 	Acute Toxic 	Health Hazard 	Corrosive 	Environmental 	Pressured Gas 
Heavy Fuel Oil (HFO)			X		X	
Methanol (CH ₃ OH)	X	X	X			
Hydrogen (H ₂)	X					X
Ammonia (NH ₃)		X		X	X	X
Iron (Fe) and Fe ₂ O ₃	X					

Key advantages of Iron Power

Iron powder has a very high volumetric energy density compared to other storage methods

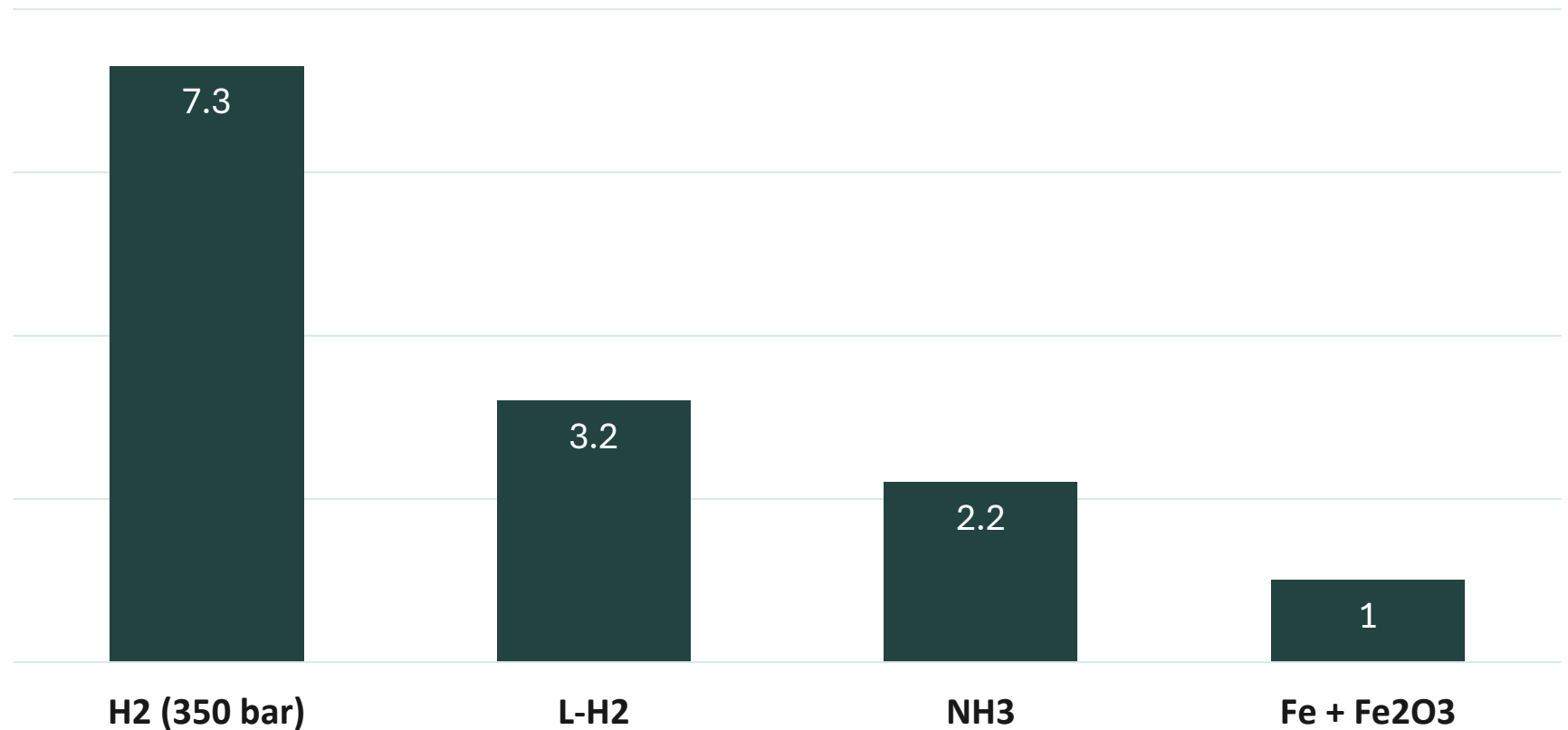
Clean

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Key advantages of Iron Power

The Iron Power value chain is cost-competitive for long-haul vessel transport from the Middle-East to Rotterdam

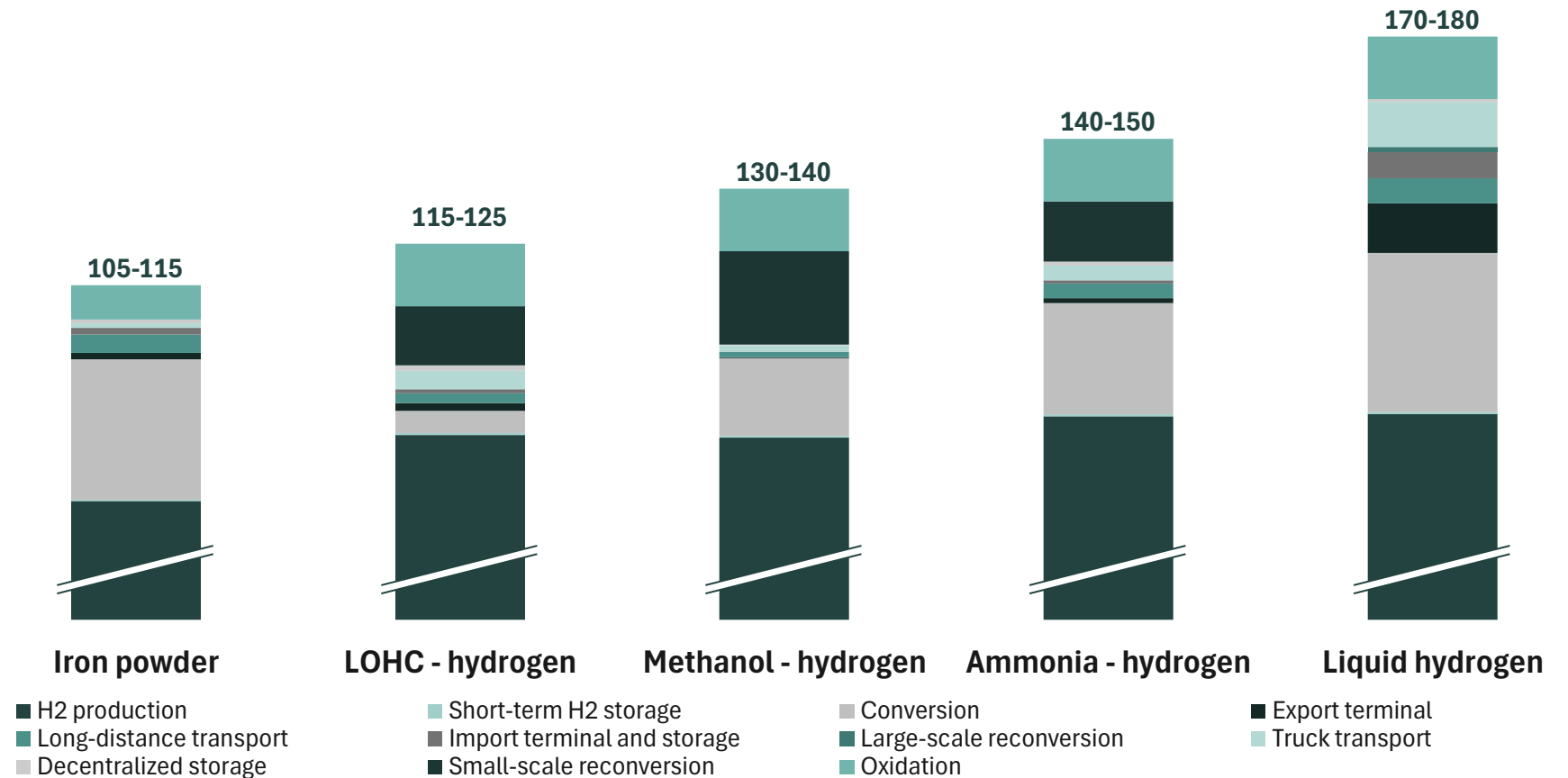
Clean

Circular

Safe

Compact

Cheap





From theory to practice

Current status of technology and future roadmap

From theory to practice

Current status of technology and future roadmap

2017



First iron flame
5 kW

2020



First industrial combustion pilot at Swinkels Brewery
100 kW

2022



Combustion research by Iron+ at Energy Lab, 200 kW

From theory to practice

Current status of technology and future roadmap

2022



Combustion research by Iron+ at Metalot Future Energy Lab, 200 kW

2023



1st gen. combustion system for district heating by start-up RIFT, 500 kW



2nd gen. combustion system by Swinkels

From theory to practice

Current status of technology and future roadmap

2023



2nd gen. combustion equipment pilot by Iron+ at Swinkels Brewery, 500 kW



1st gen. reduction system by start-up RIFT, 80 kW

2024



2nd gen. combustion equipment pilot by Ennatuurlijk

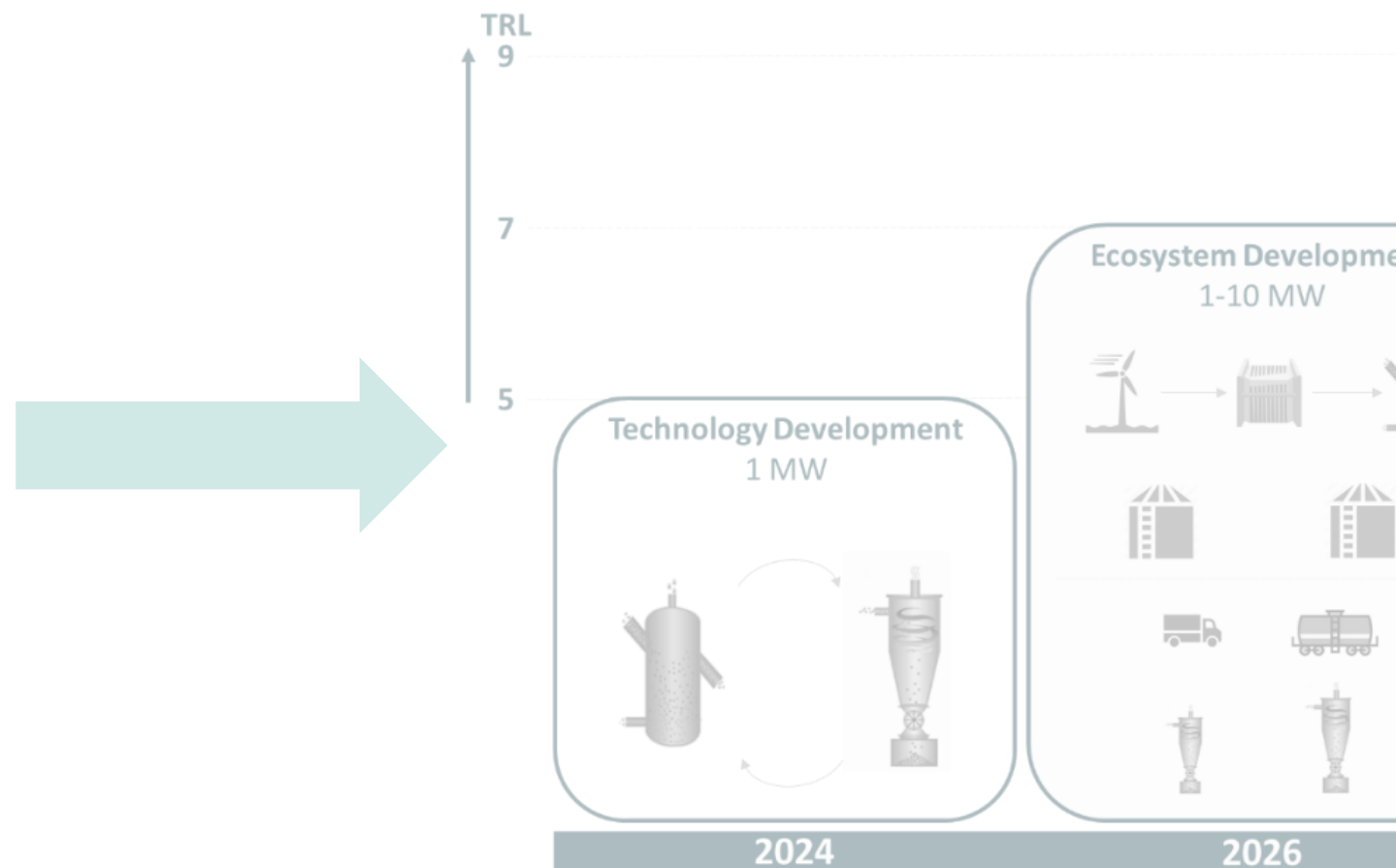
From theory to practice

Current status of technology and future roadmap

2024



2nd gen. combustion equipment test by RIFT at Ennatuurlijk district heating, 1 MW

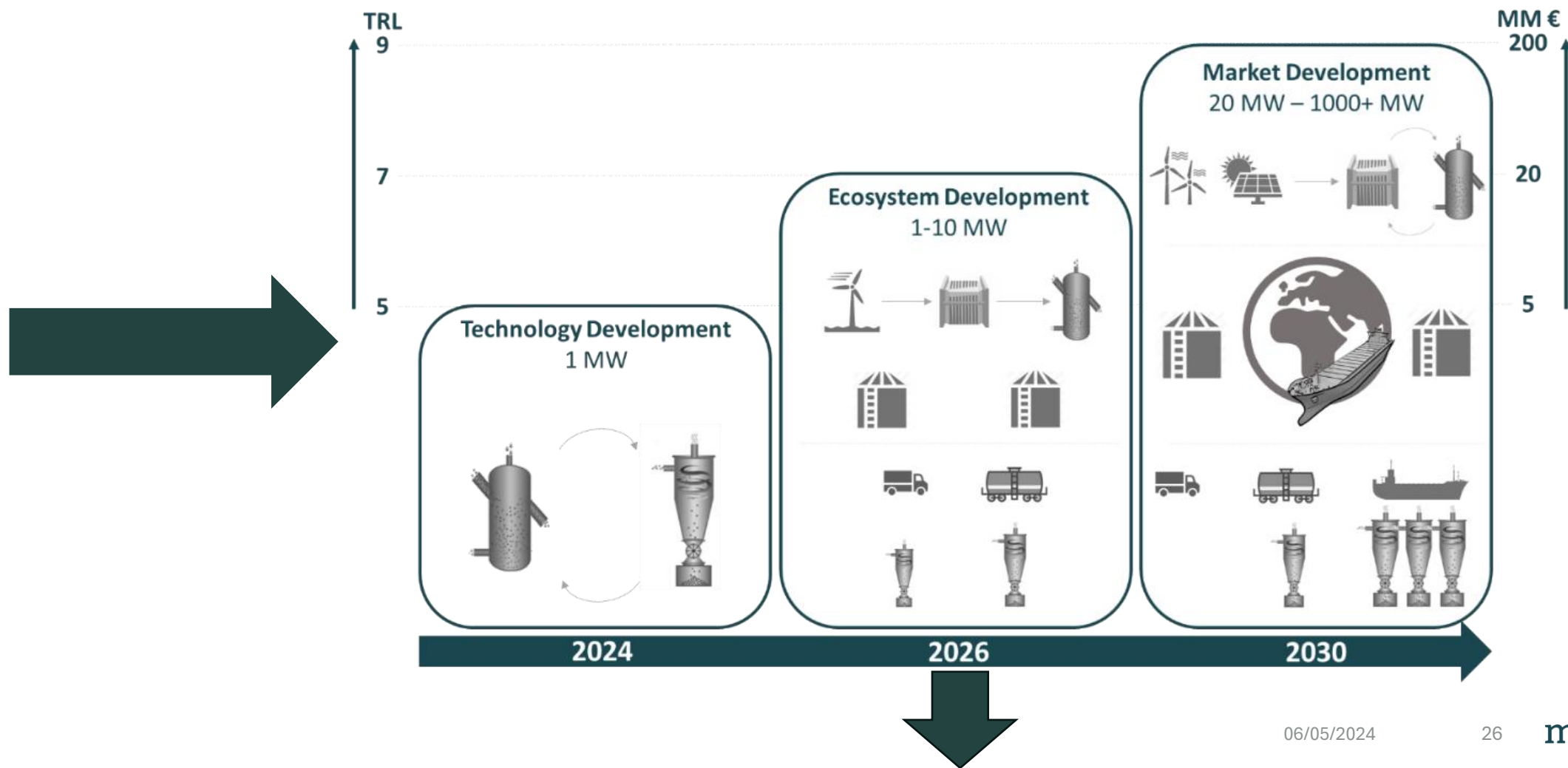


From theory to practice

Current status of technology and future roadmap

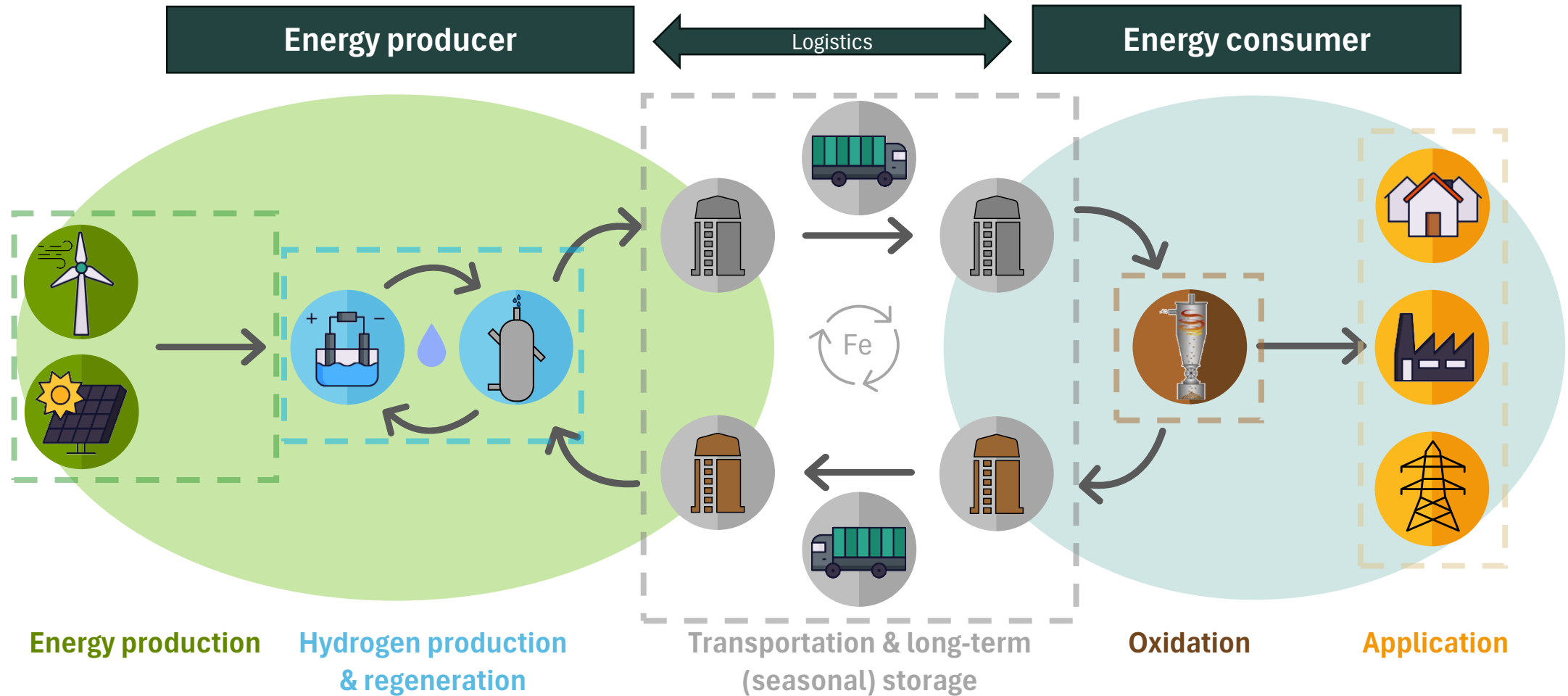


by RIFT at



Identifying early adopter cases

Implementing Iron Power in a decentralized energy hub at readily demonstrated scale (~1 MW)



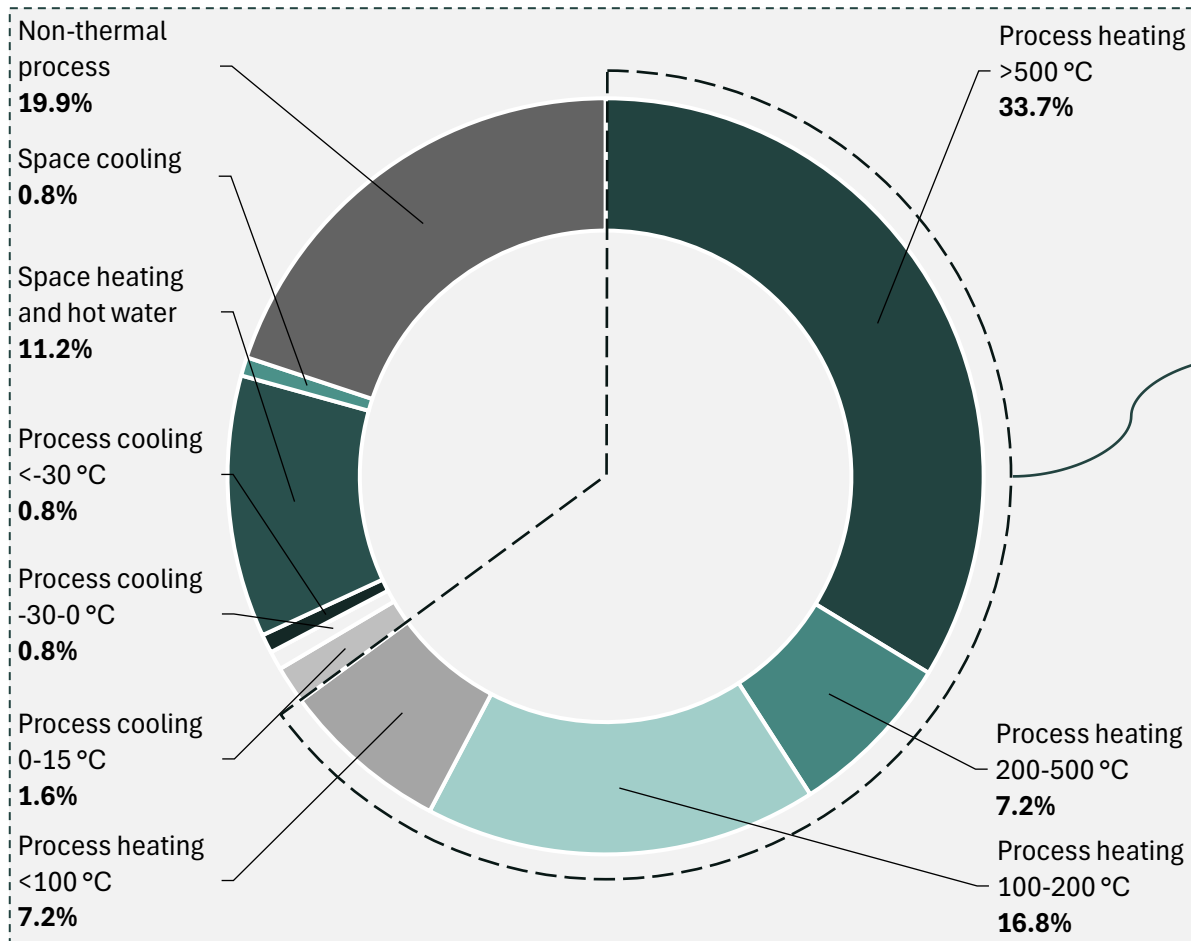


Potential impact

Long-term vision on the role of Iron Power in the energy transition

Energy consumption by industry

Breakdown of energy consumption for industrial processes



Source: European Energy Research Alliance, IEA 2023

- Thermal energy demands combined account for **around 80%**
- **Process heating consumes 64.9%** of the industrial energy
- **Electrification** not always the best solution
- Need for an alternative energy source that can produce **high temperatures**

The hydrogen backbone

Hydrogen from the planned backbone will not be a solution for all industries



Only 5 large geographical **industry clusters** will have access to hydrogen from the backbone



Not connected to the hydrogen backbone and therefore need **alternative distribution methods**



Responsible for c. **30% of industrial CO₂ emissions** in the Netherlands



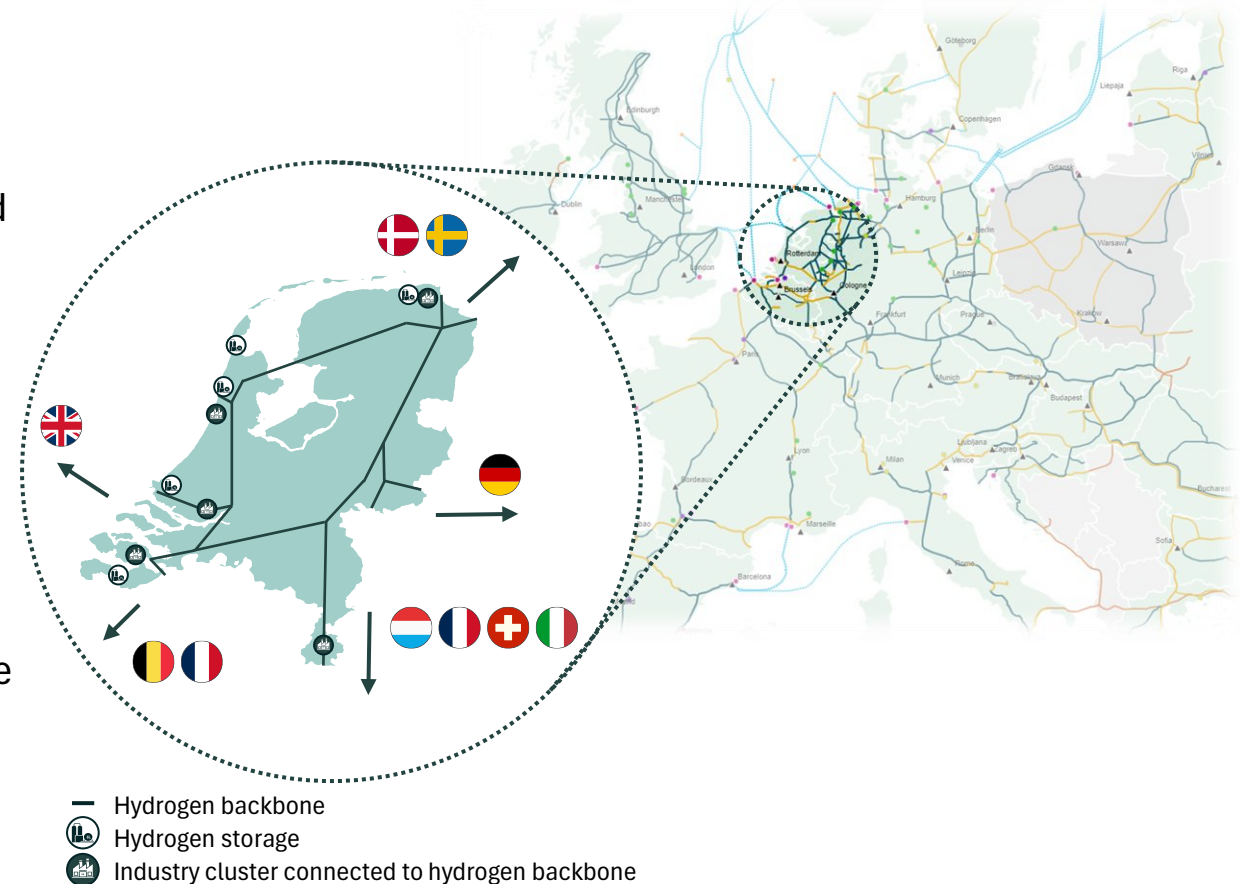
Chemical-, ceramic-, food-, metallurgical-, paper-, glass-, waste and recycling-, ICT- and oil and gas industries



Large part of 6th cluster companies is difficult to decarbonize as they need **high-grade heat** for their operations, which **excludes electrification** as solution method

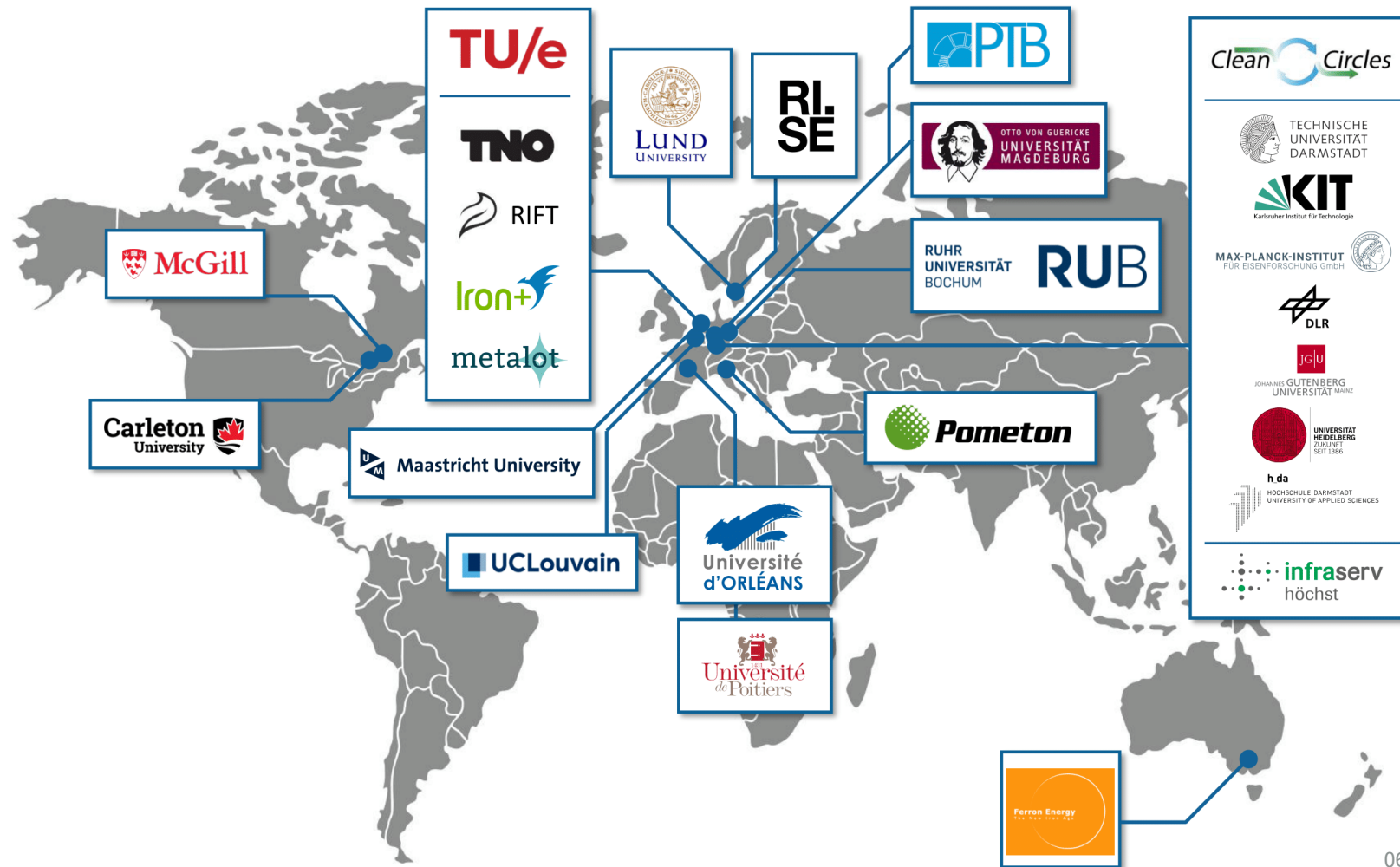


There are estimated to be **approximately 150,000 locations** in Europe with a heat demand between 1 and 50 MW



The Iron Power ecosystem

A fast-growing community with Metalot as ecosystem builder



Burning questions?



www.metalot.nl



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