

A large industrial machine, possibly a reactor or processing unit, is the central focus. It consists of a tall, cylindrical vessel with various pipes, valves, and a conical bottom section, all supported by a sturdy metal frame. The machine is situated in a large, well-lit industrial facility with a high ceiling and structural beams. The overall color palette is a cool, teal-blue, giving it a modern and technological feel.

metalot

WELCOME TO

# THE NEW IRON AGE

ENABLING THE GREEN ENERGY  
REVOLUTION WITH IRON POWDER

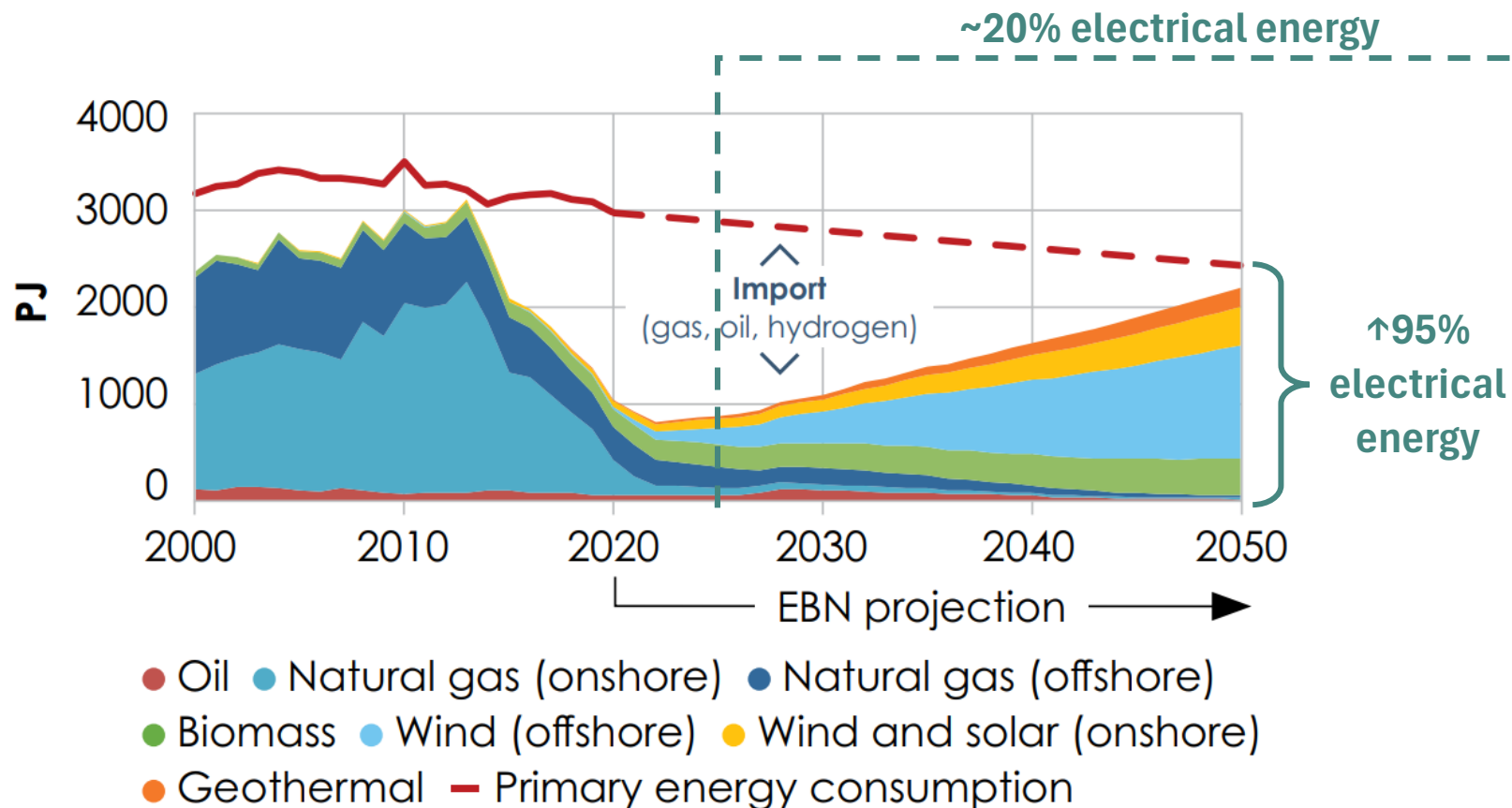


# A sustainable energy mix

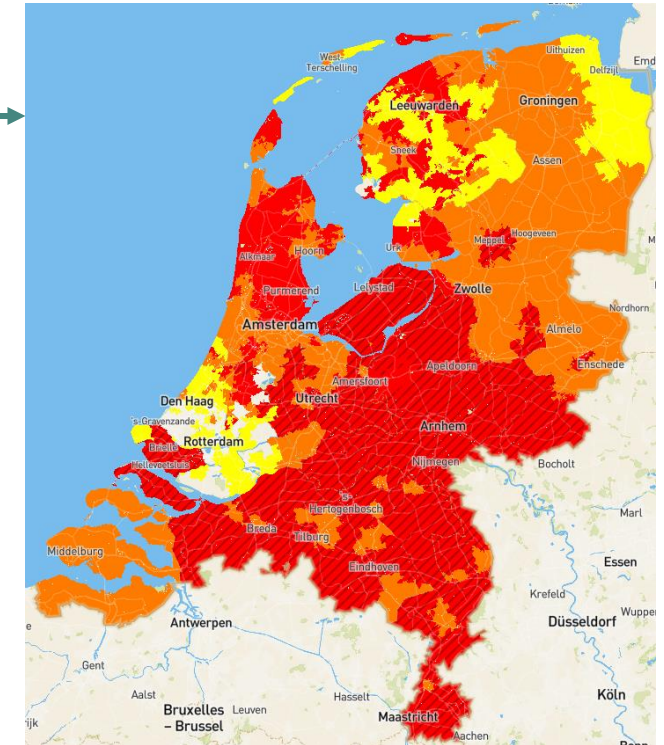
And challenges along the way

# 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

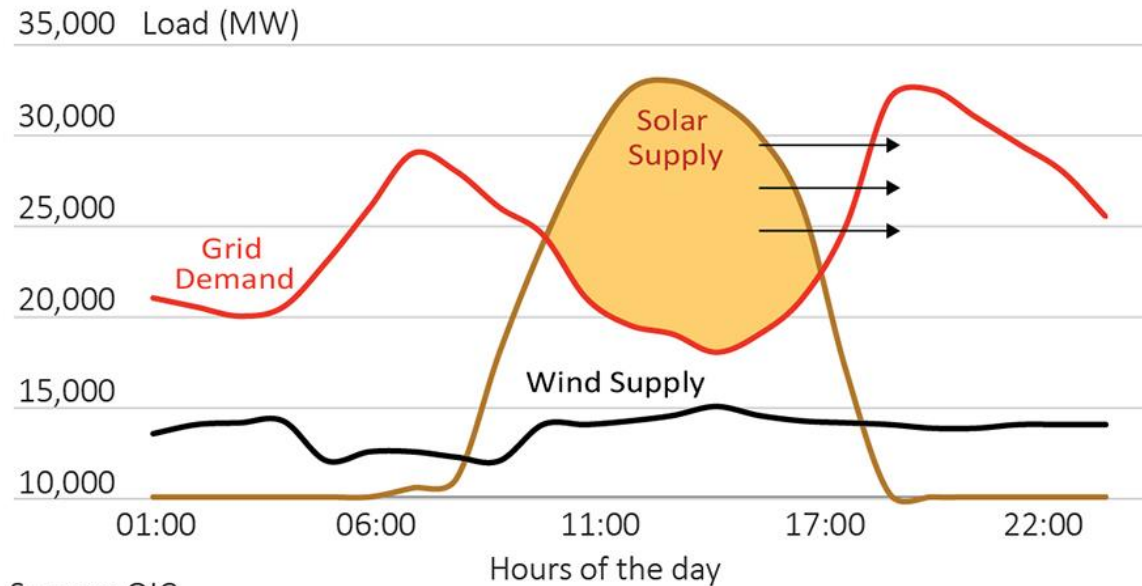
07/01/2024

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# Mismatch in green energy supply and demand

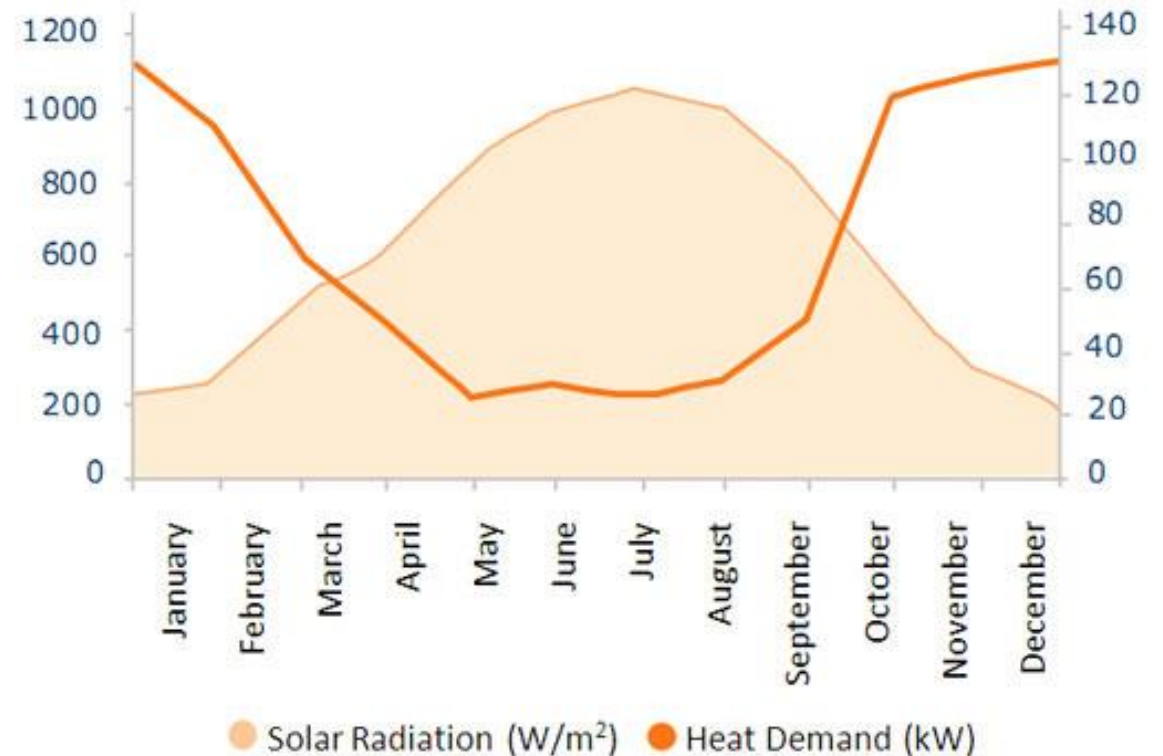
Both temporal and spatial

## Hourly



Source: QIC

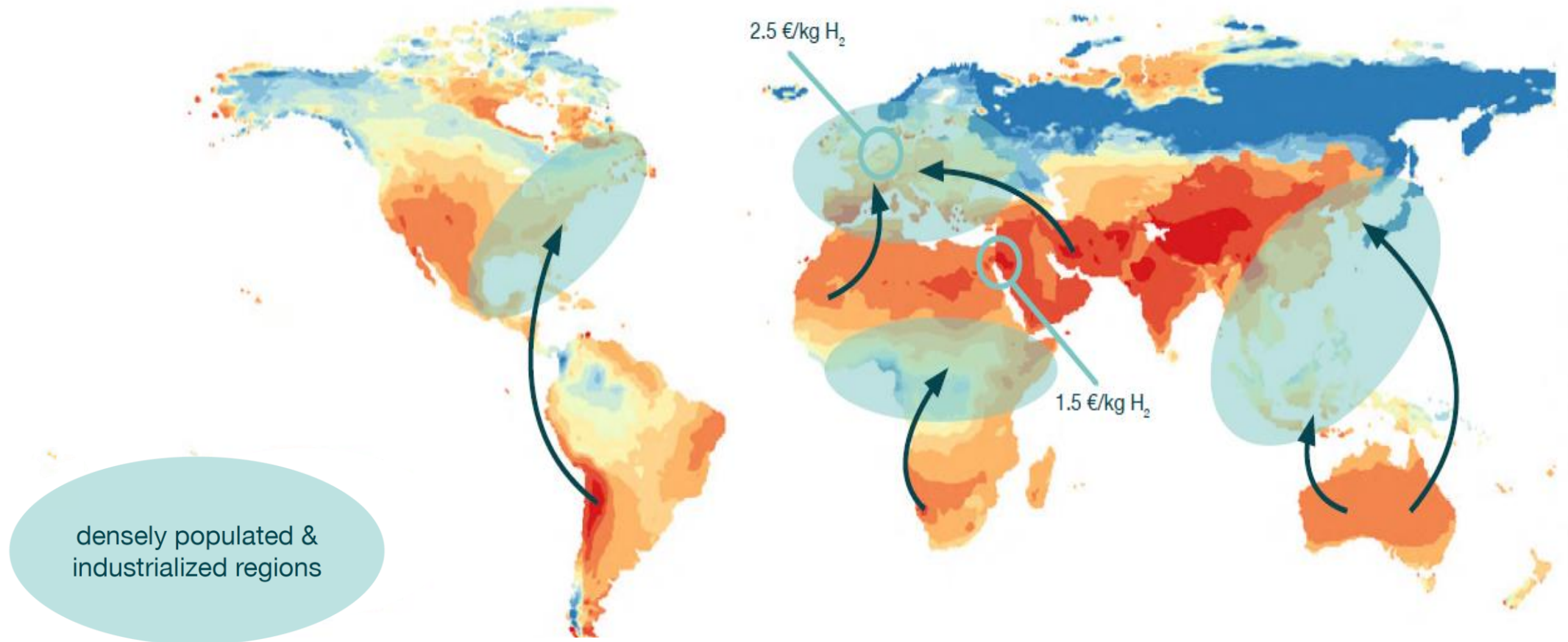
## Monthly





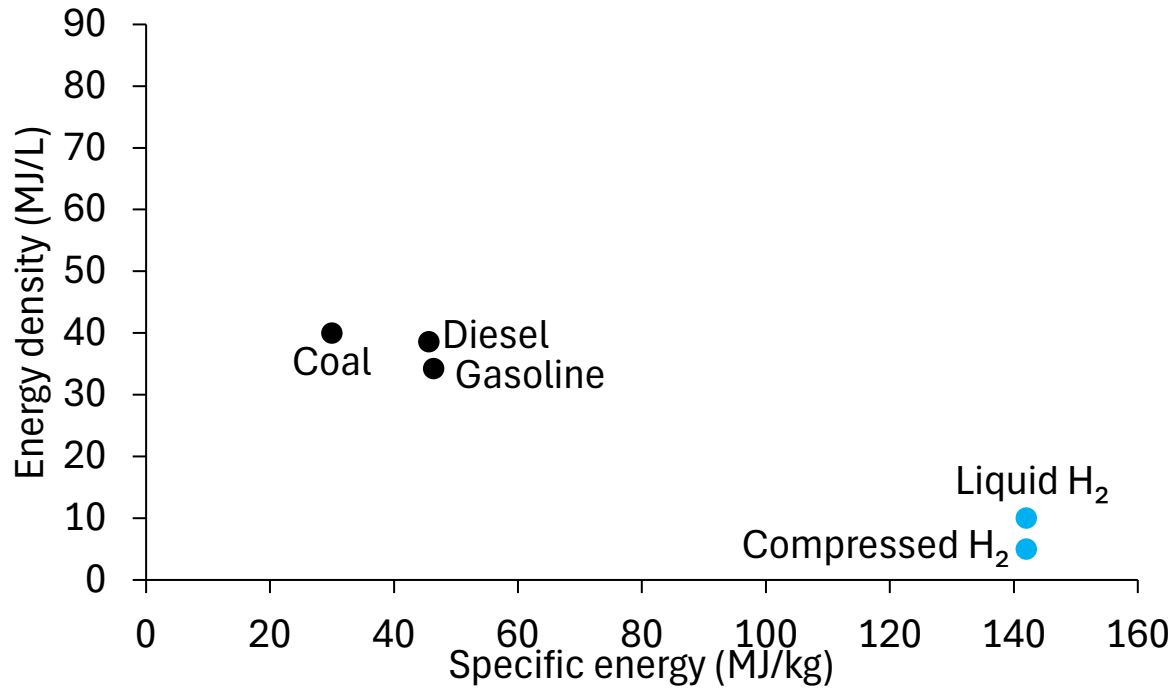
# Mismatch in green energy supply and demand

Both temporal and spatial



# Long-term energy storage becomes more important

What options do we have?



To carry the same amount of energy

Diesel

Liquified hydrogen

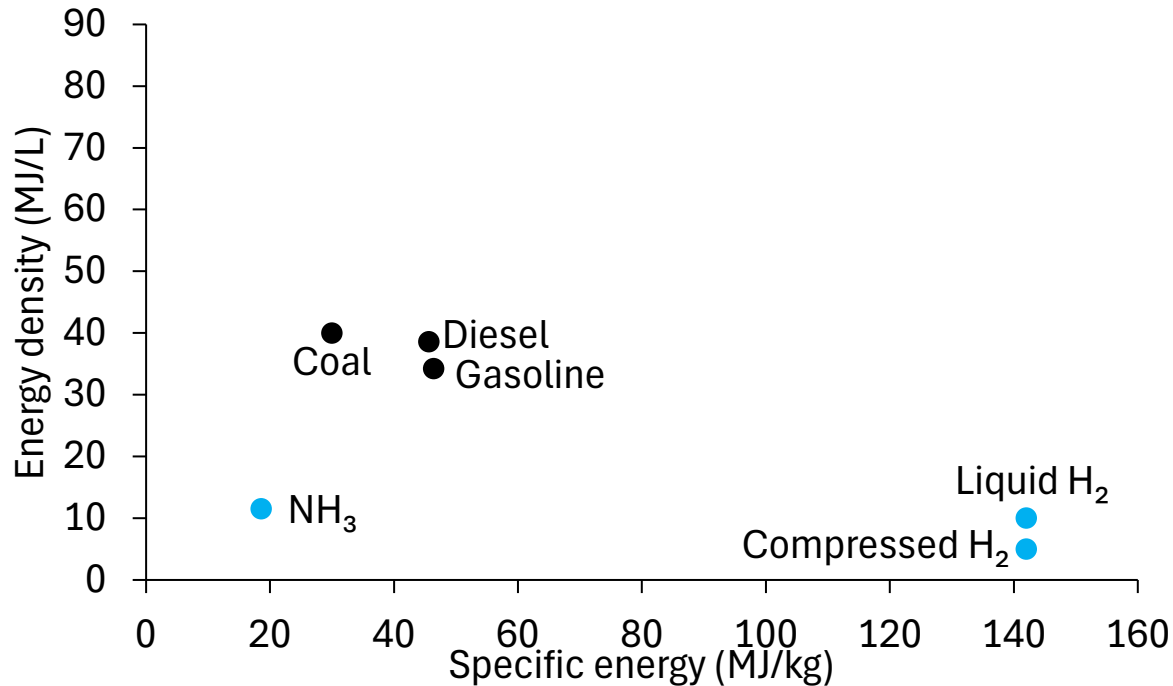
## Hydrogen

- 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

The image shows four fuel containers. The first is a black Diesel fuel pump nozzle. The next three are blue containers labeled NH<sub>3</sub>, representing Liquid ammonia. The fourth is a blue container labeled NH<sub>3</sub> U, representing Ammonia. This visualizes that a much smaller volume of ammonia is needed to store the same amount of energy as a larger volume of diesel.

## Ammonia

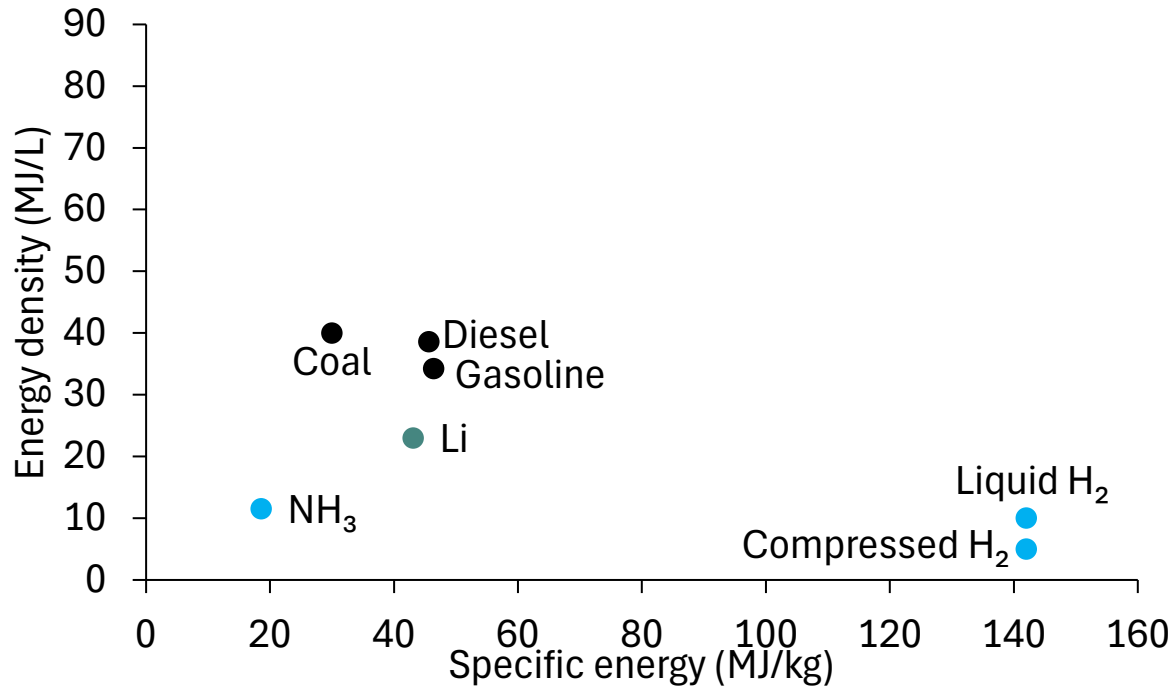
- Slightly higher energy density
- Easier to store



A standard hazard warning sign for ammonia. It features a blue header with the word "NOTICE" in white. Below the header is a white diamond-shaped hazard pictogram with a red border, divided into four quadrants: top-left shows a gas cylinder, top-right shows a tree and a dead animal, bottom-left shows a skull and crossbones, and bottom-right shows a hand being burned. Below the pictogram, the word "AMMONIA" is written in large, bold, black letters. At the bottom, a black box contains the text: "Do not handle ammonia or perform any task unless you have the required training, license and/or certification."

# Long-term energy storage becomes more important

What options do we have?



To carry the same amount of energy



## Lithium-ion battery

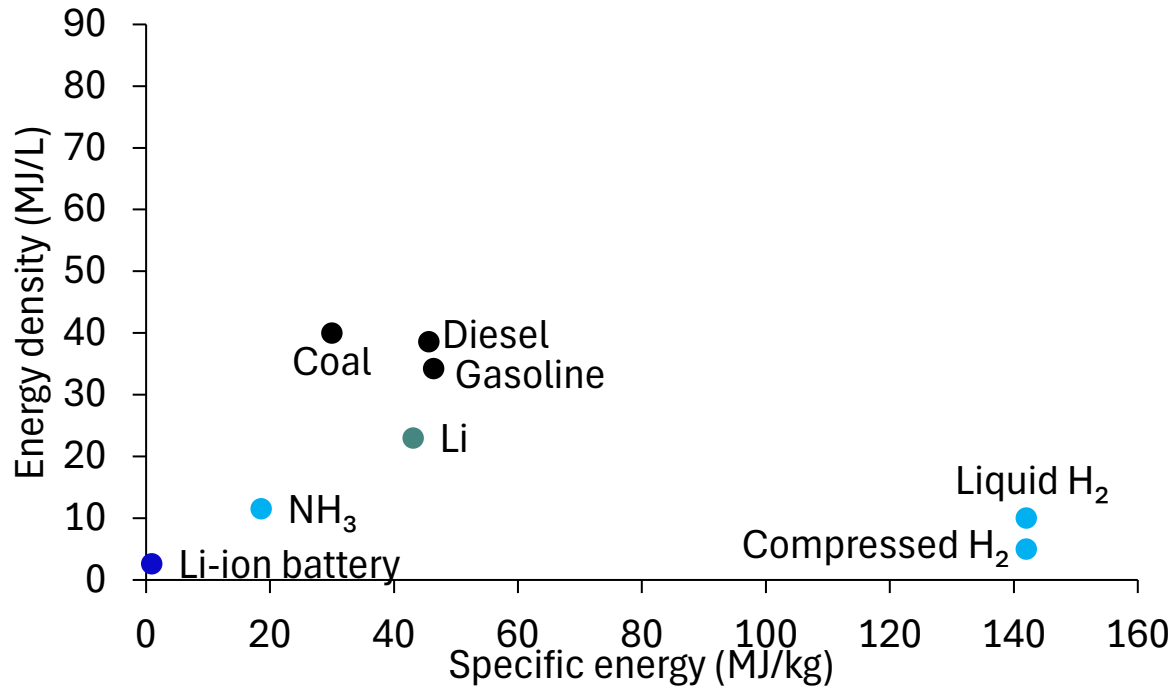
- Lithium cannot easily burn with air
- Li-ion battery carries both fuel (Li) and oxidizer (CoO<sub>2</sub>)





# Long-term energy storage becomes more important

What options do we have?



To carry the same amount of energy



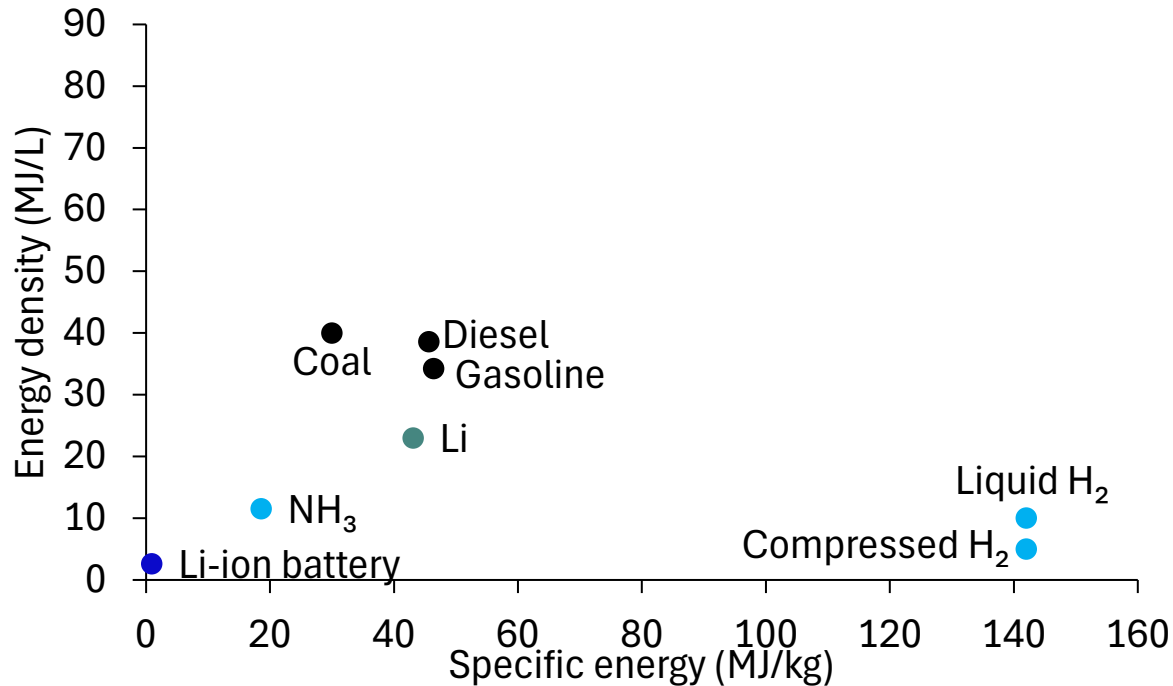
## Lithium-ion battery

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# Long-term energy storage becomes more important

What options do we have?



## Lithium-ion battery

- Lithium cannot easily burn with air
- Li-ion battery carries both fuel (Li) and oxidizer (CoO<sub>2</sub>)

Approximately 3% discharge rate per month

To carry the same amount of energy



Diesel

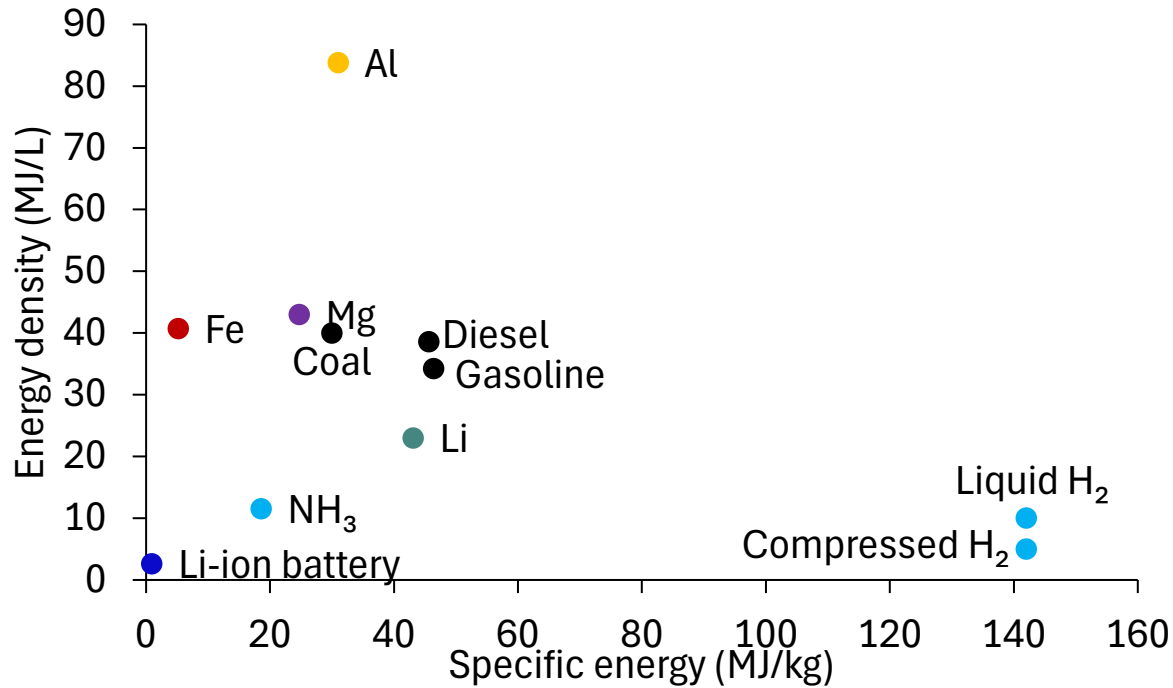


Li-ion battery



# Long-term energy storage becomes more important

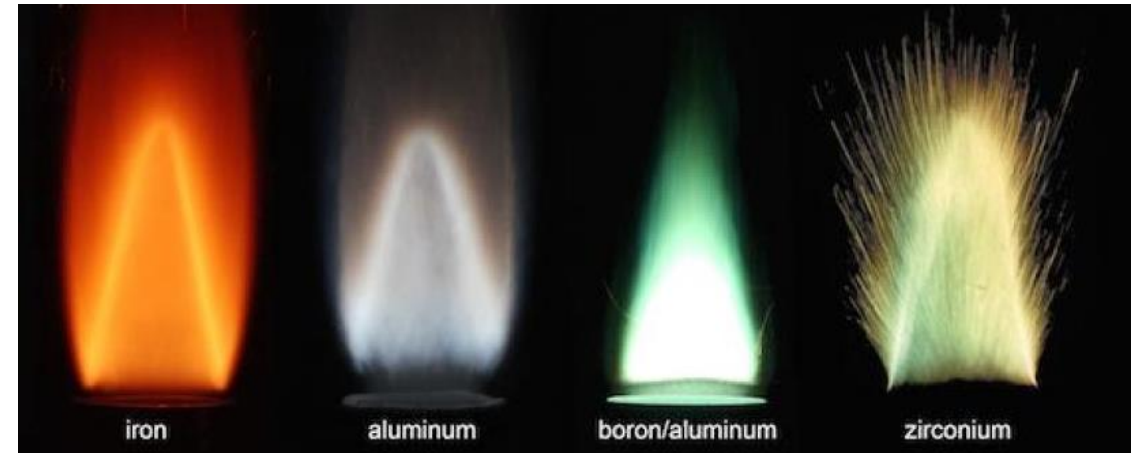
What options do we have?

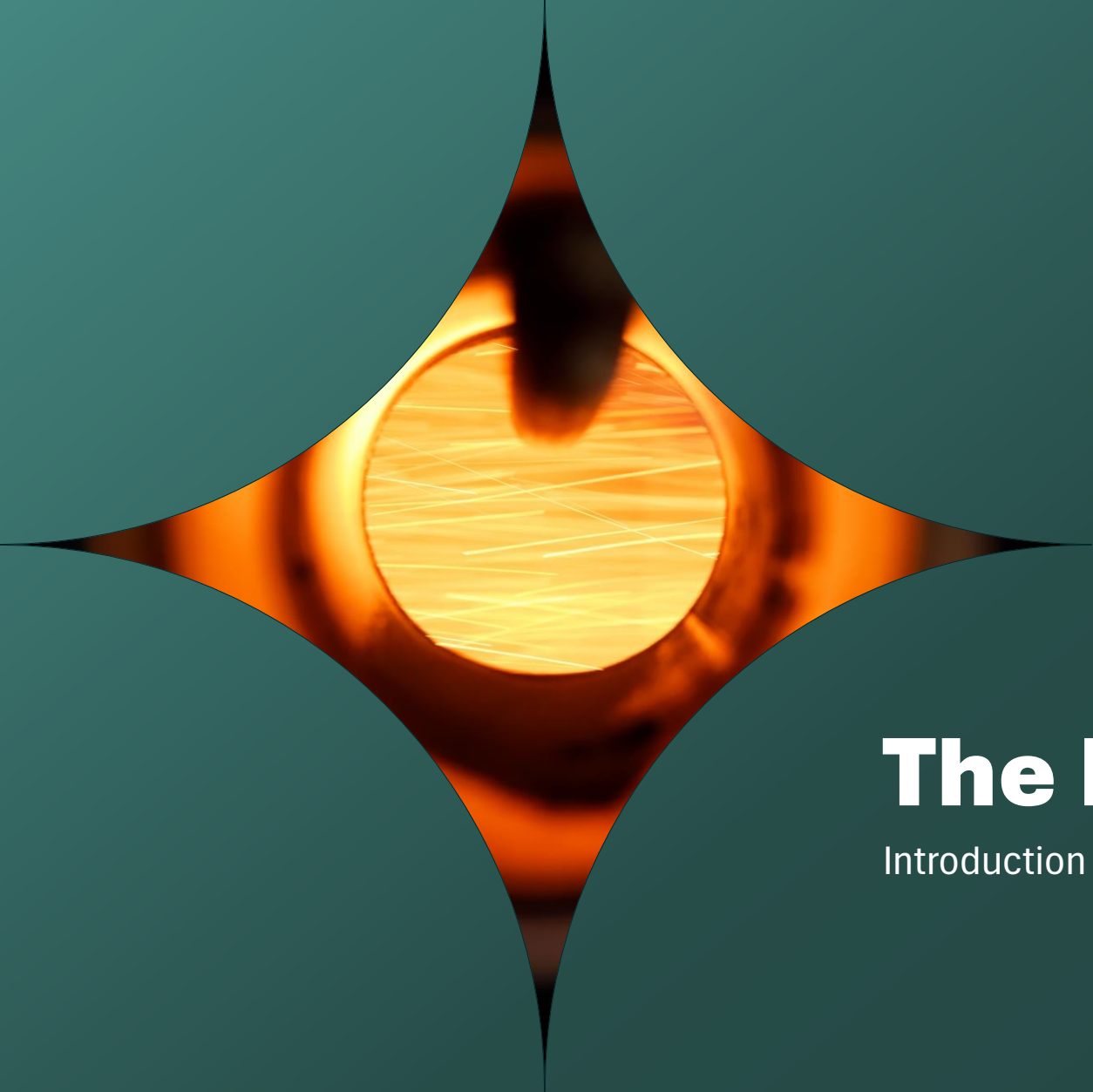


To carry the same amount of energy

Diesel      Fe      Al      Mg

## Metals





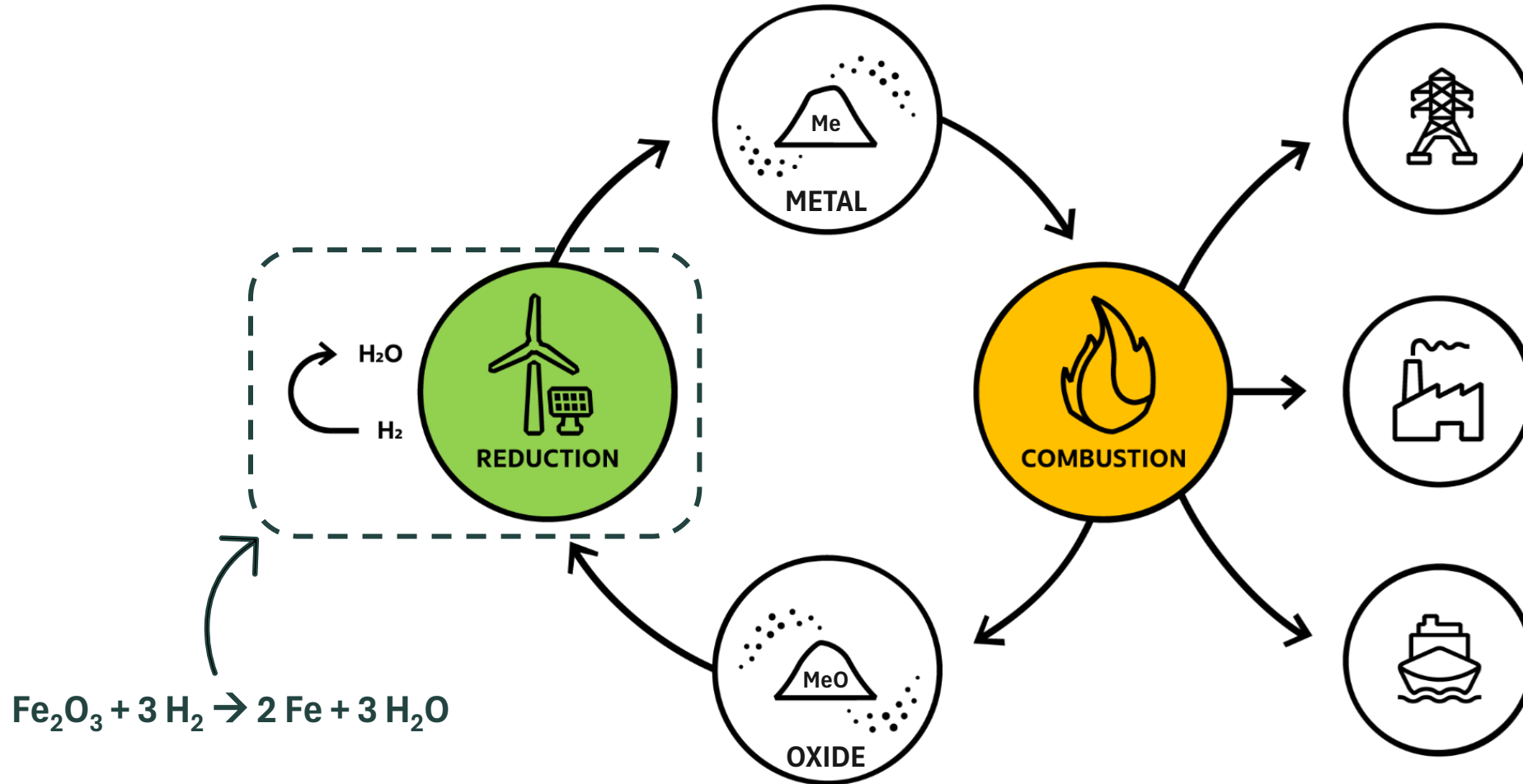
# The Metal Power Cycle

Introduction to the Metal Power Cycle and its key benefits



# Metals as sustainable energy carrier

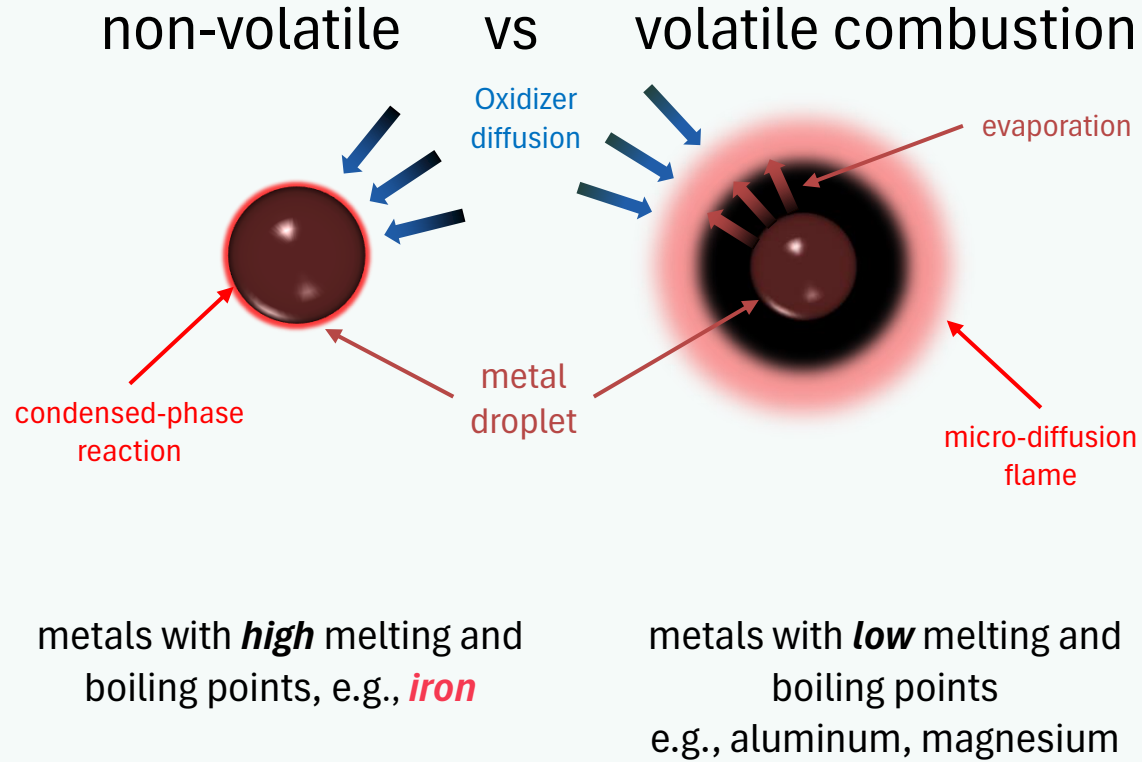
Sustainable energy storage and transportation in a circular value chain



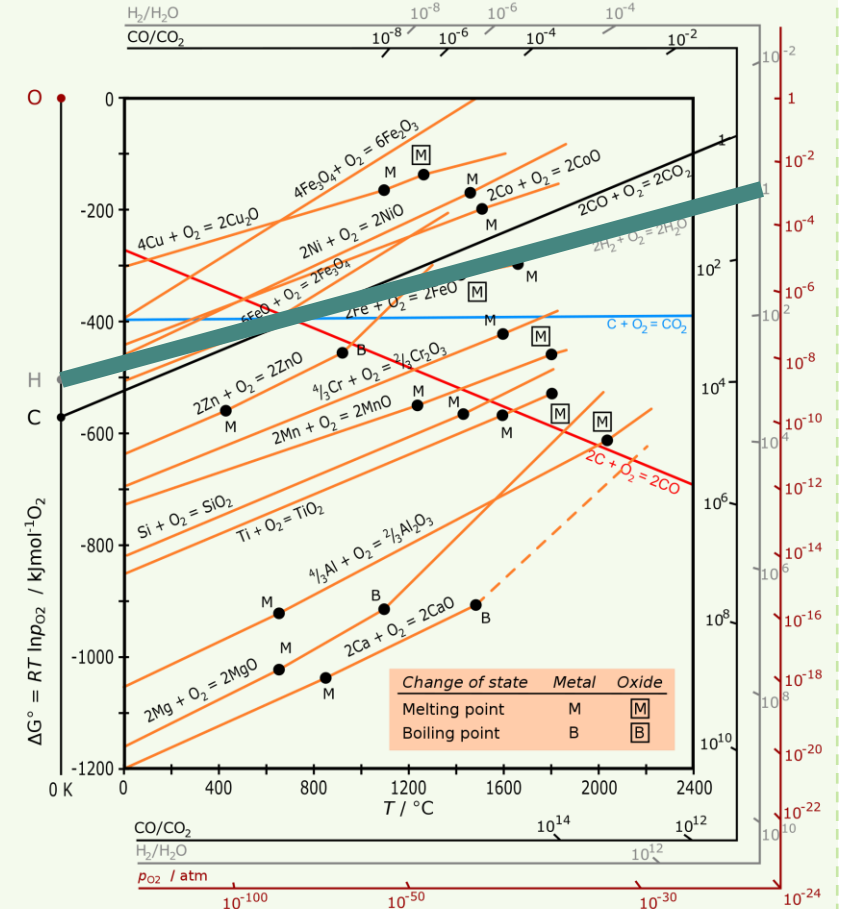
# Iron as the perfect candidate

For both oxidation and reduction

## Oxidation



## Reduction



# Key advantages of Iron Power

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Clean

Circular

Safe

Compact

Cheap

# Key advantages of Iron Power

No gaseous reaction products

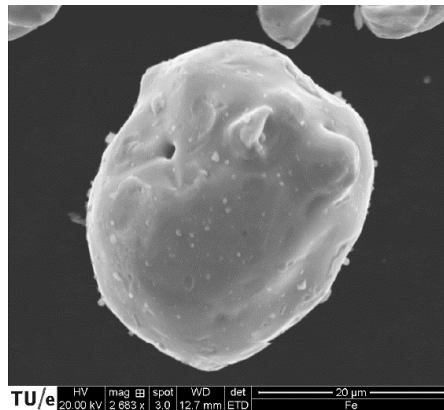
Clean

Circular

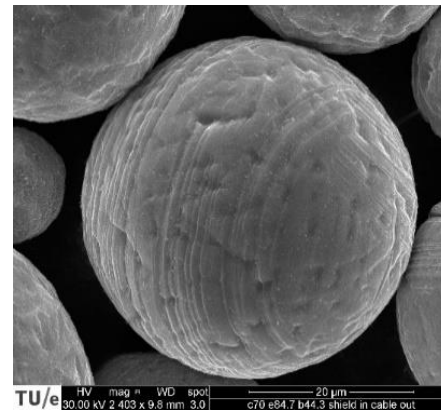
Safe

Compact

Cheap



Iron



Iron oxide

- No CO<sub>2</sub> emissions

- Very low NOx emissions



# Key advantages of Iron Power

Iron powder can be recycled many times

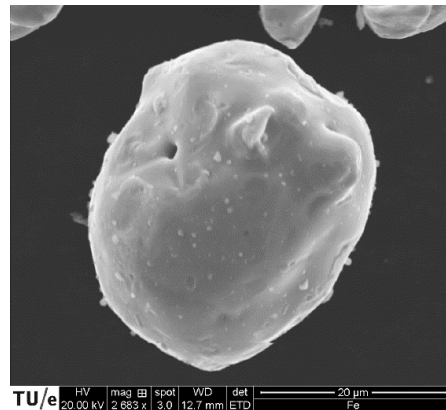
Clean

Circular

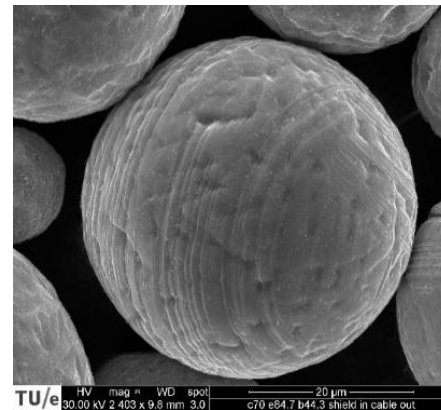
Safe

Compact

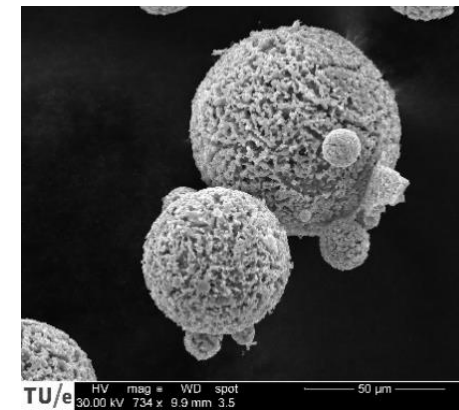
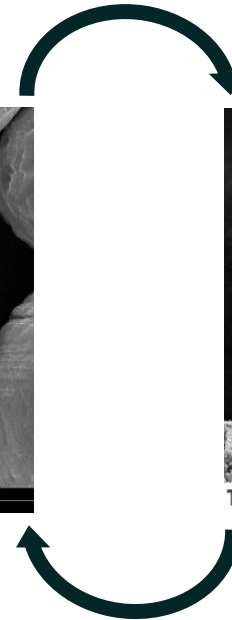
Cheap



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 <sub>3</sub> OH)	X	X	X			
Hydrogen (H <sub>2</sub> )	X					X
Ammonia (NH <sub>3</sub> )		X		X	X	X
Iron (Fe) and Fe <sub>2</sub> O <sub>3</sub>	X					

# Key advantages of Iron Power

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

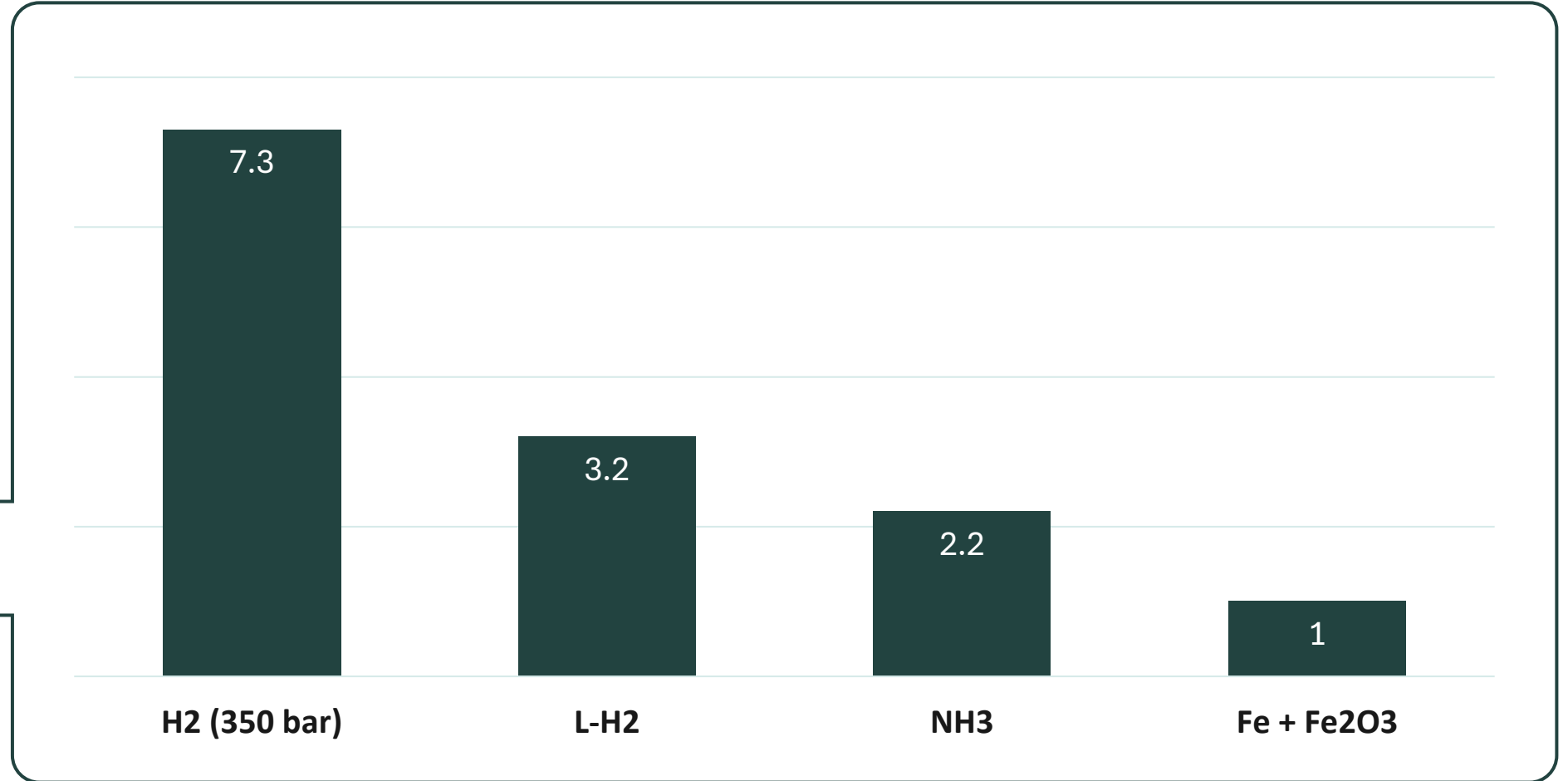
Clean

Circular

Safe

Compact

Cheap



# Key advantages of Iron Power

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

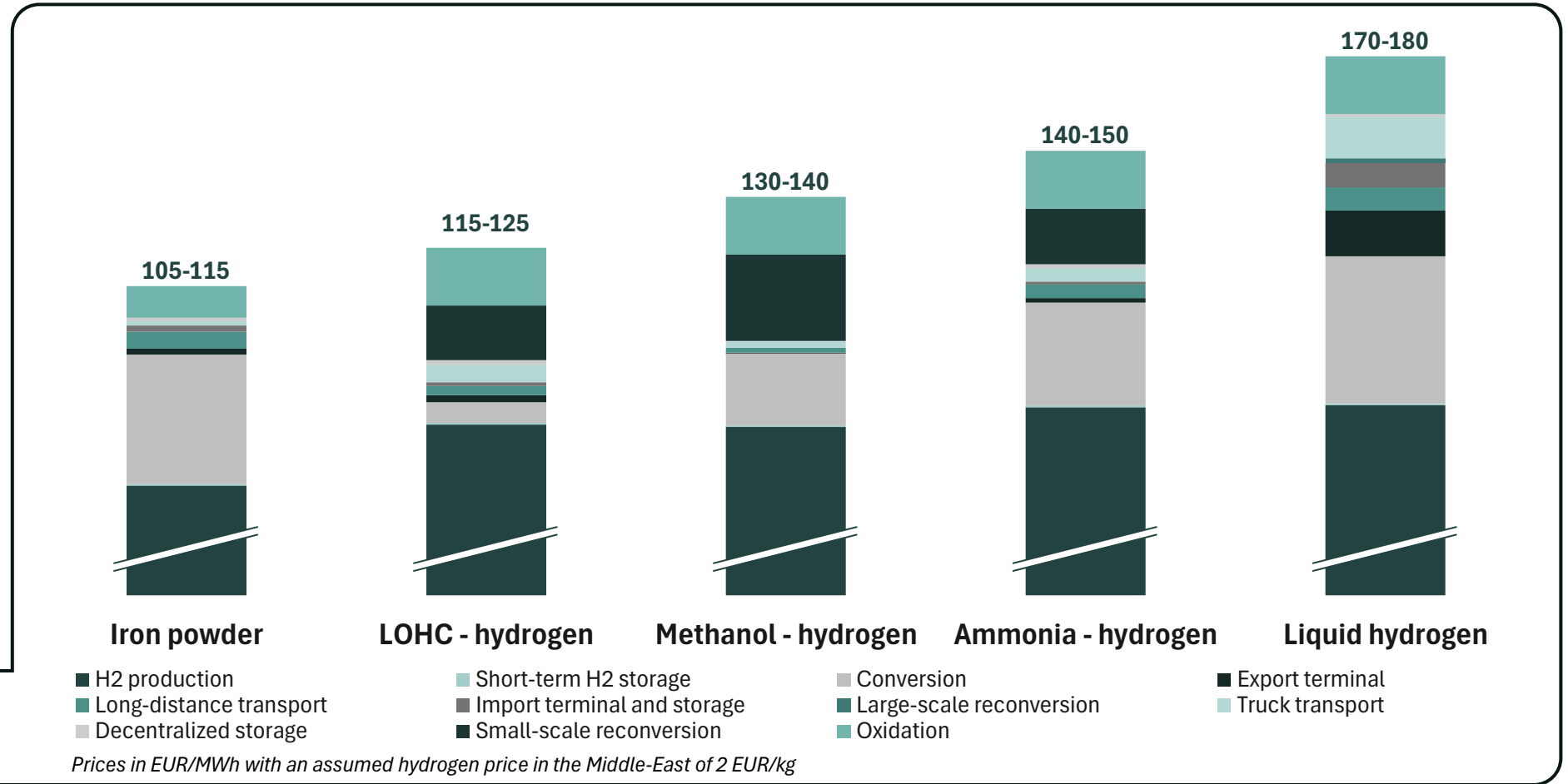
Clean

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



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

2<sup>nd</sup> gen. Swinkels



# From theory to practice

Current status of technology and future roadmap

2023



**2<sup>nd</sup> gen. combustion equipment pilot by Iron+ at Swinkels Brewery, 500 kW**



**1<sup>st</sup> gen. reduction system by start-up RIFT, 80 kW**

2024



**2<sup>nd</sup> gen. com  
Ennatuurlijk c**

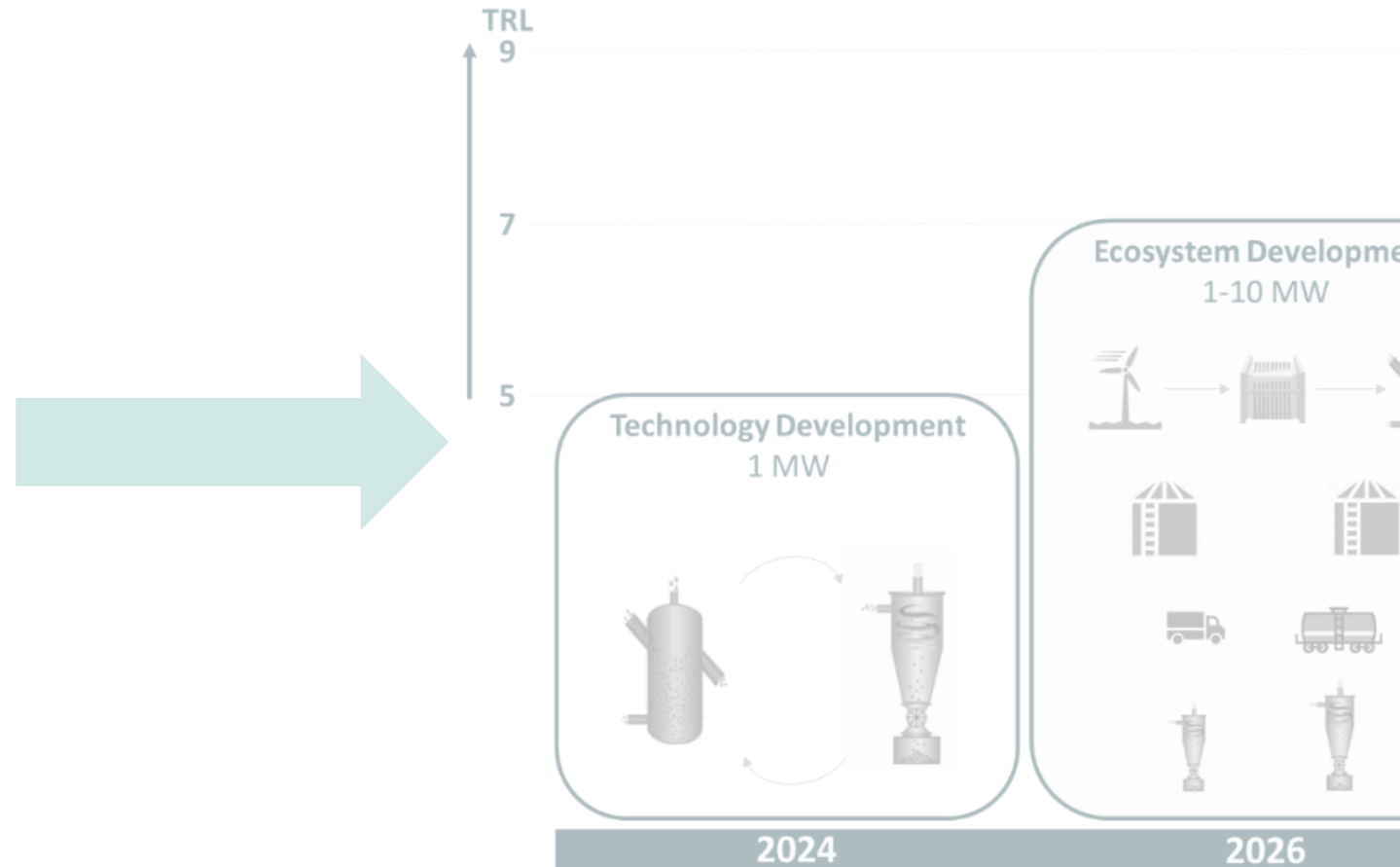
# From theory to practice

Current status of technology and future roadmap

2024



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



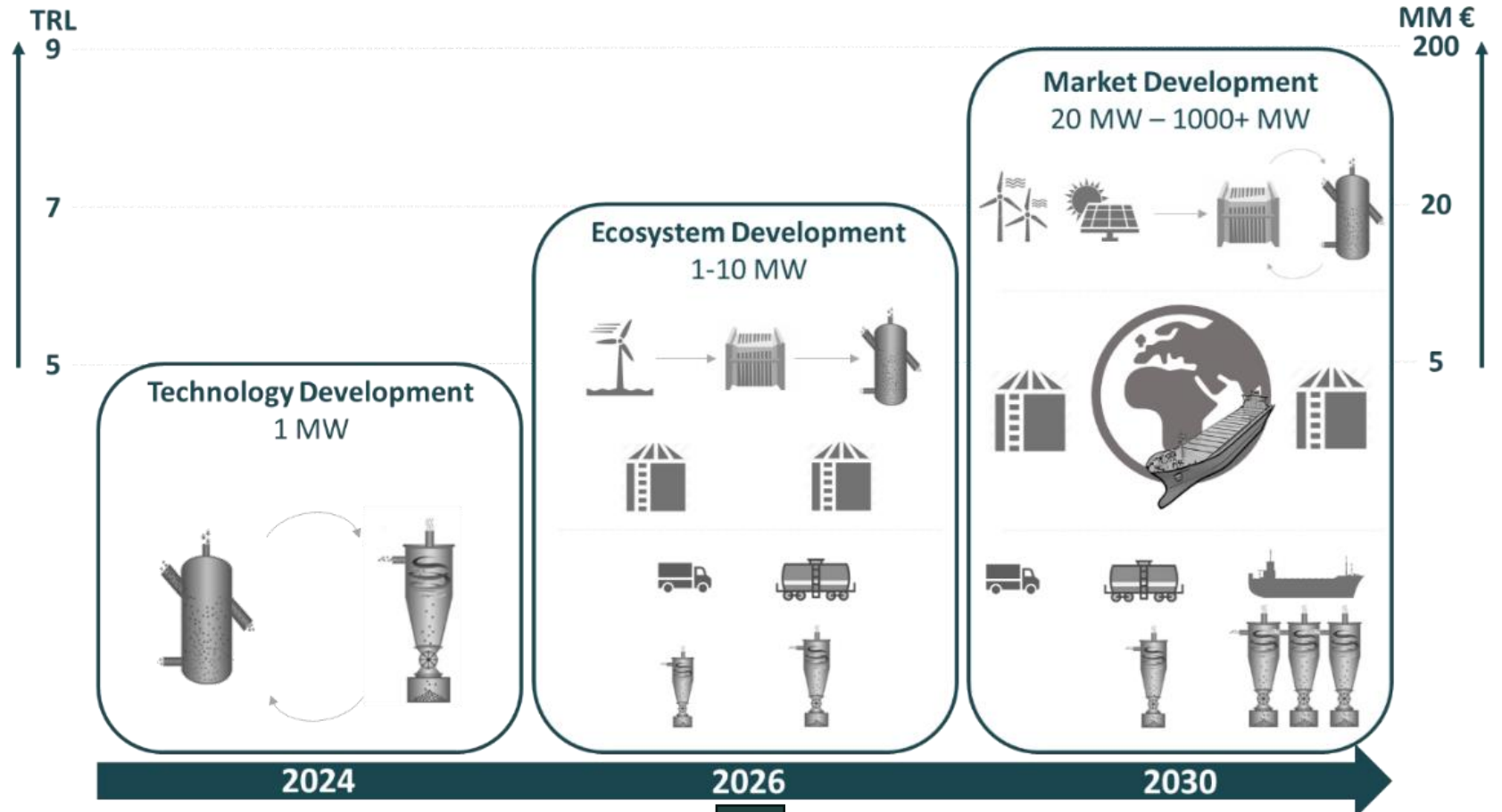


# From theory to practice

Current status of technology and future roadmap



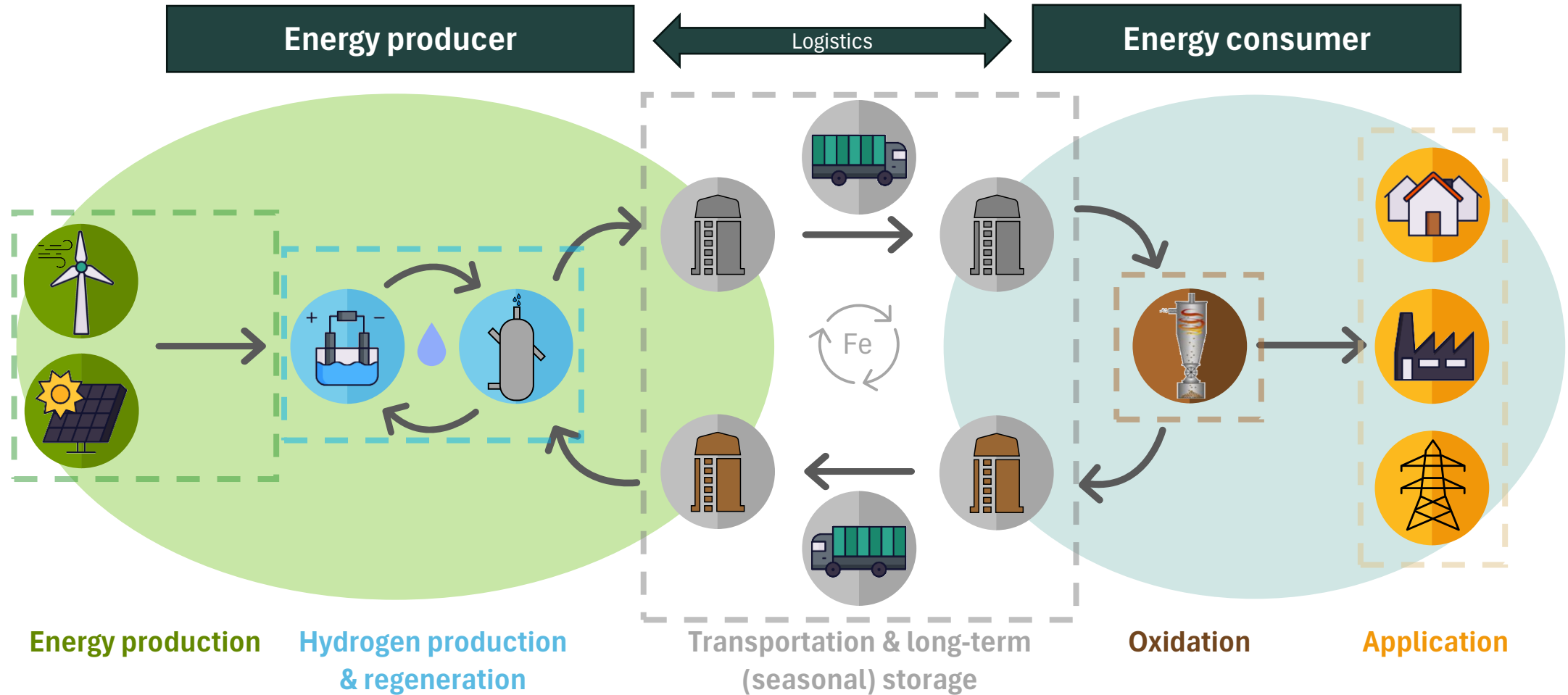
by RIFT at





# Identifying early adopter cases

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



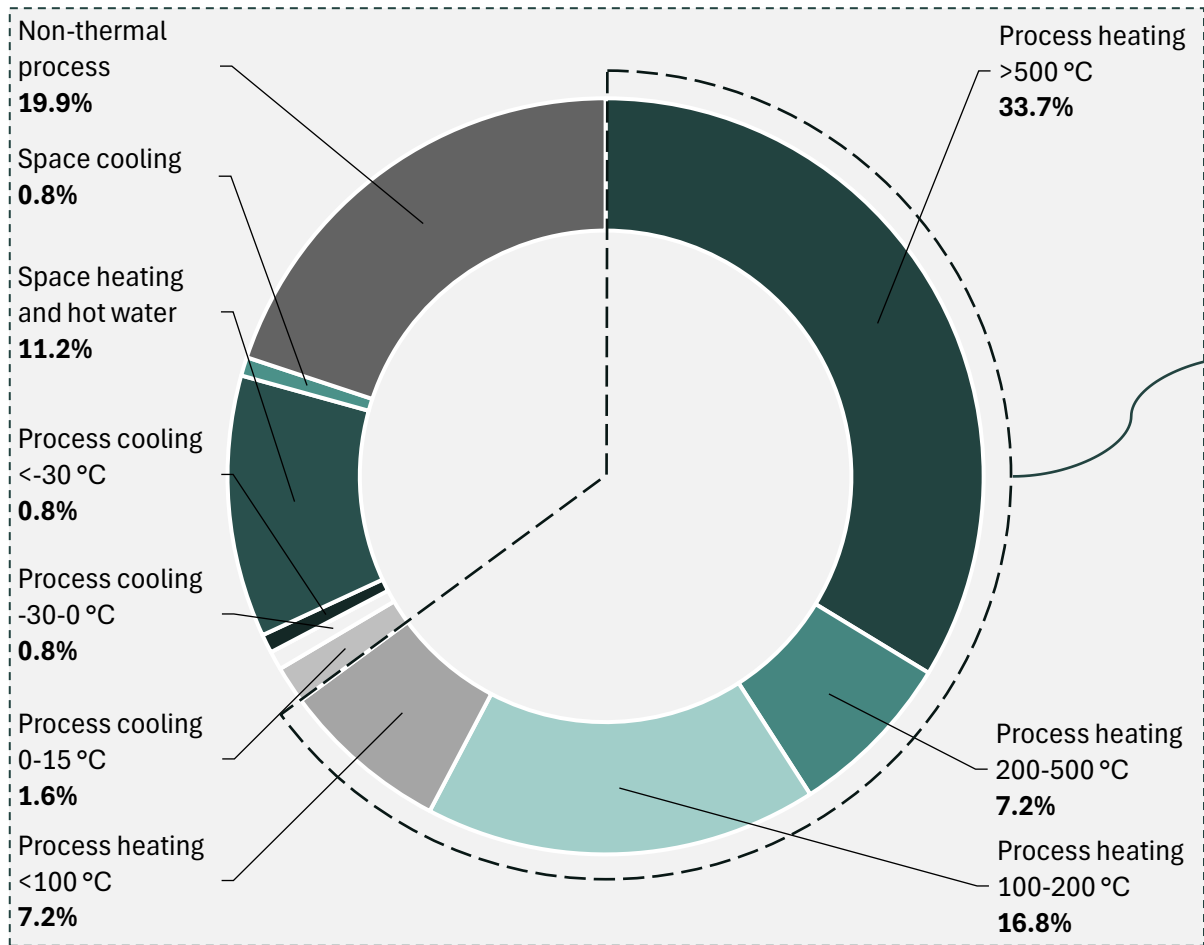


# Potential impact

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

# Energy consumption by industry

Breakdown of energy consumption for industrial processes









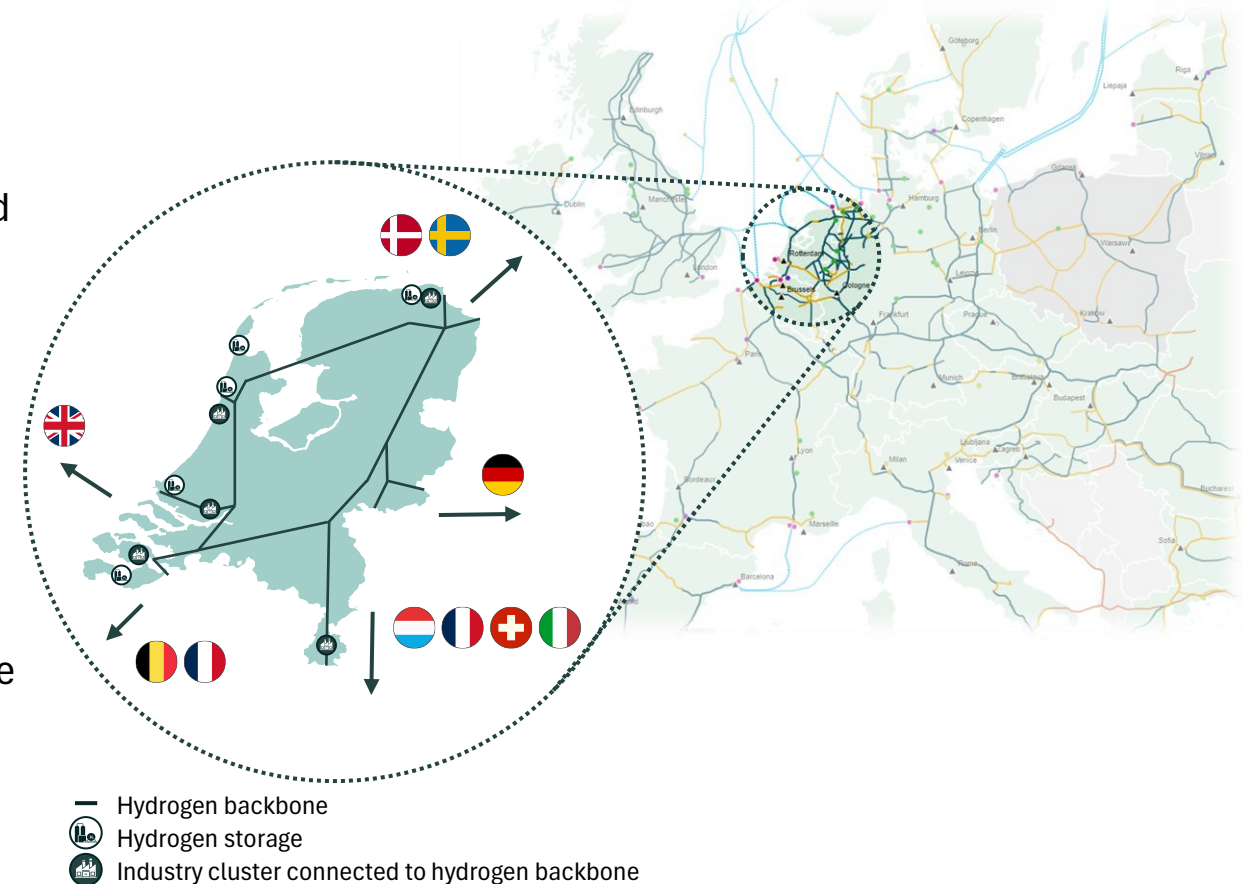
Source: European Energy Research Alliance, IEA 2023

- 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

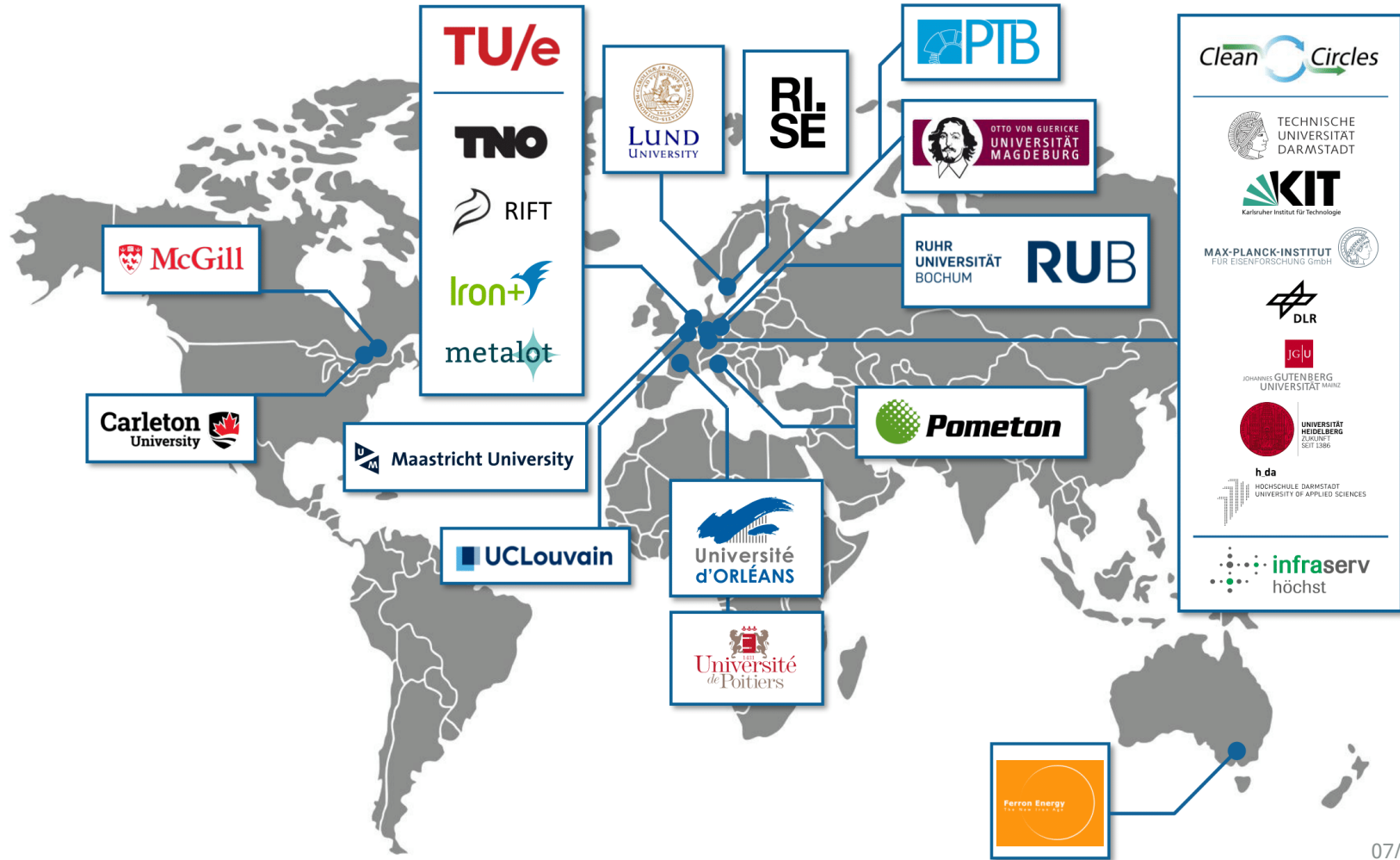
-  Only 5 large geographical **industry clusters** will have access to hydrogen from the backbone
-  Not connected to the hydrogen backbone and therefore need **alternative distribution methods**
-  Responsible for c. **30% of industrial CO<sub>2</sub> emissions** in the Netherlands
-  Chemical-, ceramic-, 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



Source: Dutch Ministry of Economic Affairs (EZK), Koploperprogramma Het Zesde Cluster, Smart Energy hubs Kracht van Oost, VNO-NCW, Metalot, Roland Berger

# The Iron Power ecosystem

A fast-growing community with Metalot as ecosystem builder



# Burning questions?



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