Critical Resources for H2-Powered Aviation – A Global and Regional Perspective

Finn Schenke, DLRK 29.09.2022

Agenda

Introduction of H2-powered aviation requires an analysis of the resource requirements

01 Aviation is responsible for 3% of global CO2 emissions (about 5% global warming potential)

02 The goal is to meet net-zero CO2 emissions in 2050

03 H2-powered aircraft could reduce the climate impact by 75-90%

Source: Clean Sky 2 JU, FCH 2 JU (2020)

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Are there any resource limitations for the implementation of global H2-powered aviation?

01 **What are the resource conflicts and scarcities caused by H2 production from a global and regional perspective?**

02 **How does the implementation of H2-powered aviation enhances these conflicts and scarcities?**

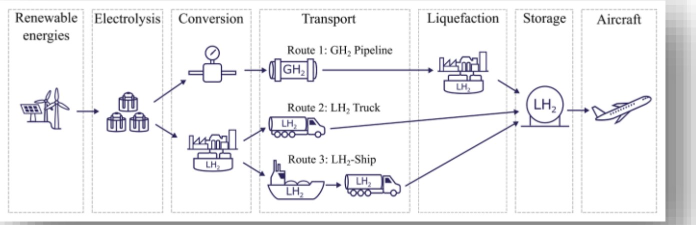
03 **Are there any substitutions for identified critical resources to deal with the limitations?**

Source: Clean Sky 2 JU, FCH 2 JU (2020)

Agenda

The research design is divided into three parts

A Development of H2 supply chains



B H2 demands and sensitivity scenarios

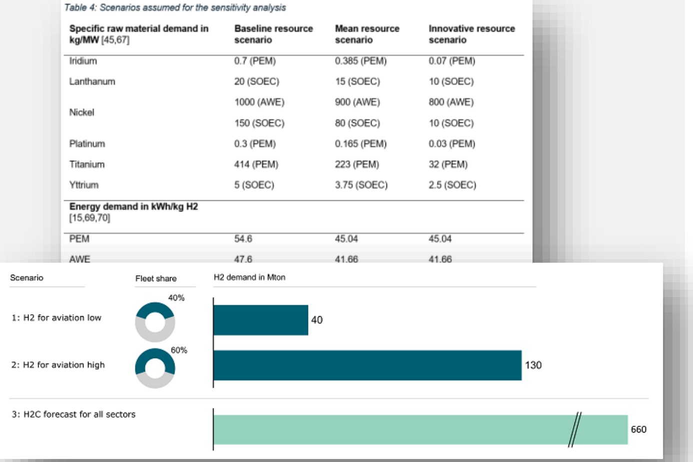
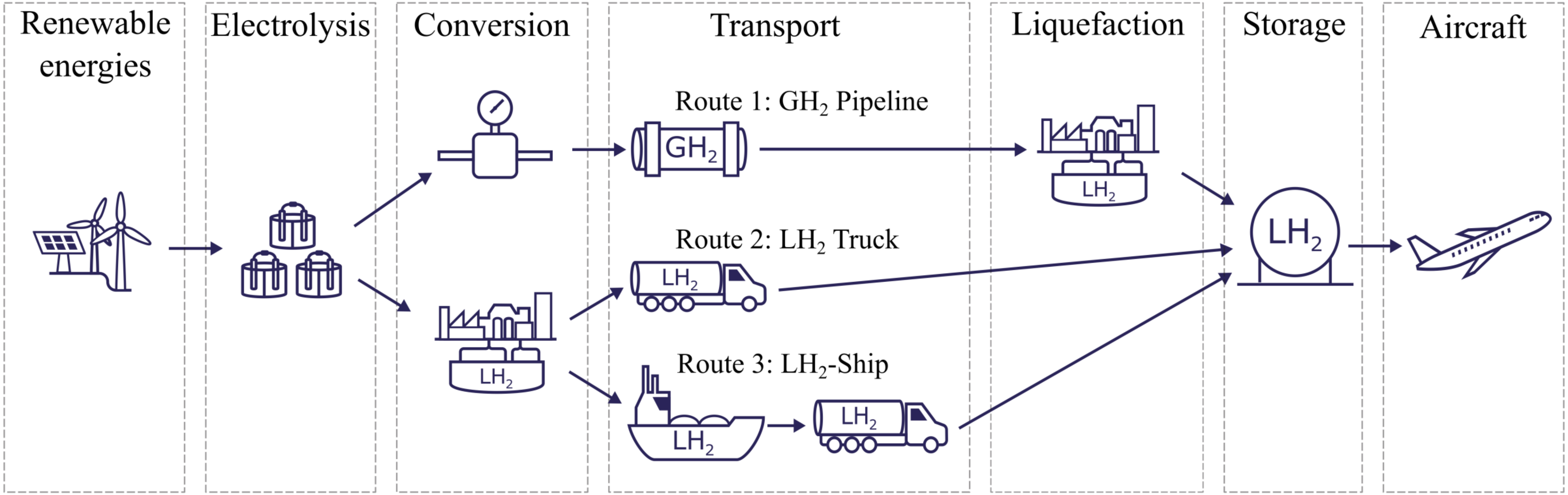


Table 4: Scenarios assumed for the sensitivity analysis

Specific raw material demand in kg/MW [45,67]	**Baseline resource scenario**	**Mean resource scenario**	**Innovative resource scenario**
Iridium	0.7 (PEM)	0.385 (PEM)	0.07 (PEM)
Lanthanum	20 (SOEC)	15 (SOEC)	10 (SOEC)
Nickel	1000 (AWE)	900 (AWE)	800 (AWE)
	150 (SOEC)	80 (SOEC)	10 (SOEC)
Platinum	0.3 (PEM)	0.165 (PEM)	0.03 (PEM)
Titanium	414 (PEM)	223 (PEM)	32 (PEM)
Yttrium	5 (SOEC)	3.75 (SOEC)	2.5 (SOEC)
Energy demand in kWh/kg H2 [15,69,70]			
PEM	54.6	45.04	45.04
AWE	47.6	41.66	41.66

C Modeling the resource requirements

A | Transport scenarios for H2-powered aviation



A | Transport scenario 2: Baseline LH2-Truck

1 Electrolysis

- Combination of AWE, PEM & SOEC
- In 2050:

  AWE 40%
  PEM 40%
  SOEC 20%

2 Liquefaction

- Hydrogen Claude cycle
- Innovative energy demand of 6 kWh/kg H2
- Specific losses 1.65% per kg H2

3 Transportation

- LH2-Truck
- Capacity of 4,300 kg
- Boil-off losses 0.95 %/d

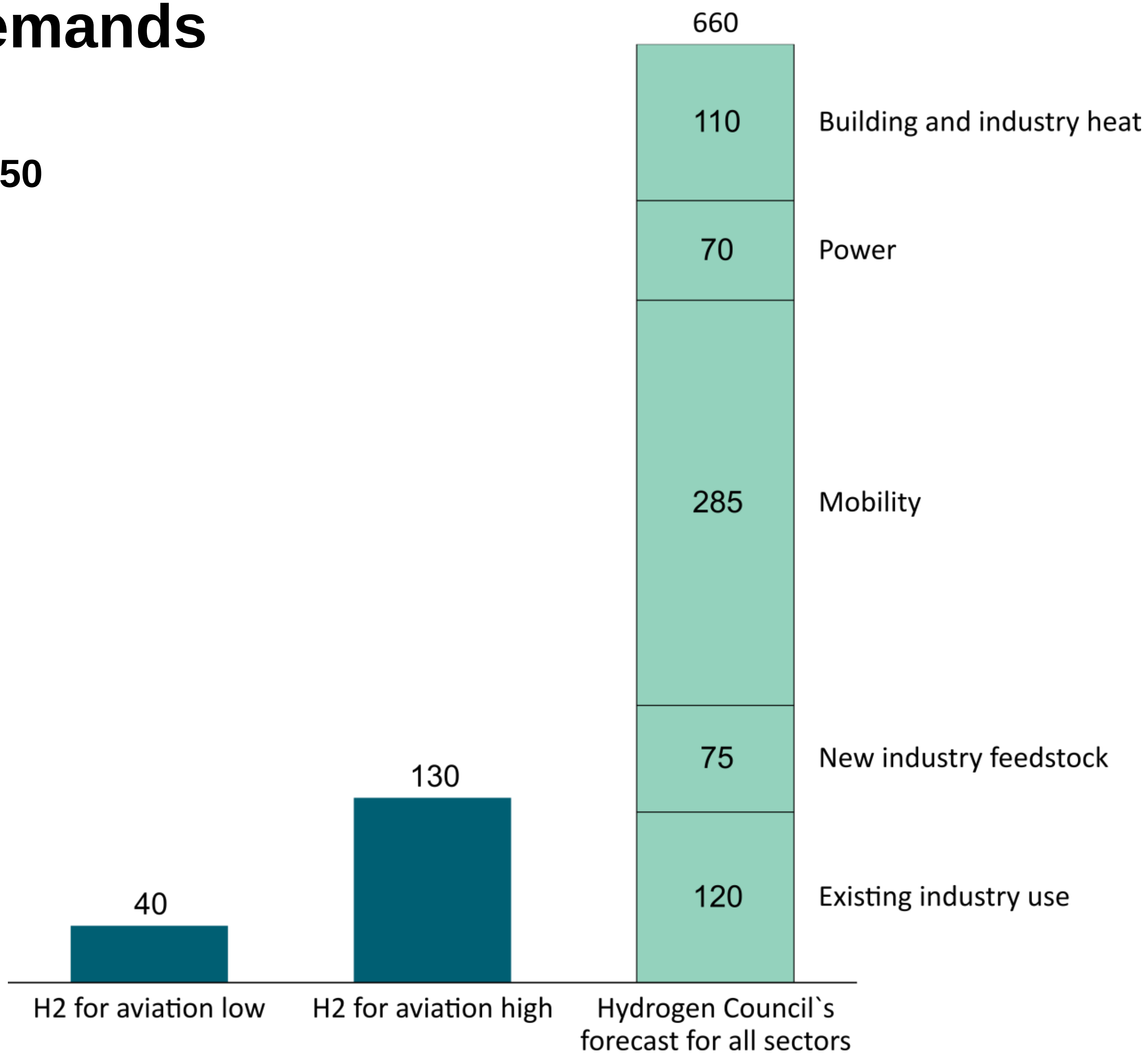
4 Storage

- Large storage tanks at the airport
- Capacity over 20,000 t
- Boil-off losses 0.06 %/d

Source: Smolinka et al. 2018, Aasadnia and Mehrpooya 2017, Hoelzen et al. 2022, Reuß et al. 2017, Alkhaledi et al. 2021

B | H2 demands

MT hydrogen per year in 2050

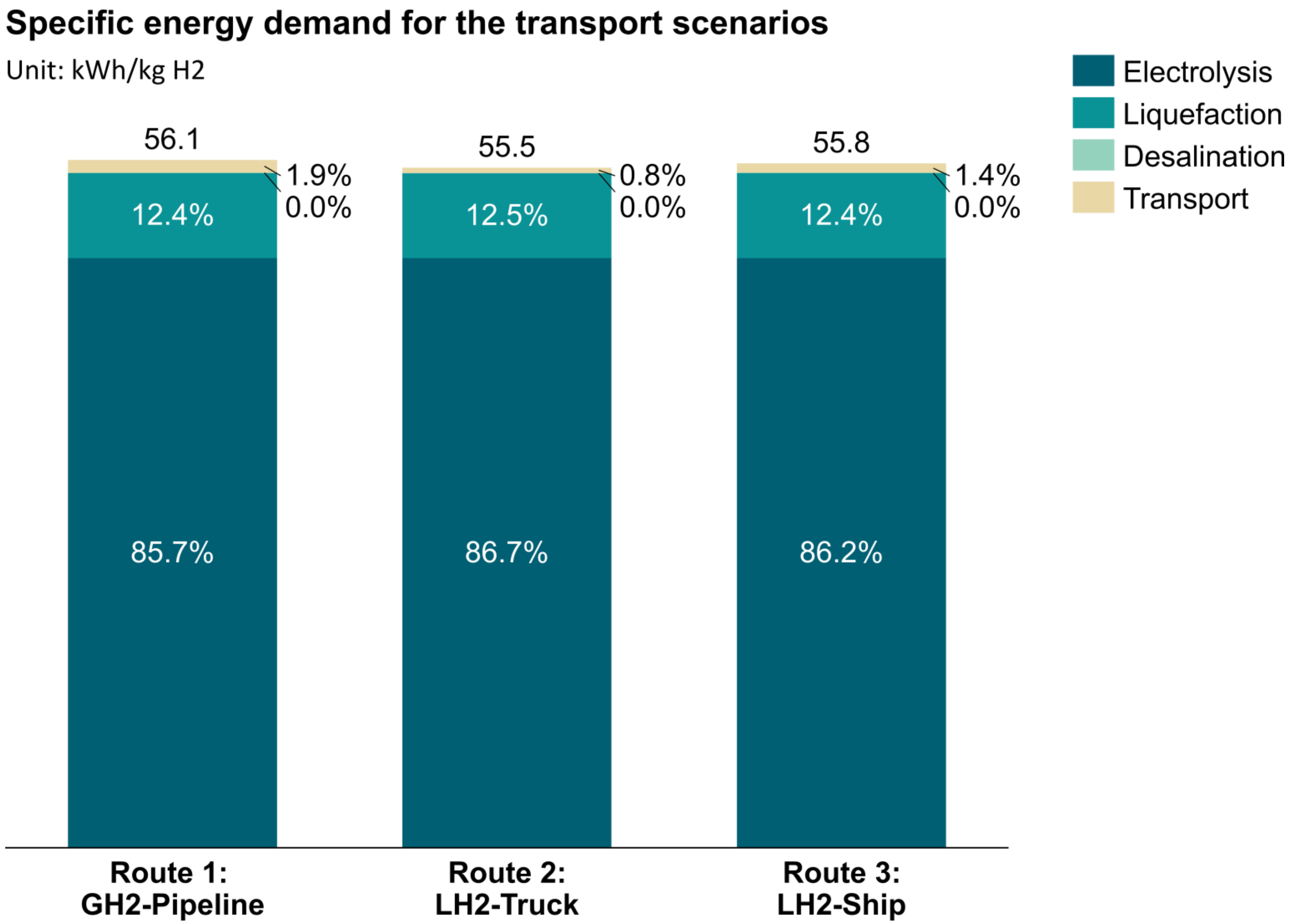


Insights

- In the low H2 for aviation scenario, 40% of all aircraft are H2-powered
- In the high H2 for aviation scenario, 60% of all aircraft are H2-powered
- The forecast for all sectors includes H2 in aviation for H2-based SAF

Source: Clean Sky 2 JU, FCH 2 JU (2020), Hydrogen Council (2021)

C | Modeling



Insights

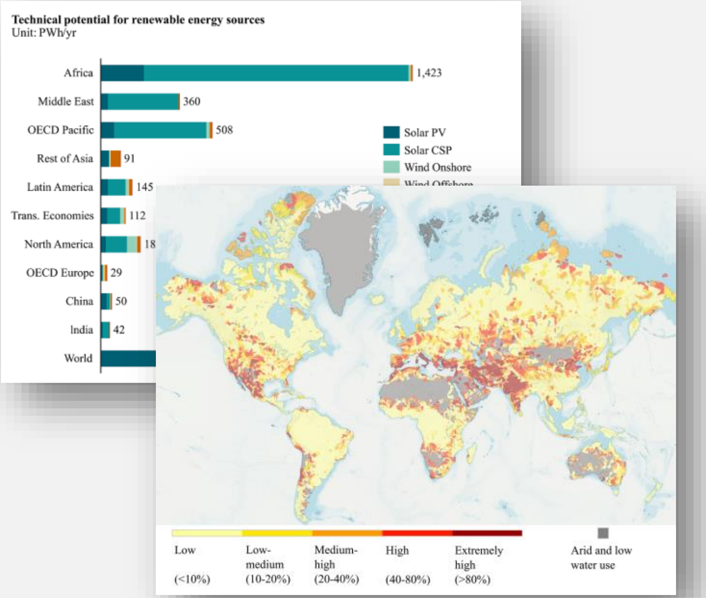
- The way of transport has only a minor impact on the total energy and water demand
- Seawater desalination has comparably small energy demand

Agenda

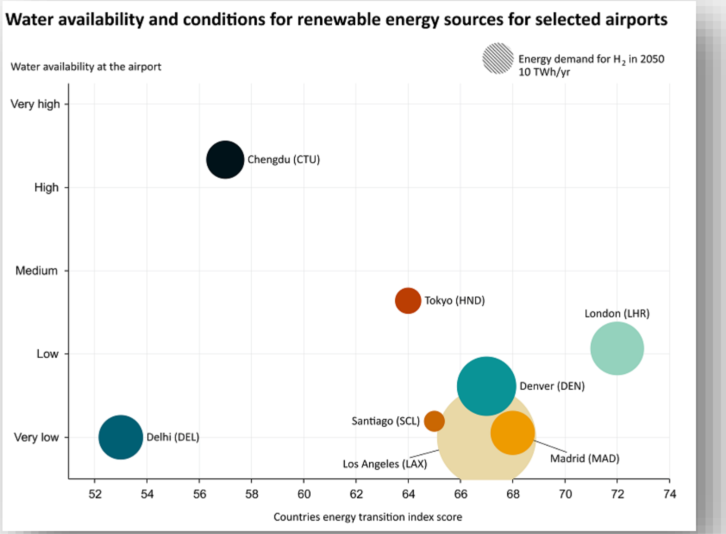
The results are evaluated from three perspectives

A Deployment phase

B Operational phase – Global

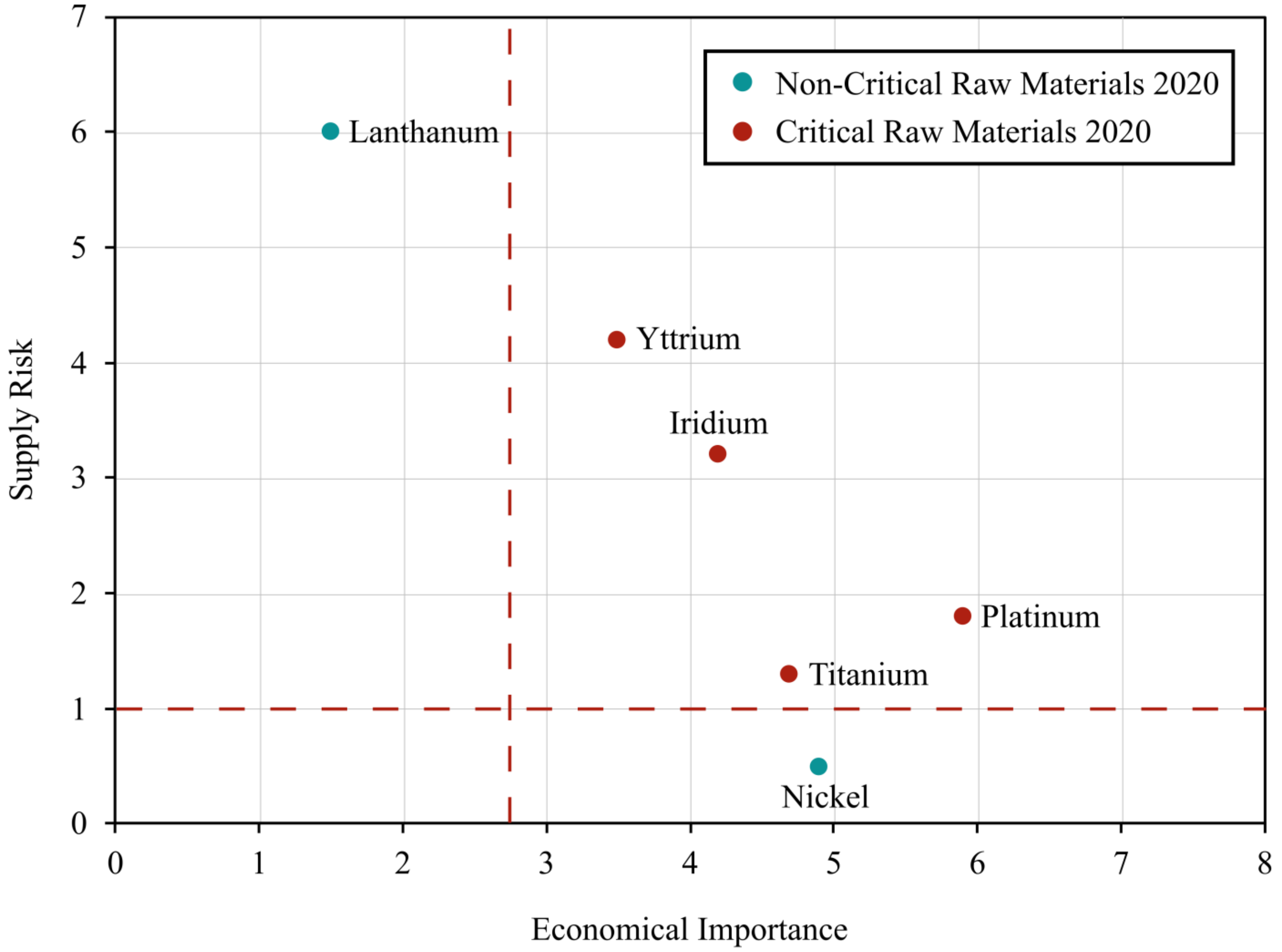


C Operational phase - Regional



A | Deployment phase – raw materials

Supply risk and economical importance for the EU of raw materials used in water electrolysis



Insights

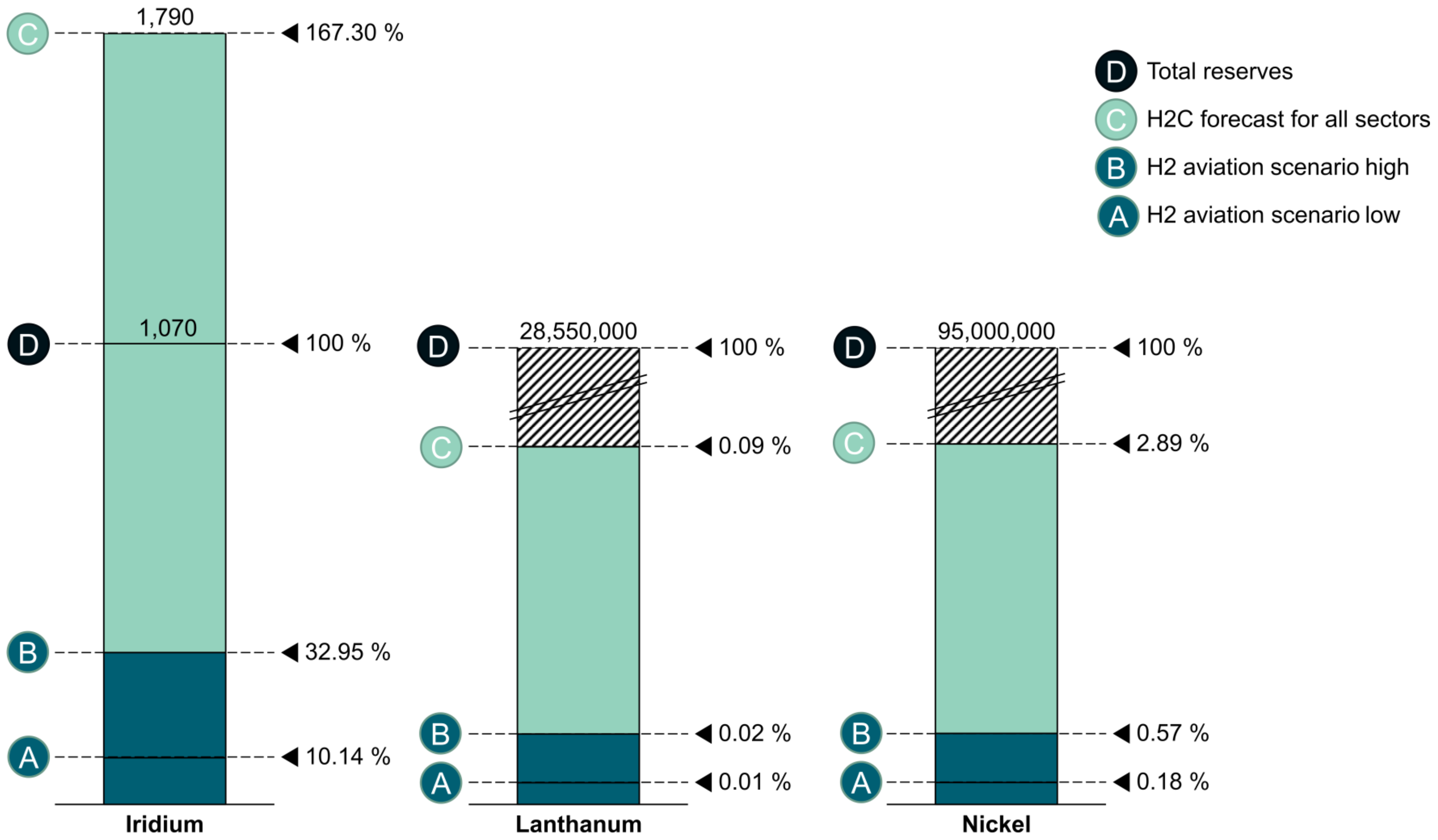
- Most of the investigated raw materials are rated “critical” by the European Commission
- Nickel and lanthanum could get critical in the future because of the application in electrical storage systems

Source: European Commission 2020

A | Deployment phase – raw materials

Total raw material demands until 2050 and share of current reserves

Unit: tons



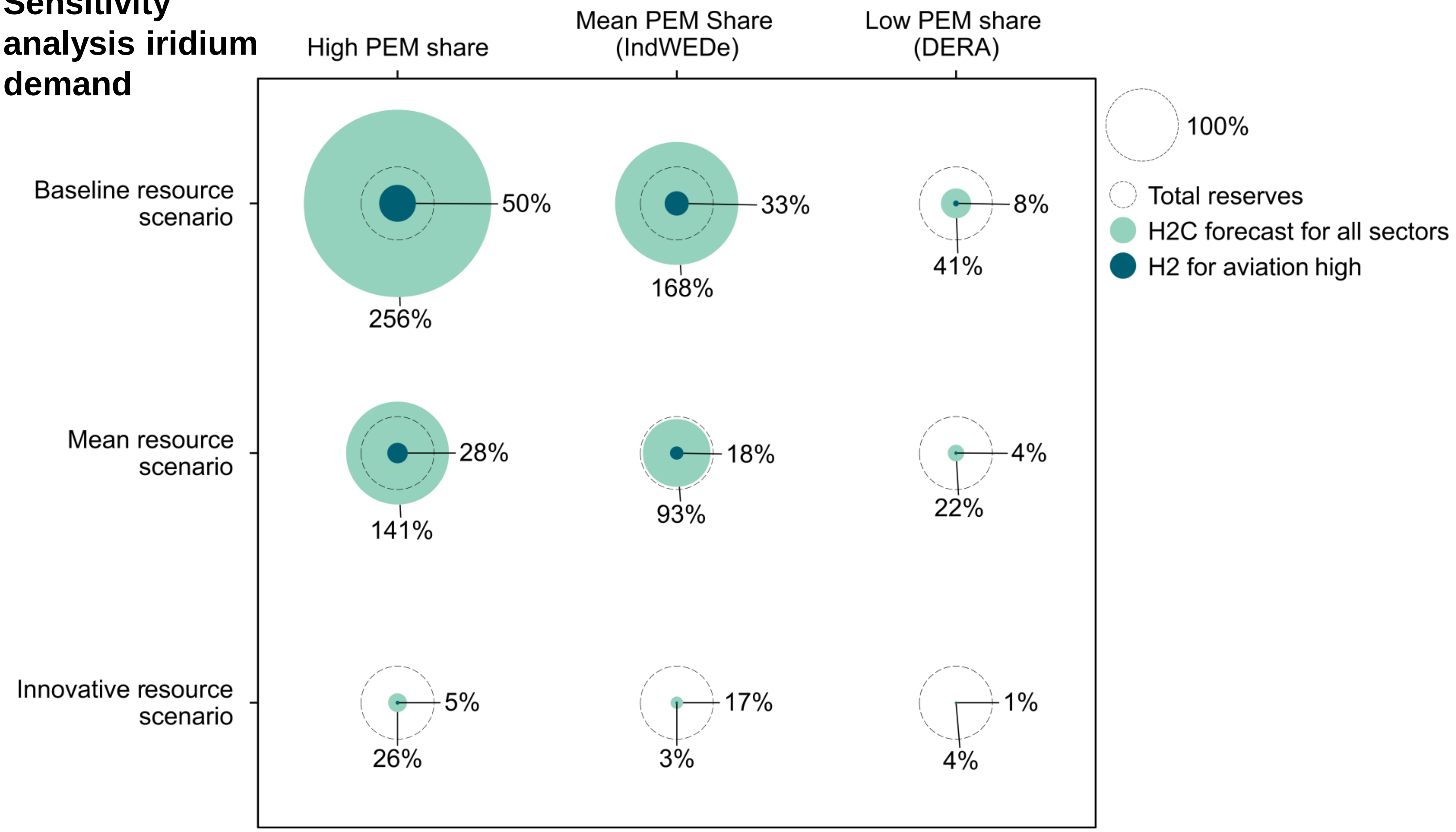
Insights

- The iridium demand in 2050 exceeds the annual production by far
- In the high PEM scenario, the iridium demand exceeds the current reserves
- The aviation's share of the raw materials are 20% in the high demand scenario
- The reserves are variable and will most likely increase in the future

Source: Own calculations, DERA

A | Deployment phase – iridium

Sensitivity analysis iridium demand



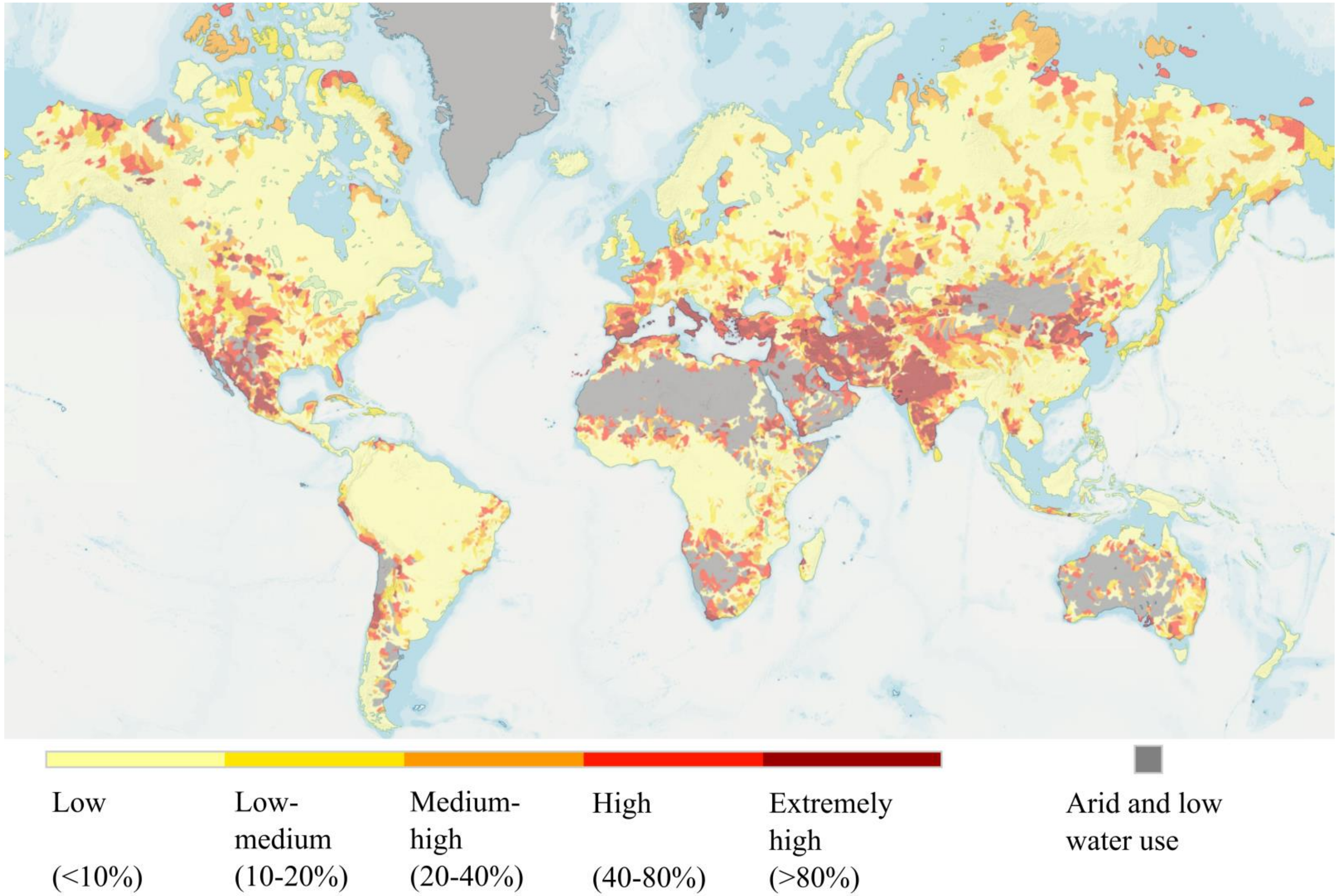
Insights

- If the specific iridium demand of the PEM electrolysis is lowered, the total demands are feasible
- The annual iridium production needs to be increased to meet the demands for H2 production

Source: USGS 2022, DERA 2021, Smolinka et al. 2018

B | Operational phase – Global perspective

Global water stress



Insights

- H2 for aviation high:
- **Energy demand: 7.2 PWh/year** in 2050 (**0.24%** of global technical RES potential)
- **Water demand: 1.72 billion m^3/year** in 2050 **(0.04%** of the global freshwater used in 2014)

Source: Aqueduct 2022, Umweltbundesamt 2009, Our World in Data 2022

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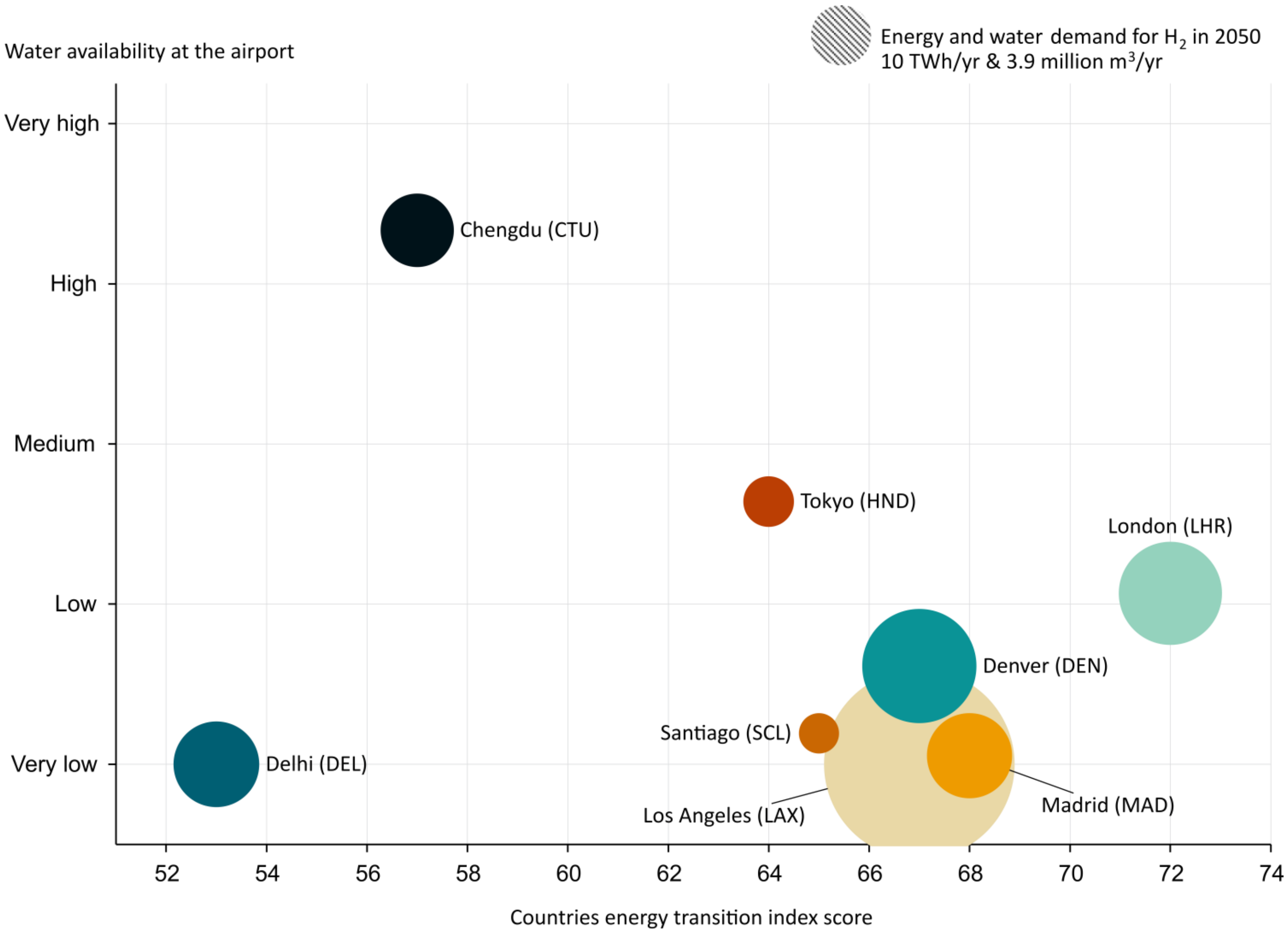
C | Regional perspective – Selected Airports

Clustering of airports based on their water availability and ETI



Insights

- Non of the investigated airports have ideal conditions for local H2 production
- At water stressed airports near the sea, seawater desalination could be used to supply water
- For airports with low availability of RES and water, H2 import is the most viable option

Source: WEF 2021, Aqueduct 2022

Agenda

Key results provide insights on the feasibility of H2-powered aviation

Key Results

Global H2 production could be limited by the **iridium** demand

From a **global perspective** the energy and water demand is feasible

68,6% of over **600** investigated airports are located in regions with water stress level under 40 %

There are airports where the conditions for renewable energy and also the water availability are insufficient

Conclusion

- The **H2-powered aviation** will most likely **not be the main reason for raw material limitations** but could be affected
- An **effective recycling infrastructure** and an **increase of production** especially for iridium is necessary to cover the future demands
- From a regional perspective, the technical **potential for renewable energy sources** as well as the **water availability can be a limiting factor** for H2 production depending on the region
- For regions with water scarcity near the sea, **desalination** is a viable alternative for the freshwater demand. For regions with low availability of renewable energy sources and freshwater, the **import of hydrogen** is the most viable option

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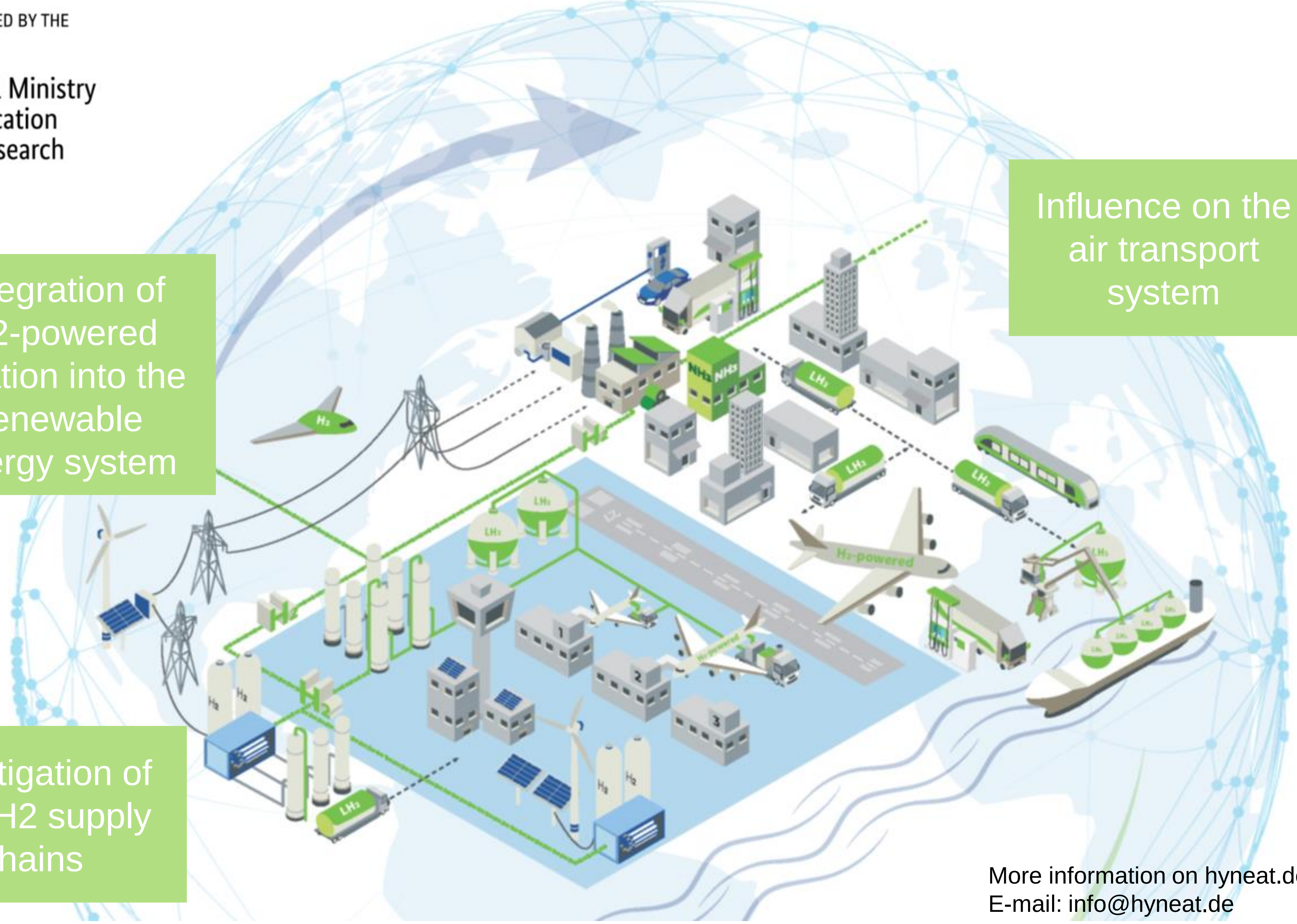
Global and local LH2 supply concepts for aviation with interconnections to the general energy transition and air transport system



Integration of H2-powered aviation into the renewable energy system

Influence on the air transport system

Investigation of the LH2 supply chains

More information on hyneat.de
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Questions & Discussion