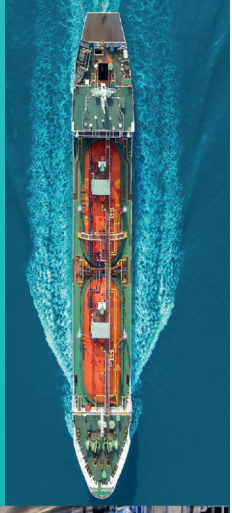




International Perspective on the Challenges and Solutions in the Hydrogen Value Chain

Prof. Dr. Christopher Hebling
Fraunhofer Institute für Solare Energiesysteme, Freiburg

RD20 conference, December 2nd 2024, Delhi India
Session: Addressing Technical Barriers to Hydrogen Implementation



Sea Change

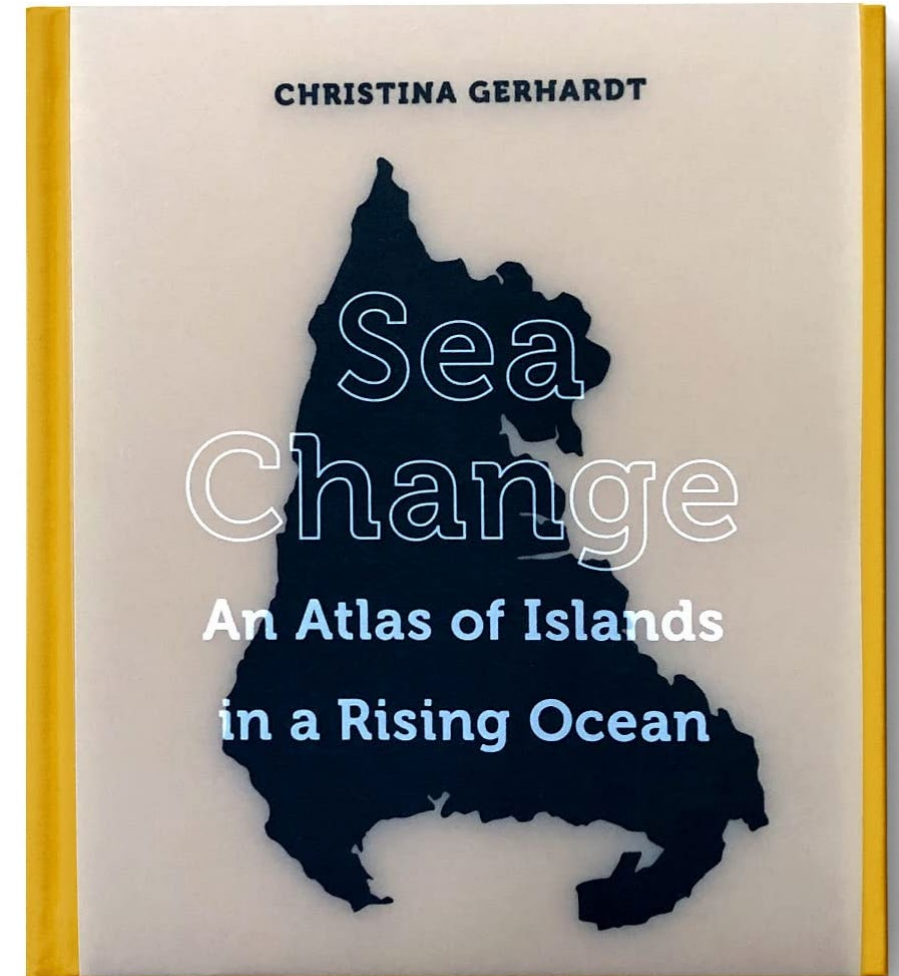
“A New Atlas of Sea Level Rise for a Rapidly changing World”

“An impassioned plea to save what remains of these remarkable island communities.”

“Sea Change is an ode to islands large and small, north and south, and the many peoples who call them home. It is a book of science and stories and, yes, even hope amidst the rising waters. . . .

I guarantee anyone who reads it will come away with a better understanding of the world's many islands and a desire to do something about protecting them.”--

“EcoLit”



Sea Change

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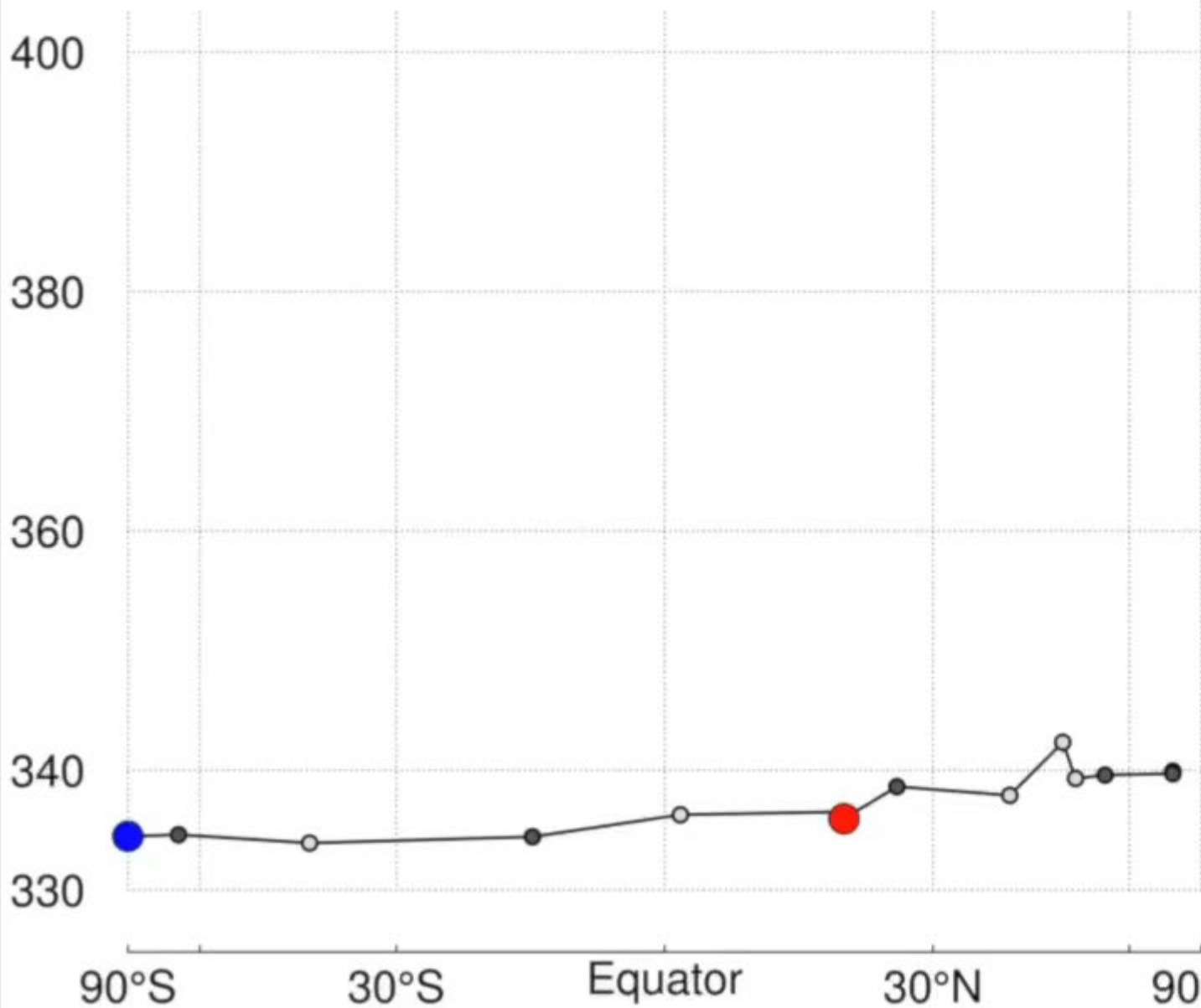
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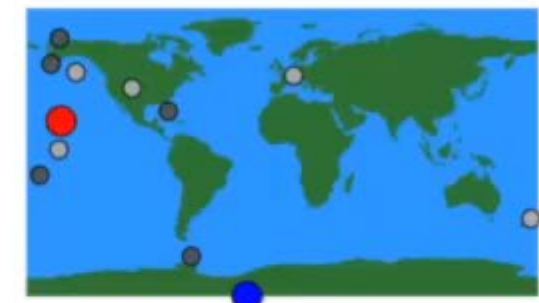
CO₂ Increase is 426.9 ppm in 2024

Climate change has taken on speed. IPCC: 1,5° is over, 2° is likely over, stabilisation at 3,5° still possible



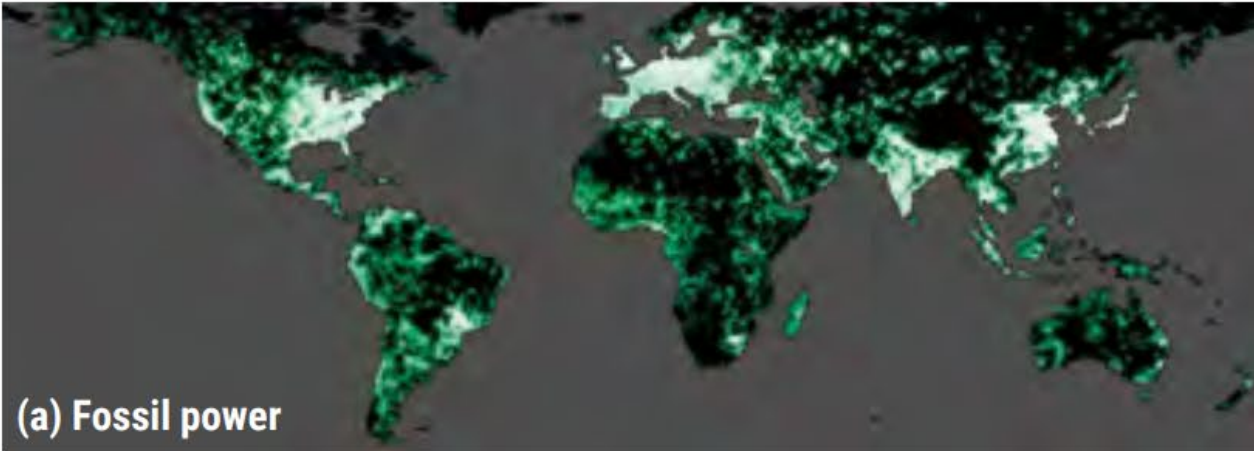
Atmospheric CO₂ (ppm)

GLOBALVIEW+CO₂ (1979–2016); <http://www.esrl.noaa.gov/gmd/ccgg/obspack/>
● Mauna Loa ● South Pole ● Background conditions ○ Local signals
Contact: andy.jacobson@noaa.gov

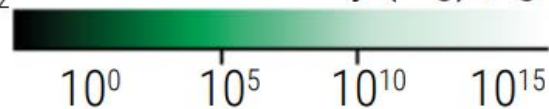


1979 1981 1983 1985

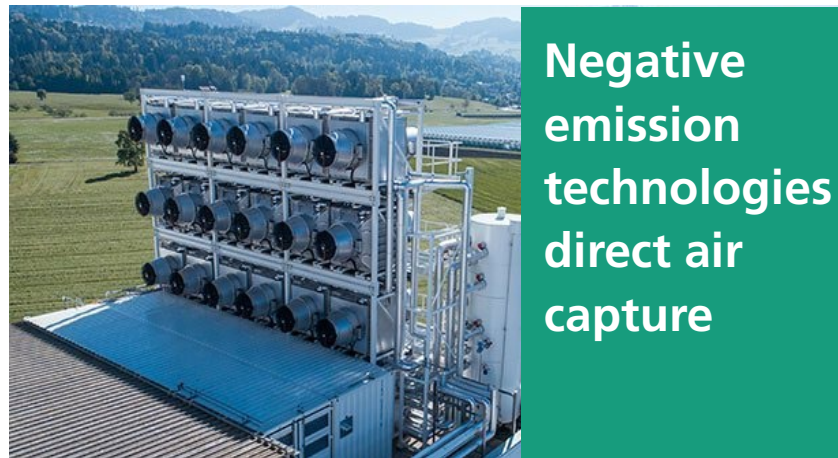
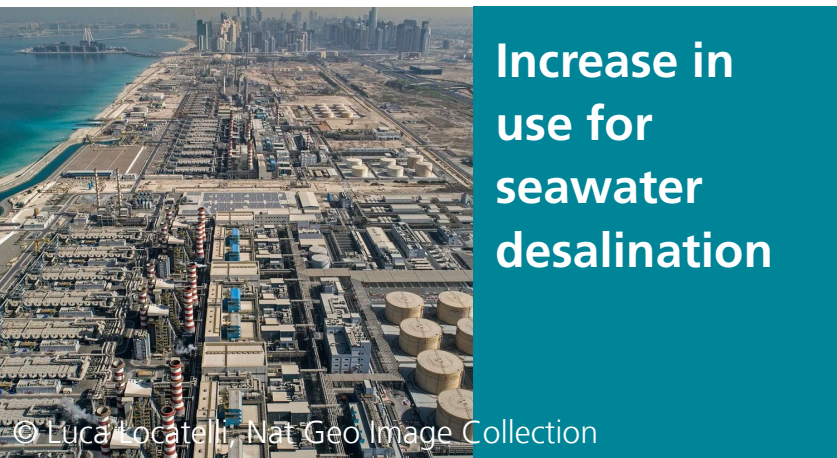
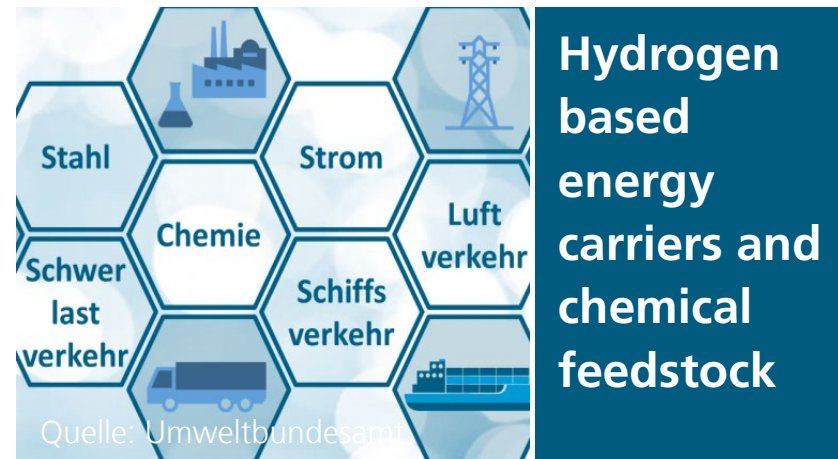
CO₂ emission intensity maps for various industries



CO₂ emission intensity (log) [kg/km²/a]









Further Drivers for Expected Globally Increased Energy Demand









6 Abbildung links: https://en.wikipedia.org/wiki/Developing_country
Abbildung Mitte: <https://www.nationalgeographic.de/umwelt/2019/01/entsalzungsanlagen-produzieren-mehr-giftige-sole-als-erwartet>
Abbildung rechts: <https://www.scinexx.de/news/technik/erste-kommerzielle-anlage-saugt-co2-aus-der-luft/>

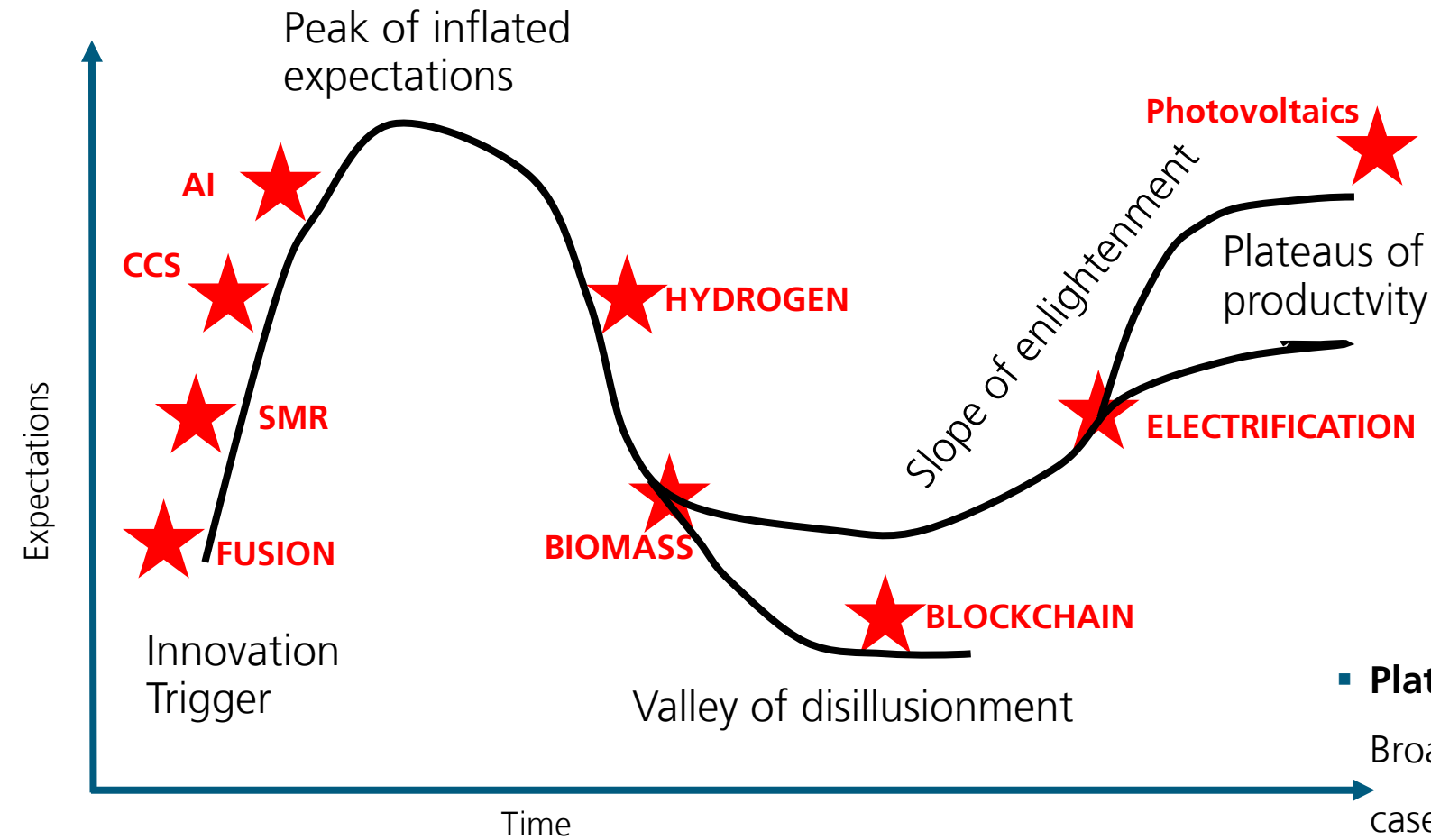
Key features of the future energy system

- 1 Electricity becomes most important primary energy**
Strong increase in electricity demand globally 
- 2 Renewables dominate electricity production**
Sun and wind most important sources 
- 3 Flexibilization as new paradigm**
Increased need for flexible electricity use and supply 
- 4 Other renewable energy sources**
Biomass, geothermal and solar thermal mainly for heat sectors 
- 5 Green molecules as globally tradable goods**
Climate-neutral energy carriers and chemical feedstock 
- 6 Ressource issues as a challenge**
Necessity of closed material cycles 

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Gartner Hype Cycles in Energy Transformation



- **Innovation Trigger:**

Technical breakthrough attracts attention, seed funding phase, start-ups

- **Peak of inflated expectations:**

First applications in the market, tremendous media hype, many unknown unknowns

- **Valley of disillusionment:**

Disappointment due to broken promises, withdrawal of technology

- **Slope of enlightenment**

Critical issues are solved, catalytic investments placed, first movers either rich or out of business

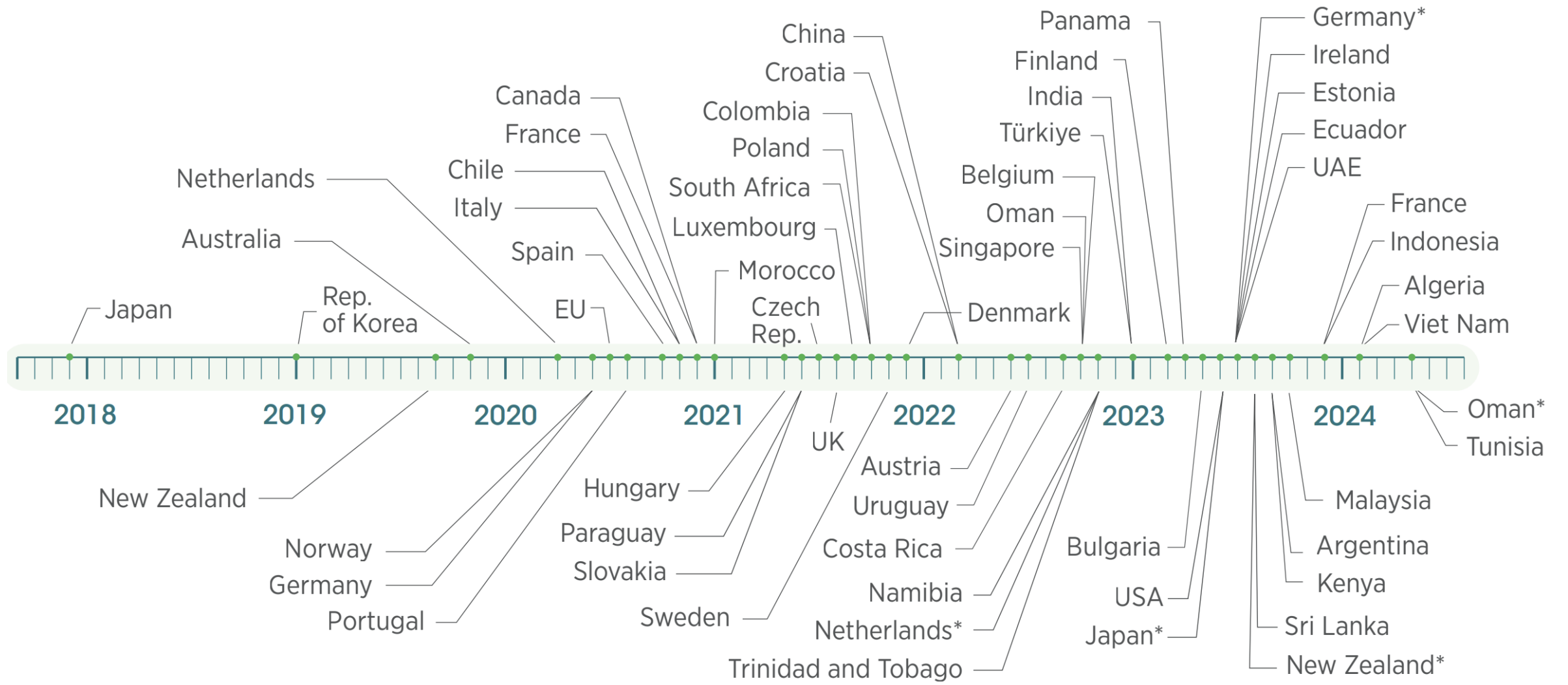
- **Plateaus of productivity:**

Broad acceptance, existing applications and business cases, longterm stability, impact to society and economy

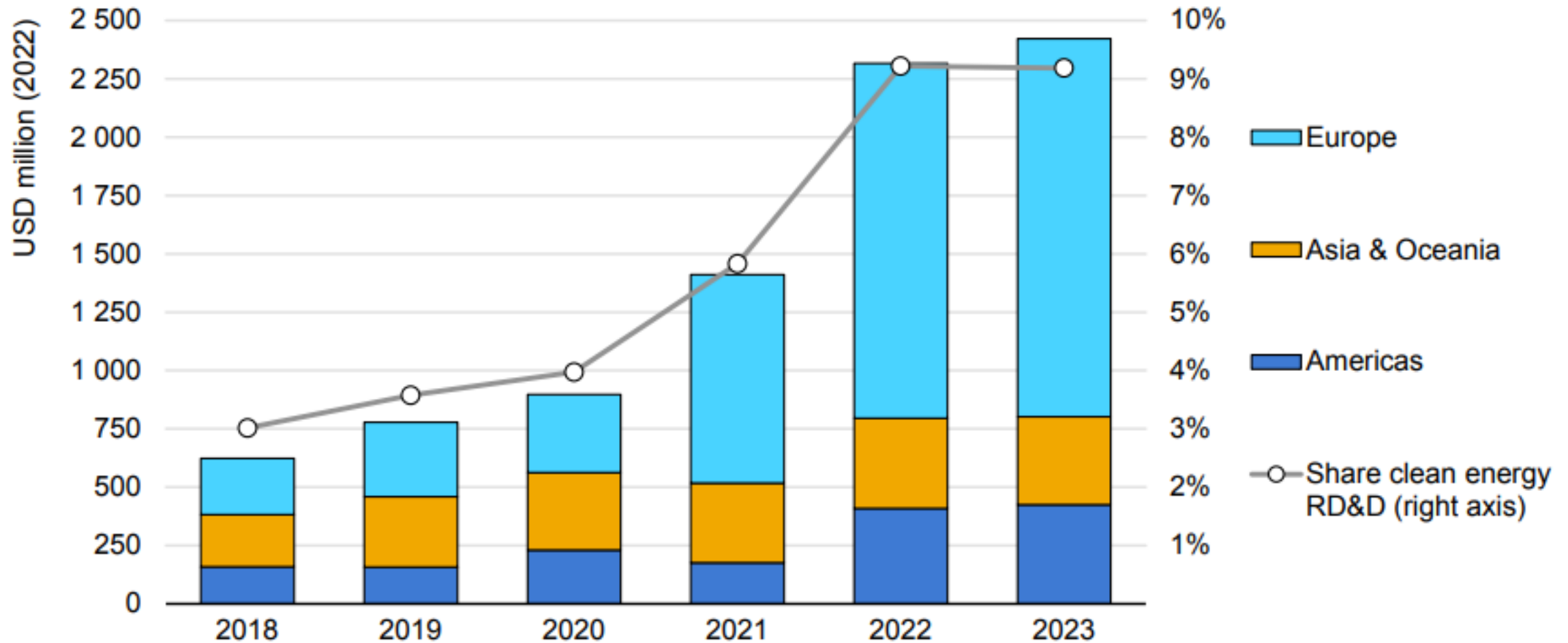
Factors for the H2-Slowdown Beyond the „Oftakers - Dilemma“

- **Geopolitical tensions** lead to higher inflation and to higher costs of capital and interest rates
- **Permitting delays** due to new technologies and systems, normative uncertainties, administrative inertia
- **Electrolyzer manufacturers not on time**, scale-up rates not as expected
- Industry **waiting** for the first **Giga-Proof of Concepts to deliver**
- Industry is **waiting for public support mechanisms**
- Too much **focus on international trade prospects**
- Too **little investments on local carbon neutral ecosystems** to begin with
- **Fading interest in Global Net-Zero** among the UN - Conference of the Parties COPxx despite Paris agreement

Hydrogen Strategies and Roadmaps (as of May 2024)

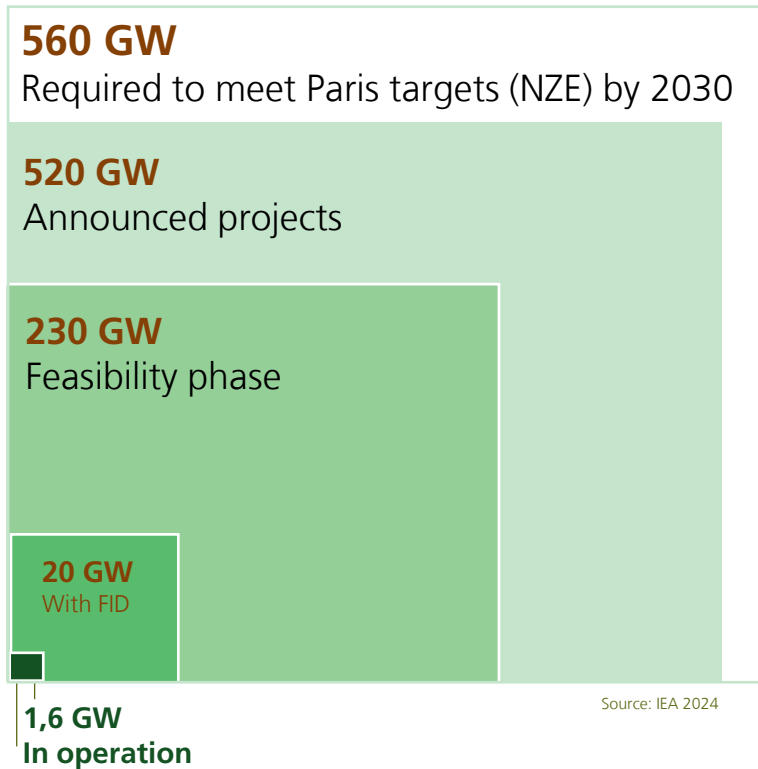


Government RD&D spending on hydrogen technologies by region, 2018- 2023



Clean Hydrogen: Ambitions vs. Reality (2024)

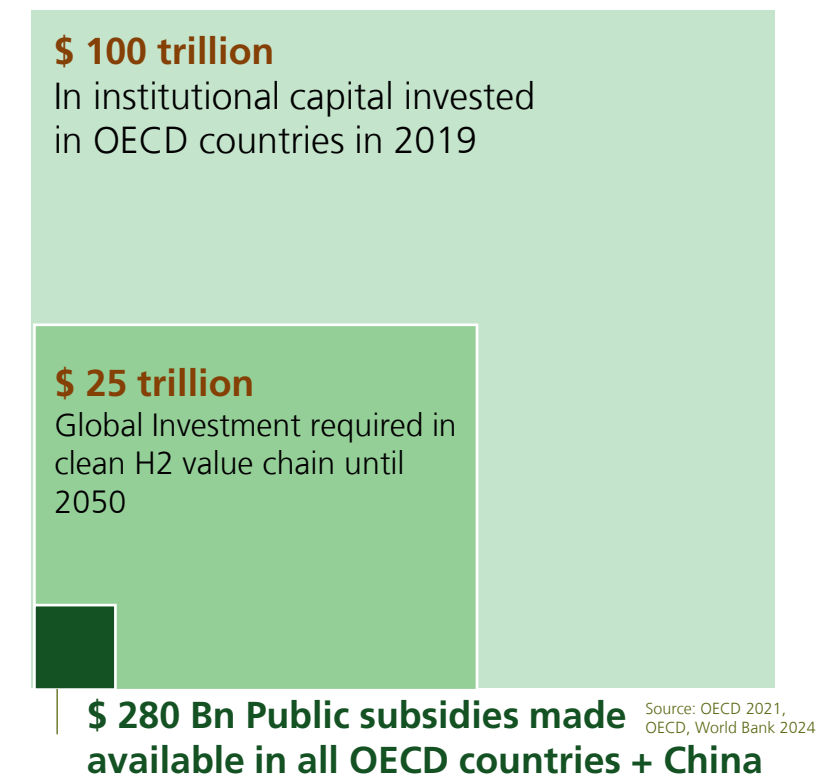
Cumulative global installed electrolyzer capacity through 2030



Clean hydrogen projects



Investment Required vs. Public Funding and Institutional Capital available



Future Investment Initiative, Riyadh 2024





Club of Rome: „Earth for all“, 2022

„The limits of growth“, 1972

„The most prominent challenge of our time is not climate change, the loss of biodiversity or pandemics:

„The most significant problem is our collective inability to distinguish between facts and fiction.“

There is an industry of false and misleading information on social media, fueling the polarization of societies and contributing to our “inability to collaborate or even agree on basic facts in the face of collective challenges.“

Among the challenges in transforming the global energy system is the **'very real danger' of societal destabilization** during restructuring the energy system.

'If the poorest majority is most affected by rising energy costs, these people will protest against energy policies.'

„Five extraordinary turning points“:

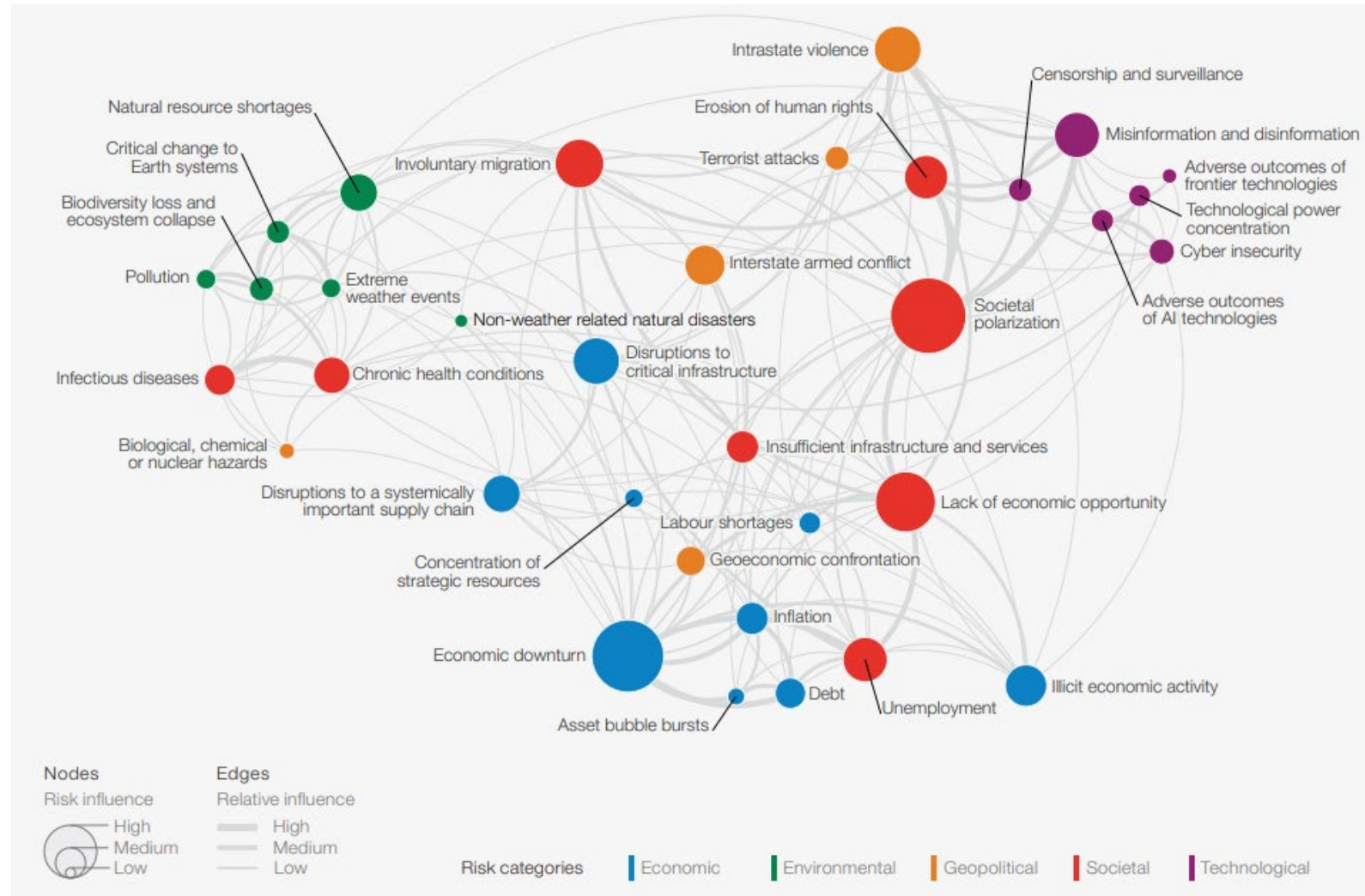
- **End of poverty**
- **Elimination of glaring inequality**
- **Empowerment of women**
- **Building a healthy food system for people and ecosystems**
- **Transition to the use of clean energy**

Global Risks Landscape







Overlaps of Economic, Societal, Geopolitical, Environmental and Technological Crises

■ The Top Global Risks in 2024/25

- 1st Misinformation
 - 2nd Extreme Weather events
 - 3rd Societal/ Political Polarization
 - 4th Cyber Insecurity
 - 5th Interstate armed conflict
-
- Rising Risk of **Divided Societies**
 - Emotions and Ideologies overshadow facts
 - Manipulative narratives can infiltrate the public discourse



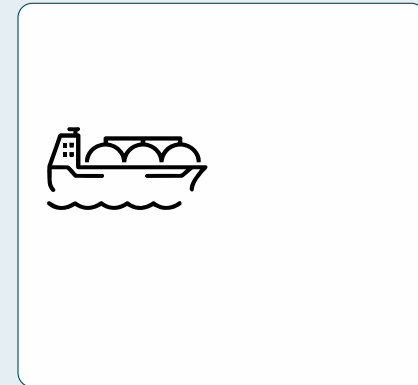
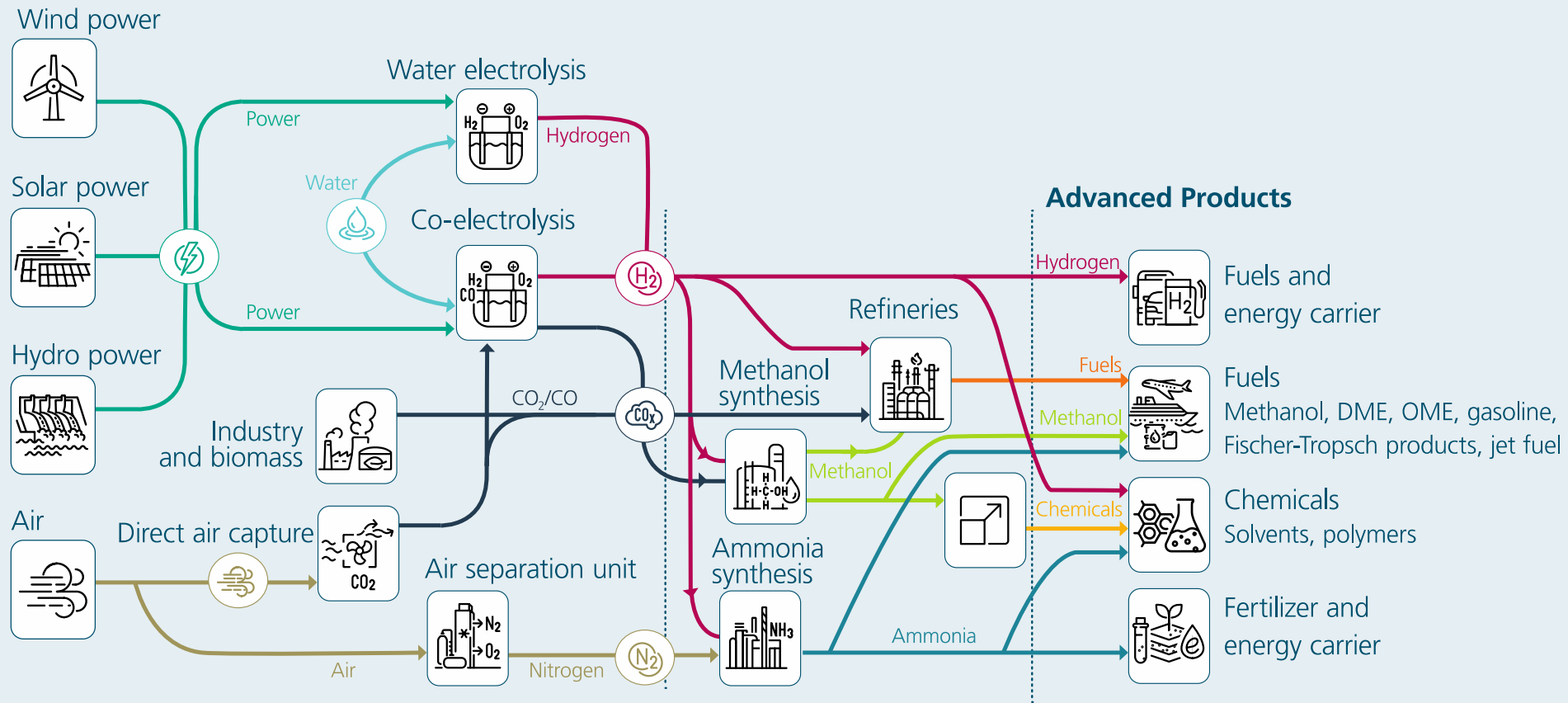
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Sustainable Energy Carriers, Fuels and Base Molecules

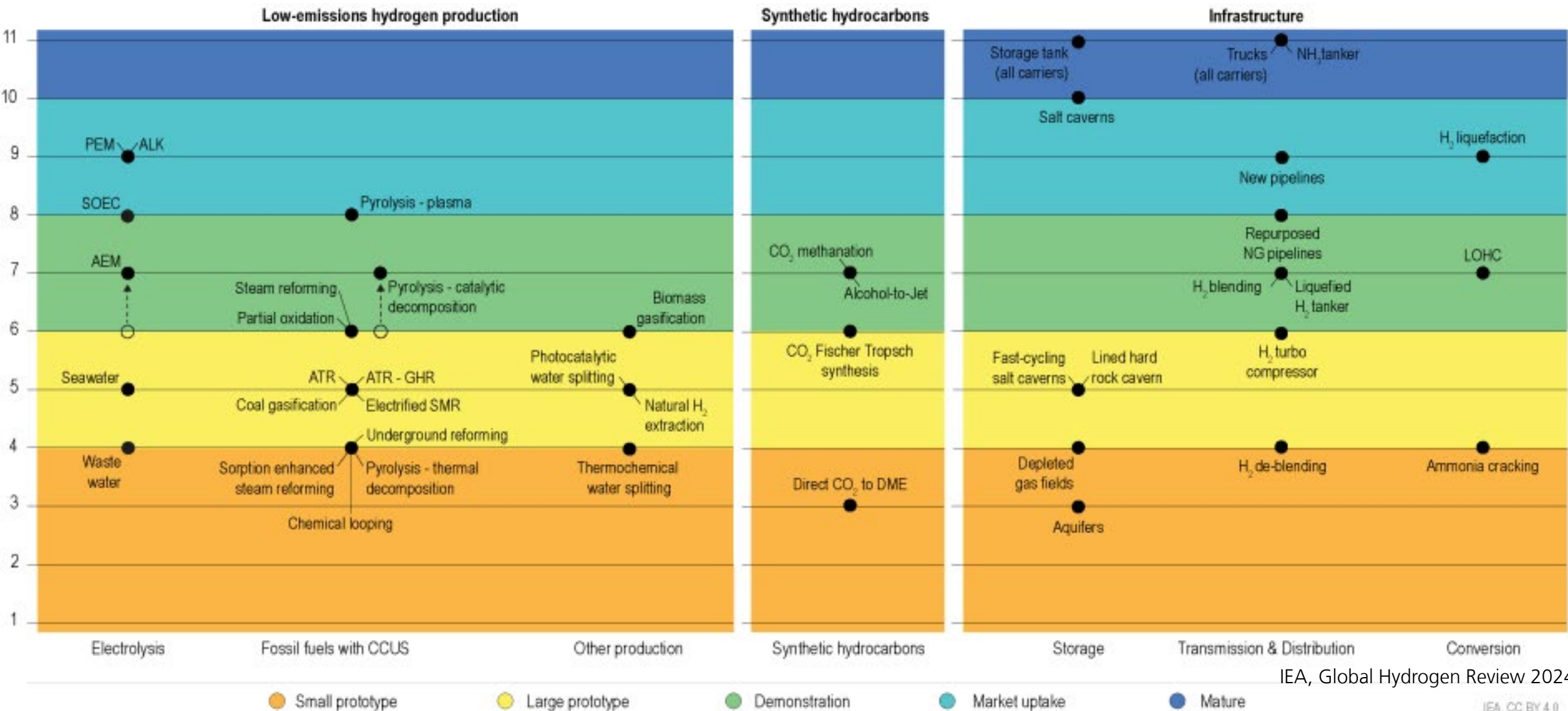
The Promise: Power-to-X - H₂-based Molecules for Mobility, Industry & Chemistry

Sustainable Feedstock



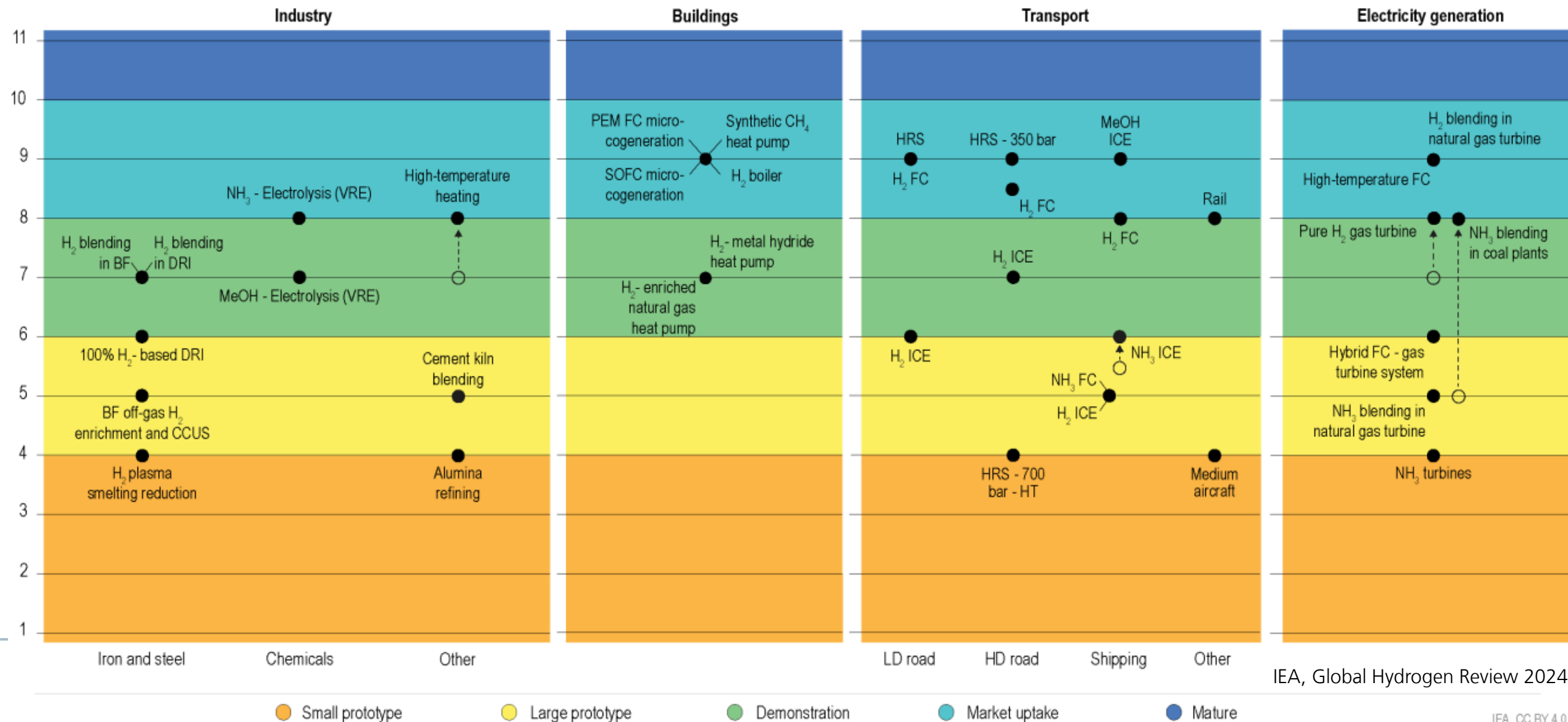
Technology Readiness Levels of H2-Production, Synthetic Fuels and Infrastructure

Innovation is critical to reduce production costs and ensure market uptake



Technology Readiness Levels of Technologies for Hydrogen End-uses by Sector

Some end-use technologies are still at the demonstration stage, but aim to enter large-scale market within this decade



Key Unlocks to Enable and Accelerate the Global Hydrogen Market

Clarity, certainty and support for demand

- creating **incentives** for uptake of clean solutions
- leveling the playing field between clean and higher carbon intensity solutions

Infrastructure expansion, repurposing and buildout

- clean H2 transport (pipeline and maritime)
- storage capacity (retrofitting, repurposing and expanding brownfield facilities)

Global standards and mutually recognized certification schemes

- Global industry standards for GHG emissions assessment of hydrogen
- Implementation of the COP28 Declaration of Intent on Mutual Recognition of Certification Schemes

1) Clarity, certainty and support for demand

Creating incentives for uptake - Leveling the playing field

- **Creating incentives** for uptake of clean solutions
- **Leveling the playing field** between clean and higher carbon intensity solutions

Accelerate demand creation for low-emissions hydrogen by leveraging industrial hubs and public procurement

- Governments should take bolder action to **stimulate demand** for low-emissions hydrogen. Policies such as **quotas, mandates and carbon contracts for difference** have started, but remain limited in geographical coverage and scale. Governments can capitalise on the **opportunity offered by existing hydrogen users** and **high-value sectors such as steel, shipping and aviation**, often co-located in industrial hubs.
- **Pooling demand in these hubs** creates scale and **reduces offtake risks for producers**. Make use of **public procurement for final products** that consume low-emissions hydrogen in production, and encourage the development of **markets where consumers are willing to pay small premiums** for low-emissions hydrogen
- Governments should provide **targeted support to project developers** in scale-up phase and drive cost reductions to **bridge the cost gap** between low-emissions hydrogen & unabated fossil-based hydrogen.

1) Clarity, certainty and support for demand

Creating incentives for uptake - Leveling the playing field

- **Creating incentives** for uptake of clean solutions
- **Leveling the playing field** between clean and higher carbon intensity solutions

- **Timely support is critical to unlock investment decisions**, as experienced in Europe with a **wave of FIDs after the confirmation of funding for several large projects**.
- Governments should also provide **long-term visibility over the level and form of support** so developers have **clarity over future business cases** and can attract investors.
- While initial projects may require substantial financial backing, **support levels will decrease as the sector matures** and costs decline. In addition to **grants and subsidies**, governments can explore other policy options such as **loan guarantees, export credit facilities, and public equity investments** which can help to reduce investment risk and lower the cost of capital, which is crucial for these capital-intensive projects.

Key Unlocks to Enable and Accelerate the Global Hydrogen Market

Infrastructure expansion, repurposing and buildout

- clean H2 transport (pipeline and maritime)
- storage capacity (retrofitting, repurposing and expanding brownfield facilities)

2) Infrastructure expansion, repurposing and buildout

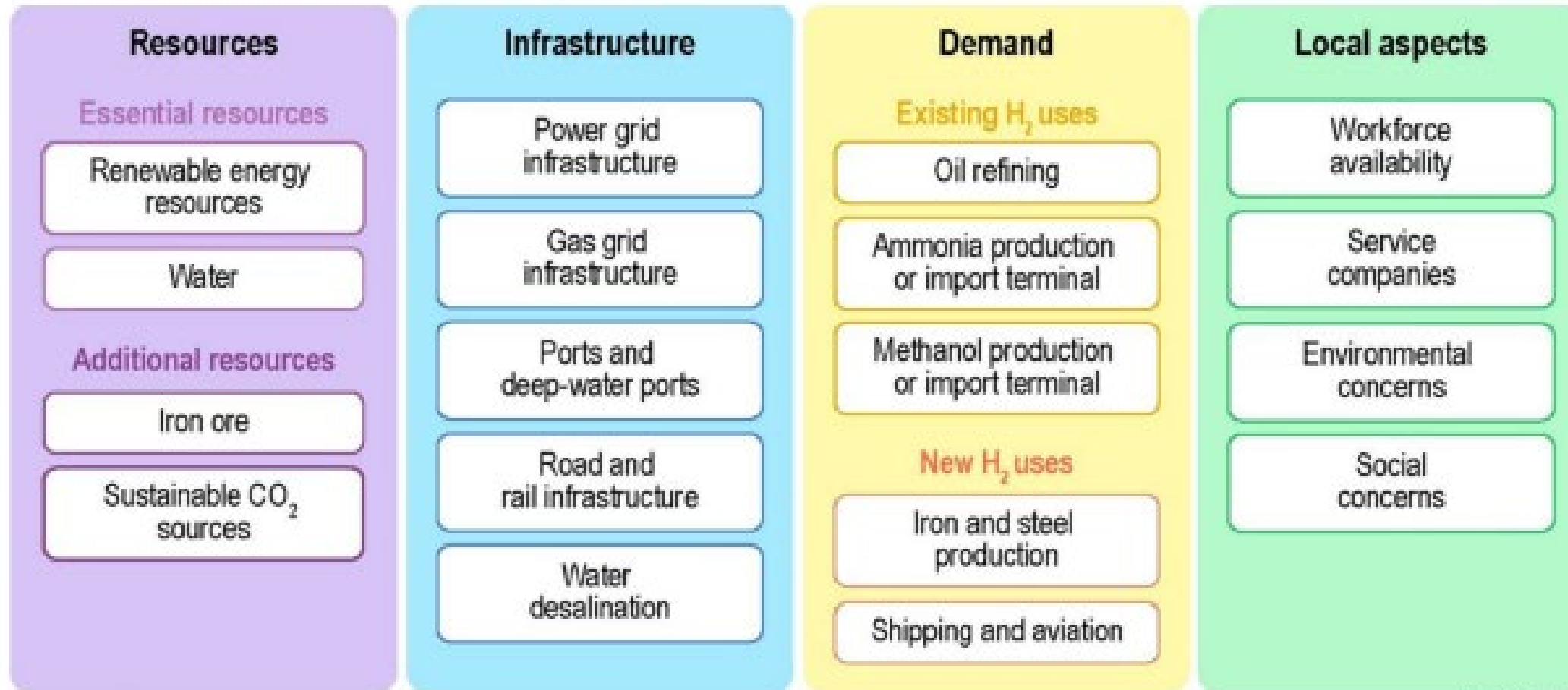
- **clean H2 transport**
(pipeline and maritime)
- **storage capacity**
(retrofitting, repurposing and expanding brownfield facilities)

Identify opportunities to start developing hydrogen infrastructure

- Governments should strengthen efforts to **accelerate the development of hydrogen infrastructure** to avoid further delays that risk slowing the scale-up of low-emissions hydrogen production and demand.
- Without timely **infrastructure deployment**, the link between supply and demand cannot be established, hindering market growth and creating uncertainty for both producers and consumers.
- **Immediate action can include early planning**, a focus on **repurposing existing natural gas pipelines** and **storage facilities** to minimise cost, **streamlining regulatory frameworks** to speed up permitting, and fostering **cross-border co-operation** on hydrogen networks.
- **Public-private partnerships** can also be leveraged to de-risk investments, ensuring that infrastructure keeps pace with hydrogen market development.

Hydrogen Hubs

Factors affecting the potential location of hydrogen hubs

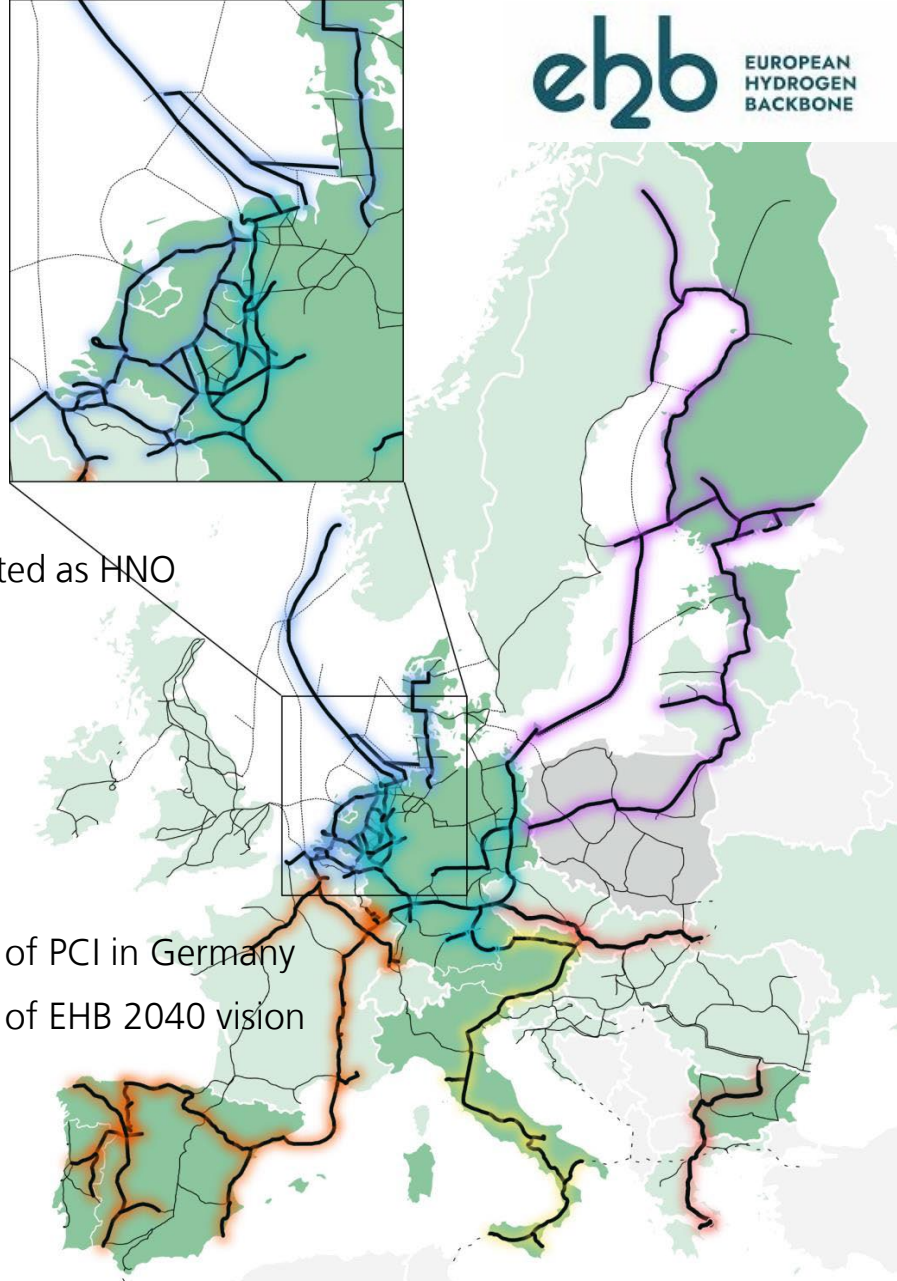


Green Molecules as Globally Tradable Goods

Pipeline Imports: European Hydrogen Backbone (EHB)

- The EHB initiative consists of a group of thirty-one energy infrastructure operators (TSOs).
- The initiative aims to accelerate critical H₂ infrastructure based on **existing and new pipelines**.
- **60%** of the EHB consists of repurposed natural gas pipelines and **40%** of new pipeline routes.
- By 2040: **53,000 km** with estimated total investments of **€80–143 billion**.

A significant initiative for the successful implementation of the hydrogen economy in Europe and Germany and a key to achieving European decarbonization goals!

- 
- EHB member TSOs
 - EHB members appointed as HNO
 - EHB PCI, corridor A
 - EHB PCI, corridor B
 - EHB PCI, corridor C
 - EHB PCI, corridor D
 - EHB PCI, corridor E
 - H2 infrastructure part of PCI in Germany
 - H2 infrastructure part of EHB 2040 vision

Infrastructure expansion, repurposing and buildout

Establishing of import / export hubs



Hydrogen trade flows can connect all regions of the world by 2050

Europe, Japan, and South Korea are the main demand centers for interregional flows of hydrogen and derivatives



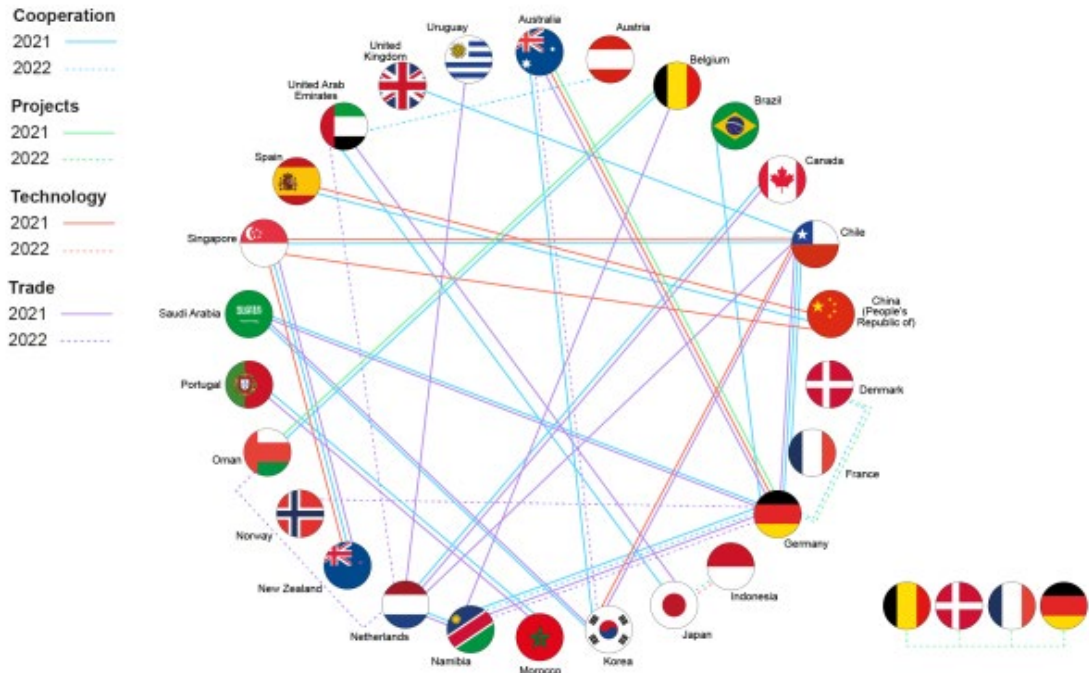
Various regions around the world have excellent renewable resources for low-cost hydrogen production. Production costs could fall below USD 2/kg H₂ by 2030 in certain locations

International Hydrogen Trade

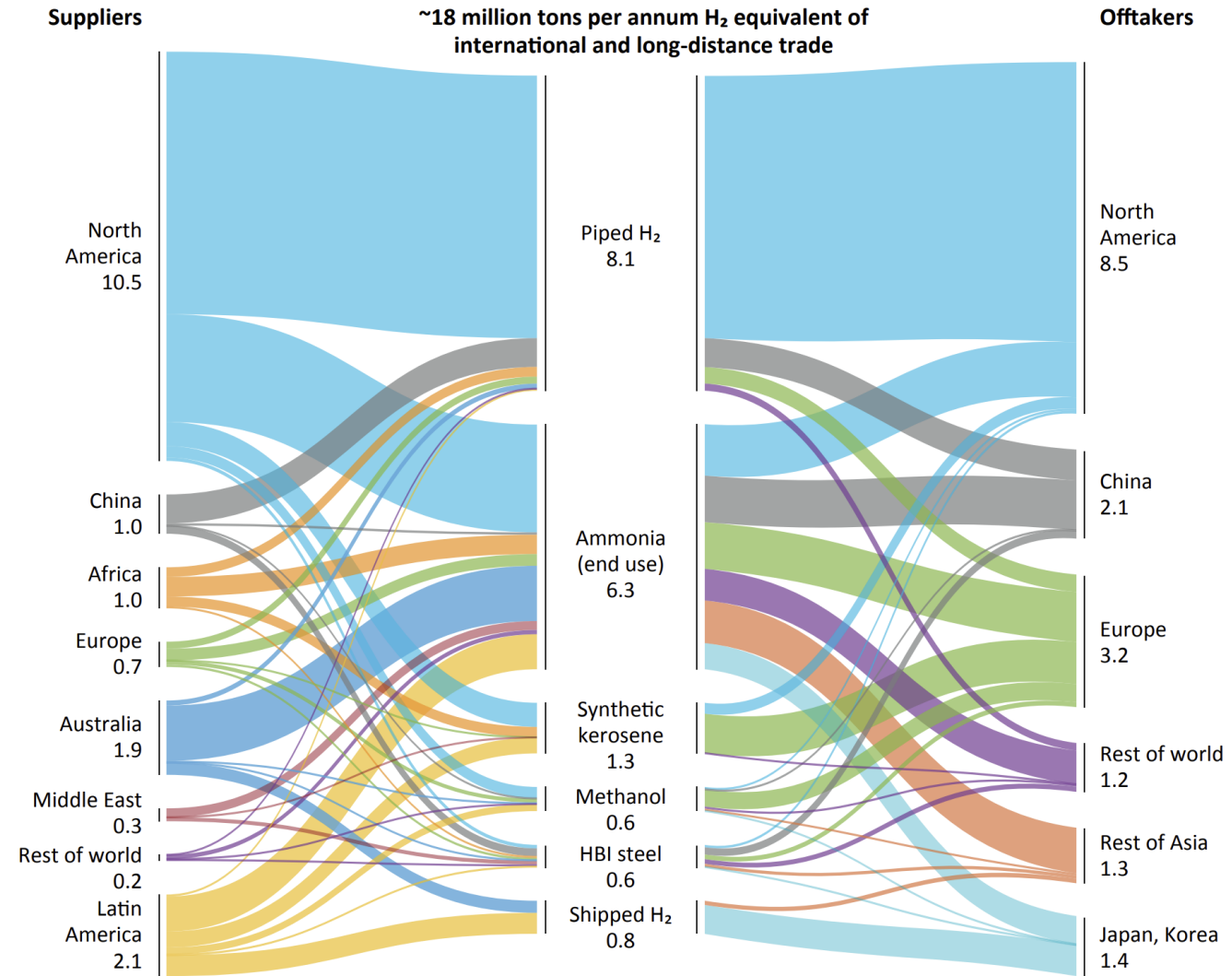
Energy partnerships and trade reorientation

2/3 of total hydrogen supply will be long distance

- 50% with pipelines
- 45% with derivatives
- 5% by ship



2030 global clean H₂ long-distance flows,¹ Further Acceleration scenario



Germany Import Strategy (July 2024)

Measures for the ramp-up of imports

1. Boosting **demand** Side
2. Development of **import infrastructure**
3. Certification **standards** and processes
4. Funding and increasing the international **supply** of hydrogen and derivatives
5. International **cooperation**
6. Innovations and improvement through **Research and Development**

Low carbon hydrogen demand in 2030 will be 95-130 TWh with an import share of 50-70%



3) Global standards and mutually recognized certification schemes



Global standards and mutually recognized certification schemes

- Global industry standards for GHG emissions assessment of hydrogen
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Strengthen regulation and certification of environmental attributes for low-emissions hydrogen

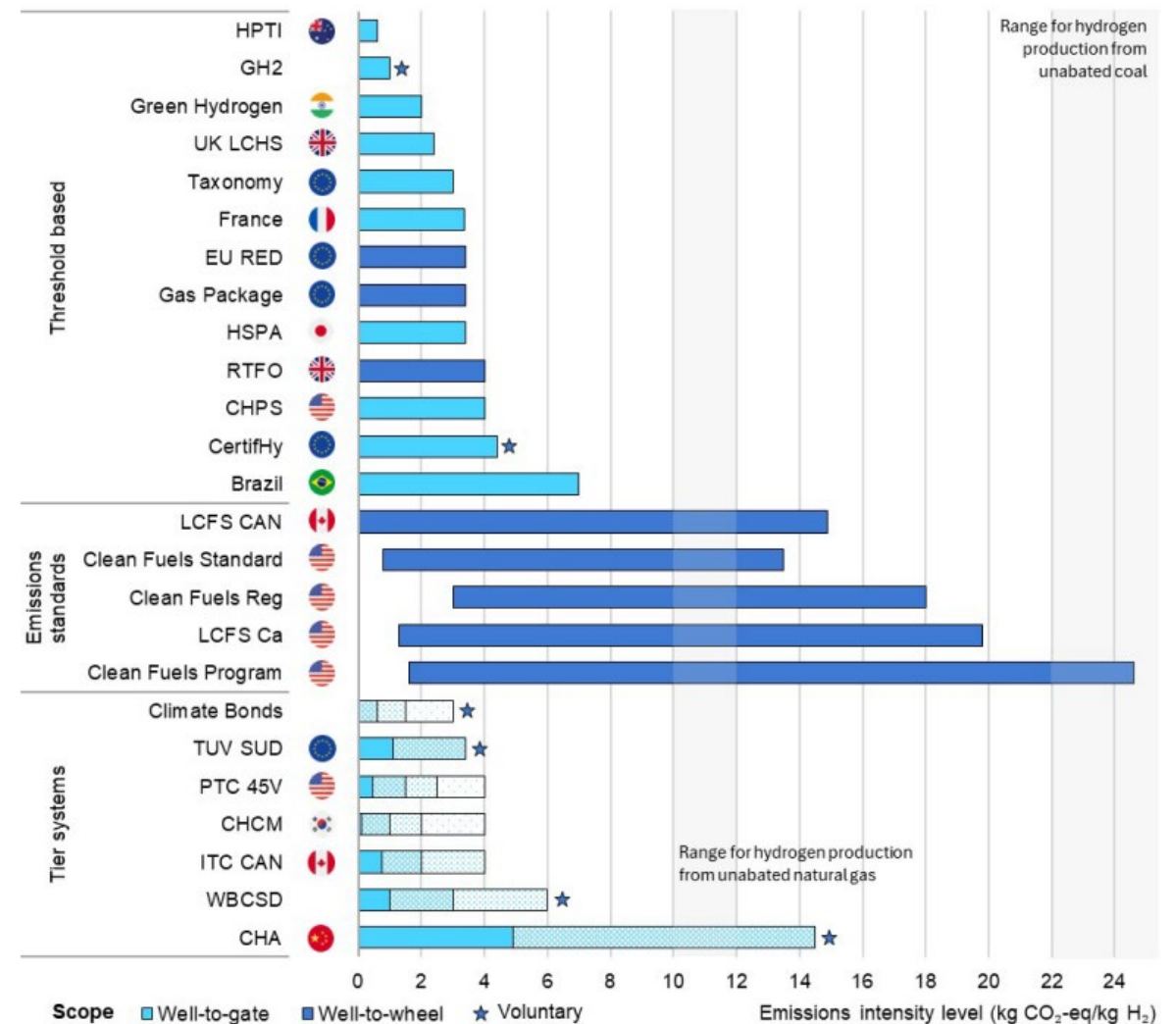
- Ensuring **regulatory consistency** with the ISO methodology and forthcoming standards can **facilitate global interoperability**.
- The release of the **ISO methodology** provides a standardised approach to **assessing GHG emissions**. Governments should **implement clear regulations** that set **thresholds for acceptable emission levels in hydrogen production**
- Governments should intensify efforts to **assess and verify upstream emissions** from fossil fuel supply, ensuring transparency by making this data accessible to market participants and the public.
- The processes of the **delegated regulation** and a uniform and a system for **guarantees of origin** should be harmonized

Certification – A crucial instrument for the H2 economy

Emissions intensity level of certification schemes and regulatory frameworks

→ More than half of the certification schemes and regulatory frameworks require carbon intensity lower than 4 kg CO₂-eq/kg H₂.

For regions that do not start from zero, the bars represent carbon-crediting schemes with default carbon intensities for defined pathways that are reflected in the figure



Hydrogen Energy Policies

Hydrogen energy policies

Aspect	China	USA	EU	Japan
Technology Advancement	Rapid R&D and deployment of green hydrogen technologies	Investing in green hydrogen tech, focus on electrolysis / storages	Green hydrogen tech, electrolysis / RE integration	R&D on green hydrogen tech, electrolysis / storage.
Major Green Hydrogen Policy	"Hydrogen Economy Development Plan" -> hydrogen industry ecosystem	The "Hydrogen Shot" -> reducing production costs and use in various sectors	"Hydrogen Strategy for a Climate Neutral Europe" RePower EU , production and usage	"Basic Hydrogen Strategy" -> energy transition and economic growth
Green Hydrogen Energy Vision	widespread green hydrogen utilization in transportation, industry, power generation	carbon-neutral in industries and transportation	Global leader in green hydrogen, fostering an integrated energy system with hydrogen	Hydrogen society , green hydrogen for power generation, transportation, industry