

GEOPOLITICAL IMPACTS OF ADVANCES IN THE HYDROGEN VALUE CHAIN

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New Delhi, INDIA • 16/10/23

ADDRESSING THE COMPLEXITY OF HYDROGEN GEOPOLITICS **REQUIRES A TRULY SYSTEMATIC APPROACH**

HYDROGEN TRAINING SYSTEMATIC APPROACH (HERE: 30 HOURS)

HYDROGEN & CLIMATE RISKS

- IPCC scenarii
- Mitigation plan vs. adaptation
- Climate policy & diplomacy
- Climate change economics
- Critical metals
- Natural H₂
- H₂ leaks impact
- H₂ vs. denialism

6 hours / 1 day

HYDROGEN TECHNOLOGIES

- Electrolysers
- Fuel cells
- SMR & CCUS
- Power-to-X
- Waste-to-X
- Pyrolysis
- Plasmatolysis
- Storage techs
- Transport techs
- Delivery techs
- H₂ derivatives

6 hours / 1 day

HYDROGEN ECONOMICS

- H₂ import/export
- Micro-/mini-grid
- H₂, merit order & spot markets
- H₂ trading
- H₂-as-a-service
- R&D&I funding
- Project finance
- H₂ subsidies
- H₂ gigafactories
- H₂ cost vs. risk

6 hours / 1 day

HYDROGEN POLICY

- H₂ strategies
- H₂ international institutions
- Certification
- Standardisation
- Upscaling policy
- Upskilling policy
- Regional H₂ implementation
- H₂ infra planning
- H₂ public opinion

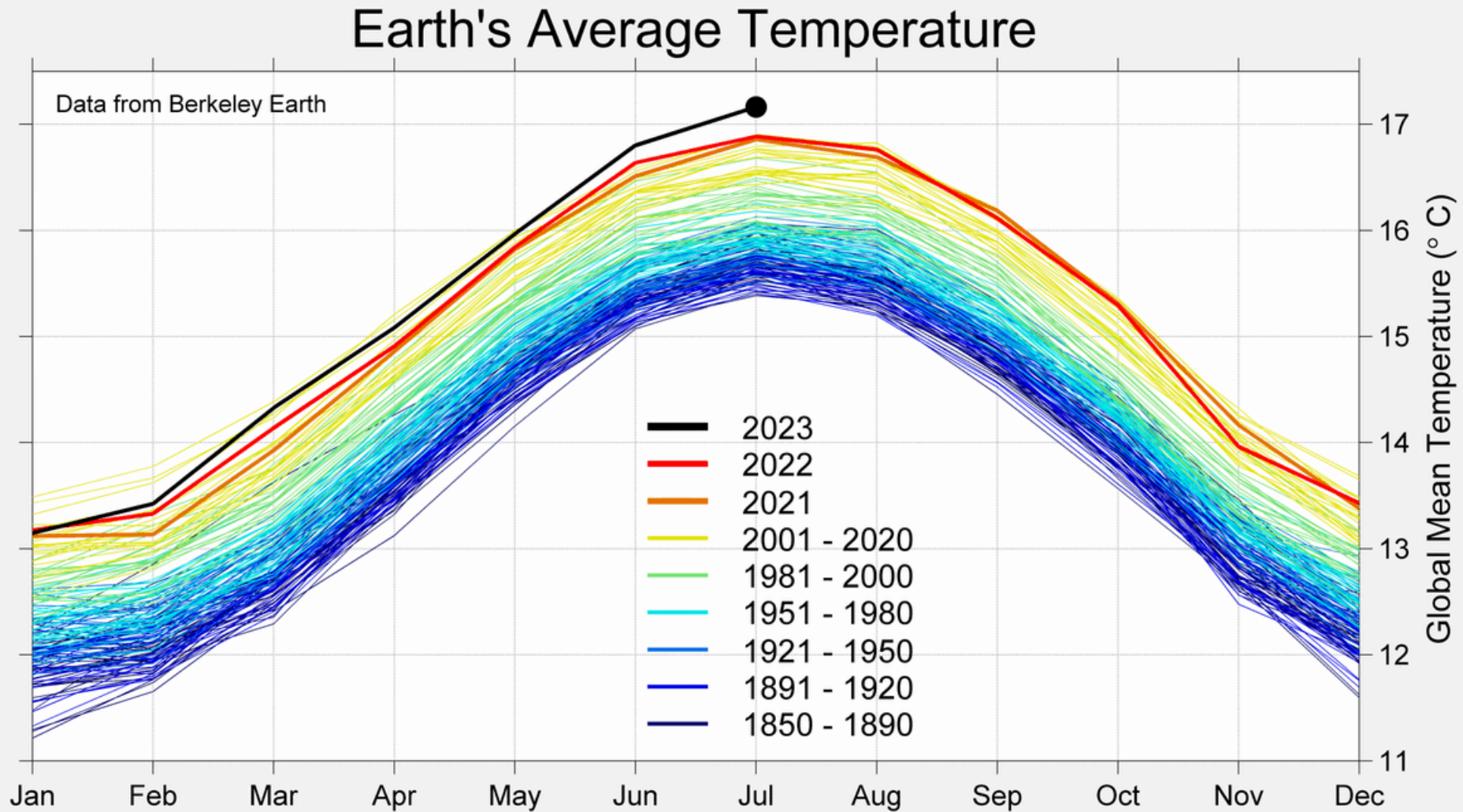
6 hours / 1 day

HYDROGEN GEOPOLITICS

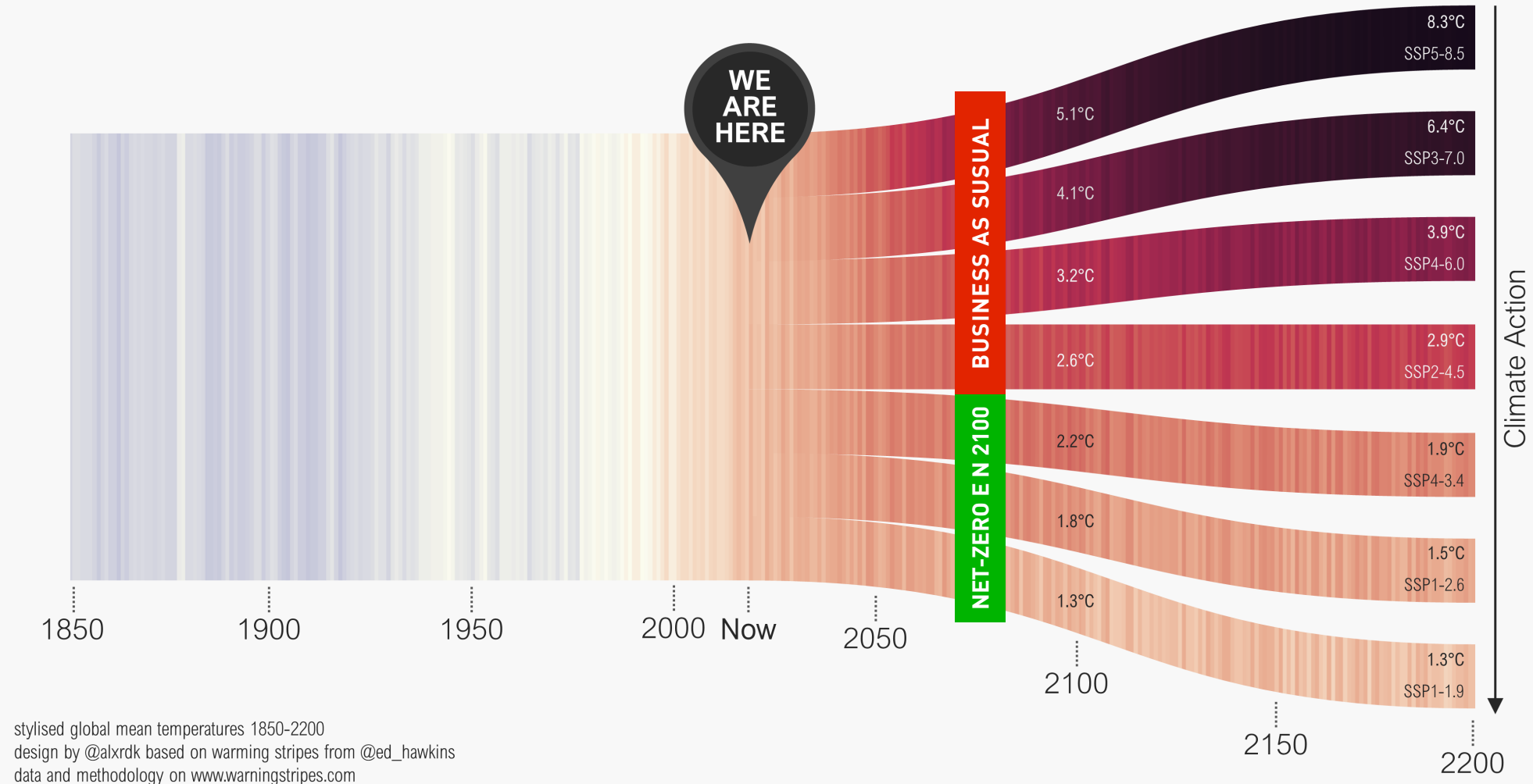
- H₂ alliances
- H₂ international institutions
- H₂ trade
- H₂ strategic competition
- H₂ for militaries
- Geopolitics of supply materials
- Market dumping
- H₂ v. GHG taxes

6 hours / 1 day

WHY (ANOTHER) H₂ HYPE? 1) WE URGENTLY NEED TO CHANGE



H₂ IS TOO EXPENSIVE, BUT LESS EXPENSIVE THAN A +4°C WORLD

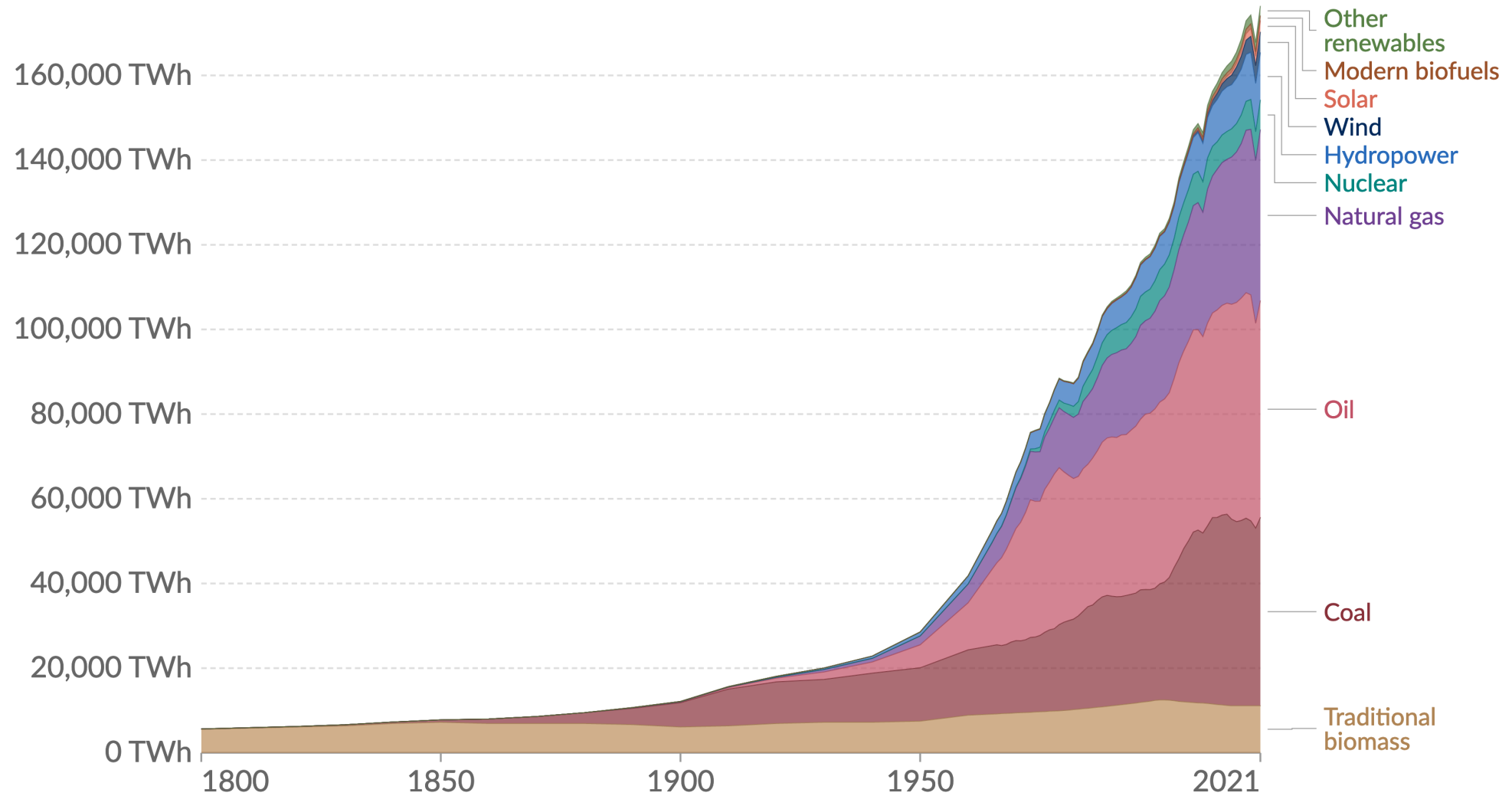


TO STAY UNDER +2°C,

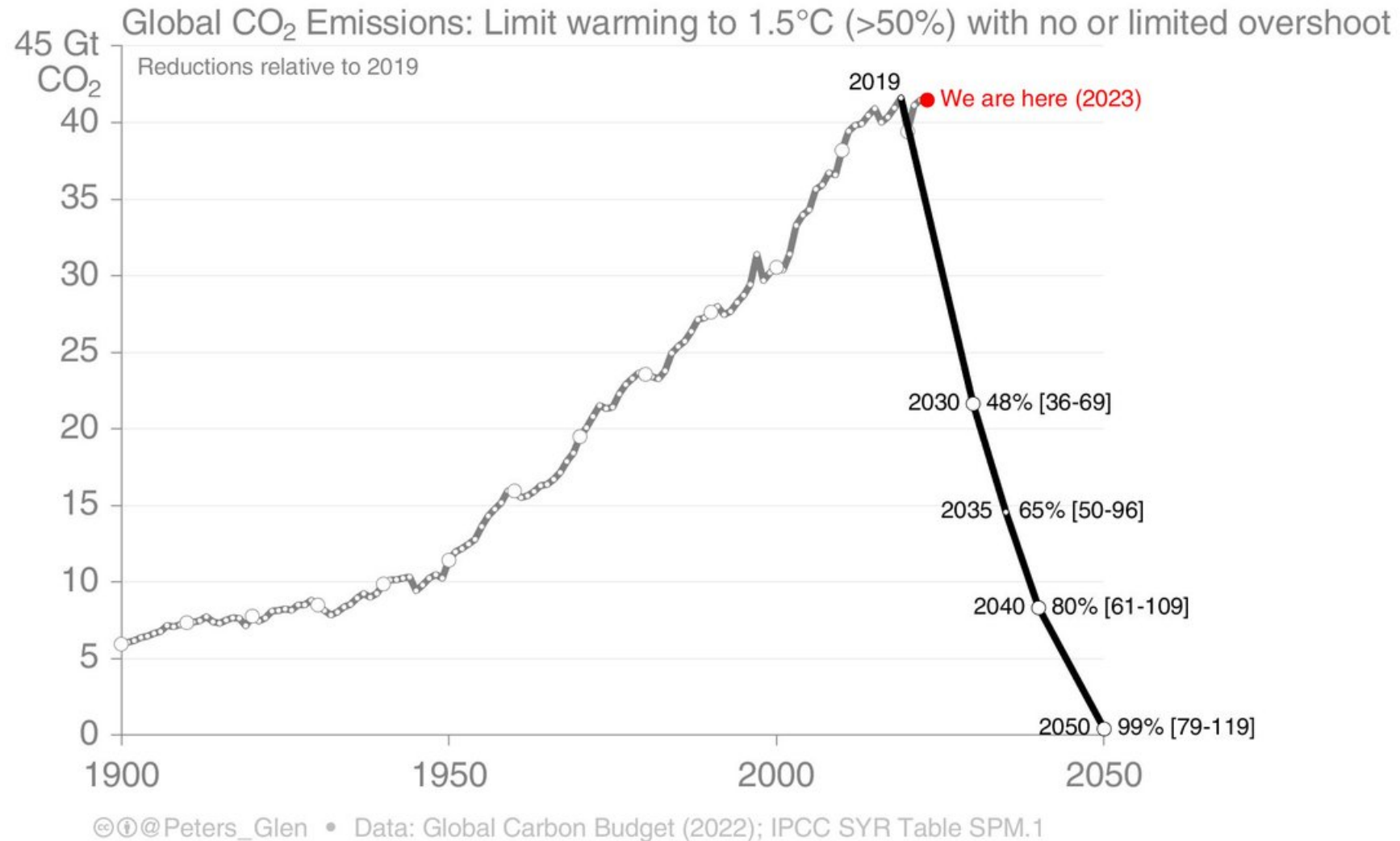
WE HAVE LESS THAN
**10,000 DAYS TO DELIVER
A CARBON-NEUTRAL WORLD.**

9574 DAYS
(TO BE PRECISE).

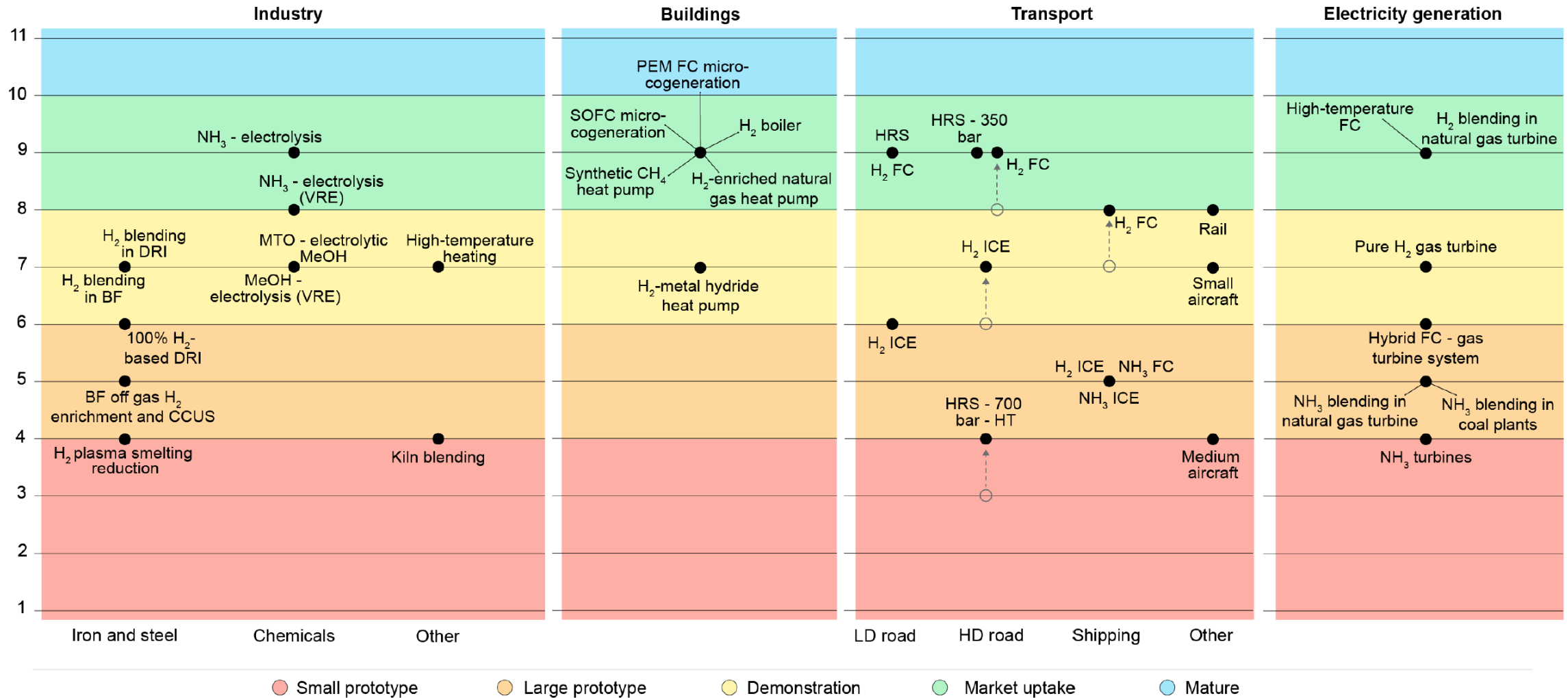
2) ACHIEVE WHAT'S NEVER BEEN DONE IN HUMAN HISTORY



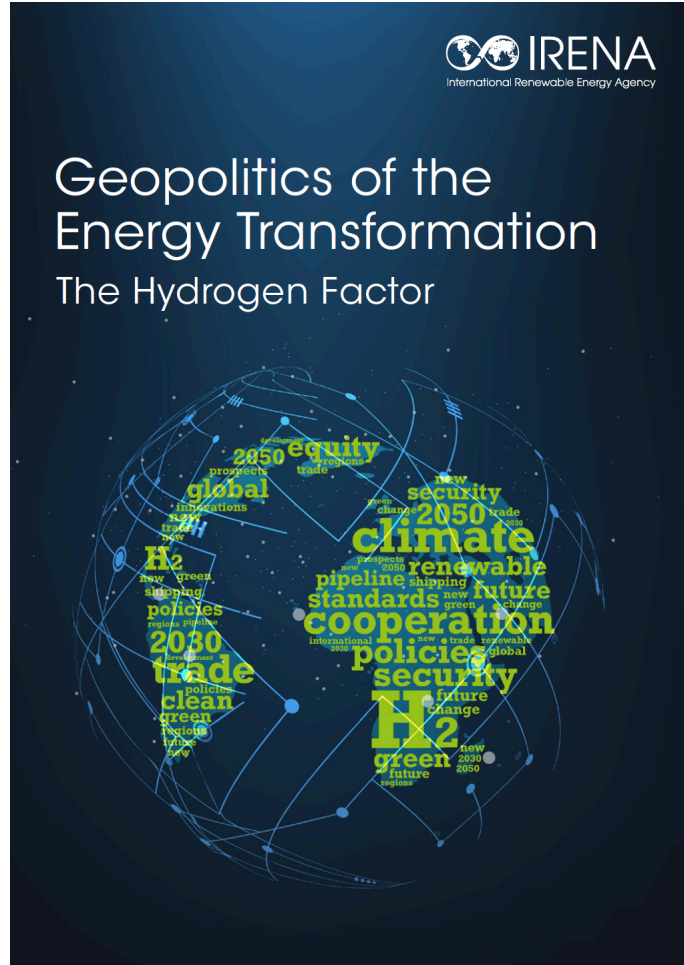
FUKUYAMA SYNDROME: "END OF HISTORY", CHANGE TOO HARD?



3) H₂/NH₃ TECHS PROGRESSING, REACHING DEMO STAGE (TRL 5-6)



4) HUGE CHANGE = HUGE MARKET & GEOPOLITICAL OPPORTUNITY



- IF H₂ = 12% OF THE GLOBAL ENERGY DEMAND
- IF 66% OF WHICH IS GREEN H₂ vs. 33% FOSSILS H₂
- THEN, NEED 5000 GW OF ELECTROLYSIS (*0,3 GW as of 2021*)
- 21000 TWh OF ELECTRICITY (*± today's global demand or 30% of the global electricity production then*)

5) TODAY'S HYDROGEN STILL IS PART OF THE PROBLEM

Global hydrogen industry in 2022 =

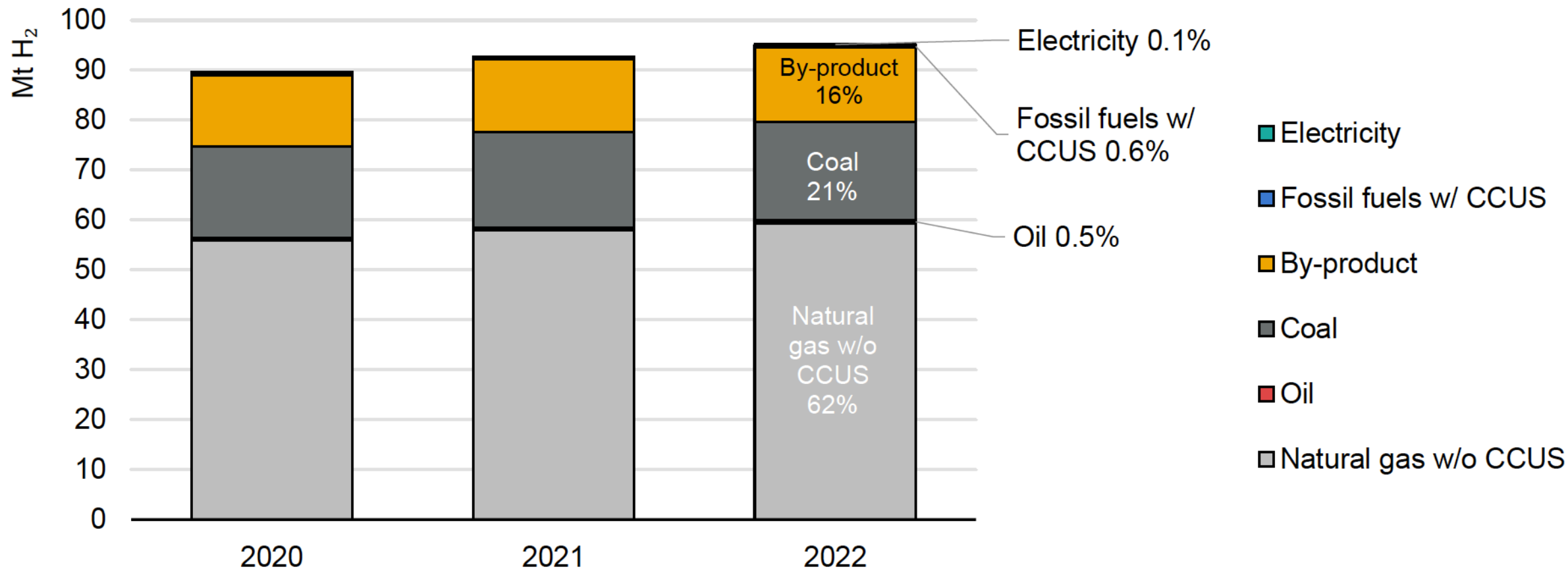
More than 900Mt of CO₂e

More than 2.2% of global CO₂ emissions

Average footprint above 9.5 kgCO₂e / kgH₂

ELEC-ORIGINATING H₂ IN 2022 = 0.1% OF GLOBAL H₂ PRODUCTION

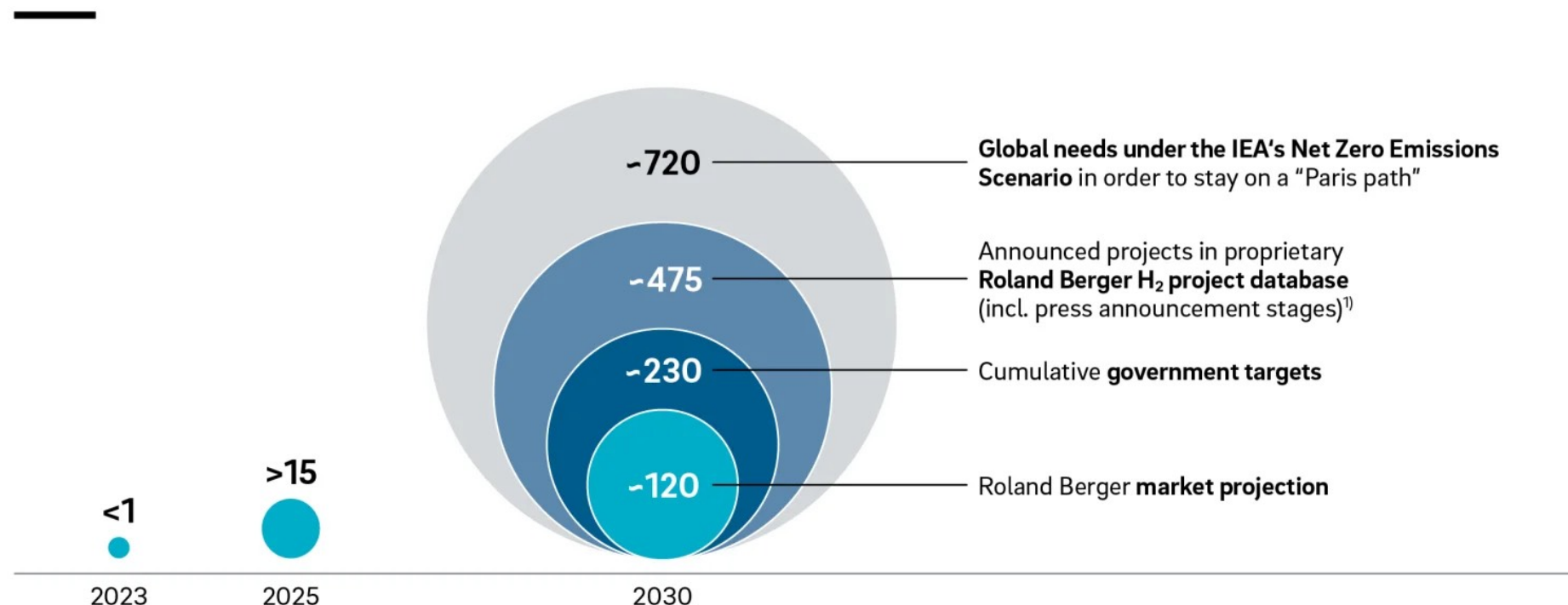
Figure 3.1 Hydrogen production by technology, 2020-2022



WE'RE NOWHERE NEAR WHERE WE SHOULD BE, CLIMATE-WISE

Global electrolyzer build-out path

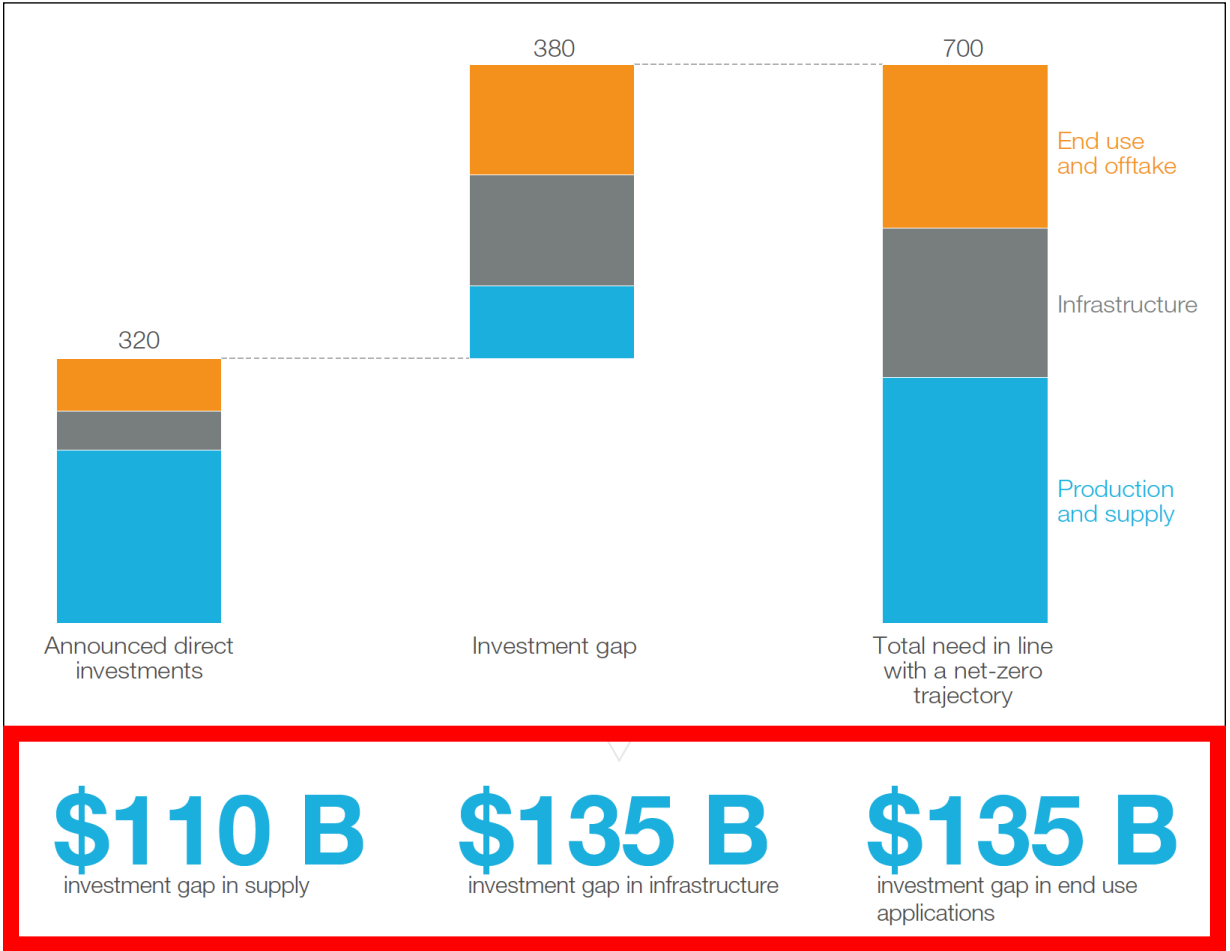
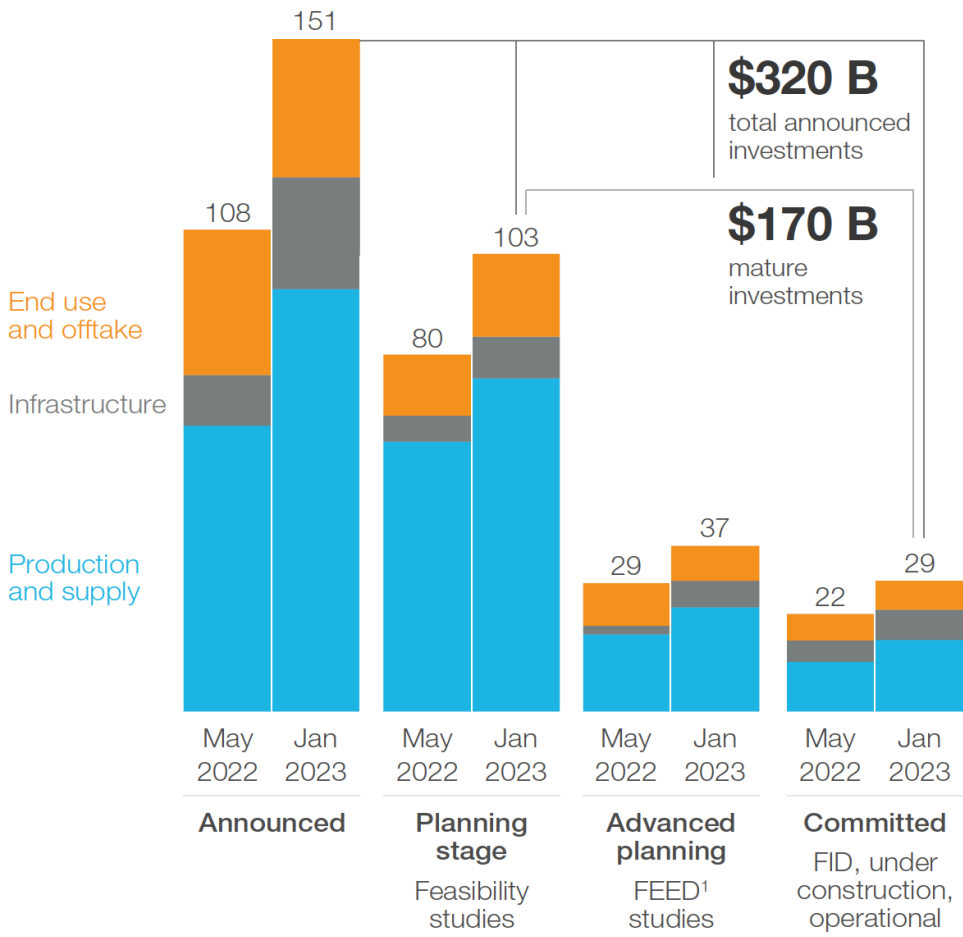
[in GW]



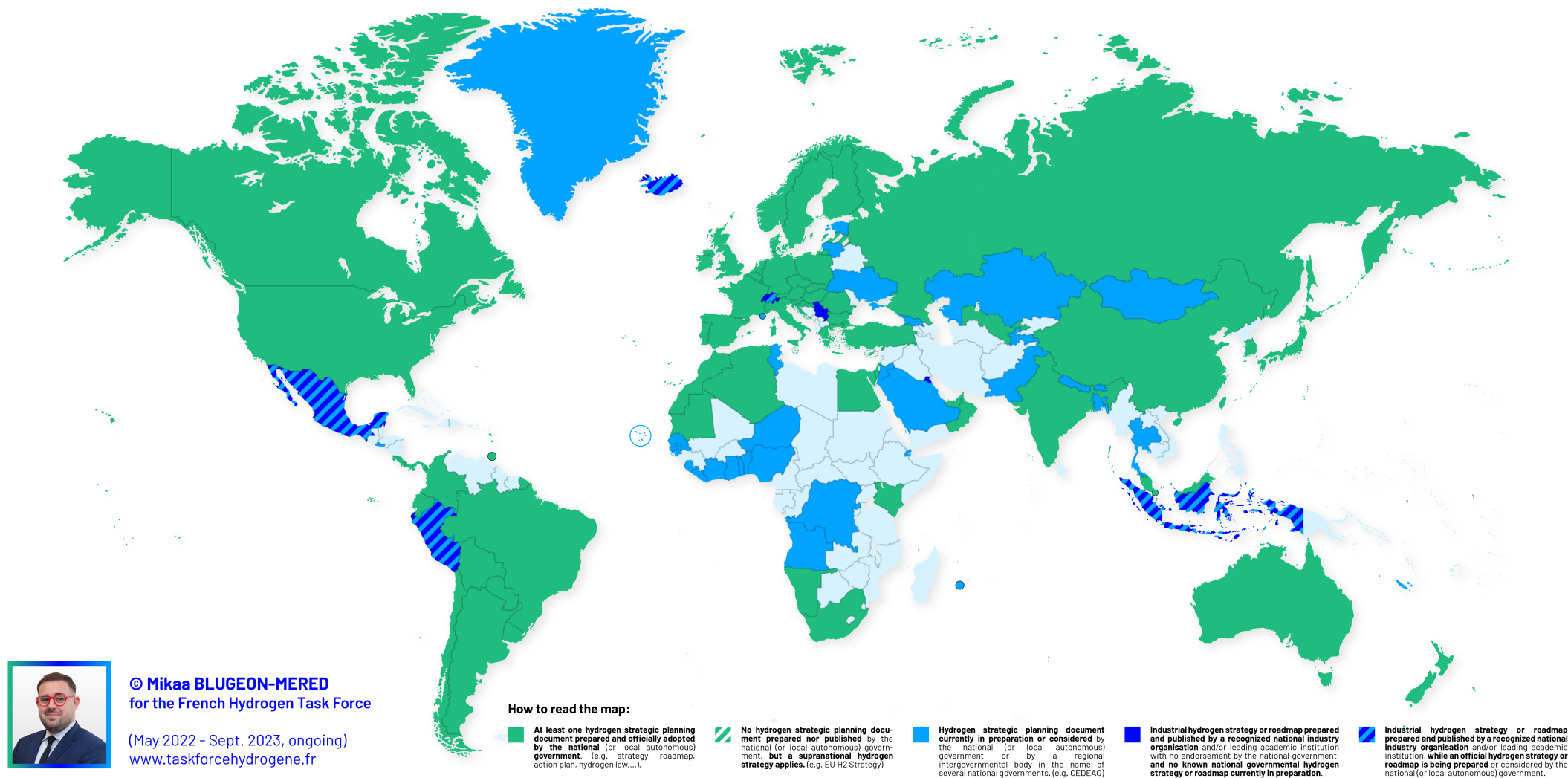
1) As of June 2023, including green H₂ projects at very preliminary studies or at press announcement stages

INVESTMENT GAP IN H₂/PTX = CHICKENS BUT NO EGG-EATERS

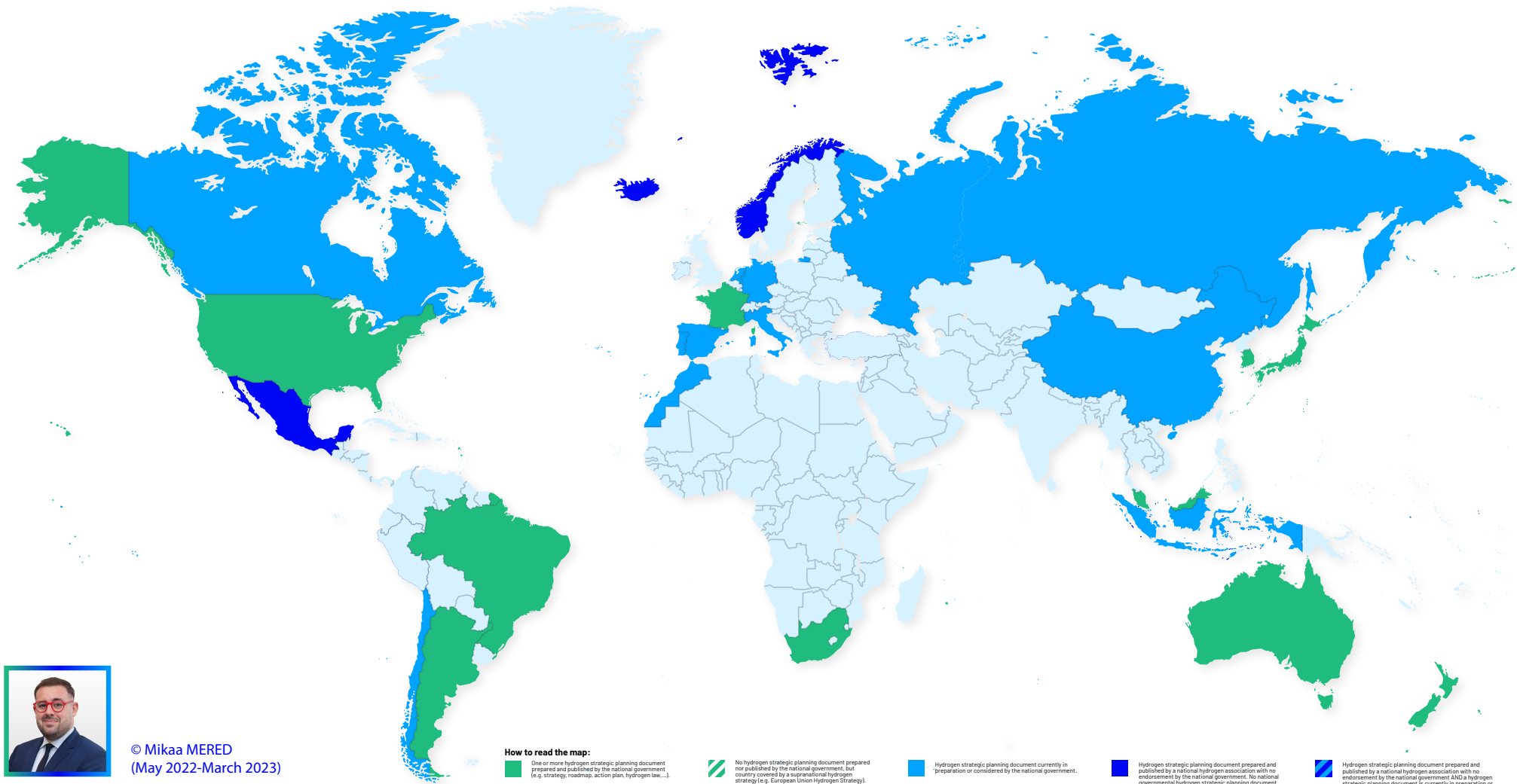
Direct hydrogen investments until 2030, \$B



H₂ STRATEGIES AT AN ALL-TIME HIGH: 59 COUNTRIES!



NATIONAL H2 "STRATEGIES" ACROSS THE WORLD (as of 31.12.2019)



© Mikaa MERED
(May 2022-March 2023)

POLICY COMPETITION => STRATEGIC COMPETITION

- 59 COUNTRIES NOW HAVE A STRATEGIC HYDROGEN DOCUMENT
- 37 OTHERS ARE CONSIDERING OR ACTIVELY PREPARING ONE
- 102 COUNTRIES ARE ACTIVELY TAKING PART IN HYDROGEN POLICY-BUILDING (INCLUDING THE E.U. & ECOWAS)
- THEY COVER 81.6% OF THE WORLD'S POPULATION, 94.4% OF GLOBAL GDP, 92.2% OF GLOBAL CO₂ EMISSIONS



© Mikaa MERED

KEY MARKET SUCCESS FACTOR ARE LEFT UNADDRESSED

**COMPETITION FOR
CRITICAL METALS &
ELECTROLYZERS
SUPPLY**

**LIMITED TALENT
POOL & TRAINING
PROGRAMS**

**COMPETITION FOR
METALLURGICAL
ENGINEERS**

**HARD SECURITY OF
INFRA & FACILITIES IN
HIGH-INTENSITY
CONFLICT**

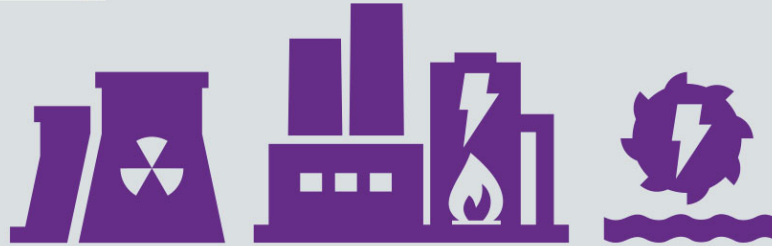
**MARKET-MAKING
MECHANISMS,
STANDARDS &
CERTIFICATION**

**PERMITTING TIME +
EMERGING "NIMBY"
& NEO-COLONIALISM
NARRATIVES**

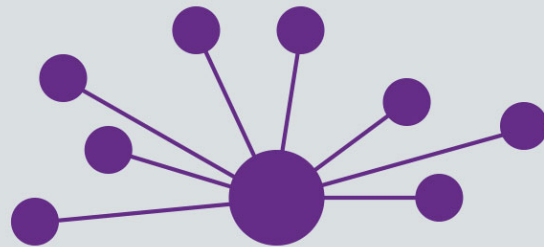
CLIMATE IMPACT OF HYDROGEN LEAKS (TECH + NORMS + CONTROL / AUDIT)

GLOBAL PTX = CENTRALIZATION or DE- or RE- CENTRALIZATION ?

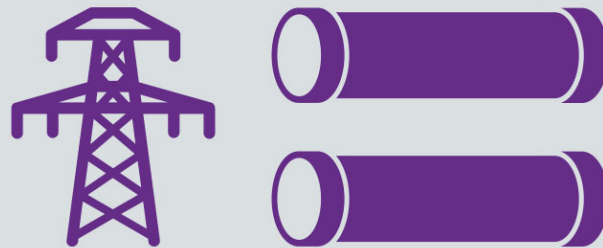
yesterday



few large power plants



centralized, mostly national



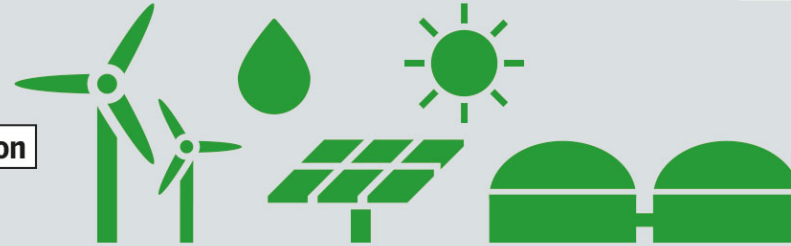
based on large power lines and pipelines

production

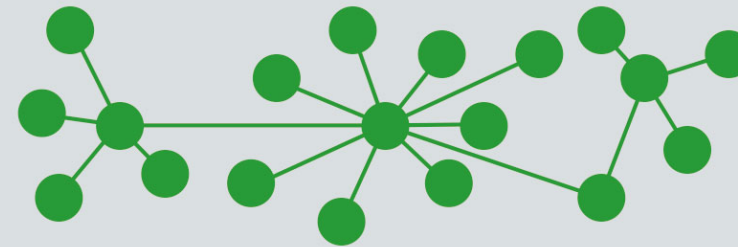
market

transmission

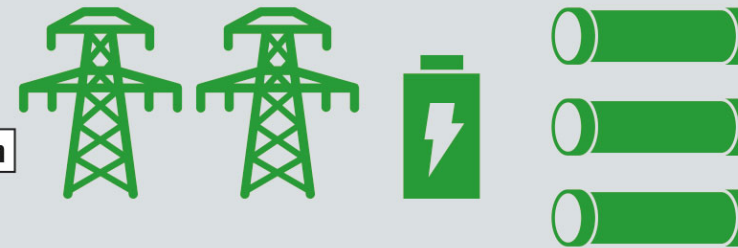
tomorrow



many small power producers

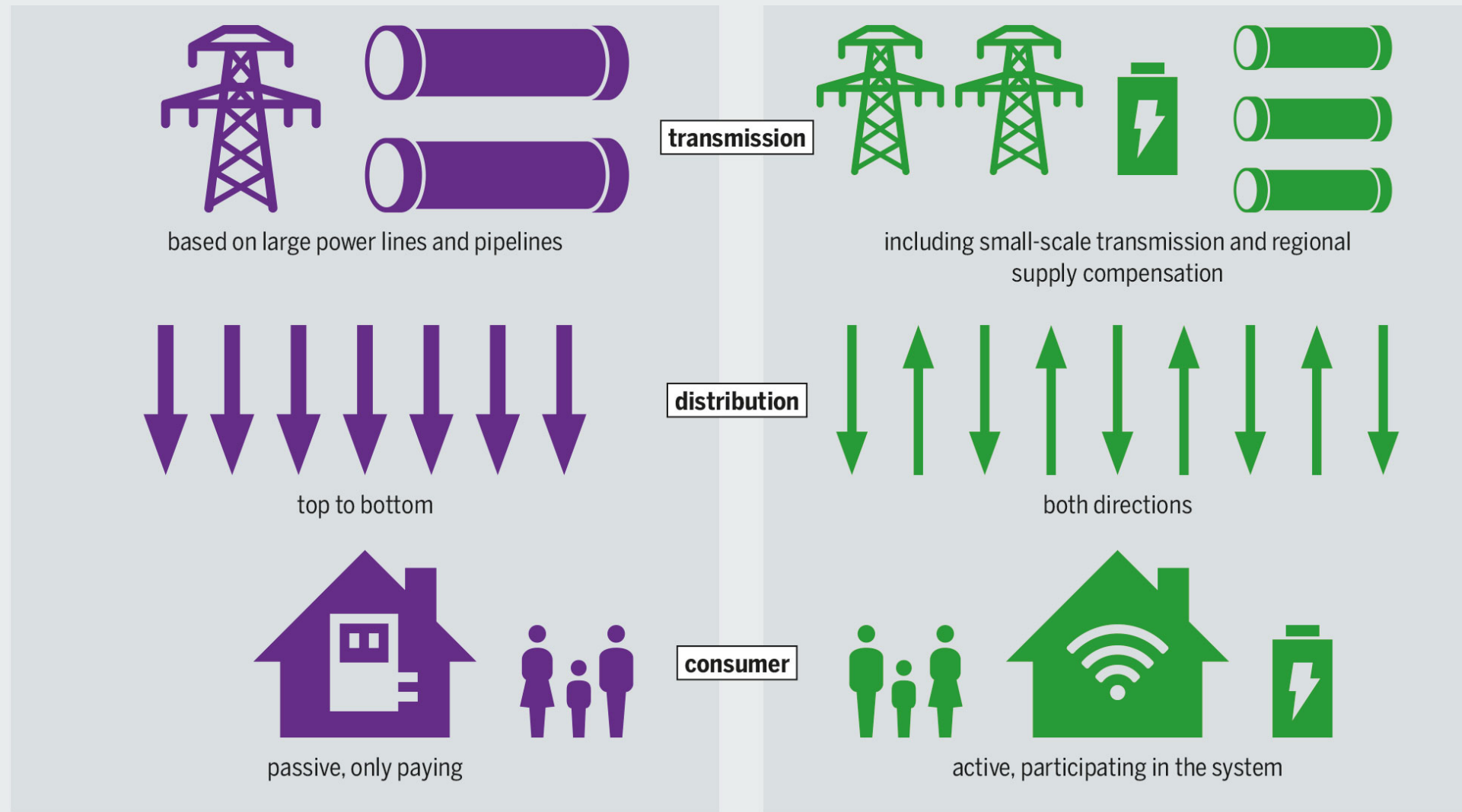


decentralized, ignoring boundaries

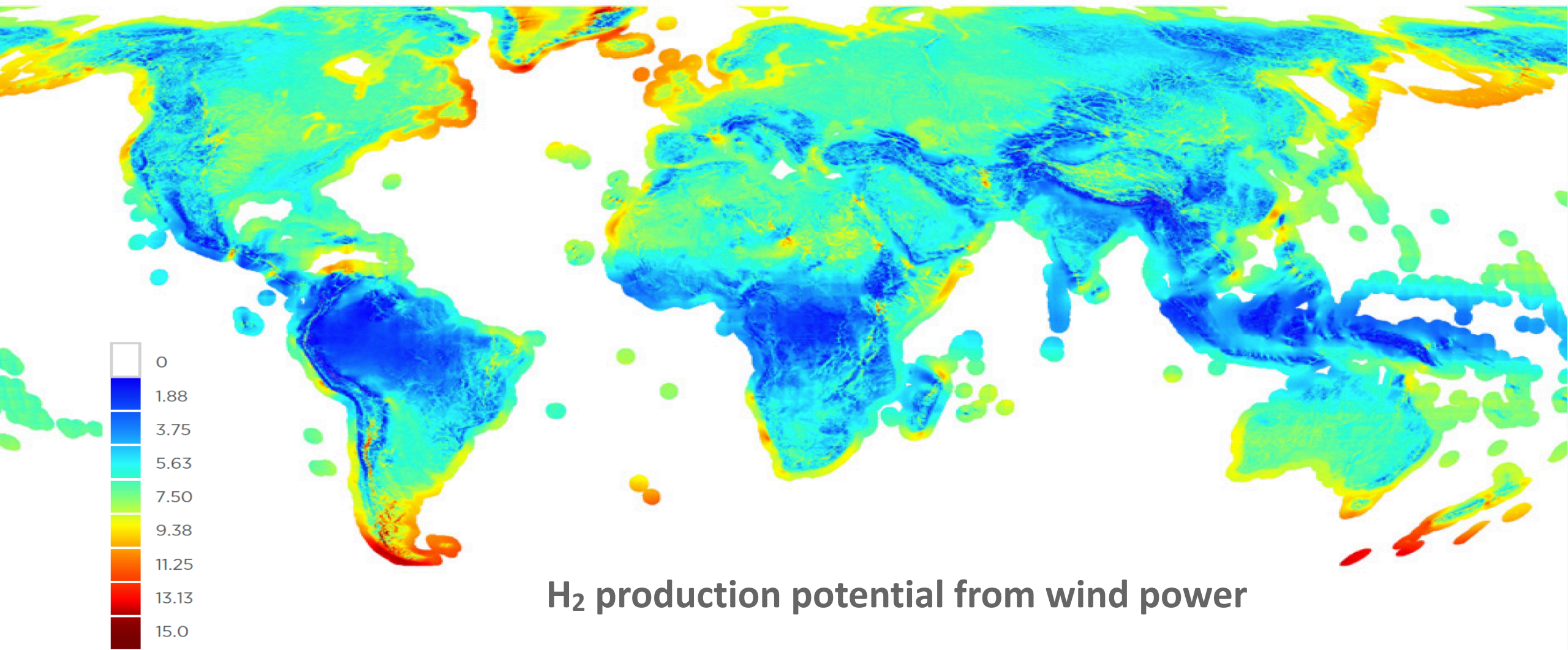


including small-scale transmission and regional supply compensation

GLOBAL PTX = CENTRALIZATION or DE- or RE- CENTRALIZATION ?

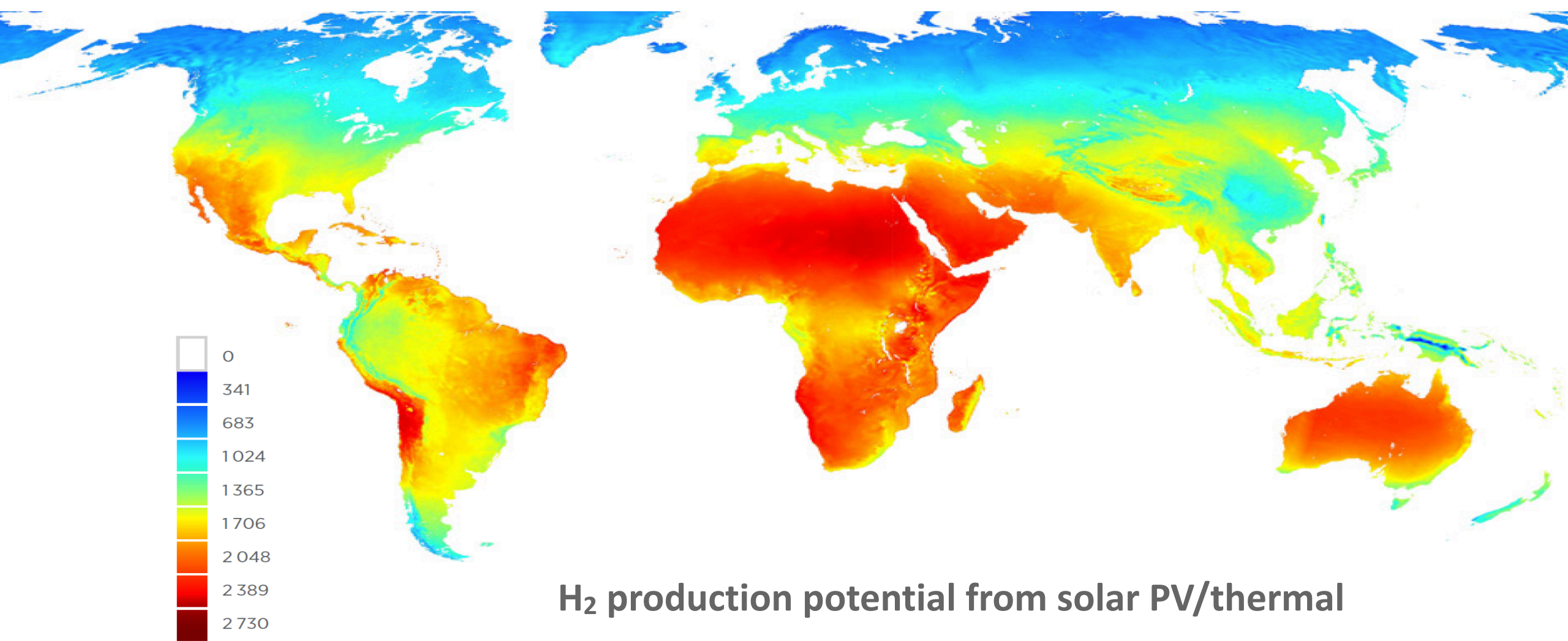


VIRTUALLY "ANYONE" CAN PRODUCE "GREEN" H₂ & MOLECULES



H₂ production potential from wind power

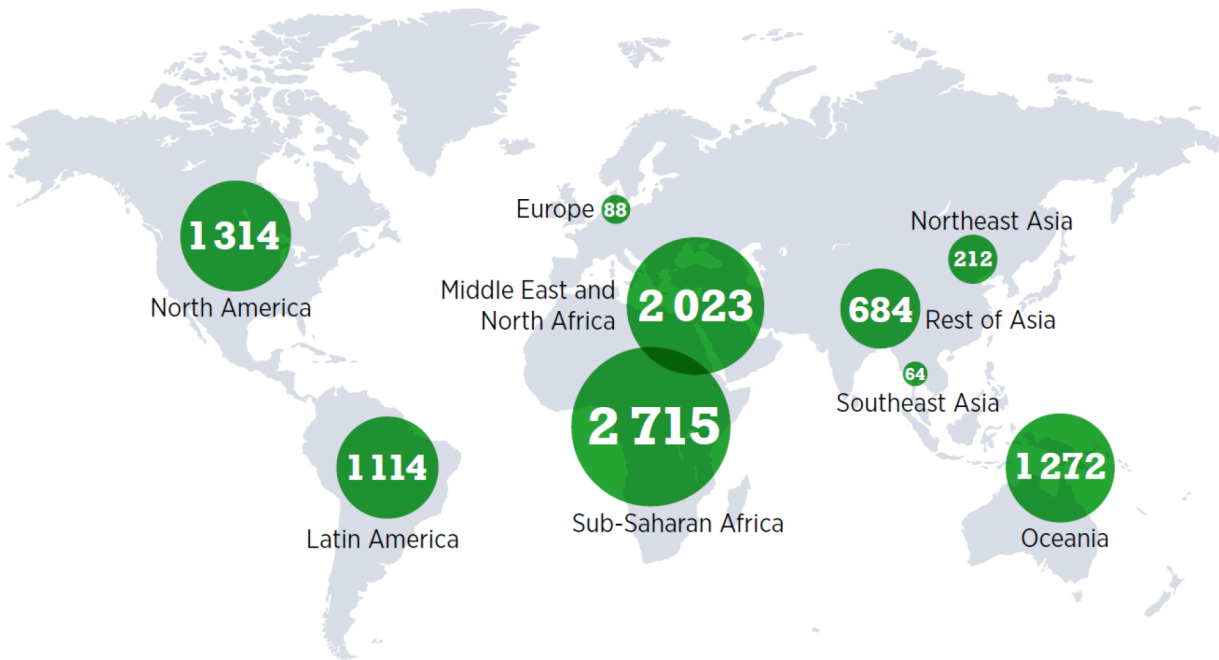
INDIA: FANTASTIC BUT NOT THE MOST OPTIMAL => COMPETITION



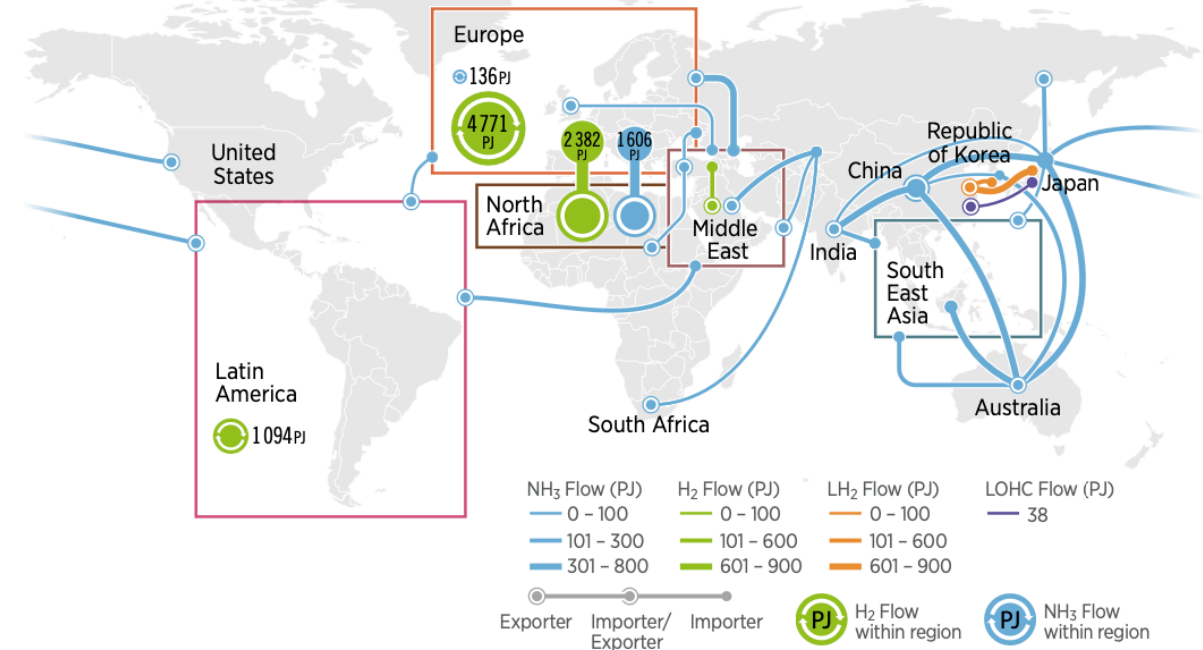
H₂ production potential from solar PV/thermal

S-S AFRICA + MENA = 50% OF LOW-COST "GREEN" H₂ BY 2050

Global green hydrogen production map by 2050 under 1,5 USD/kg (in EJ)

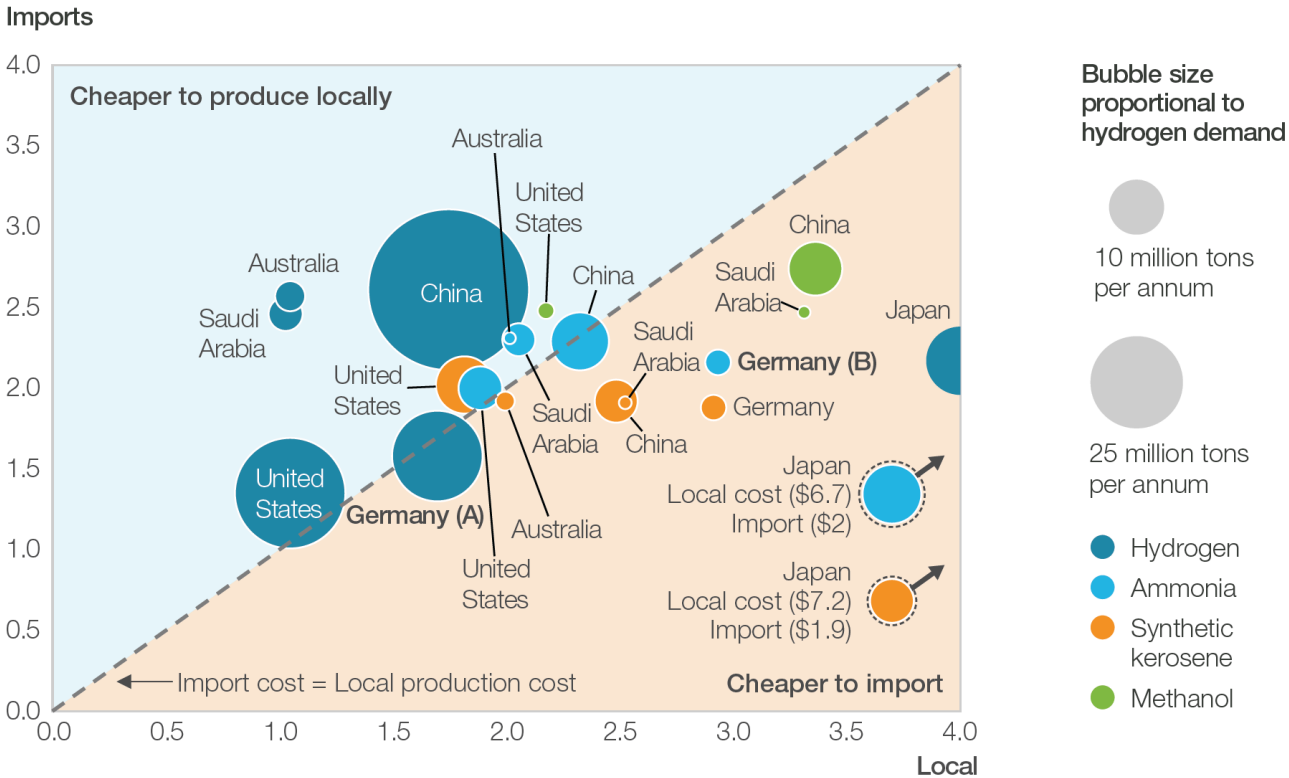


Global hydrogen trade map in 2050 under optimistic technology assumptions

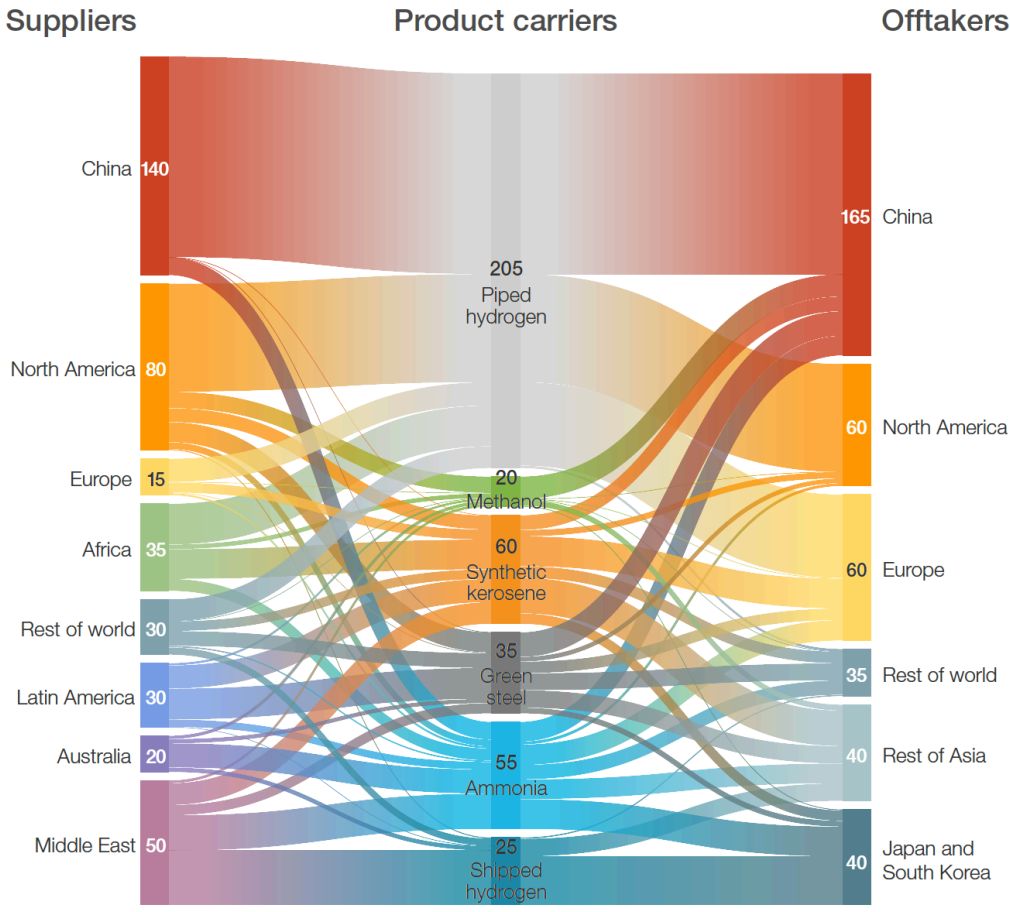


CHINA & US TO BE SELF-SUFFICIENT. SO, WHO CAN OFFTAKE ???

Cost of imports versus local production¹ in 2050, \$/kg hydrogen²



Global hydrogen and derivative interregional long-distance supply,¹ million tons per annum



1. Excludes local production and distribution.

IN THE E.U.: H₂ = ENERGY SOVEREIGNTY = GEOPOLITICAL URGENCY

E.U. ENERGY IMPORTED
FROM RUSSIA IN 2021:

- 45% OF E.U. NATURAL GAS DEMAND
- 25% OF E.U. OIL DEMAND
- 45% OF E.U. COAL DEMAND

REpowerEU POLICY
TARGETS FOR 2030:

- Reduce E.U. fossils consumption by 155GM³
(precisely the amount imported from Russia in 2021)
- x4 E.U. green H₂ production target (10Mt)
- Hydrogen imports target set at 10MT

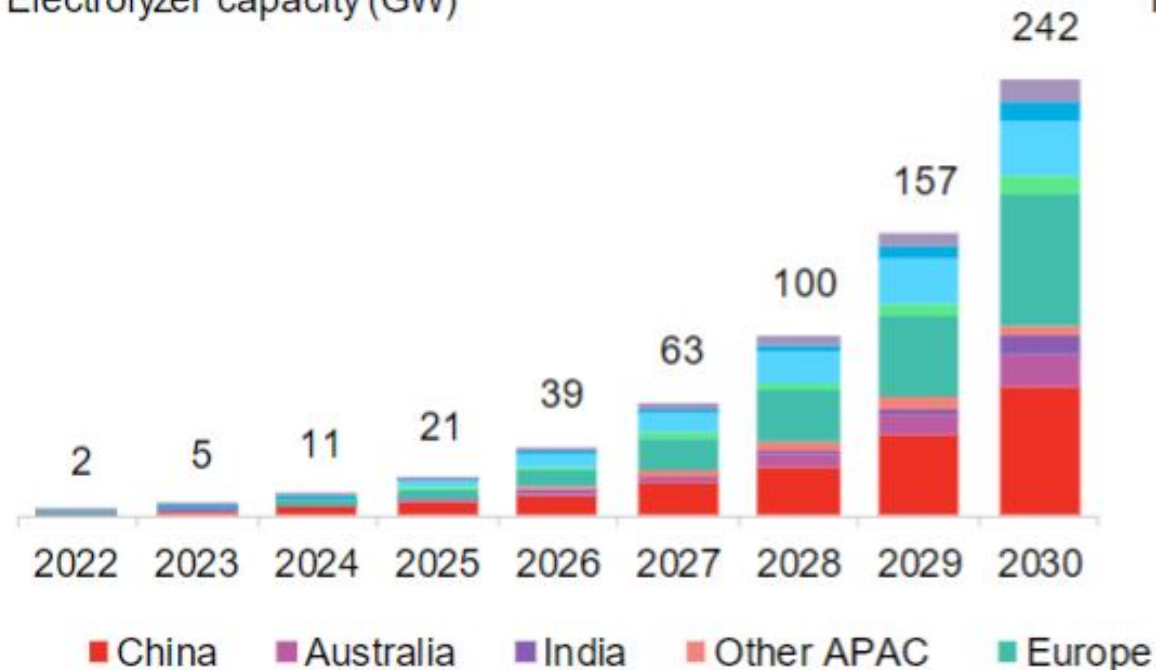
2023 UPDATED GERMAN
FEDERAL H₂ STRATEGY:

- Hydrogen production targets x2
- Hydrogen industrial penetration targets x4

EU 2030 TARGET = EU CONTROLLING 80% OF GLOBAL GREEN H₂ PROD.

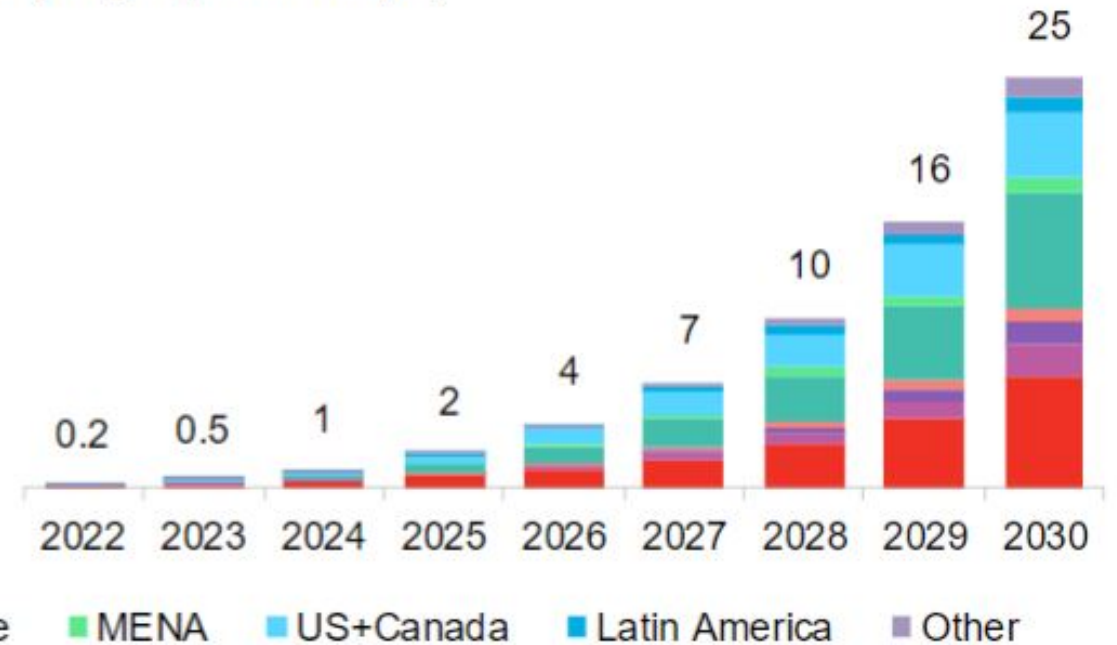
Cumulative electrolyzer capacity

Electrolyzer capacity (GW)



Green hydrogen production

Hydrogen production (Mt)



POLICY-MAKER IN ENERGY-TAKER COUNTRY HAS 2 OPTIONS:

**PRODUCE EXPENSIVE GREEN
HYDROGEN DOMESTICALLY,
REGARDLESS OF THE COST**

**AIM FOR CHEAPER
HYDROGEN IMPORTS FROM
COST-OPTIMAL GREEN H2
PRODUCTION COUNTRIES**

CREATE/RECYCLE INDUSTRIAL JOBS

+ GAIN ENERGY SOVEREIGNTY

+ GENERATE POLITICAL TRACTION

NET LOSS OF INDUSTRIAL JOBS

+ LOSS OF ENERGY SOVEREIGNTY

+ DEGLOBALISATION TREND HURTS

4 GROUPS OF HYDROGEN COUNTRIES, FROM A GEOPOLITICS POV

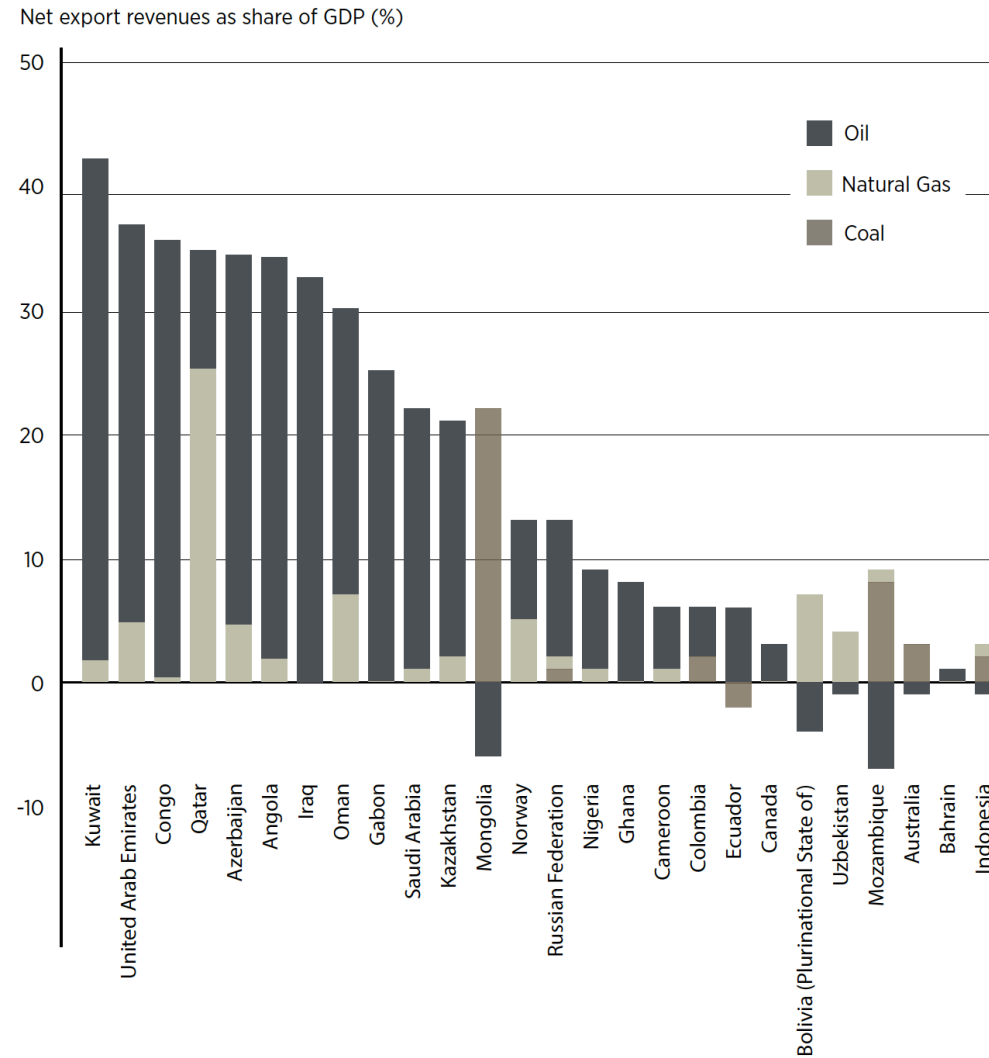
1. THOSE WITHOUT HYDROCARBONS NOR ENOUGH RENEWABLES FOR THEIR INDUSTRIAL NEEDS

2. HYDROCARBON EXPORTERS WITHOUT ENOUGH RENEWABLES => WILL DEVELOP H₂+CCUS, NOT GREEN

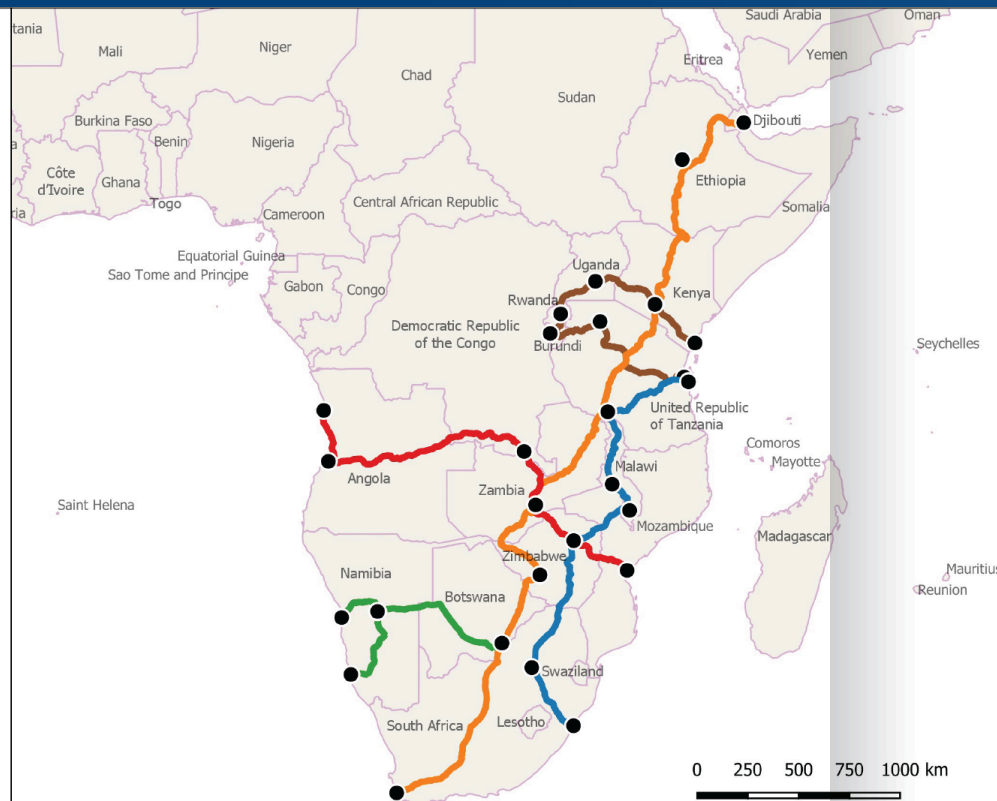
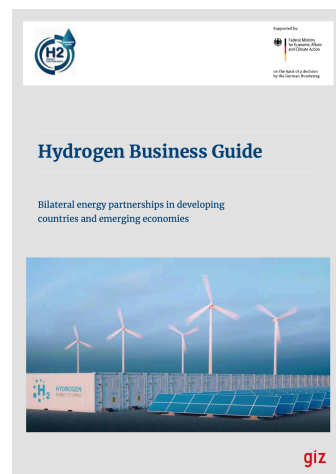
**3. HYDROCARBON EXPORTERS WITH A LOT OF RENEWABLES
=> WILL DEVELOP ALL H₂ VALUE CHAINS, TECHNO-AGNOSTIC**

4. THOSE WITHOUT HYDROCARBONS BUT WITH A LOT OF RENEWABLES => WILL DEVELOP MOSTLY GREEN H₂

FOR GROUPS 1, 2 & 3, UPSCALING H₂ IS A MATTER OF SURVIVAL



AFRICA IS THE NEW PRIME AREA IN HYDROGEN DIPLOMACY



African Hydrogen Routes

1. Beira - Harare - Lusaka - Lubumbashi - Lobito - Luanda
2. Cape Town - Gaborone - Bulawayo - Lusaka - Mbeya - Nairobi - Addis Ababa - Djibouti
3. Gaborone - Windhoek - Walvis Bay - Lüderitz
4. Durban - Johannesburg - Harare - Lilongwe - Blantyre - Mbeya - Dar es Salaam
5. Mombasa - Kampala - Kigali - Bujumbura - Mwanza - Bagamoyo - Dar es Salaam

Strategies: Hydrogen Routes

The first hydrogen economies will begin with construction of large scale P2G renewable energy facilities or hubs along important trans-African highways. They'll also be built in ports, where hydrogen stations will provide fuel for long haul heavy goods vehicles (HGVs), buses and trains powered by hydrogen fuel cells.

Hydrogen routes will connect major mining centers that use heavy duty hydrogen vehicles (such as forklifts, tugs and bulldozers.) They will connect harbors, trade centers, metropolitan areas overland and connect near-shore islands with hydrogen-powered ferries. In metropolitan areas where there's severe air pollution, lightweight and convertible hydrogen fuel cell business vehicles could provide sufficient reliable energy to run a small business during the day and to supply electricity to the owner's home at night. These vehicles will make clean transport and power available and affordable for everyone.

P2G stations and hydrogen automotive applications are complementary business solutions, systems and products. In the hydrogen economy, the consumer transports green energy from large scale, independent renewable energy production facilities and from local mini-grids to wherever they need to consume the energy.

This is a new, revolutionary concept for Africa and would remove its current dependency on the electricity grid for energy.

With its large trans-African highway network, Africa offers great business opportunities for the new and rapidly growing hydrogen technology sector.

These are five feasible hydrogen routes along existing trans-African highways and business centers:

1. Beira - Harare - Lusaka - Lubumbashi - Lobito - Luanda
2. Cape Town - Gaborone - Bulawayo - Lusaka - Mbeya - Nairobi - Addis Ababa - Djibouti
3. Gaborone - Windhoek - Walvis Bay - Lüderitz
4. Durban - Johannesburg - Harare - Lilongwe - Blantyre - Mbeya - Dar es Salaam
5. Mombasa - Kampala - Kigali - Bujumbura - Mwanza - Bagamoyo - Dar es Salaam

This is not an exhaustive or final list: other routes could also be constructed. But significantly, these five hydrogen routes connect 15 capitals (metropolitan regions) as well as several significant mining regions and 11 major harbors.

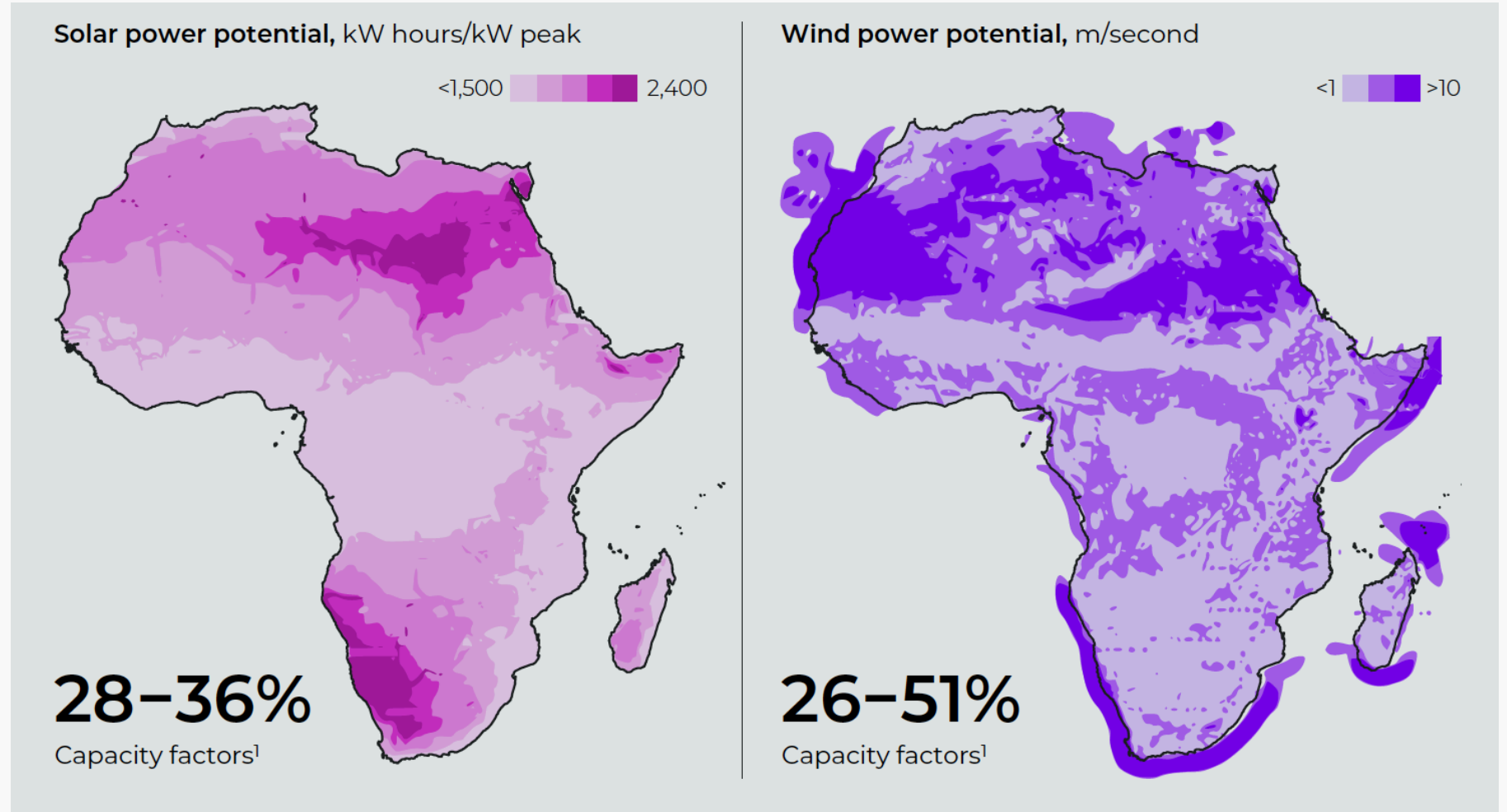


AFRICAN HYDROGEN POWERHOUSES ARE ORGANISING THEMSELVES



**MOROCCO
MAURITANIA
EGYPT
KENYA
SOUTH AFRICA
NAMIBIA**

Created in May 2022



CHINA IS ONLINE: WORKFORCE, PROJECTS, NEW TECHS

2019: H₂ degree-programs to be developed in ALL polytechnic universities

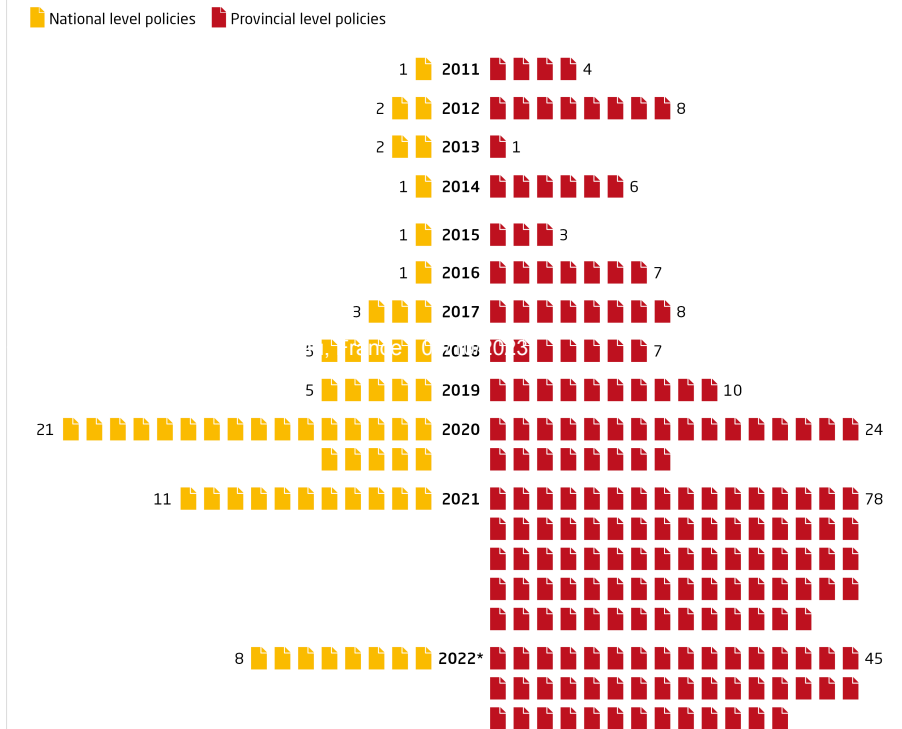
Jan. 2022: President XI asks for an nationwide "acceleration" in H₂-energy

Mar. 2022: National H₂ development plan up to 2035 - est. 22Bn USD

As of 31/12/2022: 500+ policy documents mentioning hydrogen across China

Provincial governments are driving the growth of China's hydrogen industry

Number of policies mentioning hydrogen or fuel cells issued at the national and provincial level



*Note: Year-to-date as of May 1, 2022.

Source: MERICS Policy Database

© MERICS

HOW TO UNLOCK HYDROGEN LONG-DISTANCE EXPORTS?



- **PURE GAZEOUS H₂ IN DEDICATED PIPELINES**
- **LIQUIFIED AMMONIA**
- **E-METHANOL / E-NG / DME / SAFs**
- **LOHC: LIQUID ORGANIC H₂ CARRIERS (TOL/MCH)**
- **LNOHC: LIQUID NON-ORGANIC H₂ CARRIERS (Liquid Silicium Hydrides - HydroSil)**
- **SOLID H₂ CARRIERS (Ti-Mg Metallic Hydrides, Sodium Borohydride)**
- **SEMI-FINITE PRODUCTS (steel, fertilisers, alumina, ciment, fish products...)**

SEMI-FINITE PRODUCTS: BEST PROSPECT FOR AFRICA & INDIA?



ACCELERATES INDUSTRIALISATION

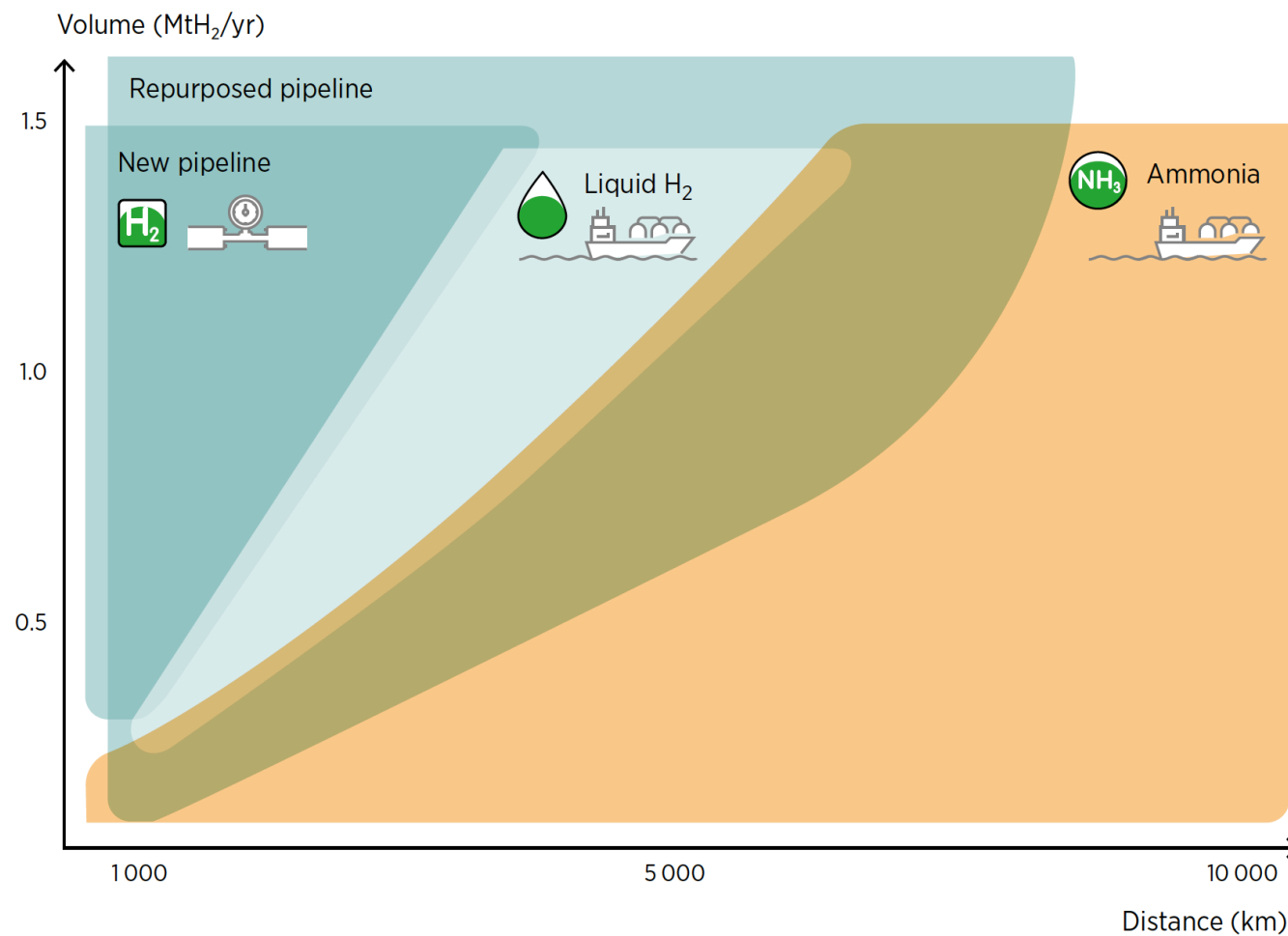
**GREATER IN-COUNTRY VALUE OUT OF A
RENEWABLE POWER-TO-X VALUE CHAIN**

**GREATER SCALE-UP SPEED THAN TRYING
TO EXPORT MOLECULES**

MORE SECTOR COUPLING OPPORTUNITIES

GREATER FUNDING B/C LESS RISKY

NH₃ SEEMS TO BE THE EXPORT-BEST MOLECULE, FOR NOW...

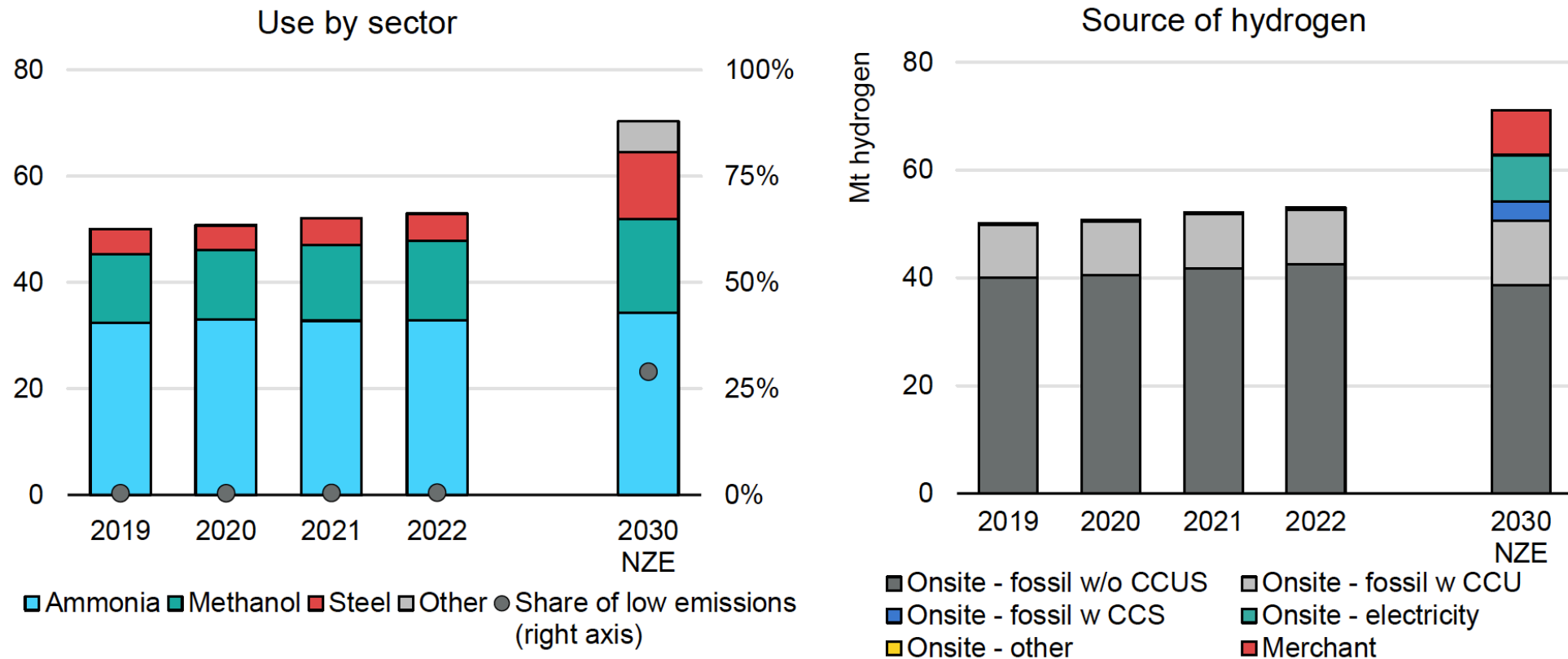


Source: IRENA (forthcoming-a)

Note: H₂ = hydrogen gas; km = kilometre. Mth₂/yr = million tonnes of hydrogen per year.

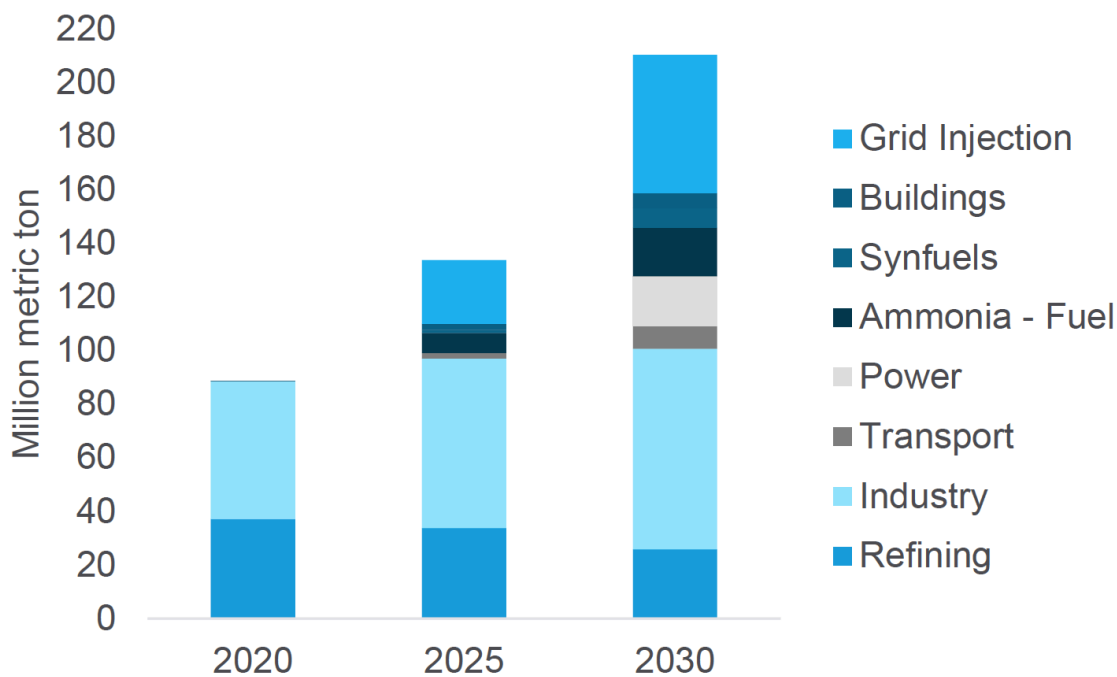
...BECAUSE IT'S LIKELY TO BECOME THE 1ST INDUSTRIAL H₂ USE...

Figure 2.4 Hydrogen use in industry by subsector and by region and source of hydrogen, historical and in the Net Zero Emissions by 2050 Scenario, 2019-2030



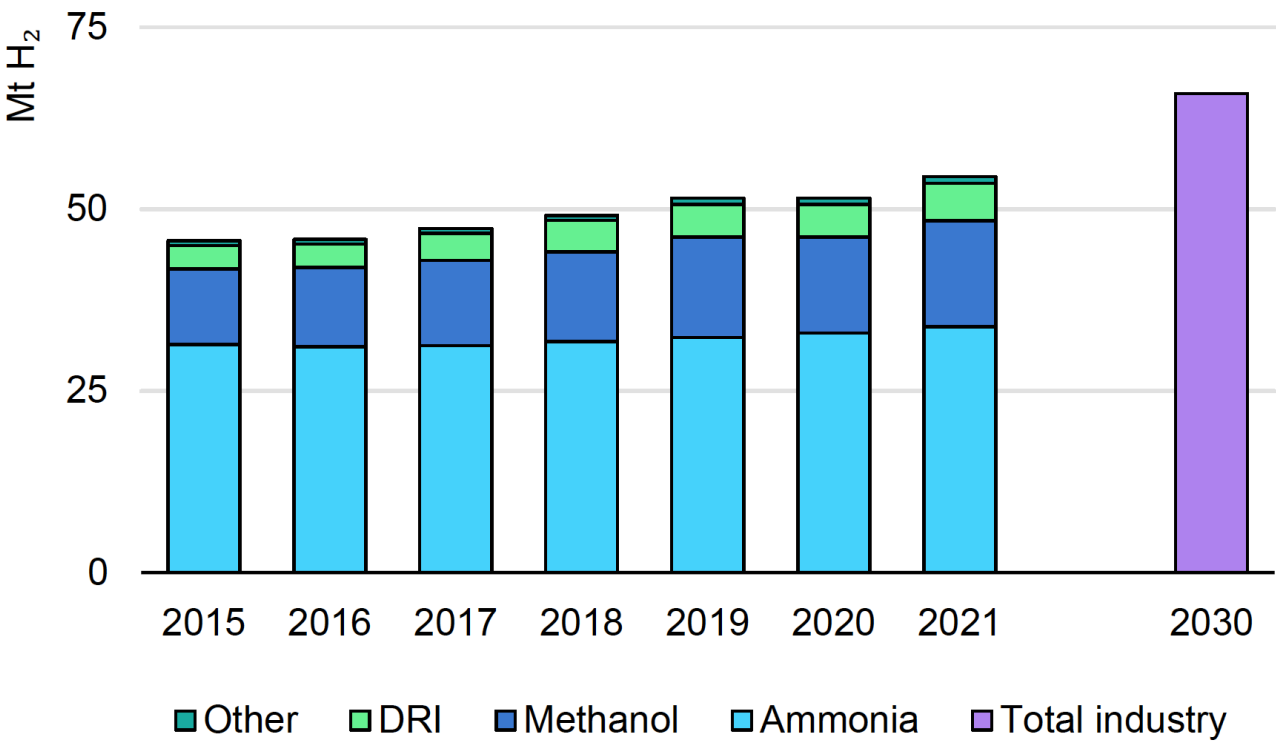
...B/C IT WORKS + INFRA AVAILABLE + OWN MARKET BEYOND H₂

Figure 1. IEA Projection of Global Hydrogen Demand by Sector in the “Net Zero by 2050” Scenario, 2020-30



Source: IEA, Citi GPS

Global hydrogen demand in industry, 2015-2030

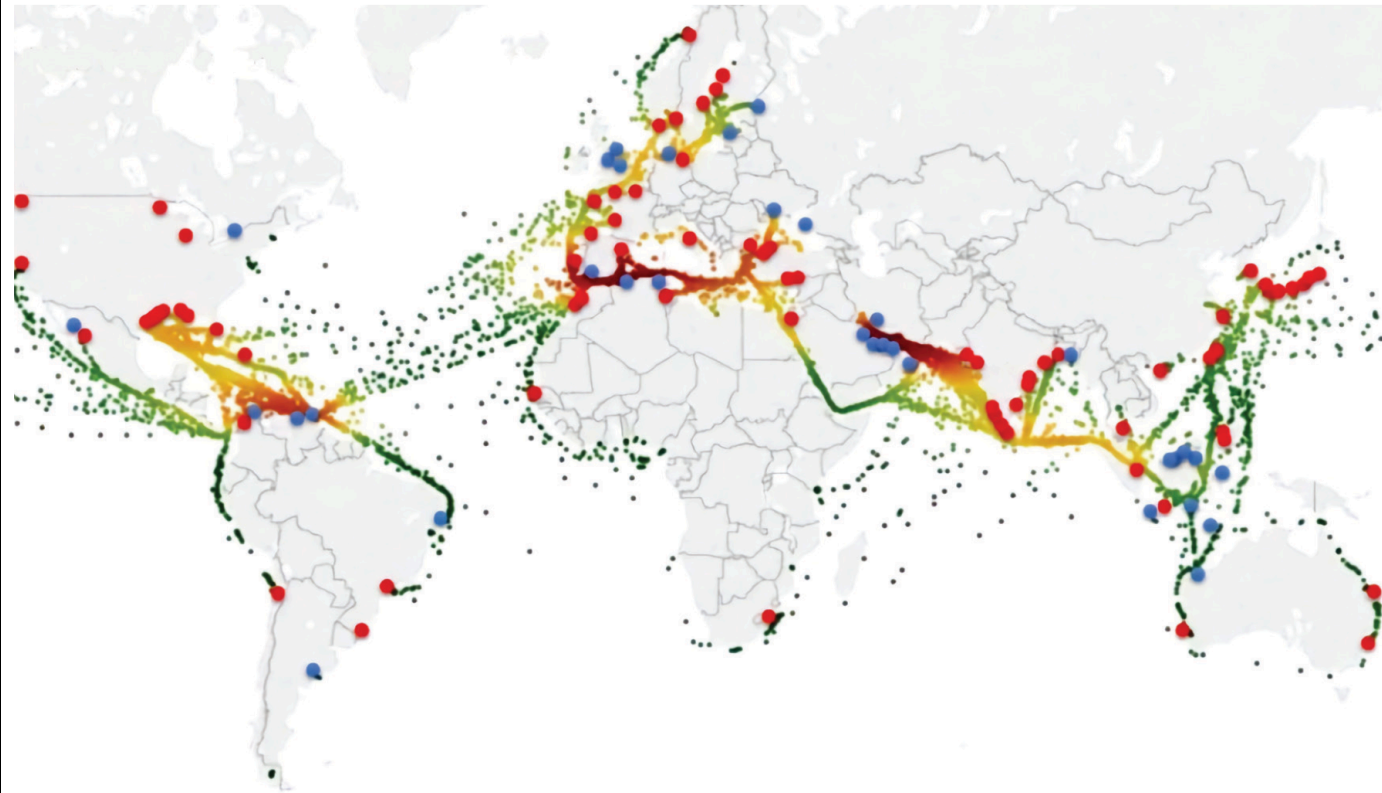


MORE THAN 130 PORT TERMINALS W/ NH₃ CAPACITY GLOBALLY

Ammonia shipping infrastructure, including a heat map of liquid ammonia carriers and existing ammonia port facilities (2017).

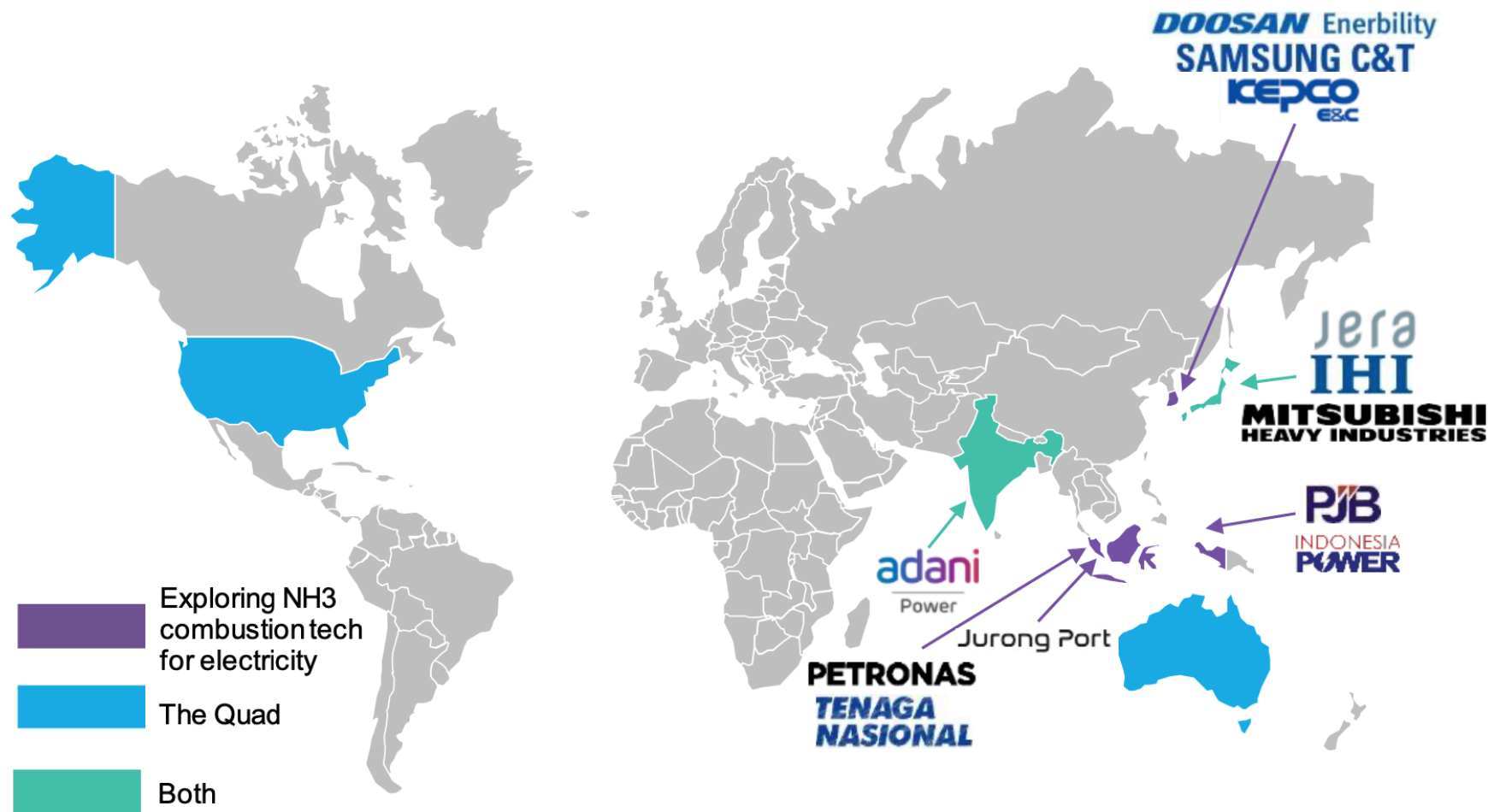
KEY

● Ammonia loading facilities ● Ammonia unloading port facilities



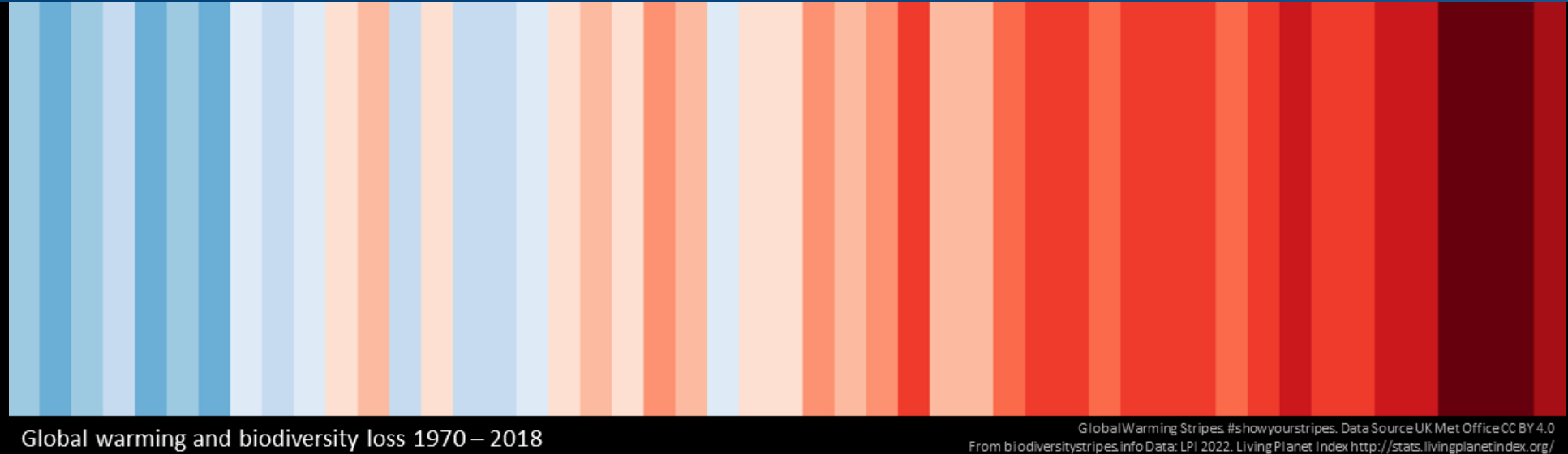
JAPAN LEADER IN AMMONIA CO-FIRING TECHS + QUAD DYNAMIC

Figure 6: Countries and major companies working on ammonia co-firing tech

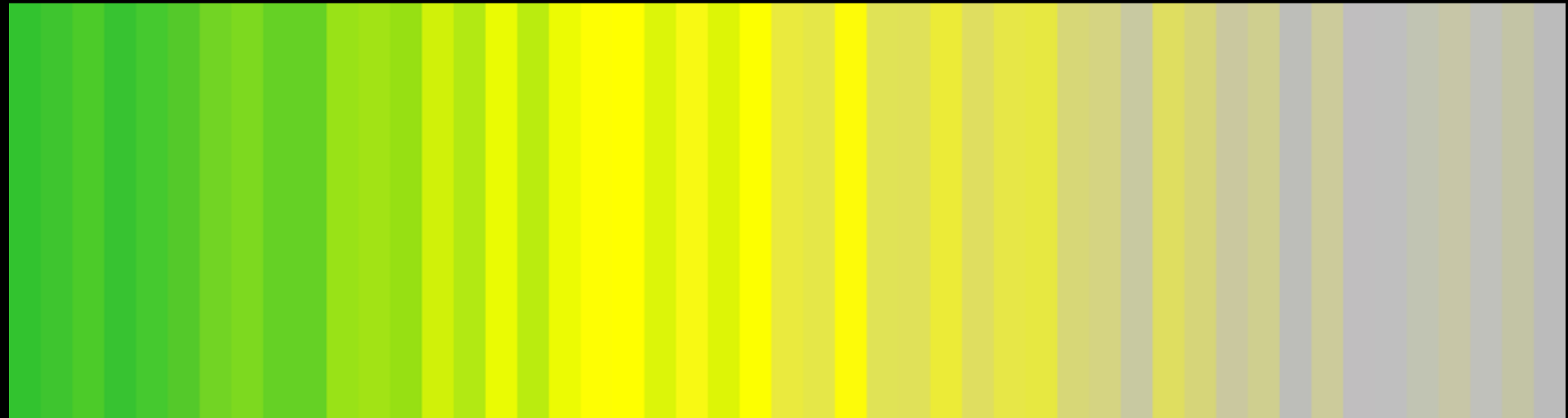


BUT, WHAT IF $\text{H}_2 \Rightarrow \text{NH}_3/\text{NH}_4$ WAS ACTUALLY A WRONG IDEA?

H_2 may help
with this \Rightarrow



NH_3 may
aggravate
that \Rightarrow



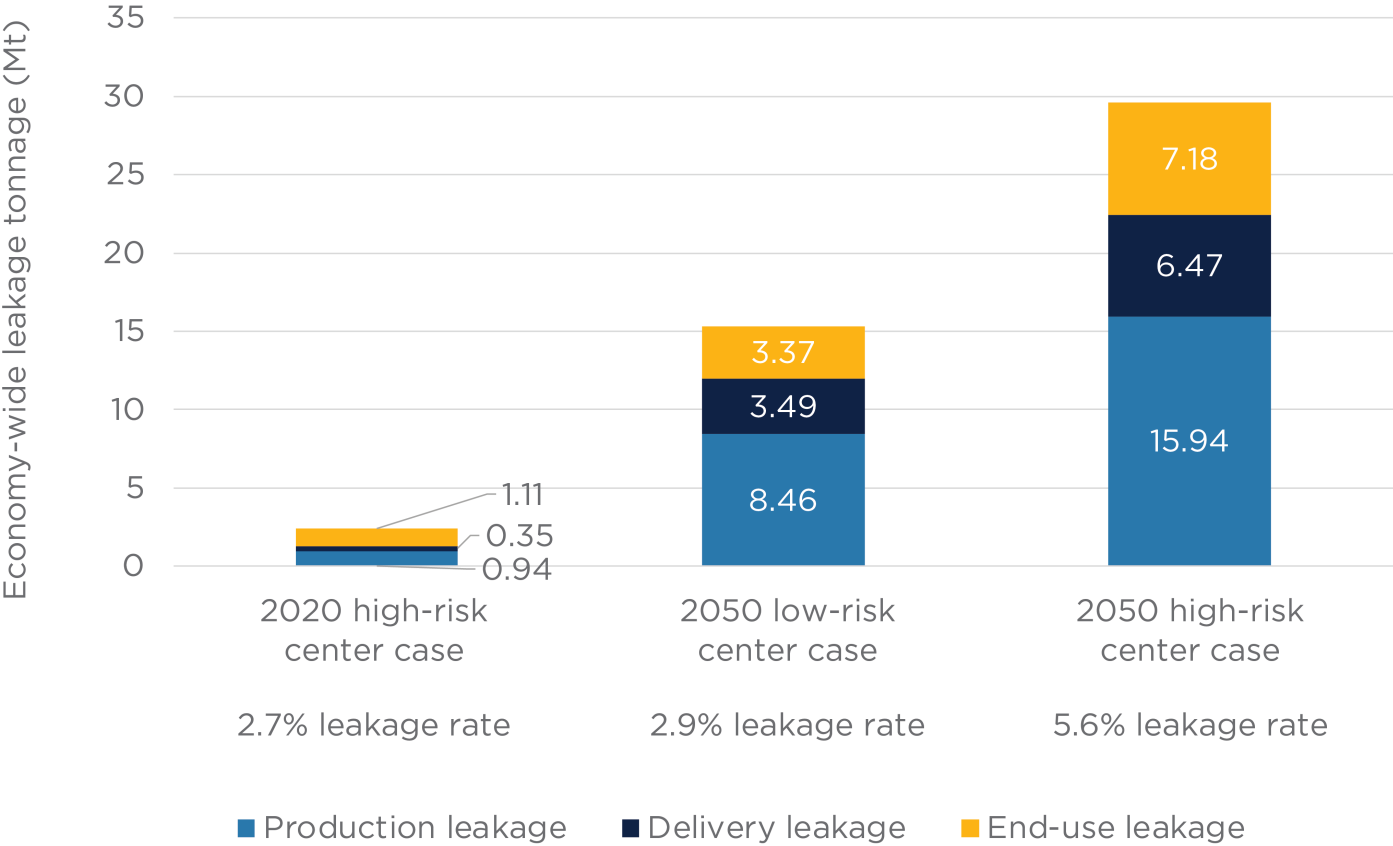
AT 300Mtpa, H₂ LEAKS AT 1% = NO CLIMATE BENEFIT WHATSOEVER

Table 1: Hydrogen leakage summary

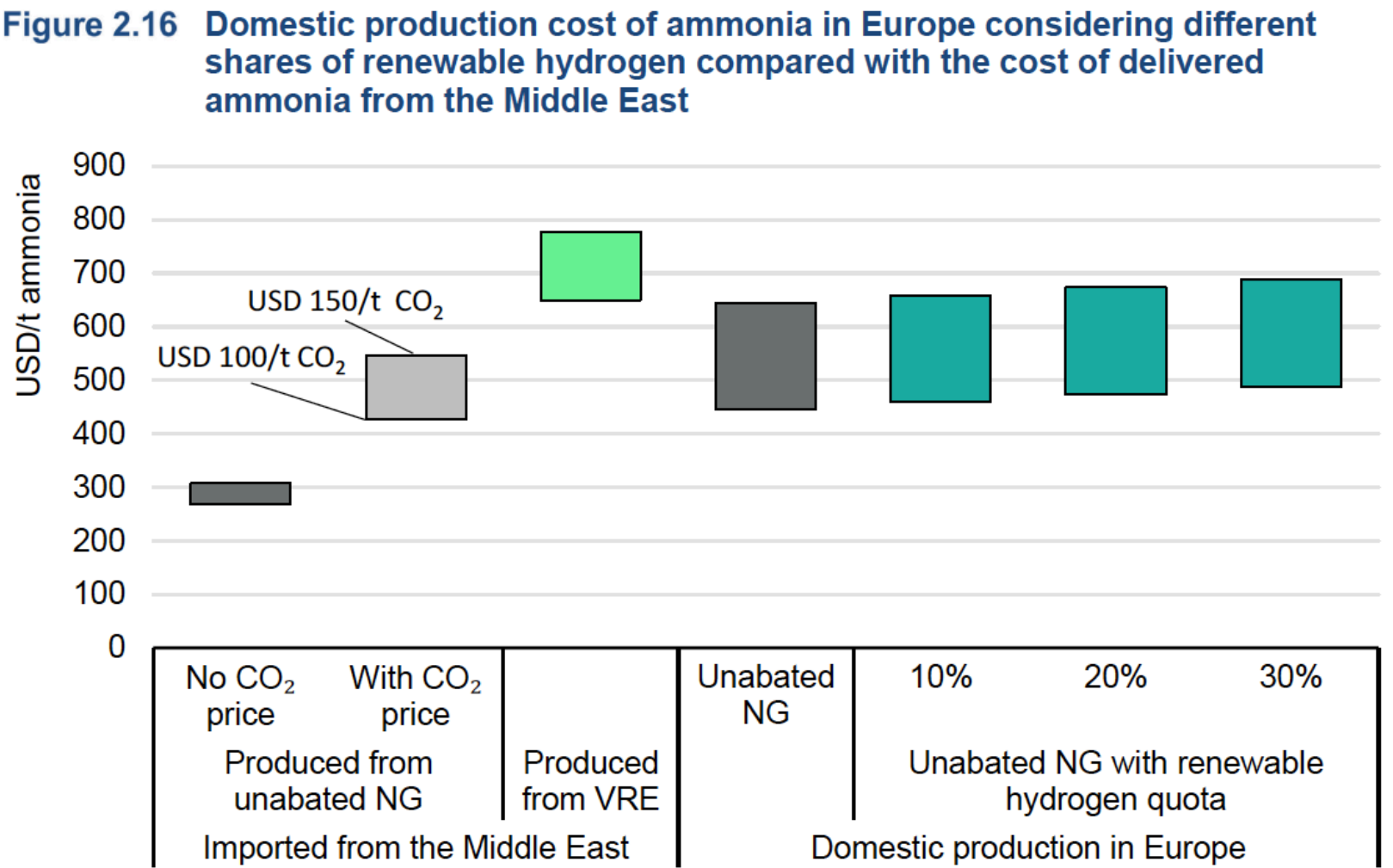
Leakage source process	Category	Scale (Mt)	2050 high-leakage center case	References	2050 low-leakage center case
Grey hydrogen	Production	8	1.0%	[Xia et al. 2019]	0.5%
Blue hydrogen	Production	197.6	1.5%	[Barrett & Cassarino, 2021]	1.0%
Green hydrogen	Production	322.4	4.0%	[Harrison & Peters, 2013]	2.0%
Natural gas blending	Application	59.9	0.9%	[Alvarez et al. 2011] [Mejia & Brouwer, 2018]	0.5%
Chemical synthetic fuels	Application	159.7	0.5%		0.2%
Iron and steel	Application	40.4	0.5%		0.2%
Electricity generation	Application	88	3.0%	[Alvarez et al. 2011] [Mejia & Brouwer, 2018]	1.5%
Road transport	Application	93.2	2.3%	[Alvarez et al. 2011] [Mejia & Brouwer, 2018]	1.0%
Aviation	Application	7.8	3.0%		
Shipping	Application	2.9	2.3%		1.0%
Refineries	Application	8.4	0.5%		0.2%
Buildings	Application	16.2	0.8%	[Fischer et al. 2018]	0.5%
Other industries	Application	28.3	0.5%		0.2%
Miscellaneous	Application	23.2	0.5%		0.5%
Pipeline transport and storage	Delivery	143.1	2.0%	[Panfilov, 2015] [US DOE targets, 2022]	1.0%
Pipeline local distribution	Delivery	76.5	0.4%	[Weller et al. 2020] [Mejia & Brouwer, 2018]	0.2%
Truck transport and storage	Delivery	55.9	5.0%	[US DOE, 2017] [Petipas, 2018]	2.5%
Direct use on site	Delivery	252.4	0.2%	[Panfilov, 2015] [Mejia & Brouwer, 2018]	0.2%

Note: Based on 2020 reference.

Figure 2: Economy-wide hydrogen leakage by process, 2020 and 2050



B/C OF POLICY: MOVING FROM "GREEN PREMIUM" TO "GRAY LIABILITY"



THE MORE ONE COMMITS, THE MORE THE BENEFITS...

U.S. IRA HYDROGEN SUPPORT MECHANISM = UP TO 137 Bn USD

JAPAN 2023 UPDATED "GX" STRATEGY = 107 Bn USD for H₂/HN₃

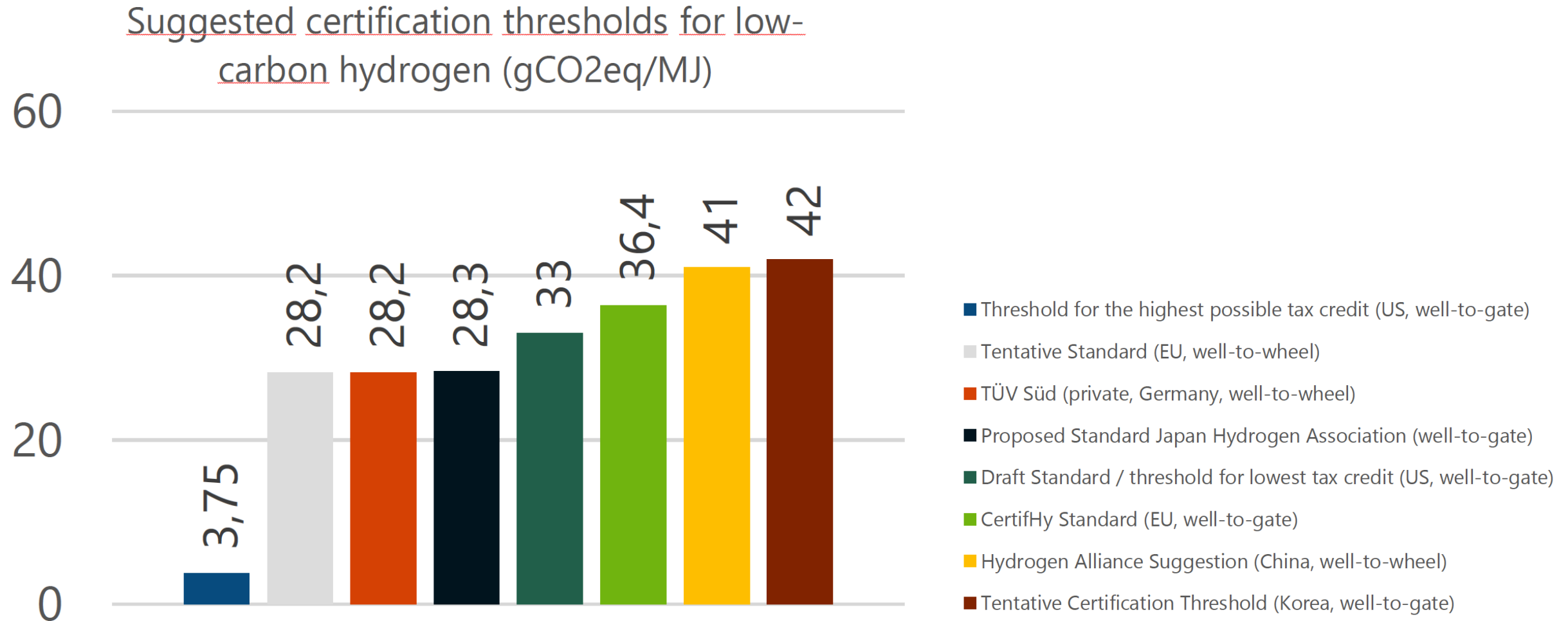
CHINA 2022 HYDROGEN PLAN = 22 Bn USD

GERMANY 2023 FEDERAL UPDATED STRATEGY = 19.5 Bn USD

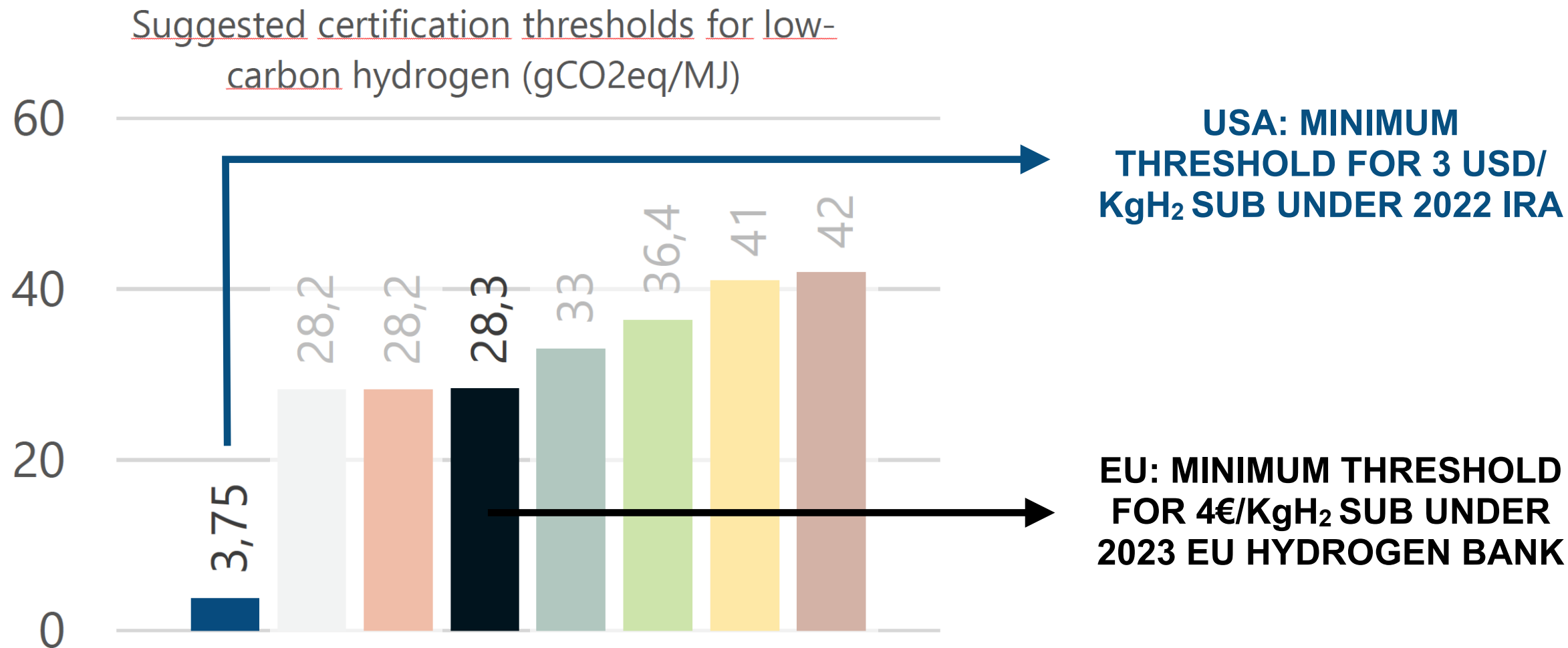
SOUTH AFRICA 2023 UPDATED STRATEGY = 16 Bn USD

FRANCE 2020 STRATEGY + 2021-2023 ADD-ONS = 15 Bn USD

NORMATIVE EFFORT + INTERNATIONAL ALIGNMENT IS CRITICAL



2023: GEOPOLITICS OF H₂ PUBLIC DE-RISKING INCENTIVES

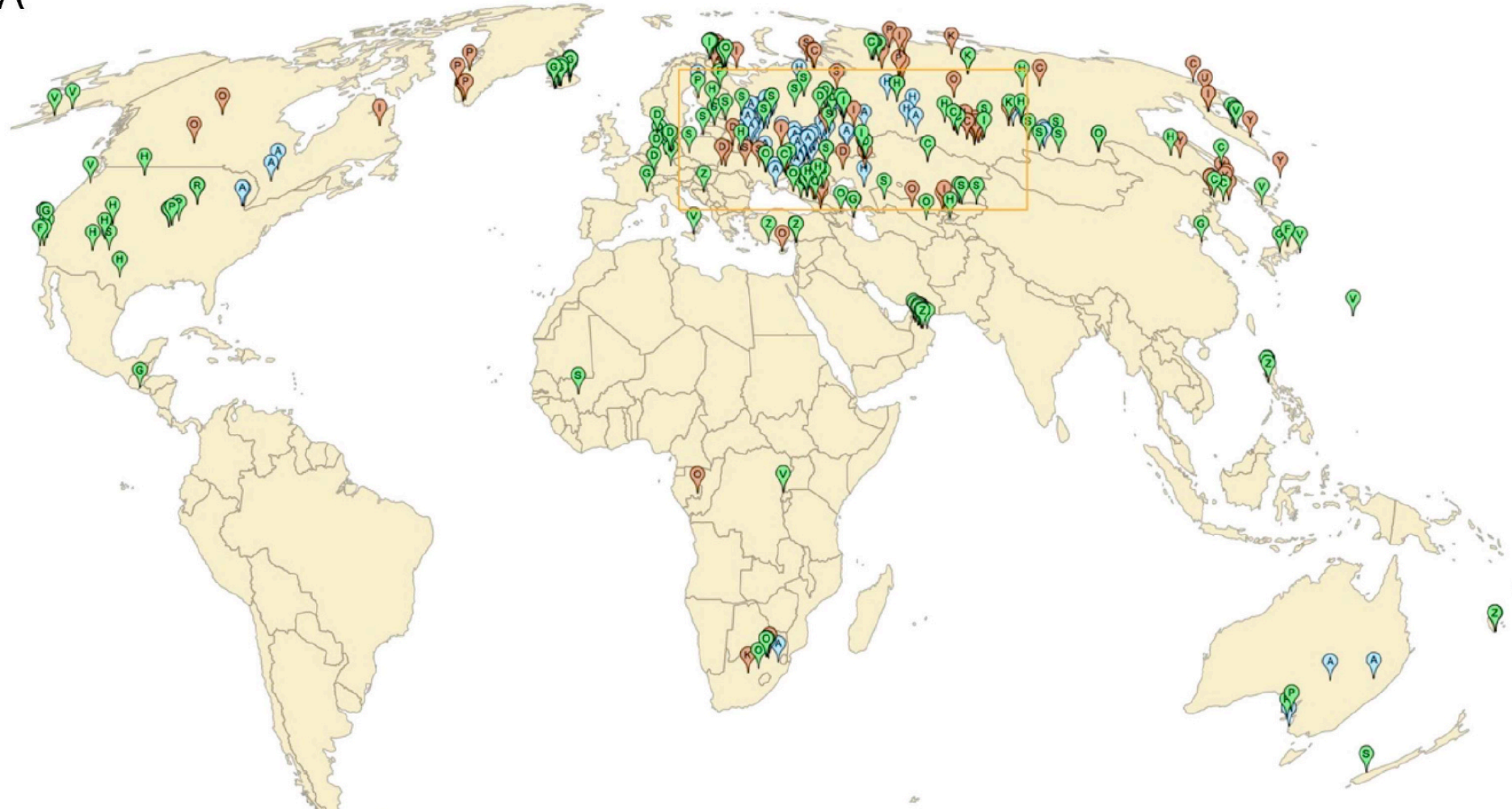


E.U. RFNBOs: WORLD'S MOST CLIMATE-EFFECTIVE CRITERIONS

- **ADDITIONALITY REQUIREMENT**
- **TIME-CORRELATION REQUIREMENT**
- **ZONING REQUIREMENT**
- **CERTIFICATION THRESHOLD $28.2\text{gCO}_{2\text{eq}}/\text{MJ}$**
- **CARBON ADJUSTMENT MECHANISMS**

NATURAL HYDROGEN = A GAME-CHANGER BY 2050

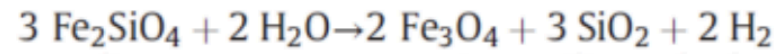
A



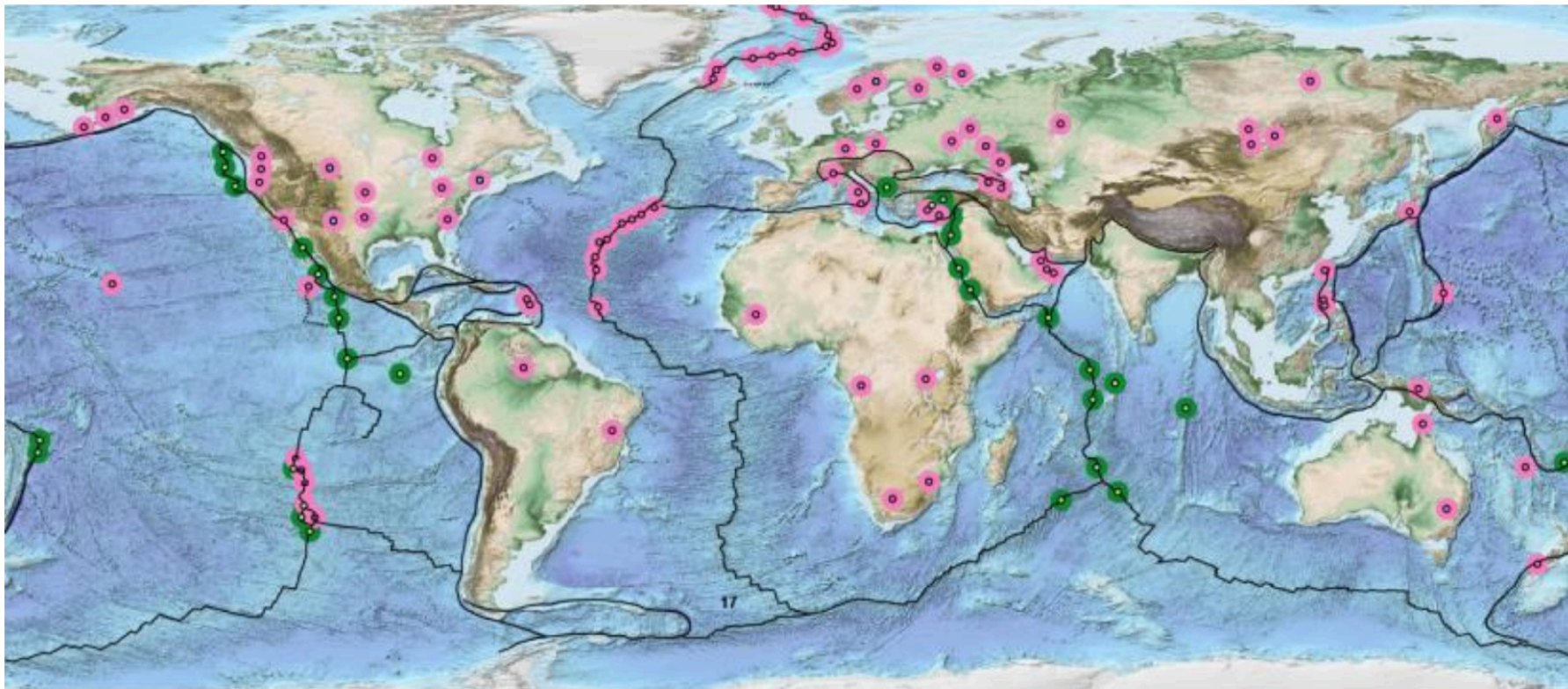
ABUNDANT + THE GREENEST OF ALL GREEN HYDROGENS

H₂

MÉTHANE ABIOTIQUE DÉRIVÉ DE H₂



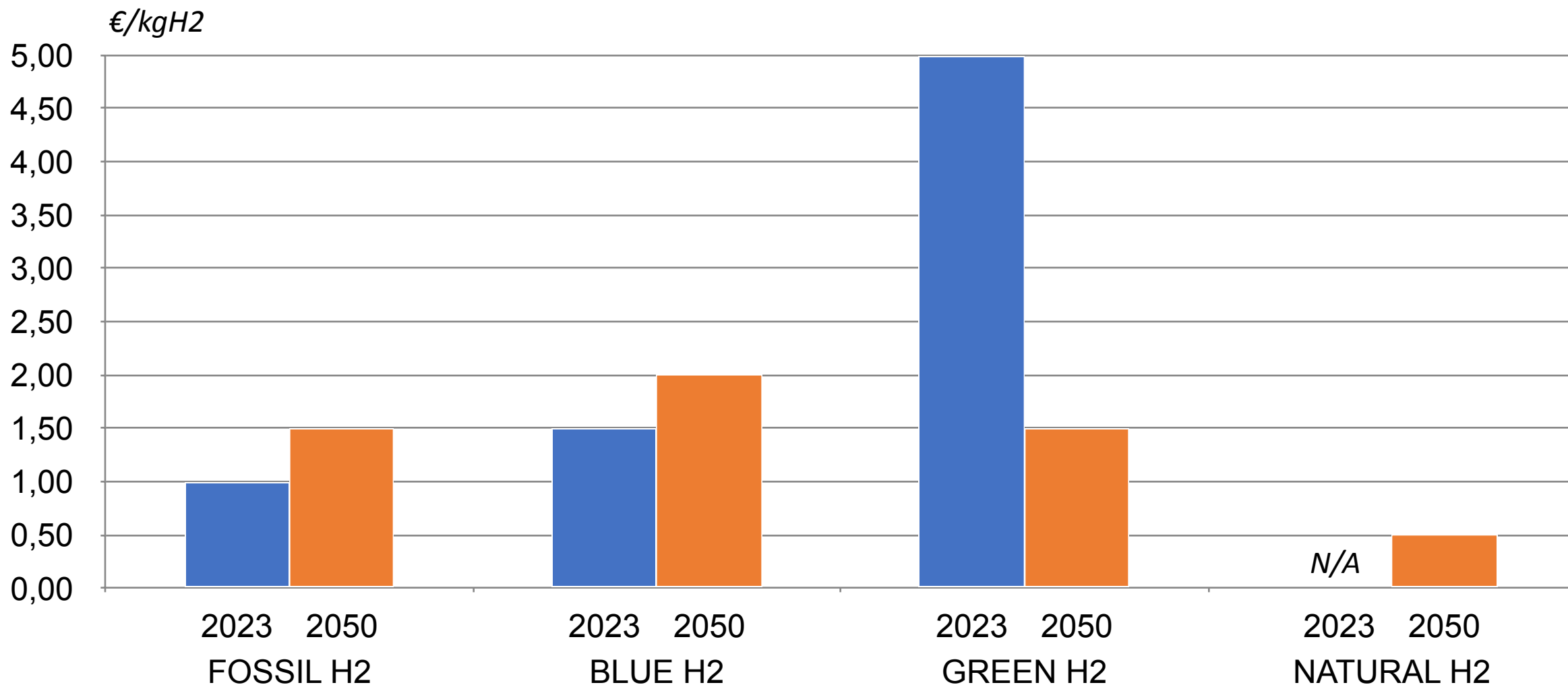
Olivine + Water → Serpentine + Magnetite + Hydrogen



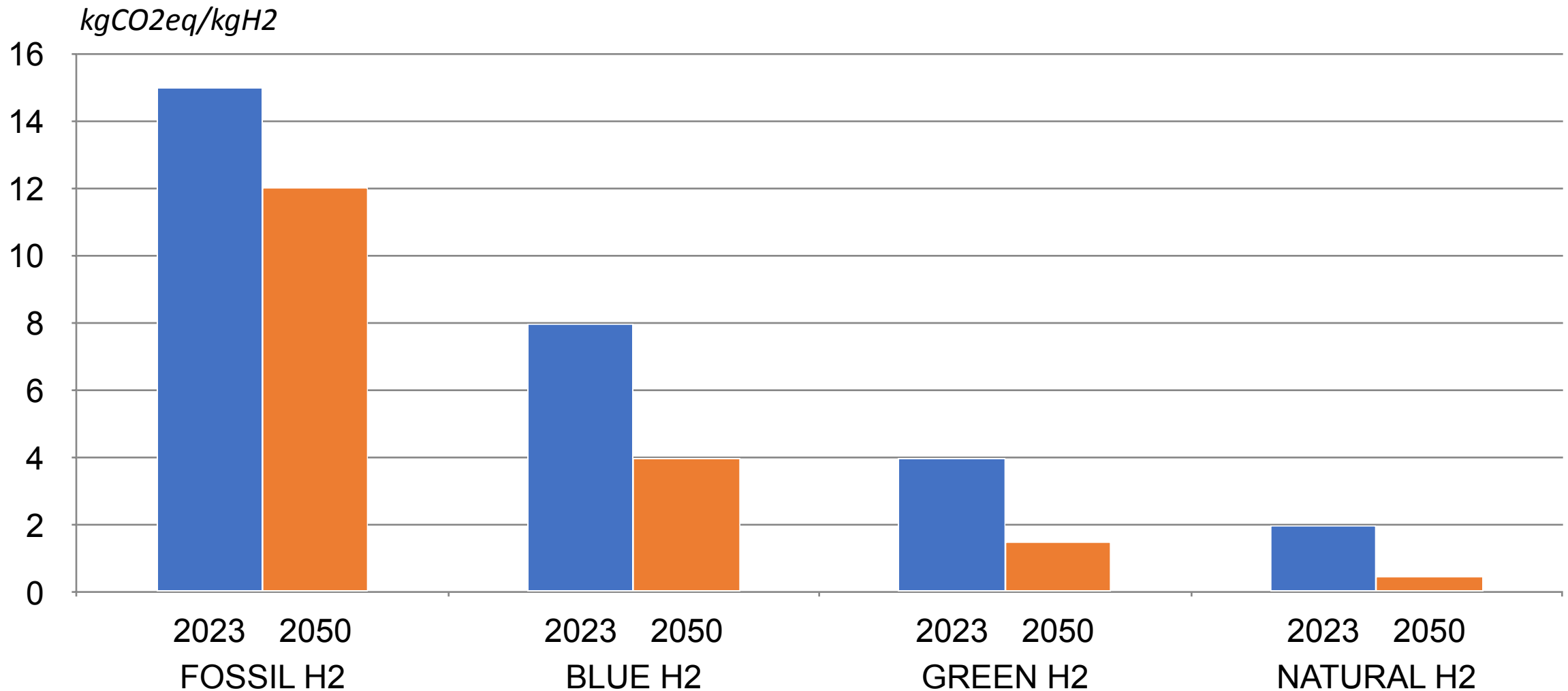
■ Mid-oceanic ridges

■ East Pacific r.:	H ₂ ≈60% (Welhan & Craig., 1979)
■ Rainbow:	H ₂ ≈50% (Charlou et al., 2002)
■ Logachev:	H ₂ ≈50% (Douville et al., 2002)
■ Lost City:	H ₂ ≈70% (Kelly et al., 2005)
■ Ashadze :	H ₂ ≈70% (Charlou et al., 2008)

RENEWABLES + HYDROGEN = LOWEST LCOH BY 2050



RENEWABLES + HYDROGEN = LOWEST CO₂eq/MWh



GREEN HYDROGEN ECOSYSTEMS' 4 KEY SUCCESS FACTORS

SCALABILITY

*(accelerates **proof** of concept + investments + de-risking mechanisms)*

SALEABILITY

*(provides **proof** that hydrogen can be clean + safe + accessible + somewhat affordable)*

SECURITY

*(of use, of supply, and **proof** that H2 can contribute to energy security)*

SOVEREIGNTY

*(**proof** that H2 can provide strategic autonomy: domestic use before exports + (re-)industrialization + sector coupling)*

S1 2022: LOW-CARBON H₂ STILL IS AN "MoU INDUSTRY"...

- 1066 low-carbon H₂ projects at MoU stage
- 217 have reached Final Investment Decision (FID) = 20.36%
- 119 FIDs are in Europe = 11.36% of total = 54.84% of FIDs
- 30 FIDs are in USA & Canada = 2.81% = 13.82% of FIDs
- 16 FIDs are in China = 1.50% = 7.37% of FIDs
- Rest of the world = 52 FIDs = 1.50% = 23.96% of FIDs

THANK YOU FOR YOUR ATTENTION!

NOW, IT'S YOUR TIME TO DELIVER ;-)

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or e-mail : **mikaa.mered@sciencespo.fr**