04/12/2020

HYDROGEN EUROPE

Hydrogen's role in the green deal & decarbonisation

Hydrogen Europe: Who we are

Our Vision

Hydrogen enabling a zero emission society

Our Mission

We bring together diverse industry players, large companies and SMEs, who support the delivery of hydrogen and fuel cells technologies. We do this to **enable the adoption of an abundant and reliable energy which efficiently fuels Europe's net-zero carbon economy.**

Hydrogen Europe

ABENGOA · Advent · AeH2 · AFHYPAC · AFS · AGFA · Air Liquide · Air Products · AIRBUS · ALSTOM · AMF Bakery Systems · AngloAmerican

ANSALDO ENERGIA · aperam · AREVA · AsahiKASEI · atawey · Audi · AVL · AVGUSTA · Baker Hughes · BALLARD · Bioway · BMW Group · bp · Brintbranchen · h2a

CaetanoBus · capitalenergy · CCS Global · Ceres Power · CENERGY · Chantiers de l'Atlantique · CHART · CHEREAU · CNH Industrial · Colruyt Group · DAIMLER · DAM Group · Danish Power Systems · DENSO Crafting the Core

DEME Concessions · AMHYD · ΔEΠA · DWV Deutscher Wasserstoff- und Brennstoffzellen-Verband · DKV · D.TEK · elcogen · EMEC · DESFA · enagas · e.on · ENGIE · equinor · convion · ENERGINET · ESB · EFCF European Fuel Cell Forum · Everfuel · EWE

Falck Renewables · faurecia · GAZ-System · Fuel Cell Powertrain · elringklinger · FEV · FINCANTIERI · Finnish Energy · Estonian Association of Hydrogen Technologies · ervia · EATON · Fronius · KEYOU · galp · FTI Consulting

gasunie · GENCELL · Greenerity · FLUXYS · GRTgaz · HY2GEN AG · H2energy · H2B2 · H2V · Haskel · HDF · Helion · Hinicio · Holthausen Clean Technology · HYTEP Czech Hydrogen Technology Platform

FREUDENBERG · HONDA · HELLENIC PETROLEUM · Howden · Hungarian Hydrogen and Fuel Cell Association · HyET · HYDROGENICS · hydrogenious LOHC Technologies · HYDROPOLE · HYGEAR

HyMove · EDF · HYSYTECH · hypion · HYUNDAI · Íslensk NýOrka · iht · INEA · IRD · ITM POWER · JSW SA · John Cockerill

kiwa · Q8 Research · H2LV · Lithuanian Hydrogen energy association · KLASTER · Logan Energy · Linde · MAYFAIR MARINE · McPhy · Mercedes-Benz FuelCell

JM Johnson Matthey · metacon · MICHELIN · Lhyfe · LANDIRENZO · Motor Oil (Hellas) · LIEBHERR · LUXFER Gas Cylinders · MTSA Technopower · group mvm · NEA Group · LOTOS · Mitsubishi Power · nel · MTU Aero Engines · hydrogen.no · Nouryon · ORLEN · Open Grid Europe · OMV · ontras · BOSCH

PAUL WURTH · Persee · PGE · Plastic Omnium · PLUG POWER · Nedstack · Port of Antwerp · NOVA SWISS · Port of Rotterdam · PowerCell · PowiDian · Proton Motor · Ricardo

H2RO · RWE · Saint-Gobain · planetpower · SAFRAN · Salzgitter Mannesmann Forschung · Mytilineos · NESTE · sfice · Shell · SMA · SMARTENERGY · SIEMENS · PGNiG · Slovak National Hydrogen Association · SHV ENERGY · SNCF · SOLARIS · REPSOL · SOLENCO POWER

SOLID POWER · storengy · Sumitomo Benelux s.a./n.v. · sunfire · Swagelok · SYMBIO · snam · Teréga · Thyssengas · TOMO GROUP · TORAY · TOYOTA

UKHFCA · Ukrainian Hydrogen Council · UFI Innovation Center · umicore · SAIPEM · Schlumberger · uniper · walter tosto · VÄTGAS SVERIGE · VATTENFALL · WIGA · thyssenkrupp · VDL · TÜV SÜD · TÜV NORD · VIESSMANN · TOTAL

VOLVO · Verbund · VAN HOOL · VOITH · WOIKOSKI · Worley · WORTHINGTON INDUSTRIES · Wystrach · YANMAR · ZEG Power · ZSI · voestalpine

Hydrogen Europe: who we are

Hydrogen Europe

FCH techno providers and/or pure players

H2 Production & distribution

AREVA H2Gen (We make it happen), AsahiKASEI (Asahi Kasei Europe), atawey, H2B2, HYDROGENICS (Shift power | energize your world), iht, ITM POWER (Energy Storage | Clean Fuel), nel, McPhy, SIEMENS, John Cockerill, thyssenkrupp, sunfire, AGFA, Agfa, Air Liquide, Linde, WOIKOSKI, HYGEAR, hydrogenious LOHC TECHNOLOGIES, HyET Hydrogen, Advent, metacon, Wystrach, NEA GROUP, INEA (Informatics Energy Automation), HYSYTECH, Haskel, Swagelok, WORTHINGTON INDUSTRIES, Everfuel, AIR PRODUCTS, NOVA SWISS

FC Transport

BALLARD, elringklinger, FUEL CELL POWERTRAIN, HyMove (Hydrogen moves your world), PM PROTON MOTOR (Fuel Cells · Power Systems), Mercedes-Benz FuelCell, POWERCELL, PLUG POWER, SYMBIO, FREUDENBERG (INNOVATING TOGETHER), MICHELIN, faurecia, op

FC Stationary

CeresPower, BOSCH (Invented for life), convion, SOLENCO POWER, elcogen, GENCELL, SOLIDPOWER, Nedstack, SAINT-GOBAIN, ENGIE, IRD, m-FIELD, INTSA TECHNOPOWER, Helion (by AREVA), Danish Power Systems, VIESSMANN (climate of innovation)

Others

Fronius, Hinicio, CCS Global, Persee, EFCF European Fuel Cell Forum, TÜV SÜD, MAYFAIR MARINE, Sumitomo Benelux s.a./n.v., Worley (energy | chemicals | resources), sfice (innovative minds), kiwa, JM Johnson Matthey (Inspiring science, enhancing life), TOMO GROUP, TORAY (Innovation by Chemistry), EMEC, umicore, hypion, H2energy

Energy companies

enagas, ervia, gasunie new energy, TERÉGA, Open Grid Europe

GAZ-SYSTEM, DESFA, ontras Gastransport GmbH, FLUXYS, GRTgaz, snam

ESB Energy for generations, Verbund, JSW SA, equinor, Falck Renewables PURE POWER TO GROW, ENGIE

fortum, ENERGINET, storengy

DTEK, uniper, VATTENFALL, EDF, mvm group, PGE Polska Grupa Energetyczna, EWE, e.on

TOTAL, MOTOR OIL (HELLAS) CORINTH REFINERIES S.A., LOTOS, galp, HELLENIC PETROLEUM, Shell, bp, OMV, Q8 Research, NESTE

H2V, PowiDian, capitalenergy, Lhyfe, HDF, AFS, Logan Energy, ISLENSK NYORKA

Industrial companies

Baker Hughes, SIEMENS, ABENGOA, ANSALDO, Howden, John Cockerill

DEME CONCESSIONS, voestalpine ONE STEP AHEAD, ArcelorMittal, Nouryon, SALZGITTER MANNESMANN FORSCHUNG

PAUL WURTH SMS group, Air Liquide, Port of Antwerp, Port of Rotterdam

aperam, SMA, thyssenkrupp, YANMAR, AngloAmerican, Linde

Transport companies

faurecia, BOSCH Invented for life, MICHELIN, AVL, FEV, DAM, UFI INNOVATION CENTER

TOYOTA, BMW Group, DAIMLER, HYUNDAI, HONDA, VOLVO

VANHOOL, COLRUYT GROUP, VDL, SOLARIS, CaetanoBus, CNH INDUSTRIAL, CHEREAU INNOVATION DRIVES YOU FORWARD, YANMAR, HOLTHAUSEN CLEAN TECHNOLOGY

ALSTOM, SNCF, MITSUBISHI POWER

AIRBUS, SAFRAN, LIEBHERR

CHANTIERS DE L'ATLANTIQUE, FINCANTIERI

National Associations

AeH2 Spanish Hydrogen Association, AFHYPAC, H2 Society, AM-HYD, DWV Deutscher Wasserstoff- und Brennstoffzellen-Verband, Brintbranchen, Finnish Energy, Lithuanian Hydrogen energy association

Hungarian Hydrogen and Fuel Cell Association, hydrogen.no, H KLASTER, H2LV, ZSIS, H2, UKRAINIAN HYDROGEN COUNCIL

HYDROPOLE, Estonian Association of Hydrogen Technologies

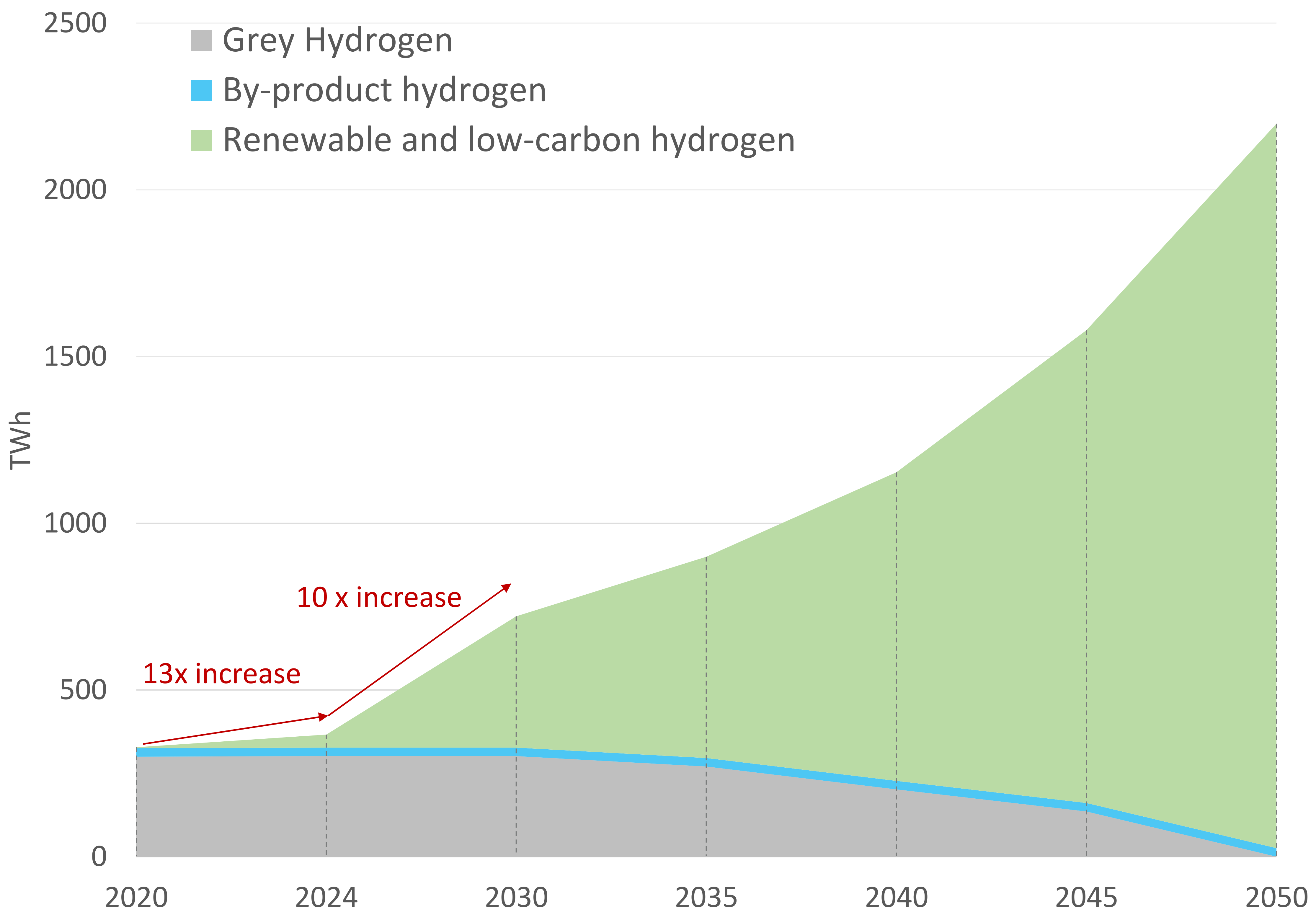
VÄTGAS SVERIGE, UKHFCA, Slovak National Hydrogen Association, HYTEP CZECH HYDROGEN TECHNOLOGY PLATFORM SINCE 2007, H2RO

What we want

Enable clean hydrogen to:

- replace all unabated fossil hydrogen consumption,
- replace fossil fuels and feedstocks in other sectors where hydrogen can play a role.

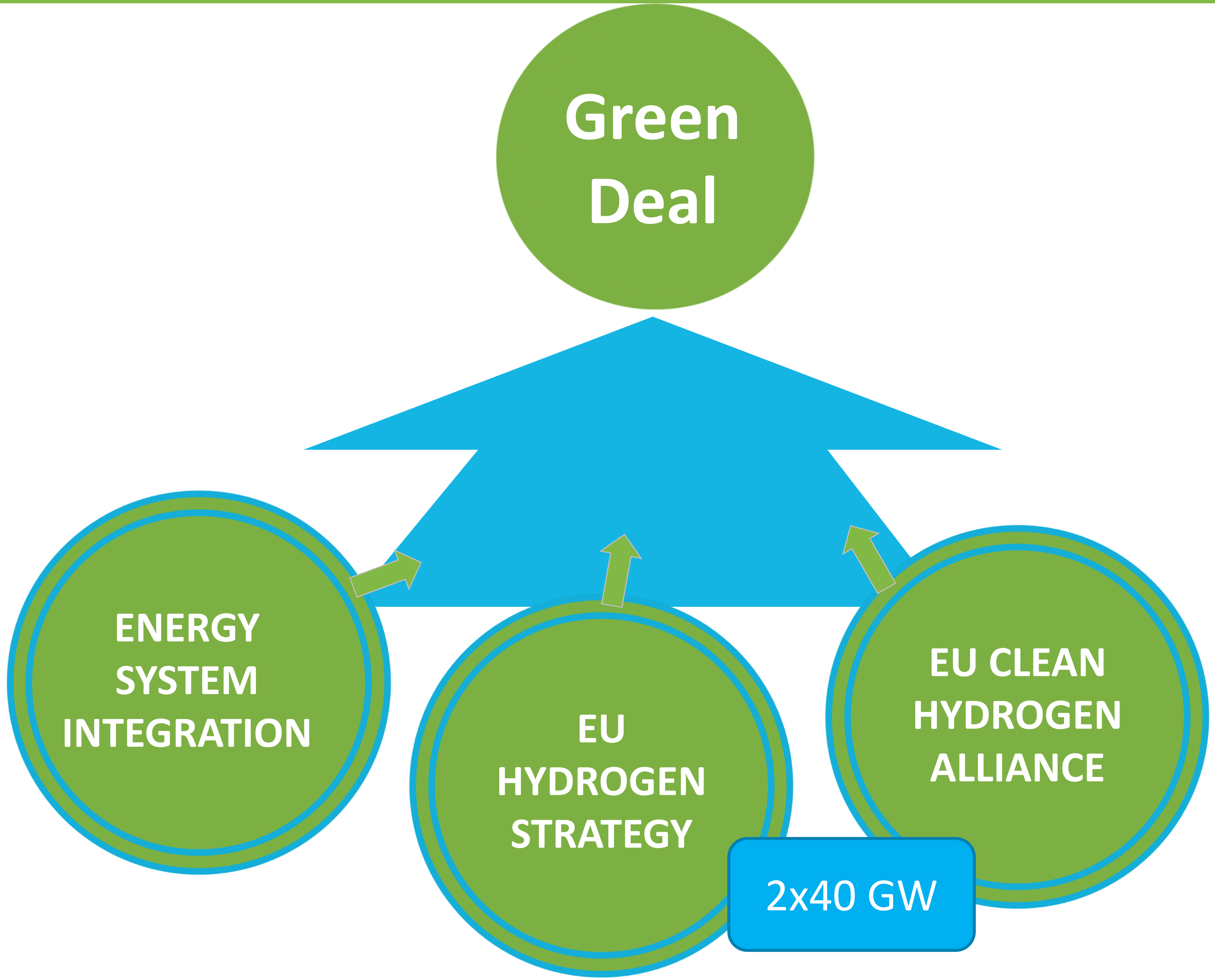
By 2024 Clean Hydrogen Production should be 13x times that of today and by 2030, it should be 130 times larger.



Source: Hydrogen Europe

Hydrogen Europe

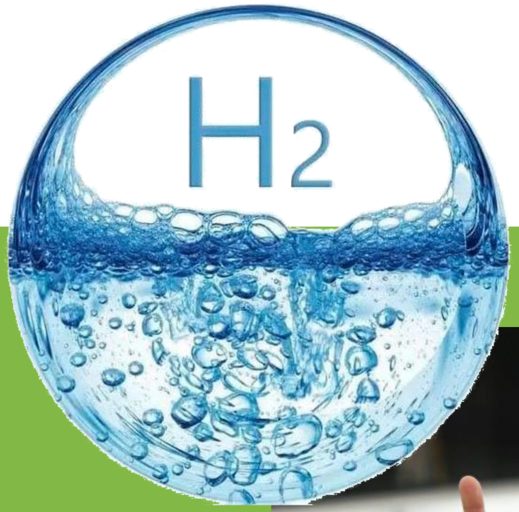
What does the EU want?



European Clean Hydrogen Alliance

Hydrogen Europe

At EU level

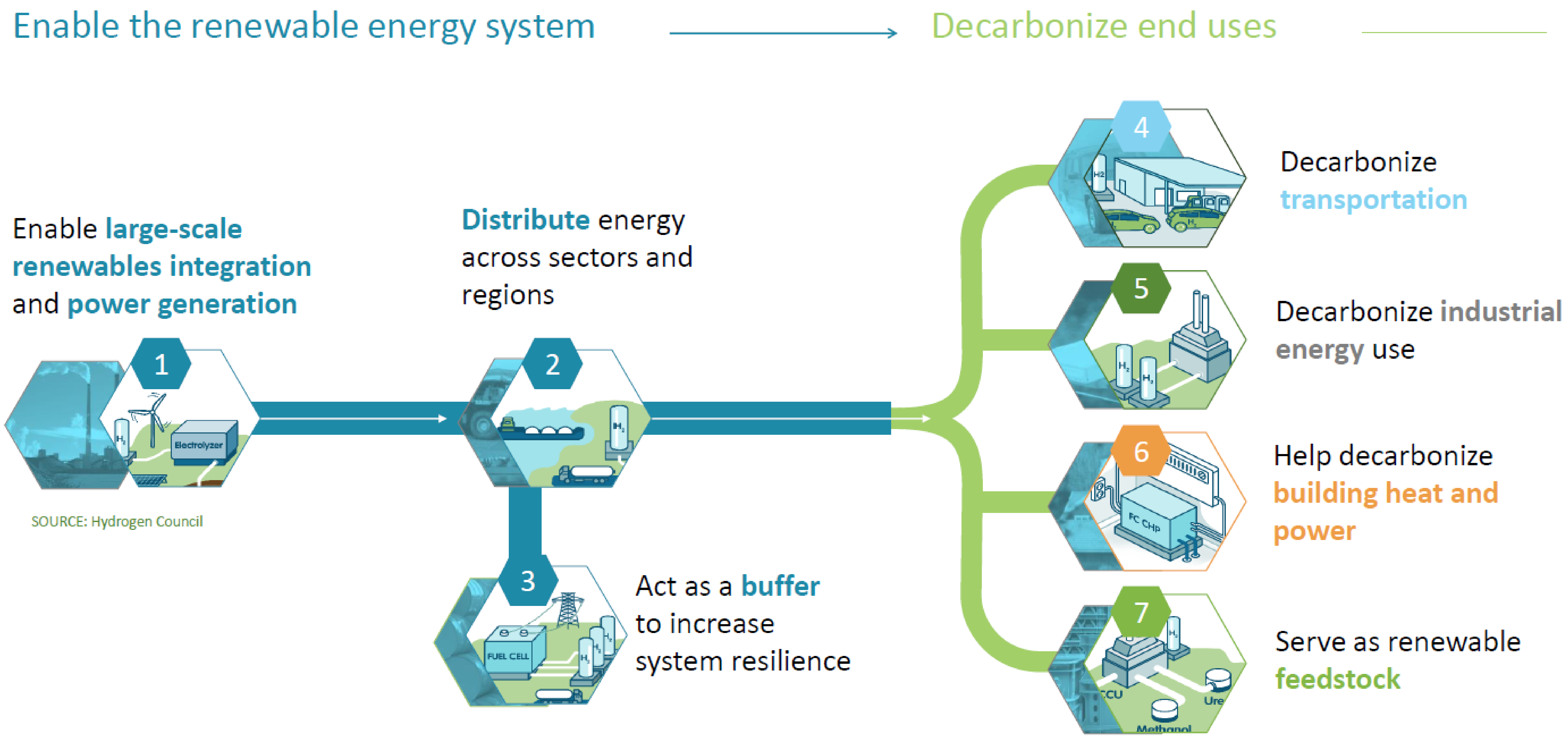


"Next Generation EU should invest in Hydrogen."
Ursula von der Leyen @State of Union speech, September 2020

"H2 rocks, and I am committed to making it a success!"
Frans Timmermans- Executive Vice-President for the European Green Deal

Hydrogen Europe

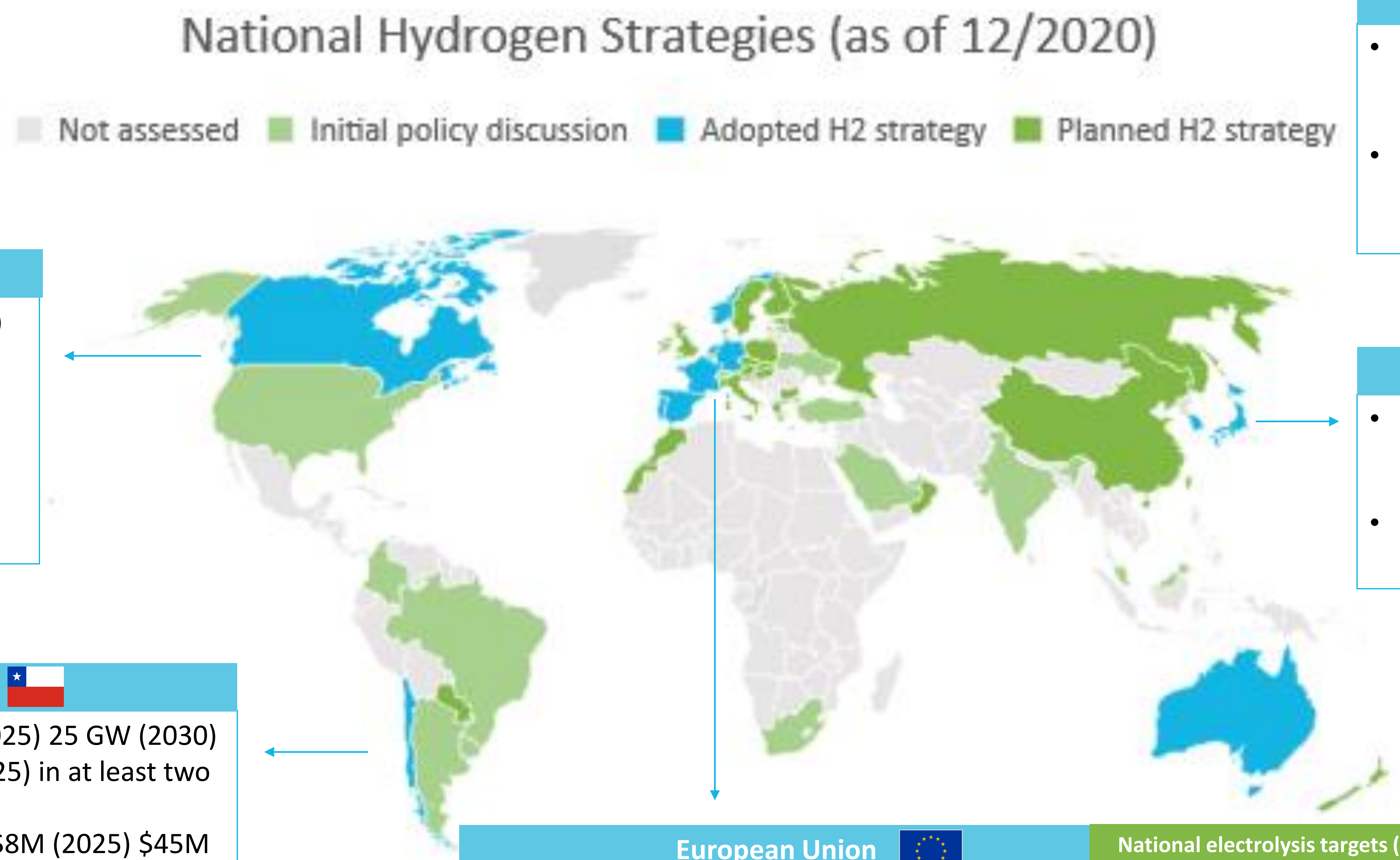
Why hydrogen?



SOURCE: Hydrogen Council

Hydrogen Europe

National Hydrogen Strategies (World Map)



The World

- Over **20 countries** have adopted a national H2 strategy
- By 2025, national strategies will cover **>80% of world's GDP**

Canada

- **Hydrogen:** 3 Mt (2025) 4 Mt (2030) 20 MT (2050) of low-carbon H2
- **Investment needed:** $C5-7bn
- **H2 share of total energy demand:** 6% (2030) 30% (2050)
- **Emission reduction:** 45 MT-CO2e (2030) 190 MT-CO2e (2050)

Japan

- **Hydrogen consumption:** 3Mt (2030) 20 Mt (2050) [Green Growth Strategy figures, 2020]
- **Mobility targets (2030):** 800,000 FCEV, 1200 FC-Buses, 900 HRS

Chile

- **Electrolysis:** 5 GW (2025) 25 GW (2030)
- **Hydrogen:** 200 kt (2025) in at least two hydrogen valleys
- **Investment needed**: $8M (2025) $45M (2030) $330M (2050)

European Union

- **Electrolysis**: 6 GW (2024) 40 GW (2030)
  Hydrogen: 1 Mt (2024) 10 Mt (2030)
- **Investment needed**: €180-470bn (2050)
- **H2 share of total energy demand:** 24% (2050)

National electrolysis targets (2030)

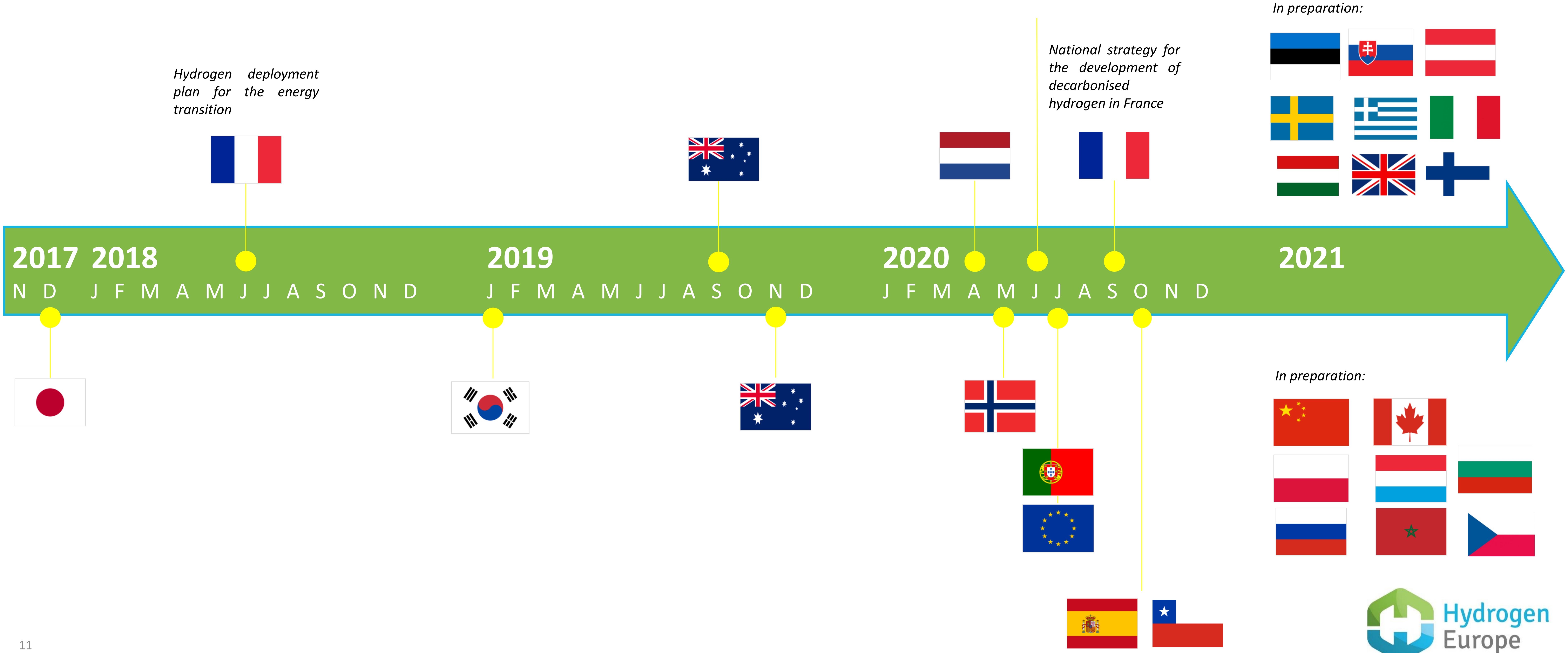
- France: 6,5 GW
- Germany: 5 GW
- Spain: 4 GW
- Netherlands: 3 - 4 GW
- Portugal: 2 - 2,5 GW
- Poland: 2 GW (draft)

Hydrogen Europe

Sources: Bloomberg, World Energy Council, IRENA, Hydrogen Europe

National Hydrogen Strategies – Reaching a momentum

Publication dates of national hydrogen strategies across the world per country.

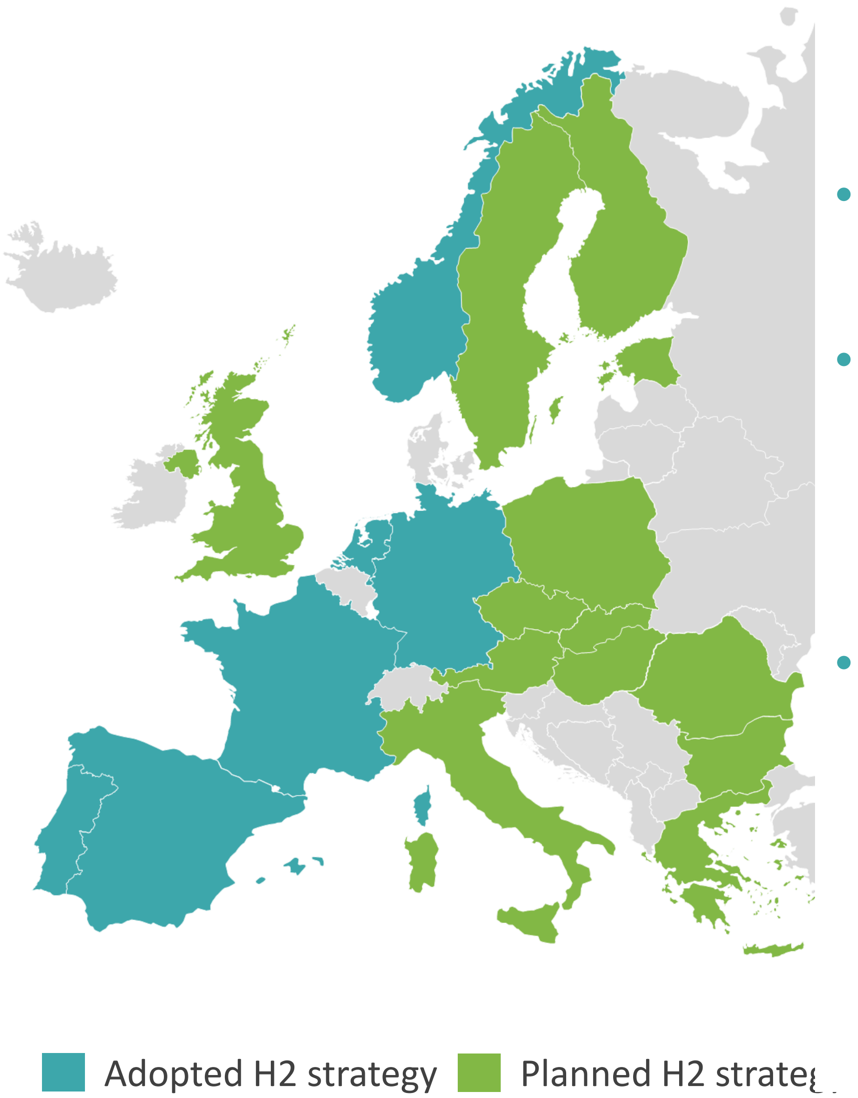


Hydrogen Europe

14/12/2020

National Hydrogen Strategies (EU)

H2 strategy adoption



- 6 countries have officially adopted an H2 strategy
- These include Netherlands, Germany, France, Spain, Portugal, and Norway
- 13 countries are currently working on their national H2 strategies

Germany	**€7bn + €2bn** external partnerships (public support)
Spain	**€8.9bn** (estimated mobilised investment)
France	**€7.2bn** (public support of which €1.5bn for an IPCEI project)
Portugal	**€7-9bn** (estimated mobilised investment). As public funds around €1bn (½ national, ½ from EU funds)
Austria	**€2bn (draft)** of public support requested by 2030 (of which €1bn by 2024) [**tbc** – 1-2 GW by 2030]
Italy	**€10bn (draft):** estimated mobilised investment of which 5bn will be EU and private investments [**tbc** – 5GW by 2030]

€46.1bn earmarked for hydrogen development

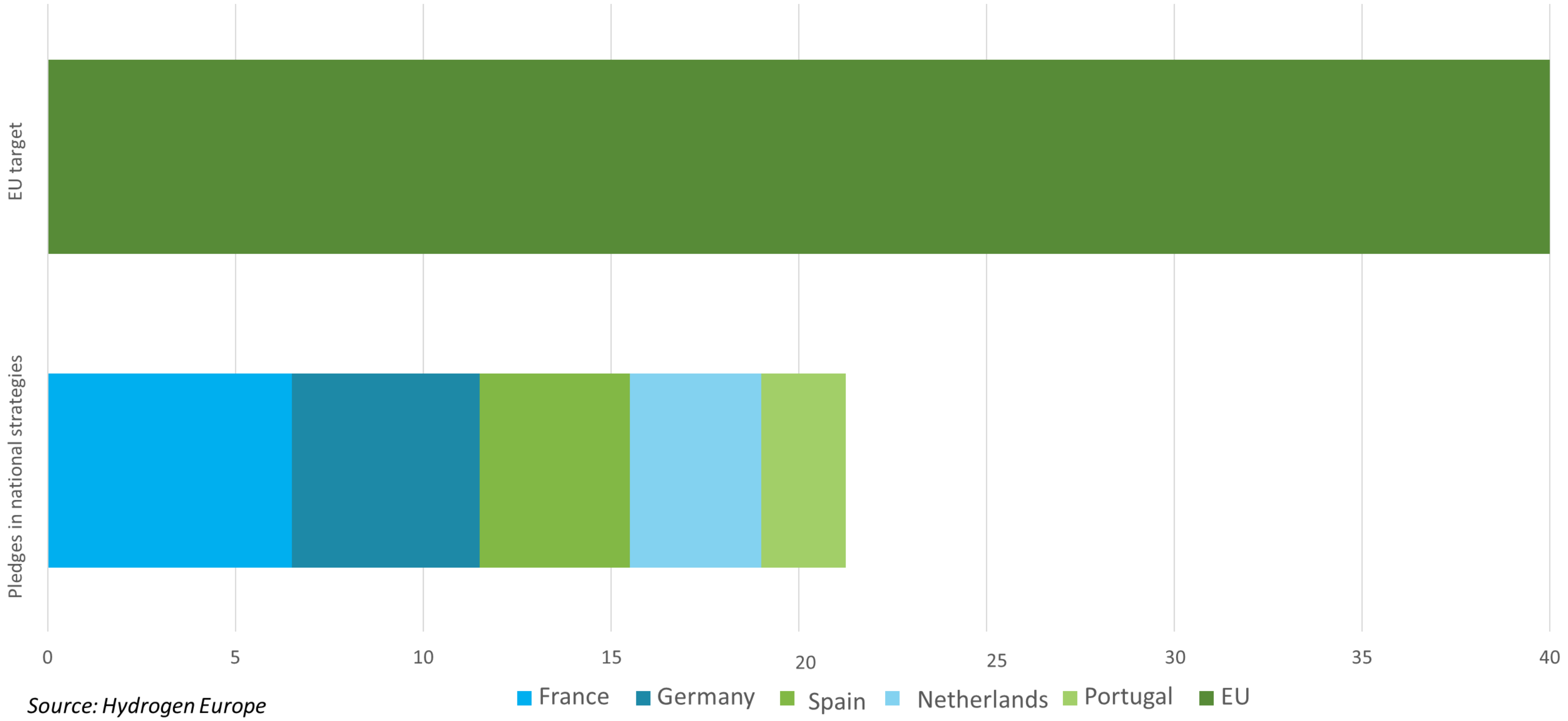
Hydrogen Europe

Plans by National Governments and Plans by Industry

National hydrogen strategies - electrolysis capacity targets[1]

21.3 GW, 53% of the 2030 EU Hydrogen Strategy's objective of 40 GW.

How far are we from the 2030 EU target for electrolyser capacity (GW)?



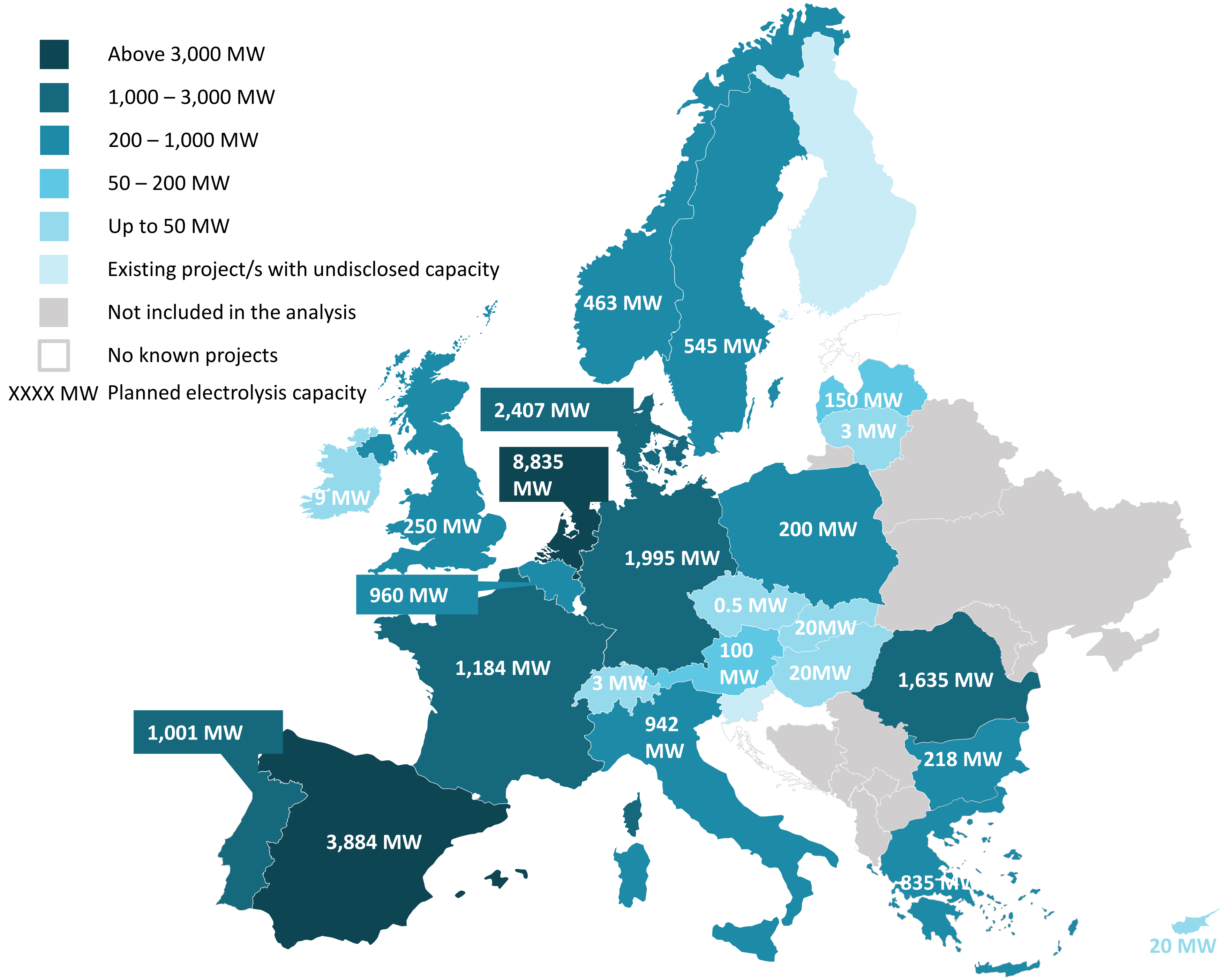
Source: Hydrogen Europe

Notes: 1. Spain, Italian, and Portuguese figures refer to mobilised investments while German and French figures refer to spent public funds 2. According to National Hydrogen Strategy Preliminary Guidelines 3. Portuguese NHS specifies between 2 and 2.5 GW and 7-9 billion of mobilised investment 4. Dutch NHS specifies between 3 and 4 GW
Source: Hydrogen Europe, Reuters

Planned PtH projects amount to 53 % of EU’s 2024 6 GW goal

Planned electrolyzer capacity by 2030 (MW)

Data as of 22/02/2020

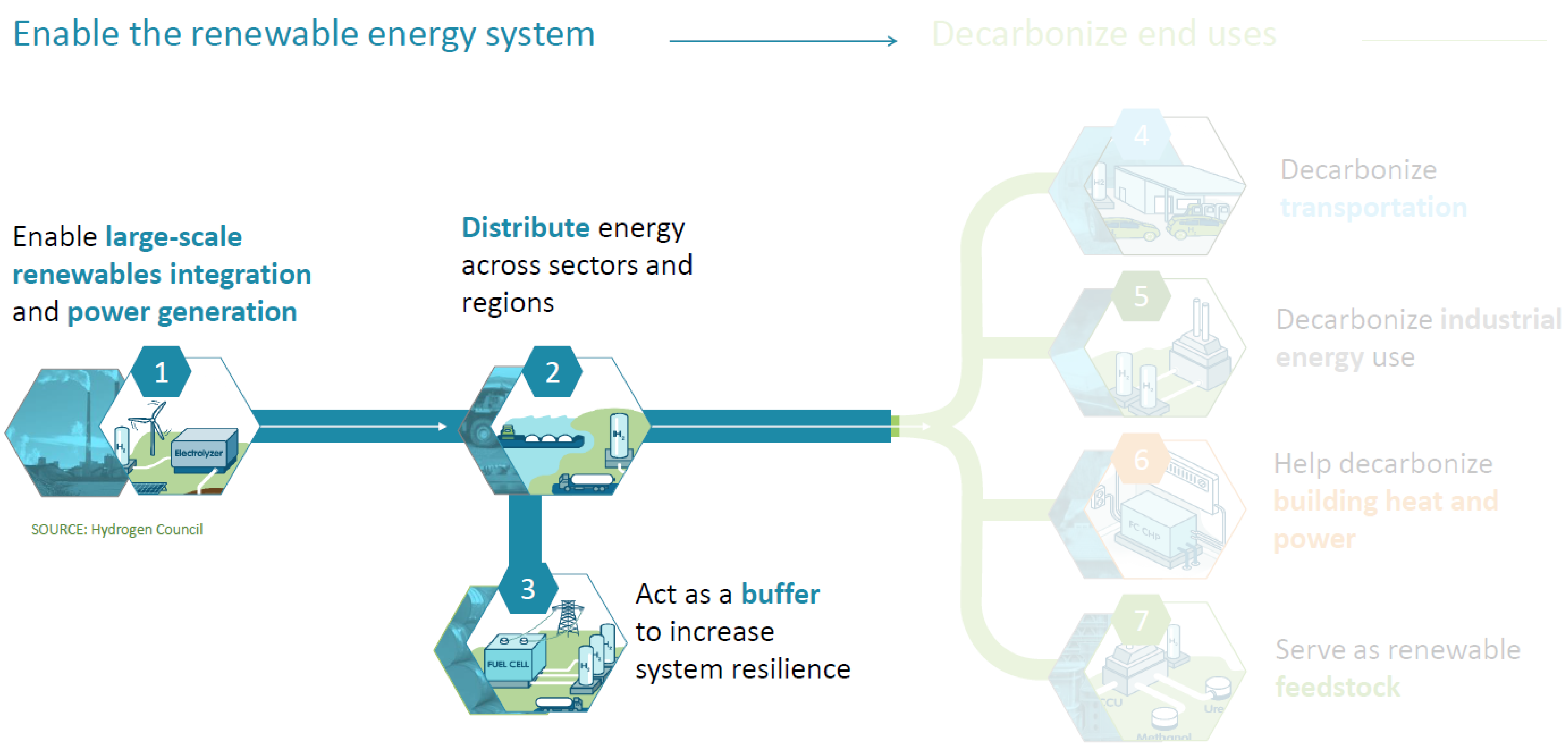


Comments

- **25 GW in EU 27 by 2030** representing 63% of EU’s 40 GW target
- Annual 2020 – 2030 capacity growth rate at **80%**
- 3.1 GW in EU 27 by 2024 compared to 6 GW EU target, **53%**
- Sizeable new PtH facilities are being announced regularly across Europe
- The currently announced projects amount to at least
  - **~€ 12.5 billion worth of investments in electrolyzer technology** by 2030 and
  - **~€ 51 billion** in associated renewable capacity

Notes: Displayed electrolyser capacities reflect projects that have an official starting date by 2030. There are numerous other projects with unknown starting dates that could be finished by 2030, but are not included in this analysis. These numbers also don’t reflect the HyDeal project that aims for 67 GW of electrolysis by 2030 alone.
Source: Hydrogen Europe

Focus on Power-to-Hydrogen



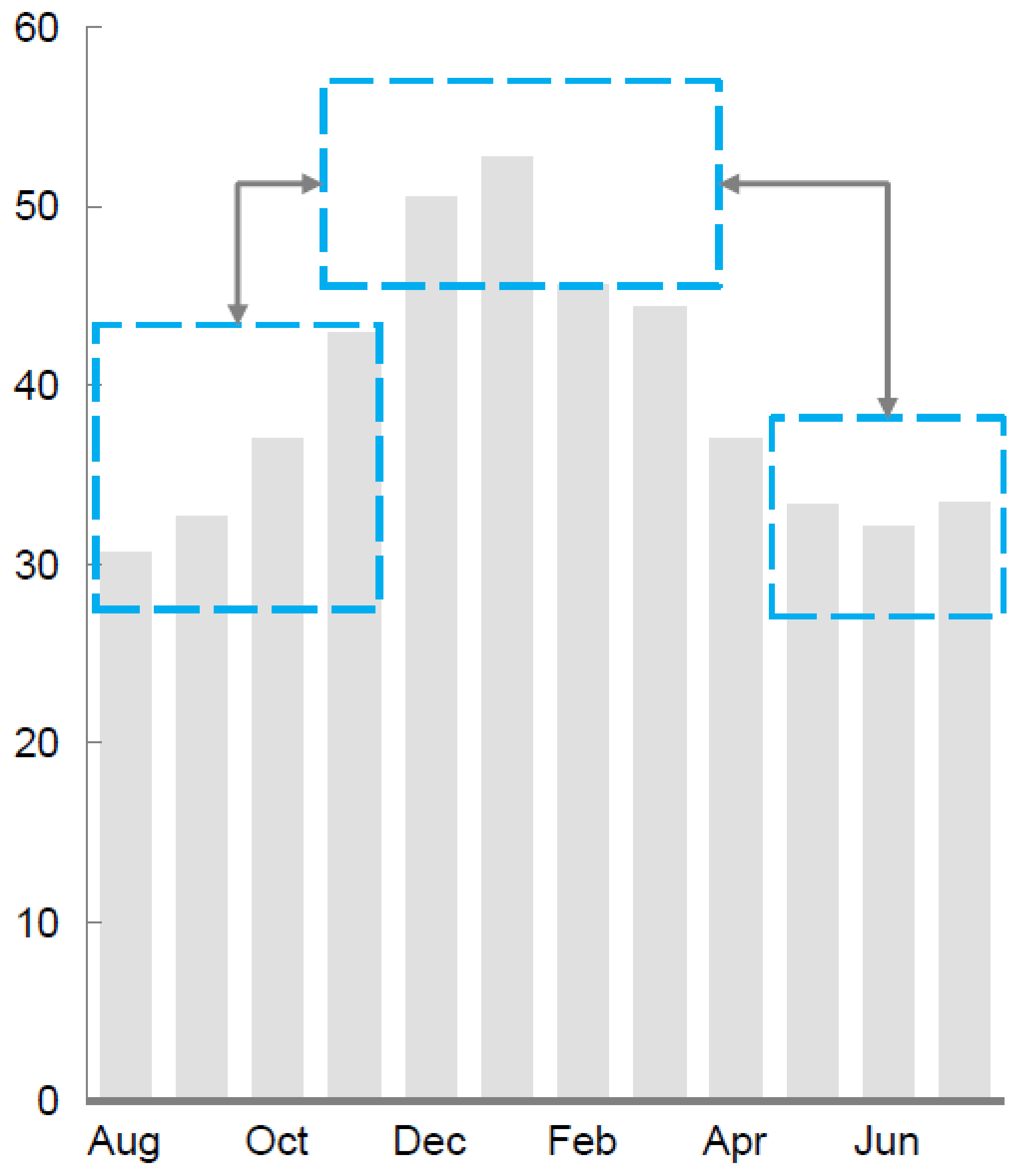
SOURCE: Hydrogen Council

Hydrogen Europe

Deployment of RES above a certain threshold and deep electrification of heating will create demand imbalances (in addition to fluctuating RES power supply)

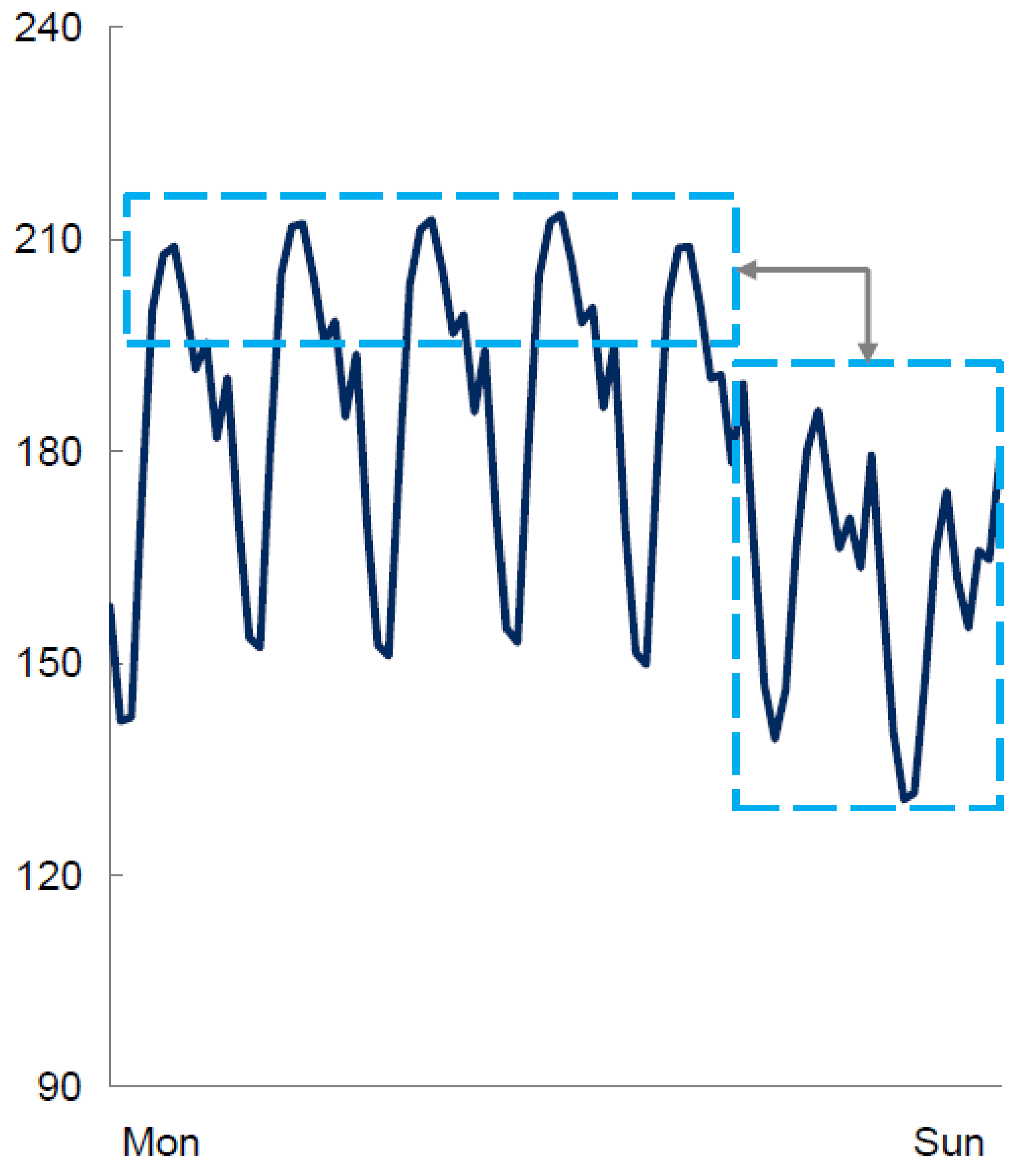
Long-term imbalance over seasons due to different demand for power in winter

Power demand, France 2014, TWh



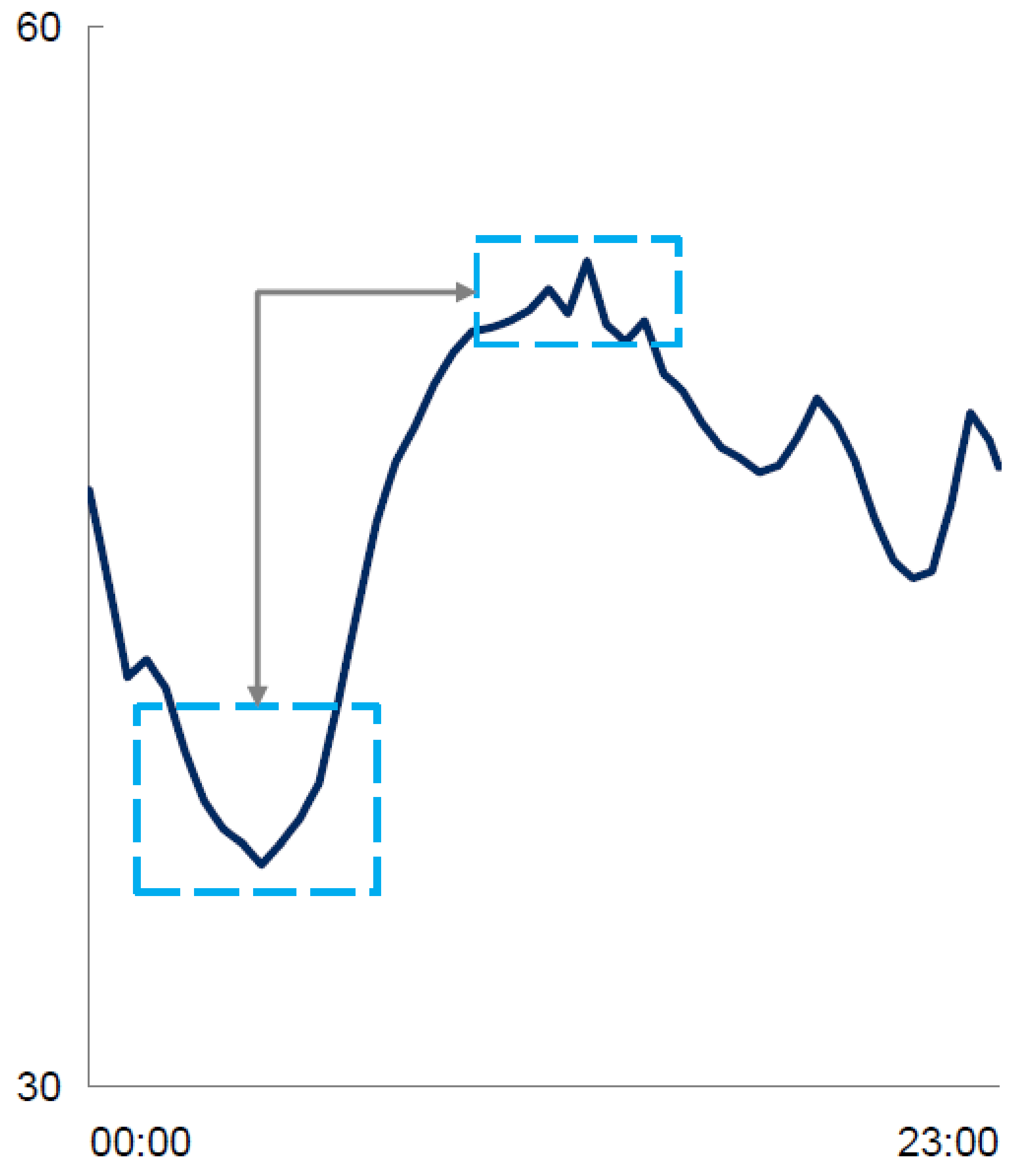
Mid-term imbalance from different demand during weekdays vs. weekends and wind patterns

Power demand, France June 2018, GWh



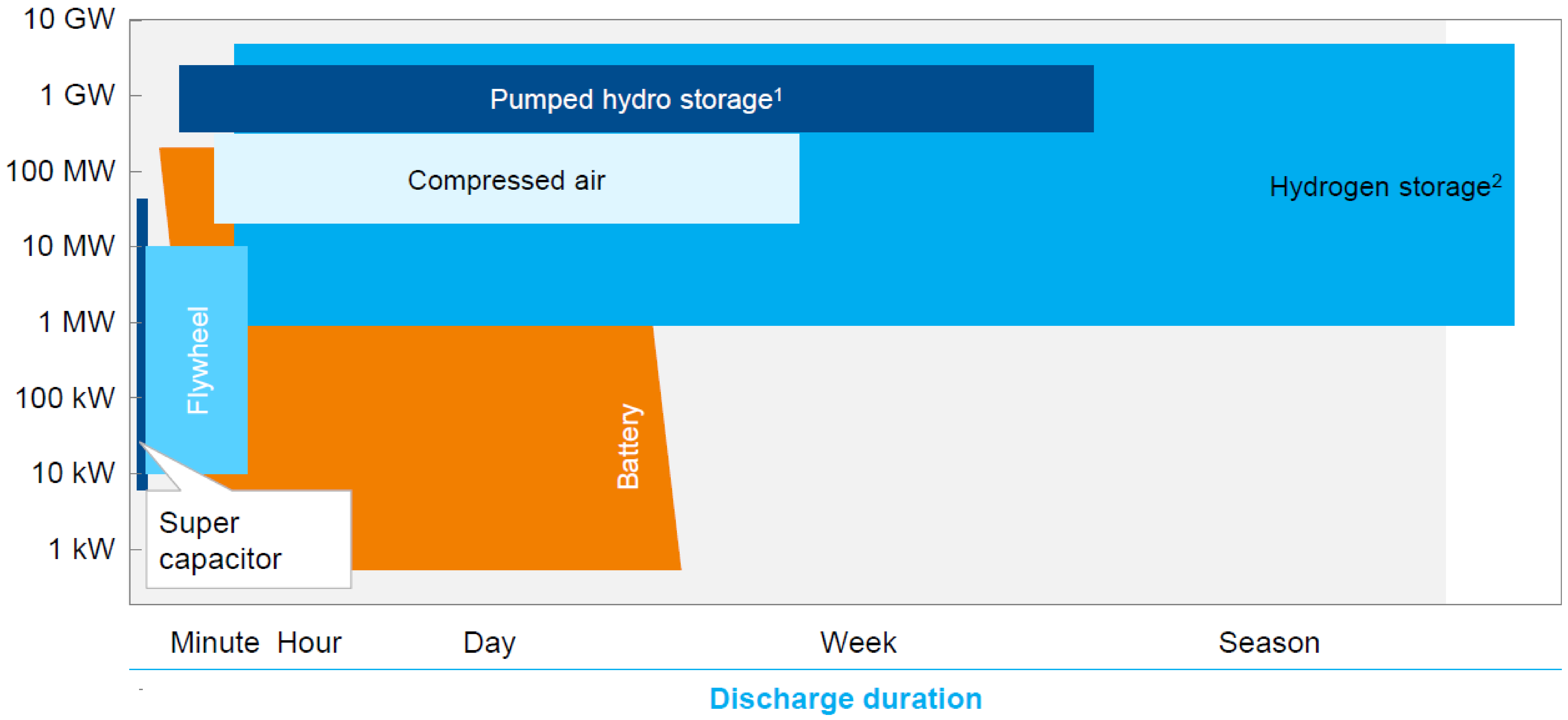
Short-term imbalances from solar irradiation and demand variations from daily routine

Power demand, France June 14 2018, GWh



Hydrogen is ideally suited for long term storage due to its long discharge duration and high discharge power

Technology overview in power and time



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To meet targets regulations in transport, heat and power sector are tightened which will force significant market changes due to foreseeable sector coupling

Options for stabilizing RES system		Suitability (Intra-day / Intra-month / Seasonal)	Assessment	Suitability for long-term storage?
Over-supply	Reduce supply	Shut down RES	▪ Technically feasible ▪ Inefficient, losses of investment	✗
Over-supply	Sector coupling	Power-to-material (P2M)	▪ No reconversion to power possible ▪ In R&D stage	✗
Over-supply	Sector coupling	Power-to-gas (P2G)	▪ Technically feasible in number of use cases ▪ Currently high investment cost	✓
Over-supply	Sector coupling	Power-to-heat	▪ Efficient, discharge only to heat (not power) possible ▪ Suitable for short-term balancing only	
Over-supply	Store and dis-charge	Power-to-gas-to-power (P2G2P)	▪ Reconversion possible ▪ Low full cycle efficiency ▪ Only if P2G not suitable/sufficient	✓
Under-supply	Store and dis-charge	Bat-tery; Compressed air, flywheel	▪ Technically feasible ▪ Only short-term supply economically viable	✗
Under-supply	Store and dis-charge	Pumped hydro; Hydro reservoir (Scandinavia; Alps; …) incl. interconnectors	▪ Limited storage capacity due to natural limitations	✗
Under-supply	Reduce demand[1]	Demand side management (DSM)	▪ Consumption pattern only allows for limited shift within day	✗
Under-supply	Increase supply	Structural renewables oversupply	▪ Technically feasible ▪ Highly inefficient and capital intensive, losses of investment	✗
Under-supply	Increase supply	Conventional backup (e.g., gas plants)	▪ Feasible if power generation is decarbonized (e.g., pre-combustion CCS)	

1 Demand reduction/demand balancing beyond expected structural demand reduction and efficiency gains (e.g., via energy-efficient renovations of buildings)

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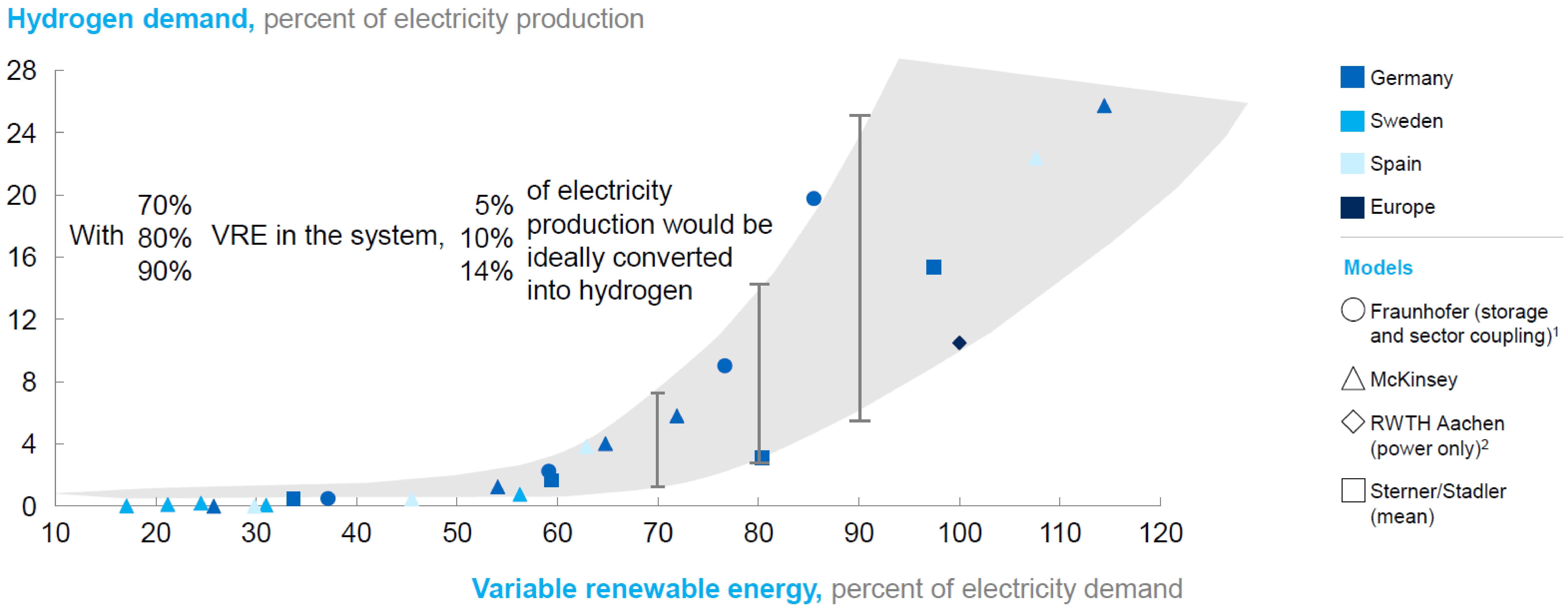
The optimal deployment of sector coupling grows steadily until roughly 60% of variable renewable sources and then accelerates rapidly



1 Least-cost modeling to achieve 2-degree scenario in Germany in 2050 in hour-by-hour simulation of power generation and demand; assumptions: no regional distribution issues (would increase hydrogen pathway), no change in energy imports and exports

2 Simulation of storage requirements for 100% European RES; only power sector storage considered (lower bound for hydrogen pathway)

But... Power-to-gas is only half of the story. We will need much more hydrogen than would be available from excess RES

Challenge

Hydrogen is the best or only choice for at-scale decarbonization of key segments, for example:

Achieving deep decarboni-zation

- H_2 TO DECARBONIZE THE GAS GRID
- FUEL CELLS/ SYNFUELS FOR HEAVY TRANSPORT AND LONG DISTANCES
- HIGH-GRADE HEAT FOR INDUSTRY & IN STEEL
- ULTRA-LOW-CARBON H_2 AS FEEDSTOCK, E.G., AMMONIA

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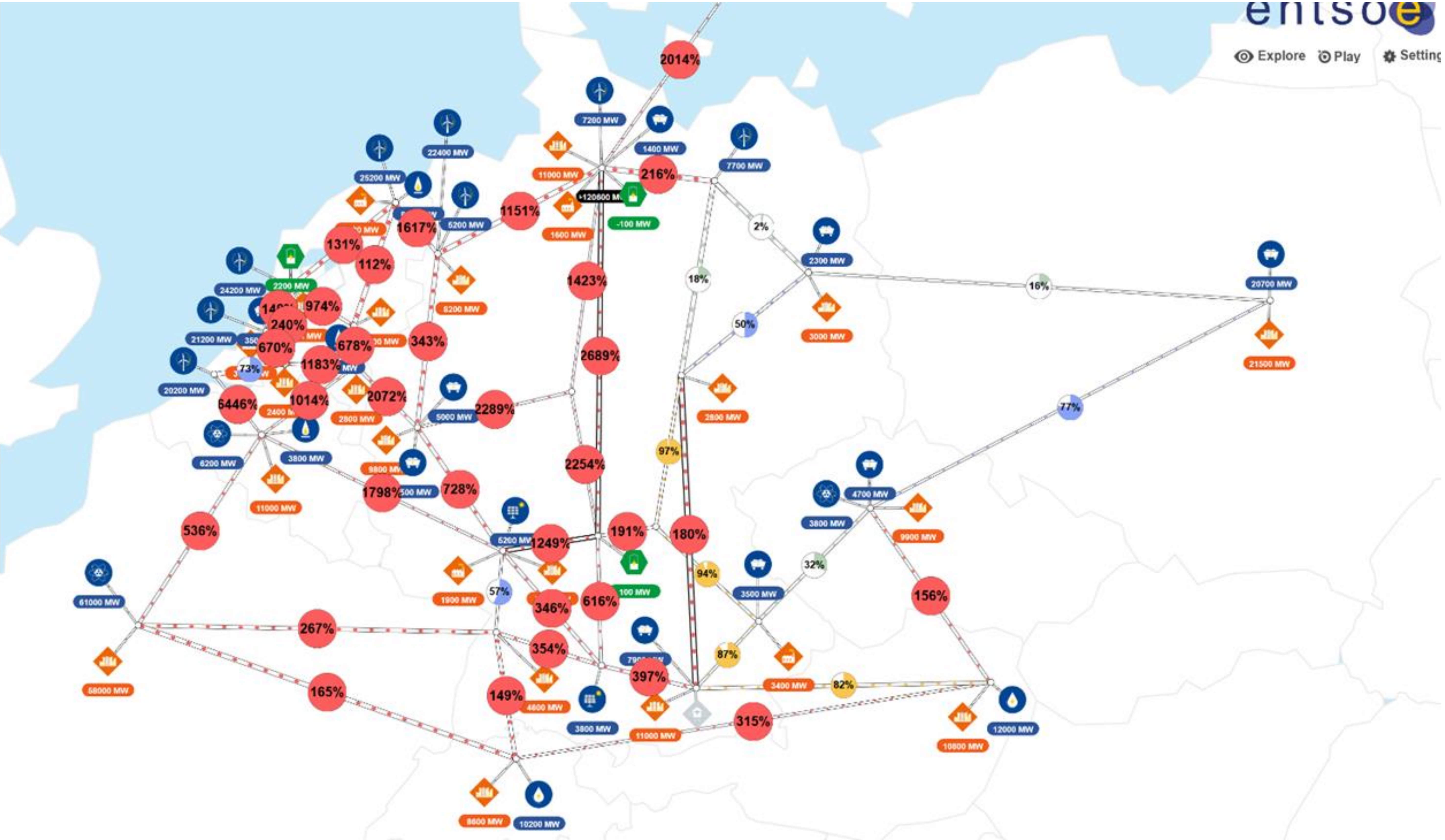
Offshore wind strategy requires Hydrogenewables



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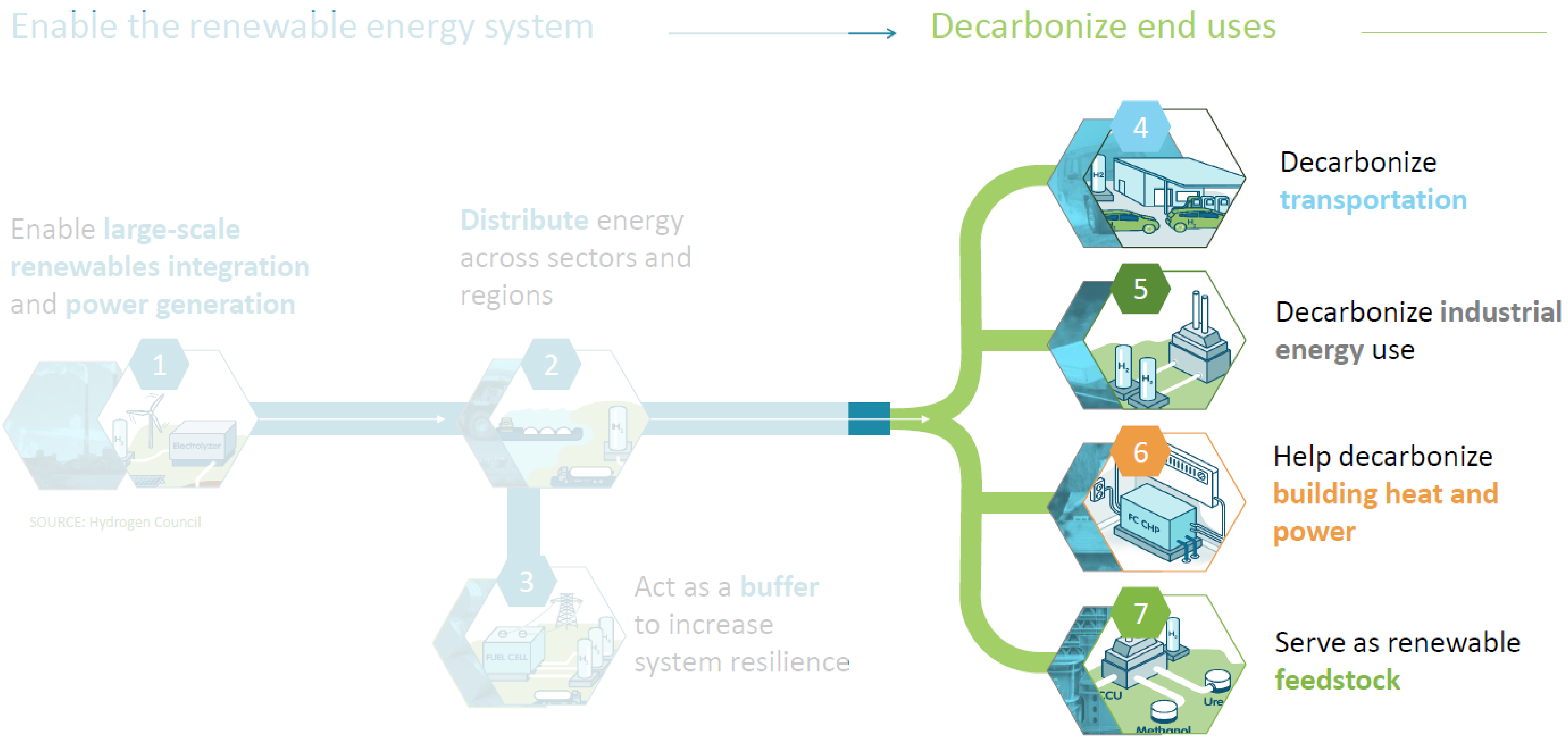
Focus on end uses



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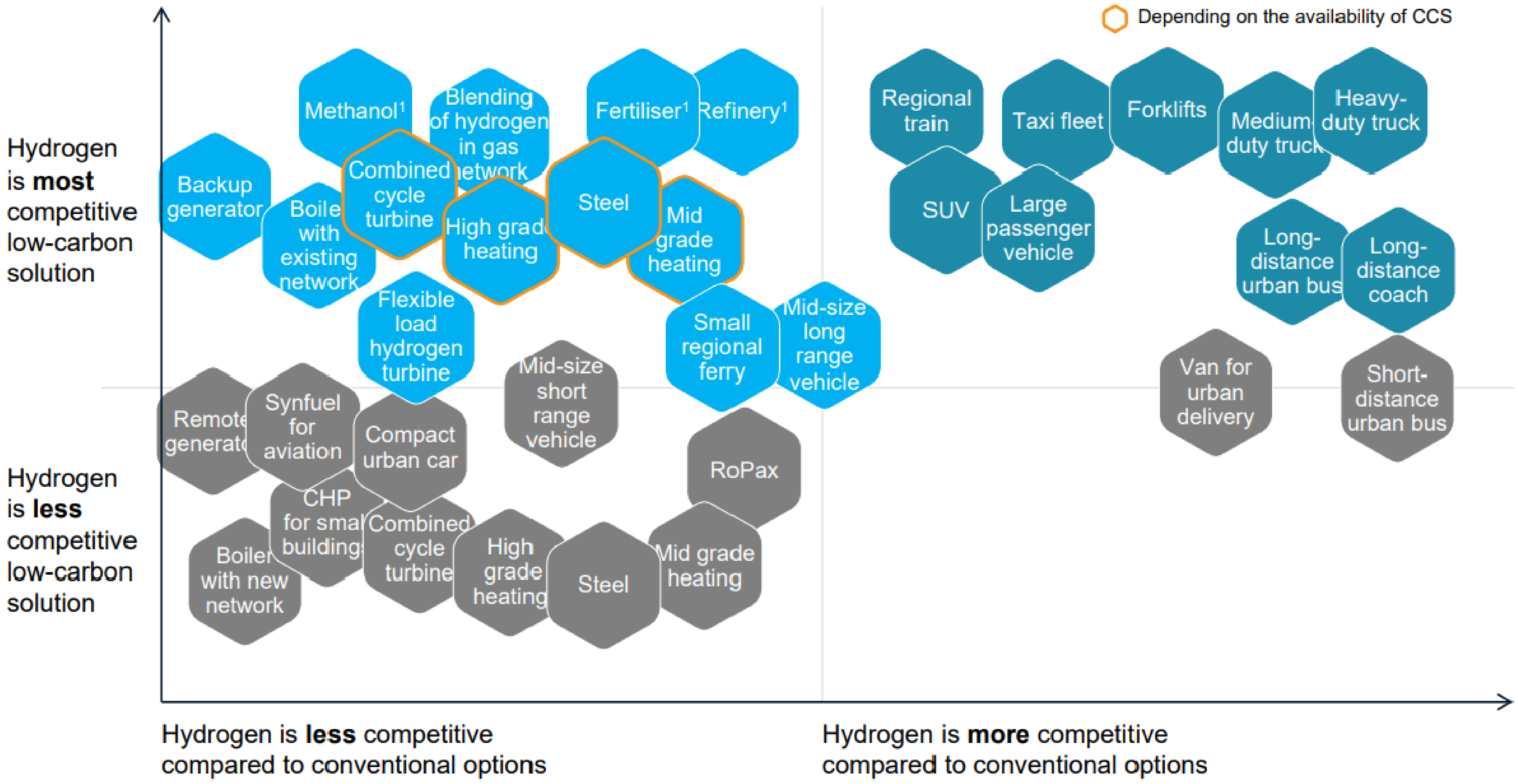
What are the potential end uses?



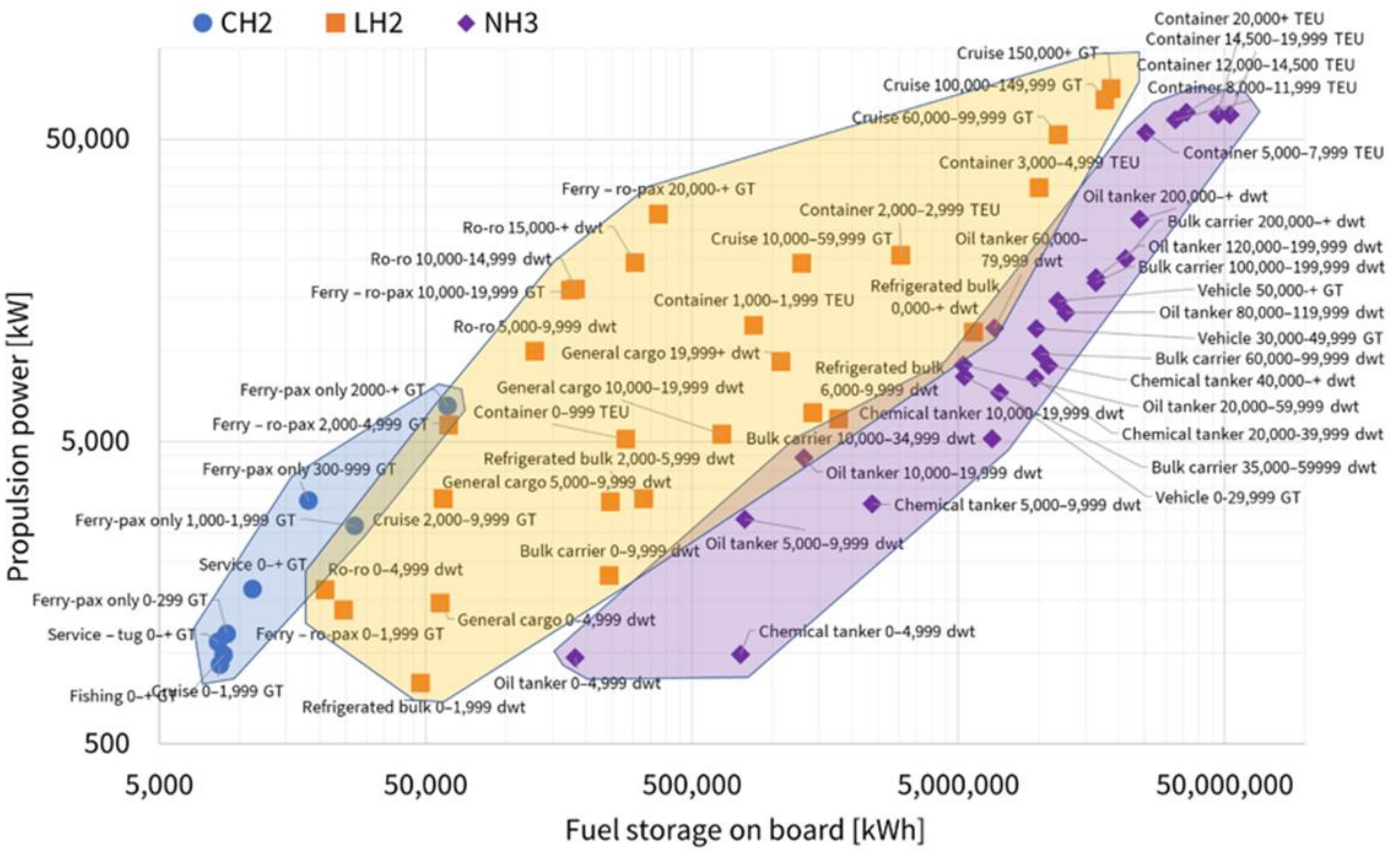
SOURCE: Hydrogen Council

PILLAR 1

Maritime applications – best served by Hydrogen and Ammonia

- Many different ship types, sizes and trades
- **HE comparison tool** shows that Hydrogen and Ammonia are best suited fuels for maritime applications

Figure 2. Optimum zero-emission option for various ship types



Source: own elaboration.

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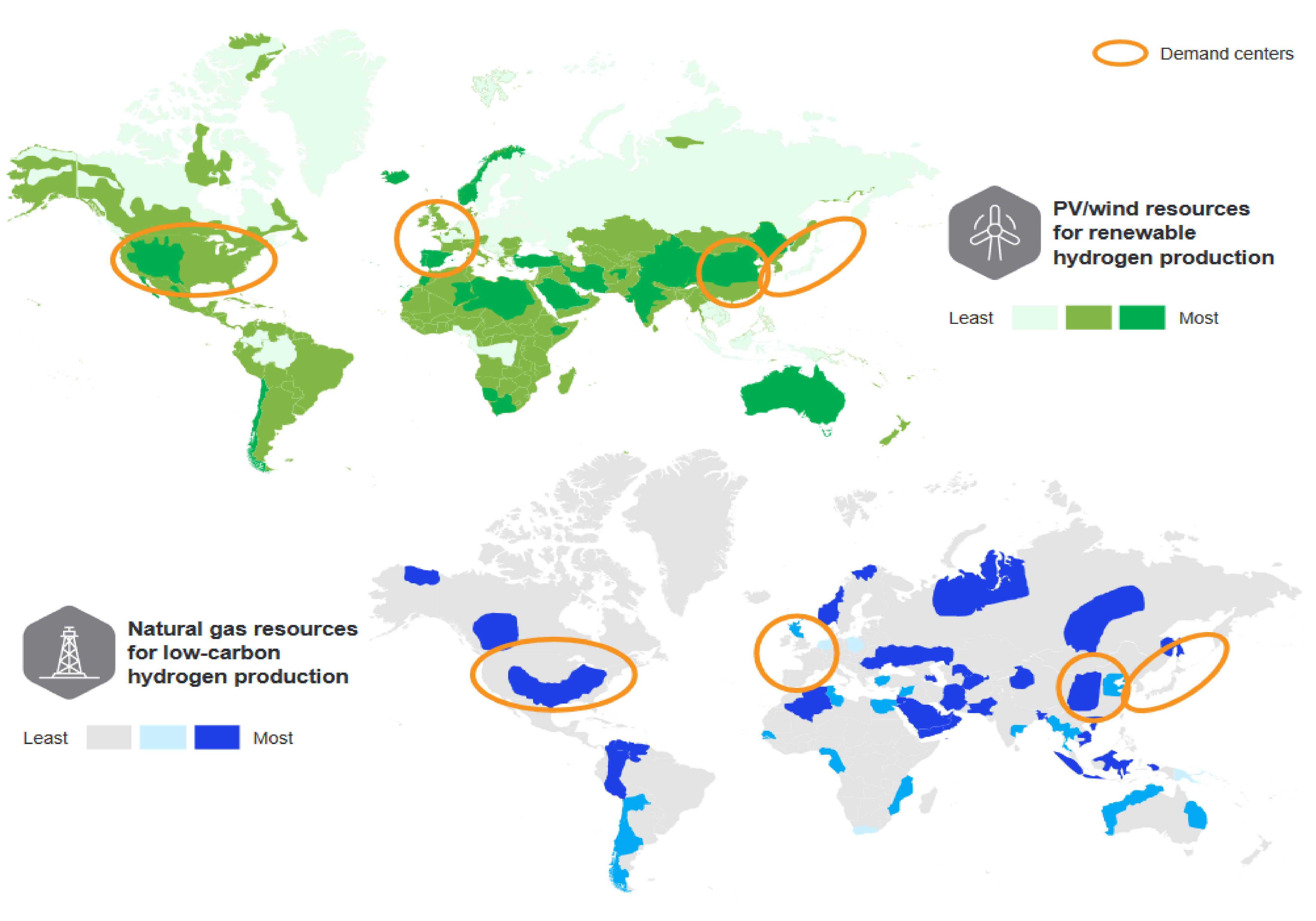
Adding it all up… You will need imports

Exhibit 11: Distribution of global hydrogen resources and demand centers



You will need imports, and this will require storage, in ports,

Hydrogen Europe

THANK YOU FOR YOUR ATTENTION!

ALEXANDRU FLORISTEAN, HYDROGEN EUROPE

Thank you for your attention!

HYDROGEN EUROPE SECRETARIAT

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