

INNOVATION INSIGHTS BRIEFING | 2021

Hydrogen on the horizon: ready, almost set, go?

Member Committee Pack

July 2021

World Energy Council, in collaboration with EPRI and PwC

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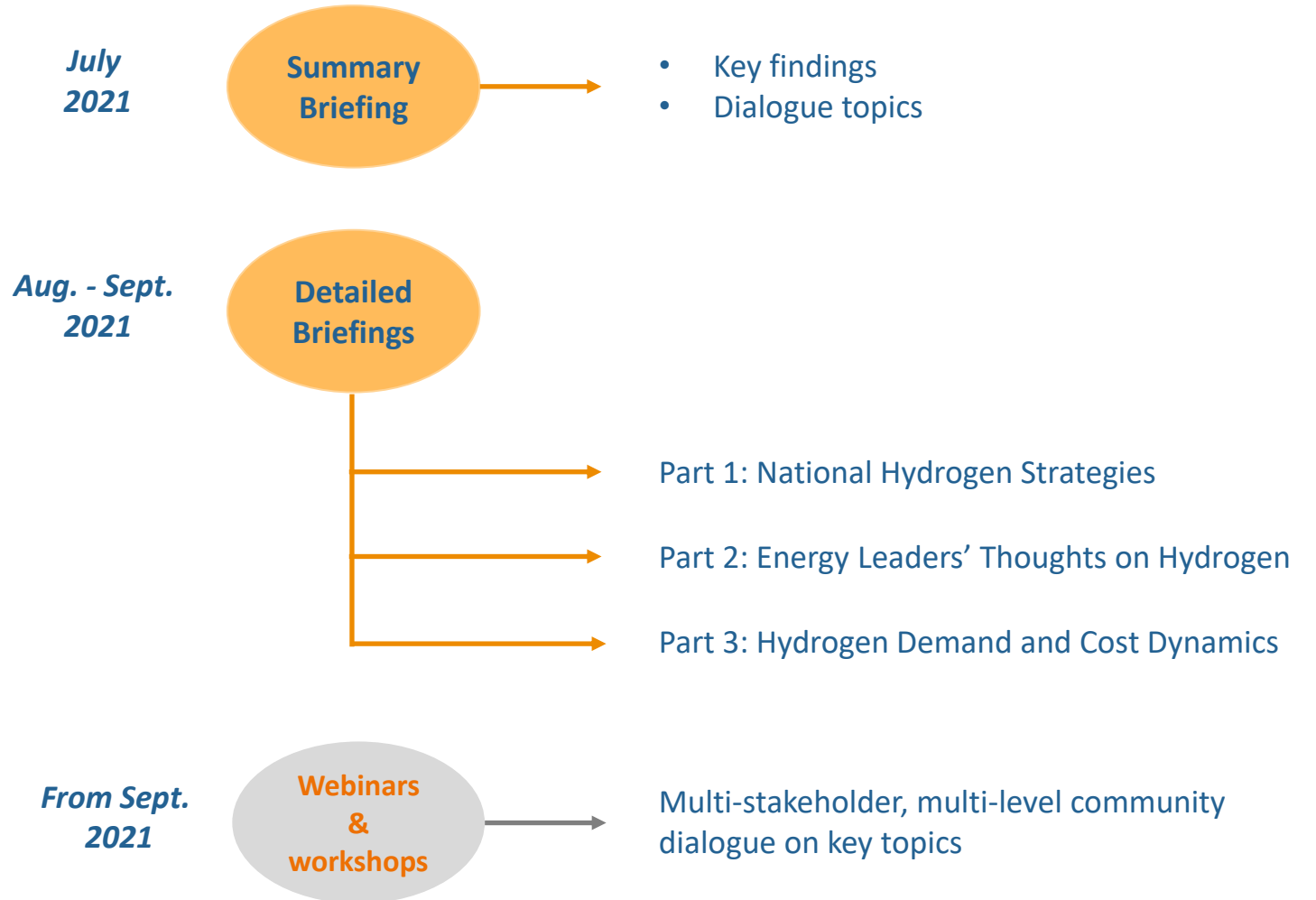
Context

Conversations about Energy Transitions frequently overlook the role of clean molecules and heat. Combined with deeper electrification, clean molecules (e.g., hydrogen-based fuels, natural gas with CCUS, biofuels, etc.) can play a major role to decarbonise further areas and uses.

This short series of Innovation Insights Briefings **aims to provide a better understanding of hydrogen development globally for the energy community, building on the expertise and experience of its global network.**

It aims to start a multi-stakeholder, multi-level community dialogue on hydrogen's role in energy transitions.

Hydrogen on the horizon: ready, almost set, go?



- **Interest in clean hydrogen is surging** around the globe, in particular due to its potential to decarbonise the hard to abate sectors.
- Understanding hydrogen demand is challenging at this embryonic stage of its development. By 2050, **the demand estimates vary significantly** between an equivalent of 5 to 20% of total final energy consumption, dependent on underlying assumptions.
- Scaling hydrogen up within the energy system faces **significant challenges**: there is an important price gap with existing alternatives, a “chicken and egg” issue surrounding supply and demand development, and hydrogen technologies are at different levels of maturity.
- **Divergences are emerging across countries and regions**: different drivers, end-use sectors, positionings in the value chain, and policy tools used. Bilateral partnerships are increasing to help form worldwide hydrogen supply chains and secure clean hydrogen supply.
- **More dialogue is needed** to better understand hydrogen’s true potential in energy systems, explore the supply-demand potential within regions and how different hydrogen strategies and initiatives could complement each other, and to learn from and with each other.
- **The colour debate needs clarity** as it could risk prematurely excluding some technological routes that could be more cost and carbon effective. Discussion should perhaps think about moving beyond colour and instead focus on carbon equivalence.

Summary Briefing

4 areas for further discussions

The World Energy Council, in partnership with EPRI and PwC, seeks to start a multi-stakeholders, multi-level community dialogue on hydrogen's role in energy transitions. Our work has identified the following 4 areas for further discussion:

- 1. Significant divergences are emerging across countries and regions**, as national hydrogen strategies reveal varying attitudes towards hydrogen's role in energy transitions. This signals a need to embrace diversity – eliminating a one size fits all mindset – and enable differing technologies and use cases to be explored.
- 2. Confusion over 'colours' is stifling innovation**, with over-simplification and colour prejudice risking the premature exclusion of some technological routes that could potentially be more cost- and carbon-effective. There is a need for further dialogue which looks beyond colour to instead explore carbon equivalence.
- 3. Demand-centric hydrogen perspectives are needed to advance the Humanising Energy and demand-driven agendas**. The current hydrogen conversation focuses heavily on supply, ignoring the role of hydrogen users. Discussions must explore what's needed to trigger demand, with a specific focus on the development of hydrogen infrastructure and a global supply chain.
- 4. The hydrogen economy could stimulate job creation and economic growth**, potentially helping to fulfil 'build forward together' ambitions post-COVID-19. Several national hydrogen strategies highlight jobs as an important driver of hydrogen development, with opportunities to reskill the existing workforce and upskill a new workforce.

Detailed Briefings

3-parts series of short detailed Innovation Insights Briefings

To help inform the dialogue on these 4 topics, we are releasing a 3-parts series of short detailed Innovation Insights Briefings, providing additional insights on: 1- National Hydrogen Strategies; 2- Energy Leaders' Thoughts on Hydrogen; 3- Hydrogen Demand and Cost Dynamics.

1- National Hydrogen Strategies

Focuses on exploring the national hydrogen strategies being increasingly published worldwide to support hydrogen development. Explores the different hydrogen stories emerging between countries and regions.

- **13 hydrogen strategies assessed**

2- Energy Leaders' Thoughts on Hydrogen

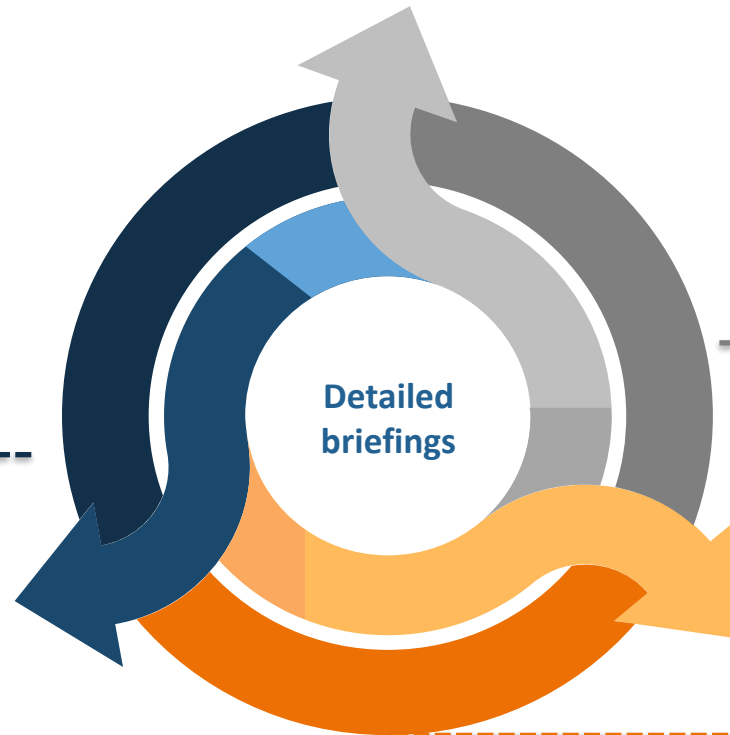
Presents energy leaders thoughts on hydrogen, and critical issues that are emerging related to hydrogen development.

- **38 interviews from 23 countries with senior experts in hydrogen**

3- Hydrogen Demand and Cost Dynamics

Focuses on the dynamics of hydrogen demand and hydrogen cost development.

- **8 reports – 13 demand scenarios**
- **6 reports – 16 cost scenarios**



Thank you!



Insights

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Annexes

These annexes contain additional content that MCs can use to further present the Innovation Insights Briefing “Hydrogen on the horizon: ready, almost set, go?”.

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INFOGRAPHICS

Interviews

The insights reflected in the briefings are the result of in-depth interviews with CEOs and senior experts on the topic of hydrogen, in addition to an assessment of 12+ published national hydrogen strategies.

The interviews which inform this briefings were conducted between **February and April 2021**, and involved 38 experts from 23 countries, reflecting 61 % of the world's Total Primary Energy Supply – TPES (2018 data, OECD) and 70% of the world's GDP (2019 data, WB).

Energy
24 %

Government
21 %

Academia/Research
21 %

Civil Society
18 %

Consulting
8 %

Finance
5 %

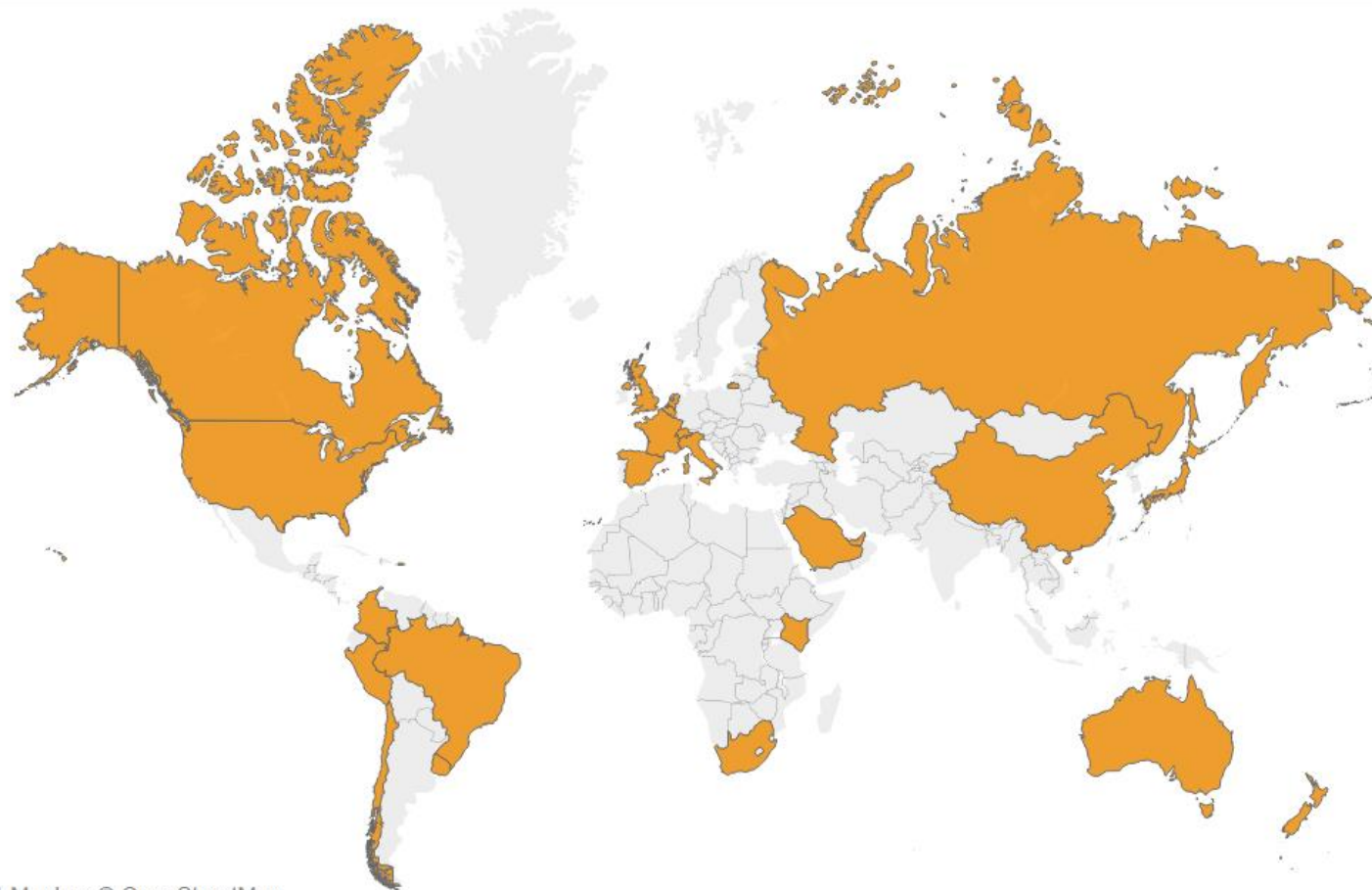
Technology
3 %

38

interviewees

23

countries



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1: Significant divergences are emerging across countries and regions

- **Significant divergences are emerging across countries and regions**, as national hydrogen strategies reveal varying attitudes towards hydrogen's role in the energy transition. This signals a need to embrace diversity – eliminating a one size fits all mindset – and enable differing technologies and use cases to be explored.
- The drivers and goals for hydrogen differ between countries, depending on their national context, and therefore the end-use priorities as well.
- Hydrogen is a good illustration of the fact that no one size fits all. And at this early stage, differing technologies and use cases should be explored. What makes sense in one place might not in another, and vice versa.

Further resources for dialogue:

Summary overview of the national hydrogen strategies

CATEGORY	Australia	ASIA Japan	South Korea	EU	France	Germany	Hungary	EUROPE Netherlands	Norway	Portugal	Spain	LAC Chile	NORTH AMERICA Canada
Strategy contains timeline for market development with targets	●	●	●	●	●	●	●	●	○	●	●	●	●
Strategy contains hydrogen cost targets	●	●	●	○	○	○	○	○	○	○	○	●	●
Strategy includes measures to support H2 development													
Direct investments	●	●	●	●	●	●	○	●	●	●	●	●	●
Other economic and financial mechanisms	●	●	●	●	●	●	●	●	●	●	●	●	●
Legislative and regulatory measures	●	●	●	●	●	●	●	●	●	●	●	●	●
Standardisation strategy and priorities	●	●	●	●	●	●	●	●	●	●	●	●	●
Research & development initiatives	●	●	●	●	●	●	●	●	●	●	●	●	●
International strategy	●	●	●	●	●	●	●	●	●	●	●	●	●
Strategy addresses social issues for H2 development	●	●	●	○	●	●	○	●	●	●	●	●	●
Strategy includes review and update	●	○	○	○	○	○	○	○	○	○	○	○	○
Strategy's H2 target source by 2030	Clean	Fossil-based with CCS	From natural gas	Low carbon	Low-carbon & fossil based	Carbon-free	Low carbon & fossil based	Blue & Green	Clean	Green	Renewable	Green	Low carbon intensity
Strategy's H2 target source by 2050	Clean	CO ₂ -free	Eco-friendly CO ₂ -free	Clean / Renewable	Low-carbon	Renewable	Low carbon & fossil based	Green	Clean	Green	Renewable	Green	Low carbon intensity
Import / Self-reliance / Export	Export; Self-reliance	Import	Import; Export (tech)	Depends on Member States	Export	Import; Export (tech)	Self-reliance	Import to export H2 (EU hub)	Self-reliance	Self-reliance; Export	Self-reliance; Export	Self-reliance; Export	Self-reliance; Export
MAIN GOALS / DRIVERS													
Decarbonisation	Lower	Immediate	Lower	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate
Diversify energy supply	Lower	Immediate	Long term	Lower	Lower	Immediate	Immediate	Immediate	Lower	Immediate	Immediate	Lower	Immediate
Foster economic growth	Immediate	Immediate	Immediate	Lower	Immediate	Immediate	Lower	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate
Integration of renewables	Lower	Lower	Long term	Immediate	Lower	Immediate	Lower	Immediate	Lower	Immediate	Immediate	Immediate	Immediate
SECTORAL PRIORITIES													
Heating	Immediate	Immediate	Lower	Lower	Lower	Lower	Immediate	Immediate	Lower	Immediate	Lower	Immediate	Immediate
Industry													
Iron and Steel	Long term	Lower	Lower	Long term	Immediate	Immediate	Long term	Immediate	Lower	Immediate	Lower	Not seen	Immediate
Chemical feedstock	Immediate	Lower	Not seen	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate
Refining	Not seen	Lower	Not seen	Immediate	Immediate	Immediate	Immediate	Immediate	Lower	Immediate	Immediate	Immediate	Immediate
Others (cement, etc.)	Not seen	Not seen	Not seen	Not seen	Immediate	Lower	Long term	Lower	Not seen	Immediate	Lower	Not seen	Immediate
Power													
Power generation	Lower	Immediate	Immediate	Lower	Not seen	Not seen	Lower	Lower	Not seen	Lower	Lower	Not seen	Lower
Back-up services	Lower	Lower	Lower	Lower	Not seen	Not seen	Long term	Lower	Not seen	Lower	Lower	Not seen	Lower
Transport													
Passenger vehicles	Lower	Immediate	Immediate	Lower	Lower	Lower	Long term	Immediate	Lower	Lower	Lower	Long term	Immediate
Medium and heavy duty	Immediate	Long term	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Lower	Immediate	Lower	Immediate	Immediate
Buses	Immediate	Long term	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Not seen	Immediate	Lower	Not seen	Immediate
Rail	Lower	Lower	Lower	Immediate	Immediate	Immediate	Lower	Immediate	Not seen	Immediate	Lower	Not seen	Long term
Maritime	Long term	Lower	Lower	Long term	Lower	Long term	Lower	Lower	Immediate	Long term	Lower	Long term	Long term
Aviation	Lower	Lower	Not seen	Long term	Immediate	Long term	Not seen	Lower	Lower	Long term	Lower	Long term	Long term

Source: World Energy Council

* Methodology: National strategies published until 30th May 2021.

Strategies content:

● Detailed ● Mentioned ○ Not seen

Goals and sector priorities:

Immediate priority Long term priority Lower priority Not seen

Source: World Energy Council

2: Confusion over “colours” is stifling innovation

- The existing strategies cite divergent forms of hydrogen based on colour or carbon intensity of production for 2030 and 2050. The choice of hydrogen production methods depends largely on the resources available and existing energy systems within each country, as well as the policy objectives being pursued (i.e., decarbonisation, fostering economic growth, etc.). They also resort to diverse terminologies with differing assumptions and attitudes towards certain technologies.
- **Confusion over ‘colours’ is stifling innovation**, with over-simplification and colour prejudice risking the premature exclusion of some technological routes that could potentially be more cost- and carbon-effective. There is a need for further dialogue which looks beyond colour to instead explore carbon equivalence.

From complexity



To one clear indicator
based on carbon intensity
(e.g. tCO₂eq, kWhs, TWh, etc.
per tH₂)

Further resources for dialogue:

Summary of colours/carbon intensity of hydrogen per country

COUNTRY	BY 2030	BY 2050
Australia	Clean	Clean
Canada	Low Carbon Intensity	Low Carbon Intensity
Chile	Green	Green
EU	Low Carbon	Clean / Renewable
France	Low carbon and fossil-based	Low carbon
Germany	Carbon free	Renewable
Hungary	Low carbon & carbon free	Low carbon & carbon free
Japan	Fossil-based with CCS	CO ₂ -free
Netherlands	Blue & Green	Green
Norway	Clean	Clean
Portugal	Green	Green
South Korea	From Natural Gas	Eco-friendly CO ₂ -free
Spain	Renewable	Renewable

Source: World Energy Council

3: Demand-centric hydrogen perspectives are needed

- **Demand-centric hydrogen perspectives are needed to advance the Humanising Energy and demand-driven agendas.** The current hydrogen conversation focuses heavily on supply, ignoring the role of hydrogen users. Discussions must explore what's needed to trigger demand, with a specific focus on the development of hydrogen infrastructure and a global supply chain.
- The ambition to better understand hydrogen demand is challenging as data on granular demand projections are yet to be published.
- Decreasing costs of clean hydrogen are expected to make applications competitive in more end-use sectors



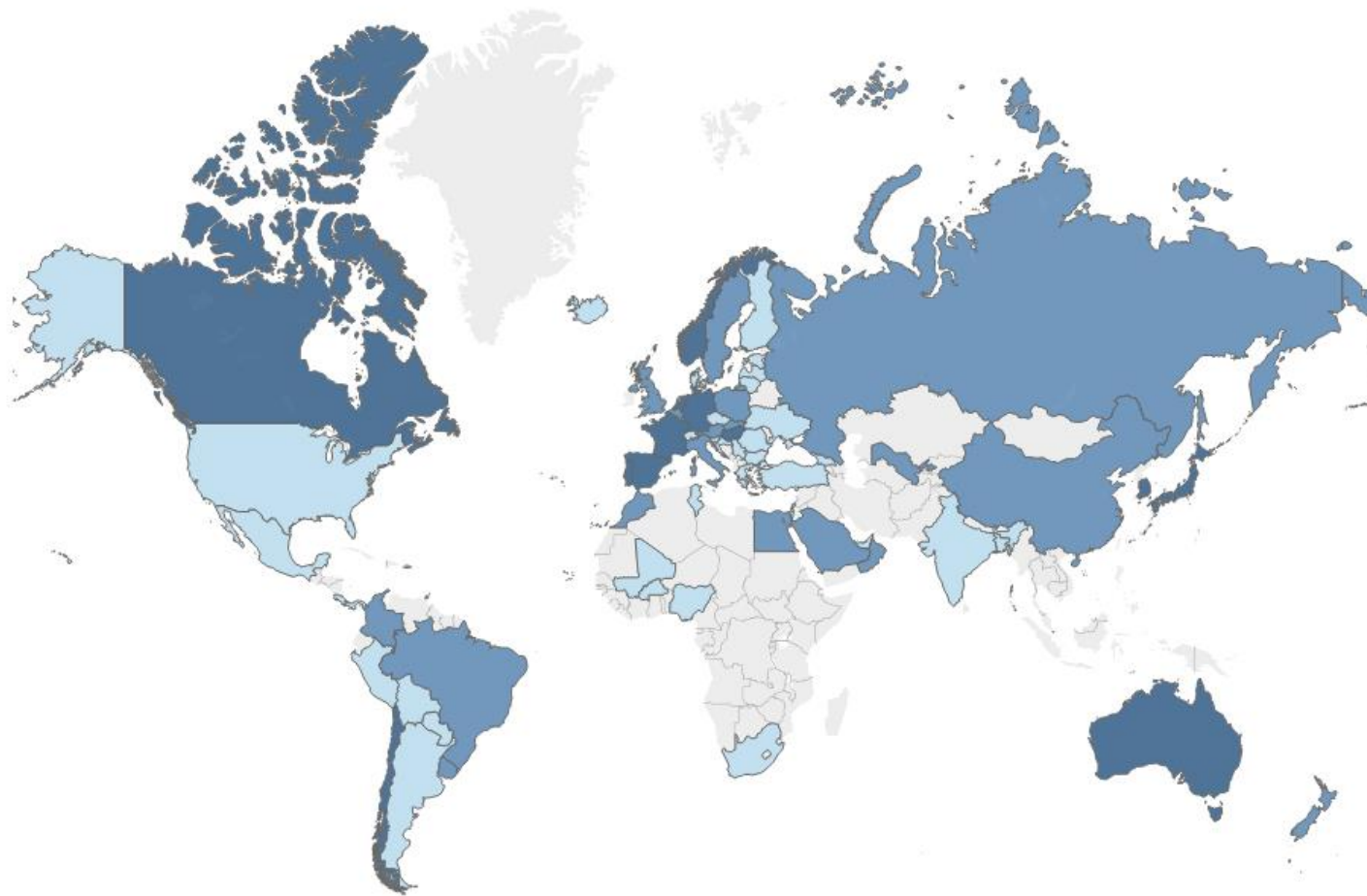
4: The hydrogen economy could stimulate job creation and economic growth

- **The hydrogen economy could stimulate job creation and economic growth**, potentially helping to fulfil ‘build forward together’ ambitions post-COVID-19.
- Several national hydrogen strategies highlight jobs as an important driver of hydrogen development, with opportunities to reskill the existing workforce and upskill a new workforce.
- Hydrogen could reuse or repurpose existing infrastructure and operations to help retain the workforce in countries with fossil fuel resources and related industries. Alternatively, it could help create new jobs in countries exploring export opportunities of both clean hydrogen and related technologies.
- The need for training has been highlighted as a critical short-term issue, with the more general need to improve hydrogen literacy for the overall population as well as training a skilled workforce.



Detailed Briefings

Part 1: National Hydrogen Strategies



State of play

- Published national strategy
- National strategy in preparation
- Policy discussions/Initial demonstration projects

As of 15th July 2021:

12 hydrogen strategies published

19 national strategies in preparation

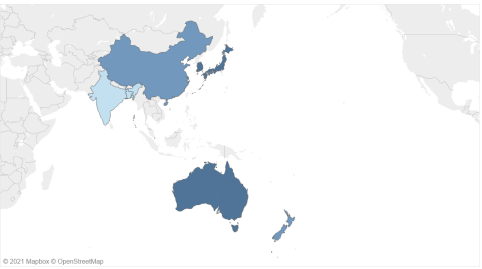
39 countries with policy discussions /
initial demonstrations projects

Detailed Briefings

Part 1: National Hydrogen Strategies

The development of a “hydrogen economy” is still at its early stages with few countries having published strategies, though there is broadening worldwide interest and support. To date, 12 countries and the European Union (EU) have published their hydrogen strategies.

Asia



- Japan’s early commitment catalysed interest in the Asian-Pacific region, with South Korea and Australia publishing their own strategies shortly afterwards.
- Japan and South Korea are targeting the power sector and transport. Both countries will rely mostly on clean hydrogen imports.
- Australian strategy places stronger focus on hydrogen production and export. Domestic market will occur in transport, and clean ammonia production.

Europe



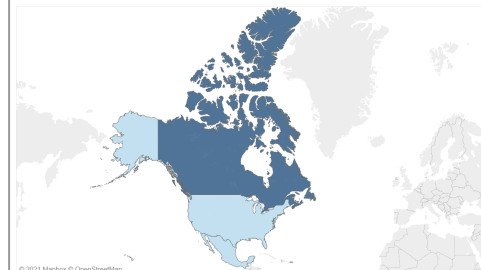
- Germany was an early mover in Europe and helped push the European Union hydrogen strategy during its EU presidency.
- 7 countries have published their strategy in 2020.
- Primary goal for using clean hydrogen in Europe is to decarbonise industry; transport is also targeted.
- Significant imports are expected in central Europe. Spain and Portugal will be self-reliant, with long term export aims.

Latin America and the Caribbean



- Chile is the first mover in the region, with many neighbouring countries also now in the process of developing their strategies.
- Chile has excellent renewable energy conditions, therefore its immediate aim is to replace fossil fuel derived hydrogen with renewable hydrogen.
- Priority sectors are industry and long-distance transport.
- Long term target of exporting renewable hydrogen.

North America



- Canada sees short term opportunities in transport where mature end-use applications are already available and technology readiness is high.
- Focus as well on decarbonising heating through natural gas blending with hydrogen.
- A major hydrocarbon exporter, exports clean hydrogen is on the agenda.

Detailed Briefings

Part 1: National Hydrogen Strategies

To enable clean hydrogen within their energy systems, countries are considering a wide variety of **policy instruments** and tools with some particularly innovative measures.



Setting the Vision: national strategies, energy policies, roadmaps



Enabling switching to clean hydrogen, through direct financial support and financial incentives



Facilitating international hydrogen markets formation



Creating the conditions for market development, through the revision of existing legislation and regulations, and efforts towards harmonised standardisation



Defining hydrogen sources (diverging on hydrogen colours and technology classifications)

Detailed Briefings

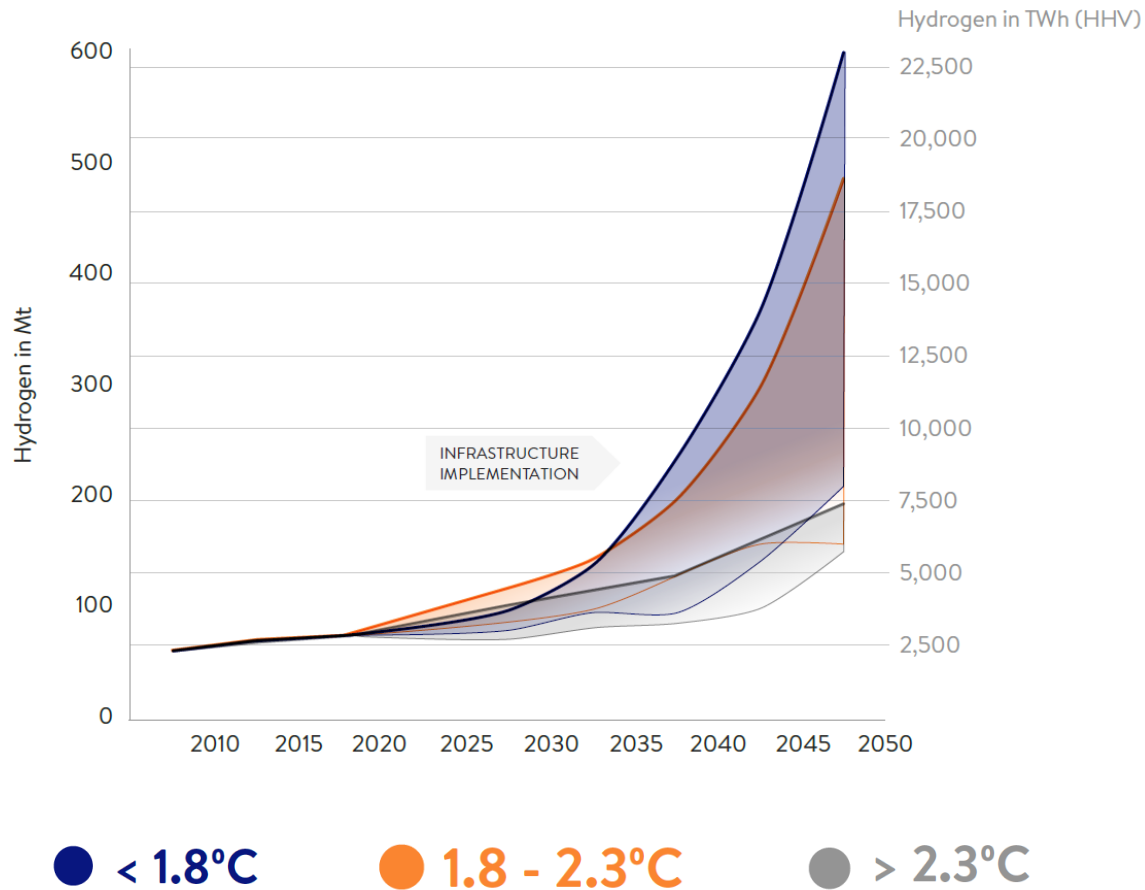
Part 2: Energy Leaders' Thoughts on Hydrogen



Detailed Briefings

Part 3: Hydrogen Demand and Cost Dynamics

Range Of Hydrogen Demand Assessment By 2050



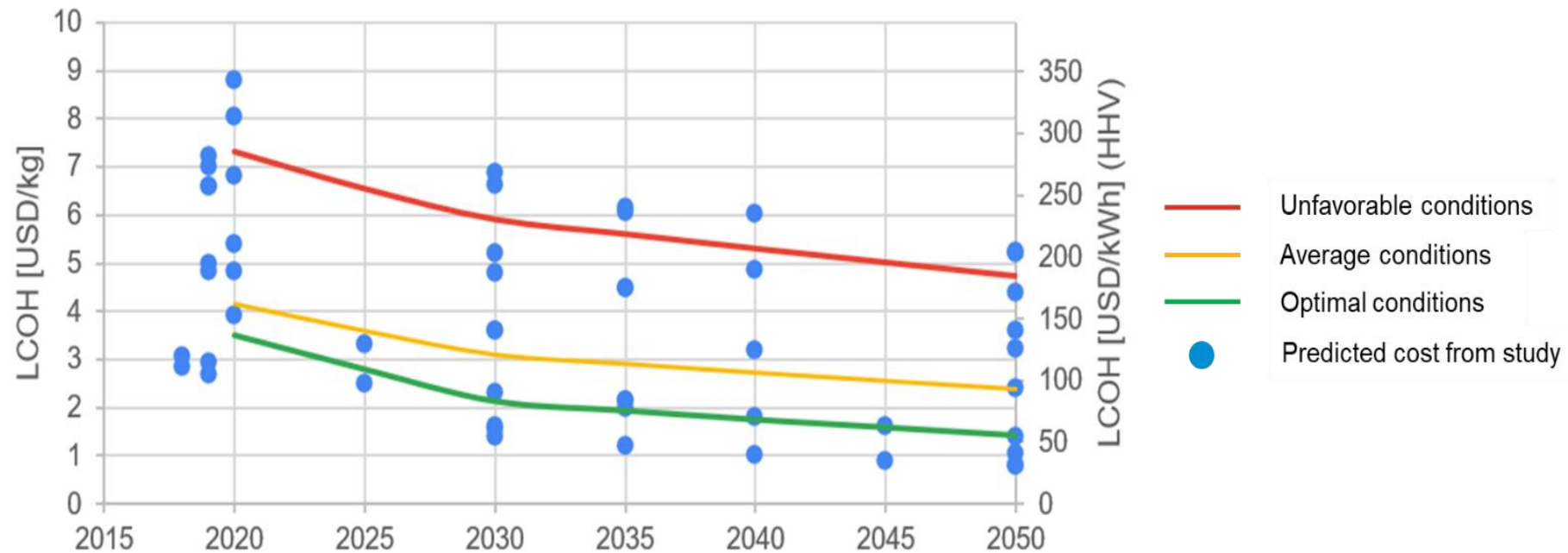
Source: PwC

- Hydrogen demand trajectories up to 2050 can vary depending on the development of complementing technologies, such as energy efficiency, electrification, carbon capture, and hydrogen technologies itself.
- Hydrogen demand projections vary significantly due to differing underlying assumptions regarding decarbonisation ambitions.
- Analysis revealed a broad range of possible future hydrogen demand.
- All estimates predict a limited but steady growth of hydrogen demand until 2030, mainly due to:
 - Current hydrogen projects under construction and in operation are almost exclusively at pre-commercial phase;
 - Putting in place the infrastructure for large scale hydrogen use takes many years.

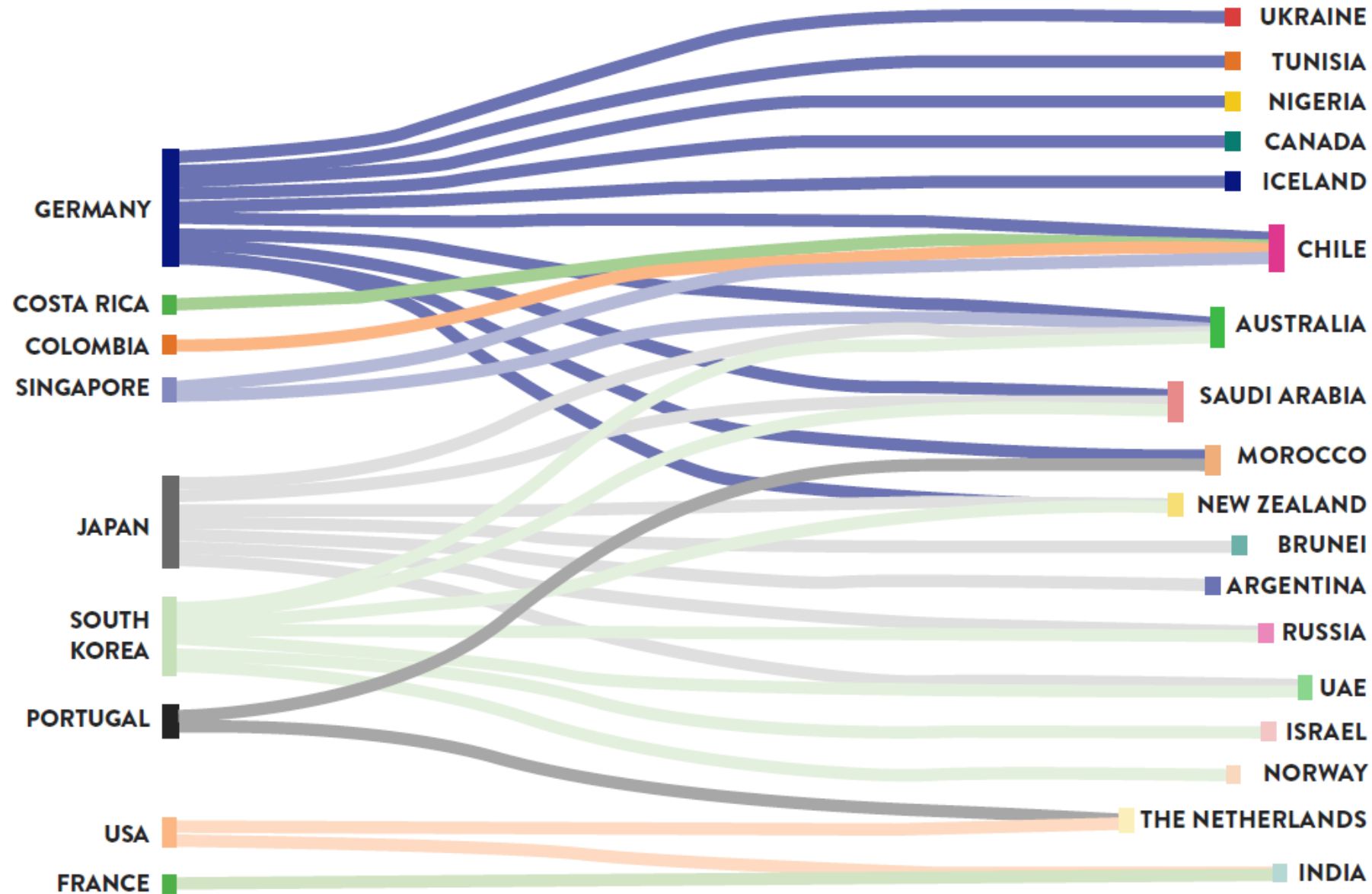
Detailed Briefings

Part 3: Hydrogen Demand and Cost Dynamics

- The future cost of hydrogen will be critical to its uptake across the various end sectors.
- The hydrogen cost for the end-user will be a function of production and distribution costs.
- Many of the production technologies are still new so learning curve and scale effects can help drive down future costs.
- Distribution costs for hydrogen covering storage and transportation are likely to be substantial and could limit growth.

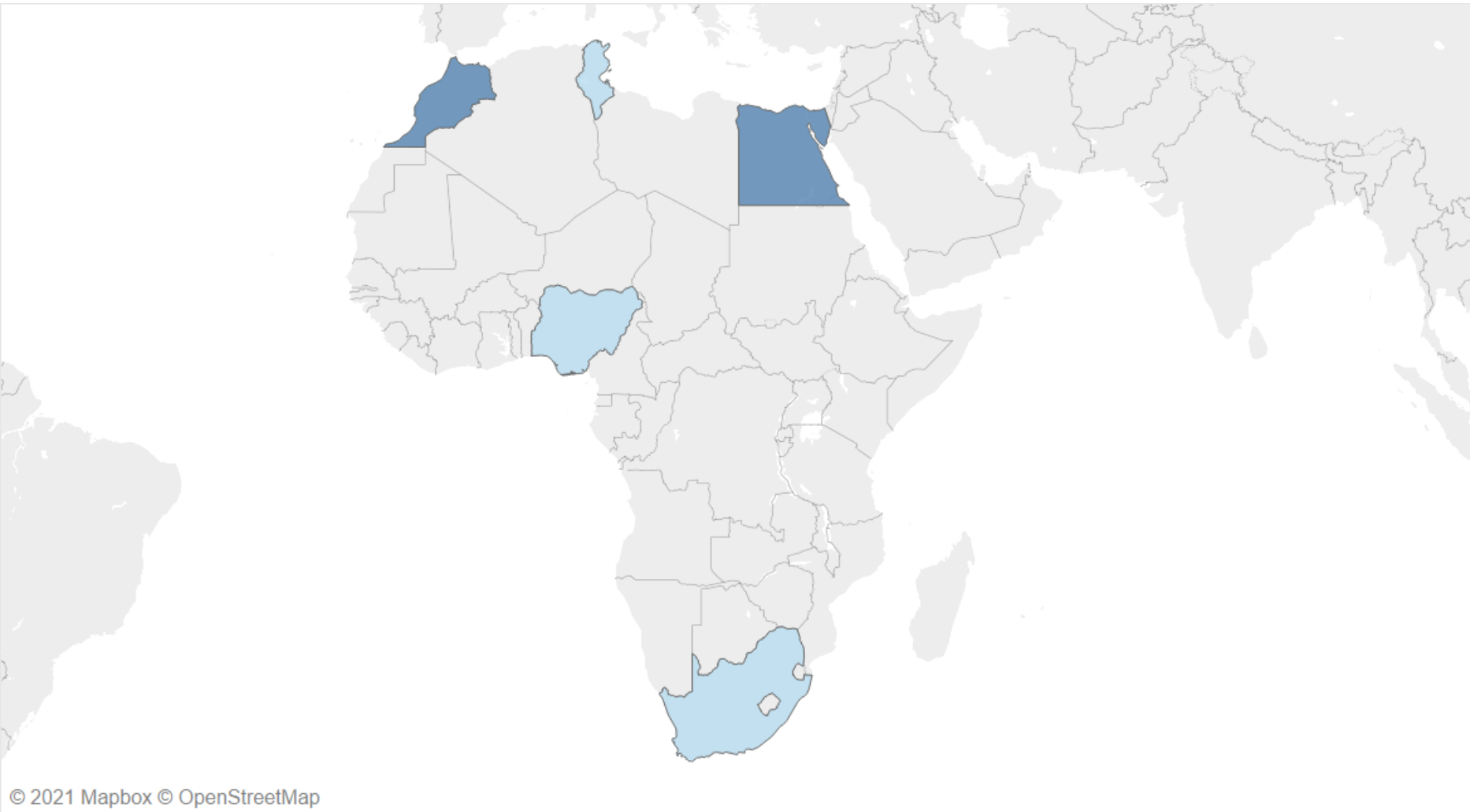


Bilateral Partnerships

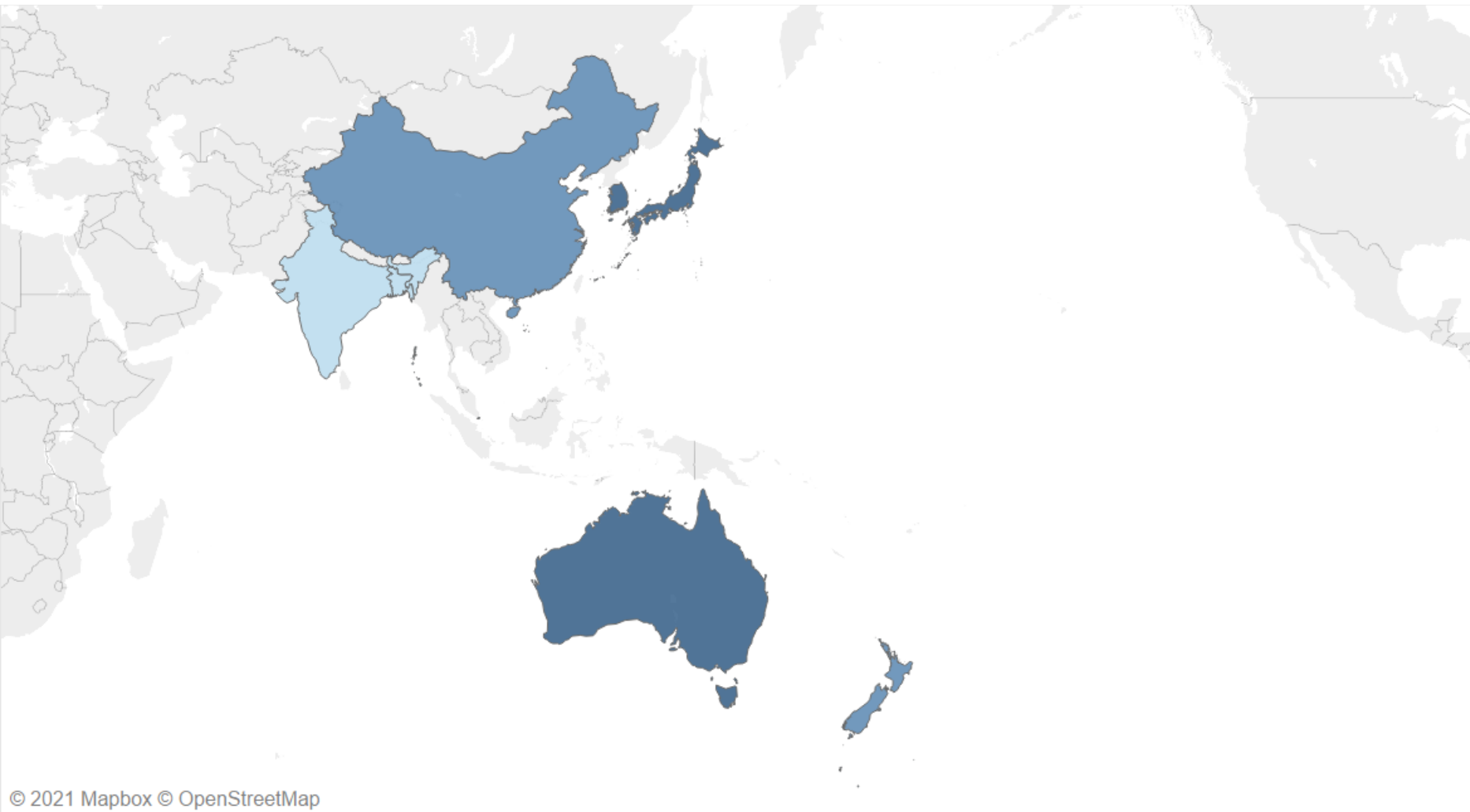


- Bilateral partnership are multiplying worldwide.
- Germany, Japan and South Korea are the most active countries in forming bilateral partnerships around hydrogen.

State of Play – Africa



State of Play – Asia Pacific



State of play

- Published national strategy
- National strategy in preparation
- Policy discussions/Initial demonstration projects

State of Play – Europe



State of play

- Published national strategy
- National strategy in preparation
- Policy discussions/Initial demonstration projects

State of Play – Latin America and Caribbean



State of Play – Middle East and Gulf States



State of play

- Published national strategy
- National strategy in preparation
- Policy discussions/Initial demonstration projects

State of Play – North America

