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Tendencias en la transición energética global
Hidrógeno Verde Sostenibilidad e Innovación

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Congreso Colombiano de Hidrógeno

20 de abril de 2023

2022 was another record year for renewable electricity

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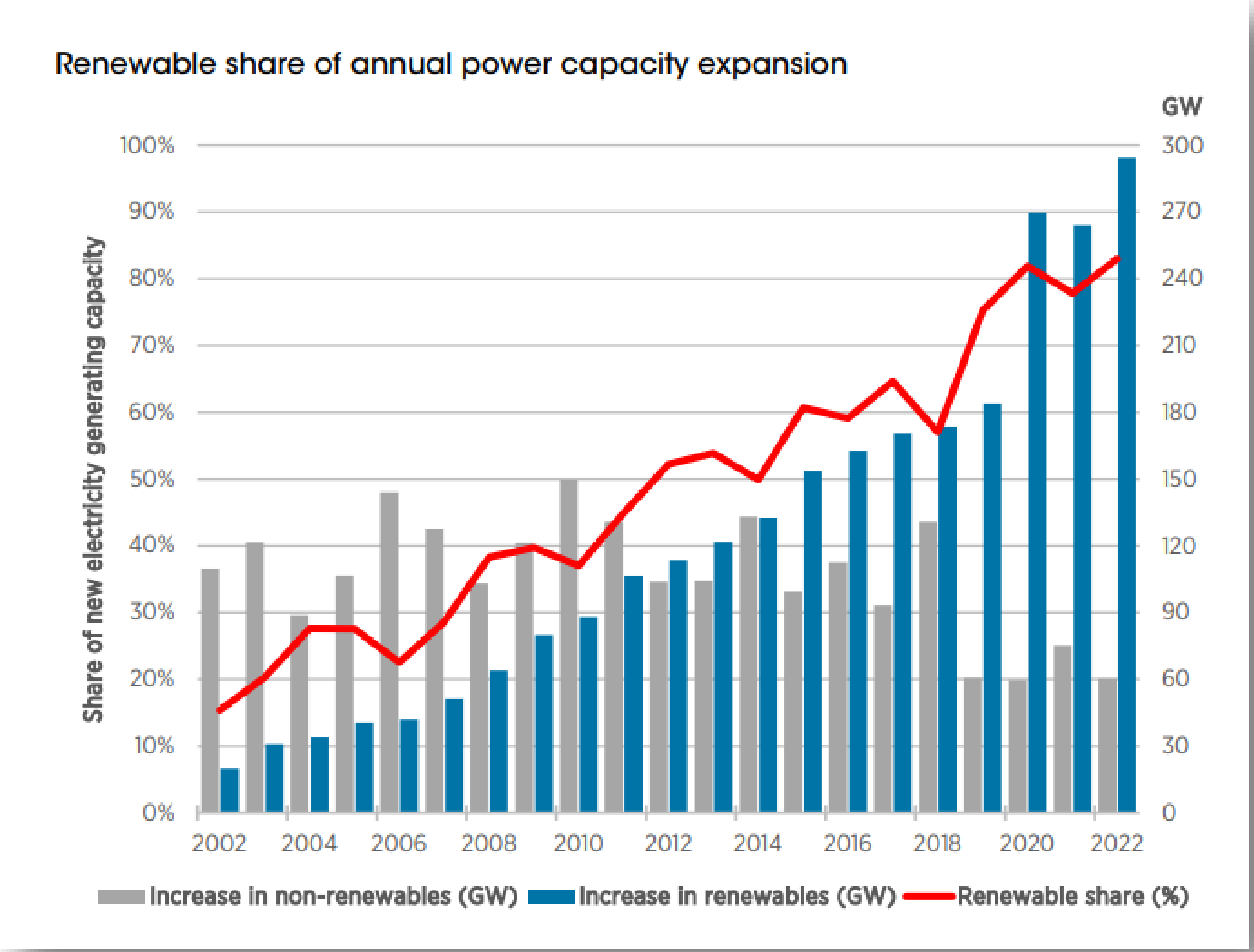

- In 2022 **295 gigawatts (GW)** of renewables added worldwide
- Renewables represented **83% of capacity additions and reaching 40% of cumulative installed power generation** globally in 2022
- Annual **solar PV 191GW/yr** and **wind 75GW/yr**
- Leading **China, the European Union and the United States**
- Cost for PV and onshore wind avg 4 cents USD/kWh – **best locations 1.5 cents USD/kWh**
- **Half a trillion USD** invested in RE in 2022

But energy is more than electricity and the challenge is still significant

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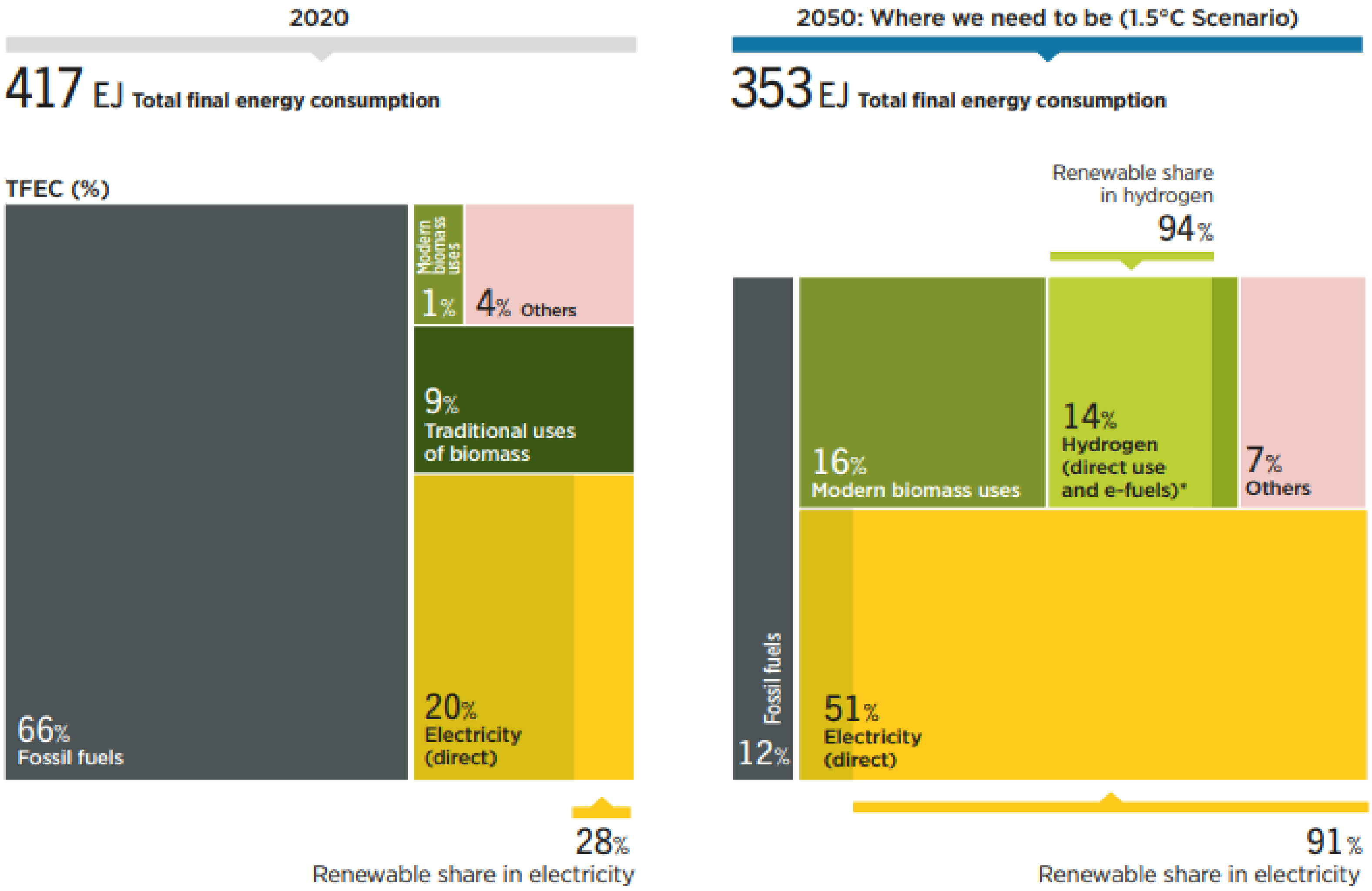
- The **global energy transition is off-track**
- Current plans are **not enough to limit the global temperature** increase below to 1.5°C.
- **Investments** in renewables must **quadruple**
- By 2050 in a 1.5oC Scenario -> **electricity is the king energy carrier**
- It has to **come from renewables**
- ~ **50% direct use** and ~ **14 indirect use as** Green Hydrogen
- 6x grow in H2 supply from 100 Mt/y to **600 Mt/y in 2050** and mostly green

Breakdown of total final energy consumption by energy carrier between 2020 and 2050 under the 1.5° C Scenario:



Green hydrogen costs depend on electrolyser cost and electricity cost

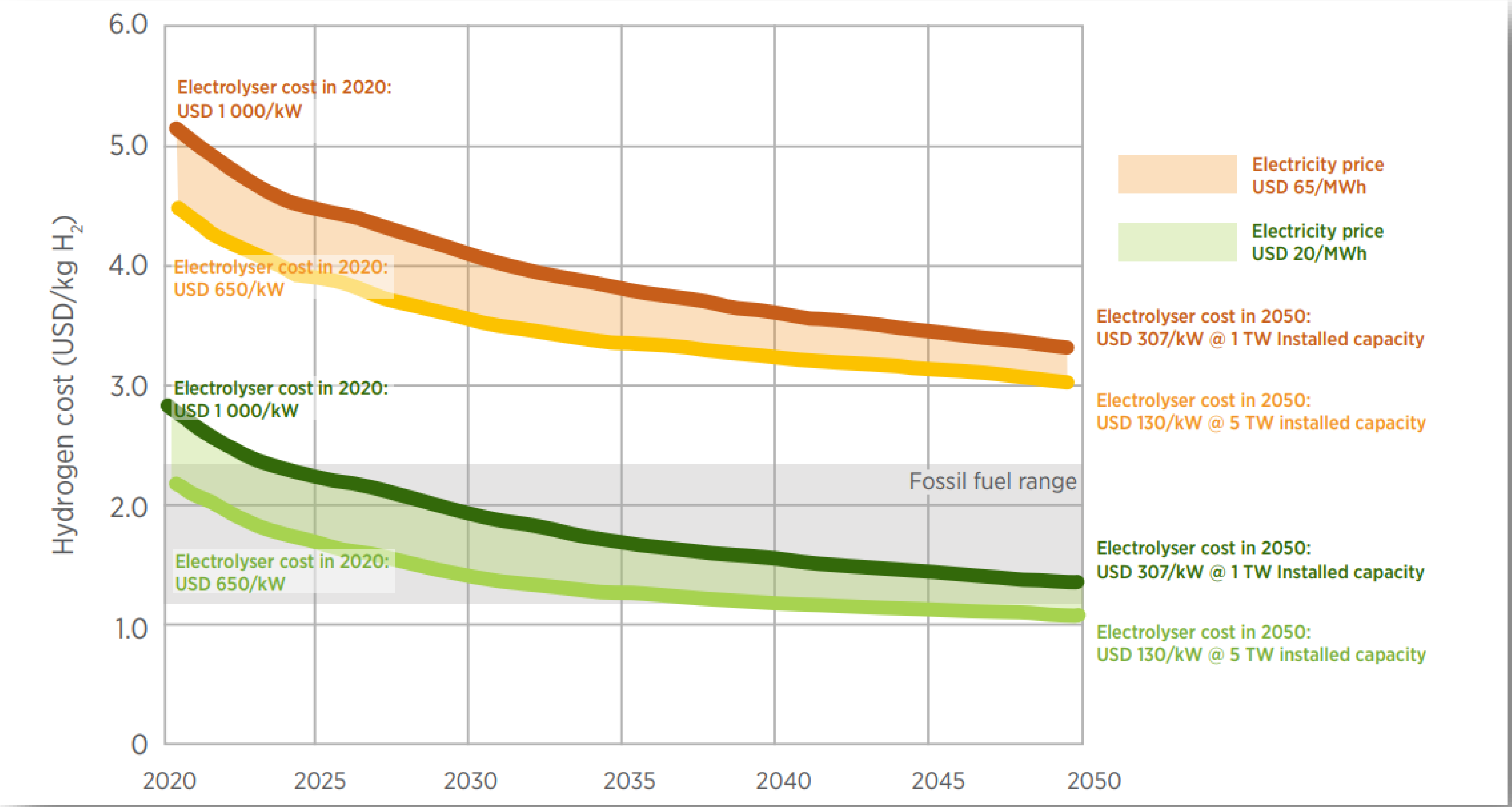
Costs

- Electrolysers – 800-1200 USD/kW today; and USD 500-600 by 2030
- Need to reduce production cost substantially to 1.5 USD/kg hydrogen

Investments

- Global to **2050**: around **15 trillion USD cumulative** in investments (10% of all energy transition investments)

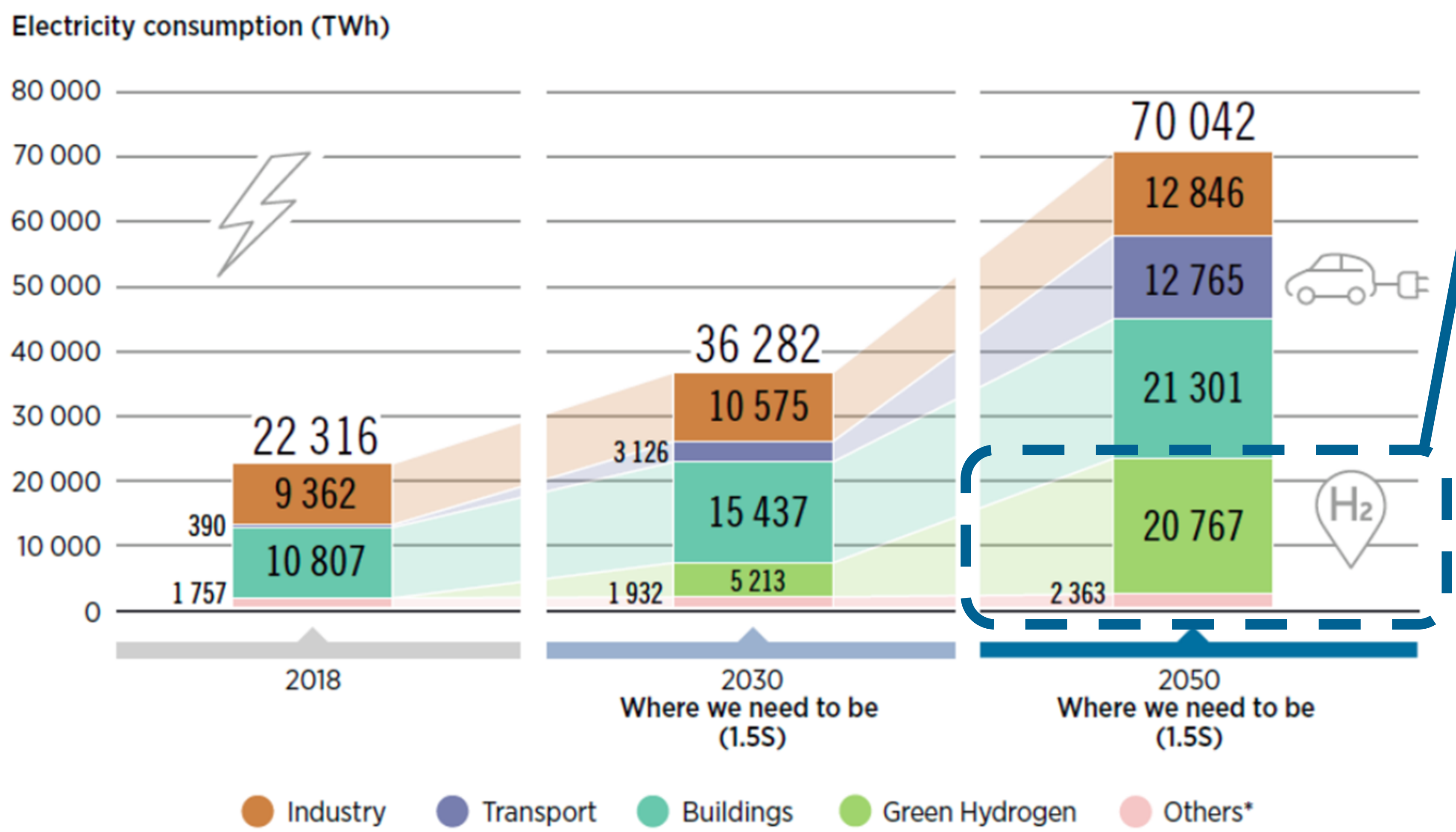
- Colombia: 60 billion USD now to 2050 -> avg 2.2 billion USD/y



Source: IRENA, 2022. Global hydrogen trade to meet the 1.5C goal. Part I: Trade outlook for 2050 and way forward.

Massive green hydrogen deployment needs massive renewable electricity deployment

Electricity consumption by sector, 2018, 2030 and 2050 (TWh/yr) in the 1.5°C Scenario



Key considerations

1- By 2050 more than 20,000 TWh of electricity demand for green hydrogen production – that is almost as much electricity as we consume globally today

2- From < 1 GW to 4,400 GW electrolyser capacity by 2050 -> Cautious with peak demand

3- We need a smart approach to integrate electrolysers in power systems, synergies with renewable generation

Colombia:

- **2030** –> 0.12 Mt/y -> 1.2 GW electrolysers -> **2.5 GW RE**
- **2050** -> 1.85 Mt/y -> 20 GW electrolysers -> **40 GW RE**

Source: https://irena.org/publications/2022/Mar/World-Energy-Transitions-Outlook-2022

Hydrogen trade - 30% internationally traded H2, 50/50 pipeline and shipping by 2050

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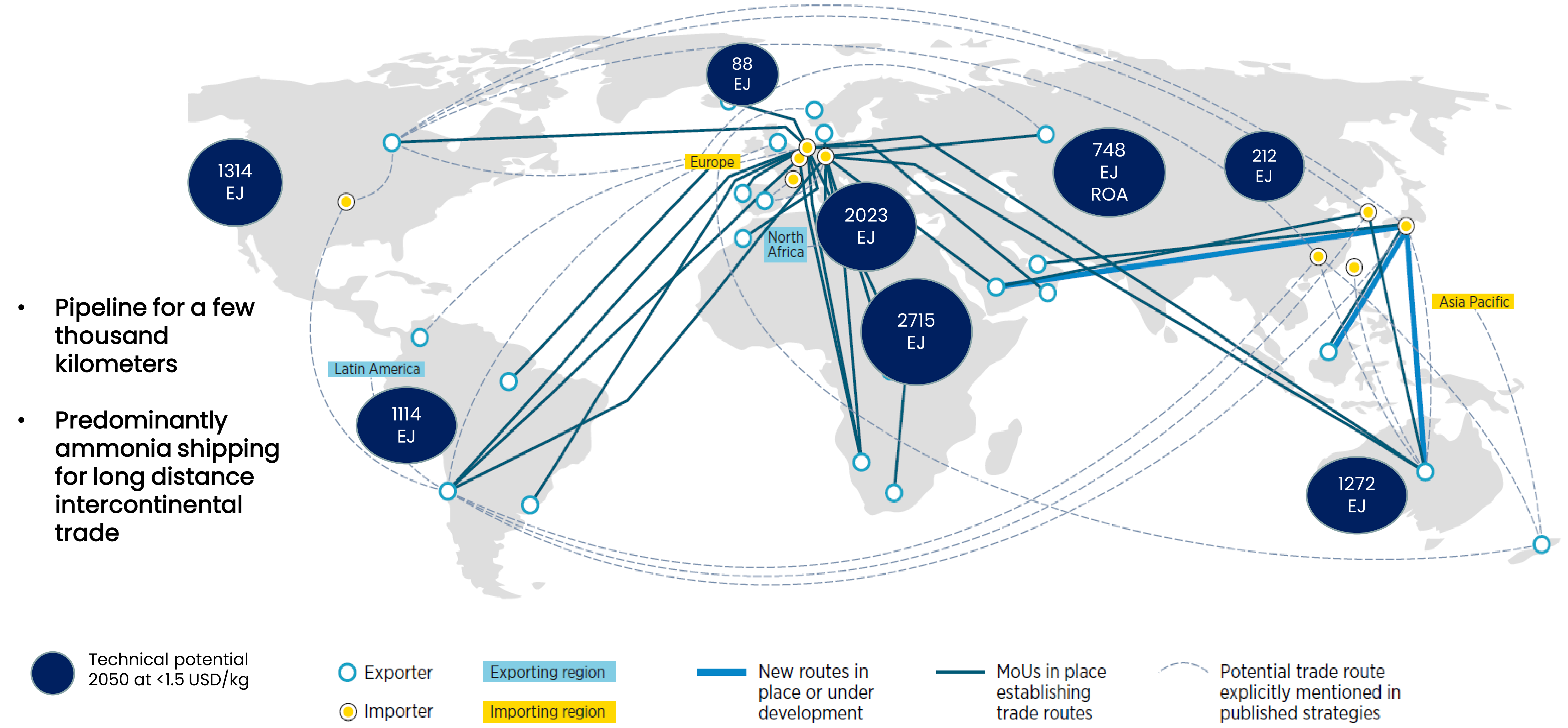

- Pipeline for a few thousand kilometers
- Predominantly ammonia shipping for long distance intercontinental trade

Source: https://www.irena.org/publications/2022/Apr/Global-hydrogen-trade-Part-II

Technology update different hydrogen carriers

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	Ammonia	Liquid Hydrogen	LOHC	Methanol
Infrastructure for export	• Already produced large-scale and traded globally. • Liquefied, it can then be transported by a chemical tanker. • Direct use as a feedstock (for chemical industry) possible without major infrastructure modification. • Used as a hydrogen carrier, it needs to be reconverted to H_2 via cracker. • Large-scale cracking still to be proven.	• Can be transported by ship using specially modified isolation tanks. • Distribution from the landing port may follow by trailer. This allows direct delivery to customers. • Alternatively, the liquid hydrogen can be reconverted to gas and fed into grid infrastructure.	• Can be transported as oil is today using existing infrastructure, making it suitable for multi-modal transport. • An example of LOHC is toluene, which is converted to methylcyclohexane (MCH) when reacted with hydrogen. • For transport, the toluene is "hydrogenated", placed in chemical tanks, and transported to the destination. • Once received, it can be "dehydrogenated" to release the hydrogen, while the toluene can be sent back for reuse.	• The liquid methanol is first stored in storage tanks at the port and then loaded onto chemical tankers. • At the port of destination, the methanol can be transported via existing distribution routes for chemical raw materials (including trailer and rail transport). • The infrastructure for importing chemicals and thus methanol is available and could be used straight away. • However, this only applies to the use of methanol as a chemical feedstock.
Conversion and safety considerations	Liquification at 20°C at 7.5 bar or -33°C at 1 bar Ammonia is a toxic and corrosive gas and, if handled incorrectly and thus released into the environment, has negative environmental effects.	Liquification at - 253°C	Requires high-temperature heat (150-400°C) for dehydrogenation	With a boiling point equal to 65°C and a flash point equal to 11°C, methanol is flammable.
Technical considerations	• High energy density and hydrogen content • Carbon-free carrier • Can be used directly in some applications (e.g. fertilizers, power generation, maritime fuel).	• High energy losses for liquefaction (30-36% today), which calls for larger energy supply • Boil-off (0.05-0.25% per day) during shipping and storage	• High (25-35%) energy consumption for dehydrogenation (importing region) • Requires further purification of the hydrogen produced • Hydrogen is produced at 1 bar, requiring compression • Only 4-7% of the weight of the carrier is hydrogen • No clear chemical compound that is the most attractive • Carrier losses every cycle (0.1% per cycle)	• Methanol is a commonly used basic chemical raw material. • It potentially can also be used as an energy carrier. However, The extraction of hydrogen (dehydrogenation) is a complex, energy-intensive process. • The production of methanol based on hydrogen requires carbon dioxide. • The carbon dioxide source (for example, from an industrial point source or capture from ambient air) is a critical factor in energy efficiency.

Where can green hydrogen and its derivatives be a solution?

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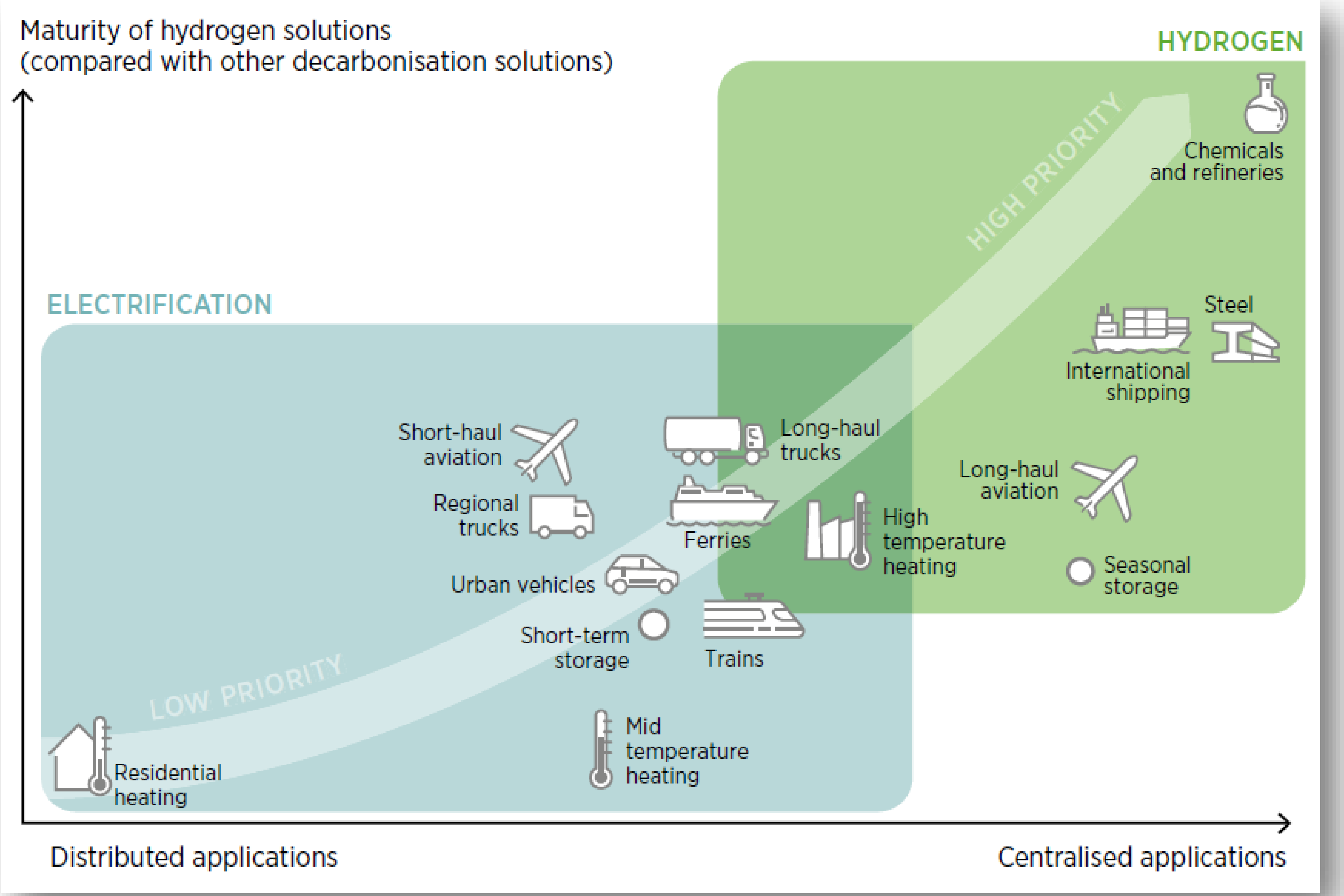
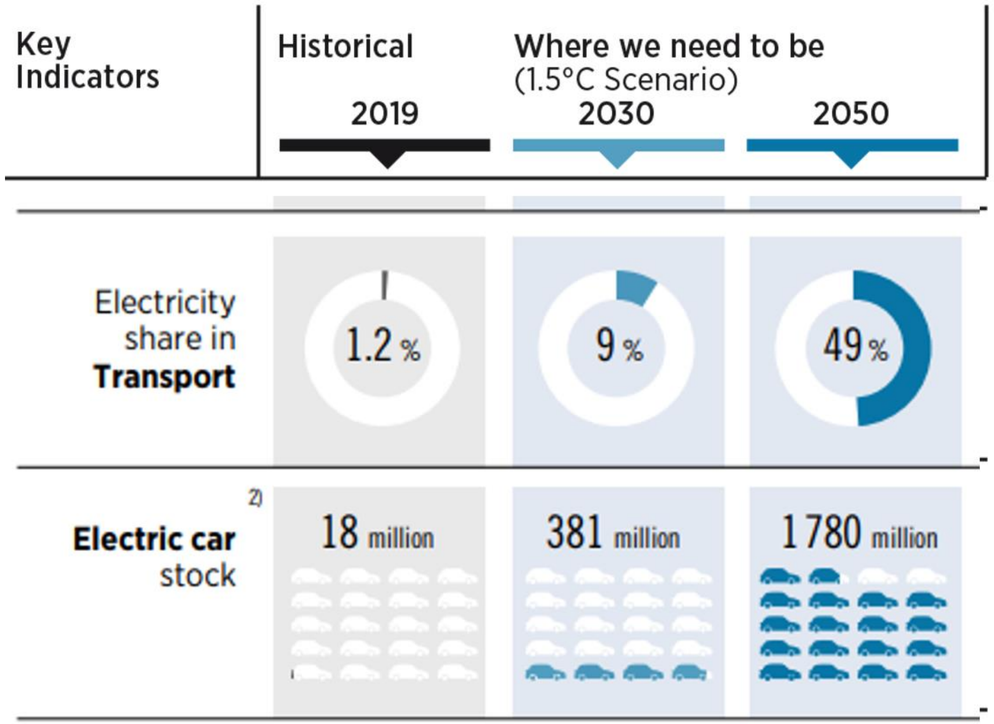
- H2 to be used in sectors where direct electrification is challenging – **Chemicals, Iron & Steel, Shipping and Aviation-**
- **Not a major role** in **road transport** (**BEV**) and **residential/commercial heating** (**HPs**)



Source:
https://www.irena.org/publications/2022/Jan/Geopolitics-of-the-Energy-Transformation-Hydrogen
https://www.irena.org/publications/2022/Mar/World-Energy-Transitions-Outlook-2022

Road transport

Passenger cars



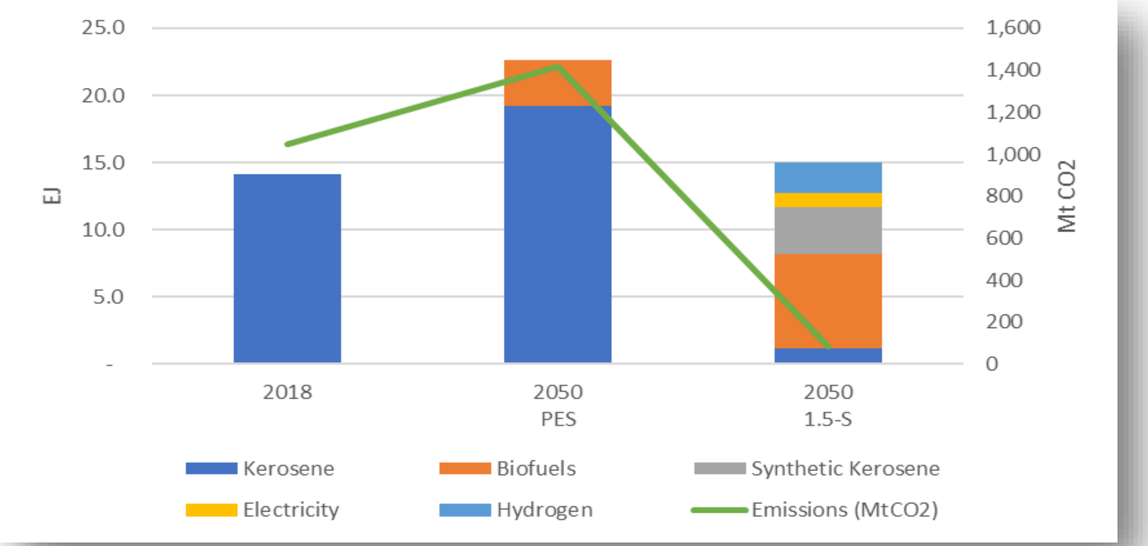
- BEV sales in order of **13 million BEVs/y in 2022**
- FCEV total stock **0.06 million FCEVs** in total
- FCEV need **3x more energy and 5x higher TCO**
- Innovative battery chemistry and end-of-life methods

Buses & Trucks

- Sales in order of **200k BEV buses/y and 70k BEV trucks/y** – China dominates the market
- FCEV buses and trucks are **~ 2% - 4% of BEV sales**
- Battery developments (autonomy and payload) + Fast charging and done at resting areas and depots
- Smart electrification – peak demand management
- Recently cities of Montpellier (FR) and Wiesbaden (GER) retired orders for H2 buses and stick to BEV
- Economics -> FCEV H2 5x costly to operate
- NL 1,600 requests for Dutch zero-emission truck subsidies were for battery-electric models, none for FCEV

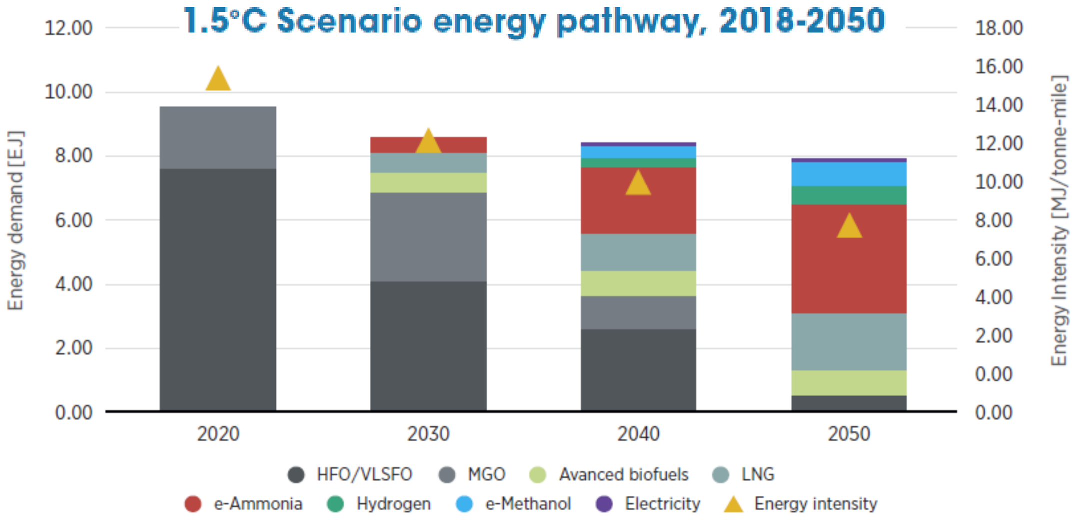
Other transportation modes

Aviation



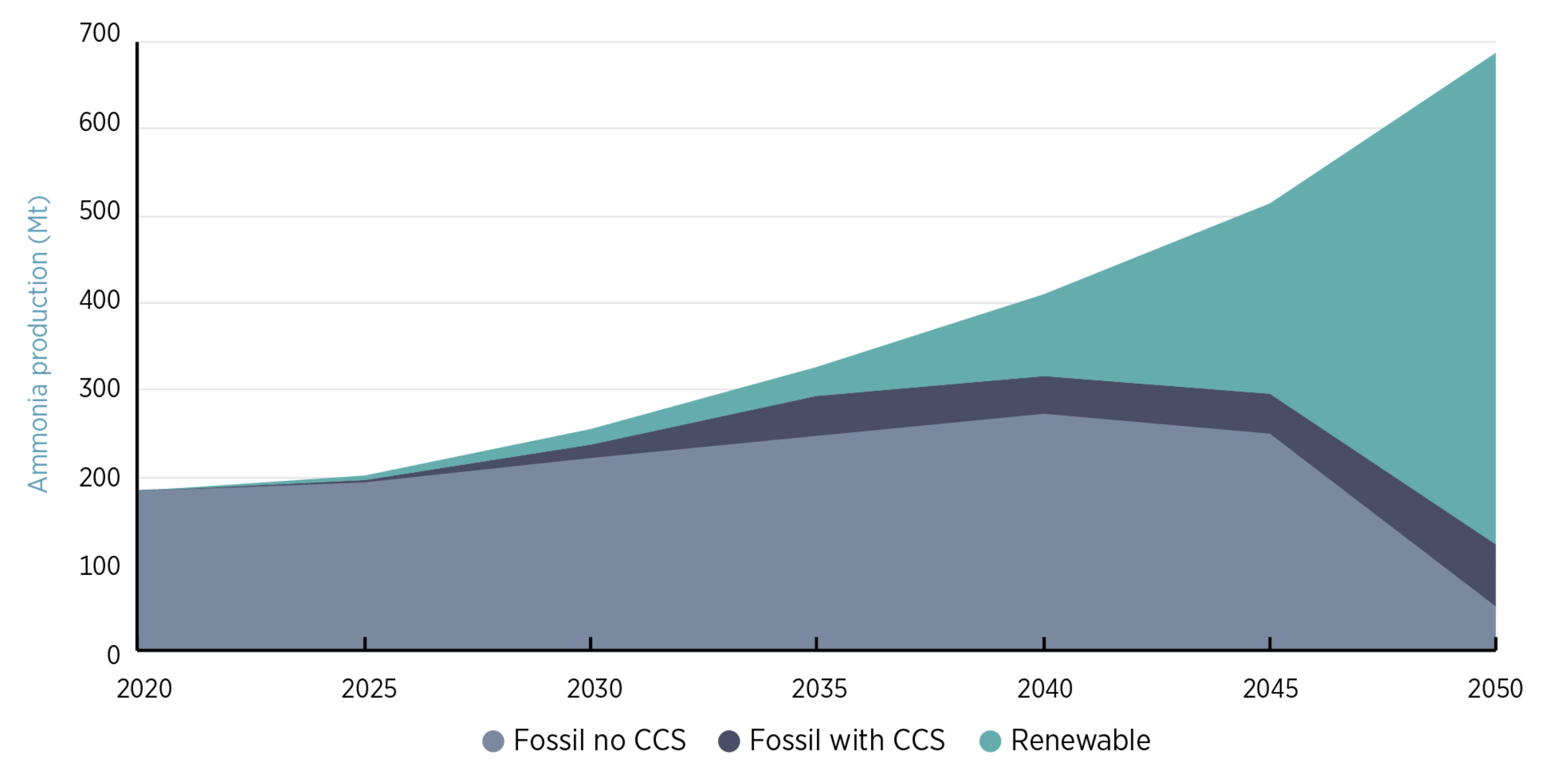
- 304 billion litres of Sustainable Aviation Fuel (SAF) by 2050 – **204 bn litres biojet and 100 bn litres e-kerosene**
- **Hydrogen and electric aircraft for short-haul flights** (22% of energy demand)
- Country example: demand ~ 1 Mt jet fuel/y -> 0.3 Mt h2/y ->3 GW electrolysers -> 6 GW RE

Shipping



- By **2050**, shipping will require a total of **46 million tonnes of green hydrogen** for e-fuels production.
- 73% would be needed for the production of **e-ammonia**, 17% for **e-methanol** and; 10% liquid hydrogen.
- Opportunity for H2 hubs in Port (Barranquilla, Buenaventura, Cartagena)

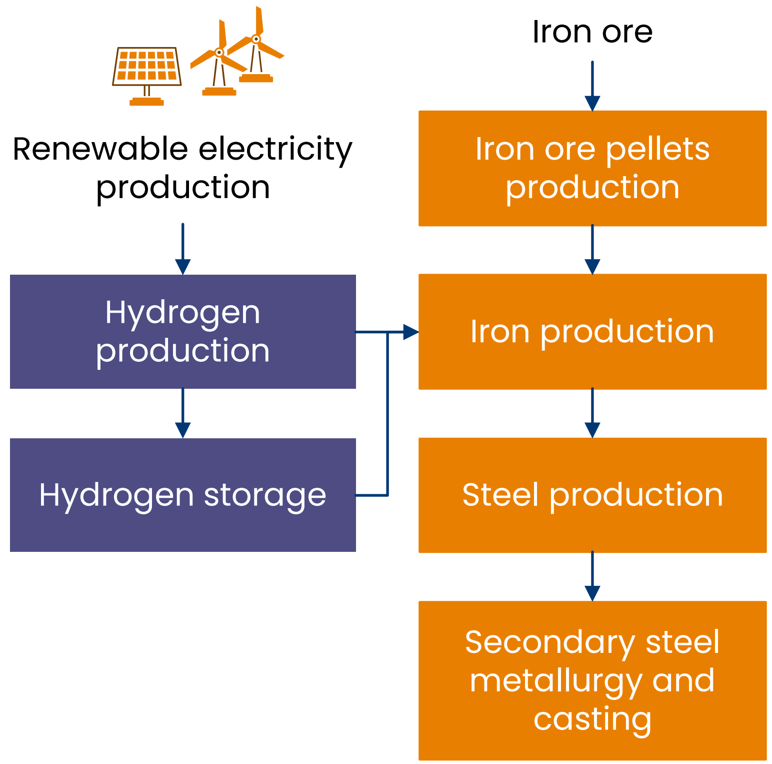
Chemicals – ammonia as an example



- **Ammonia** spot price from 300 to **>1000 USD/t in 2022**
- **Green ammonia** today 750 – 1200 and **2050 300 – 600 USD/t**
- Fertilizers is a key market linked to food security
- Colombia: demand ~ 2 Mt/y fertilisers -> ammonia based would need ~400kt h2/y -> 4 GW electrolisers -> 8 GW RE
- Apart from ammonia other H2 chemical applications: Refining, Methanol (MtO)

Hydrogen-based iron ore reduction

Schematic of hydrogen-based steel



Benefits

- Environmentally **sustainable** production method
- High emissions reduction potential **~ 95%**
- High technology readiness level **(TRL)**
- High Industry acceptance ~ **19 plants** announced

Challenges

- Higher **costs** of production
- **Reliable supply** of green hydrogen
- Geographical constraints of **hydrogen production and storage facilities**
- Limited operational **experience**
- Need for **high grade** iron ore

Market

- Current global annual steel demand is ~ 2 billion t/y growing 2% per year
- **Colombia** produces ~ 1.3 Mt/y: from DRI 50 kt H2 / Mt steel -> **65kt H2/y** -> 650 MW electrolisers -> 1.4 GW RE

Water consumption of hydrogen in 2050 compared with selected sectors today (billion cubic metres)

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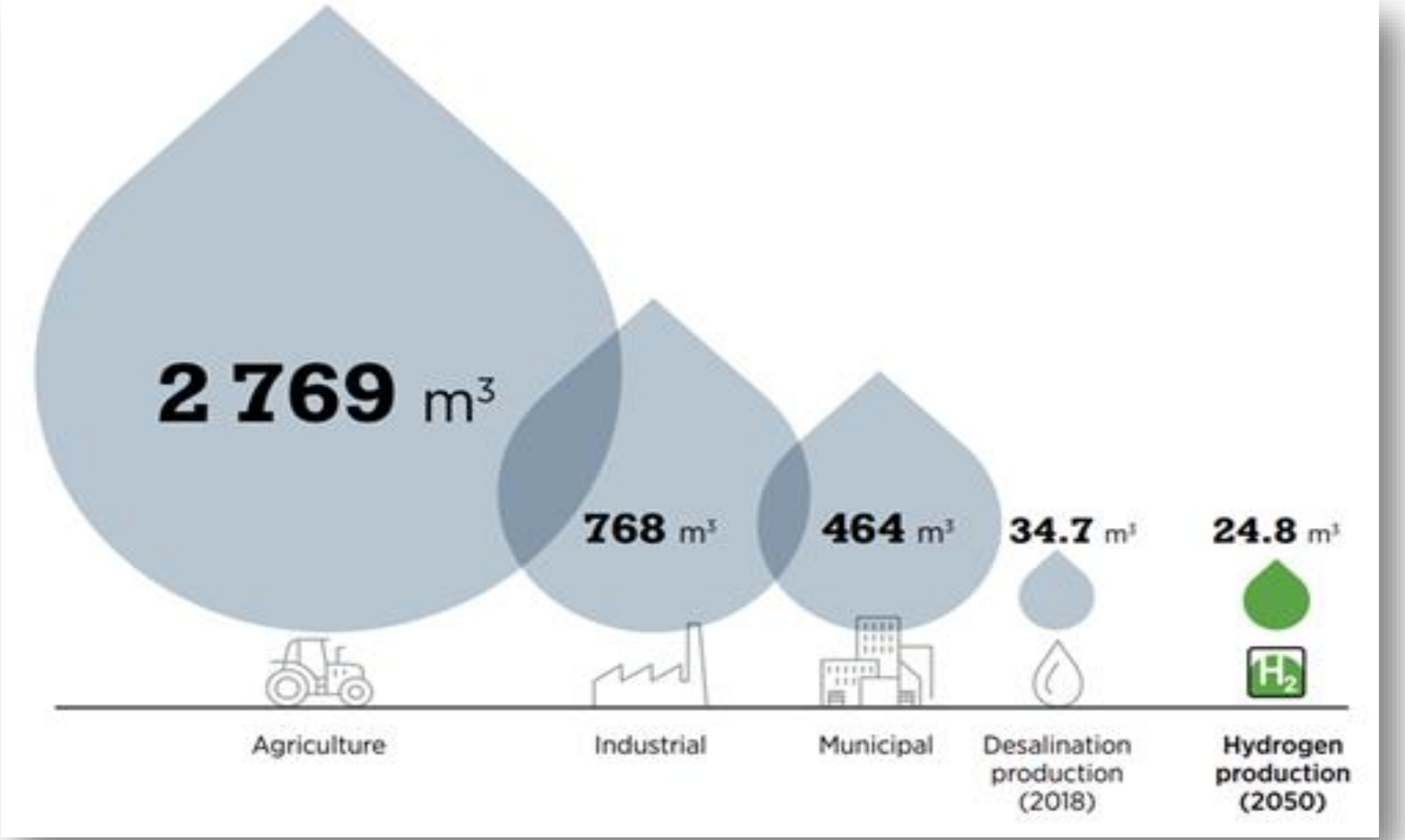

Potential socio-economic benefits of renewable hydrogen production

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POTENIAL SOCIO-ECONOMIC BENEFITS

WATER SECURITY

- Water stressed regions with coast access could use desalination.
- Even though desalination is energy intensive, and the electricity should be renewable, renewable hydrogen could potentially represent an opportunity to improve water security.
- Desalination for renewable hydrogen adds 1–2% to energy consumption and the cost of production.
- Renewable hydrogen could potentially contribute to accelerate the desalination industry and lead to a massive scale-up of desalination capacity.
- This could also increase freshwater supply for other uses than electrolysis or reduce the cost of desalination.
- It should be noted, however, that desalination plants produce brine enriched with salt and chemicals, so ecological effects could arise from its return to the sea.

ENERGY ACCESS

- The lack of energy access, low electrification rate and low deployment of renewables pose challenges for renewable hydrogen deployment in developing countries.
- Hydrogen production plans targeting export have to take these competing needs for renewable capacity into account.
- Projects could include provisions for a minimum share of energy for local users or by larger economies of scale, lower financing costs and supply chain development for renewables leading to lower costs of energy.
- Green hydrogen can absorb excess renewable electricity, leading to higher system efficiencies and energy security.[19]

INDUSTRY

- Renewable hydrogen can offer new industrial opportunities for the production and use of commodities, such as green steel.
- Even some of the poorest countries in the world may be able to exploit their renewable energy potential to produce green hydrogen locally, generating economic opportunities and increasing energy security.
- Such potential can be realised only through an international effort to channel resources, share technologies and transfer know-how.[1]

We need harmonisation to develop H2 certification

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Title	Label	Emissions Threshold (kg CO2e/kg H2)	Boundary	Power Supply Requirement for Electrolysis	Hydrogen Production Pathway	Chain of Custody (CoC) Model
Australia Smart Energy Council Zero Carbon Certification Scheme	Renewable H2	No threshold				Unclear
China China Hydrogen Alliance Standard and Assessment for Low-carbon Hydrogen, Clean Hydrogen, and Renewable Hydrogen Energy	Renewable H2	4.9				Not specified
	Clean H2	4.9				Not specified
	Low-carbon H2	14.5		n/a		Not specified
European Union CertifHy Green and Low-Carbon Hydrogen Certification	Green H2	4.4				B&C
	Low-carbon H2	4.4				B&C
Germany TUV SUD CMS 70	Green H2 (non-transport)	2.7				B&C
	Green H2 (transport)	2.8				Mass
Japan Aichi Prefecture Low-Carbon Hydrogen Certification	Low-carbon H2	No threshold				B&C
International Green Hydrogen Organisation Green Hydrogen Standard	Green H2	1.0				Not specified

KEY

Indicates threshold value

Includes upstream methane
To point of production
To point of use

Power Supply Requirements
GO + Additionality
GO required
No GO / additionality specified
Solar, Wind or Hydro
Nuclear
Grid (or unspecified)

Hydrogen Production Pathway Specified
Electrolysis
Fossil SMR/ATR with carbon capture
Biogas SMR

- Regulations are moving towards **2.5 – 4 kg CO2e/Kg H2**

Joint study with

RMI

Innovation – patents aiming at reducing the cost of electrolysis

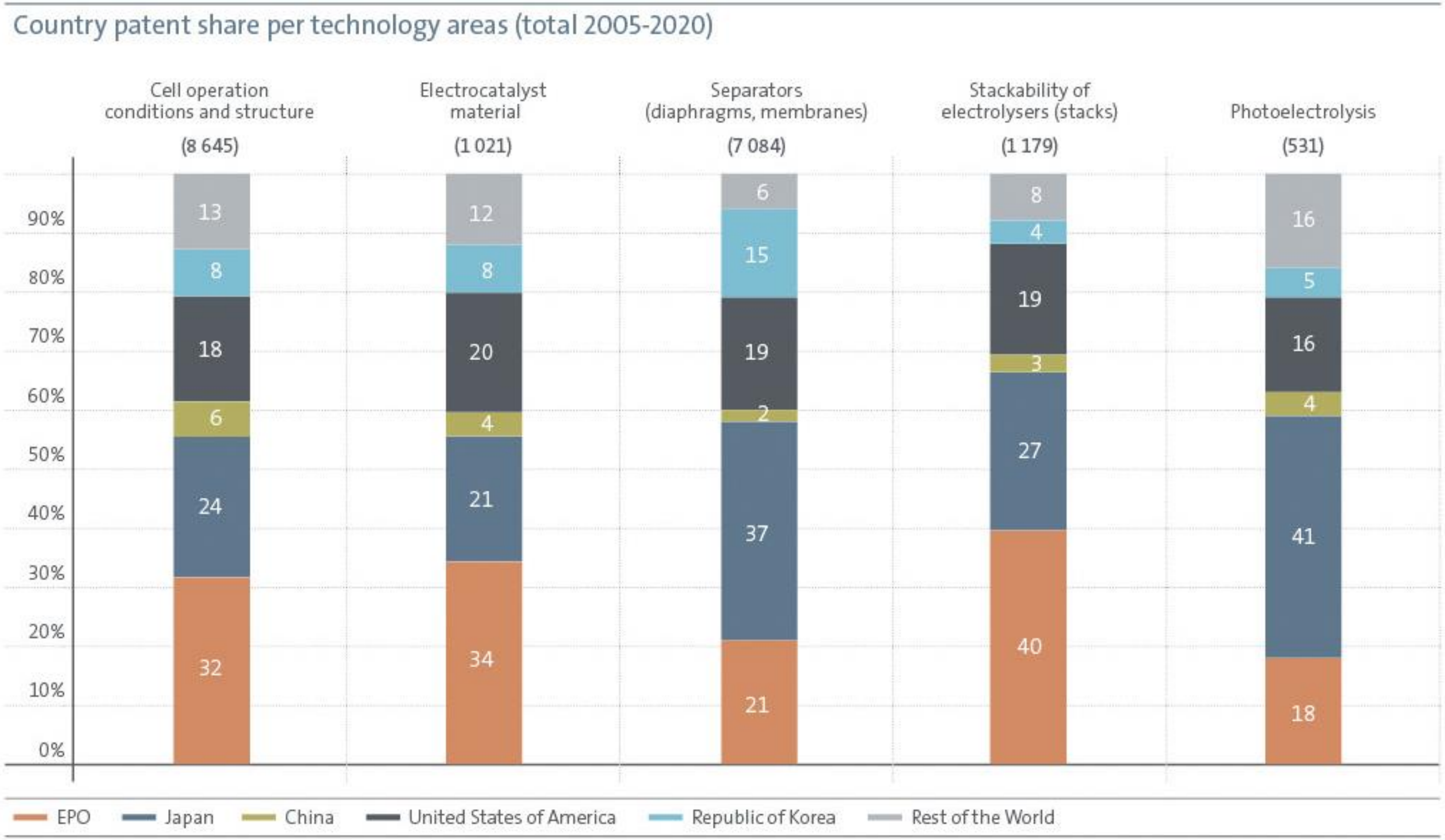

Figure 7: This is a summary chart of the country share of international patents in relation to the five subtechnology areas identified. The country refers to the country of the patent applicants. Europe groups together the 38 member states of the European Patent Organisation.[21] Numbers in bold and in parenthesis at the top of each column are the total number of international patent applications in that technology area.

- Europe & JP: 50% of the total IPFs filed in all areas
- Europe leads in the stackability of electrolysers (41%), electrocatalyst material (34%) and cell operation conditions and structure (32%)
- Japan first in photoelectrolysis (39%) and separators (diaphragms, membranes) (36%).
- USA averages 18% across all technology areas
- Rep. of Korea highest share in separators (diaphragms, membranes) (16%)
- China 4% international patents but dominates domestic filings.

30 Innovations for power-to-hydrogen smart strategies – Forthcoming Innovation Landscape Report (June 2023)

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Technology and infrastructure	Market design and regulation	System planning and operation	Business models
Electrolyser technology	**Power market**	**Strategic planning**	**Primary revenue streams**
1. Pressurised ALK electrolyser 2. PEM electrolyser 3. SOEC electrolyser 4. AEM electrolyser	10. Additionality principle 11. Renewable PPAs for green hydrogen 12. Cost-reflective electricity tariffs 13. Electrolysers as grid service providers	21. Electricity TSOs, including grid-connected hydrogen facilities in their planning 22. Co-locating electrolysers with renewable generators (onshore and offshore)	26. Local hydrogen demand 27. Hydrogen trade 28. Hydrogen industrial hub
Hydrogen infrastructure	**Hydrogen market**	**Smart operation**	**Stacking other revenue streams**
5. Compressed hydrogen storage 6. Liquefied hydrogen storage 7. Hydrogen-ready equipment	14. Certificates 15. Hydrogen purchase agreements scheme 16. Carbon contracts for difference	23. Smart hydrogen storage operation and power-to-power routes 24. Long-term hydrogen storage 25. Co-operation between electricity and gas operators	29. Revenues from providing services to the power system 30. Sale of electrolysis by-products (oxygen and heat)
Digital technologies	**Standards and regulations**		
8. Digital backbone for green hydrogen production 9. Hydrogen leakage detection	17. Regulatory framework for hydrogen network 18. Streamlining permitting for electrolyser projects 19. Quality infrastructure for green hydrogen 20. Regulatory sandboxes		

Seven Collaborative Frameworks – Governments collaboration platform with engagement of industry

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Green Hydrogen

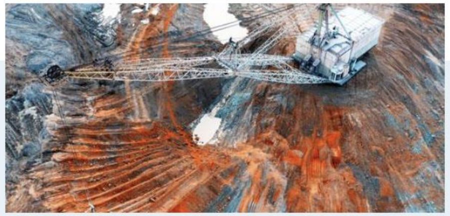
The Collaborative Framework serves as an effective vehicle for dialogue, co-operation and coordinated action to accelerate development and deployment of green hydrogen and its derivatives for the global renewable energy transformation

Offshore Renewables

Oceans are a source of abundant renewable energy potential, capable of driving a blue economy. Energy harnessed from oceans, through offshore renewables, can contribute to the decarbonisation of the power sector and other end user applications relevant for a blue economy (e.g. shipping, cooling, water desalination).

Hydropower

Hydropower is the largest source of renewable energy worldwide, and its development is considered essential in driving the energy transition forward. The Collaborative Framework on Hydropower was established as a response to an explicit request from Members to expand the Agency's work on Hydropower. The Framework seeks to advance priority areas, coordinate concrete actions and foster international collaboration on the topic of hydropower.



Critical materials

This Collaborative Framework aims to provide an inclusive platform to foster dialogue, coordinate activities, strengthen peer-to-peer exchange, increase transparency and develop a set of insights into the gaps and solutions for the energy transition that relies on critical materials.

- Additional three CFs: high shares of renewables / Just and Fair transition / Geopolitics

Alliance for Industry Decarbonization

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Secretariat
IRENA

Co-Chair *Siemens Energy*

Co-Chair *Tata Steel*

	Technology			Process	Enabler	
Working groups name	Renewables	CCUS	Green hydrogen	Heat process optimization and integration	Human Capital	Finance
						
Working group leader	*Enel Green Power*	*JSW*	*Tata Steel*	*Siemens Energy*	*to be confirmed*	*Taqa Arabia*
Working group members	• KIS Group • Subsea 7 • ATC Development • Repsol • Elsewedy Electric • Taqa Arabia • OQ • Equinor	• Equinor • Repsol • Eni • TAQA Group • OQ • Tata Steel • Subsea 7	• Enel Green Power • Subsea 7 • Repsol • KIS Group • Vale • Elsewedy Electric • Siemens Energy • JSW	• Eni • ATC Development • Tata Steel • Equinor	• Eni (tbc as Group Leader) • TAQA Arabia • Enel Green Power	• ATC Development • Elsewedy Electric • KIS Group • Siemens Energy

Ecosystem knowledge partners
Roland Berger, State of Green, Green Climate Fund

20 members

Ecosystem partners: State of Green and Green Climate Fund

Members by sector

- Energy
- Services
- Steel
- Chemicals
- Mining
- Waste & Water

IRENA INNOVATION WEEK 2023

Renewable solutions to decarbonise end-use sectors

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International Renewable Energy Agency

25 – 28 September 2023 • Bonn, Germany

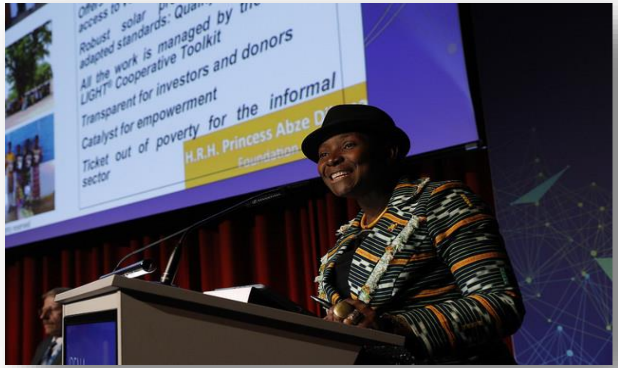
Join us at Innovation Week 2023, which builds upon previous editions of IRENA Innovation Weeks in 2016 and 2018, and the virtual edition in 2020.

The discussions will focus on emerging solutions to **decarbonise the transport, buildings and industry sectors**, both via direct and indirect **electrification**.

- Aims to:
    - **Connect** industry experts and policy makers
    - **Showcase** emerging innovative solutions
    - **Inspire and inform** the energy transition

2018 event included over 80 expert speakers & 350 participants from over 70 countries.

2020 virtual event included over 100 expert speakers & 1600 participants from over 130 countries.



Thank You

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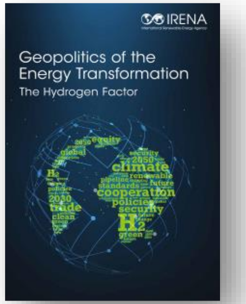
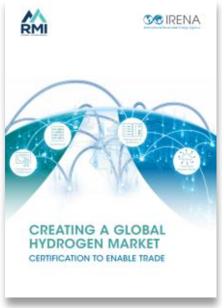
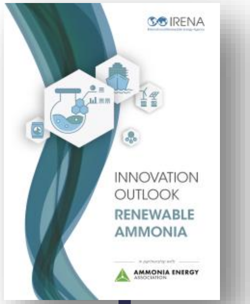
Supply

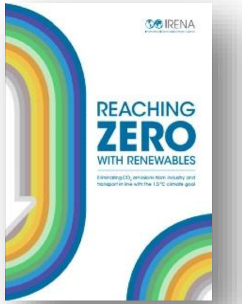
Trade



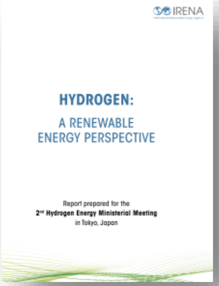


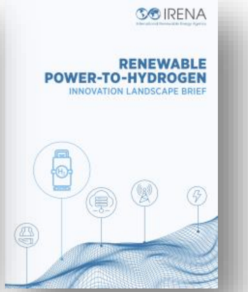


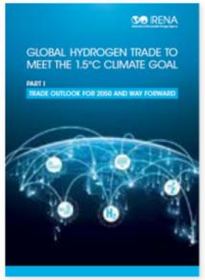
Demand

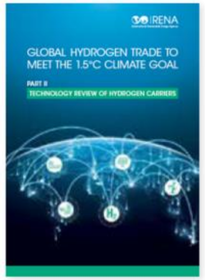


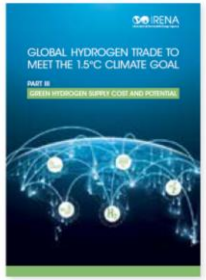
Sector coupling

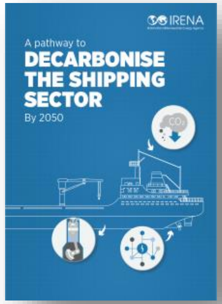


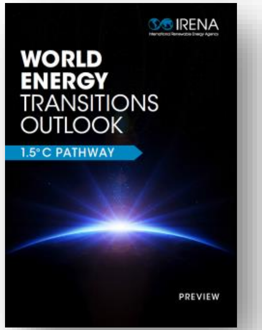












Policies & cross cutting