Introducción a los Mercados Internacionales de Productos y Derivados

Francisco Boshell
Head of Innovation and End Use Applications

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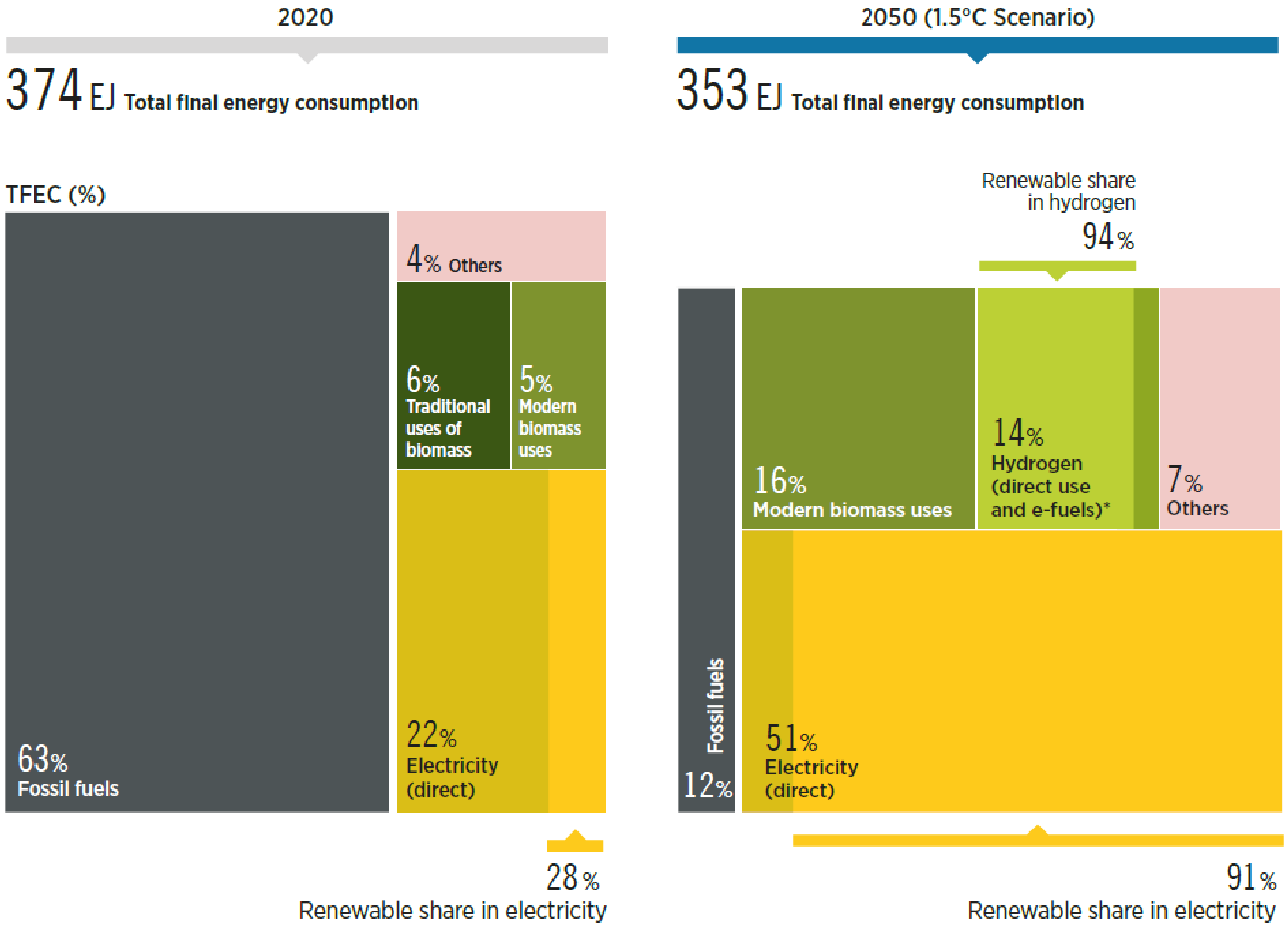
But energy is more than electricity and the challenge is still significant

- 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**

FIGURE 1.2 Breakdown of total final energy consumption by energy carrier between 2020 and 2050 under the 1.5°C Scenario



Source: IRENA (2023), World Energy Transitions Outlook 2023: 1.5° C Pathway, Volume 1

Estimates for global hydrogen demand in 2050

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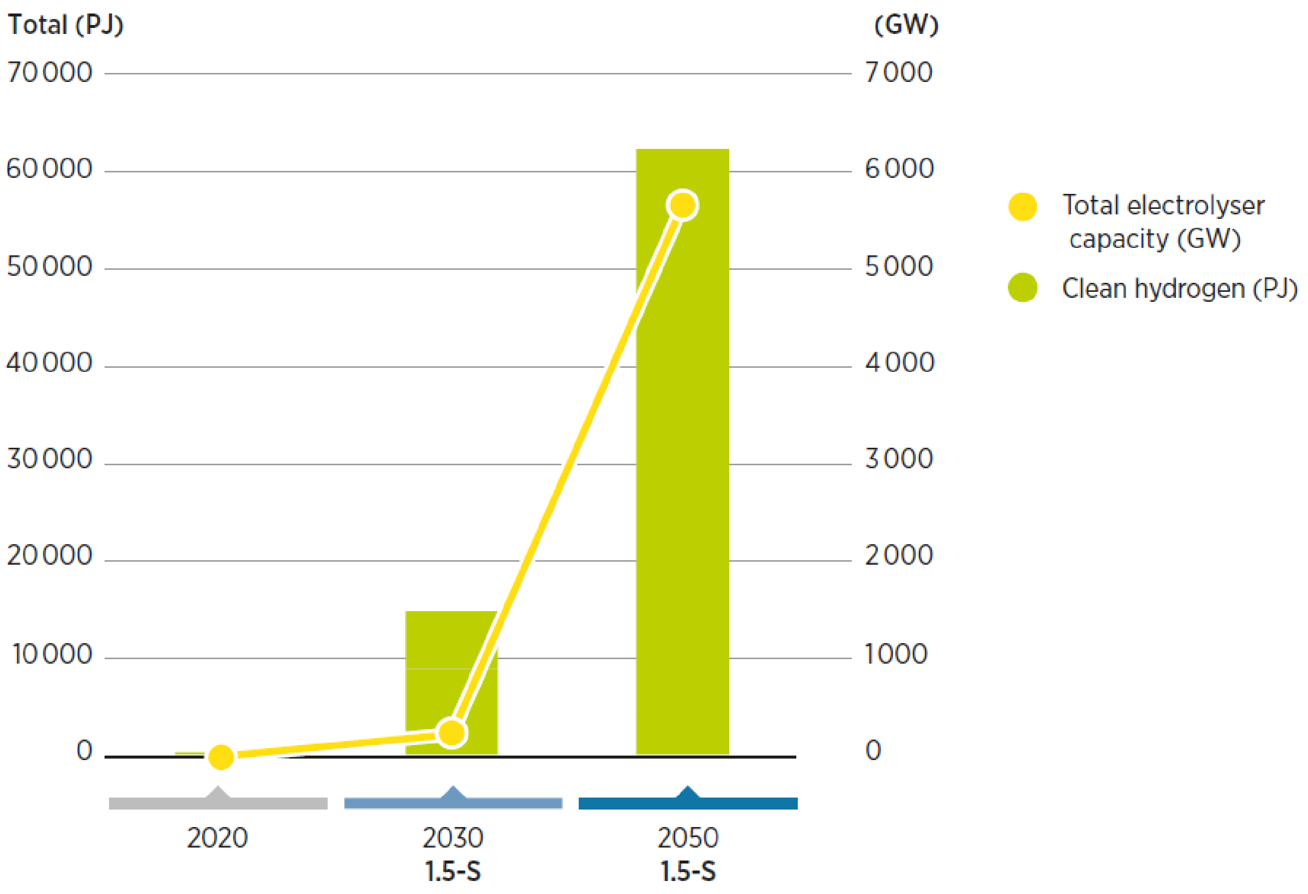
FIGURE 2.5 **Global clean hydrogen supply in 2020, 2030 and 2050 in the 1.5°C Scenario**



Notes: 1.5-S = 1.5°C Scenario; GW = gigawatt; PJ = petajoule.

- 6x grow in H2 supply from 90 Mt/y today to **530 Mt/y in 2050** and mostly green
- 2050: **94% green** and 6% blue
- Project pipeline as of Feb 2023:
  - **279 green** projects – 229 GW
  - **5 blue** projects – 7 GW-e
  - [announcements sum up to 410 green and 23 blue projects]
  - Source: https://www.fitchsolutions.com/power/global-low-carbon-hydrogen-project-pipeline-low-risk-markets-experience-more-development-success-amid-globally-growing-pipeline-28-02-2023
- Background:
  - CCS tech commercialization & deployment rates
  - Requirements from buyers
  - Dependency of imported gas

Source: IRENA (2023), World Energy Transitions Outlook 2023: 1.5° C Pathway, Volume 1

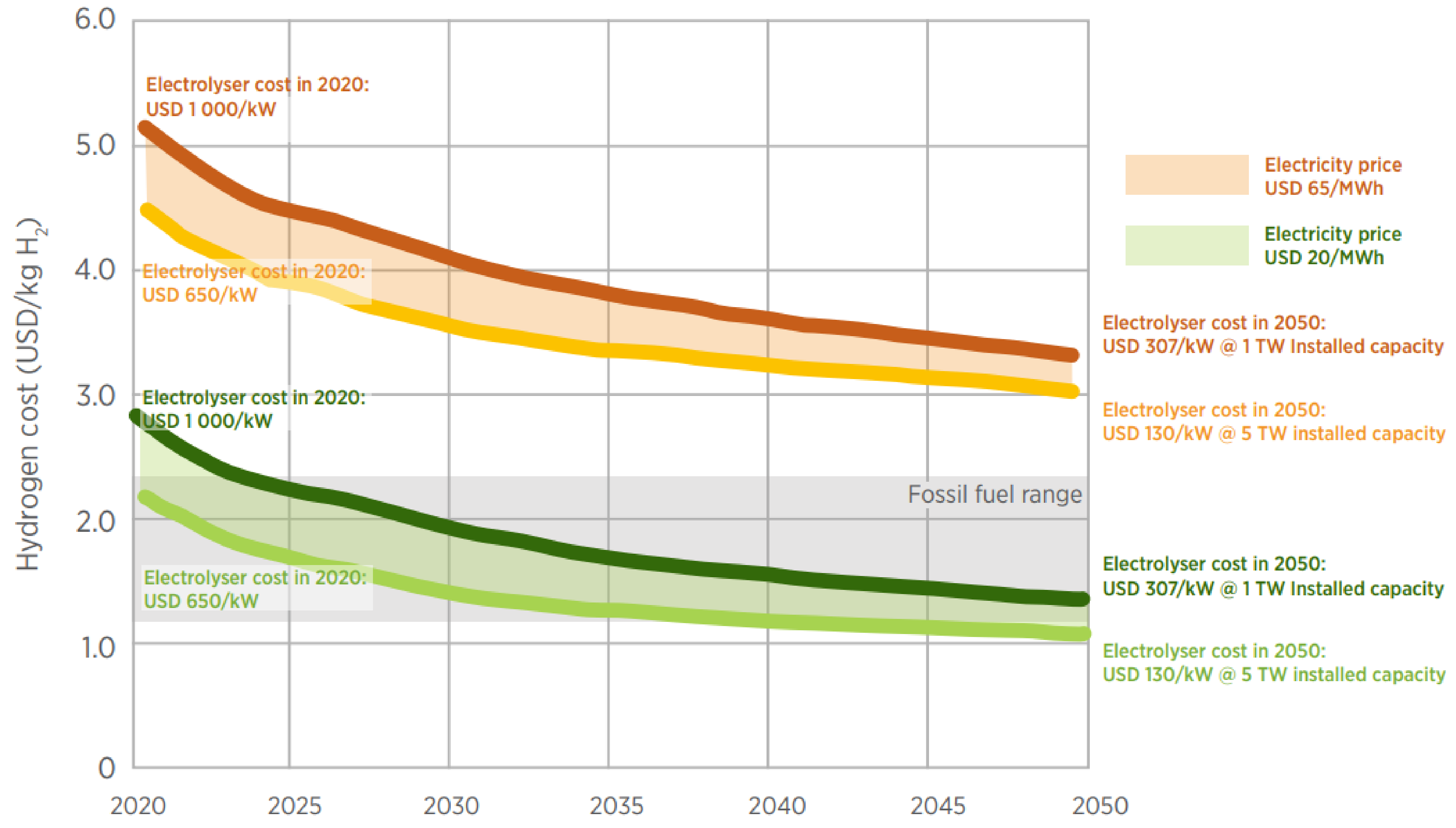
Green hydrogen costs depend on electrolyser cost and electricity cost

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

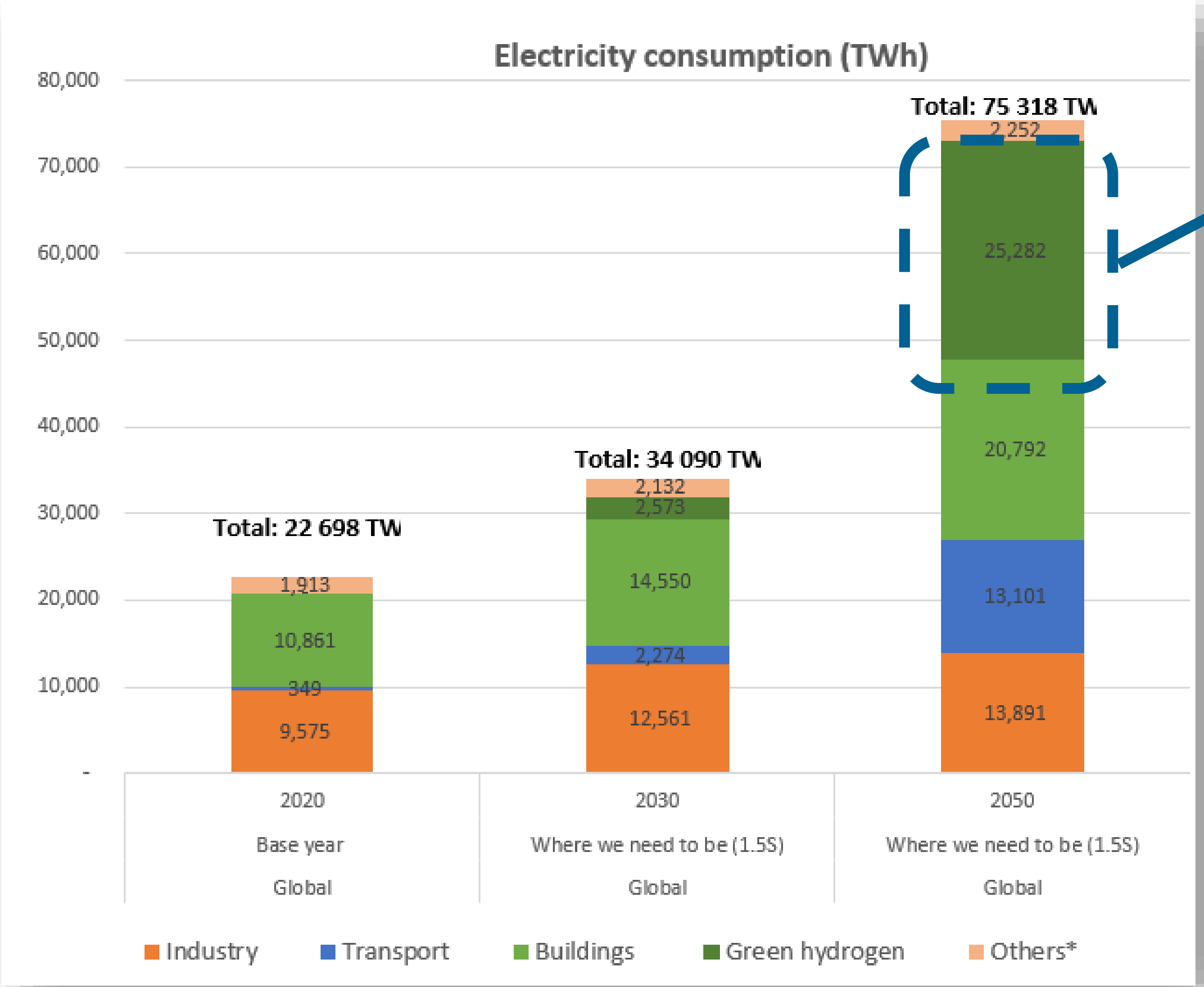
Investments

- 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



Key considerations

1- By 2050 more than 25,000 TWh of electricity demand for green hydrogen production – that is almost as much electricity as we consume globally today

2- From < 1 GW to 5,500 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: IRENA (2023), World Energy Transitions Outlook 2023: 1.5° C Pathway, Volume 1

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

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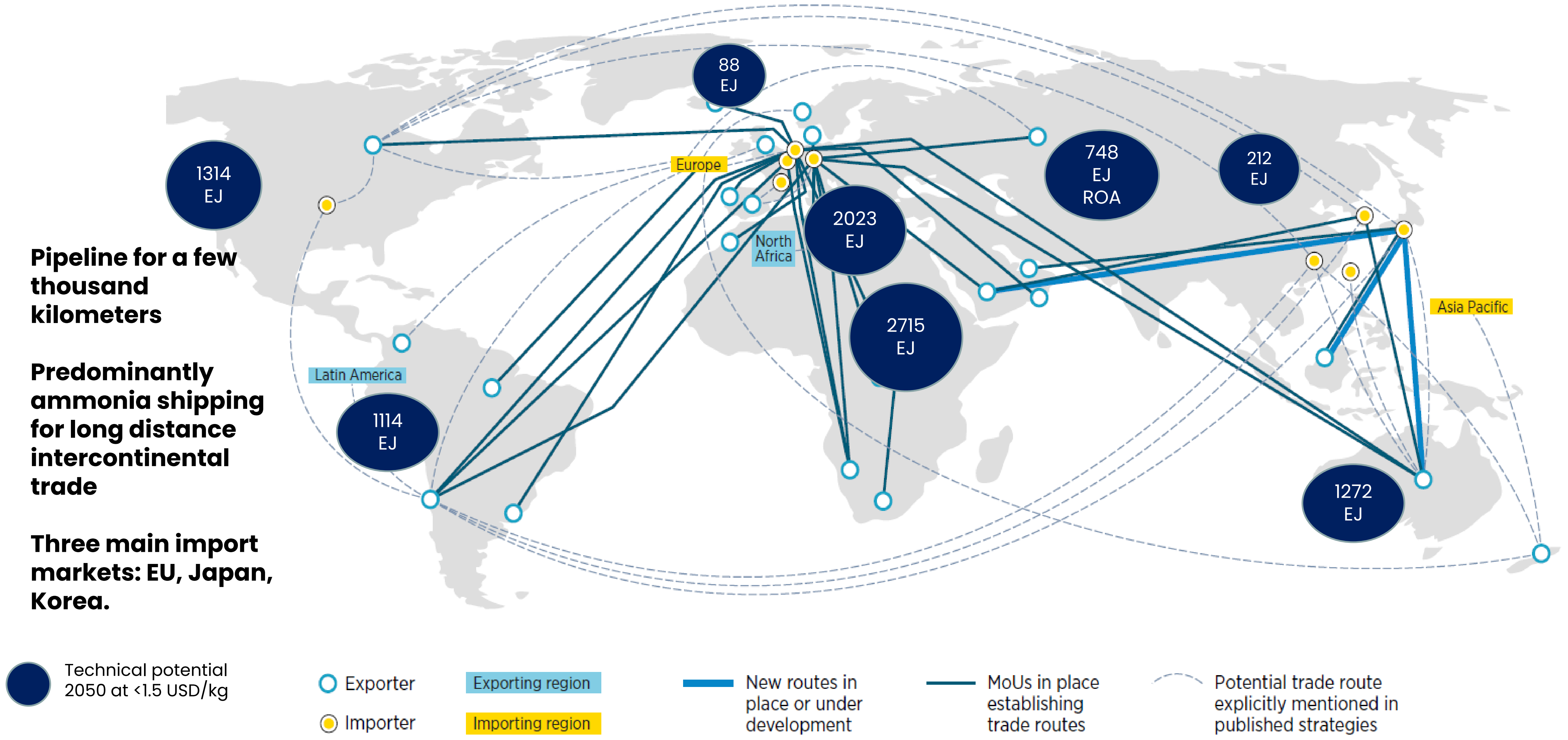

- **Pipeline for a few thousand kilometers**
- **Predominantly ammonia shipping for long distance intercontinental trade**
- **Three main import markets: EU, Japan, Korea.**

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

Hydrogen pipelines – are we ready?

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Key considerations

- Countries planning either **repurposing existing gas pipelines** or building new pipelines for blended or pure hydrogen
- **Uncertainty** on safety and durability aspects
  - Some associations say it is possible today
  - Some governmental agencies are cautious
  - Scientific community calls for **more research** in the field

La red de Portugal, lista para transportar un 10% de hidrógeno este año
REUTERS / 25 JUNIO 2023

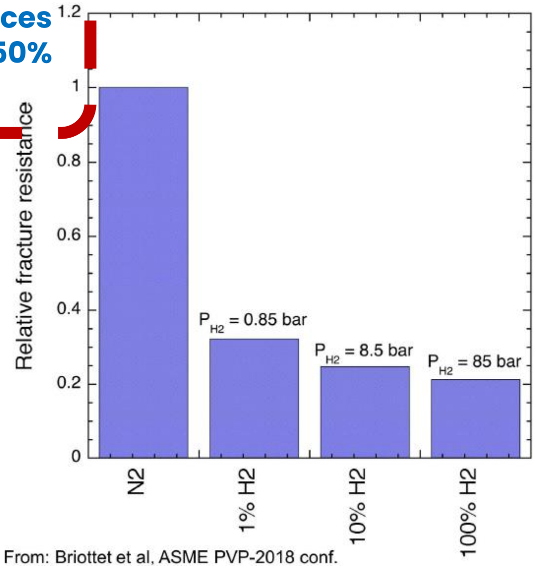
28 March, 2023
DVGW study confirms: Germany's gas pipelines are hydrogen ready

CPUC Issues Independent Study on Injecting Hydrogen Into Natural Gas Systems

- Hydrogen blends of up to 5 percent in the natural gas stream are generally safe. However, blending more hydrogen in gas pipelines overall results in a greater chance of pipeline leaks and the embrittlement of steel pipelines.

Low pressure H2 has substantial effect on fracture resistance of pipeline steels

Just 1% H2 blending reduces relative fracture resistance by 50%



From: Briottet et al, ASME PVP-2018 conf.

- **Measurements of fracture resistance in gaseous mixtures of H2 and N2 show substantial effects of H2**
- **1% H2 is only modestly different than 100% H2**

<1 bar of H2 reduces fracture resistance

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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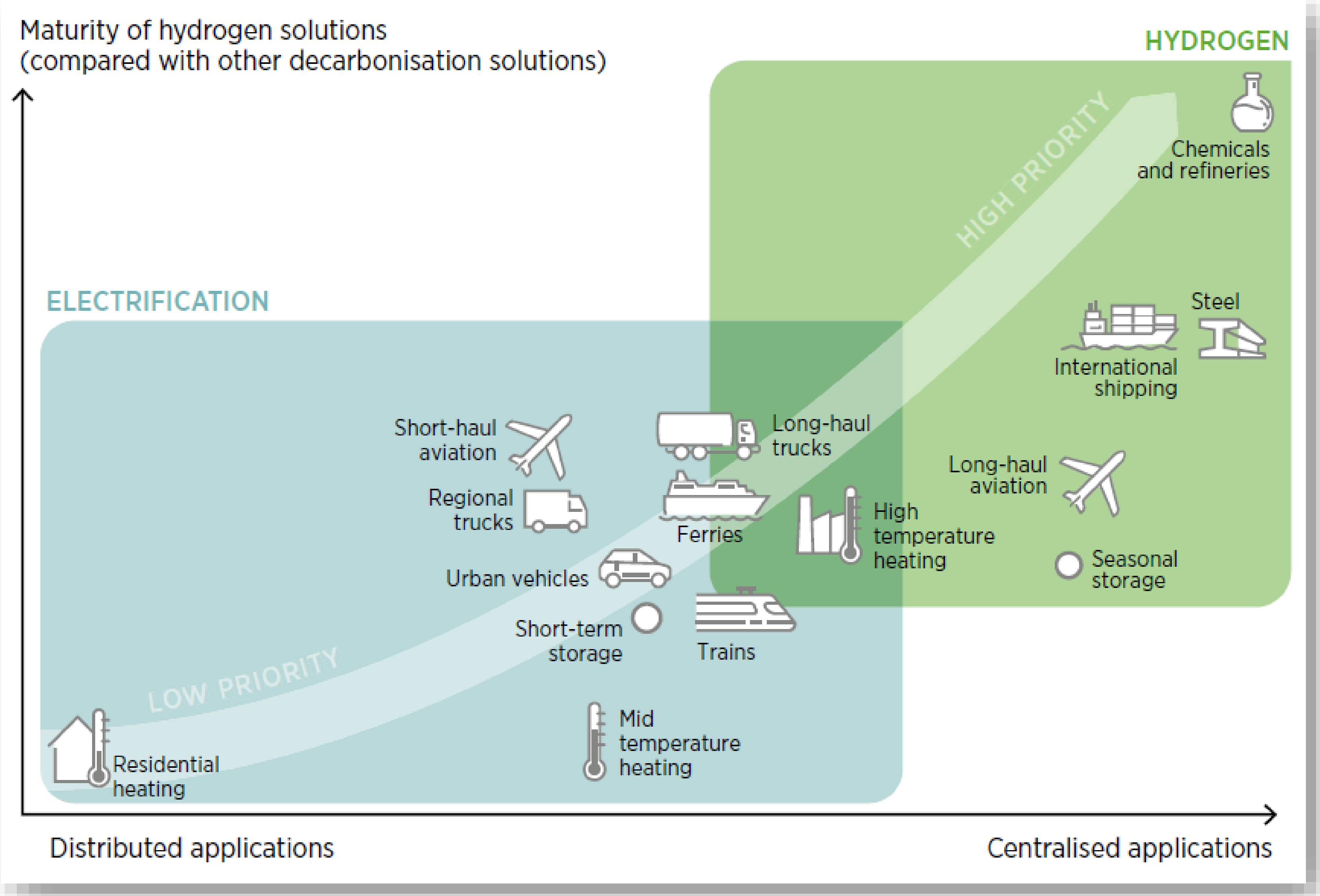
- H2 to be used in sectors where direct electrification is challenging **– Chemicals, Iron & Steel, Shipping and Aviation-**

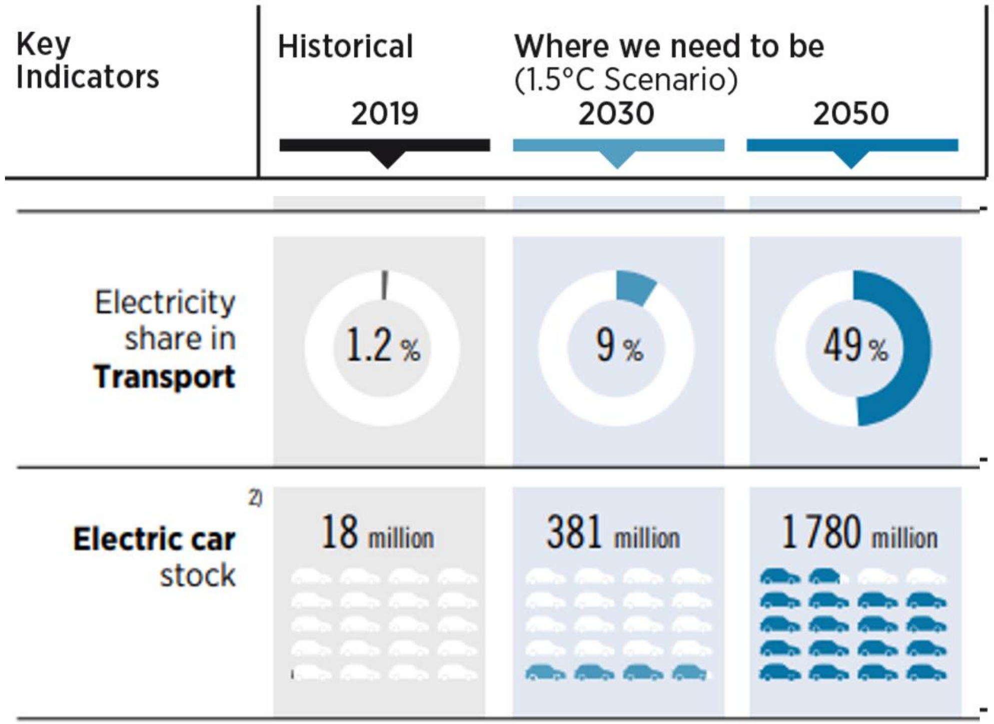
- **Not a major role** in sectors that can be directly electrified including **road transport (BEV)** and **residential/commercial heating (HPs)**



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

Road transport

Passenger cars



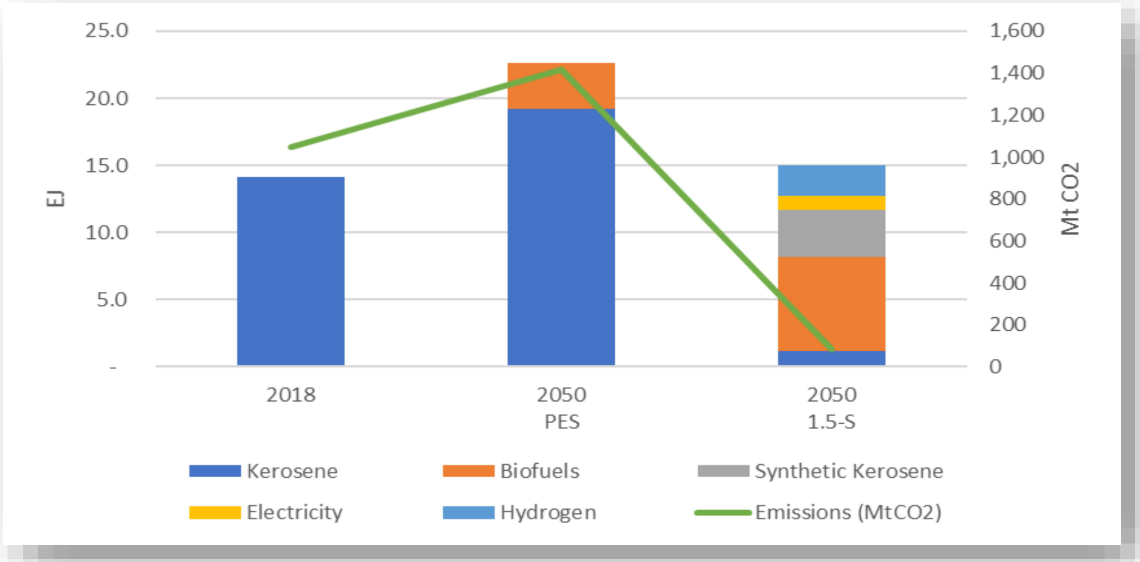
- BEV sales in order of **13 million BEVs/y in 2022**
- FCEV total stock **0.06 million FCEVs** in total
- FCEV need **3x more energy and 5x higher TCO**
- Innovative battery chemistry and end-of-life methods

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 enable electric trucks and buses** (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 more costly to operate**
- NL 1,600 requests for Dutch zero-emission truck subsidies were for battery-electric models, **none for FCEV**

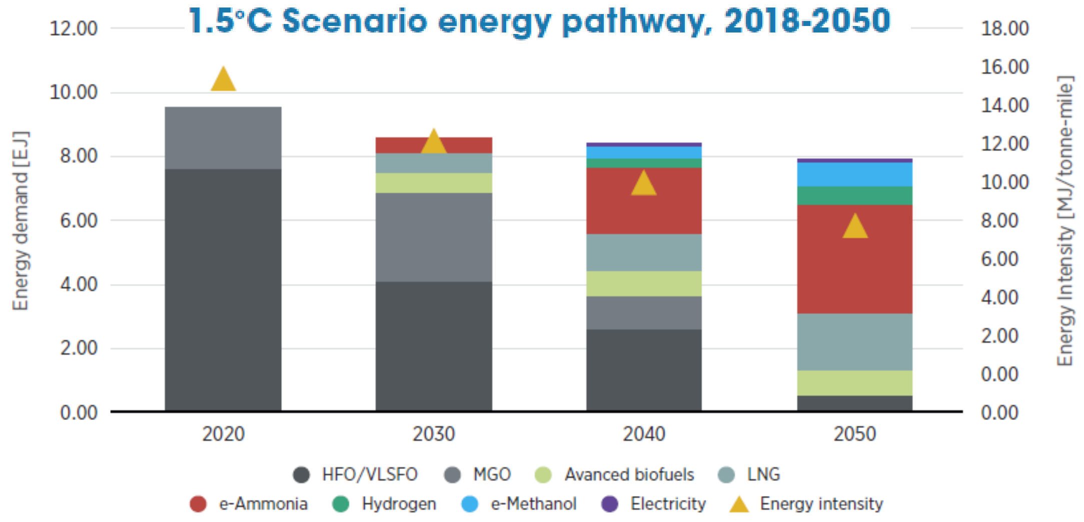
Other transportation modes

Aviation



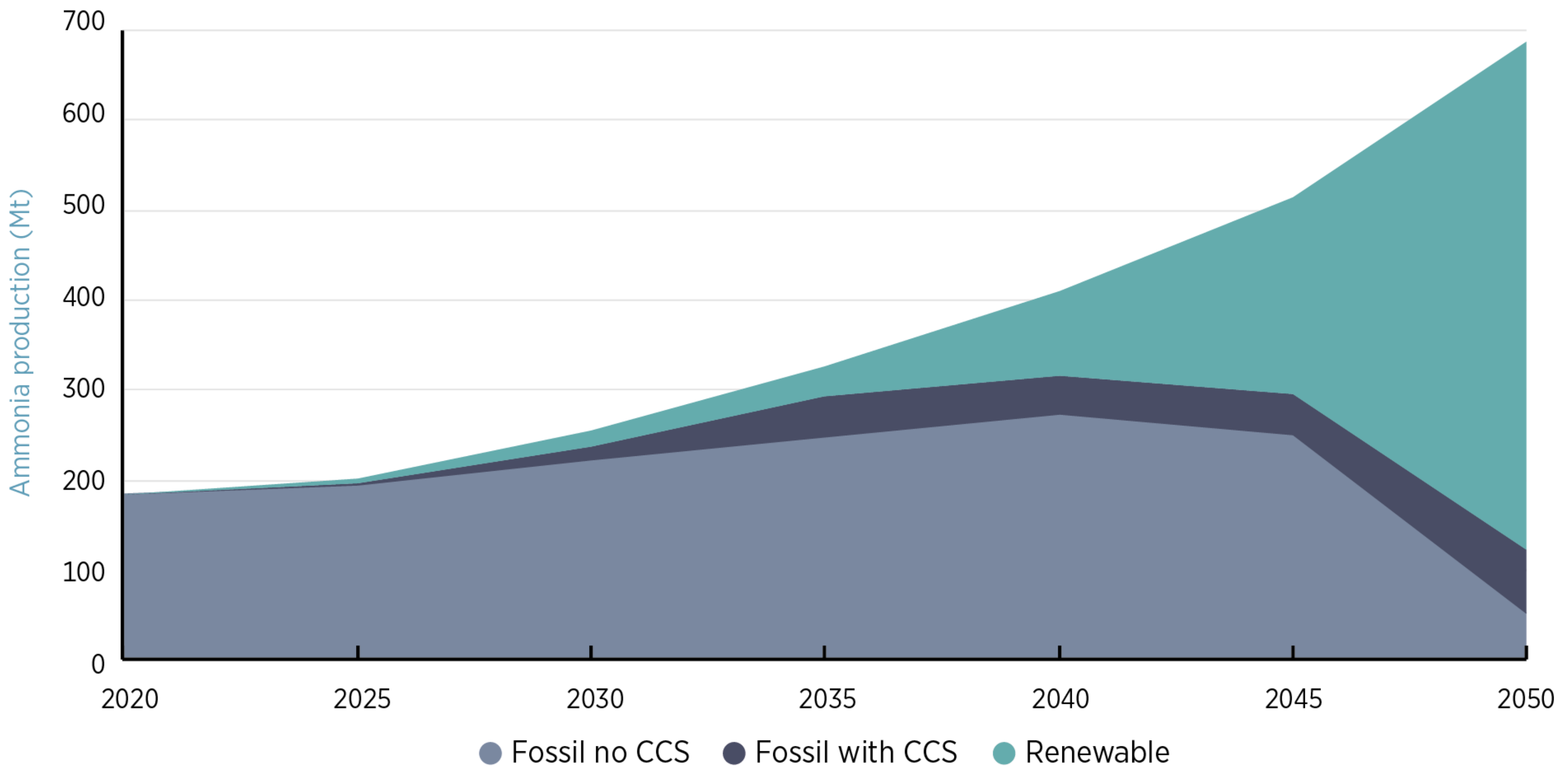
- 304 billion litres of Sustainable Aviation Fuel (SAF) by 2050 – **204 bn litres biojet and 100 bn litres e-kerosene**
- **Hydrogen and electric aircraft for short-haul flights** (22% of energy demand)
- Country example: **Colombia** demand ~ 1 Mt jet fuel/y -> **0.3 Mt h2/y** ->3 GW electrolysers ->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

Shipping



- By **2050**, shipping will require a total of **46 million tonnes of green hydrogen** for e-fuels production.
- 70% would be needed for the production of **e-ammonia**, 20% for **e-methanol** and; 10% liquid hydrogen.
- Opportunity for **H2 hubs in Port** (Barranquilla, Buenaventura, Cartagena)

Chemicals – ammonia as an example

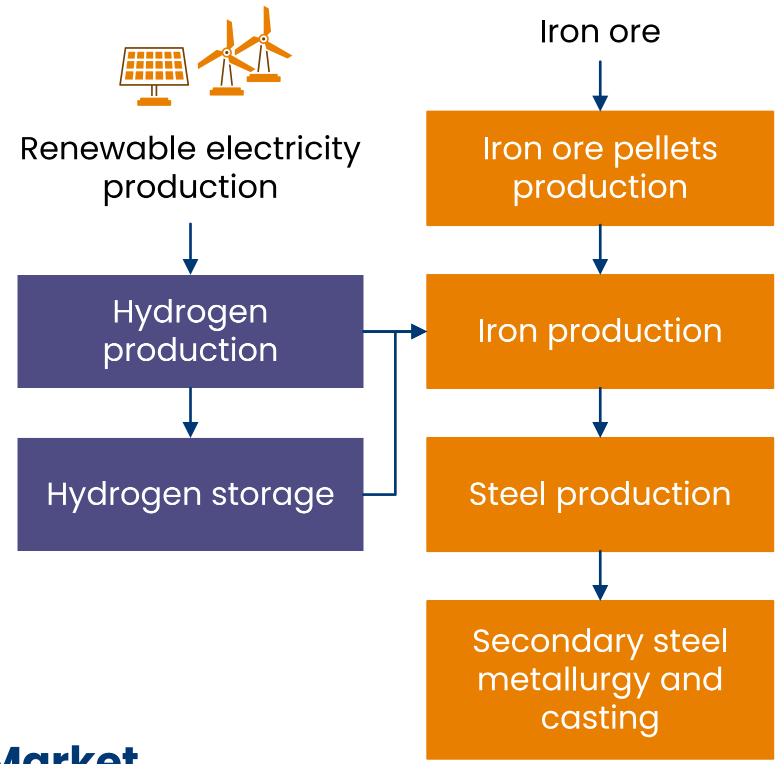


- **Ammonia** spot price from 300 to **>1000 USD/t in 2022**
- **Green ammonia** today 750 – 1200 and **2050 300 – 600 USD/t**
- Fertilizers is a key market linked to **food security:** https://fertighy.com/
- **Colombia**: demand ~ **2 Mt/y fertilisers** -> ammonia based would need ~**400kt h2/y** ->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

Source: https://www.irena.org/publications/2022/May/Innovation-Outlook-Renewable-Ammonia

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 and growing 2% per year – assume all is coming from DRI that would be ~ 100 Mt GH2/year
- Commodity: **HBI** from GH2 reduction
- **Colombia** produces ~ 1.3 Mt/y: from DRI 50 kt H2 / Mt steel -> **65kt H2/y** -> 650 MW electrolisers -> **1.4 GW RE**

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 – 4 kg CO2e/Kg H2
- USA H2 roadmap: **2 kg CO2e/Kg H2**
- H2 market to become a **oligopsony**: what is the **aim of regional certifications?**

Joint study with

RMI

Source: https://www.irena.org/Publications/2023/Jan/Creating-a-global-hydrogen-market-Certification-to-enable-trade

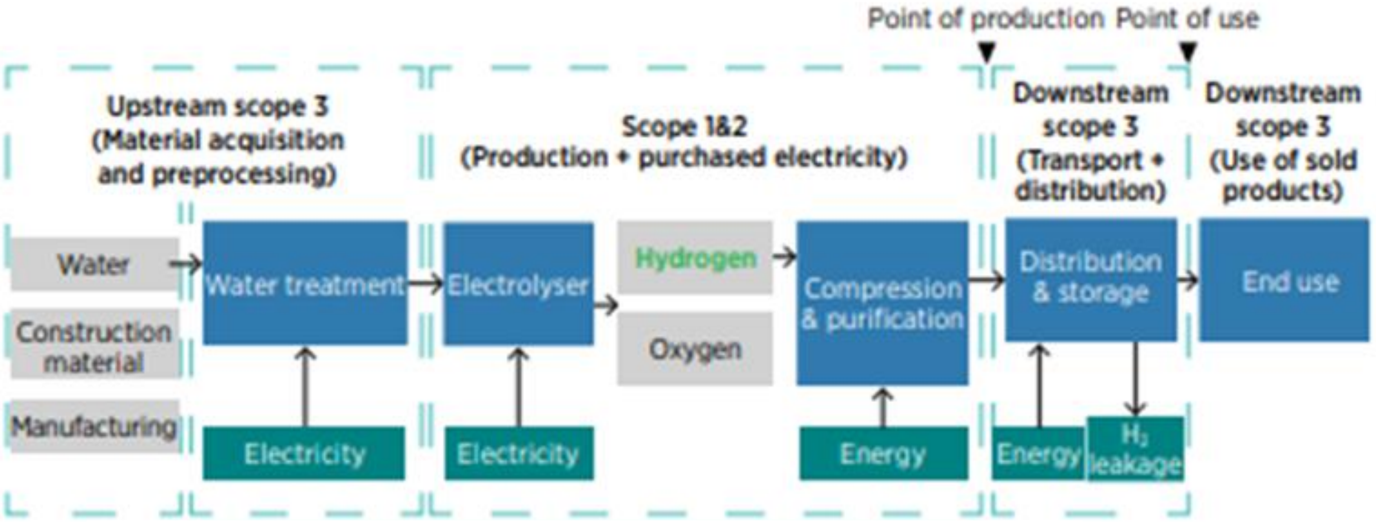
Methodology for accounting carbon emissions from H2 value chain – (ISO based on IPHE)

ISO/WD 19870:2023

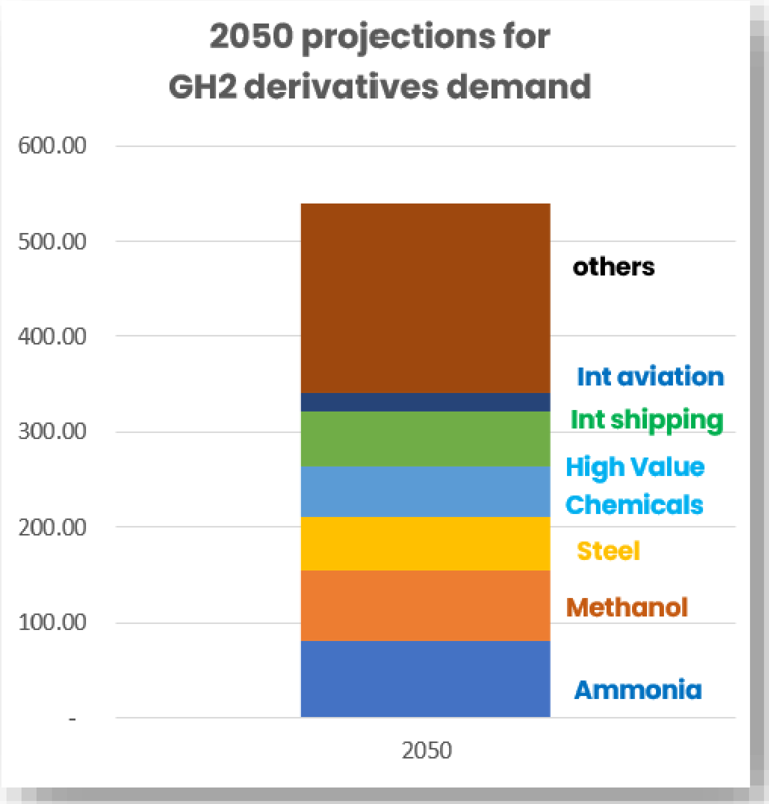
ISO TC 197/SC 1/WG 1

Date: 2023-05-08

Methodology for determining the greenhouse gas emissions associated with the production, conditioning and transport of hydrogen to consumption Gate



Take aways



Demand by 2050 in a 1.5 oC scenario up to (MT GH2):

- **Ammonia – 80**
- **Methanol – 75**
- **Steel – 55**
- **HVC – 52**
- **Shipping – 55**
- **Aviation – 18**

RE electricity expansion is crucial

Infrastructure deepens on type of commodity / product to be produced, consumed and traded. For synthetic HCs -> inventory of potential biogenic C sources

Size of export market?

Start by local markets – based on country capacity and priorities

International collaboration is key

Thank You

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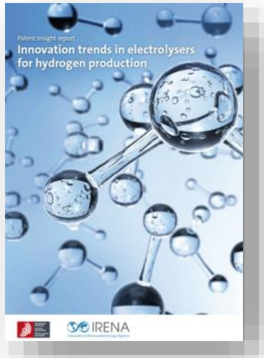
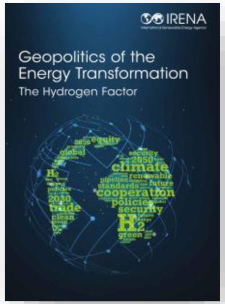
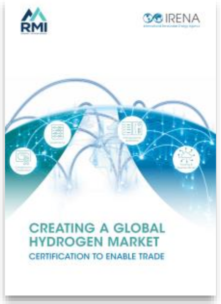
Supply

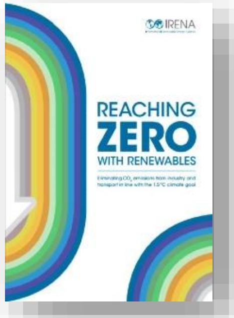


Trade





Demand



Sector coupling