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El papel de la electrificación –directa e indirecta- en la transición energética

Francisco Boshell
Head of Innovation and End-Use Applications
IRENA

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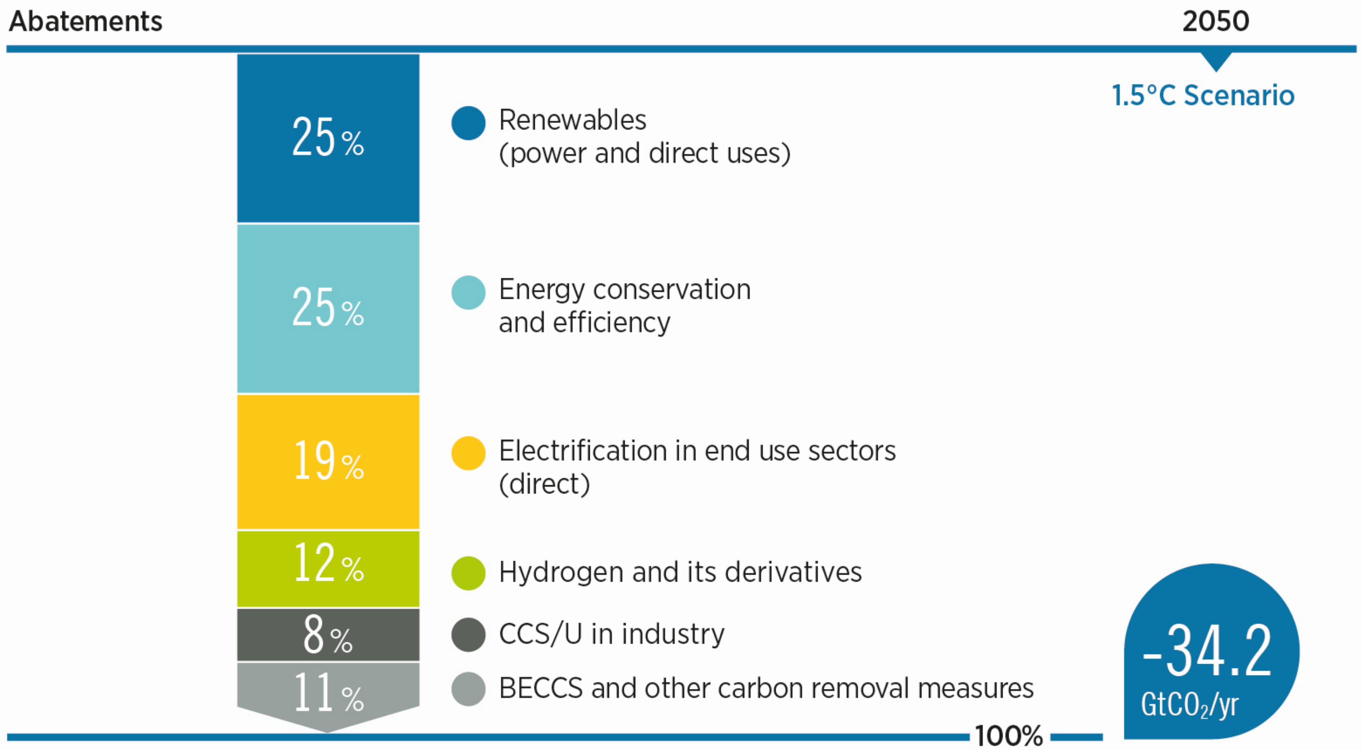
Renewables, efficiency and electrification would dominate decarbonisation

FIGURE 1.5 Carbon dioxide emissions abatement under the 1.5°C Scenario in 2050



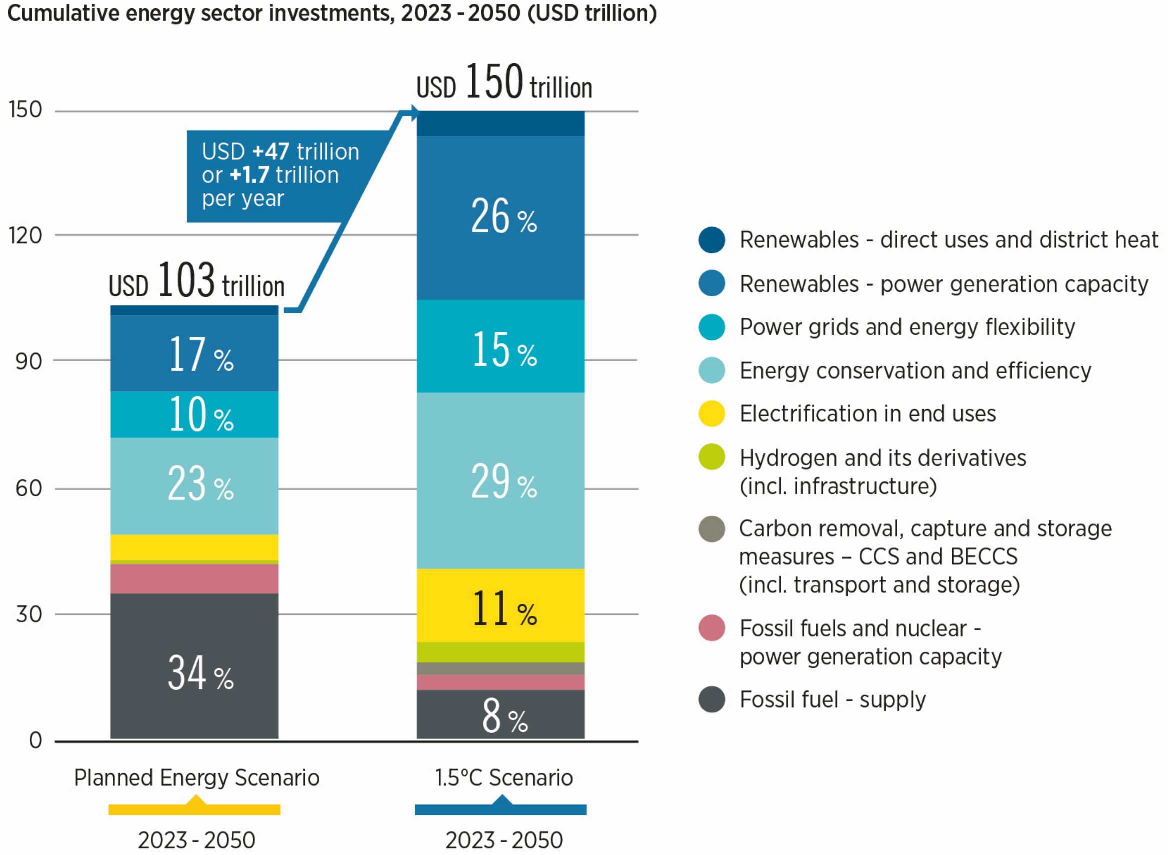
- Renewable + Energy Efficiency are the key for a a global **decarbonisation** of the energy system in 2050

Notes: BECCS = bioenergy with carbon capture and storage; CCS/U = carbon capture and storage/utilisation; GtCO2/yr = gigatonne of carbon dioxide per year.

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

Investment priorities: renewables, efficiency and electrification

FIGURE 3.1 **Global investment by technological avenue: Planned Energy Scenario and 1.5°C Scenario, 2023-2050**



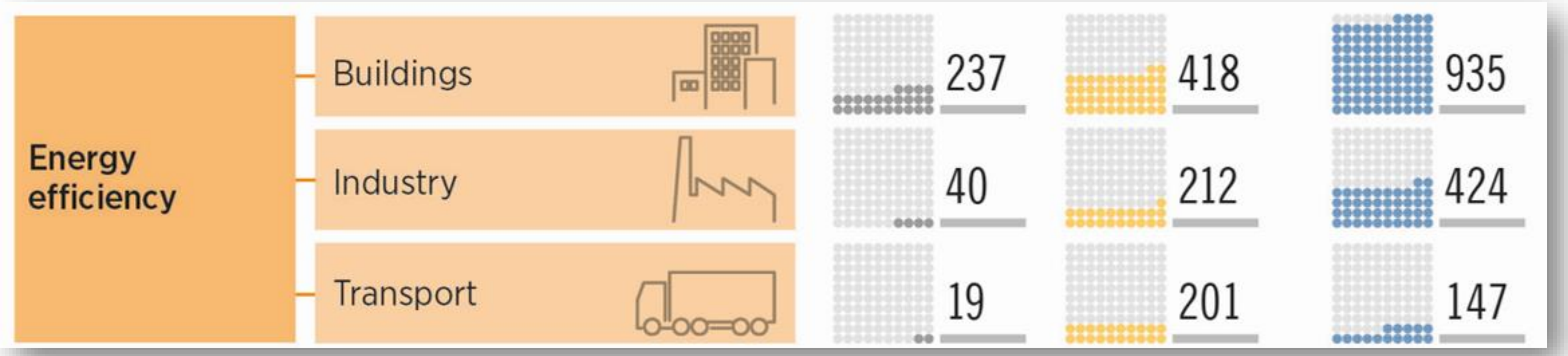
- A combination of **scale-up** and **reallocation** of investment in **energy transition technologies** with supporting **infrastructures** and **efficiency measures** is needed for achieving 1.5°C target (**USD 1.7 trillion/yr more in average**)

Notes: BECCS = bioenergy, carbon capture and storage; CCS = carbon capture and storage.

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

Energy efficiency investment needs to be scaled up significantly in the coming decades

Investments in EE per sector in billion USD



- Energy **efficiency** accounts for the largest share of the **building** sector investments, reaching **77%** followed by investment in **heat pumps (17%).**
- Investments in the **industry** sector are focused on energy **efficiency** and **conservation** measures.

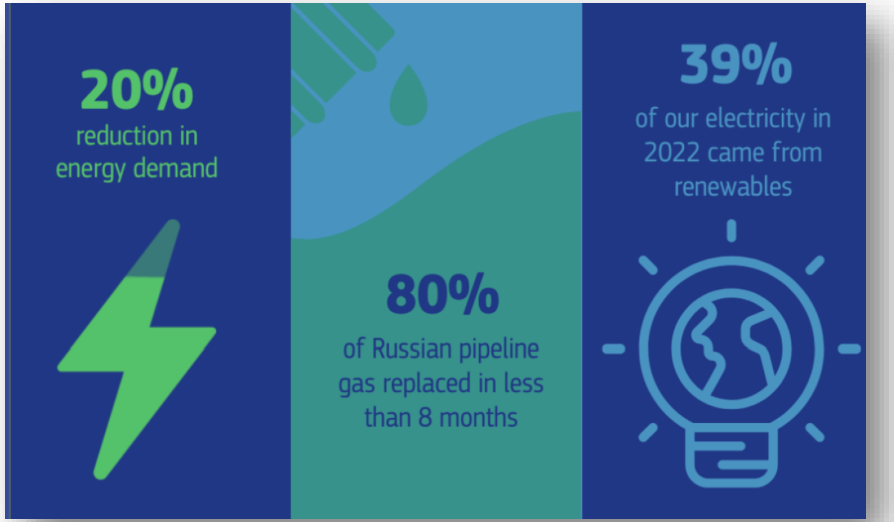
Source: IRENA (2023), World Energy Transitions Outlook 2023: 1.5°C Pathway, Volume 1

EU case – efficiency in gas demand for security reasons

Confronted by soaring energy costs after Russia invaded Ukraine last year, the 27-member bloc agreed last July to reduce gas usage between August 2022 and March 2023 by 15%.

The actual reduction figures have exceeded the "voluntary" target, thanks to mild weather and high prices that forced households and businesses to limit energy usage.

According to the EU statistics agency Eurostat, gas consumption in the EU fell by 19.3% between August and January, compared to the same period between 2017 and 2022.

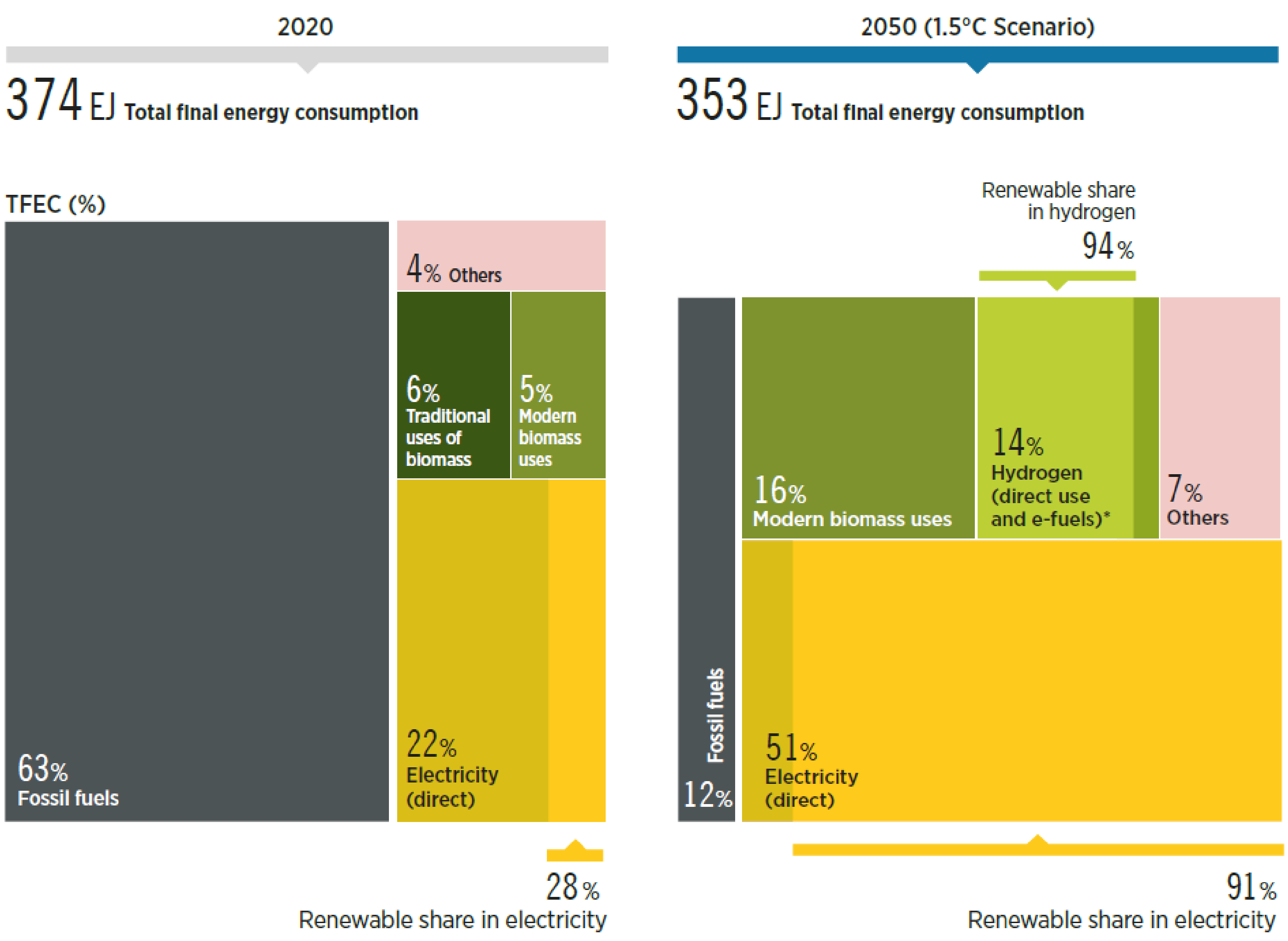


Source" European Commission

Future global energy mix in a Paris Agreement aligned scenario

- 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

Innovation landscape for smart electrification

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- **The toolbox includes 100 innovations**

ELECTRIFICATION	2020	2030	2050	progress
Share of direct electricity in final energy consumption	22% [19]	29 %	51 %	
Passenger electric cars on the road	10.5 million [20]	360 million	2 180 million	
Investments needs for charging infrastructure of EV's and EV adoption support	30 USD billion/yr [21]	137 USD billion/yr	364 USD billion/yr	
Investment needs for heat pumps	64 USD billion/yr [22]	237 USD billion/yr	230 USD billion/yr	

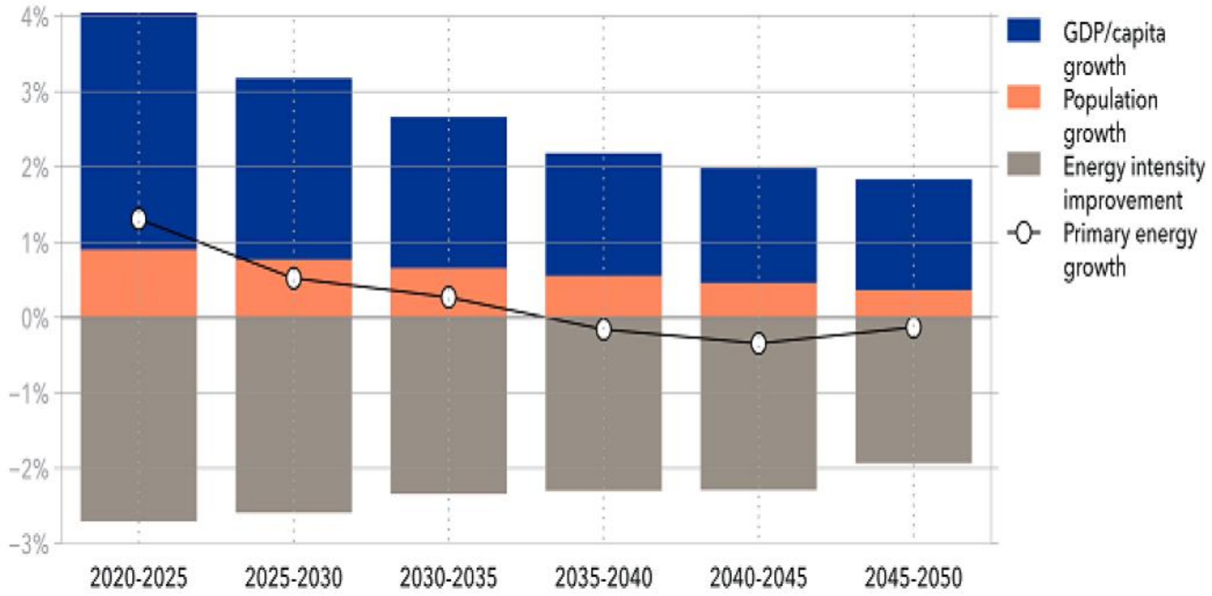
Source: IRENA (2023), Innovation Landscape for Smart Electrification

Efficiency gains due to renewable electrification

FIGURE 18

World energy intensity and annual reduction rate

Units: Percentages/yr



Rapid electrification powered by renewables is the core driver of accelerating energy efficiency in the next three decades. The typical thermal efficiency for utility-scale electrical generators is some 30 to 40% for coal and oil-fired plants, and up to 60% for combined-cycle gas-fired plants. In comparison, solar PV and wind generation are 100% efficient, and conversion losses as a percentage of input energy in power generation reduce from 51% in 2019 to 19% in 2050.

Source: DNV GL

Direct electrification efficiency vs indirect electrification

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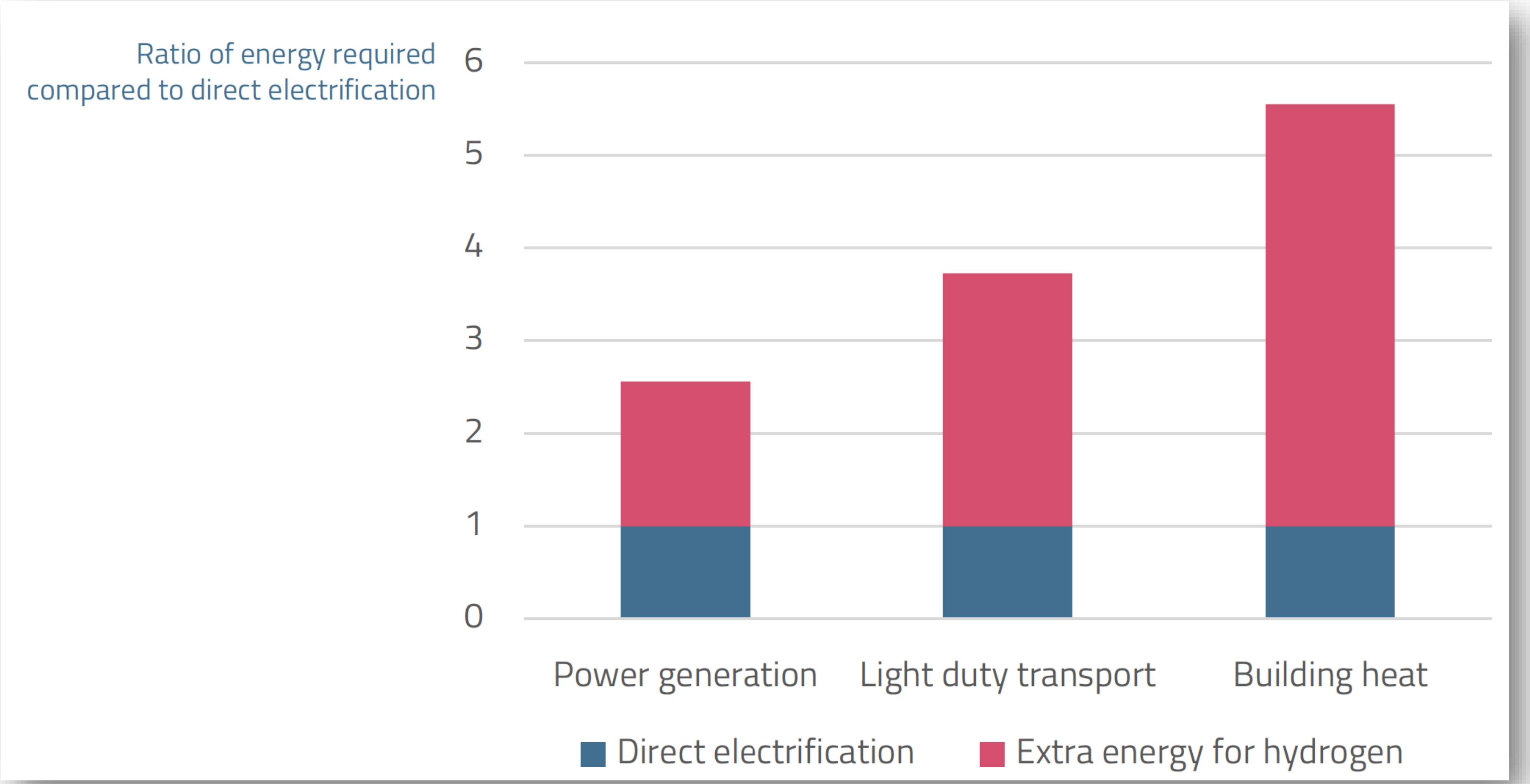
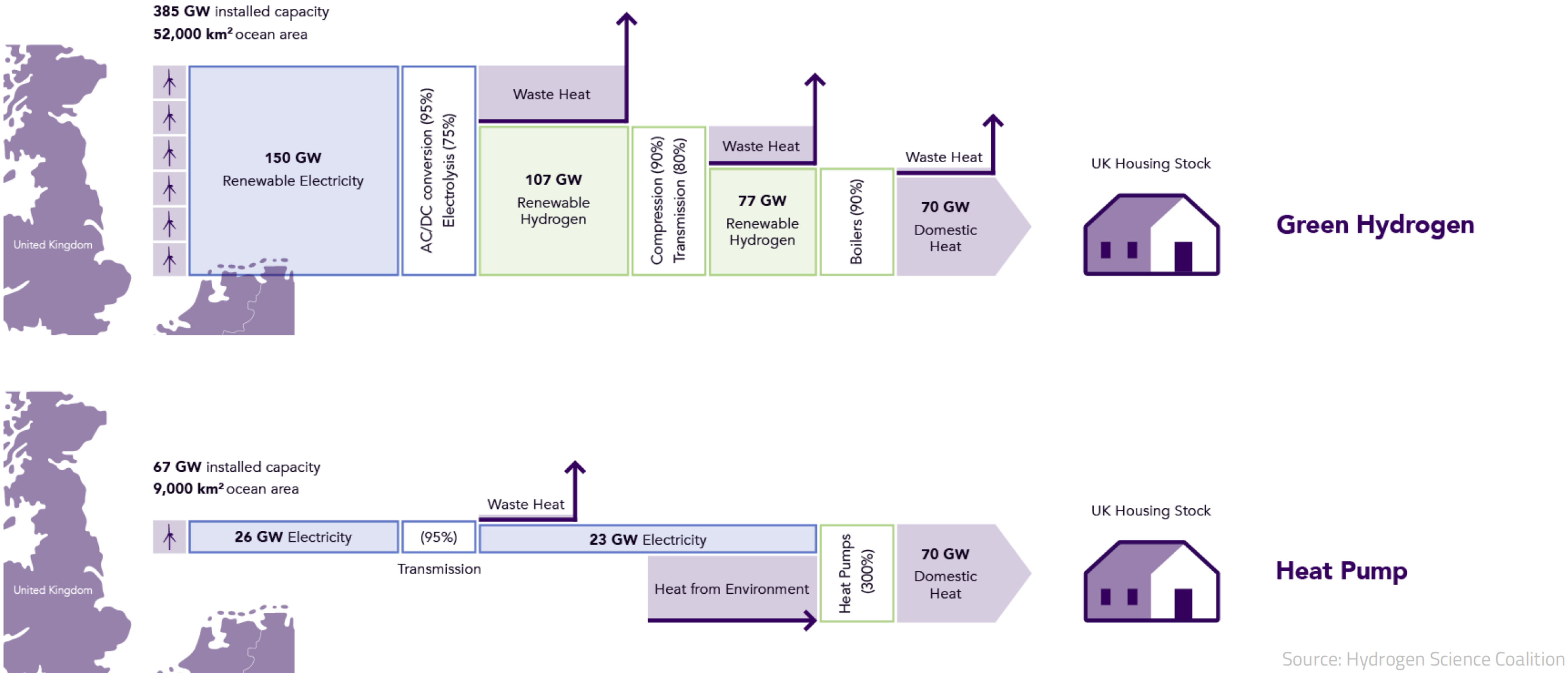


Source: Future Clean Architects based on RMI

We need to think about level of service, not fuel



Source: FCA

Estimates for global hydrogen demand in 2050

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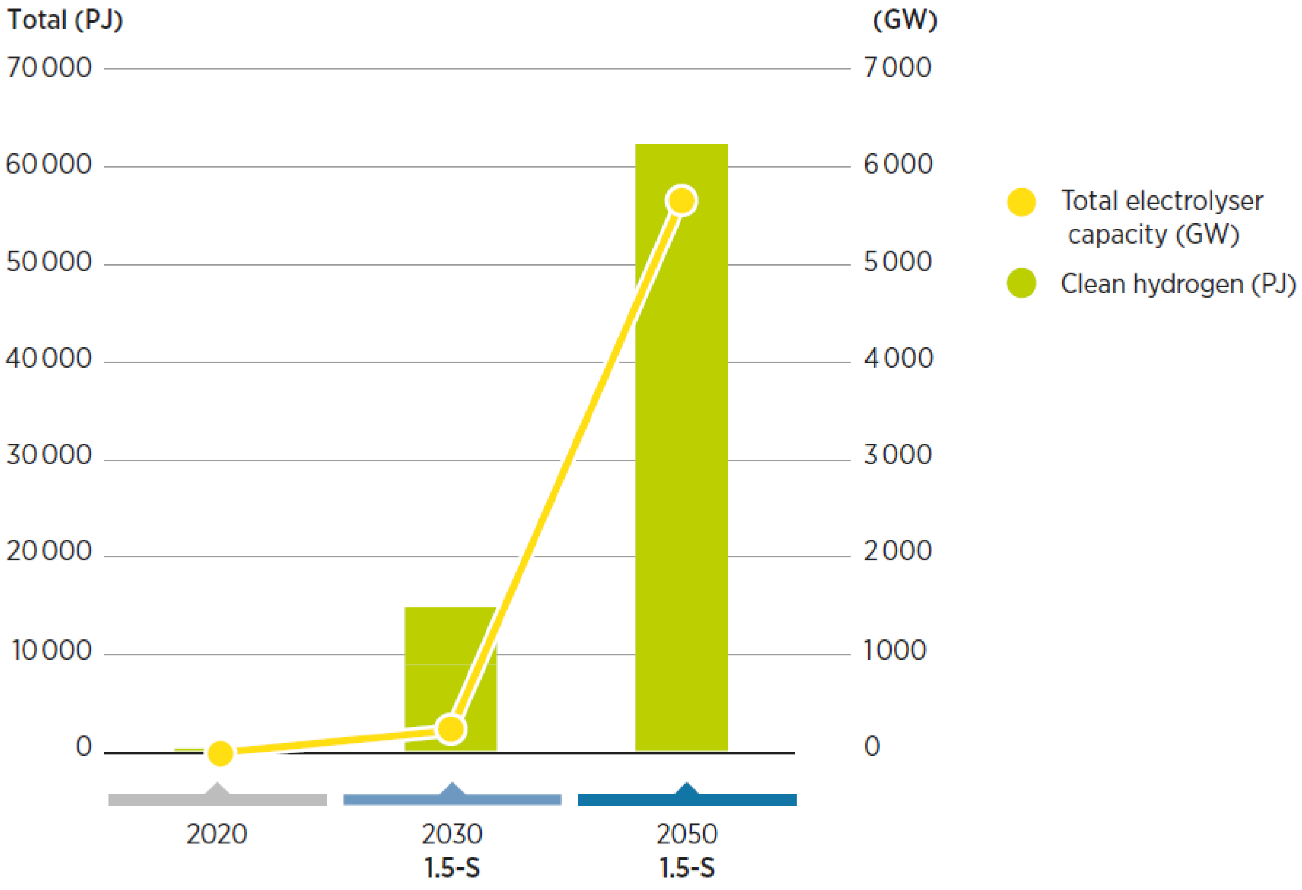
FIGURE 2.5 **Global clean hydrogen supply in 2020, 2030 and 2050 in the 1.5°C Scenario**



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

- Hydrogen is a **energy carrier** not an energy source
- 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

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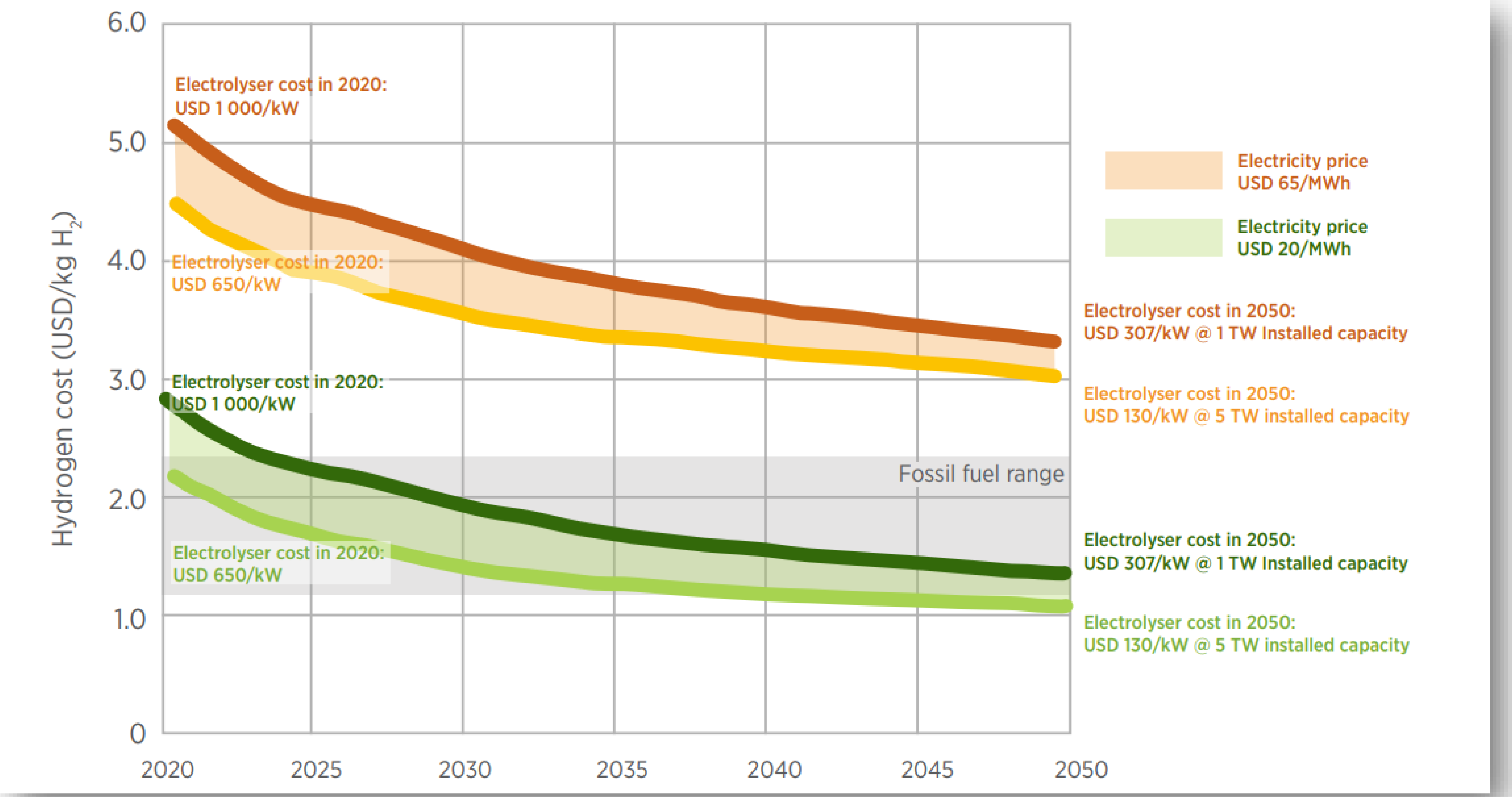
Costs

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

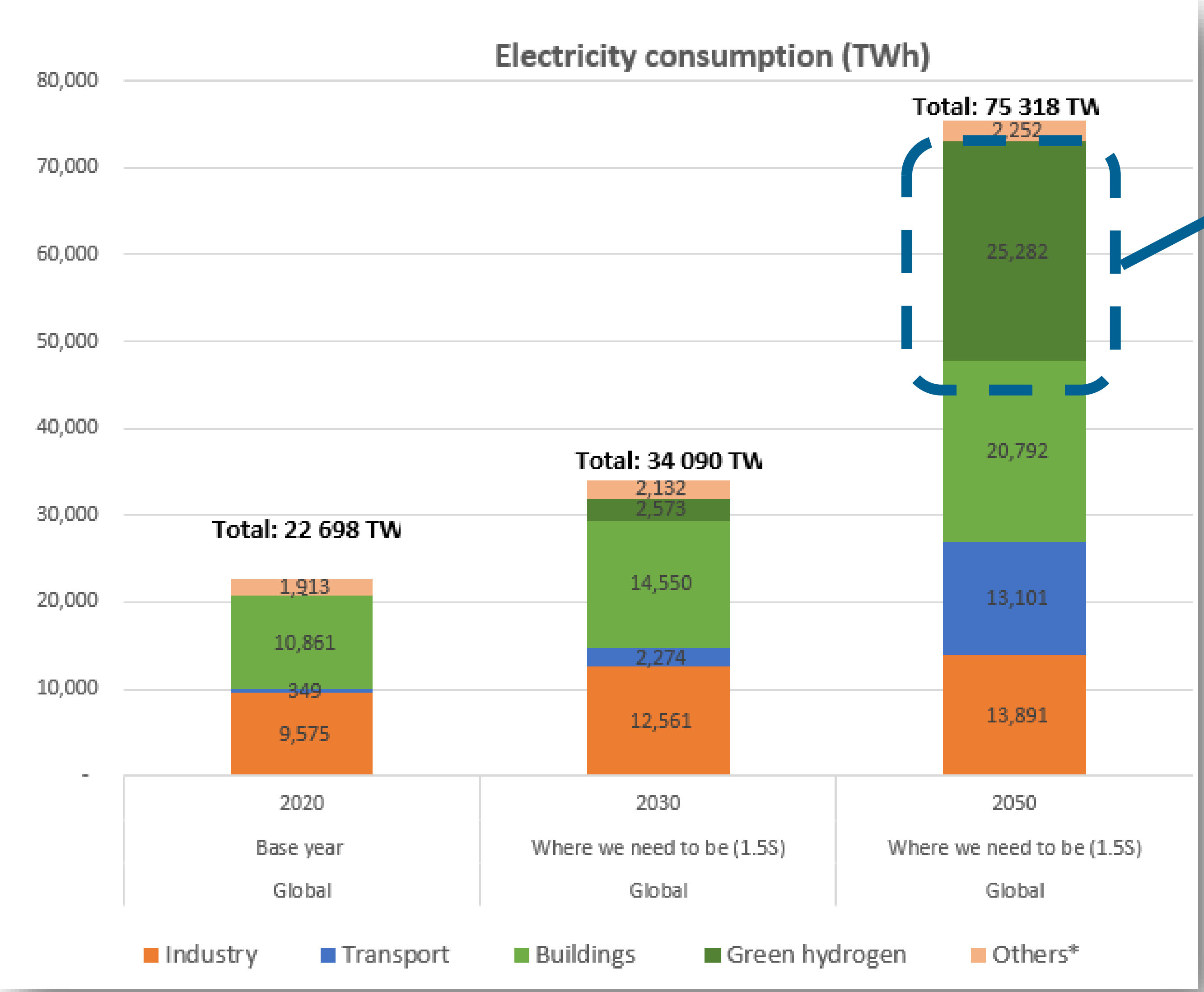
Investments

- 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

Innovation drivers for green hydrogen trade – Different market than oil markets

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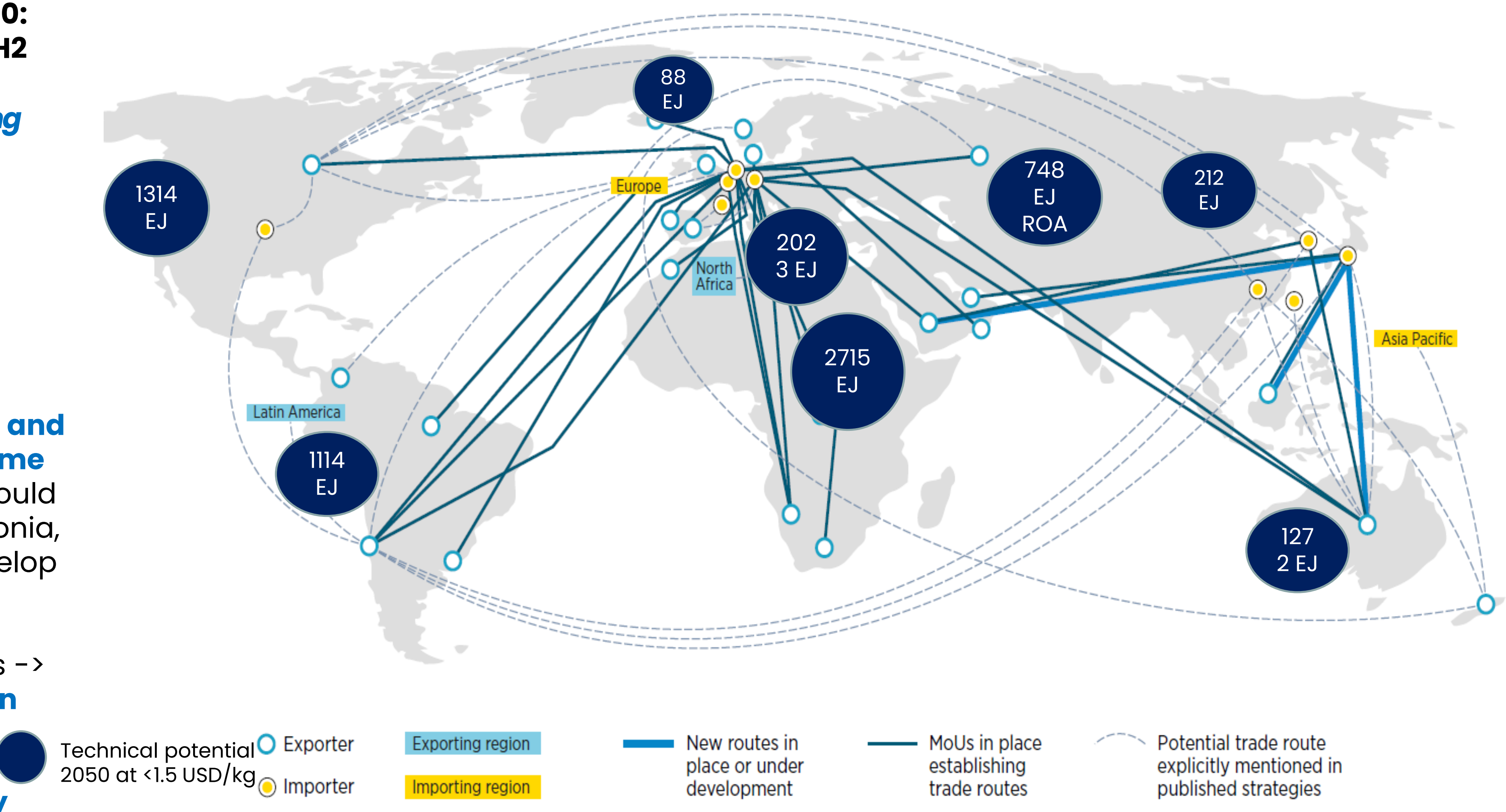
Future hydrogen trade 2050:
1/4 internationally traded H2

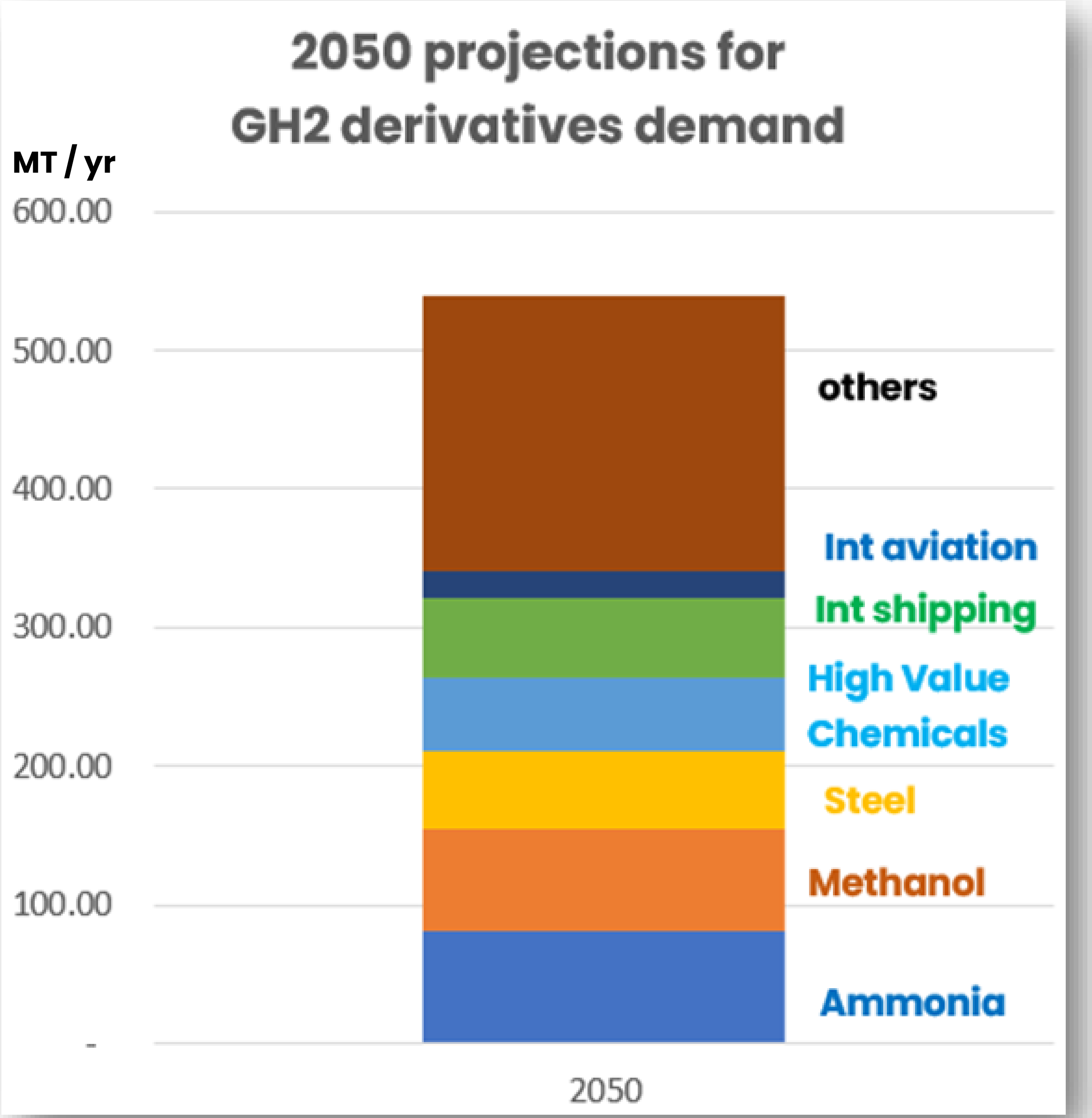
Key considerations triggering innovation

- 70 MT via pipelines -> **Enhanced standards to ensure safety and performance**
- 60 MT via ships -> **Infrastructure planning and development for maritime transportation.** What would be the H2 carrier (ammonia, methanol, LOHC) to develop the infrastructure
- A few importing markets -> Harmonisation of **carbon certification balancing market growth and environmental integrity**



Source: IRENA (2022), Global hydrogen trade to meet the 1.5°C climate goal: Part II – Technology review of hydrogen carriers

Innovation drivers for green hydrogen demand



Green hydrogen 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)**

Key considerations triggering innovation

- Pull demand for PtX -> **procurement instruments**
- Synthetic fuels -> **source of sustainable carbon**
- Variety of commodity to be traded **-> infrastructure implications**

Road transport

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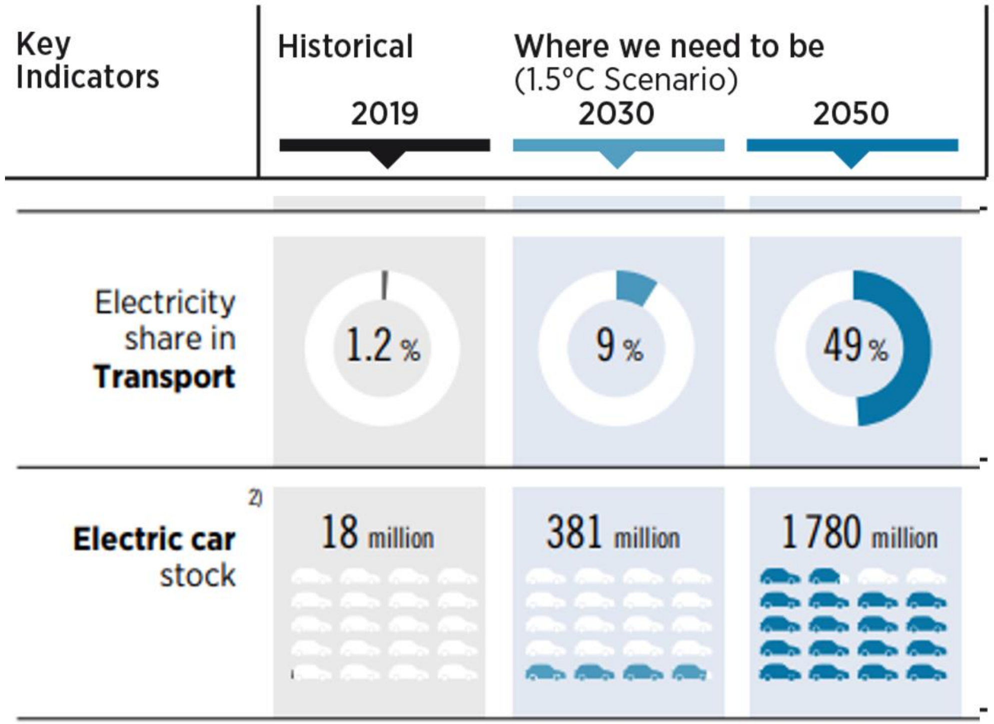
Passenger cars



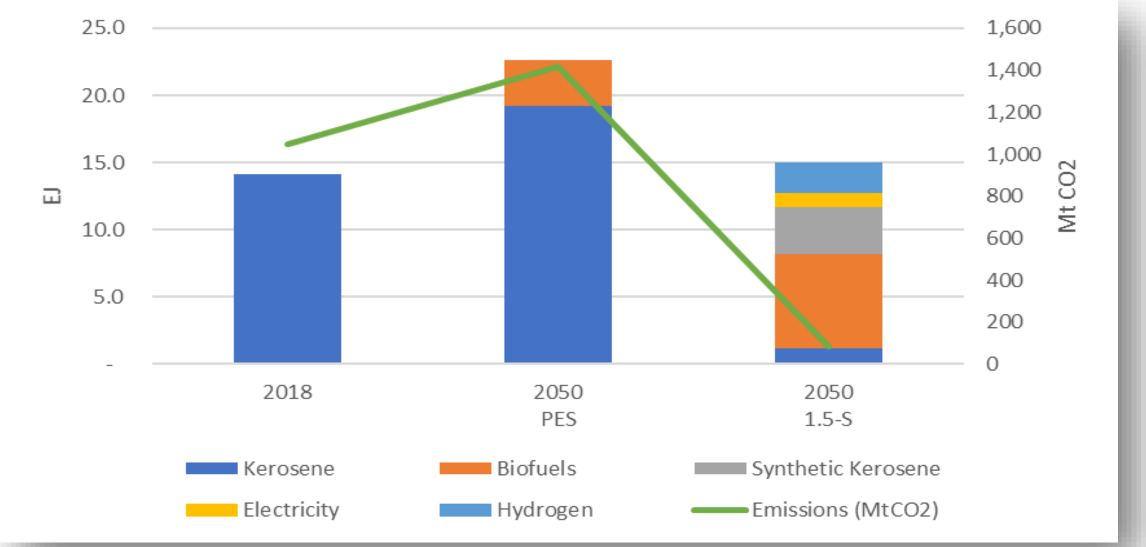
- BEV sales in order of **13 million BEVs/y in 2022**
- FCEV total stock **0.06 million FCEVs** in total
- FCEV need **3x more energy and 5x higher TCO**
- Innovative battery chemistry and end-of-life methods

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**

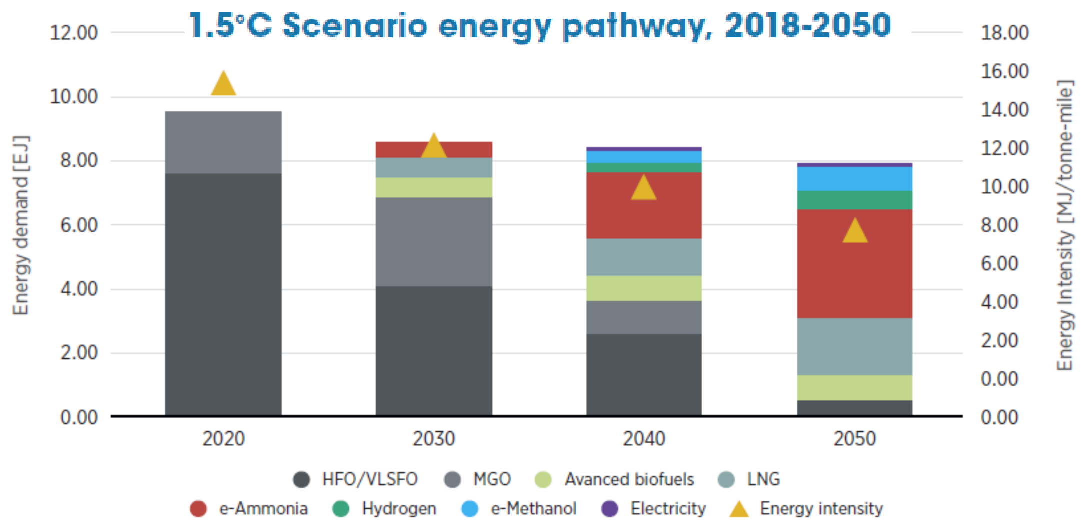
Other transportation modes

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

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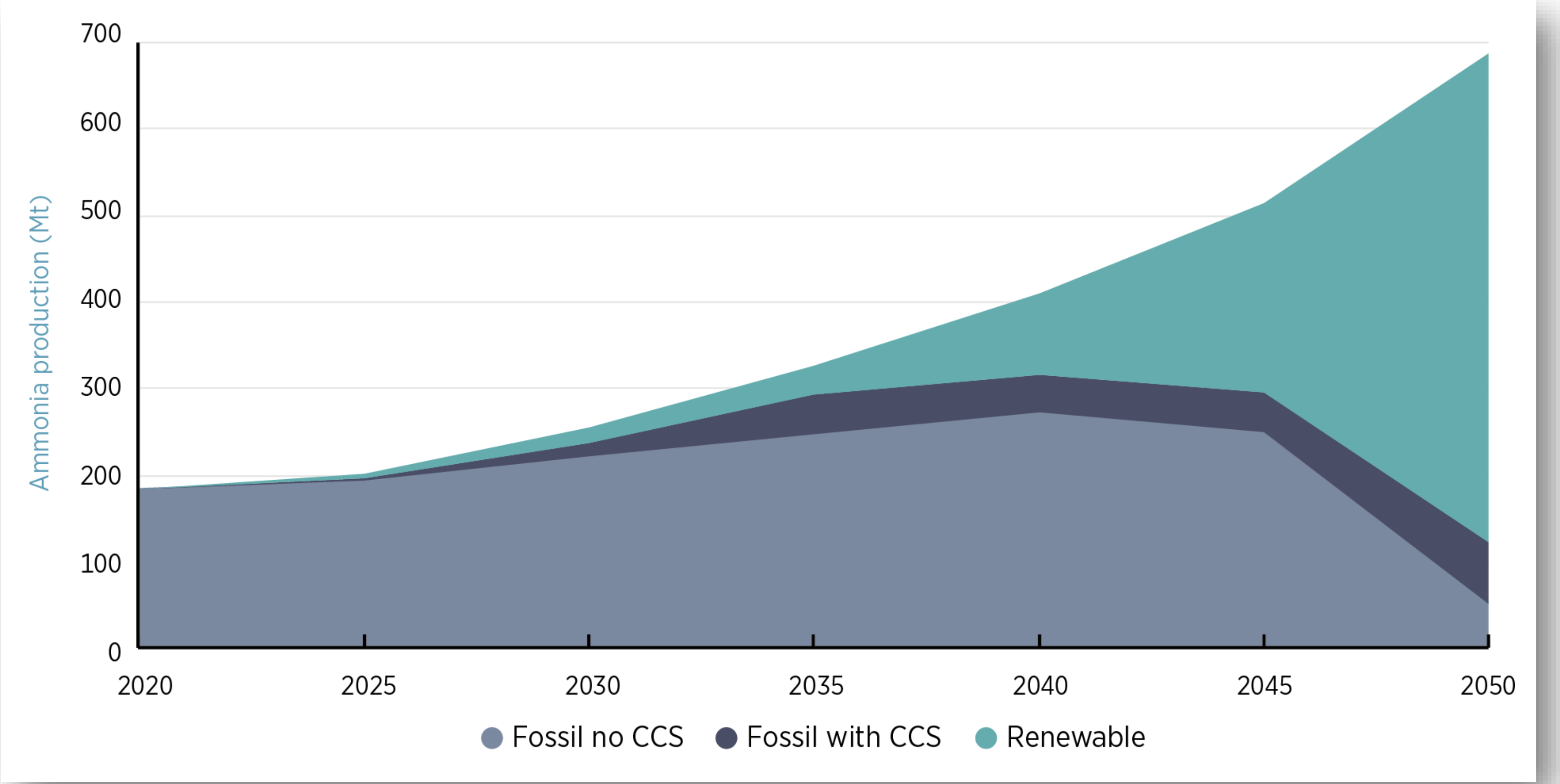
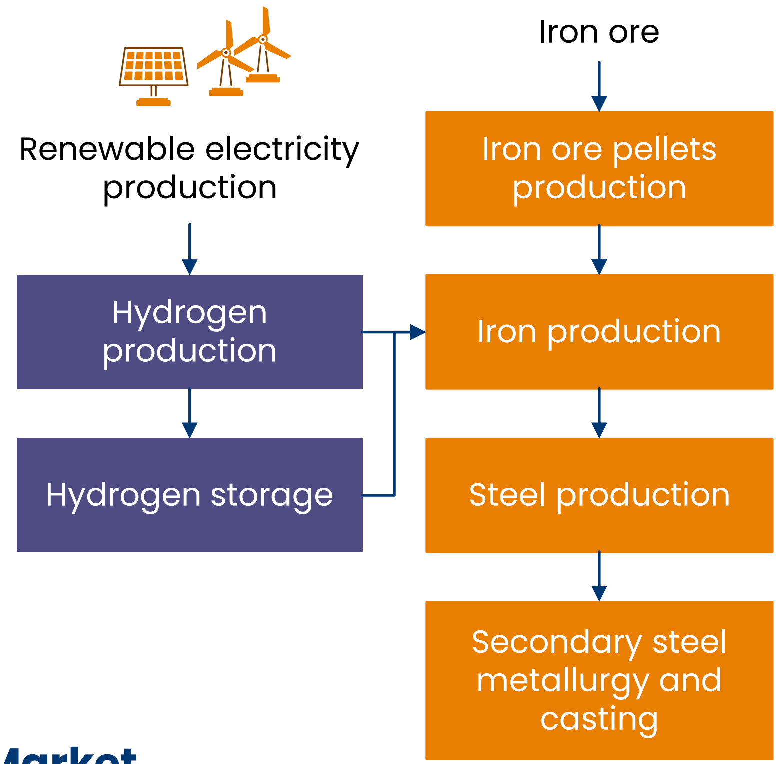


- **Ammonia** spot price from 300 to **>1000 USD/t in 2022**
- **Green ammonia** today 750 – 1200 and **2050 300 – 600 USD/t**
- Fertilizers is a key market linked to **food security:** https://fertighy.com/
- **Colombia**: demand ~ **2 Mt/y fertilisers** -> ammonia based would need ~**400kt h2/y** -> 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

Three potential markets at the moment – EU (largest 10 MT by 2030), Japan (2 MT) and Korea (2 MT)

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EU focus is on GREEN (not multi-color) H2 – Requirements:

1. ***What evidence would be required to demonstrate that hydrogen qualifies as renewable?***

Reply: The RED does not include a definition of renewable hydrogen. Instead, the RED includes a definition of renewable fuels of non-biological origin (RFNBO), which covers hydrogen produced via electrolysis from renewable electricity as well as its derivatives. The term renewable hydrogen is often used as a simplification for hydrogen that qualifies as a RFNBO under the RED [4]. To count as an RFNBO, hydrogen is required to 1) fulfil the definition of an RFNBO as set out in Article 2(36) of RED, 2) comply with the rules set out in Article 27(3) of the RED for the sourcing of renewable electricity 3) achieve 70% emissions savings and (4) be traced through the supply chain in line with the rules set out in Article 30(1) and (2) RED. In this context the hydrogen delegated acts, adopted pursuant to Articles 27(3) and 28(5) of RED set out detailed rules for sourcing of renewable electricity that is used for the production of RFNBOs and for determining the GHG emission intensity (GHG methodology)[5].

Source: European Commission

Want to export to EU?

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Three pillars for RE hydrogen:

1. Additionality
2. Regional deliverability
3. Hourly matching

Certification:

5. ***What means do fuel producers have to demonstrate that they comply with the criteria?***

Reply: For certification of renewable hydrogen, producers can rely on a well-established system of certification by third parties, so-called voluntary schemes[6]. These are international companies with experience of more than a decade in certifying biofuels, biomass and other products worldwide. The Commission has been empowered to recognise voluntary and national schemes for certifying renewable hydrogen. The Member States are required to accept evidence from schemes that have been recognised by the Commission.

6. ***How does the recognition process for voluntary certification schemes work?***

Reply: Voluntary schemes may submit applications for recognition to the Commission[7]. Before recognition, the schemes undergo a thorough assessment. Schemes meeting all criteria are recognised by the Commission via Commission Implementing Decisions. More details can be found on a dedicated website.

7. ***How can hydrogen producers get certified?***

Reply: Hydrogen producers have the option to either contact a voluntary scheme or to approach a national scheme set up by the EU Member States to get certified.

Source: European Commission

But likely the real market for export to EU will not be h2 molecules but h2 derivatives – and the Carbon?

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Source of carbon

29. What can be considered as biogenic CO_2 under the GHG methodology and how is it treated?

Reply: Biogenic CO_2 comprises CO_2 that stems from the production or the combustion of biofuels, bioliquids or biomass fuels. CO_2 from the treatment of biogenic wastes is also eligible. In order to be eligible to count as emissions from existing use or fate e ex-use, biogenic CO_2 must comply with the sustainability and greenhouse gas saving criteria and must not have received credits for emission savings from CO_2 capture and replacement, set out in Annex V and VI to Directive (EU) 2018/2001. Biogenic CO_2 stemming from processes which are out of the scope of the sustainability and greenhouse gas saving criteria are also eligible.

32. In the case of production of RFNBO/RCF from CO_2 of fossil origin, is there a limitation for use of this carbon source, besides not being possible to consider savings under $e_{ex\text{-}use}$?

Reply: No, it is not forbidden to use fossil-based CO_2, but it would make it more challenging to achieve the 70% threshold. Additionally, fossil CO_2 is only allowed until 2040.

Source: European Commission

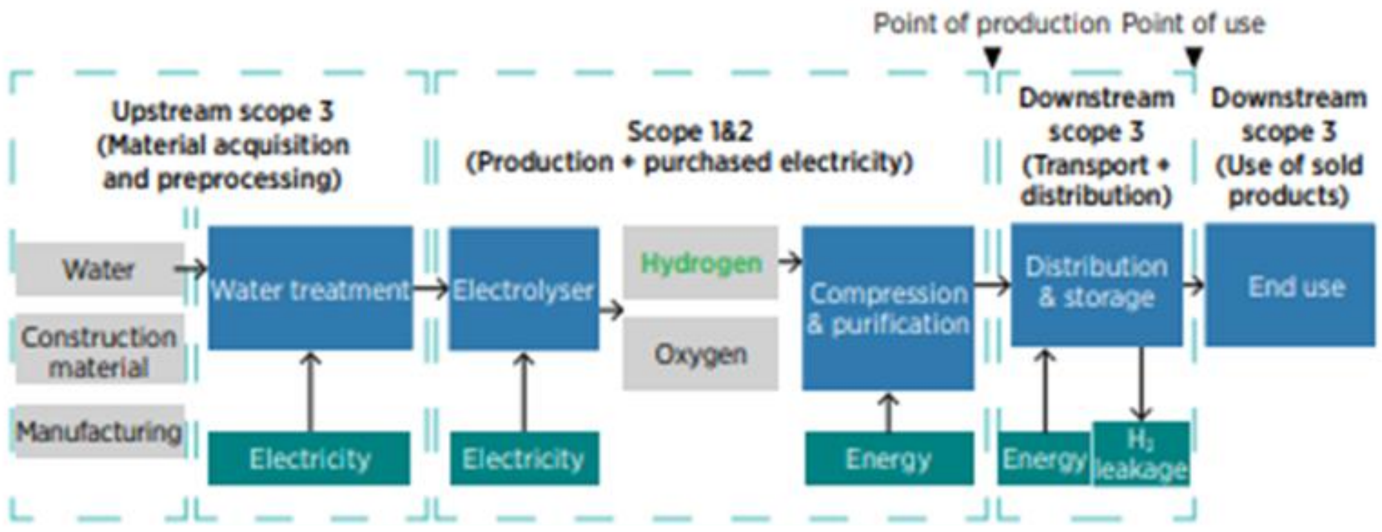
Methodology for accounting carbon emissions from H2 value chain – (ISO based on IPHE)

ISO/WD 19870:2023

ISO TC 197/SC 1/WG 1

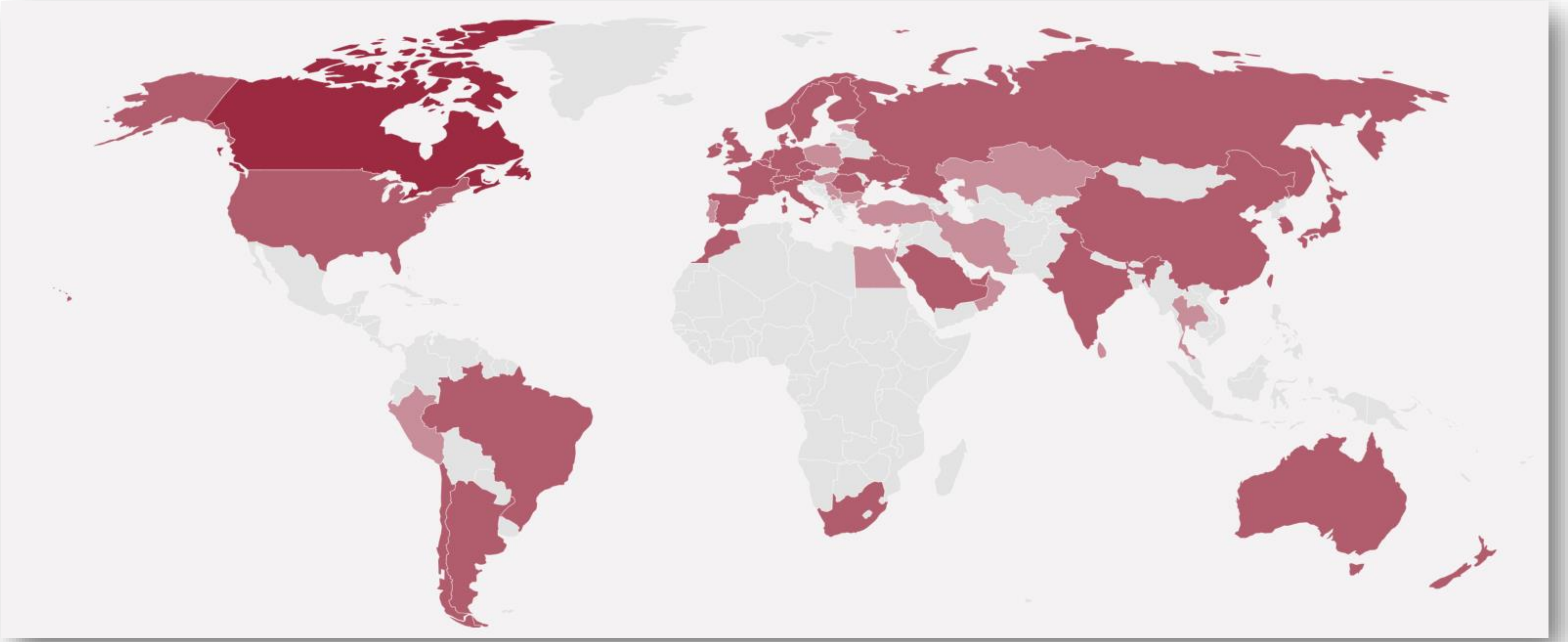
Date: 2023-05-08

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



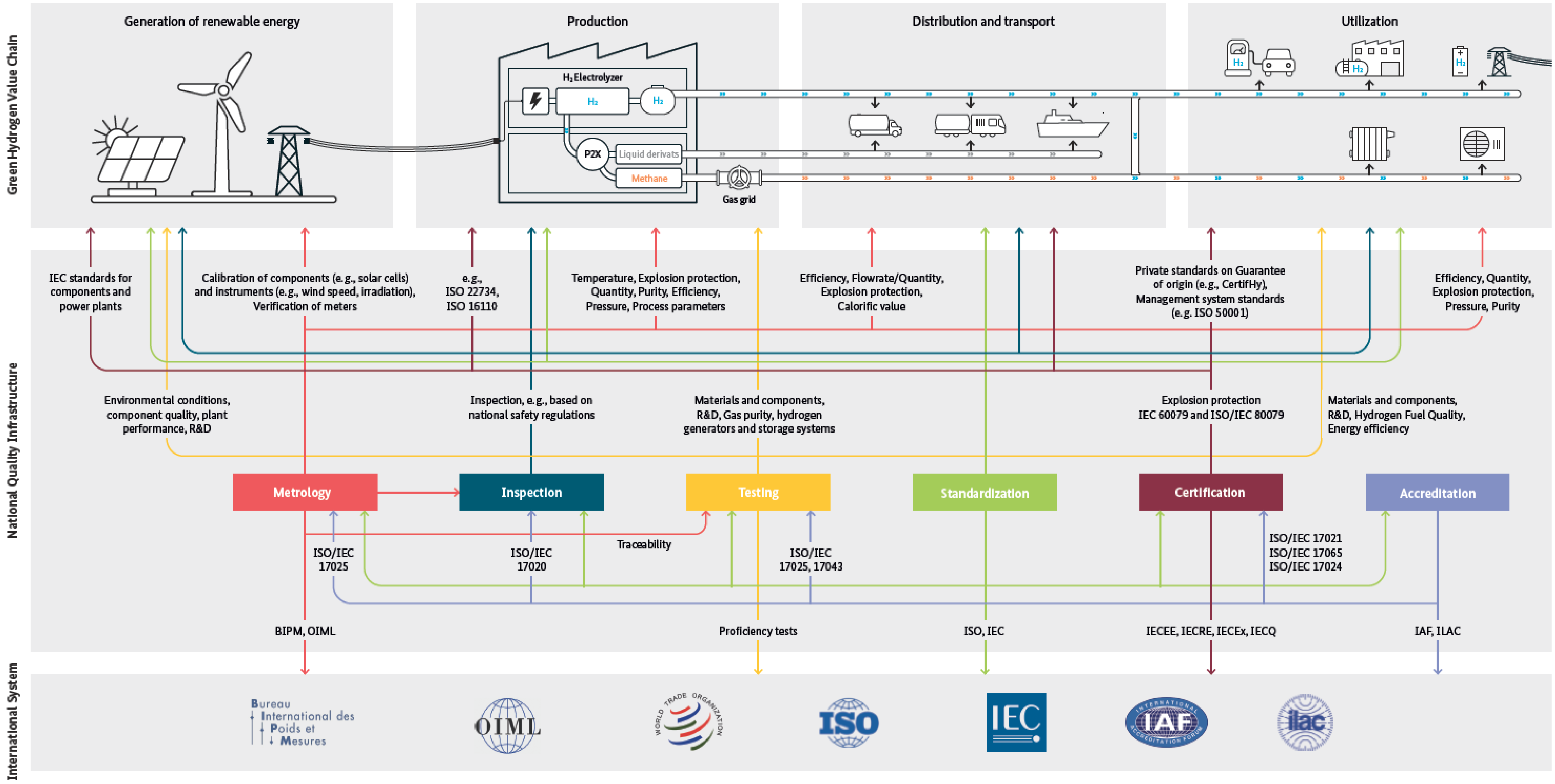
Source: European Commission

Members ISO TC 197 - are developing countries engaged?



Source: ISO TC197 website

Quality Infrastructure –standards, certification and beyond- taking a holistic approach including Personnel



Developing a Green Hydrogen Strategy (pre-requisite)

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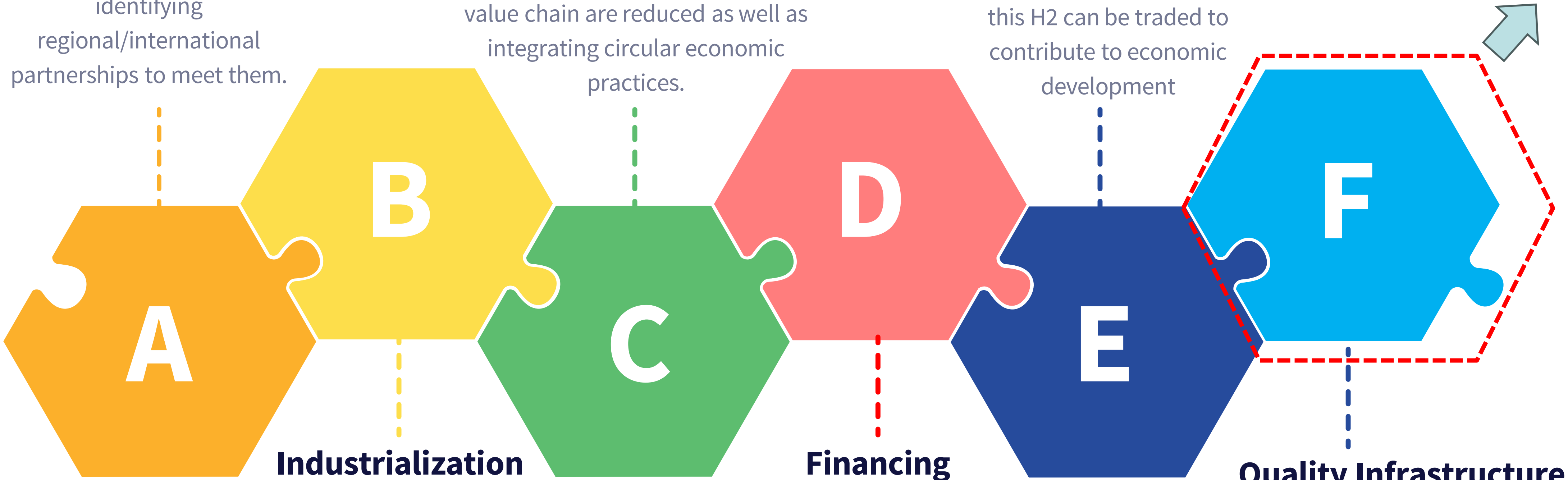
- Develop a cogent and coherent **hydrogen strategy that can guide the implementation of the most important facets within the GH2 economy**. Some of the key tenets necessary in these strategies are as follows:

Ambition and Collaboration
Having clear targets and identifying regional/international partnerships to meet them.

Sustainability
Ensure that emissions across H2 value chain are reduced as well as integrating circular economic practices.

Trade Potential
Have a clear map and overview on the channels through which this H2 can be traded to contribute to economic development

Often overlooked!



Industrialization
Hydrogen is viewed as conduit to drive industrial development by integrating with other sectors

Financing
Explicitly identifying tangible mechanisms through which finance can be attracted for GH2

Quality Infrastructure
QI ensure the safety, sustainability, and reliability of this energy carrier and access to different markets

Source: Forthcoming H2 Policy Toolkit by IRENA, UNIDO and DIN

Germany’s National Hydrogen Strategy includes QI

„The chief components of this measurement and quality assurance infrastructure which needs to be built up and networked at national and European level are metrology and physical and chemical safety technology.

…, there is a need for scientifically accepted and regulated measurement methods and assessment criteria, and internationally accepted standards and technical standards.“

The National Hydrogen Strategy 2020, FEDERAL MINISTRY FOR ECONOMIC AFFAIRS AND CLIMATE ACTION, page 8

Source: German Metrology Institute PTB

Scenarios for implementation of proposed QI roadmap

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Renewable Energy Generation	Production			Distribution and transport	Utilization
	Electro-lysis	Conversion into derivates	Storage		

Scenario 3: National production and use of green hydrogen

Scenario 1: Import of green hydrogen for national use

- Market survaillance of hydrogen: Testing and calibration services in the areas of gas quality and quantity.

Scenario 2: Green hydrogen production for export

- Quality infrastructure services for renewable energy generation and green hydrogen production and transport.

All scenarios

- Development of the basic national quality infrastructure considering the results of the QI analysis (see step III).
- Quality assurance of all QI services, including QMS, internationally recognized accreditation, establishment of treacability and use of calibrated equipment, participation in interlaboratory comparisions.
- Regulation, standardization and conformity assessment on safety of components and systems requied along the H2 value chain.
- Mutual recognition of certification schemes relevant along the H2 value chain according to international standards.

Systemic innovation to grow sustainable GH2 markets

POWER TO HYDROGEN

SMART HYDROGEN PRODUCTION KIT

- Grid connected electrolysers
- Off-grid electrolysers

ESSENTIAL KIT

TECHNOLOGY AND INFRASTRUCTURE

Electrolyser technology

- **1** Pressurised ALK electrolyser
- **2** PEM electrolyser
- **3** SOEC electrolyser
- **4** AEM electrolyser

Hydrogen infrastructure

- **5** Compressed hydrogen storage
- **6** Liquefied hydrogen storage
- **7** Hydrogen-ready equipment

Digital technologies

- **8** Digital backbone for green hydrogen production
- **9** Hydrogen leakage detection

MARKET DESIGN AND REGULATION

Power market

- **10** Additionality principle
- **11** Renewable PPAs for green hydrogen
- **12** Cost-reflective electricity tariffs
- **13** Electrolysers as grid service providers

Hydrogen market

- **14** Certificates
- **15** Hydrogen purchase agreements
- **16** Carbon contracts for difference

Standard and regulations

- **17** Regulatory framework for hydrogen network
- **18** Streamlining permitting for electrolyser projects
- **19** Quality infrastructure for green hydrogen
- **20** Regulatory sandboxes

SYSTEM PLANNING AND OPERATION

Strategic planning

- **21** Electricity TSOs, including grid-connected hydrogen facilities in their planning
- **22** Co-locating electrolysers with renewable generators (onshore and offshore)

Smart operation

- **23** Smart hydrogen storage operation and P2P routes
- **24** Long-term hydrogen storage
- **25** Co-operation between electricity and gas operators

BUSINESS MODELS

Primary revenue streams

- **26** Local hydrogen demand
- **27** Hydrogen trade
- **28** Hydrogen industrial hub

Stacking other revenue streams

- **29** Revenues from providing services to the power system
- **30** Sale of electrolysis by-products (oxygen and heat)

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Source: IRENA

Some ideas for the revision of Colombia's hydrogen roadmap

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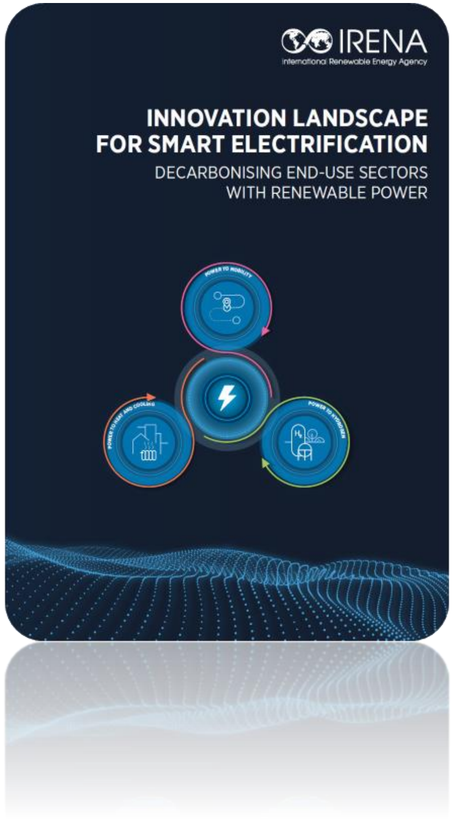


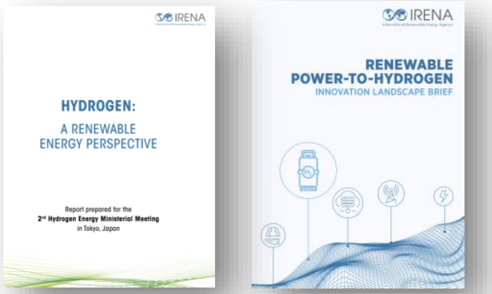
- More detailed on **required RE electricity capacity expansion and grid** infrastructure
- Consider **high value applications for local demand** and future export – **Innovative regulatory and financial instruments**
  - •Ammonia – Fertilizers
  - •Methanol – shipping fuels
- Plan to **develop infrastructure to produce h2 derivatives**, as unlikely to export h2 as molecule
- Inventory of **bio-Carbon** for synfuels
- Include **Quality Infrastructure** in the roadmap –**standards, certification, metrology, skills**–
- **Engage in ISO TC 197** –ICONTEC, metrology institute, testing and certification bodies–
- Harmonise **certification requirements**

Thank you – innovation@irena.org

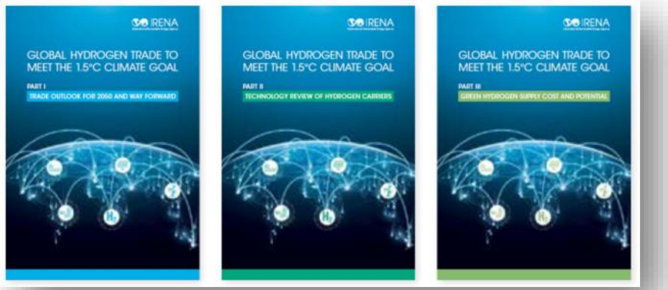
IRENA
International Renewable Energy Agency

Supply

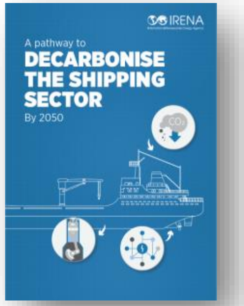
Sector coupling



Trade



Demand



Policies & cross cutting