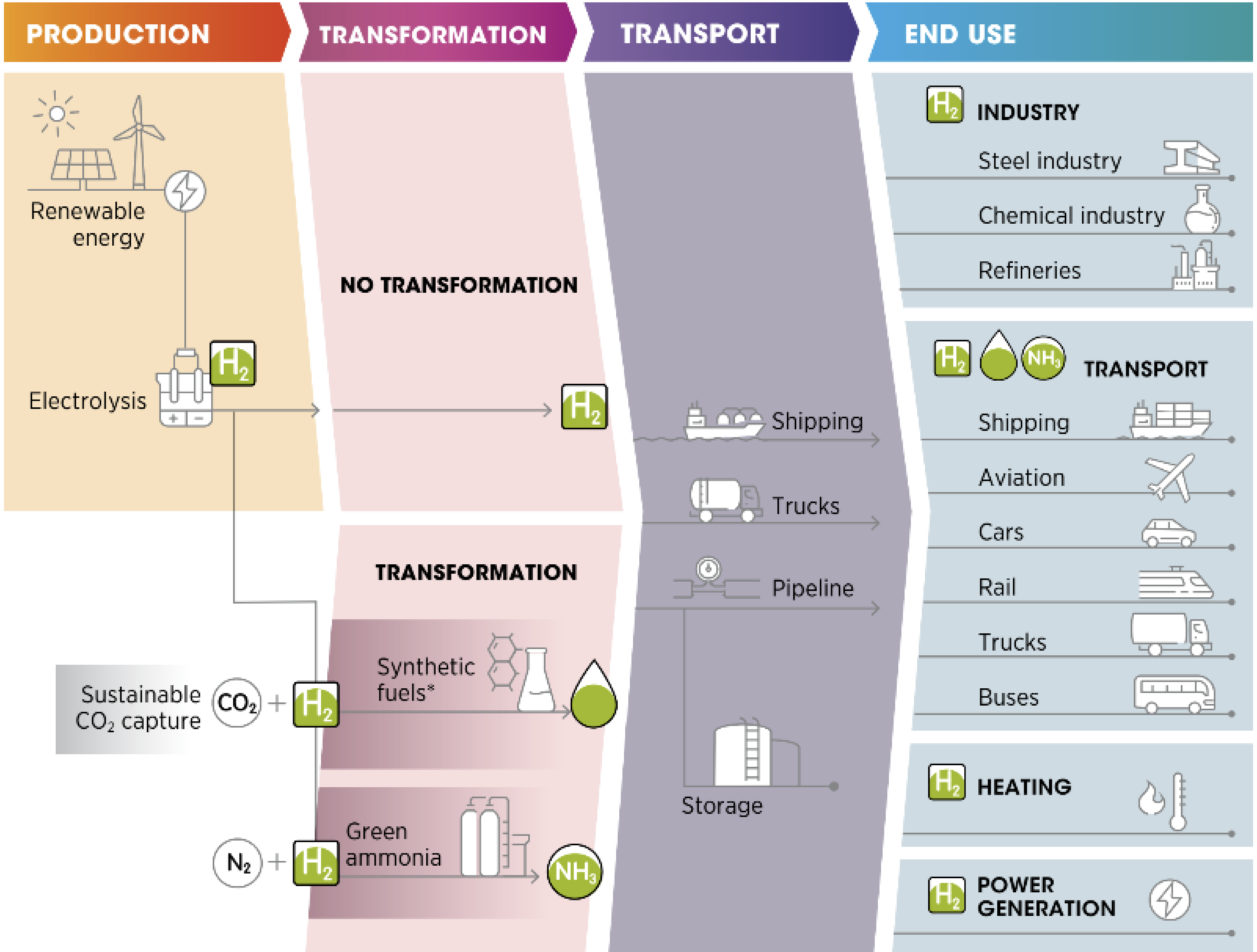
Basics of hydrogen economy

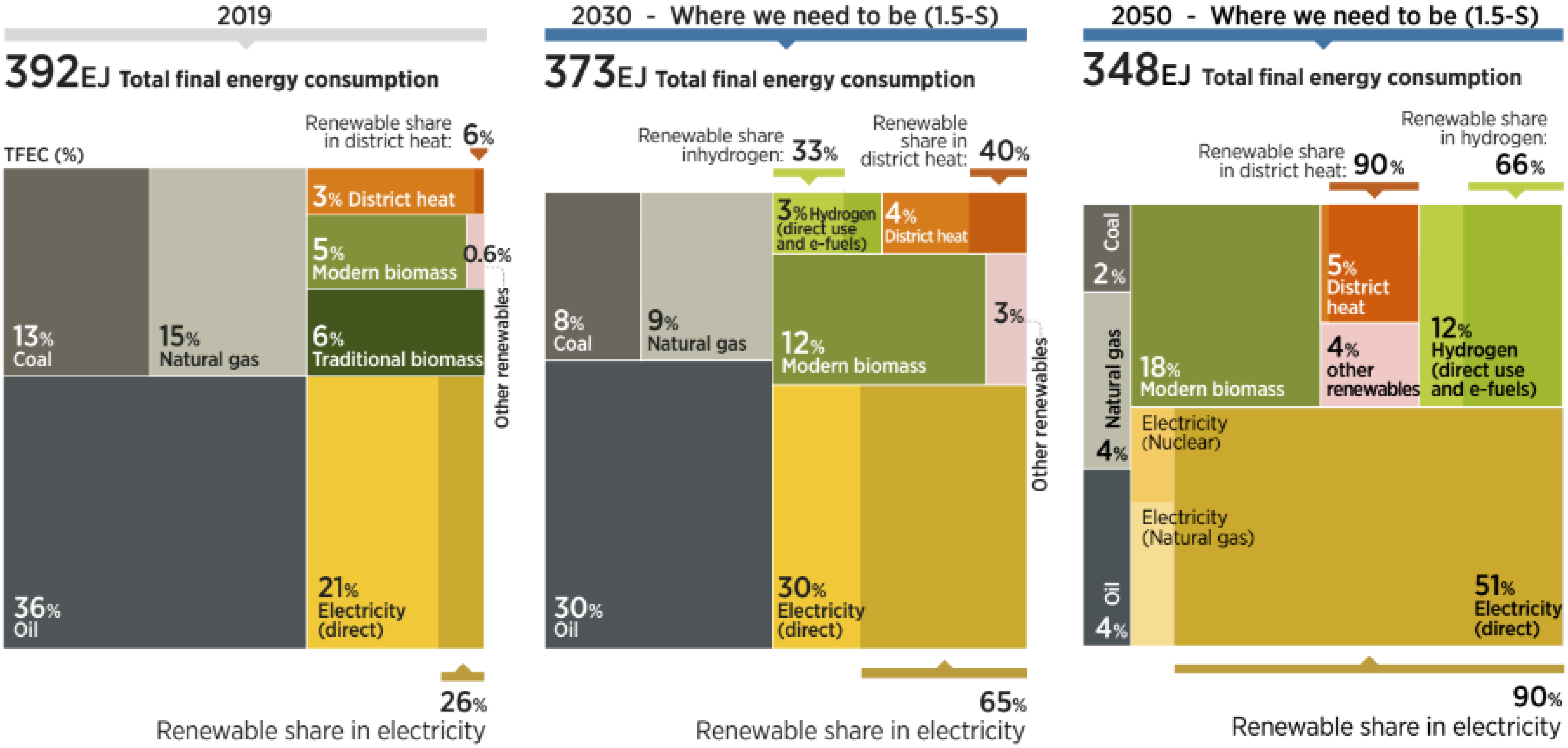
UNCTAD-DSI workshop on technology assessment in South Africa

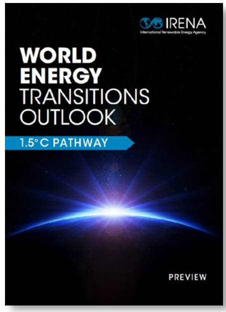
Hydrogen value chain



The future of hydrogen

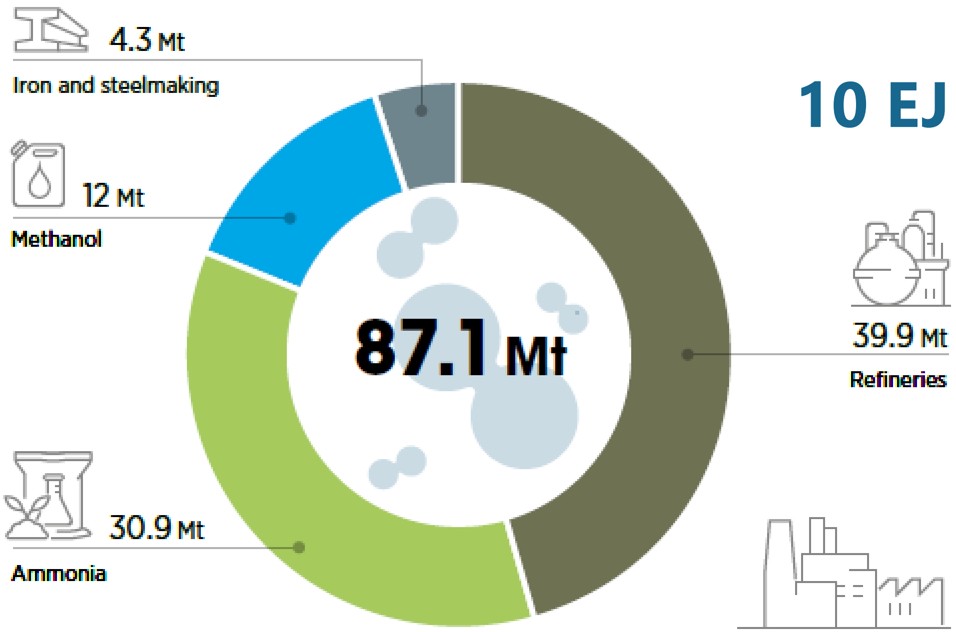
The role of renewable energy in the energy transition, accordingly to IRENA



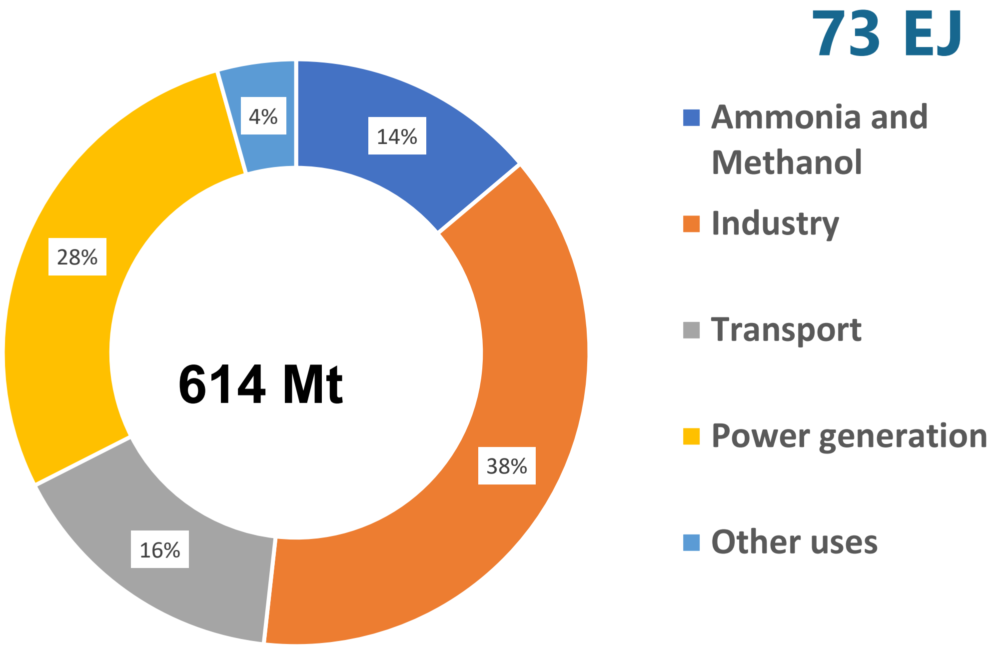


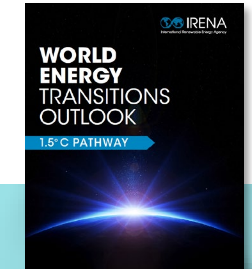
Hydrogen present and future

Hydrogen demand, 2020



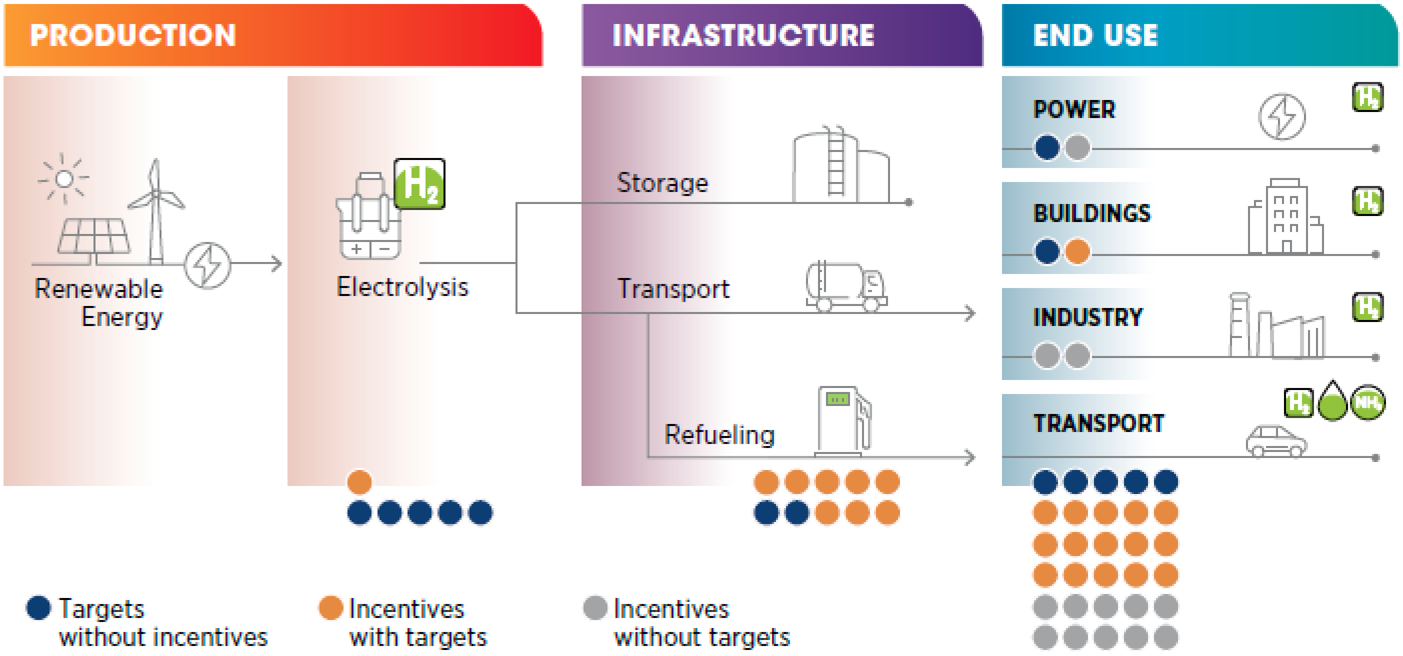
Hydrogen use in 2050 - WETO



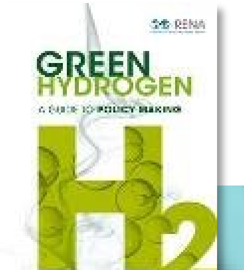


The “old wave” of hydrogen

Hydrogen policies at a global level by segment of the value chain (2019)



15 countries + EU considered

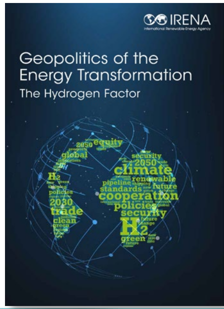


Colors of hydrogen (and terminology)

Selected colour-code typology of hydrogen production

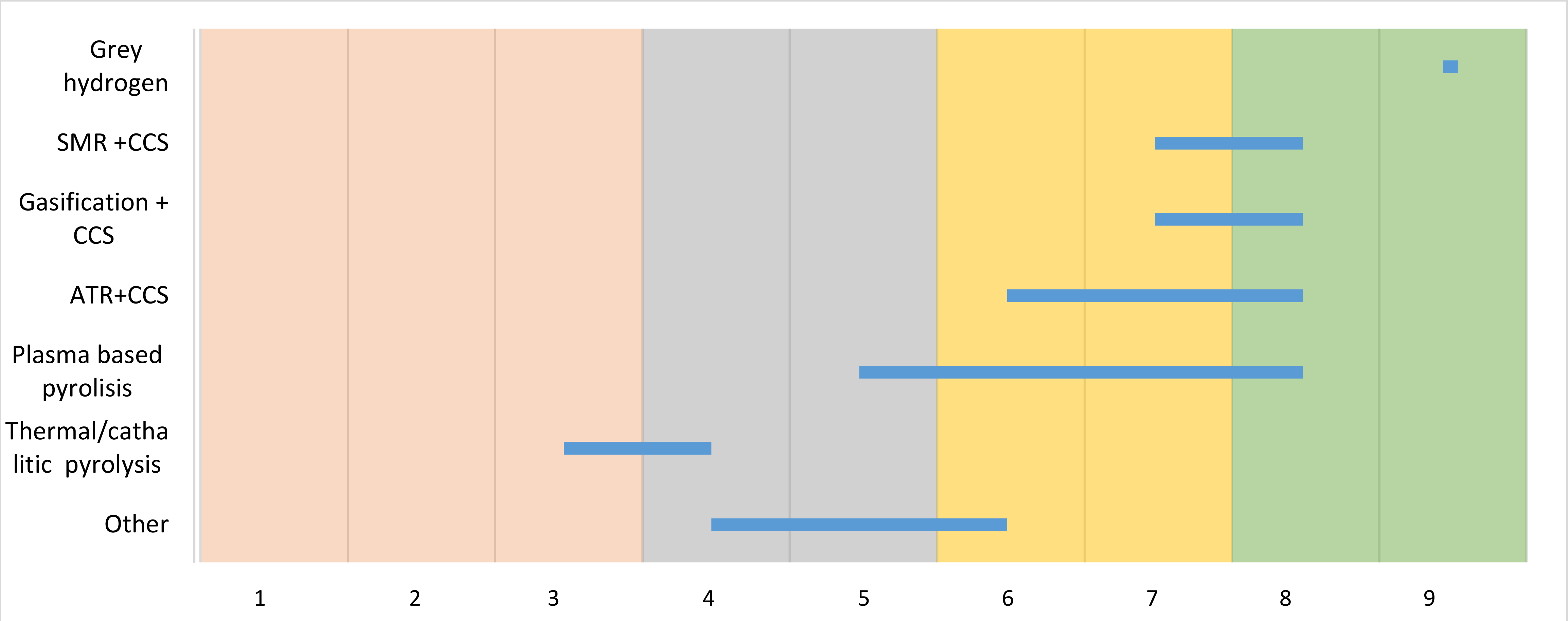
	GREY HYDROGEN	BLUE HYDROGEN	GREEN HYDROGEN
Process	Reforming or gasification	Reforming or gasification with carbon capture	Electrolysis
Energy source	Fossil fuels	Fossil fuels	Renewable electricity
Estimated emissions from the production process[a]	Reforming: 9 – 11[b] Gasification: 18 – 20	0.4-4.5[c]	0

Note: a) $CO_{2\text{-eq}}$/kg = carbon dioxide equivalent per kilogramme; b) For grey hydrogen, 2 kg $CO_{2\text{-eq}}$/kg assumed for methane leakage from the steam methane reforming process. c) Emissions for blue hydrogen assume a range of 98% and 68% carbon capture rate and 0.2% and 1.5% of methane leakage.



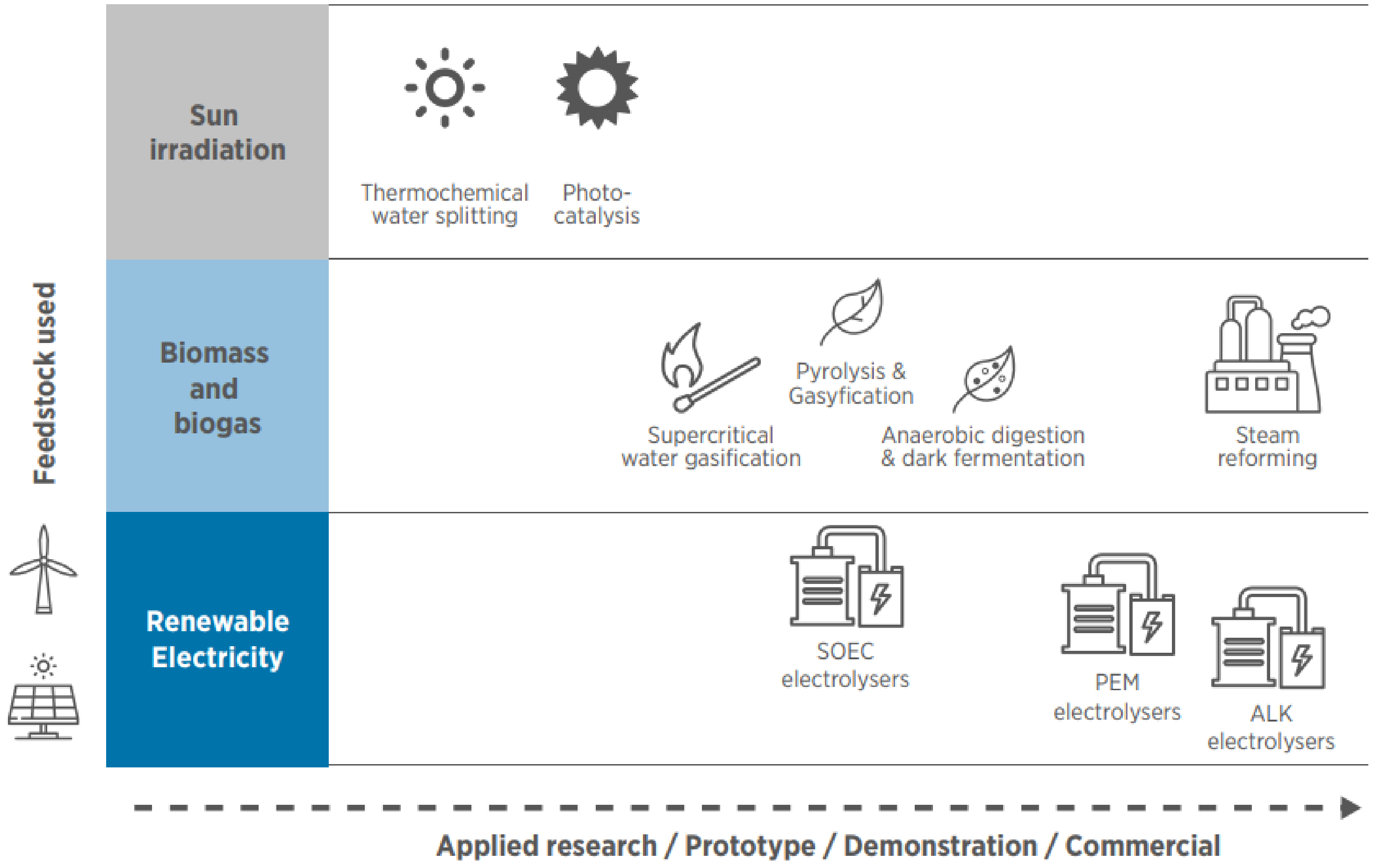
Grey and blue hydrogen

Technological readiness of grey and blue hydrogen technologies



Green hydrogen technologies

Renewable hydrogen production pathways and current levels of maturity

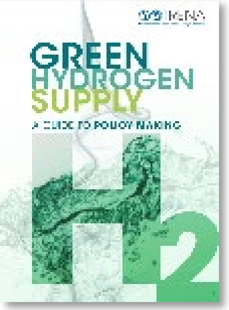


Green hydrogen technologies

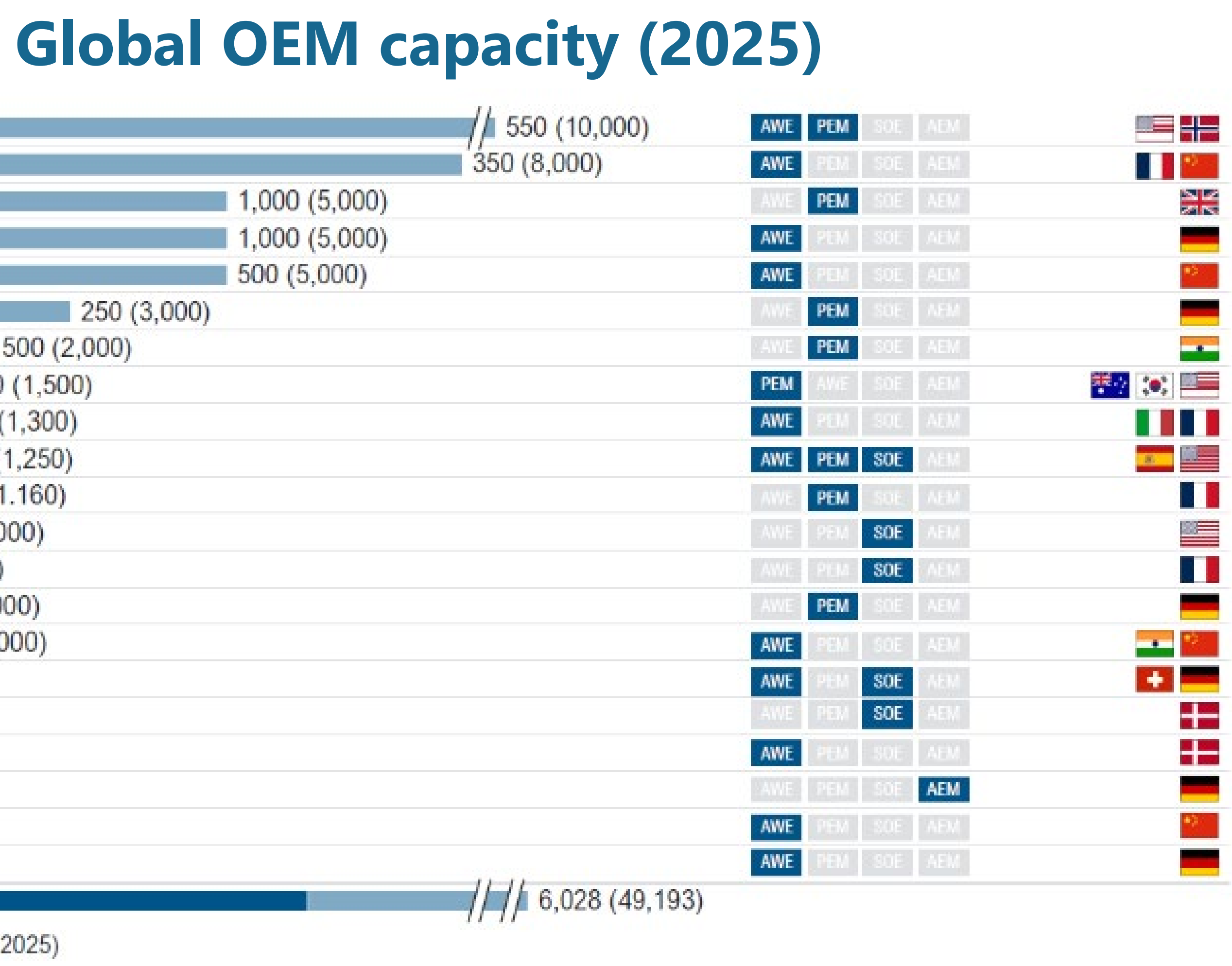
IRENA
International Renewable Energy Agency

Water electrolysis technologies

		Alkaline	PEM	SOEC	AEM
	Development status	**Commercial**	**Commercial**	**Demonstration**	**Under research**
Operating conditions	Temperature (°C)	70-90	50-80	700-850	40-60
	Pressure (bar)	~30	<70	1	<35
Cost parameters	CAPEX (system) (USD/kW)	600	1000	> 2000	
	Lifetime (hours)	50 000	60 000	20 000	5 000
	Efficiency (kWh/kg)	50-78	50-83	40-50	40-69
Flexibility	Load range	15-100%	0-160%	30-125%	5-100%
	Start-up	1-10 min	1 sec-5 min		
	Ramp up/down	0.2-20% per second	100% per second		
	Shutdown	1-10 minutes	Seconds		



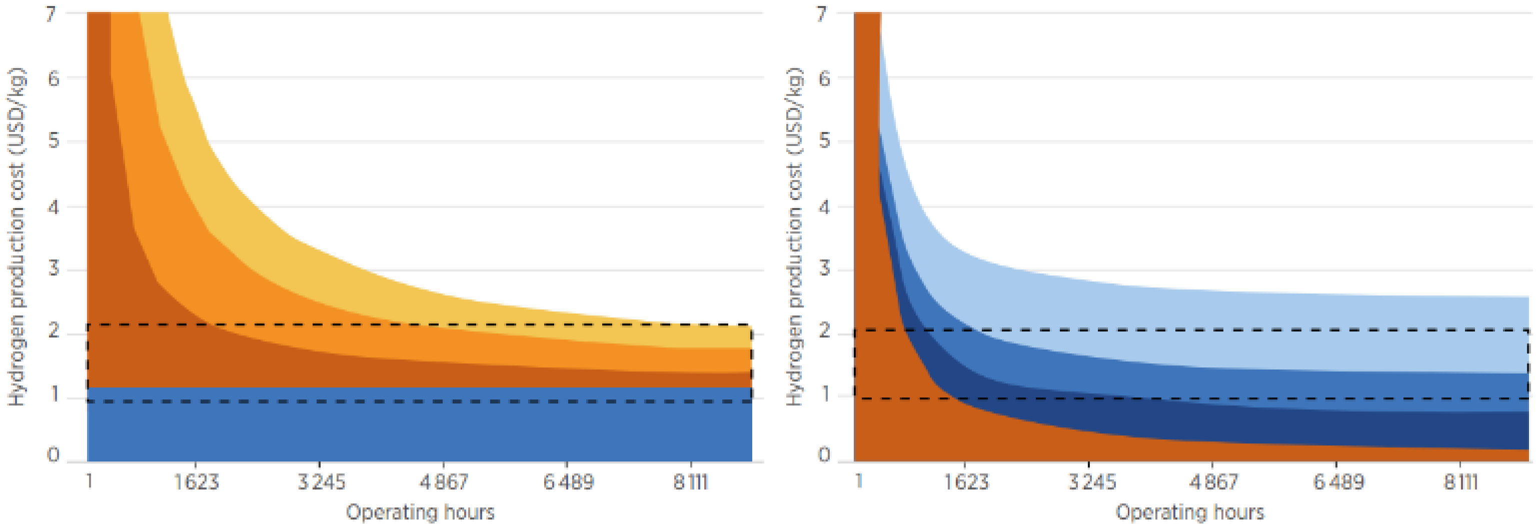
Electrolyser manufacturing



Source: Roland Berger, Quarterly H2 and Fuel Cell Market Radar MENA (2022)

Hydrogen production cost

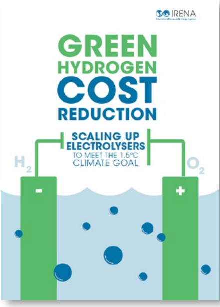
Hydrogen production cost depending on electrolyser system cost, electricity price and operating hour

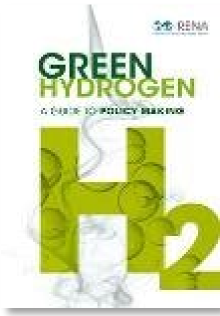


- Electrolyser system cost (USD 770/kW) + fixed costs
- Electrolyser system cost (USD 500/kW) + fixed costs
- Electrolyser system cost (USD 200/kW) + fixed costs
- Electricity price (USD 20/MWh)
- Grey hydrogen cost range

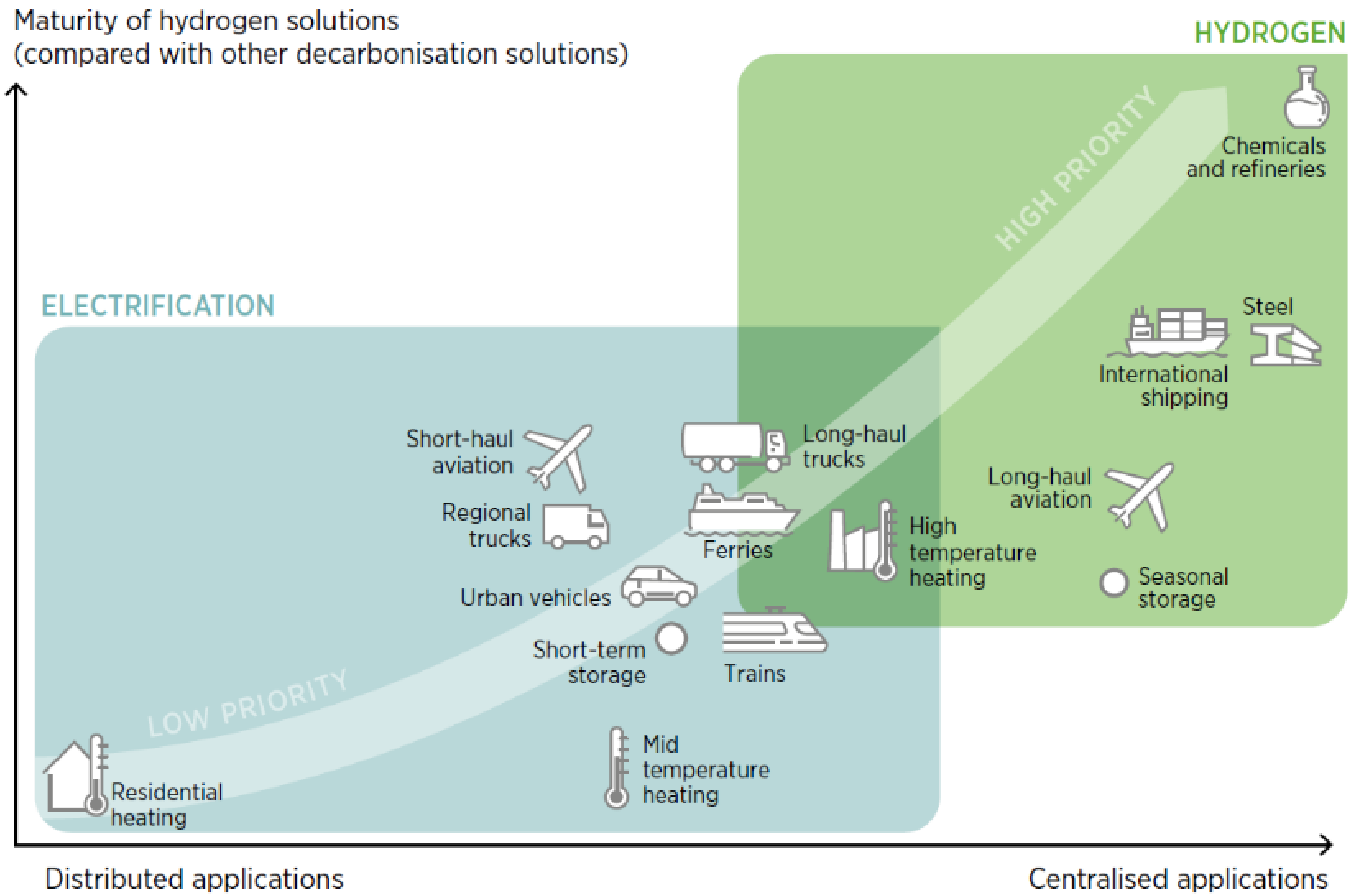
- Electrolyser system cost (USD 200/kW) + fixed costs
- Electricity price (USD 10/MWh)
- Electricity price (USD 20/MWh)
- Electricity price (USD 40/MWh)
- Grey hydrogen cost range

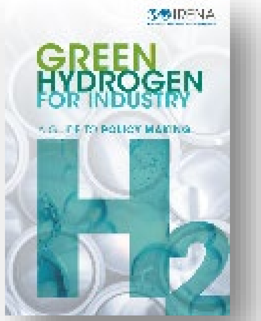
Note: GJ = gigajoule. Efficiency = 65% (lower heating value). Fixed operational cost = 3% of the capital costs. Lifetime = 20 years. Interest rate = 8.0%. Fossil fuel range: grey hydrogen, considering fuel costs of USD 1.9–5.5/GJ for coal and fossil gas.





Green hydrogen policy priority





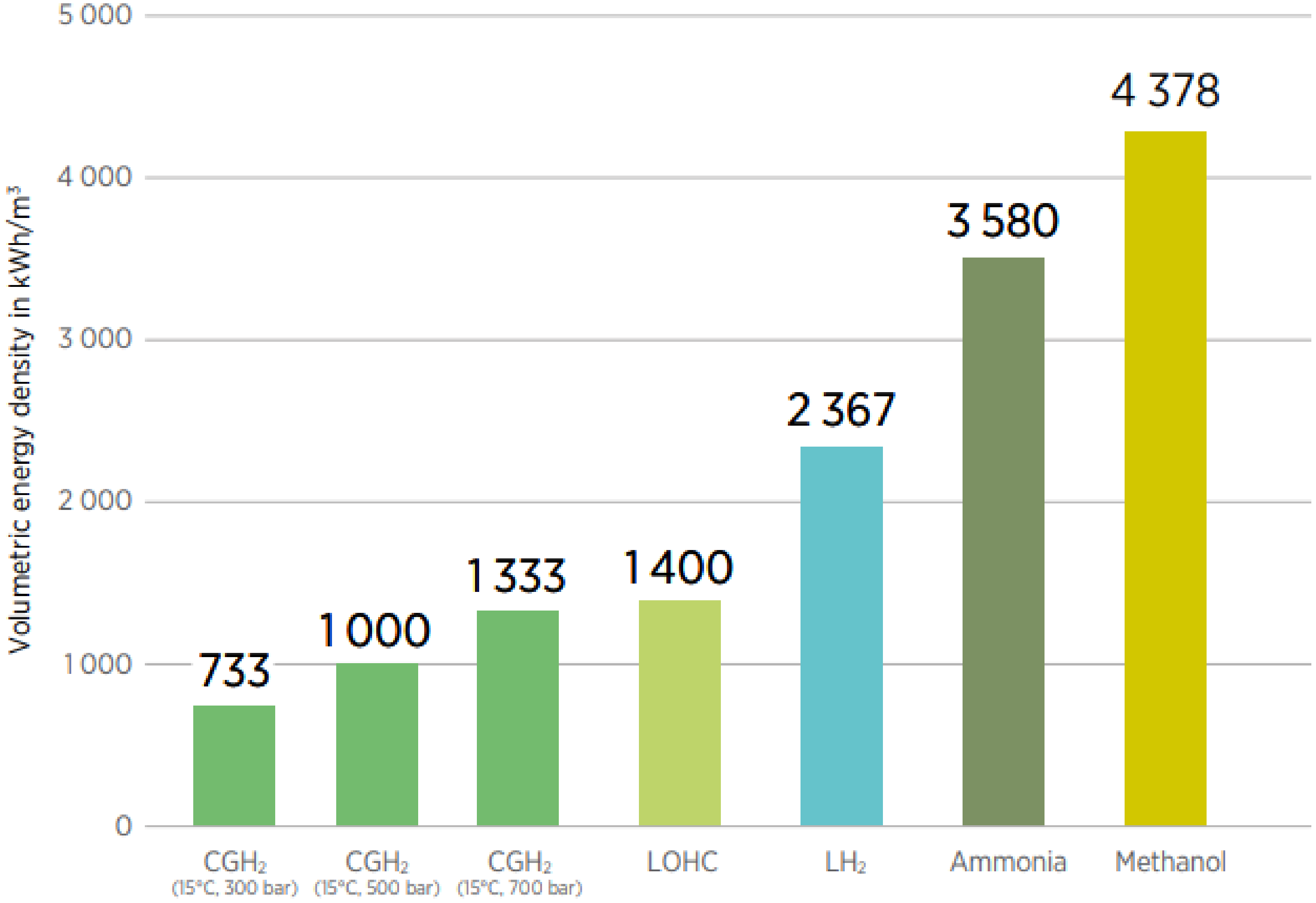
Remember the alternatives

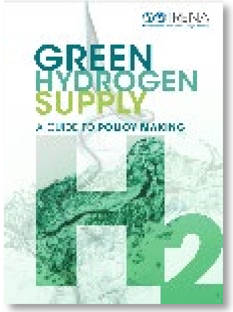
Hydrogen as a complement to alternative ways to decarbonise end uses

	RENEWABLES	DIRECT ELECTRIFICATION	ENERGY EFFICIENCY	GREEN HYDROGEN
HEATING	• Solar water heaters, direct geothermal use, biomass (low-grade heating)	• Heat pumps	• Retrofit of buildings • Technological advancement	• High-grade heating
INDUSTRY	• Solar drying, biomass (productive uses)	• Electric industrial application (e.g. arc furnaces)	• Use of best available technologies	• Steelmaking refineries • Chemical industry
LAND TRANSPORT	• Biofuels	• Battery electric vehicles	• Performance standards • Travel avoidance • Engine design	• FCEVs
SHIPPING	• Biofuels • Wind energy	• Short-distance shipping	• Ship design • Operation optimisation • Travel avoidance	• Green ammonia • Methanol
AVIATION	• Biojet fuels	• Short-distance aviation	• Plane design • Travel avoidance	• Hydrogen and synthetic fuels for aviation

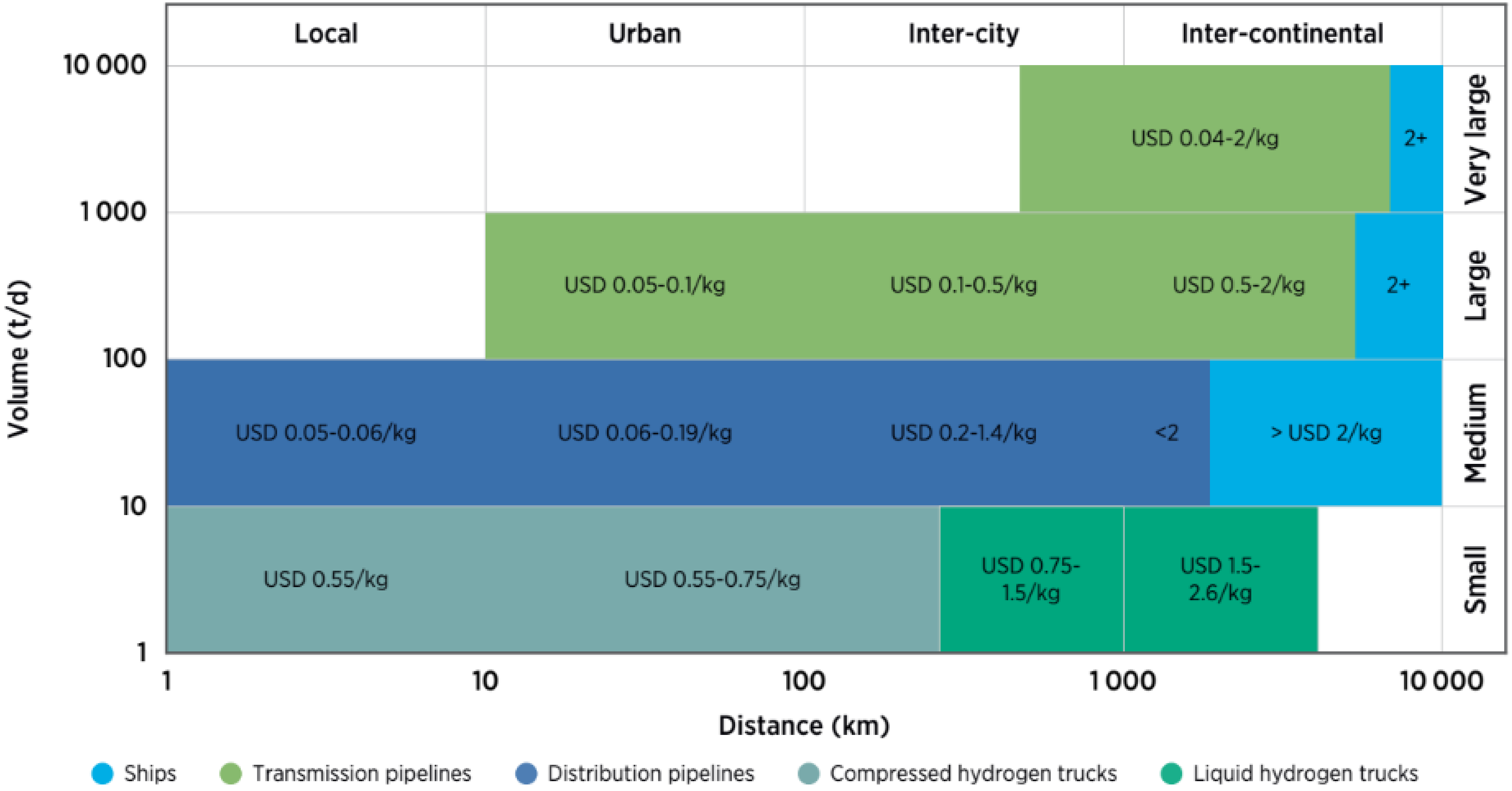
Volumetric energy density matters

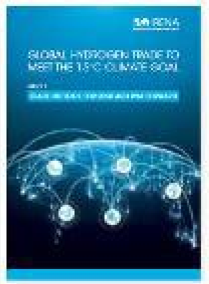
Volumetric energy density of various solutions to transport hydrogen





Hydrogen transport cost based on distance and volume





Storage status

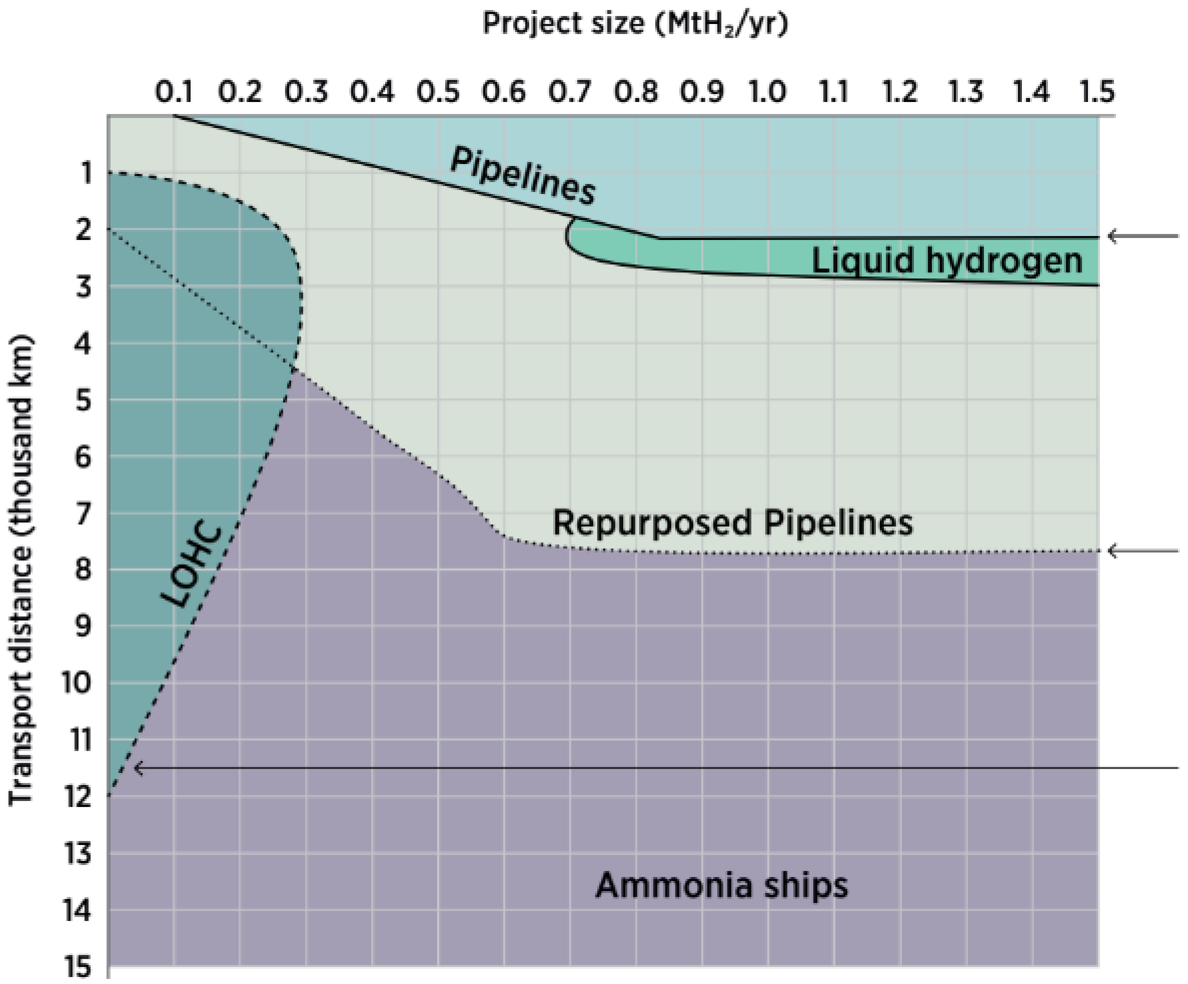
	Gaseous state				Liquid state			Solid state
	Salt caverns	Depleted gas fields	Rock caverns	Pressurized containers	Liquid hydrogen	Ammonia	LOHCs	Metal hydrides
Volume	Large	Large	Medium	Small	Medium	Large	Large	Small
Period (max)	Months	Season	Months	Daily	Weeks	Months	Months	days
Benchmark LCOS ($/kg)	$0.23	$1.90	$0.71	$0.19	$4.57	$2.83	$4.50	Not evaluated
Possible future LCOS	$0.11	$1.07	$0.23	$0.17	$0.95	$0.87	$1.86	Not evaluated
Geographical availability	Limited	Limited	Limited	Not limited	Not limited	Not limited	Not limited	Not limited

Source: BNEF (2020)

Underground storage geographical issue

World map of salt basins

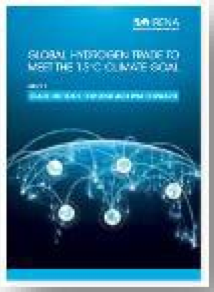
Most cost-effective hydrogen transport pathway by 2050



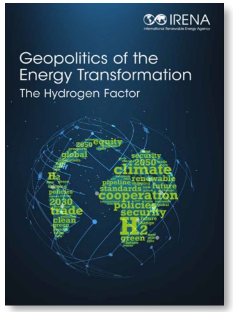
Solid lines are the base case. Pipelines are attractive for short distances, liquid hydrogen has a niche role and ammonia shipping is the most attractive for most combinations

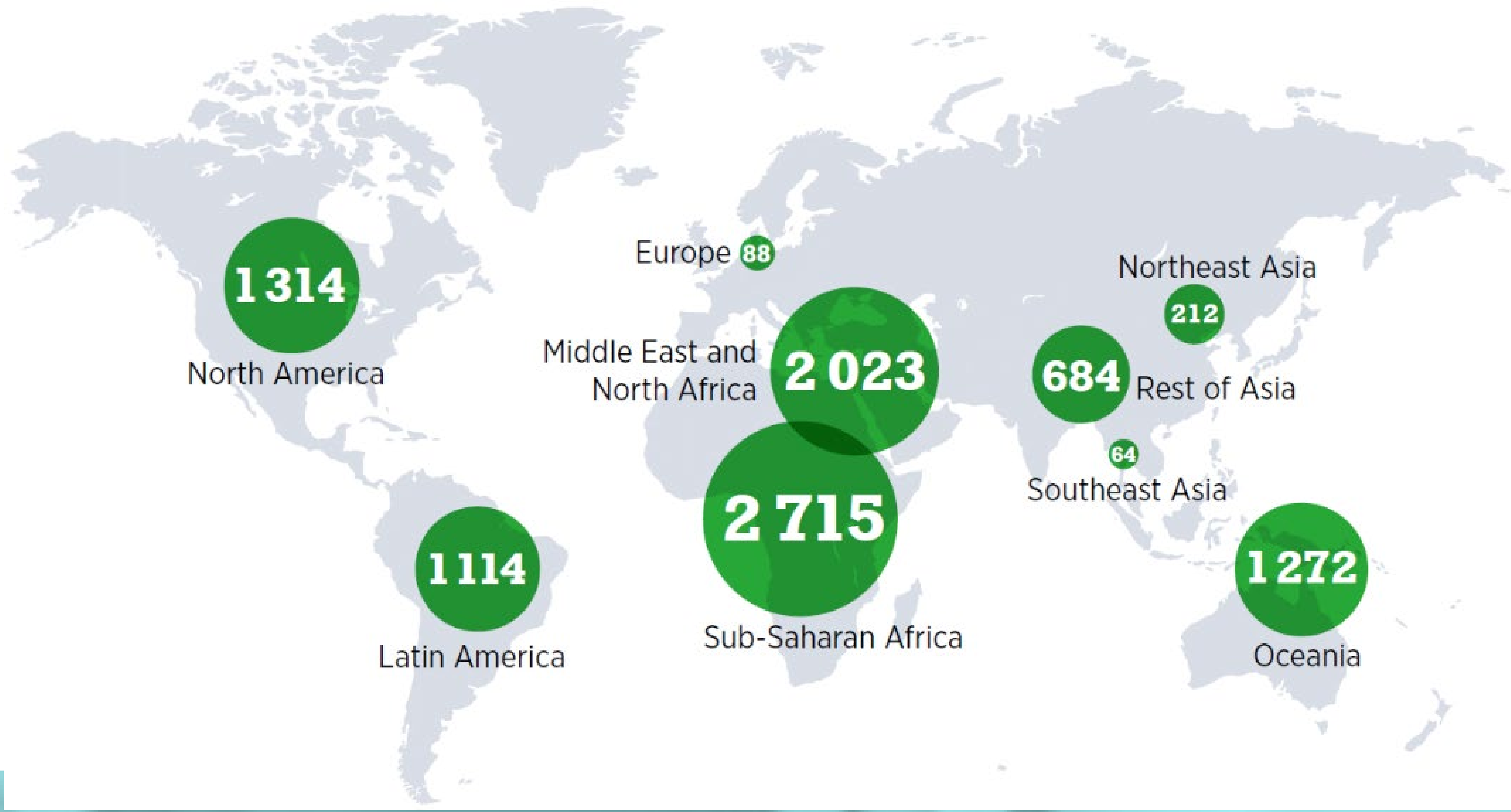
Dotted lines are for regions that have an existing network that can be repurposed to hydrogen, expanding significantly the area where pipelines are attractive

Dashed lines represent a case where innovation is slower and all the costs are higher. In this instance, LOHC can be attractive for smaller projects



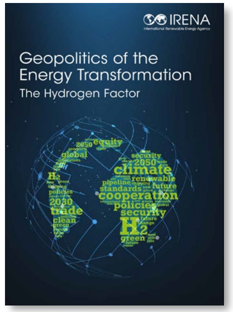
Technical potential for producing green hydrogen under USD 1.5/kg by 2050, in EJ

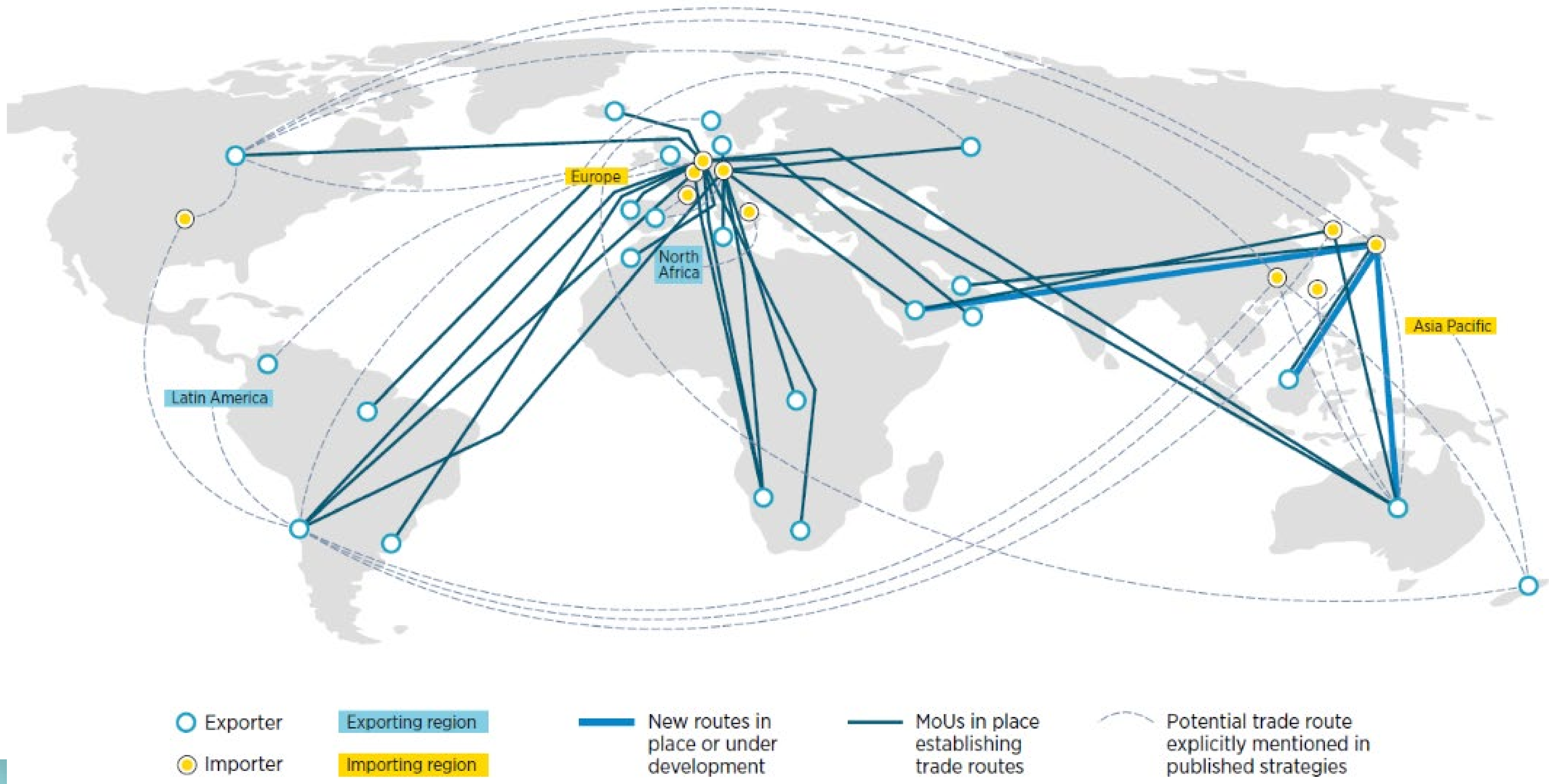




An expanding network of hydrogen trade routes, plans and agreements

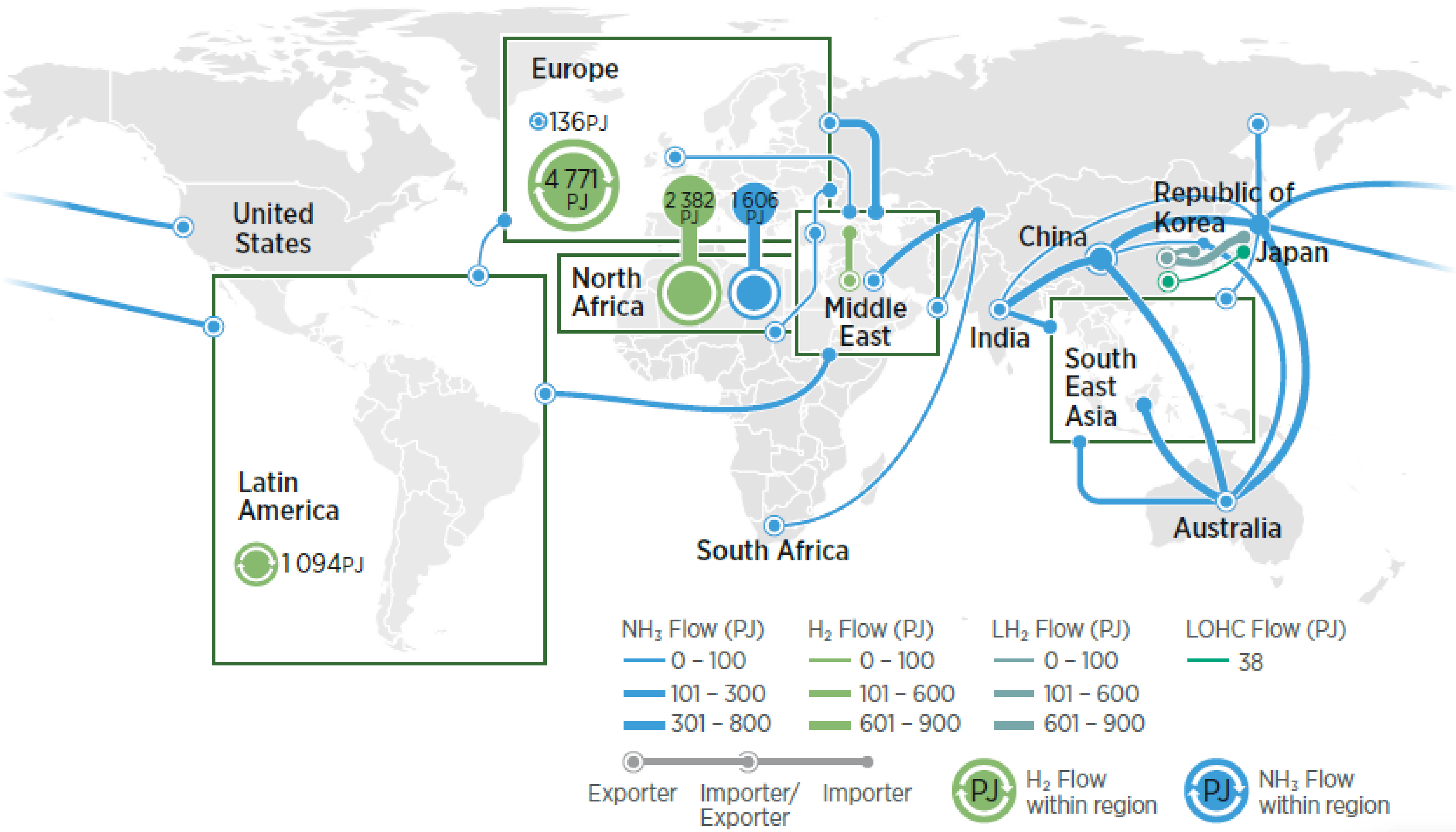
International Renewable Energy Agency





Considerations on trade

- In IRENA's 1.5°C scenario, 25% of the total global hydrogen demand (equivalent to about 150 Mt of hydrogen per year) could be satisfied through international trade;
- pipeline-enabled trade would be concentrated in Europe (85%) and Latin America;
- countries that have good-quality resources and low WACC would become the largest green hydrogen exporters



Source: IRENA (2022)

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