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Sustainability of Hydrogen Value Chain: Fact Checking

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→ Storage

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01.

TECHINT
Engineering & Construction

Company Presentation



Techint Group in the world



89,000

Total employees



8.7

Million tons of production capacity for seamless and welded pipes



15.6*

Million tons of production capacity for crude steel*



2.3

Billion dollars in annual net sales



36.3

Billion US dollars in annual income



200

Thousand barrels of oil equivalent (BOE) produced per day



1.9

Billion US dollars in annual net sales



1.3

Million patients

Data to 2024.

(*) Shipments of pig iron not included.

(**) Tenova operates in the mining industry under the brand name TAKRAF Group.

What we do

At Techint E&C, we add value through an innovative approach, with local presence and global vision.

For 80 years, we have provided comprehensive solutions at an international level for the Oil & Gas, energy, mining, infrastructure and industrial markets, through project management, engineering, procurement, construction, services, operation and maintenance.

We carry out our projects with the highest standards of safety, quality and compliance, respecting the environment and promoting the development of local communities.



TECHINT
Engineering & Construction

SADDN
Chile

A reliable partner for project implementation



80

Years of global experience



+3,500

Projects completed successfully around the world



1.9

Million hours of engineering during 2024



+18,000

People working all over the world



2.3

billion dollars in annual net sales

International scope

Local partner

TECHINT
Engineering & Construction

- Monterrey
Mexico
- Mexico City
Mexico
- Quito
Ecuador
- Lima
Peru
- Chincha, Ica
Peru
- La Negra, Antofagasta
Chile
- Santiago
Chile
- Neuquén
Argentina
- Houston
United States
- Veracruz
Mexico
- Bogota
Colombia
- Rio de Janeiro
Brazil
- São Paulo
Brazil
- Montevideo
Uruguay
- Buenos Aires
Argentina

- Madrid
Spain
- Seville
Spain
- Milan
Italy
- Cairo
Egypt
- Mumbai
India

- Engineering centers
- Regional headquarters
- Commercial and operational centers
- Logistics centers
- Machinery park

Integral solutions

For EPC projects

→ **Constructability Solutions:**

Experience in meeting deadlines and costs in challenging conditions.

→ **Efficiency in project control:**

Updated management tools
(PMI Certification).

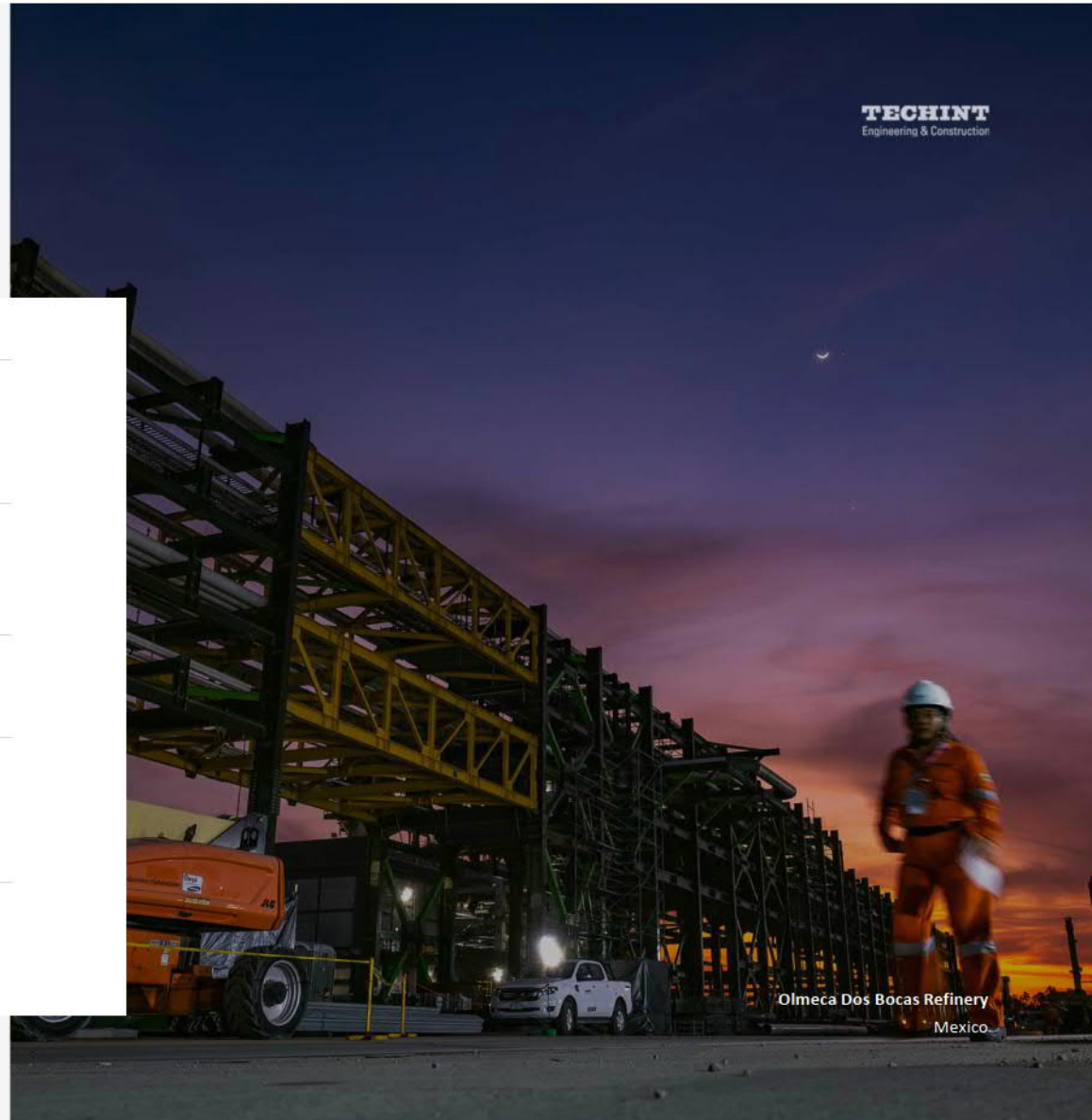
→ **Knowledge management:**

Robust process for sharing lessons learned.

→ **Offshore Unit:**

Construction and integration of equipment, modules and jackets for offshore projects.

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Olmeca Dos Bocas Refinery
Mexico

Engineering Solutions

Tailored to each project

→ Feasibility studies and cost estimates

→ Conceptual engineering

→ Basic engineering and FEED

→ Value engineering

→ Research on bottleneck removal and renewal

→ Detailed engineering

→ Modularized projects

→ Engineering Project Management

→ Pre-commissioning, commissioning and start-up services for plants

→ Construction Assistance



02.

Sustainability



Sustainability

Definition and Use in the Context: point of views

Sustainable development

Sustainability is “Meeting the needs of the present without compromising the ability of future generations to meet their own needs.”

1987 UN Brundtland Commission

ESG Environmental, Social, and Governance

A framework used to identify, assess, and manage non-financial factors that can affect the long-term risk, performance, and value of an organization, project, or investment

Integrated Sustainability

For an owner–operator, sustainability is the ability of an industrial asset to operate safely, efficiently, compliantly, and competitively on long terms, adapting to regulatory, technological, environmental, and market changes while preserving economic margins and strategic optionality

Financial sustainability

“refers to the ability of a project to generate sufficient cash flows over time to cover its operating costs, service its debt, and provide an adequate return on invested capital, without relying on ongoing external supports.”

Worldbank

Owner economic sustainability

“the ability of an industrial asset to generate durable industrial margins over its entire life cycle, while maintaining cost competitiveness, regulatory viability, and adaptability to market and technological change”

Integrated Sustainability



Dimensions and parameters

DIMENSION	WHAT IT REPRESENTS (Owner View)	KEY PARAMETERS
Industrial & Operational Sustainability	Ability of the asset to operate safely, reliably, and efficiently over decades	Plant availability and reliability, intrinsic process safety, maintainability, unplanned downtime, operational robustness
Economic Sustainability	Capacity to generate durable industrial margins over the full asset life	Long-term margin stability, cost competitiveness, life-cycle OPEX and CAPEX, margin sensitivity to energy and feedstock
Environmental Sustainability	Environmental performance as a long-term cost and constraint driver	Emissions intensity, energy efficiency, water and waste intensity, cost of environmental compliance, carbon exposure
Regulatory & Policy Sustainability	Ability to remain compliant and economically viable under evolving regulation	Permit durability, future regulatory cost exposure, alignment with industrial and climate policies, carbon pricing impact
Market & Product Sustainability	Long-term acceptability and demand for the product	Structural demand outlook, substitution risk, ESG acceptability of products, market positioning (commodity vs specialty)
Social & Workforce Sustainability	Stability of operations through people and social acceptance	HSE performance, workforce skills and retention, contractor management, community acceptance, social license to operate
Governance & Risk Management Sustainability	Quality of decision-making and control over long-term risks	ESG risk integration, internal controls, incident management, compliance systems, accountability and escalation mechanisms
Asset Longevity & Capital Preservation	Ability to preserve and enhance asset value over time	Technical lifetime, degradation rate, reinvestment intensity, revamping needs, cost of life extension
Adaptability & Optionality	Capacity to evolve with technology, markets, and regulation	Retrofit potential, fuel/feedstock flexibility, electrification readiness, CCS or abatement options, modularity
Financial Self-Sufficiency	Ability to sustain the asset without structural external support	Stable operating cash flow, self-funding of maintenance and upgrades, resilience to shocks, limited subsidy dependence

Sustainability



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In short, simple terms (what we will use for our check)

SUSTAINABILITY DIMENSIONS	SIMPLIFIED PARAMETER for CHECK	GOOD	MID	POOR
Industrial & Operational	TECHNOLOGICAL MATURITY			
Economic	PRODUCTION COST			
Environmental	EMISSION INTENSITY (CO2) GEOGRAPHICAL INDEPENDENCY			
Regulatory & Policy	REGULATORY COMPLIANCE			
Market & Product	PRODUCT DEMAND			
Social & Workforce	SAFETY COMMUNITY ACCEPTANCE			
Governance & Risk Management	SUPPLY CHAIN RISKS TAXES			
Asset Longevity & Capital Preservation	DURABILITY			
Adaptability & Optionality	POSSIBLE REVAMP/MODERNIZATION			
Financial Self-Sufficiency	INDEPENDENCY from SUBSIDIES			

03.

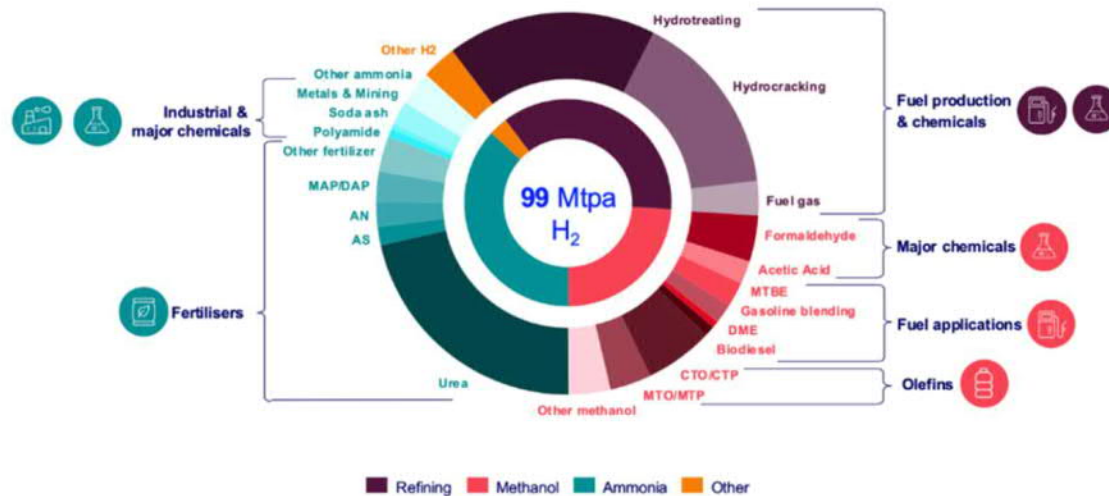
The Hydrogen Value Chain



Overview

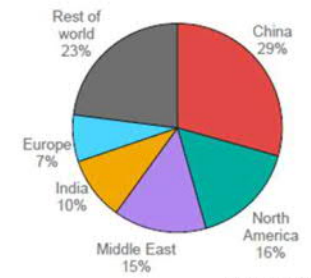
Hydrogen Market and Perspectives

Existing hydrogen use by sector: ammonia, methanol and refining dominate



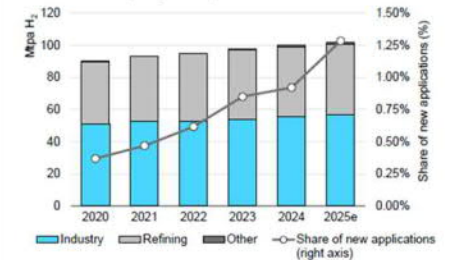
Source: Wood Mackenzie, Lens Hydrogen

Hydrogen use by region, 2024



Source: IEA - Global Hydrogen Review 2025

Hydrogen use by sector, 2020-2025



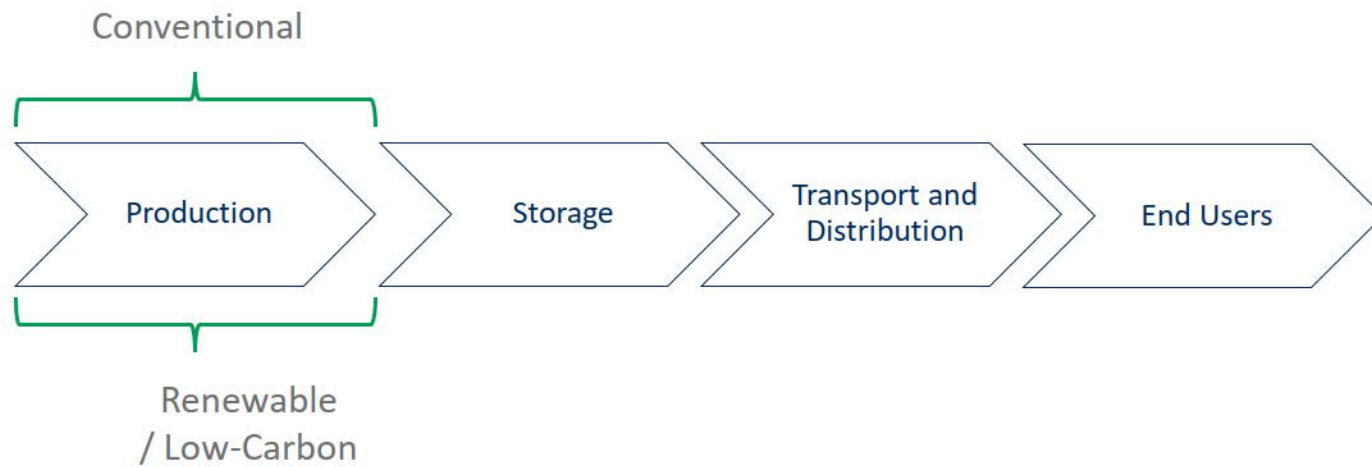
Source: IEA - Global Hydrogen Review 2025

Overview

The Value Chain



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The Hydrogen Value Chain

Production



Production

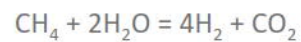


Conventional

Low Carbon

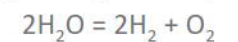
Green

Steam Methane Reforming (SMR)

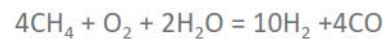


CCS

Electrolysis (Alk, PEM, SOEC)



Autothermal Reforming (ATR)



CCS

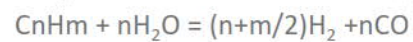
Other Methods

Methane Cracking

Thermochemical Water Splitting

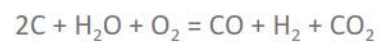
BioHydrogen (fermentation)

Naphta Steam Reforming



CCS

Coal Gasification



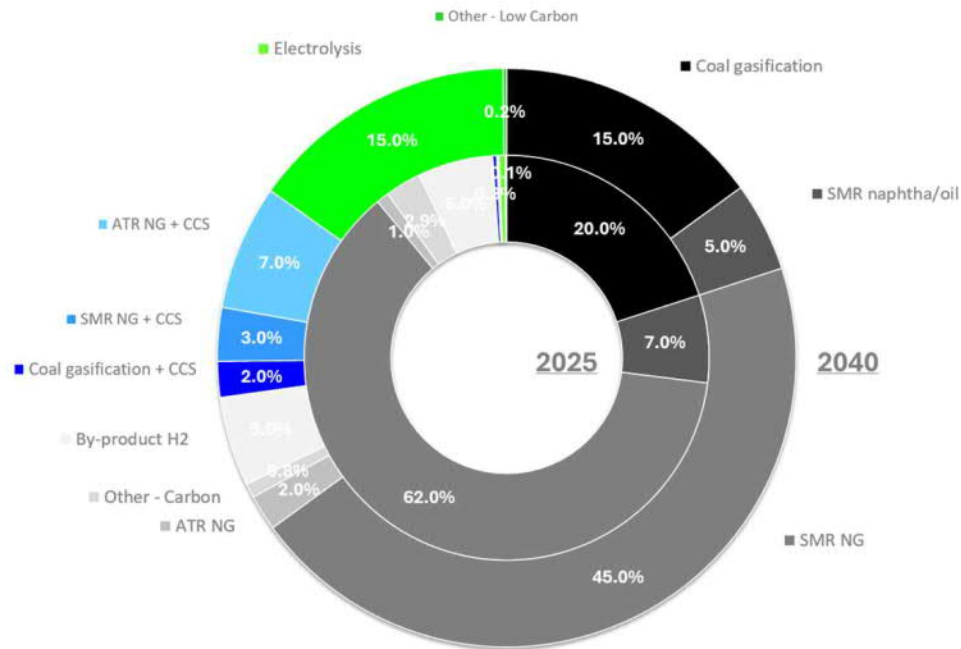
CCS

As By-Product

Catalytic Reforming, Steam Cracking, Chlor Alkali electrolysis

Production

Hydrogen Production by Method 2025 vs 2040



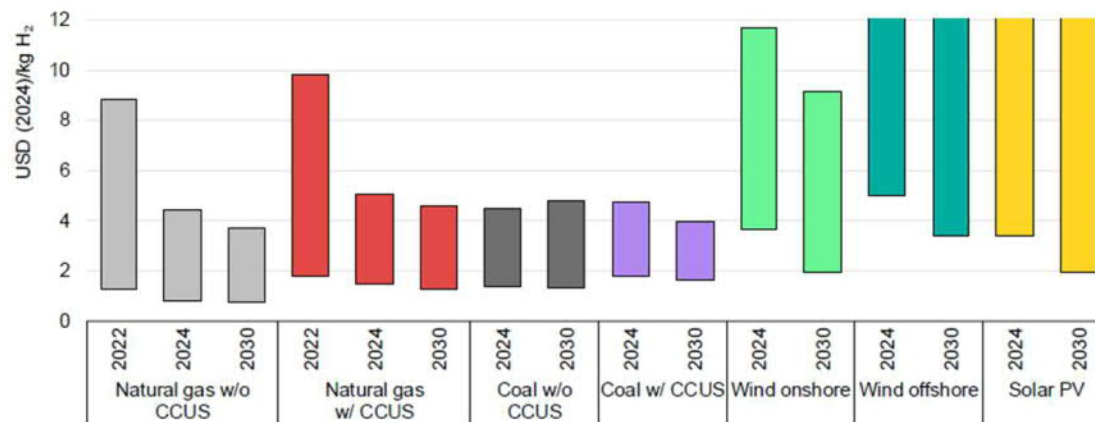
Method	2025	2040
Coal gasification	20.0	15.0
SMR naphtha/oil	7.0	5.0
SMR NG	62.0	45.0
ATR NG	1.0	2.0
Other - Carbon	2.9	0.8
By-product H2	6.0	5.0
Coal gasification + CCS	0.0	2.0
SMR NG + CCS	0.3	3.0
ATR NG + CCS	0.2	7.0
Electrolysis	0.5	15.0
Other - Low Carbon	0.1	0.2
TOTAL	100.0	100.0

Global Production	Mt/y
2025	100.0
2040	150.0

Production

Production Costs – by method

Hydrogen production cost by pathway, 2024, and in the Stated Policies Scenario, 2030
 (for specific conditions and assumption for calculations, ref. IEA – Global Hydrogen Review 2025)



Cost ranges reflect regional differences in fossil fuel prices, renewable costs, CO₂ prices, technology CAPEX and OPEX as well as cost of capital.

Source: IEA - Global Hydrogen Review 2025

Natural Gas Price	
Year	USD/Mbtu
2022	5.7 - 50
2024	1.7 - 25
2030	1.6 - 21

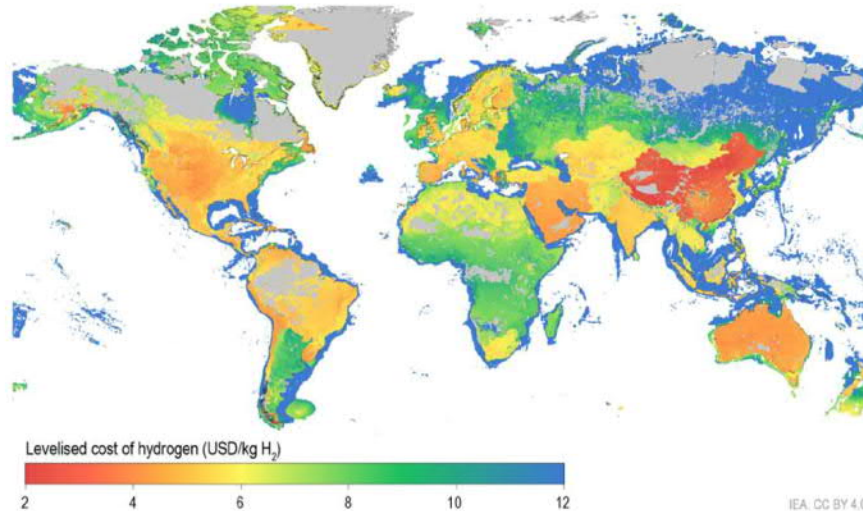
Production cost PV electricity	
Year	USD/MWh
2024	20 - 110
2030	13 - 85

CO ₂ price	
Year	USD/t CO ₂
2022	0 - 90
2024	0 - 70
2030	0 - 106

Production

Production Costs – by geography

Hydrogen production cost from electrolysis using hybrid solar PV and onshore wind, and from offshore wind, in the Stated Policies Scenario, 2030



Source: IEA - Global Hydrogen Review 2025

Electricity Market Price PV LCOE	
Region	€/MWh
Italy	45 – 70
Finland	60 – 90
USA	30 – 55
China	25 – 45
South America	20 – 40

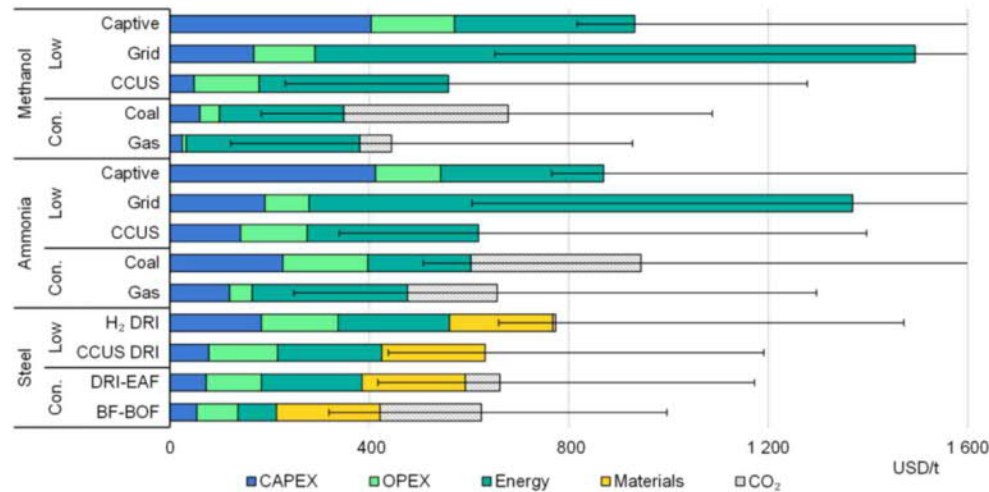
Electricity Market Price WIND LCOE	
Region	€/MWh
Italy	55 – 80
Finland	45 – 65
USA	35 – 60
China	30 – 50
South America	30 – 55

Electricity Market Price GRID	
Region	€/MWh
Italy	100 - 110
Finland	35 – 50
USA	45 – 70
China	50 – 70
South America	40 – 80

Production

Cost of Hydrogen derivatives

Levelised cost of production of selected materials by technology, 2024



Source: IEA - Global Hydrogen Review 2025

CO ₂ Prices	
Region	USD/t CO ₂
Advanced economies	0 - 70
Selected emerging markets and developing economies	0
Other emerging markets and developing economies	0

CO ₂ Transport and Storage cost for CCS/CCUS	
Region	USD/t CO ₂
Europe	47
Middle East	14
USA	14
China	15
Rest of the world	23

Production

Electrolyzers



Main materials for electrolyzer manufacturing (by technology)

Electrolyzer technology	Definition	Precious / rare materials	Typical material quantity (order of magnitude)	Supply-chain risk
Alkaline (ALK)	Alkaline Water Electrolysis with liquid electrolyte (KOH/NaOH)	Electrodes: Nickel (Ni), Cobalt (Co)* Plates: Nickel (Ni) Separator: Zirconium (Zr)*	Pt group: ~0 Ni: several kg/MW Co, Zr (if used): fractions to few kg/MW	Low
PEM	Proton Exchange Membrane Electrolysis	Electrodes: Iridium (Ir), Platinum (Pt) Plates: Titanium (Ti) Membrane: Fluoropolymers	Ir: 0.3–1.0 kg/MW Pt: ~0.05–0.3 kg/MW Ti: tens of kg/MW	High
AEM	Anion Exchange Membrane Electrolysis	Electrodes: Nickel (Ni), Cobalt (Co), Iron (Fe) Plates: Nickel (Ni) Membrane: advanced polymers	Pt group: ~0 (target) Ni/Fe/Co: few kg/MW (high uncertainty)	Medium (technology-driven)
SOEC	Solid Oxide Electrolysis Cell (high-temperature, ceramic)	Electrodes: Nickel (Ni), Lanthanum (La), Strontium (Sr), Cobalt (Co) Electrolyte (solid): Yttrium (Y), Zirconium (Zr)	Pt group: ~0 Ni: kg/MW Y/Zr: kg/MW La/Sr/Co: fractions to few kg/MW	Medium

* Sometimes

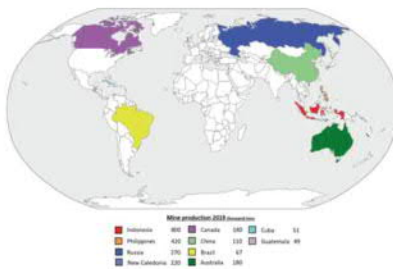
Production

Electrolyzers

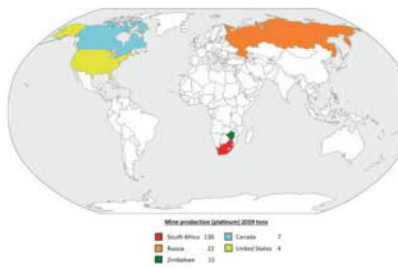


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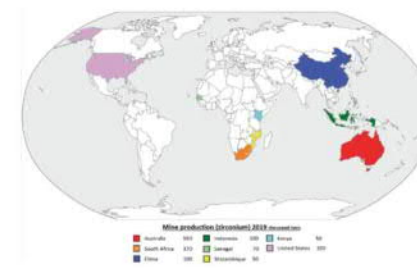
Nickel producing countries



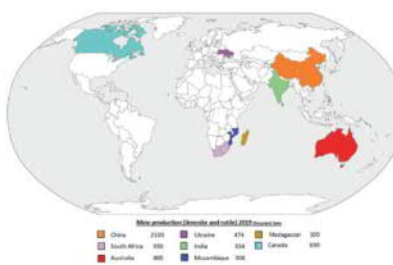
Platinum group metals producing countries



Zirconium producing countries



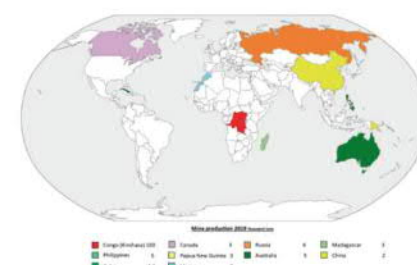
Titanium producing countries



Yttrium producing countries



Cobalt producing countries



Source: Elements and Mineral Resources – Springer Nature Link 2022

Hydrogen Production – Sustainability Check



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Conventional Technologies

SUSTAINABILITY DIMENSIONS	SIMPLIFIED PARAMETER for CHECK	GOOD	MID	POOR
Industrial & Operational	TECHNOLOGICAL MATURITY	X		
Economic	PRODUCTION COST	X		
Environmental	EMISSION INTENSITY (CO2) GEOGRAPHICAL INDEPENDENCY	X		X
Regulatory & Policy	REGULATORY COMPLIANCE		X	
Market & Product	PRODUCT DEMAND	X		
Social & Workforce	SAFETY COMMUNITY ACCEPTANCE	X	X	
Governance & Risk Management	SUPPLY CHAIN RISKS TAXES		X X	
Asset Longevity & Capital Preservation	DURABILITY	X		
Adaptability & Optionality	POSSIBLE REVAMP/MODERNIZATION	X		
Financial Self-Sufficiency	INDEPENDENCY from SUBSIDIES			X

Hydrogen Production – Sustainability Check



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Green Technologies

SUSTAINABILITY DIMENSIONS	SIMPLIFIED PARAMETER for CHECK	GOOD	MID	POOR
Industrial & Operational	TECHNOLOGICAL MATURITY		X	
Economic	PRODUCTION COST			X
Environmental	EMISSION INTENSITY (CO2) GEOGRAPHICAL INDEPENDENCY	X		X
Regulatory & Policy	REGULATORY COMPLIANCE	X		
Market & Product	PRODUCT DEMAND	X		
Social & Workforce	SAFETY COMMUNITY ACCEPTANCE	X X		
Governance & Risk Management	SUPPLY CHAIN RISKS TAXES			X (depend on technology) X (electricity prices)
Asset Longevity & Capital Preservation	DURABILITY		X	
Adaptability & Optionality	POSSIBLE REVAMP/MODERNIZATION		?	
Financial Self-Sufficiency	INDEPENDENCY from SUBSIDIES			X

The Hydrogen Value Chain

Storage

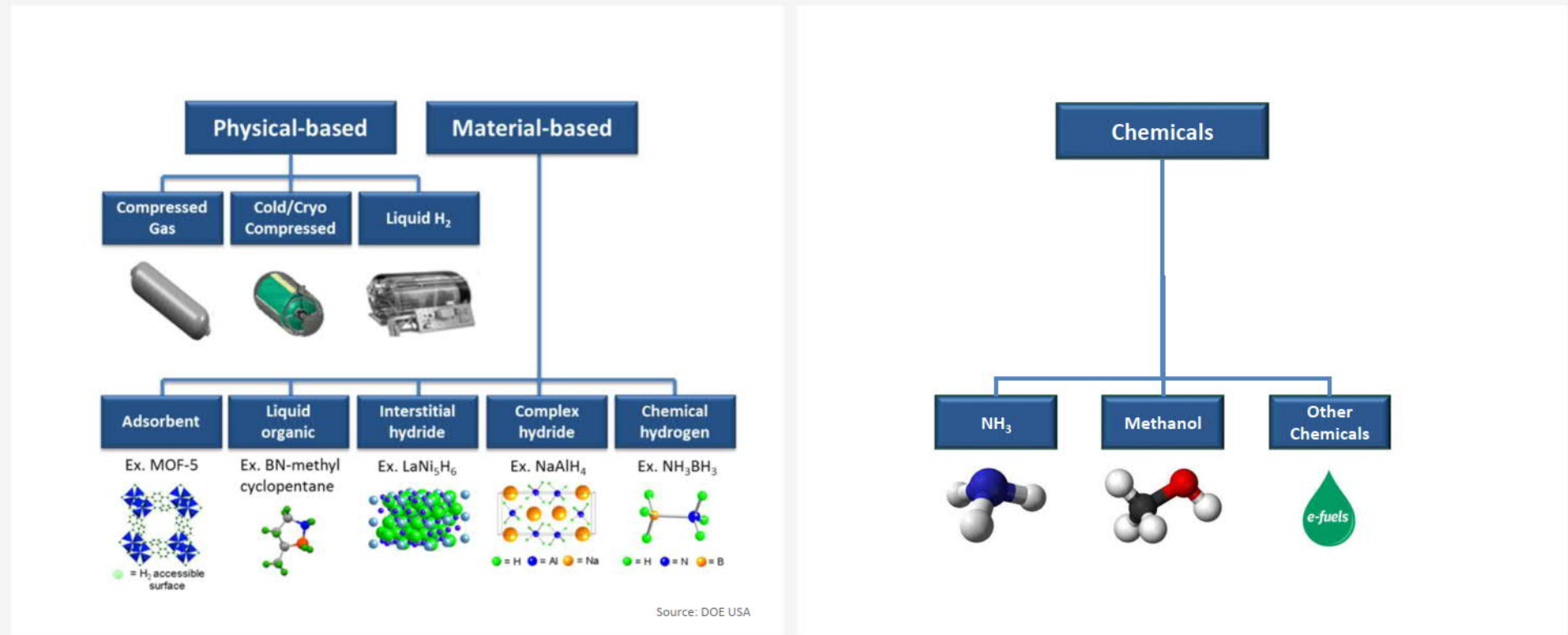


Storage

Available commercial technologies



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Storage

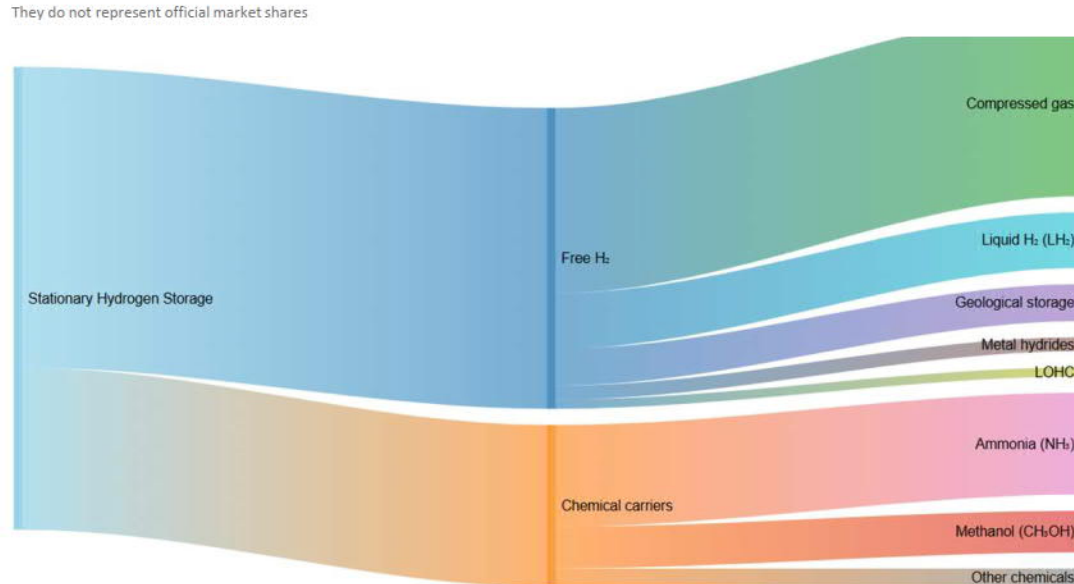
Available commercial technologies



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Stationary Hydrogen Storage Pathways – Normalized Sankey (100%)

The proportions shown are indicative system-level estimates, derived from IEA and industry sources, and normalized to 100% for visualization purposes. They do not represent official market shares



Physical Hydrogen Storage System Market

2 bn USD

Compressed Gas Storage in:

High pressure cylinders *: 10^1 kg @ 10^2 bars

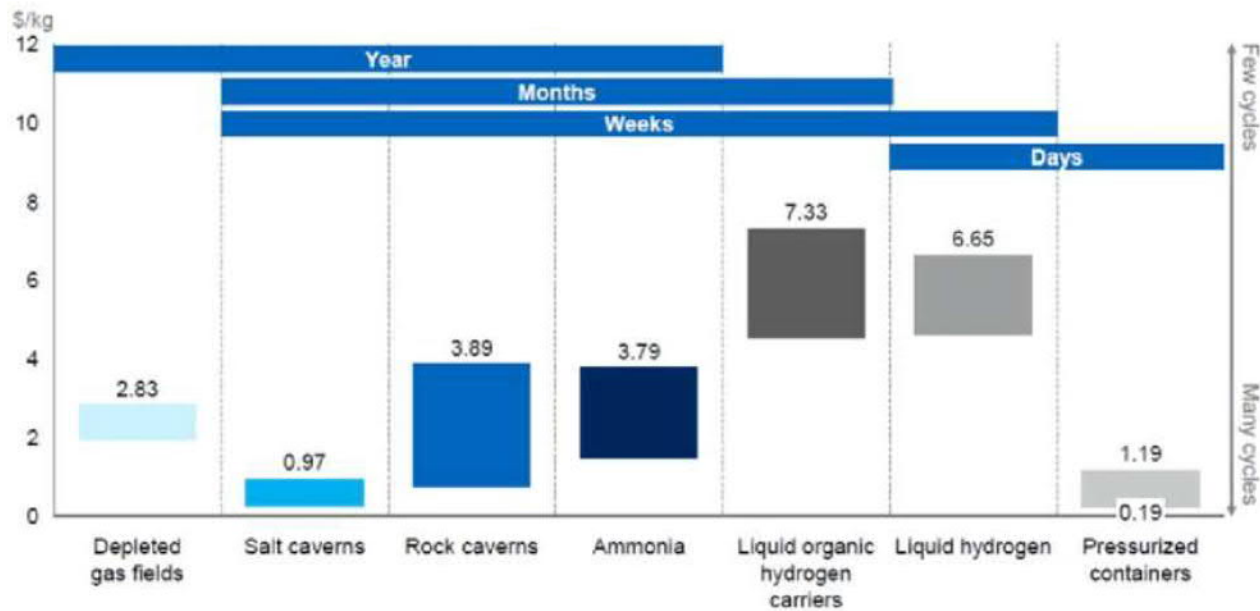
Pressure vessels *: 10^2 kg @ 10^1 bars

Pipelines: 10^3 kg / km @ $5 \cdot 10^1$ bars

(* each single vessel)

Storage

Costs



Source: Bloomberg, H2Plus, 2019

Levelized Cost of Stationary Storage [€/MWh]

$$LCoS = \frac{\text{Total Cost}}{\text{Total Energy Delivered}} =$$

$$= \frac{\text{AnnuityFactor} \cdot (\text{CAPEX} - \text{ResidualValue}) + \text{O}}{\text{Lifetime} \cdot \text{DoD} \cdot \text{Capacity} \cdot \text{Roundtrip Eff.}}$$

CAPEX: capital costs [€]

OPEX: operat. costs over the lifetime [€]

Lifetime (cycles) [yr]

DoD: Depth of Discharge [%]

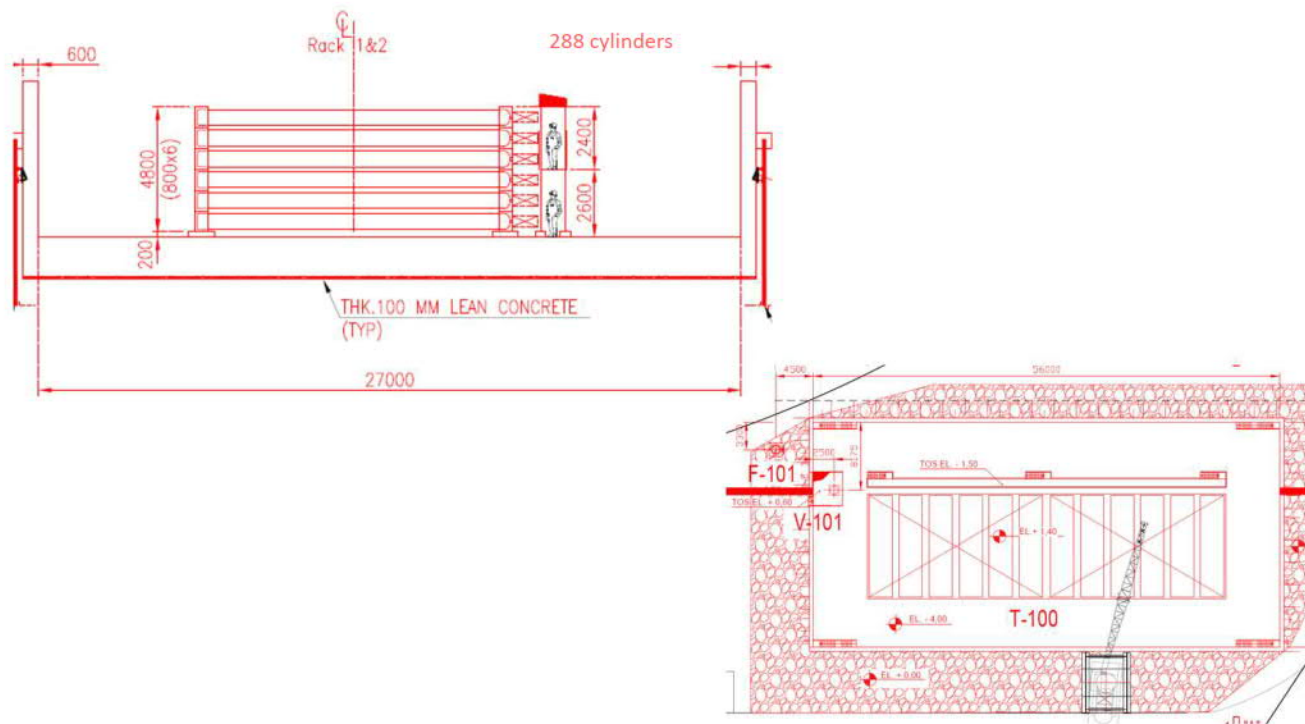
Capacity [MWh]

Roundtrip efficiency [%]

AF: Annuity Factor (financial)

Storage

Pressure Storage – An example of practical limitations



Hydrogen Storage in High Pressure Cylinders

Cylinder size

Length 12200 mm x dia 610 mm
~50 kg Hydrogen @ 22 bar

Required Storage Capacity

8 h consumption of a large size NH₃ production plant (3000 MTPD)
176 t/h Hydrogen

Number of Cylinders

$176000/50 = 3520$ units required

Hydrogen Storage – Sustainability Check



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P = Pressure storage; L = Liquid Storage; C = Chemicals

SUSTAINABILITY DIMENSIONS	SIMPLIFIED PARAMETER for CHECK	GOOD	MID	POOR
Industrial & Operational	TECHNOLOGICAL MATURITY	P L C		
Economic	PRODUCTION COST	P	C	L
Environmental	EMISSION INTENSITY (CO2) GEOGRAPHICAL INDEPENDENCY	P -	L -	C -
Regulatory & Policy	REGULATORY COMPLIANCE	P L C		
Market & Product	PRODUCT DEMAND	P C	L	
Social & Workforce	SAFETY COMMUNITY ACCEPTANCE	C	P L P L C	
Governance & Risk Management	SUPPLY CHAIN RISKS TAXES	P C -	-	L -
Asset Longevity & Capital Preservation	DURABILITY	P C	L	
Adaptability & Optionality	POSSIBLE REVAMP/MODERNIZATION	C L	P (limited capacity)	
Financial Self-Sufficiency	INDEPENDENCY from SUBSIDIES	P C L		

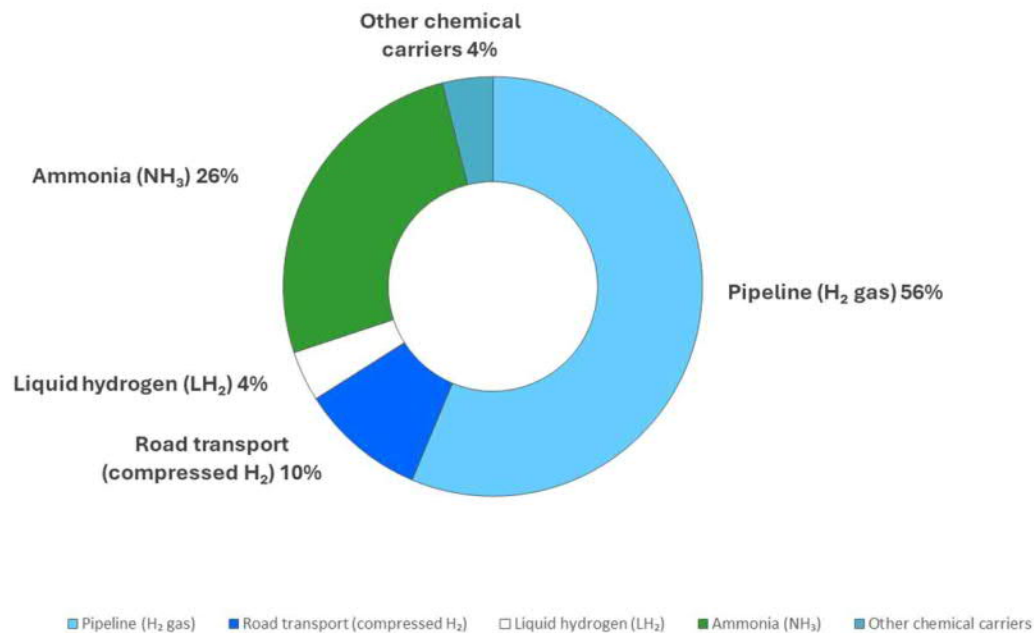
The Hydrogen Value Chain

Transport and Distribution



Transport and Distribution

Methods



The proportions shown are indicative system-level estimates, derived from IEA and industry sources, for visualization purposes



<https://www.h2inframap.eu/>

Pure H₂ or Blended H₂

100% Hydrogen @70 bars in dedicated pipelines

0% - 10% @70 bars blended with Methane in conventional gas grid lines

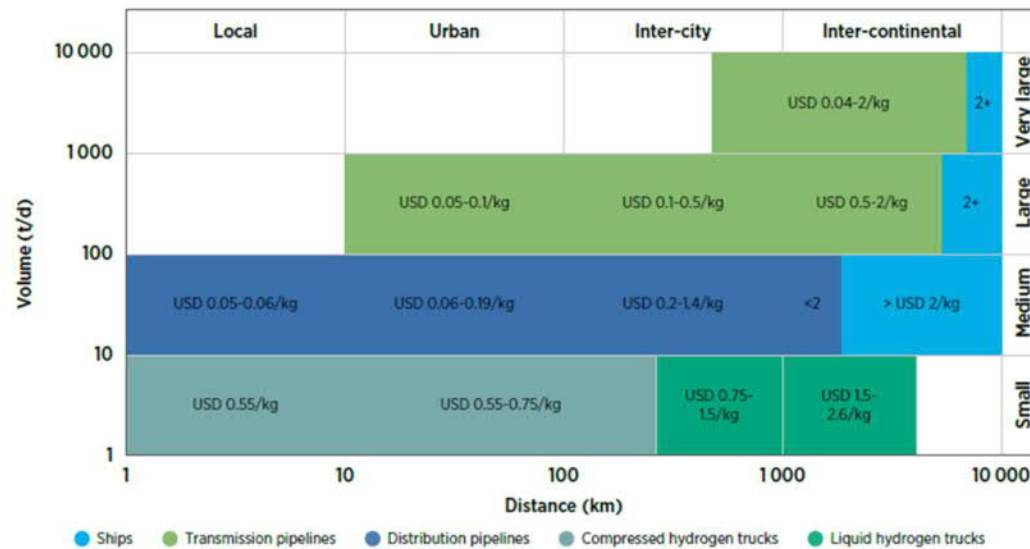
>10% @70 bars blended with Methane in recertified gas grid lines

(WARNING: distribution lines can include domestic users)

Transport and Distribution

Costs

Hydrogen transport cost based on distance and volume (2022)



Source: IRENA Global Trade Hydrogen 2022

Factors affecting Storage Costs

- Physical state
- Transportation Method
- Project size
- Transport Distance
- Infrastructures
- Preparation plant (e.g.: LOHC charging)
- Reconversion plants (e.g.: NH3 cracking)

Ships: Ammonia as Carrier

LH2 Ship Capacity	
Volume	H2 equivalent
operating 1250 m3	90 t H2-eq
future (expected) 40000 m3	2840 t H2-eq

NH3 Ship capacity	
Volume	H2 equivalent
operating 60000 m3	7300 t H2-eq
delivery 2026 93000 m3	11000 t H2-eq

Hydrogen Transport – Sustainability Check



P = Pipelines; S = Ships; T = Trucks

SUSTAINABILITY DIMENSIONS	SIMPLIFIED PARAMETER for CHECK	GOOD	MID	POOR
Industrial & Operational	TECHNOLOGICAL MATURITY	P T		S (LH2)
Economic	PRODUCTION COST	P (by capacity)	T (by capacity)	S (by capacity)
Environmental	EMISSION INTENSITY (CO2) GEOGRAPHICAL INDEPENDENCY	- S T	- P	-
Regulatory & Policy	REGULATORY COMPLIANCE	P T		S (still to be defined)
Market & Product	PRODUCT DEMAND	-	-	-
Social & Workforce	SAFETY COMMUNITY ACCEPTANCE	P T (low visibility)	T S? (still to be checked)	S P (perception)
Governance & Risk Management	SUPPLY CHAIN RISKS TAXES	P T -	S -	
Asset Longevity & Capital Preservation	DURABILITY	P	S T	
Adaptability & Optionality	POSSIBLE REVAMP/MODERNIZATION	P S T		
Financial Self-Sufficiency	INDEPENDENCY from SUBSIDIES	S T	P (public financing)	

The Hydrogen Value Chain

Bottlenecks



Bottlenecks



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4 topics (and their rationales) to think about

→ **Storage capacity**

(Green) Hydrogen chain has developed from the need to store intermittent renewable energy: production capacity must have a suitable storage capacity to allow continuous steady operations

→ **Transportation efficiency (quality/quantity)**

Hydrogen must be available where there are the (large) infrastructures that can use it

→ **End user design**

Use of Hydrogen as fuel is not efficient: heat energy vs. electric energy; end users not designed for its use (e.g.: airplanes, domestic ovens). Best efficiency for Chemical industry end use

→ **Existing Infrastructures (and their ownership)**

New infrastructures are required (ports, cracking plants, distribution pipelines,...) while existing infrastructures (refineries, conventional chemical plants,...) must be still amortized in many cases

→ **National/Regional Policies (for or against):**

National interests can drive onwards or backwards the development of a decarbonized world

04.

Competition

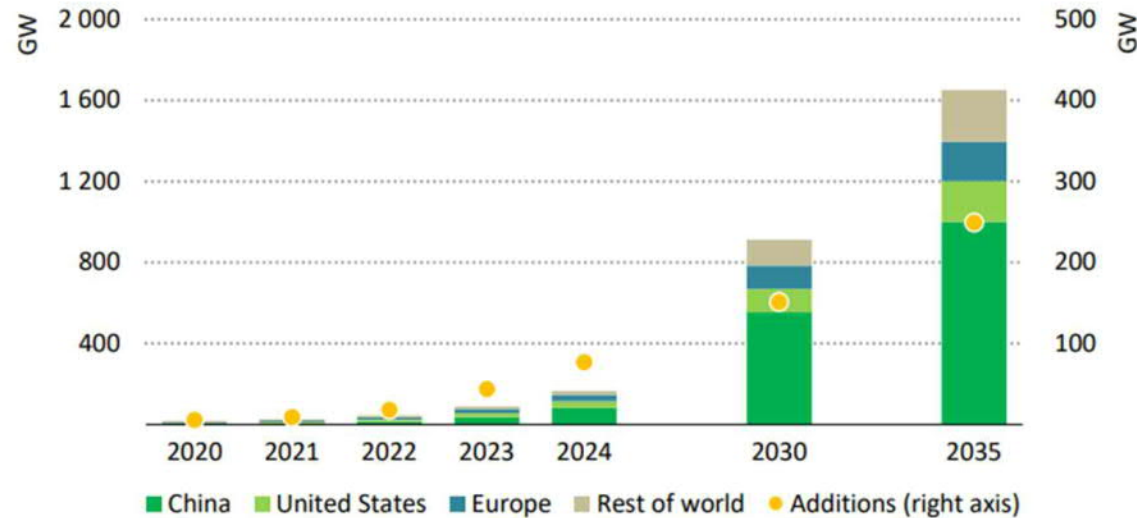


Competition: Electricity with BESS

Battery Energy Storage System



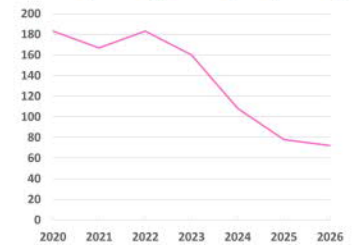
Global installed battery storage capacity and additions, 2020-2024, and in the STEPS*, 2030 and 2035



* Stated Policies Scenarios

Source: IEA World Energy Outlook 2025

Battery Storage Cost (USD/MWh)



Source: BloombergNEF

Technology	% Installed
Lithium Iron Phosphate	75-80%
Lithium Ni Mn Co Oxide	10-15%
Lithium Ni Co Al Oxide	10-15%
Flow batteries (VRFB)	2-5%
Sodium-based (NaS + Na-ion)	<1-2%

BESS – Sustainability Check

SUSTAINABILITY DIMENSIONS	SIMPLIFIED PARAMETER for CHECK	GOOD	MID	POOR
Industrial & Operational	TECHNOLOGICAL MATURITY		X	
Economic	PRODUCTION COST		X	
Environmental	EMISSION INTENSITY (CO2) GEOGRAPHICAL INDEPENDENCY	X X		
Regulatory & Policy	REGULATORY COMPLIANCE	X		
Market & Product	PRODUCT DEMAND	X (energy)		
Social & Workforce	SAFETY COMMUNITY ACCEPTANCE	X X		
Governance & Risk Management	SUPPLY CHAIN RISKS TAXES	*	X (Lithium)	
Asset Longevity & Capital Preservation	DURABILITY		X ?	
Adaptability & Optionality	POSSIBLE REVAMP/MODERNIZATION	?	X	
Financial Self-Sufficiency	INDEPENDENCY from SUBSIDIES	X		

* Not Yet...

05.

Conclusions (Key Takeaways)



Conclusion

Key Takeaways



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→ Sustainability has many dimensions (integrated sustainability)

Despite being widely referenced, ESG alone is not sufficient to define a project's sustainability

→ Green Hydrogen Value Chain has yet to increase in integrated sustainability

Conventional grey solutions are still strong in economic competition: policy support is essential for a sustainable future, at least during transition

→ There is no single, universally optimal solution; rather, an effective approach relies on a combination of solutions optimized for the specific circumstances

Solutions that appear very "green" can, under a broader life-cycle perspective, be more harmful

→ Hydrogen solves specific problems that electricity alone cannot — but it should be used only where it adds system value

"Hydrogen Value Chains" does not mean "Green Value Chain" by itself. Other technologies can be merged and other, further ones, must be developed, to ensure a fully integrated sustainable Green Value Chain

Food for thoughts (1)

Refineries could disappear in the future, replaced by a full green economy?

Maybe, but we live in the Plastic Age (with its C – Carbon - demon).

Further big steps are required...

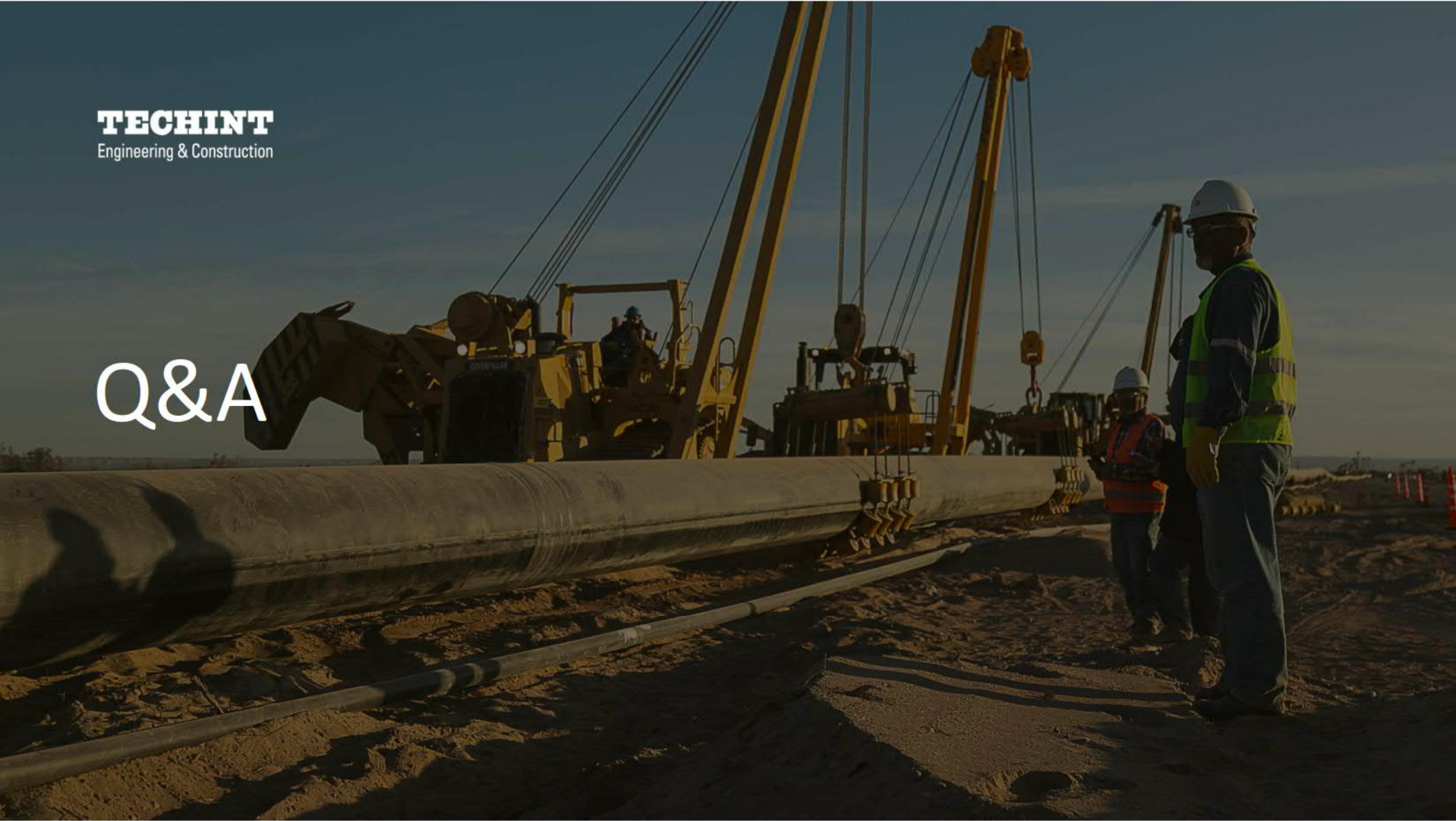
Food for thoughts (2)

Can renewable energies truly meet our ever-increasing energy demand?

The real constraint is not renewable production, but the system's capacity to integrate, store, and deploy it when required.

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Q&A



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