Delivering the EU hydrogen ambition

Hydrogen Council

10 May 2022
<table>
<thead>
<tr>
<th>20mt target needs doubling the announced project capacity</th>
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<tbody>
<tr>
<td>● To deliver on the cumulative target of 20mt of H2 in Europe by 2030 the European and the global industry should double their efforts</td>
</tr>
<tr>
<td>◦ Estimated export capacity gap: 5mt</td>
</tr>
<tr>
<td>◦ Estimated indigenous RE H2 production gap: 6mt</td>
</tr>
<tr>
<td>● Global export capacity is ramping up targeting primarily Asian markets</td>
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<table>
<thead>
<tr>
<th>The industry is ready to deliver</th>
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<tbody>
<tr>
<td>● Announced clean hydrogen production capacity more than doubled since January 2021</td>
</tr>
<tr>
<td>● Out of 328 mature projects in Europe 94,6% awaiting FIDs</td>
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<table>
<thead>
<tr>
<th>Rapid and decisive policy action is key</th>
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<tbody>
<tr>
<td>● In order to unlock Europe’s hydrogen potential and imports from third countries, we need</td>
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<tr>
<td>1. Accelerated funding support rollout</td>
</tr>
<tr>
<td>2. Security of demand and regulatory certainty (e.g. quotas, targets)</td>
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<tr>
<td>3. Pragmatic qualification requirements for RE H2 and H2 imports (Delegated Acts on RFNBOs)</td>
</tr>
<tr>
<td>4. Support harmonisation of standards &amp; certification systems internationally</td>
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</table>
Mind the gap: 11 MT p.a. H₂ required on top of announcements by 2030 with 5 MT p.a. from imports

Cumulative production capacity EU, MT p.a.

- Low-carbon
- Renewable
- Import
- Domestic

Gap vs domestic ambition:
- 2025: 2 MT p.a.
- 2030: 8 MT p.a.

EU 2030 domestic ambition:
- 10 MT p.a.

Export announcements likely to reach the EU:
- 5 MT p.a.

Gap vs import ambitions:
- 20 MT p.a.

EU 2030 total ambition:
- 20 MT p.a.

1. Includes export-oriented projects in countries likely to export to EU+UK: Argentina, Brazil, Kazakhstan, UAE, Oman, Saudi Arabia, Egypt, South Africa, Lebanon
2. Includes export-oriented projects in countries unlikely to export to EU+UK: Australia, Chile

Source: Hydrogen project tracker, as of April 2022, McKinsey
Not all announced export volumes likely to land in the EU – a number of exporters targeting mainly Asian markets

List of announced hydrogen export projects

<table>
<thead>
<tr>
<th>Country</th>
<th>COD</th>
<th>Capacity (ktonpa)</th>
<th>Carrier</th>
<th>H₂ pathway</th>
<th>Project name</th>
<th>Destination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norway</td>
<td>2025</td>
<td>198</td>
<td>NH3</td>
<td></td>
<td>Barens Blue</td>
<td>EU</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>2024</td>
<td>n/a</td>
<td>Not disclosed</td>
<td></td>
<td>Scot2Ger</td>
<td>EU</td>
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<tr>
<td>Oman</td>
<td>2022</td>
<td>238</td>
<td>NH3</td>
<td></td>
<td>Acme Oman</td>
<td>Uncertain</td>
</tr>
<tr>
<td>Oman</td>
<td>2038</td>
<td>1750</td>
<td>NH3</td>
<td></td>
<td>Oman 25 GW</td>
<td>Uncertain</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>2025</td>
<td>237</td>
<td>NH3</td>
<td></td>
<td>Helios (Neom)</td>
<td>Uncertain</td>
</tr>
<tr>
<td>Argentina</td>
<td>2030</td>
<td>2200</td>
<td>Not disclosed</td>
<td></td>
<td>Argentina 15 GW</td>
<td>Uncertain</td>
</tr>
<tr>
<td>Brazil</td>
<td>2025</td>
<td>615</td>
<td>LOHC</td>
<td></td>
<td>Base One</td>
<td>Uncertain</td>
</tr>
<tr>
<td>Canada</td>
<td>2027</td>
<td>198</td>
<td>NH3</td>
<td></td>
<td>Petronas Alberta</td>
<td>Unlikely EU</td>
</tr>
<tr>
<td>Australia</td>
<td>2025</td>
<td>361</td>
<td>NH3</td>
<td></td>
<td>H₂ Hub Gladstone</td>
<td>Unlikely EU</td>
</tr>
<tr>
<td>Australia</td>
<td>2026</td>
<td>198</td>
<td>NH3</td>
<td></td>
<td>BP Lightsource JV Australia</td>
<td>Unlikely EU</td>
</tr>
<tr>
<td>Australia</td>
<td>2028</td>
<td>460</td>
<td>LH2 / NH3</td>
<td></td>
<td>Murchison Renewable H₂</td>
<td>Unlikely EU</td>
</tr>
<tr>
<td>Chile</td>
<td>2026</td>
<td>150</td>
<td>NH3</td>
<td></td>
<td>HNH</td>
<td>Unlikely EU</td>
</tr>
<tr>
<td>Chile</td>
<td>2027</td>
<td>250</td>
<td>NH3</td>
<td></td>
<td>ACH – MRP</td>
<td>Unlikely EU</td>
</tr>
</tbody>
</table>
Europe: 328 $\text{H}_2$ mature projects to date
94.6% of projects awaiting FID

46% of global $\text{H}_2$ projects are located in Europe
88% of clean $\text{H}_2$ projects in Europe are renewable $\text{H}_2$

<table>
<thead>
<tr>
<th>Region</th>
<th>Number of $\text{H}_2$ projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td>328</td>
</tr>
<tr>
<td>North America</td>
<td>101</td>
</tr>
<tr>
<td>China</td>
<td>83</td>
</tr>
<tr>
<td>Australia</td>
<td>54</td>
</tr>
<tr>
<td>Latin America</td>
<td>26</td>
</tr>
<tr>
<td>Rest of world</td>
<td>119</td>
</tr>
</tbody>
</table>

1. Includes: at FID, under construction, operational

Source: Hydrogen project tracker
Rapid and decisive policy action is key

1. Provide security of demand and regulatory certainty (e.g. quotas, targets)
2. Adopt pragmatic qualification requirements for RE H2 and H2 imports (Delegated Acts on RFNBOs)
3. Accelerate funding support rollout
4. Support harmonisation of standards & certification systems at international level
Annex
Insights from the Hydrogen Council database:
520 projects gaining momentum around the world

- **43** Giga-scale production
  Renewable H₂ projects >1 GW, low-carbon H₂ projects >200 ktpa

- **221** Large-scale industrial usage
  Refinery, ammonia, methanol, steel, and industry feedstock

- **133** Transport
  Trains, ships, trucks, cars and other hydrogen mobility applications

- **74** Integrated H₂ economy
  cross-industry, and projects with different types of end-uses

- **51** Infrastructure projects
  H₂ distribution, transportation, conversion, and storage
Global export capacity ramping up
7 MTp.a. announced by 2030

Fraction renewable capacity

- Low-carbon
- Renewable

<table>
<thead>
<tr>
<th>Year</th>
<th>Low-carbon</th>
<th>Renewable</th>
</tr>
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<tbody>
<tr>
<td>2020</td>
<td>0</td>
<td>&lt;1</td>
</tr>
<tr>
<td>2021</td>
<td>0</td>
<td>&lt;1</td>
</tr>
<tr>
<td>2022</td>
<td>22</td>
<td>1</td>
</tr>
<tr>
<td>2023</td>
<td>24</td>
<td>2</td>
</tr>
<tr>
<td>2024</td>
<td>25</td>
<td>1</td>
</tr>
<tr>
<td>2025</td>
<td>26</td>
<td>2</td>
</tr>
<tr>
<td>2026</td>
<td>27</td>
<td>3</td>
</tr>
<tr>
<td>2027</td>
<td>28</td>
<td>4</td>
</tr>
<tr>
<td>2028</td>
<td>29</td>
<td>5</td>
</tr>
<tr>
<td>2029</td>
<td>2030</td>
<td>7</td>
</tr>
</tbody>
</table>

- 86% Low-carbon
- 90% Renewable
- 88% Low-carbon
- 91% Renewable
- 92% Low-carbon
- 94% Renewable
Announced clean hydrogen production capacity more than doubled since January 2021

Cumulative production capacity, MT p.a.

1. Preliminary studies or at press announcement stage
2. Feasibility study, front-end engineering and design stage, final investment decision has been taken, under construction, commissioned

3x capacity
increase in capacity announced in the past 9 months

93 GW
electrolysis capacity by 2030 announced

+13.2 MT
additional capacity (low-carbon and renewable) announced for post-2030
Hydrogen History is Made January 2022

Left Kobe for Australia on December 24th, 2021

Maiden Voyage Ceremony at Port of Hastings on January 21st, 2022

Return to Kobe in March, 2022

1869 Oil (153y)
1959 LNG (63 yrs)
2022 Hydrogen
H₂ carriers

Key insights

- Hydrogen carrier costs are comparable
- Well-established practices give ammonia an early lead
- Scaling cost opportunity of liquid H₂ currently untapped
- Cost-curve uncertainty over LOHC

H₂ imports to Western Continental Europe

Unit landed cost for Saudi Arabia to Western Continental Europe 2030, USD/kg H₂

1. About 77% of all losses occur in the re-conversion stage

Source: McKinsey Global Hydrogen Trade Model
Ammonia projects account for ~80% of 2025 H2 export projects

Renewable & low-carbon hydrogen planned for export by carrier type
% of total Mtpa H2

- NH3
- LH2
- LOHC
- Undecided

80% NH3 projects where carrier is decided

Non-exhaustive

International shipments of H2: completed and announced

- Successful pilot
- Planned export route, untested

Global trade routes are shaping up, while pilots are focused on Asia

World’s first foreign-origin H2
- Route: Brunei to Japan
- Carrier: LOHC (Methylcyclohexane)
- Year of shipment: 2019
- Load size: 210 t H2/year

World’s first low-carbon NH3 cargo
- Route: Saudi Arabia to Japan
- Carrier: Low-carbon NH3
- Year of shipment: 2020
- Load size: 40t NH3 (~7t of H2)

H2 Energy Supply Chain Pilot
- Route: Australia to Japan
- Carrier: LH2
- Year of shipment: 2022
- Load size: Pilot-phase capacity of 1,250m3 (~90 t LH2 capacity)

Source: Press search, Hydrogen project tracker, as of April 2022, McKinsey

1. Based on announced projects and estimated commissioning date
Costs of importing $\text{H}_2$ to Europe: 2-4 USD/kg by 2030

Hydrogen cost curve for selected exporters to Europe

<table>
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<tr>
<th>Unit landed cost 2030, USD/kg $\text{H}_2$</th>
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Key takeaways

- EU RES capacity likely to be insufficient to meet the EU ambition in a cost-effective manner.
- Pipeline supplies could be secured from Norway and Spain.
- Yet pipeline infrastructure unlikely to be operational by 2030.
- Importing shipped $\text{H}_2$ is likely to be more expensive.
- Sales price will likely be higher, being determined by demand curve, profit margins and the marginal producer.

1. Assuming availability of new hydrogen pipeline infra.

Source: McKinsey Global Hydrogen Trade Model
Infrastructure availability and constraints

Terminal & shipping capacity for LH₂ & LOHC due to be built
NH₃ infrastructure available at scale

**NH₃ Shipping currently available at scale**

**Terminals total capacity, in MMT/yr**

- **EU**: -1
- **Russia**: -3
- **Middle East**: -4
- **US**: -5
- **Chile**: 0
- **Australia**: 0
- **China**: 1
- **Japan**: 2
- **South Korea**: 3
- **India**: 3

**Ammonia ships, # of carriers available globally**

<table>
<thead>
<tr>
<th>Year</th>
<th>1970</th>
<th>75</th>
<th>80</th>
<th>85</th>
<th>90</th>
<th>95</th>
<th>2000</th>
<th>05</th>
<th>10</th>
<th>15</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>12</td>
<td>17</td>
<td>58</td>
<td>80</td>
<td>92</td>
<td>122</td>
<td>162</td>
<td>182</td>
<td>183</td>
</tr>
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**10 MMT/yr**

**2.5 mn m³**

- **Export terminal capacity globally, vs total potential global demand of ~275MMT by 2050**
- **Total carrier volume capacity**

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1. Based on 100% adoption in chemicals, power generation & maritime. Power and maritime could also adopt gaseous or liquid H₂.
2. Includes exports terminals in regions that do not have gas deposits, e.g. in Le Havre, France or Huelva, Spain, but with significant ammonia exports.

**Source:** Fertecon

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**LH₂:** First ships being launched in 2021

Starting LH₂ shipments in 2021 (75T) between Australia & Japan, following a $500M investment, by freezing H₂ to -253C, but due to small ship size likely insufficient to meet 2030 demand

**LOHC:** Initial trials, but no large-scale projects yet

Initial trial in 2020 of using toluene as energy carrier to ship LOHC from Brunei to Japan within a container, but not yet upscaled

**H₂:** No capacity available, with projects in R&D phase

Ambitions to develop new shipping type, based on CNG designs, for up to 2MT H₂, but still in R&D phase
Key constraints and risks

Over-regulation & lack of certainty stalling FIDs

Slow rollout of funding support

Security of demand

High inflation

Risk of recession

Market volatility

Constraints that can be addressed by immediate policy action
Who we are

Thought Leader

Unique Source of Global Industry Data

Trusted Partner to Global Organisations

Hydrogen for Net-Zero
A critical cost-competitive energy vector
November 2021
# Program Portfolio

<table>
<thead>
<tr>
<th>Program Portfolio</th>
<th>Description</th>
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</table>
| **Sustainability Program**                             | In collaboration with our international partners, facilitate the development of  
- International industry standards for assessment of H2 sustainability attributes  
- Robust tradeable certification systems  
- Reporting and disclosure standards |
| **Industry Evolution Program**                          | - Deliver insights into the evolution of the global industry based on data from >130 industrial leaders in hydrogen  
- Provide insights into tangible energy system-wide benefits of hydrogen  
- Identify cost-effective patterns for global cross-border trade in hydrogen |
| **Safety/Regulatory Program**                          | - In collaboration with our international partners, facilitate the development of international safety regulations, codes and standards for the industry  
- Foster knowledge sharing and best practice exchange in the industry |
| **Finance & Bankability Program**                       | - Address barriers to project financing through collaboration with the Council’s Investor Group members  
- Foster knowledge sharing and best practice exchange among international investors |
Unlocking social value of the hydrogen economy

Public-private cooperation will play a key role in unlocking the positive contribution that hydrogen can bring to several UN Sustainable Development Goals, including:

- **Good health and well being** ⇒ Reducing air pollution
- **Diversity, equity and inclusion** ⇒ Helping unlock diverse talent pool
- **Affordable and clean energy** ⇒ A clean and versatile energy vector
- **Decent work and economic growth**
  - Fuelling green growth & deliver sustainable jobs
  - Creating opportunities for indigenous communities through employment and new business creation
- **Industry, innovation and infrastructure** ⇒ Fostering decarbonization of the industry, innovation and deployment of clean infrastructure
- **Sustainable cities and communities** ⇒ Clean transportation and heating
  ⇒ Sustainable jobs for local communities
- **Climate action** ⇒ Key solution to decarbonizing economies