Net-Zero: The Emergence of an Ammonia Economy in Europe

Runeel Daliah, M.Sc.
Principal Analyst

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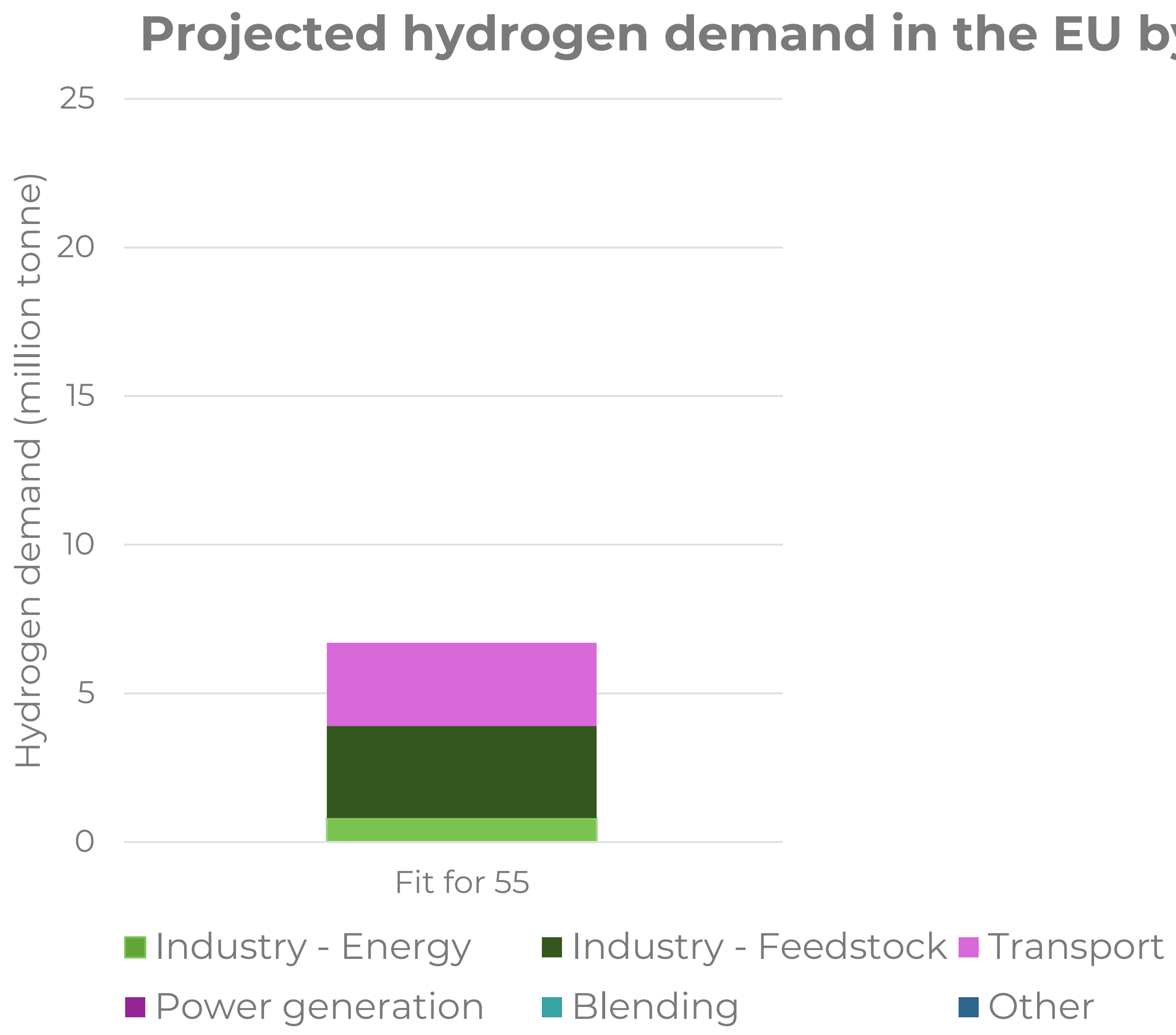
In 2021, the EU required 7 Mtonne of hydrogen by 2030



The Fit for 55 package is a legal obligation for the EU to reduce its emissions by at least 55% by 2030.

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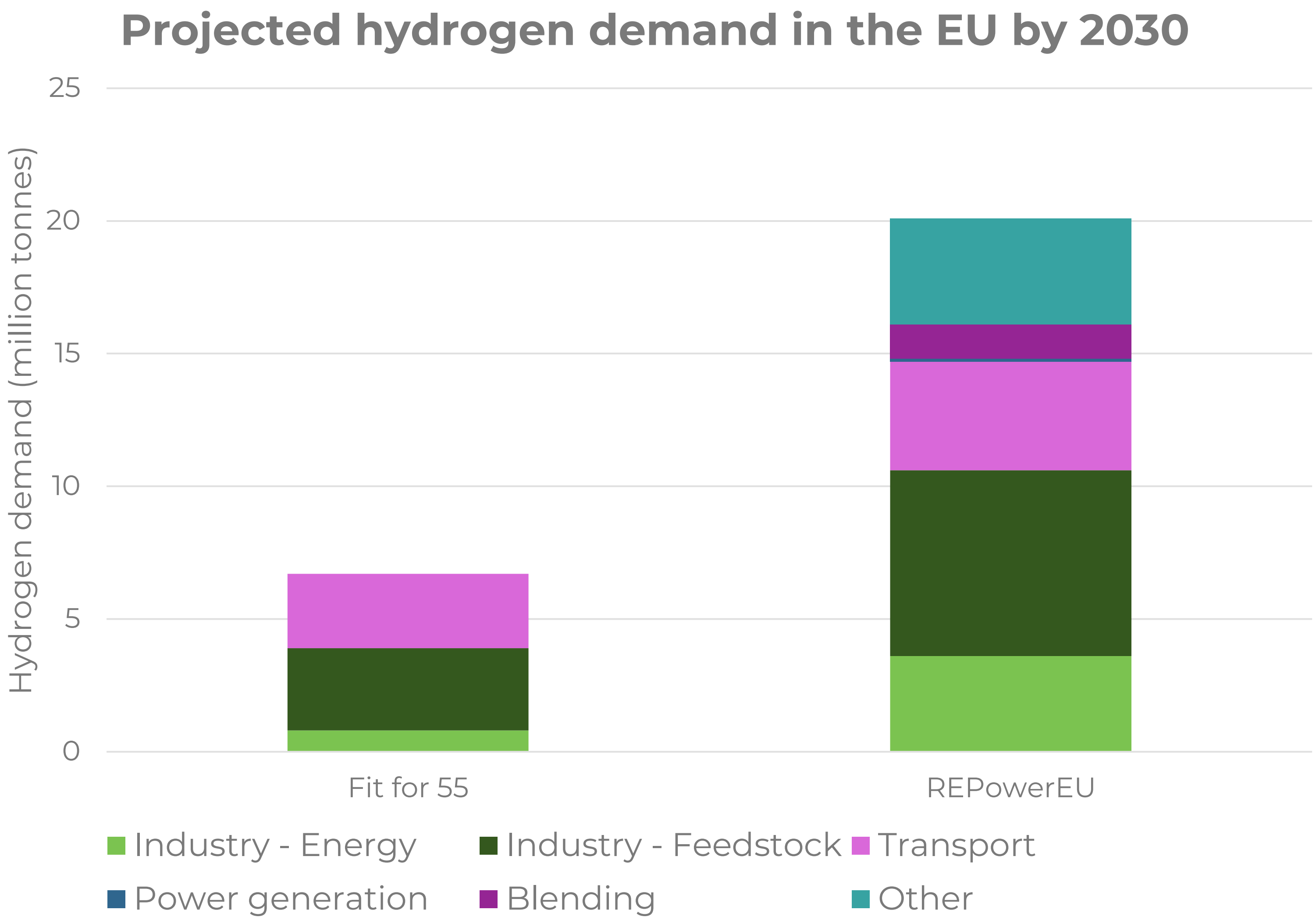
In 2022, the EU revised its demand to 20 Mtonne of hydrogen by 2030



REPowerEU is a plan to rapidly reduce reliance on Russian fossil fuels and accelerate the EU's transition to carbon-neutrality.

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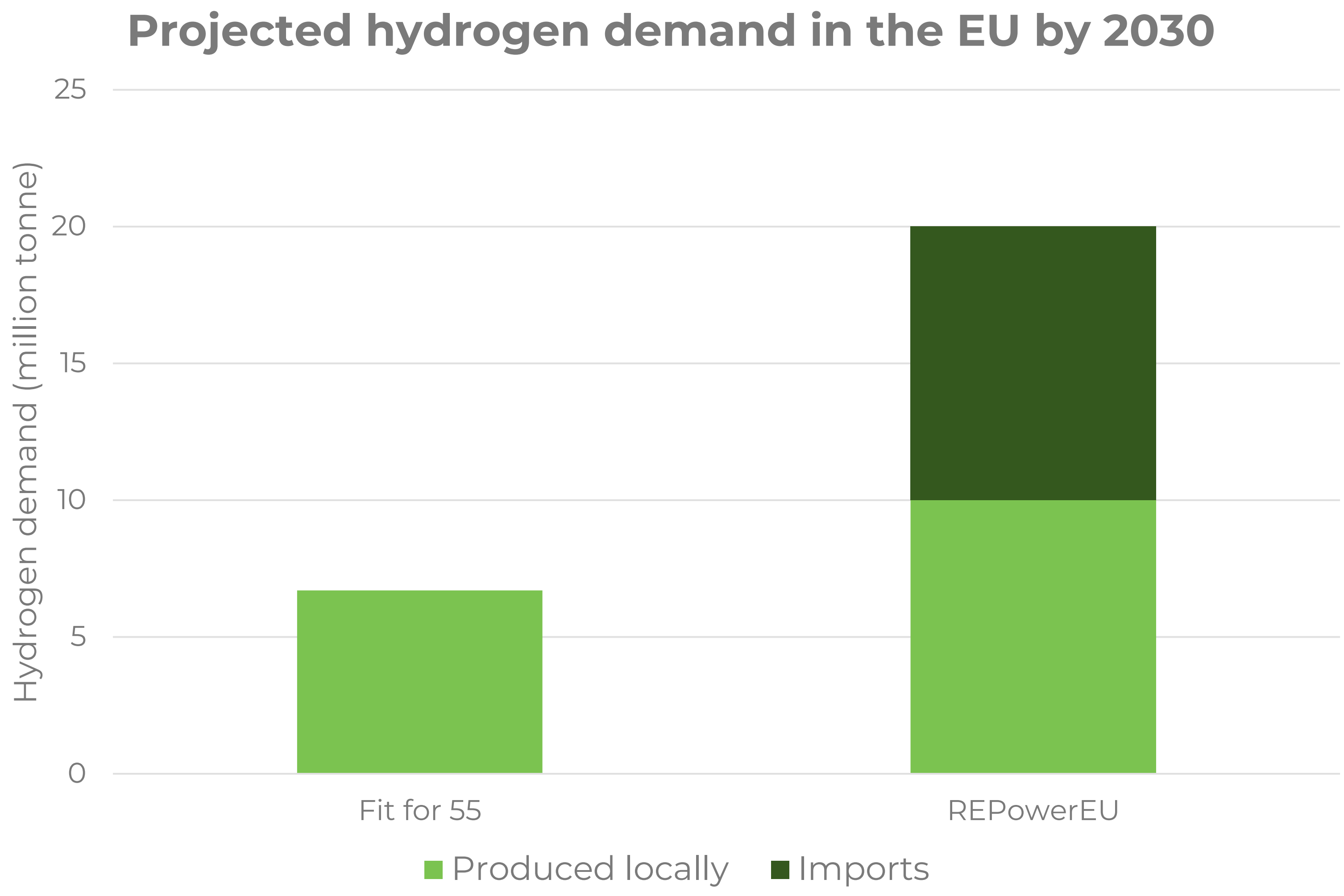
The EU will produce half of its hydrogen locally and import the rest



Up to 17.5 GW of electrolyzer manufacturing capacity is needed by 2025, at a cost of EUR 2 billion.

In addition, the EU will import up to 10 Mtonne of hydrogen by 2030.

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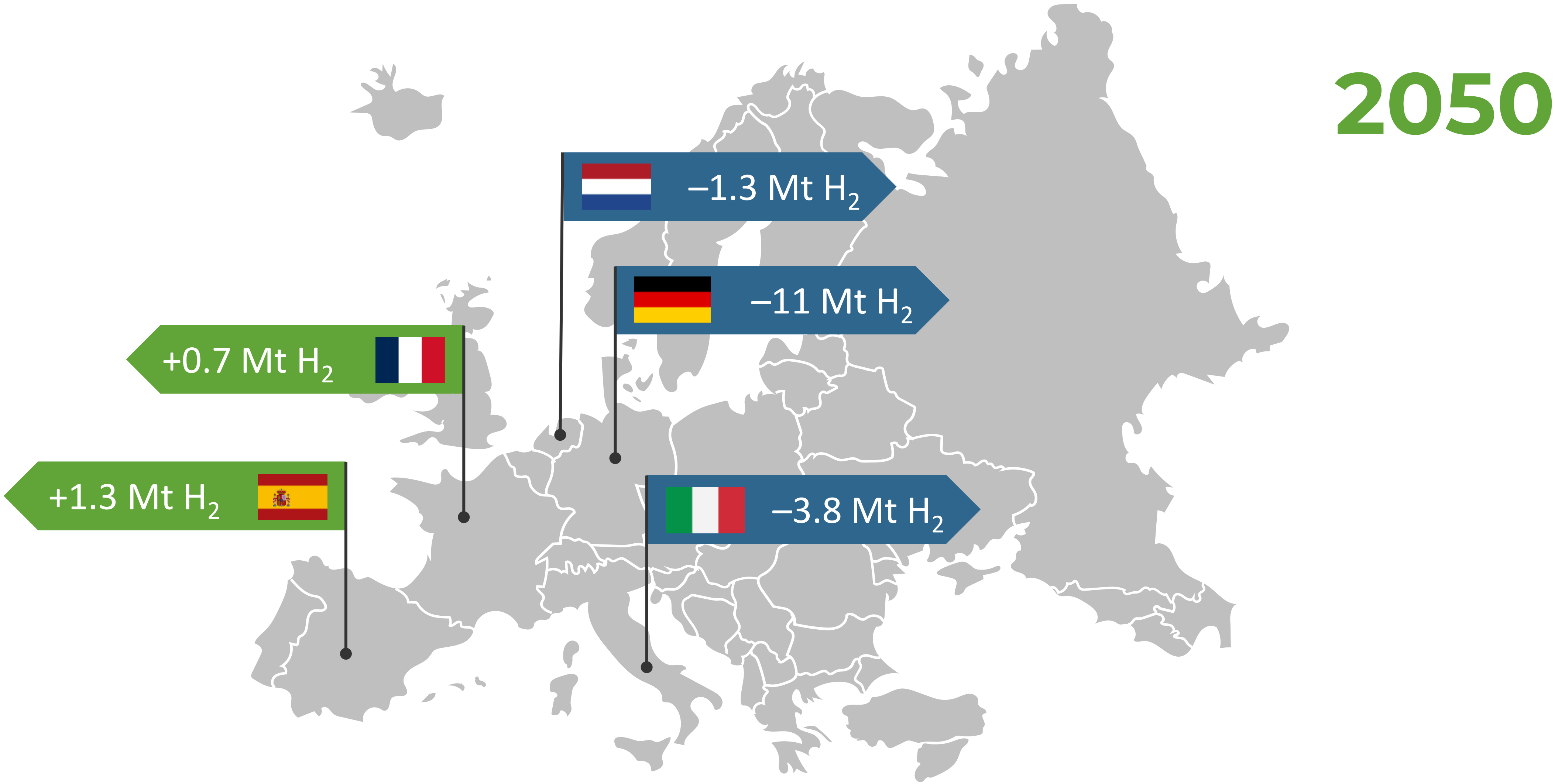
Some countries will be net importers, while others will be net exporters



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Source: World Energy Council, "Decarbonized hydrogen imports into the European Union: Challenges and opportunities" (2021).

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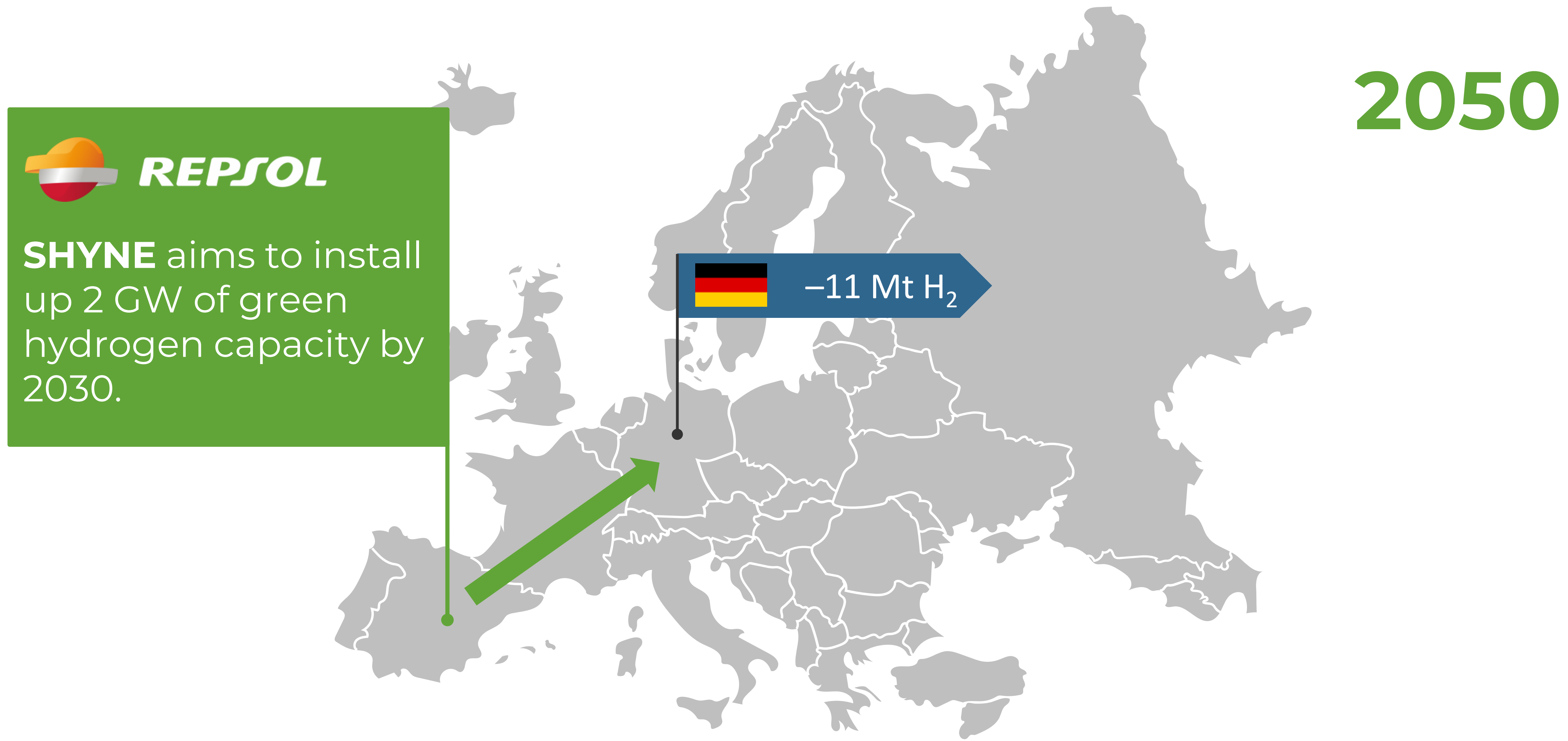

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Source: World Energy Council, "Decarbonized hydrogen imports into the European Union: Challenges and opportunities" (2021).

The EUR 3 billion **H2MED** project consists of two pipelines with a combined length of 700 km.

Approximately 2 Mtonne of hydrogen will be transported through the pipeline, which will connect Portugal, Spain, France, and Germany.

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Hydrogen pipelines

Drivers:

- Hydrogen pipelines have lower operating expenditures than other forms of long-distance hydrogen transport.
- Pipelines have extra-long lifetimes of above 50 years and low public visibility.

Barriers:

- Construction of a hydrogen pipeline infrastructure is highly capital intensive with quite long timelines.
- Once built, pipelines remain fixed and can’t be adjusted to cater to varying demand centers of hydrogen.
- Hydrogen pipelines require high utilization rates to be economically feasible and thus rely on the assurance of high trade volumes.

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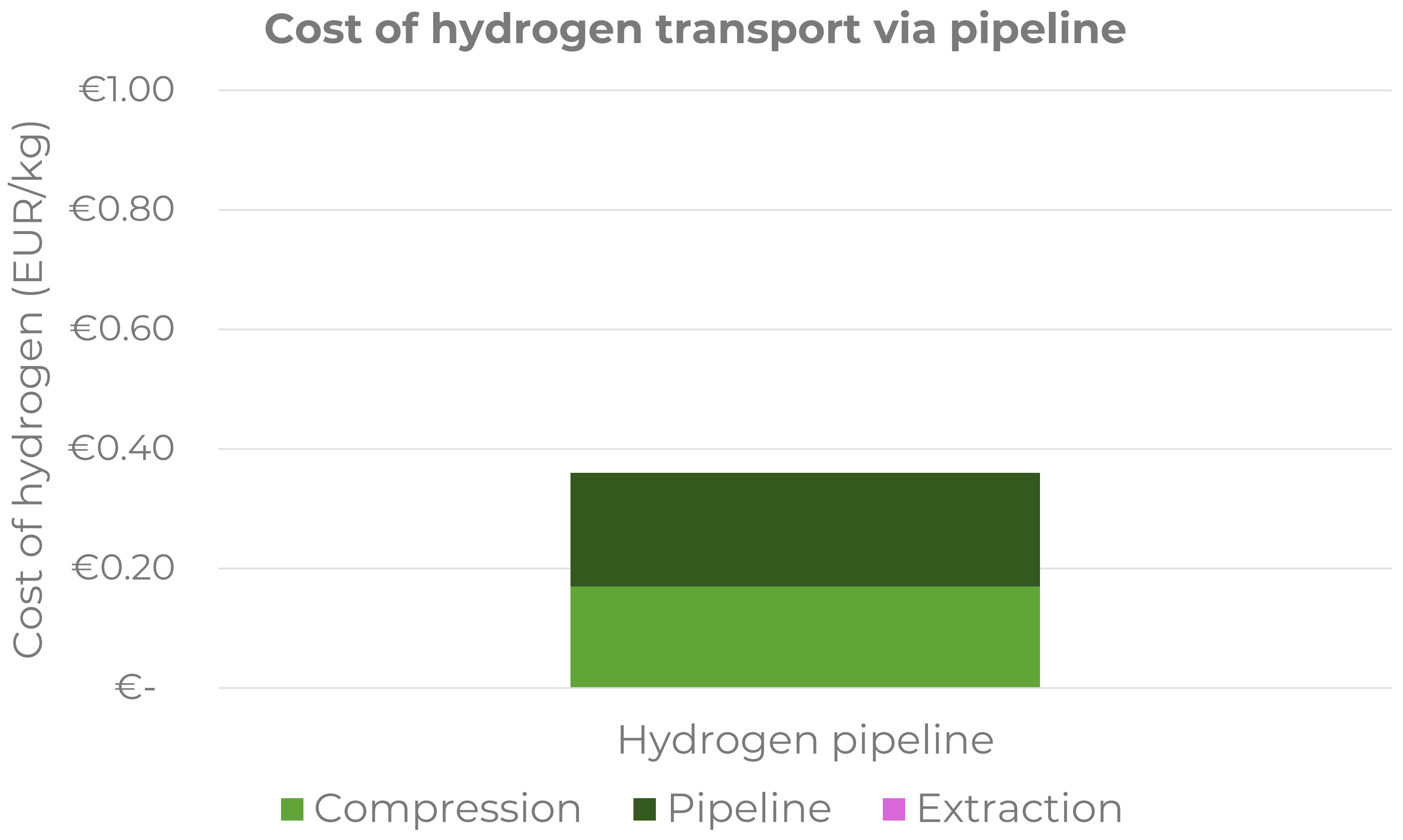
The cost of transporting pure hydrogen via pipeline is EUR 0.40/kg of hydrogen



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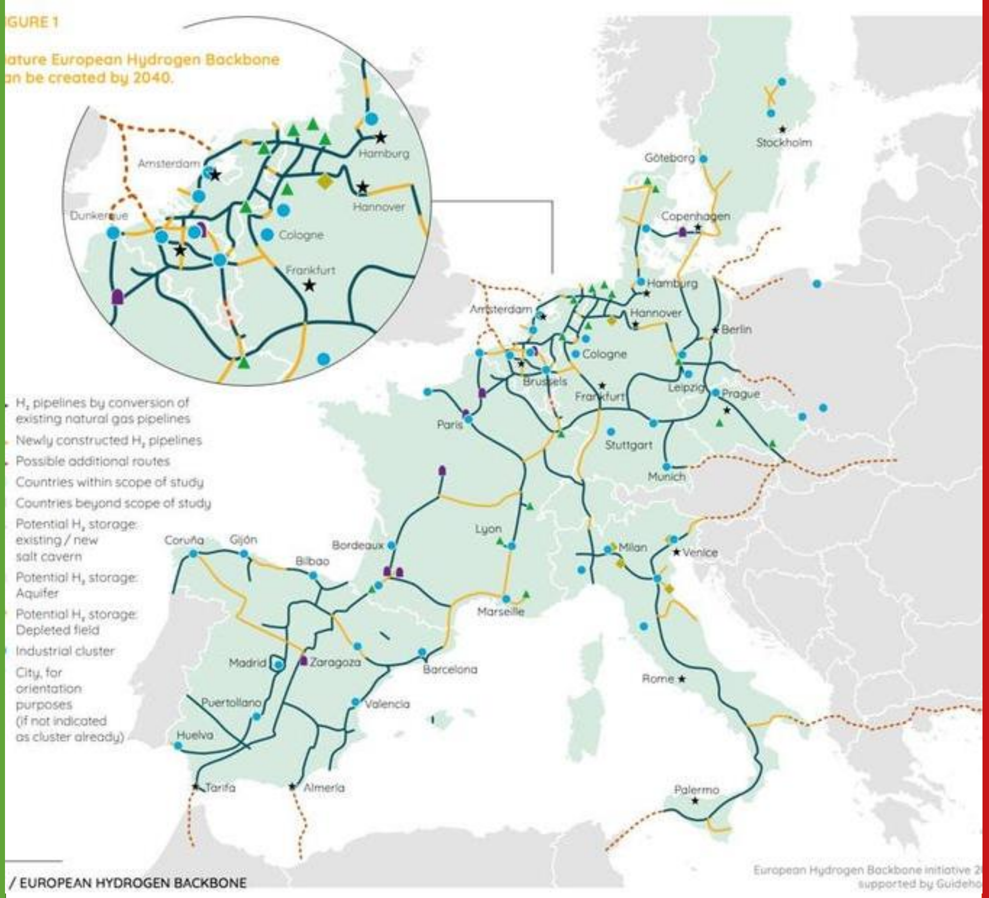
The **European Hydrogen Backbone** (EHB) provides a roadmap for an EU-wide network of hydrogen pipelines.

Backed by 32 energy infrastructure operators, the EHB aims to build new pipelines but also retrofit existing natural gas pipelines.



EUROPEAN HYDROGEN BACKBONE

Hydrogen blending

Drivers:

- Hydrogen blending uses existing natural gas infrastructure, thus eliminating investment in scaling up the distribution network.
- Natural gas pipelines already connect to industrial clusters, which will be the first adopters of hydrogen.

Barriers:

- Hydrogen can be blended only at a level of up to 20% without needing modifications.
- Blending hydrogen with natural gas reduces the energy content of the mixture, resulting in greater consumption of the natural gas.
- Extracting hydrogen from a mixture of natural gas is capital intensive, which will add to the cost.

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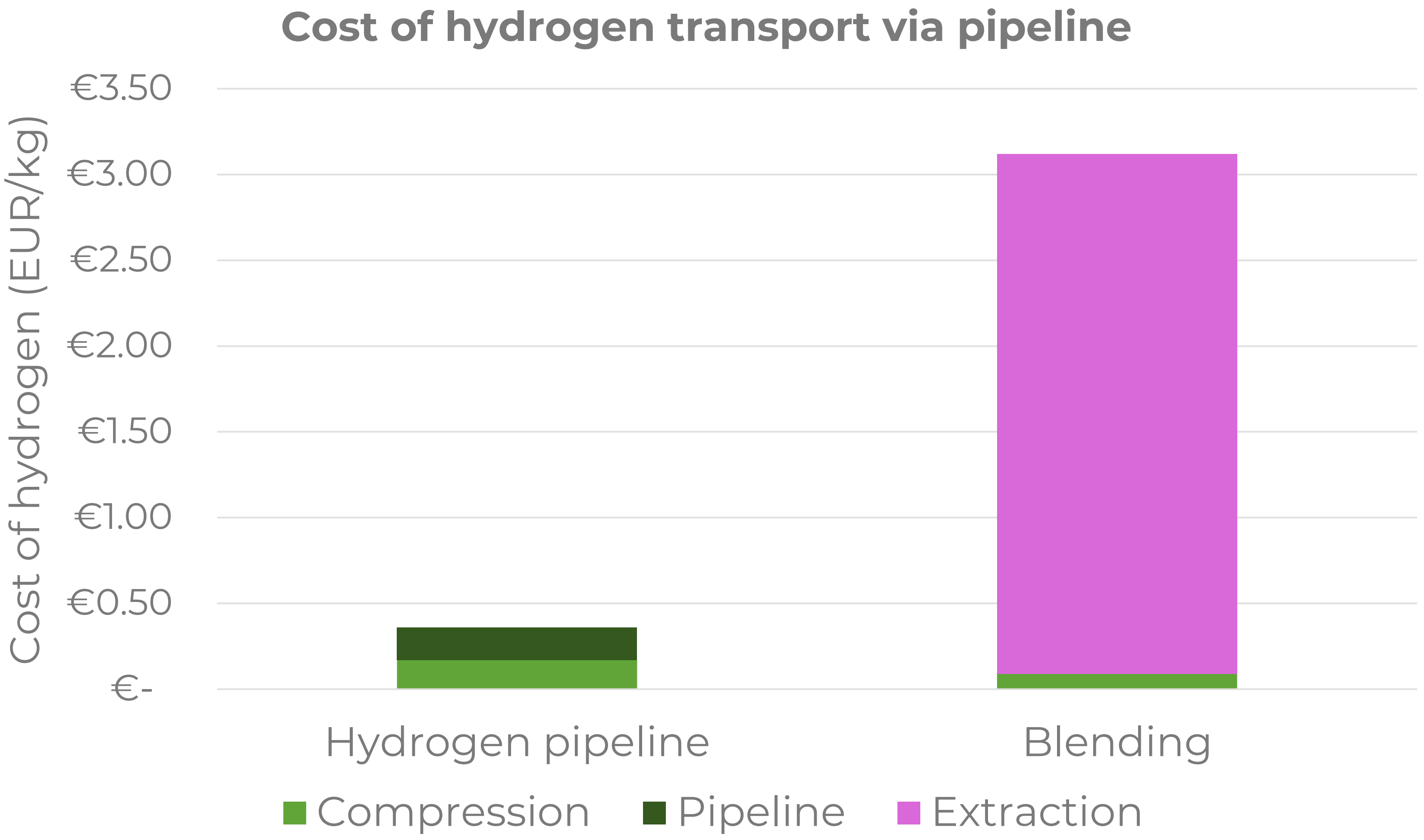
The cost of blending hydrogen at a level of 20% into a natural gas pipeline is EUR 3/kg of hydrogen



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CASE STUDY

DiviGas

Novel membrane manufacturer

- DiviGas develops hollow-fiber membranes cross-linking polybenzimidazole with sulfonate polymers to improve gas separation performance.
- Membrane can handle H_2 concentrations as low as 35% today; lower concentrations are possible in the future.

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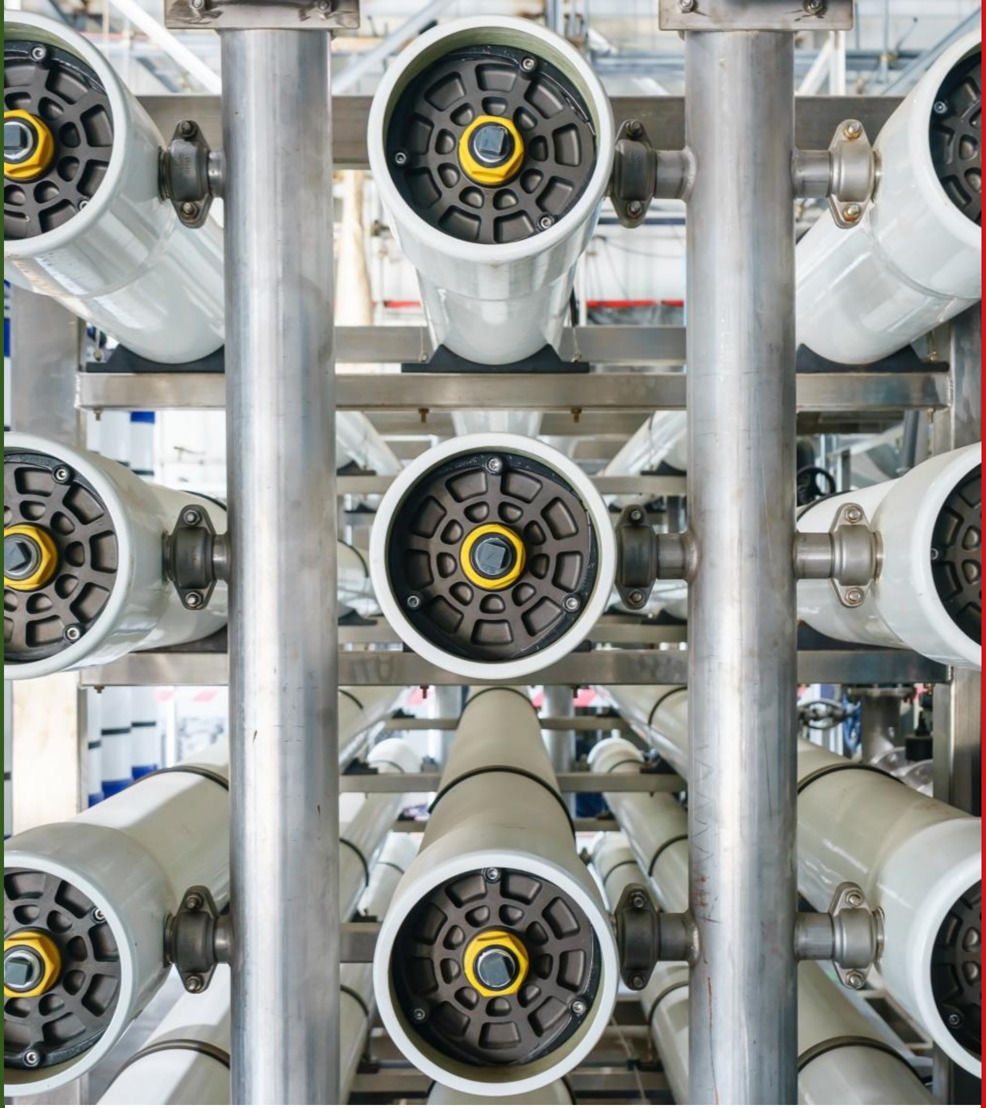
DiviGas produces its hollow-fiber membranes in a roll-to-roll process that it claims uses off-the-shelf equipment with minimal customization. The company is still at the pre-commercial stage, but its solution offers clear performance advantages over conventional separation techniques.



DIVI GAS

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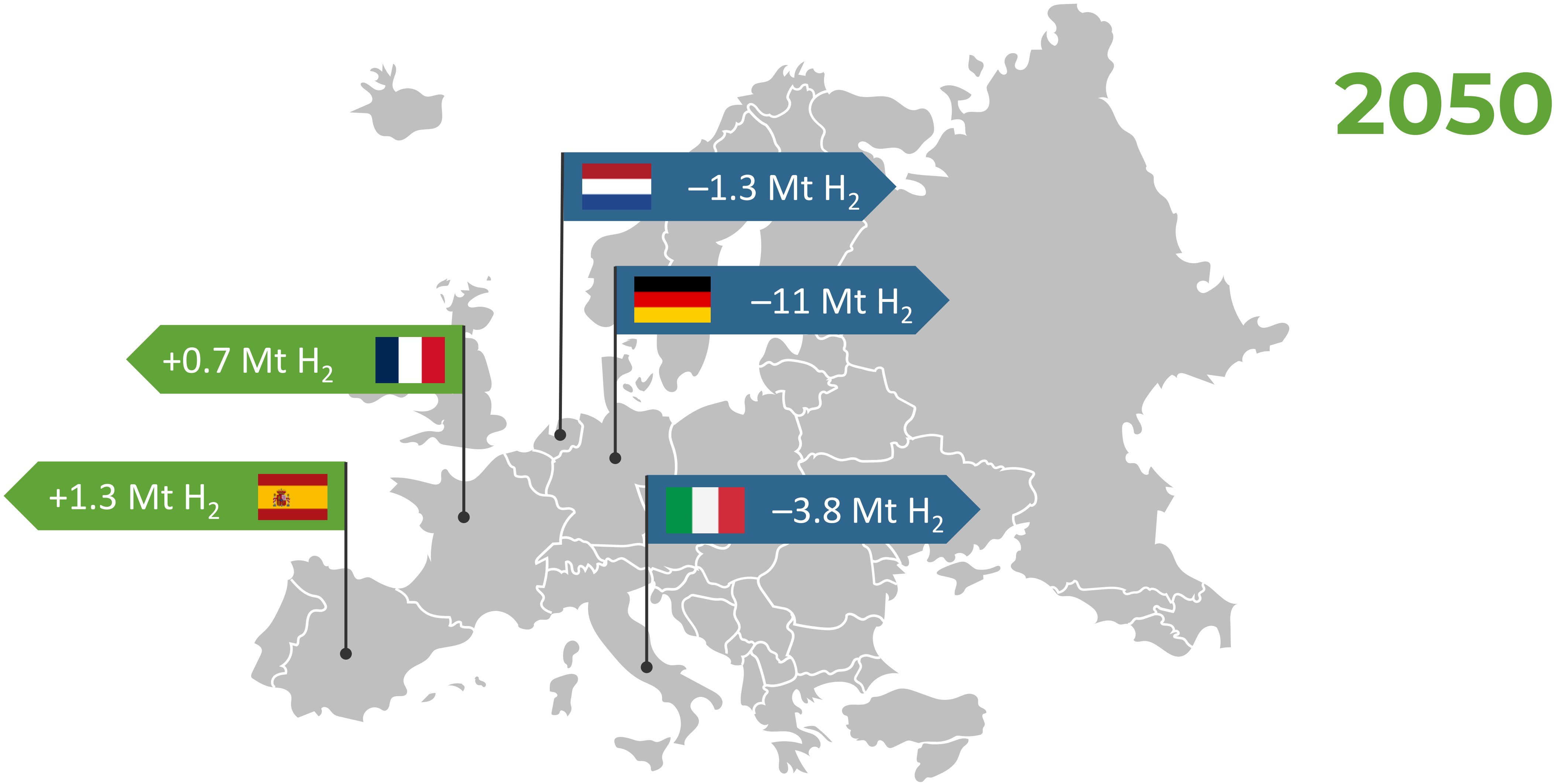

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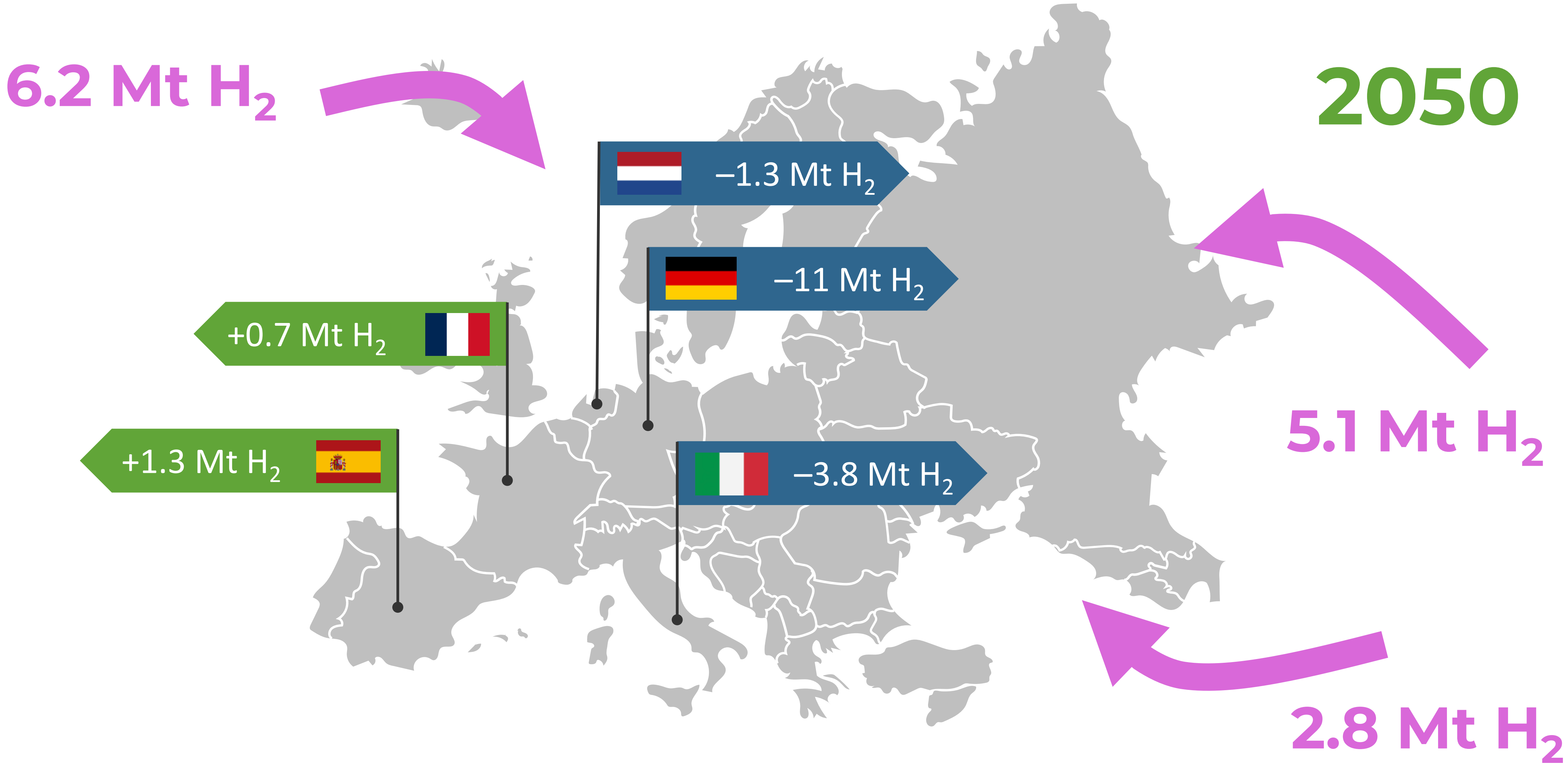
But that’s still not enough. You need international imports of hydrogen



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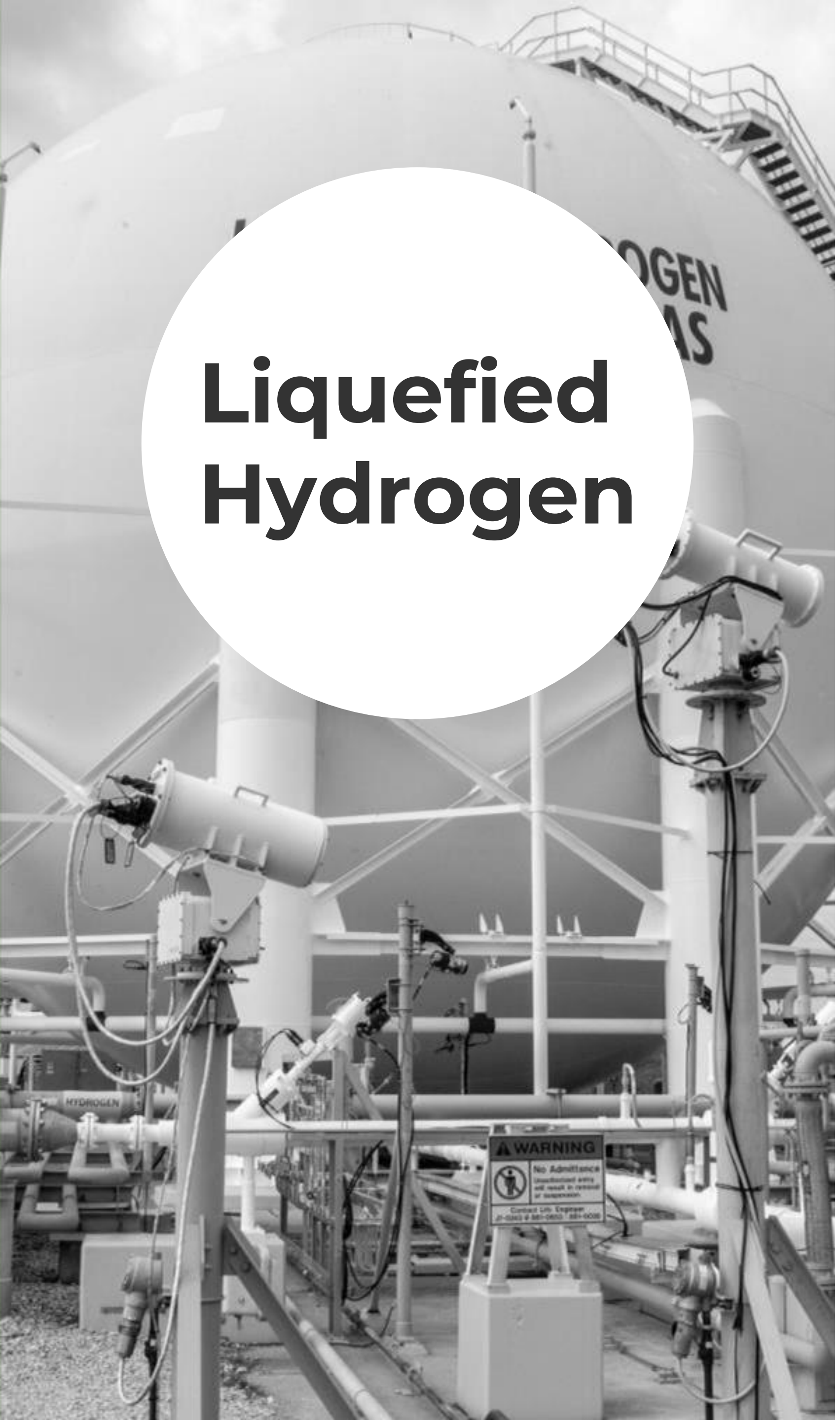
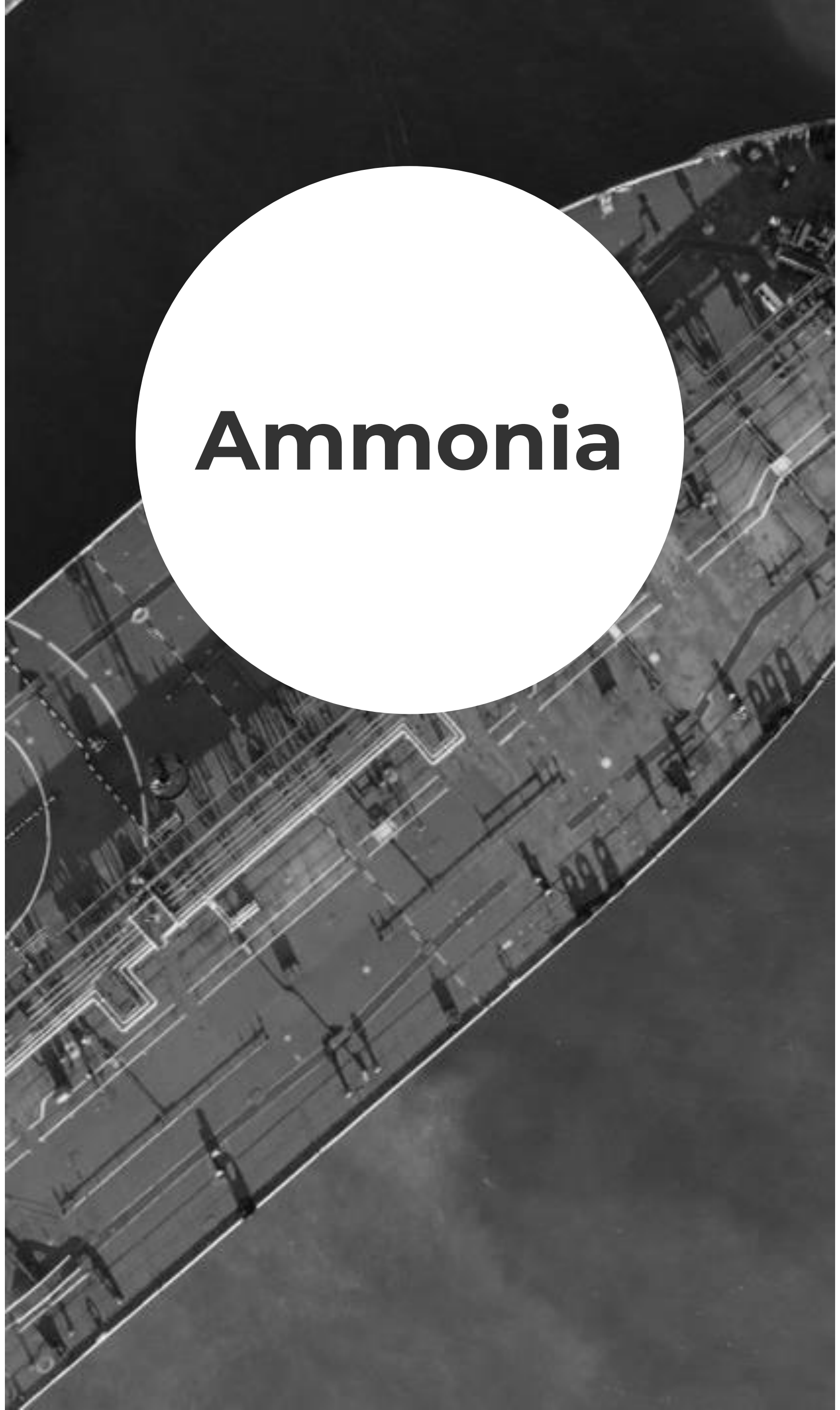
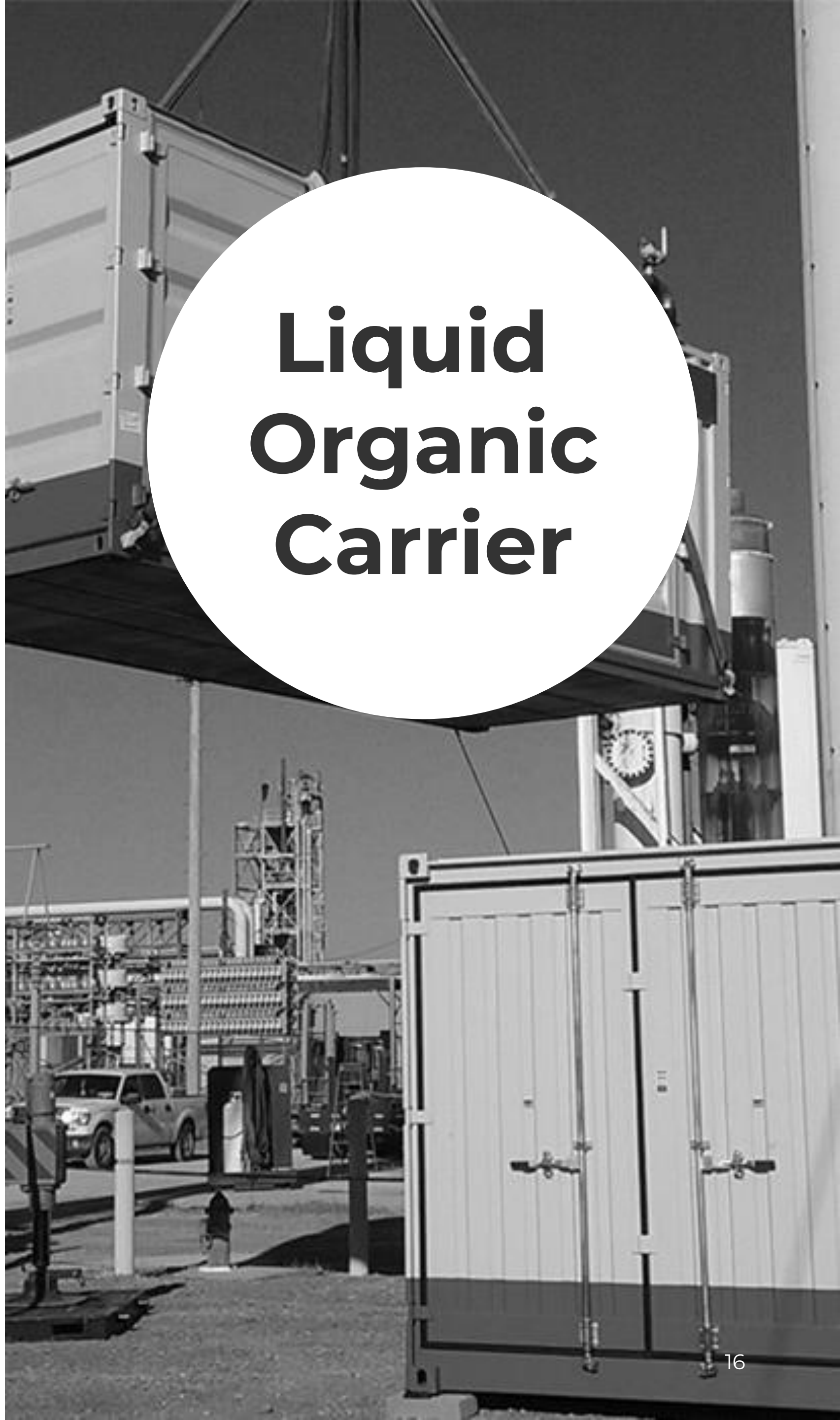
Source: World Energy Council, “Decarbonized hydrogen imports into the European Union: Challenges and opportunities” (2021).



Liquefied Hydrogen



Ammonia



Liquid Organic Carrier

Liquefied hydrogen

Drivers:

- Liquefied hydrogen has a high hydrogen density of 66 kg H_2/m^3 and is stored at ambient pressure.
- Liquefied hydrogen is pure hydrogen and thus doesn't have contamination risks.
- Liquefaction technology is well understood and, while not widely adopted yet, can be scaled up quickly.

Barriers:

- The low temperatures needed for liquefaction require a high amount of energy and lead to high rate of hydrogen loss through boil-off.
- Liquefied hydrogen can't utilize existing LNG infrastructure for transport and requires specialized tankers that aren't yet commercial.

Image source: NASA

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Anthony Veder, **Engie**, **Shell**, and **Vopak** will assess the feasibility of transporting liquefied hydrogen from Portugal to the Netherlands via the Port of Rotterdam.

The first shipment is due for 2027.

Image source: Port of Rotterdam

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Ammonia

Drivers:

- In its liquid state, ammonia has an exceptionally high hydrogen weight fraction.
- Ammonia is a globally traded commodity chemical and thus benefits from an already mature supply chain.
- Ammonia can, in principle, be combusted directly in gas turbines, removing the need for hydrogen extraction.

Barriers:

- Ammonia is highly toxic, which limits its adoption to port-to-port use — inland distribution and consumption are unlikely.
- Hydrogen extraction from ammonia is immature, energy intensive, and can result in trace ammonia contaminants in the hydrogen product.

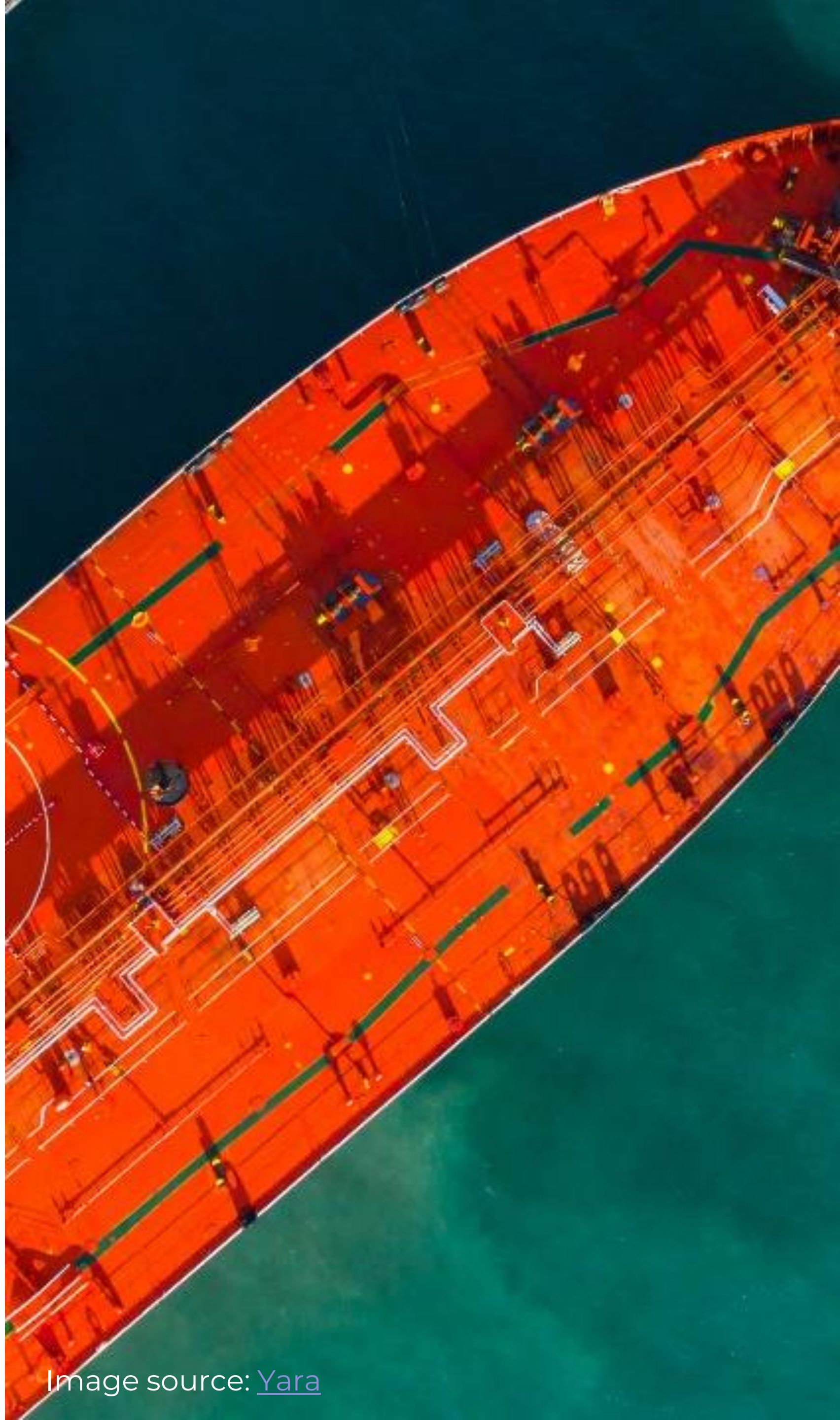

Image source: Yara

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Gasunie, **HES International**, and **Vopak** have signed an agreement to develop an import terminal for green ammonia at the Port of Rotterdam.

The terminal is expected to be operational by 2026.

Image source: [Port of Rotterdam]

Vopak

gasunie crossing borders in energy

HES International

Port of Rotterdam

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Liquid organic carrier

Drivers:

- Liquid organic hydrogen carriers (LOHCs) remain in liquid state at ambient pressure and temperature, minimizing hydrogen loss through leaks.
- LOHCs are compatible with existing hydrocarbon infrastructure and don't require new equipment.
- LOHCs have mild toxicity and flammability and can be used for inland storage and transport with minimal safety precautions.

Barriers:

- LOHCs can't be used directly and require hydrogen extraction, which is energy intensive.
- LOHCs require a concurrent scale-up of the manufacturing of the carrier material.

Image source: Hydrogenious LOHC Technologies

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EVOS, **Hydrogenious LOHC Technologies**, and the **Port of Amsterdam** will jointly develop LOHC import facilities at the port.

The facilities are expected to be operational by 2028


Image source: Port of Amsterdam

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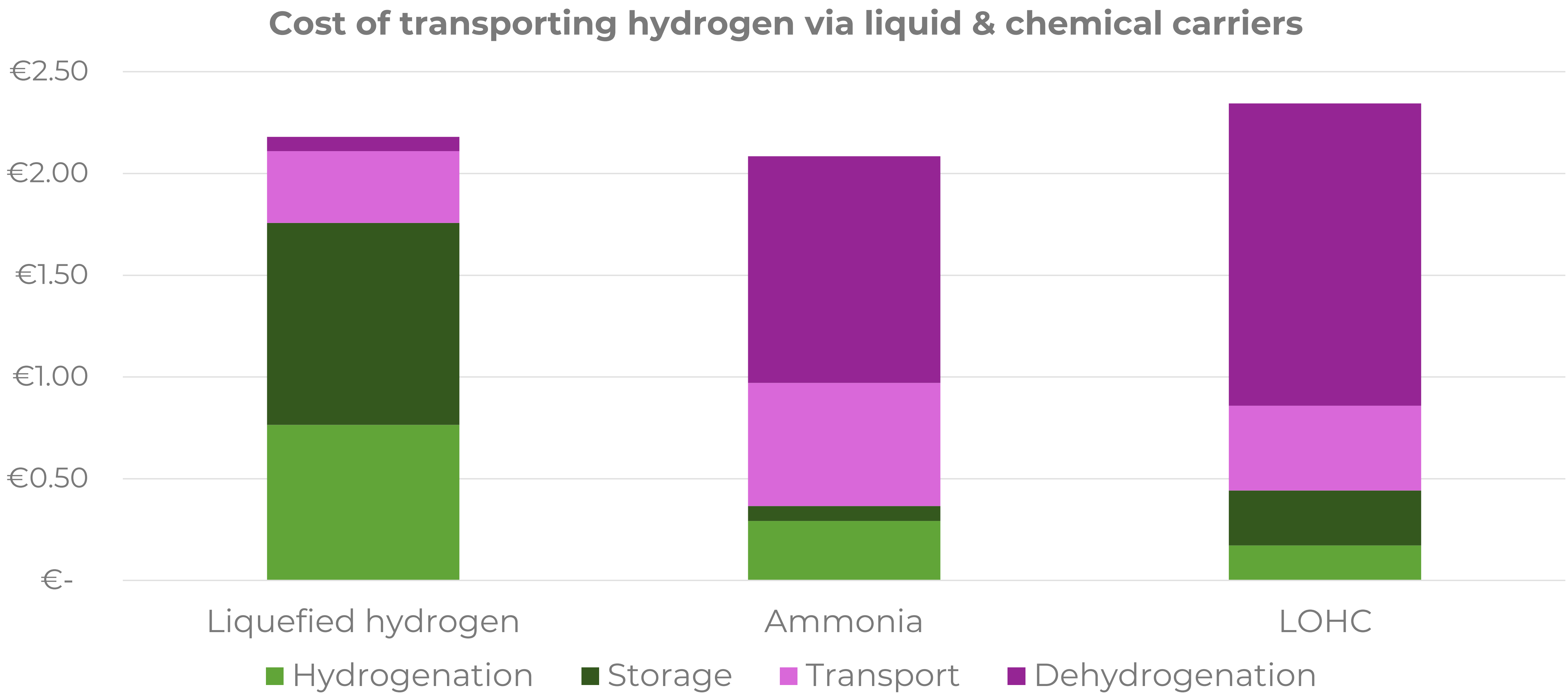
International shipping of hydrogen will add EUR 2–EUR 2.50/kg of hydrogen



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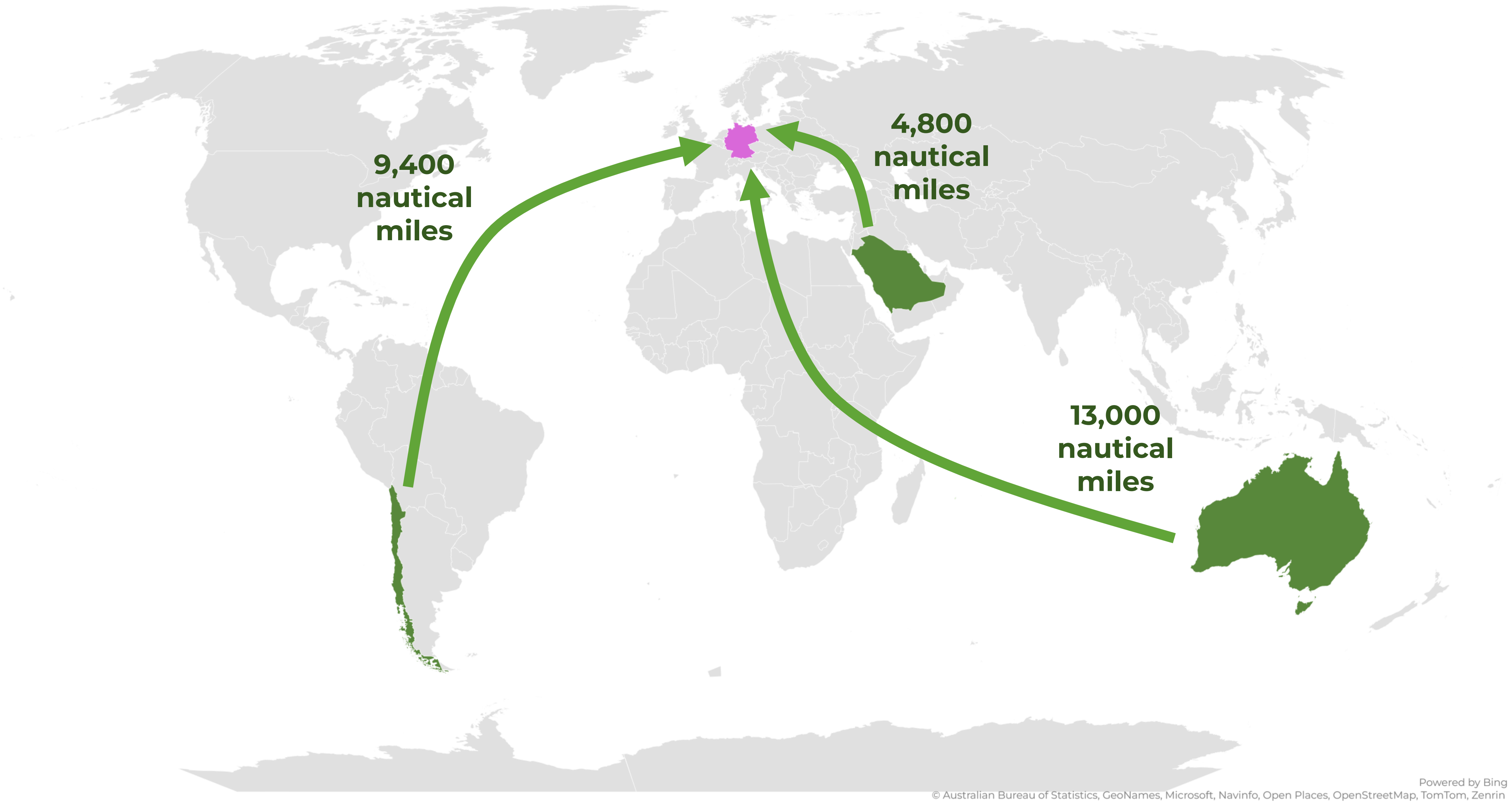

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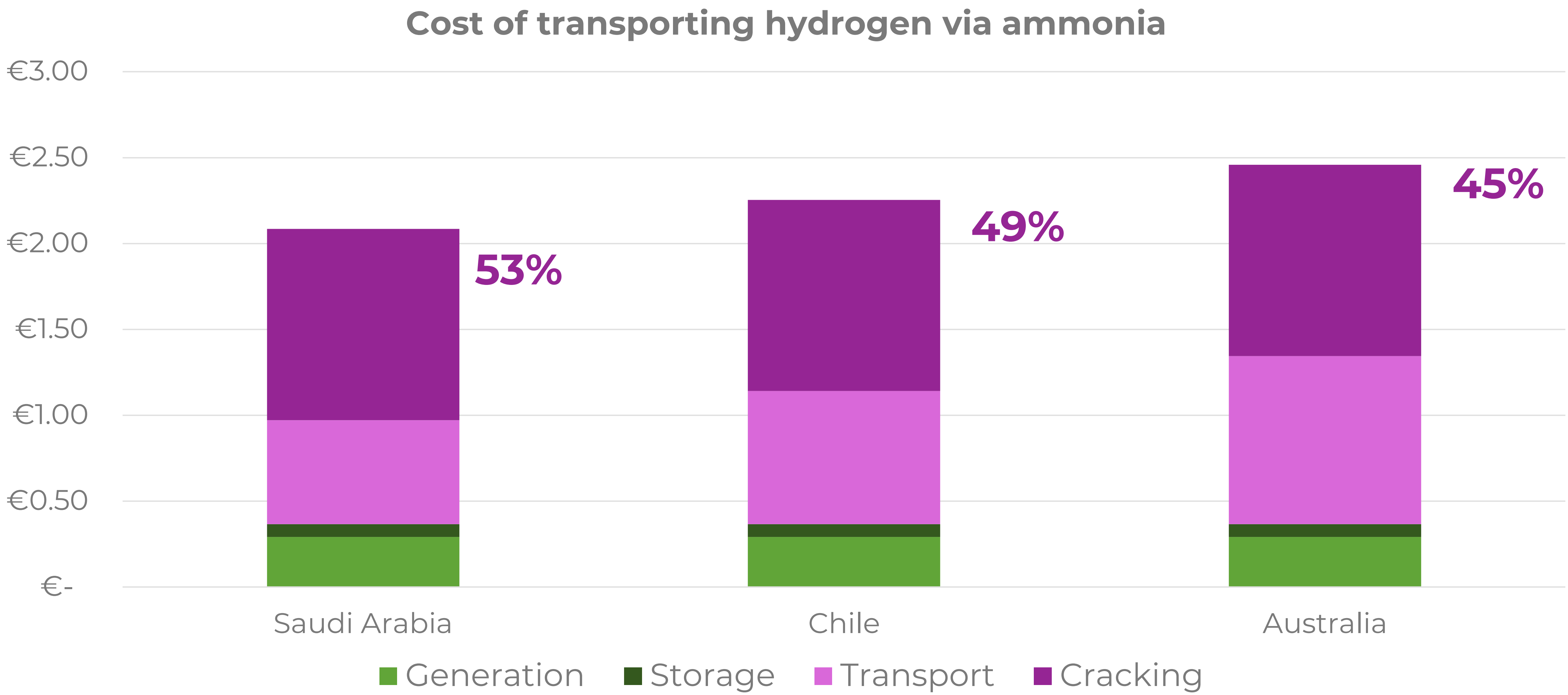
Transporting ammonia isn't the problem; *cracking* ammonia is



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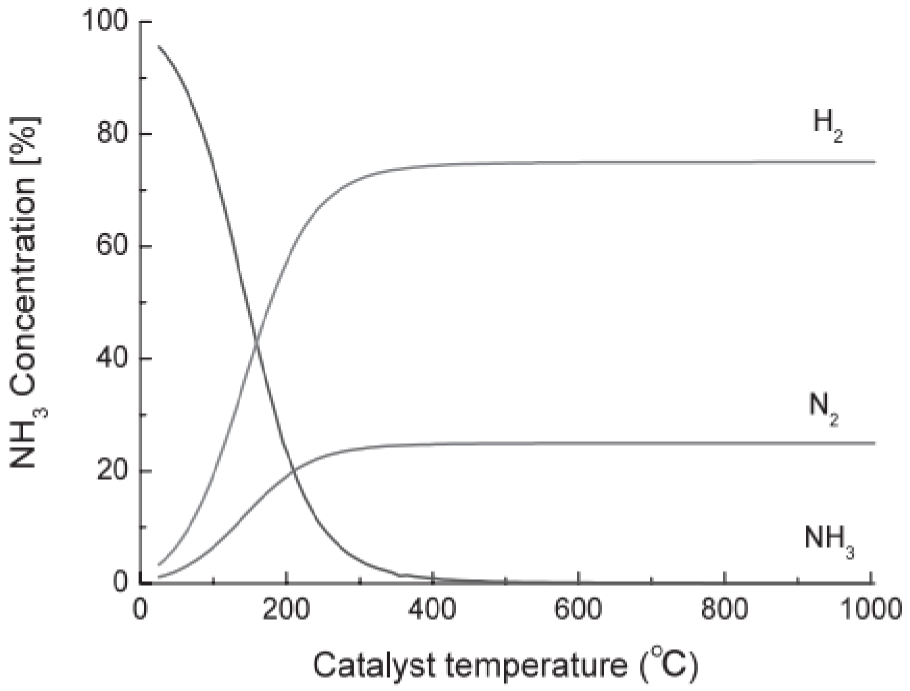
Ammonia cracking requires a catalyst and high temperatures to overcome the slow decomposition rate

Ammonia can be cracked into hydrogen using a catalyst. Without a catalyst, the decomposition reaction is too slow. Once the reaction runs, it creates a thermodynamic equilibrium composition in the gas.



Equilibrium gas composition for ammonia at atmospheric pressure (vol. %).

Designing a good ammonia decomposition system requires:

1. A cost-effective way of achieving high temperature
2. A cost-effective gas treatment to remove ammonia

The system design is a trade-off between energy costs for heating and costs of ammonia recovery.

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Catalytic platforms will be the de facto technology for ammonia decomposition at industrial scale

Commercial activity in ammonia decomposition is set to skyrocket in the near term. A full ammonia value chain isn't complete without ammonia decomposition, which means that increasing efforts in development and commercialization should be expected.

Competition will intensify in the near term as companies will want to establish a leadership position by being the first to deploy an industrial-scale facility.

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AMMONIA CRACKING TECHNOLOGY LANDSCAPE

1 CATALYTIC

TOPSOE	JM	CLARIANT	thyssenkrupp	KBR
FORTESCUE FUTURE INDUSTRIES	Hitz Hitachi Zosen	NIPPON SHOKUBAI	MITSUBISHI HEAVY INDUSTRIES	أرامكو السعودية saudi aramco
AIR PRODUCTS	Air Liquide	Linde		
Duiker Combustion Engineers	MVS ENGINEERING LTD.	NUBERG	AIRRO	OXGRIN
GENCELL	AMOGY	AMMONIGY	H2 SITE	Starfire Energy
Bettergy	AMMPOWER			

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Air Liquide will build a pilot ammonia cracking unit at the Port of Antwerp, Belgium.

The plant will be operational by 2024.

Image source: Port of Antwerp

Key Takeaways

1 **There won't be enough hydrogen in Europe**

Half the hydrogen will have to be imported

2 **Ammonia will be the main carrier for hydrogen**

It's the most cost effective and easiest to implement

3 **It all starts at the port**

The first hydrogen hubs in Europe will leverage port infrastructure

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Thank you

A link of the webinar recording will be emailed within 24–48 hours.

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JUNE 8

Net-Zero: The Emergence of an Ammonia Economy in Asia

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