



Green Energy Carriers

Iberdrola Green Hydrogen

October 2025

Iberdrola - A Pioneer in Renewable Hydrogen



Largest utility in EU by market cap +€100Bn

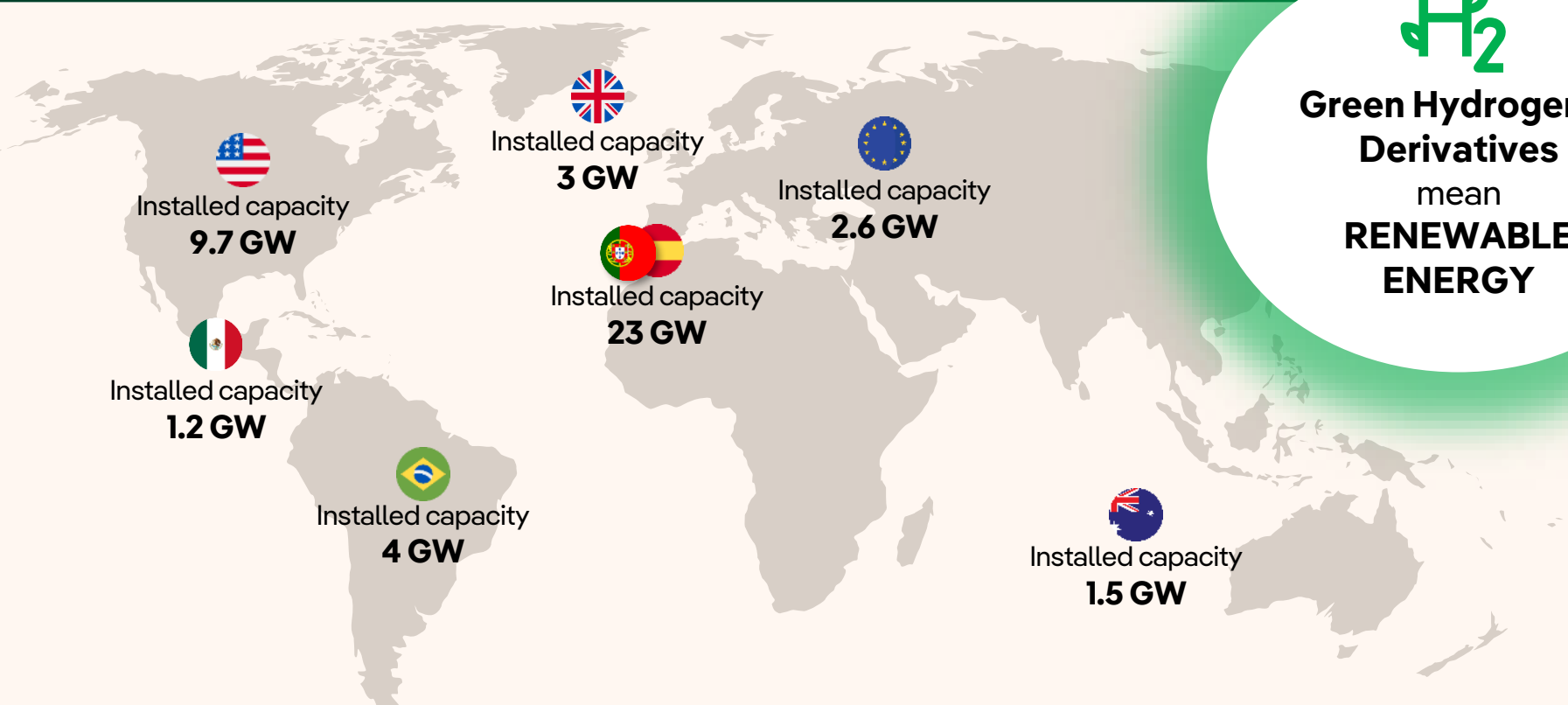
€45Bn in Revenues and €17Bn Ebitda in 2024

1st Mover in Green H2 with 3 REAL plants



Green Hydrogen & Derivatives mean **RENEWABLE ENERGY**

- Onshore Wind 20.7 GW
- Solar PV 8.3 GW
- Offshore 2.5 GW
- Hydro 13.3 GW
- Batteries 0.31 GW



45 GW installed capacity, 51 GW in 2026 and 80 GW by 2030

84% emissions free installed capacity

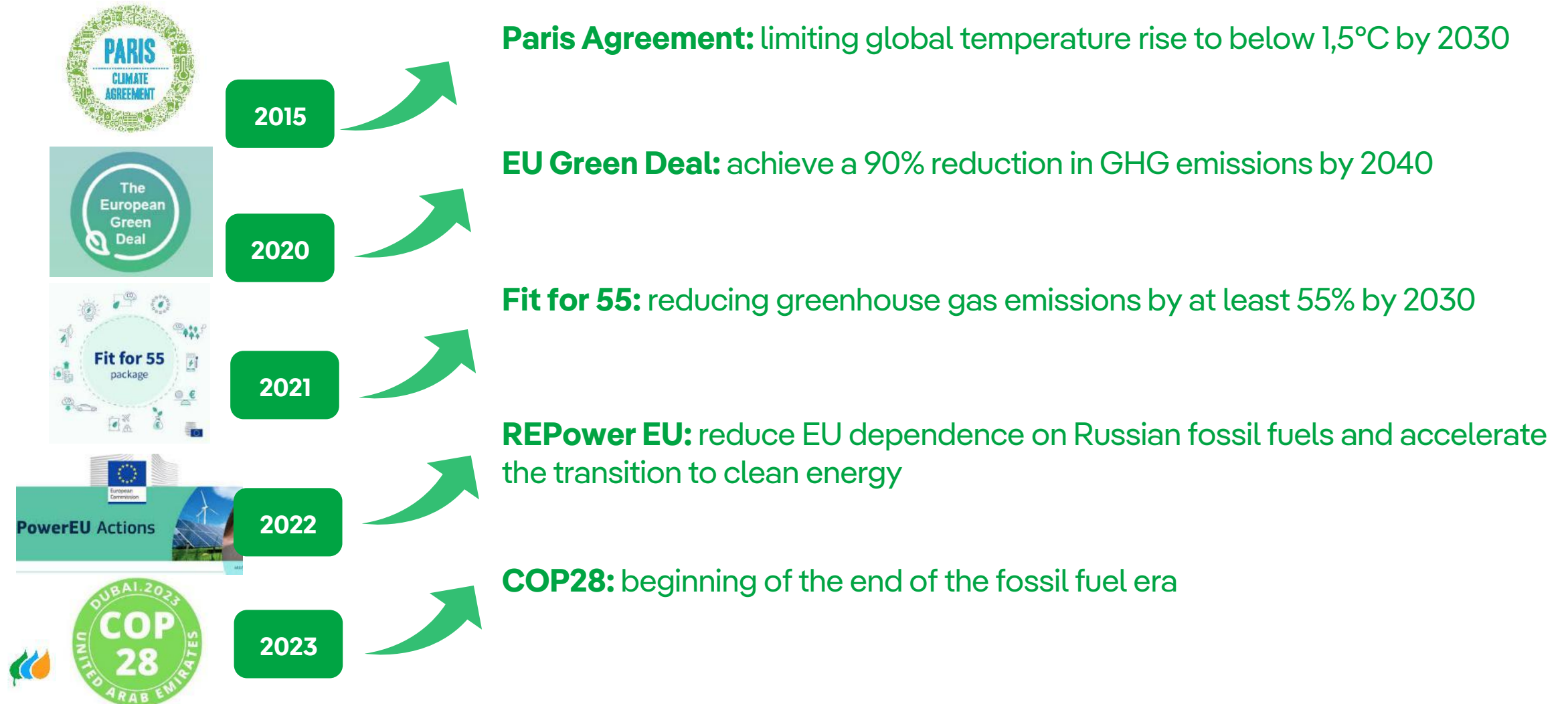
Vast portfolio with complementary generation technologies

Well-positioned to develop the H2 and derivatives business globally

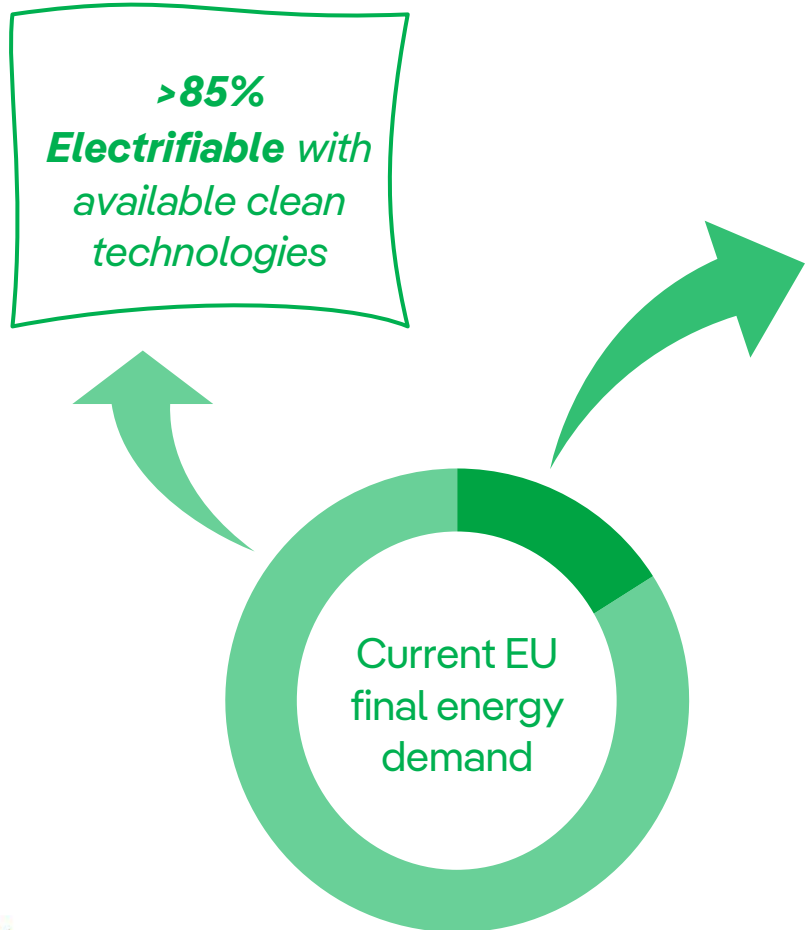
Decarbonization as a driver of change



International Agreements → Actions against Climate Change



Decarbonization enablers



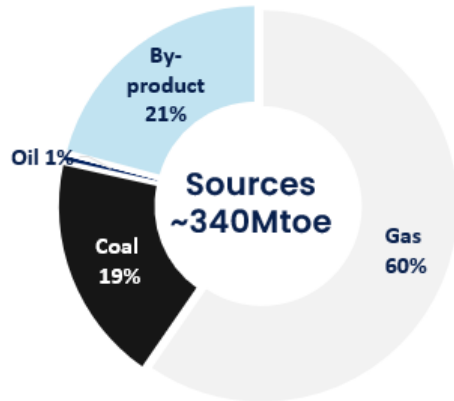
Green Hydrogen & Derivatives: Crucial to decarbonize the “hard to abate” sectors

Short-term applications	Medium-term	Long-term
<p>Local Production at consumption point</p> <p>Refineries Chemicals</p> <p>1st Priority: replacing grey H2 with green H2 in current uses</p>	<p>Global Scale Green H2 Derivatives</p> <p>Niche Premium Chemistry & Fertilizers</p> <p>New uses: hydrogen carrier, bunkering and e-SAF</p>	<p>Other Applications</p> <p>Heavy mobility</p> <p>High Temperature processes</p>

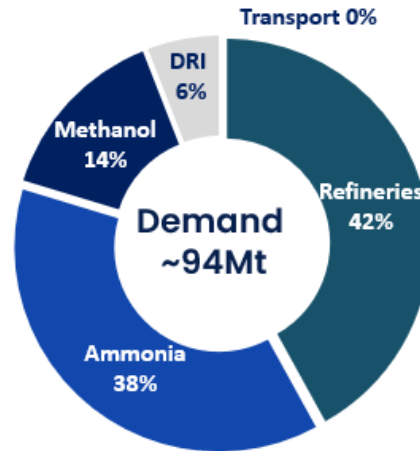
The 2021 annual H2 demand was approximately 94 Mt (+5% vs 2020)



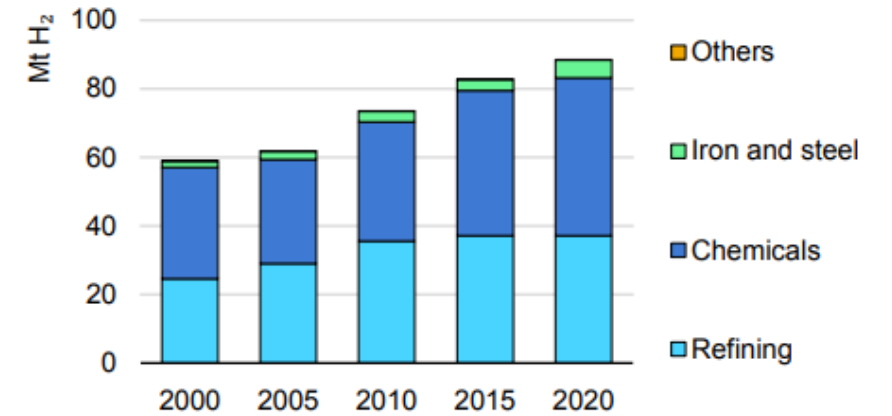
H2 Production Today



H2 End Use



H2 Demand by Sector 2015-2030



Production of H2 uses 340 Mtoe of primary energy and emits 900 Mt CO₂ (equivalent to ~2.3% global emissions, or Germany's CO₂ annual production)

Most of H2 today is produced by Steam Methane Reform (SMR)

Green Hydrogen: the opportunity



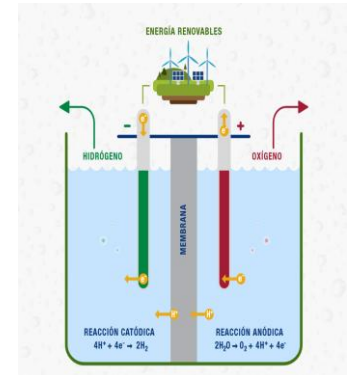
Hydrogen needs to be produced

Hydrogen type	Fuel source, Process	Indicative LCOH in 2030 ¹ EUR/MWhH ₂ (HHV)	Carbon emissions intensity kgCO ₂ /kgH ₂
Brown	Coal, Gasification		18 - 20
Grey	Natural gas, Steam reformation		8 - 12
Turquoise	Natural gas, Pyrolysis		5 - 11
Blue	Natural gas, Steam/autothermal reformation		0.6 - 1
Yellow	Grid electricity, Electrolysis		0 - 9
Green	Renewable electricity, Electrolysis		0
Pink	Nuclear electricity/heat, Electrolysis		0 - 0.4

Source: Aurora Energy Research, IEA, CE Delft, NREL, NETL, EC JRC-IE.

Green H₂

It is produced through the electrolysis of water from renewable electricity. It is an emission-free process.



Hydrogen produced through electrolysis has a **zero-carbon footprint**, provided the electricity used comes from **renewable sources**.

Green H2 Market– European subsectors

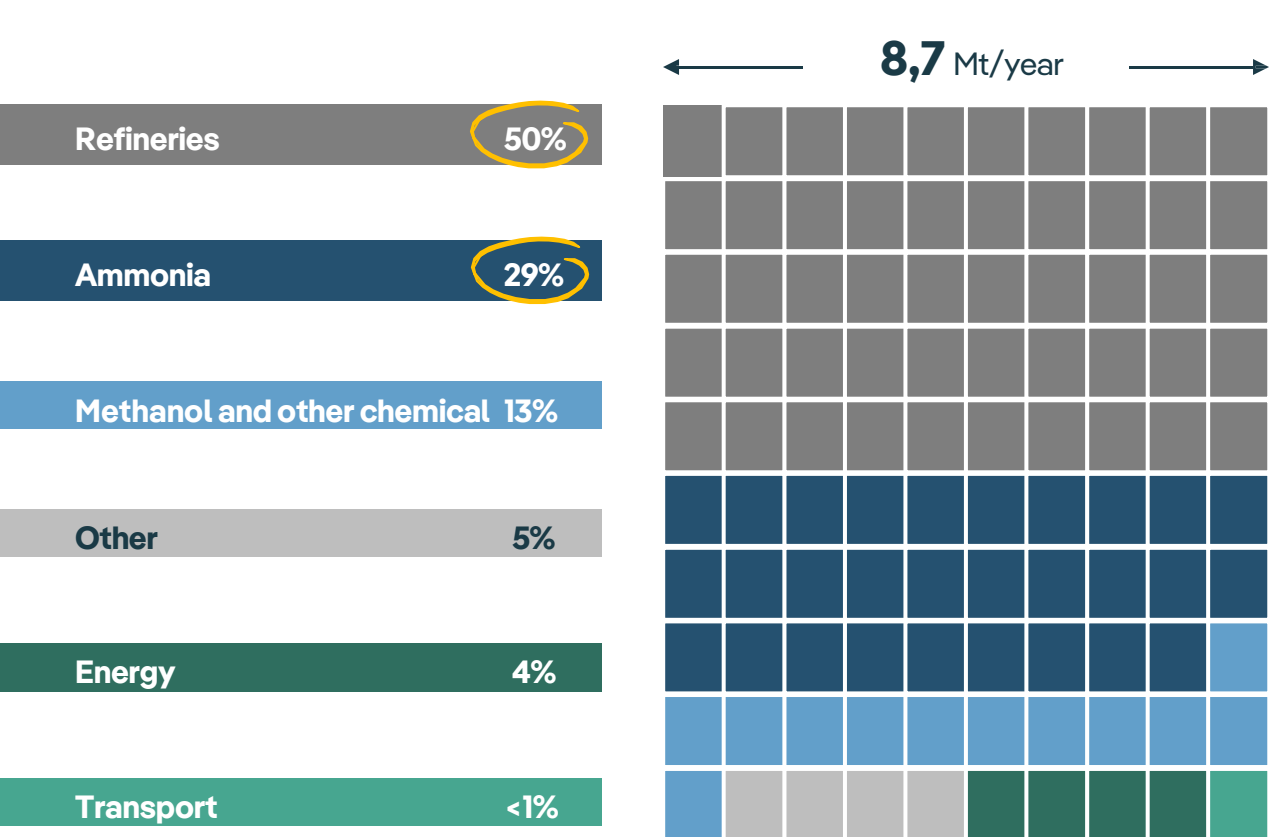


Renewable hydrogen to replace grey hydrogen



Most of the H2 demand in Europe comes from refineries and ammonia production facilities → 80% of total consumption

Total H2 demand by subsector in Europa (2022)



Main hydrogen applications in **refineries**:

- Hydrocracking
- Hydrotreating
- Hydrogenation

Using H2 to reduce sulphur content in diesel fuels

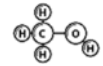


Main hydrogen applications in **ammonia**:

- Refrigerant
- Cleaning products
- Fertilizers
- H2 carrier
- Bunkering

Traditional applications

Emerging applications



Main hydrogen applications in **methanol**:

- Chemical Precursors
- Additives
- Bunkering

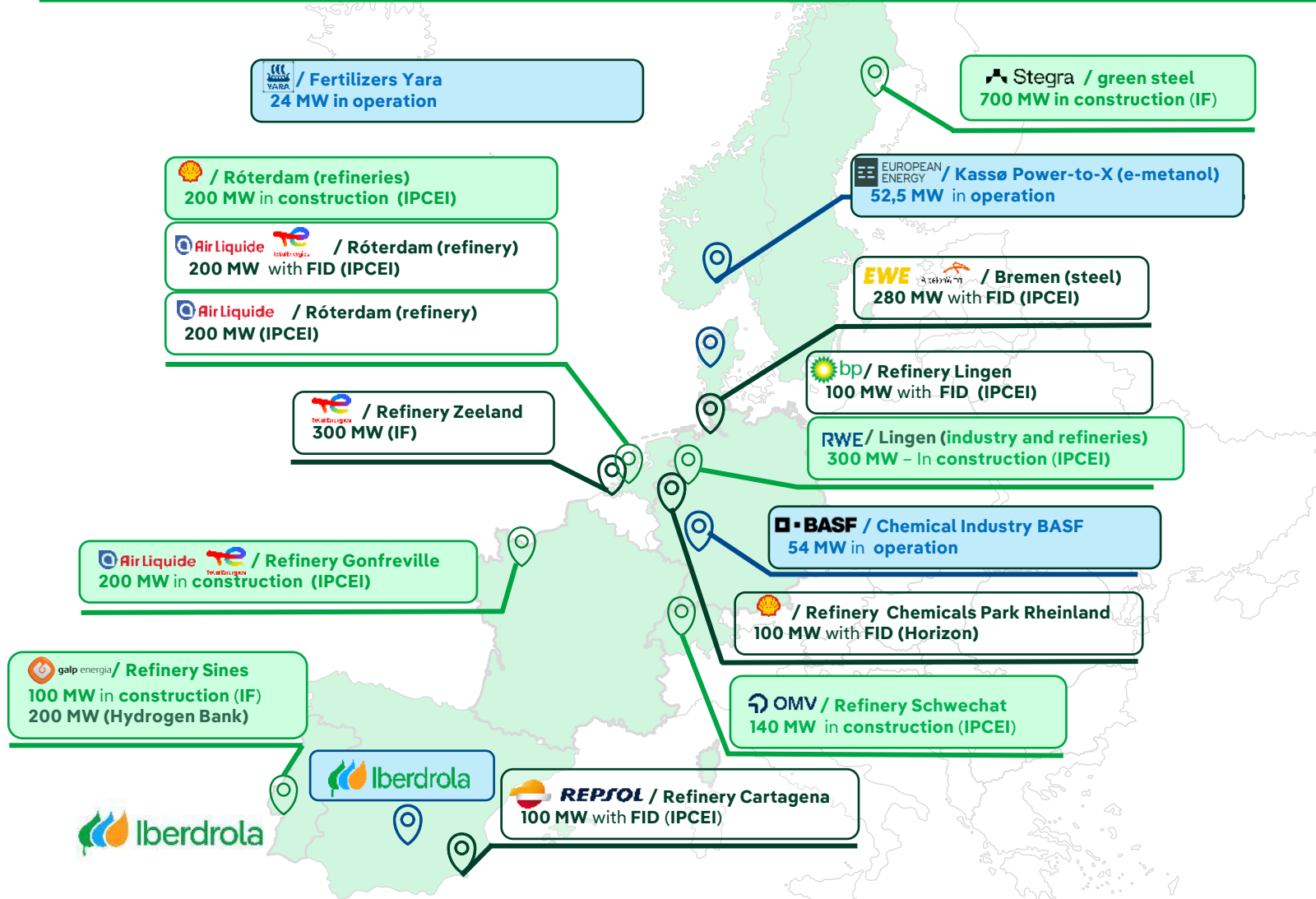
Emerging application

Traditional applications

Green Hydrogen Projects in Europe



Over 5 GW of advanced projects in Europe



Main figures in Europe (*):

- 571 MW** In operation:
 - First projects over 50 MW were launched in 2025
- 2.840 MW** Under construction:
 - Including 993 MW in Germany
- >2.000 MW** Mature projects with funding

Projects by country:

Top 10 countries in Europe with largest operational and under construction water electrolysis capacity and number of projects by July 2025

Country	Operational MW	Construction MW	Operational number of projects	Construction number of projects
DE	~100	~1000	62	22
SE	~100	~700	8	2
FR	~100	~400	10	7
NL	~100	~300	35	11
NO	~100	~200	11	5
DK	~100	~200	12	1
PT	~100	~200	1	3
ES	~100	~200	4	2
RO	~100	~200	2	3
EL	~100	~200	2	2

(* Source: Clean Hydrogen Monitor (2025))

Iberdrola Green Hydrogen Projects



One of Europe's largest electrolyzer



20 MW

Green H2 plant in Puertollano

- Operating since 2023
- Capacity: 3,000 tpa for fertilizers
- H2 plant connected to a 100 MW solar PV + BESS
- Part of a larger IPCEI project

1st green H2 mobility project in Spain



2.5 MW

Green H2 station in Barcelona

- Operating since 2022
- Capacity: 400 tpa for buses
- 46 buses charged every day
- 2nd phase - 5 MW

Decarbonization of fragrances



1.25 MW

Green H2 plant in Benicarló

- Operating since January 2025
- Capacity: 100 tpa
- 100% decarbonization of grey H2 consumption onsite

Spain's largest green H2 project for refineries



25 MW

Green H2 plant in Castellón

- Under construction
- Capacity: 2,800 tpa
- COD: Q2 2026
- Log-term alliance through a 50:50 joint venture with bp

Advancing energy supply for RFNBO H2 since 2022

Many projects announced focus on producing green hydrogen in Iberia for export to NWE, either via a carrier or pipeline

Hydrogen Insight
Iberian green hydrogen production for export will exceed proposed pipeline capacity after 2032
 Results from the H2Med project's call for interest suggest vast surplus of H2 production in Portugal, Spain and France for export to...
 11 feb 2025

New agreements to solidify Spain and Netherlands' hydrogen connection

COLLABORATION
 April 19, 2024, by Aida Čučuk
 Dutch Port of Amsterdam, together with international partners, has reached two agreements on green hydrogen and hydrogen derivatives. Additionally, Evos Amsterdam signed a memorandum of understanding (MoU) with Spanish... to explore hydrogen export out of the south of Spain to Amsterdam.

Portugal selects 37 projects for hydrogen production
 By NS Energy Staff Writer 31 Jul 2020
 OIL & GAS DOWNSTREAM PROJECT
 The selected European industrial partners including EDP, Galp, Martifer, REN, and Vestas will evaluate the feasibility of the H2 Sines project



Portuguese consortium plans 1 Gw green hydrogen cluster
 A consortium will develop the huge project with Danish wind turbine maker Vestas by 2030.
 JULY 30, 2020 PILAR SÁNCHEZ MOLINA
 HYDROGEN MARKETS MARKETS & POLICY UTILITY SCALE STORAGE SPAIN



The planned facility will begin as a 10 MW pilot electrolysis installation.
 Image: Power Innoations

Moeve Global
Cepsa and Port of Rotterdam will create a green hydrogen corridor
 The corridor will connect two European main ports: Rotterdam and Algeciras. The agreement accelerates the decarbonization and will support...

Hydrogen Insight
Spain to become major green hydrogen exporter to Europe, with domestic production double that of local demand by 2030
 Spain is likely to have more than double the green hydrogen production capacity compared to domestic demand by 2030.
 31 ene 2024

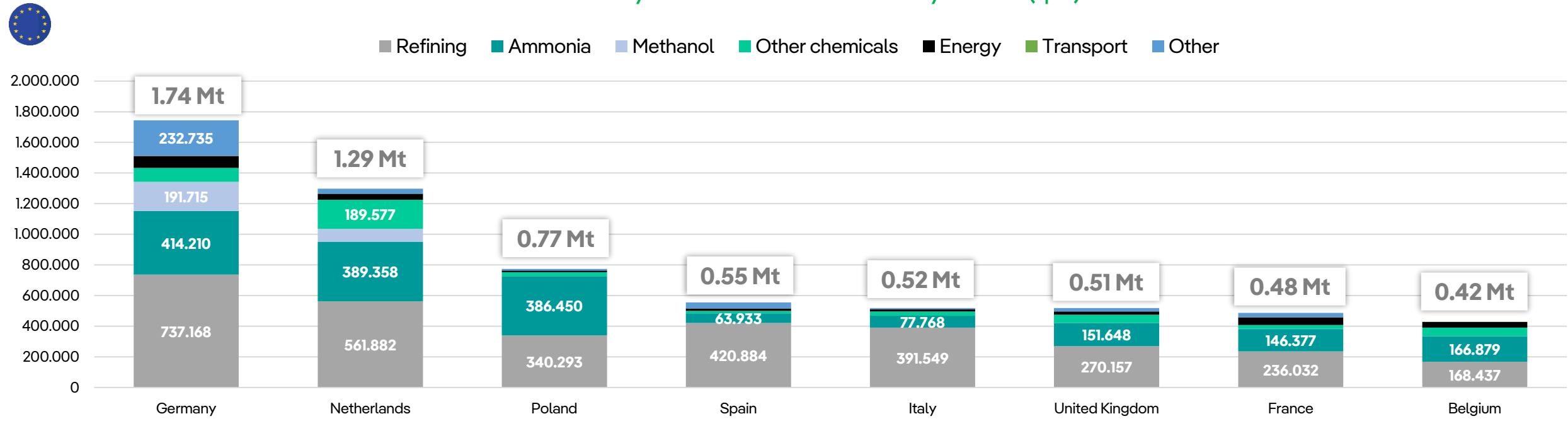


Is the green hydrogen produced in Iberia competitive enough to be transported to Northern Europe?

H2 Market– Top EU Countries



2023 EU Key Countries H2 Demand by sector (tpa)



- **Refining demand** is very relevant in Germany, the Netherlands and Spain. Portugal is not in the top countries in terms of H2 consumption (#20) but 84% of their demand is related to refineries (GALP, mainly).
- H2 **demand for ammonia** is especially relevant in Germany (414 kt), the Netherlands (389 kt) and Poland (340 kt). There are other 3 key countries with a second level of consumption: Belgium (167 kt), UK (152 kt) and France (146 kt). Lithuania (149 kt) and Romania (124 kt) are relevant consumers of ammonia, mainly for fertilizers.
- Germany is the largest consumer of **methanol** with 44% of total consumption in Europe. Norway is the second with 92kt and The Netherlands comes third with 85kt.

Green Hydrogen Characteristics



Property	Unit	H2	NG
Density (gas)	kg/m ³	0,089	0,743
Density (liquid)	Kg/m ³	70,79	431
Energy density (mass)	MJ/kg	120	53,6
Energy density (mass)	kWh/kg	33,33	14,89
Energy density (volume)	MJ/l	0,01	0,04
Boiling point	°C	-253	-160

Production of 1 kg GH₂:

Electricity:

60 kWh_e (including BoP)
55 kWh_e (only EZ)

Water:

Deionized water 10 l
Tap water 15 l
(1 shower ~ 100 km bus)

H₂ comparison (kg) with other fuels based on the LHV

H ₂	Gasoline	Diesel	Methane	NG	Propane	Butane	Methanol
1	2,78	2,8	2,4	2,54-3,14	2,59	2,62	6,09

Hydrogen

Advantages

- Versatility
- Not toxic
- Zero combustion emissions
- Calorific power
- Electricity carrier

Disadvantages

- Energy intense
- Flammable
- Security
- Logistics
- Density

Green H₂ vs Grey H₂

Advantages

- Zero emissions
- Water consumption (10 vs 23 l/kgH₂)
- Greater flexibility
- Purity
- Energy independence

Disadvantages

- Higher production costs



Why use ammonia or other energy carriers to transport hydrogen?

Higher energy density by volume

- Gaseous hydrogen has very low density, even when compressed at high pressure.
- Ammonia and other carriers allow more energy to be transported in less space.

Existing infrastructure

- Ammonia is already transported globally as a fertilizer, with pipelines, ships, and tanks readily available.
- This reduces the upfront investment costs for new green hydrogen projects.

Stability and safety

- Hydrogen requires cryogenic temperatures or very high pressures for storage.
- Ammonia is more stable at ambient temperature and less prone to explosive leaks.

Reversible conversion

- Ammonia can be “cracked” to recover hydrogen at the destination.
- Although this process requires energy, it is viable for industrial or maritime applications.

Direct applications

- In some cases, ammonia can be used directly as a fuel, for example in maritime transport.
- This avoids the need to reconvert it back into hydrogen.

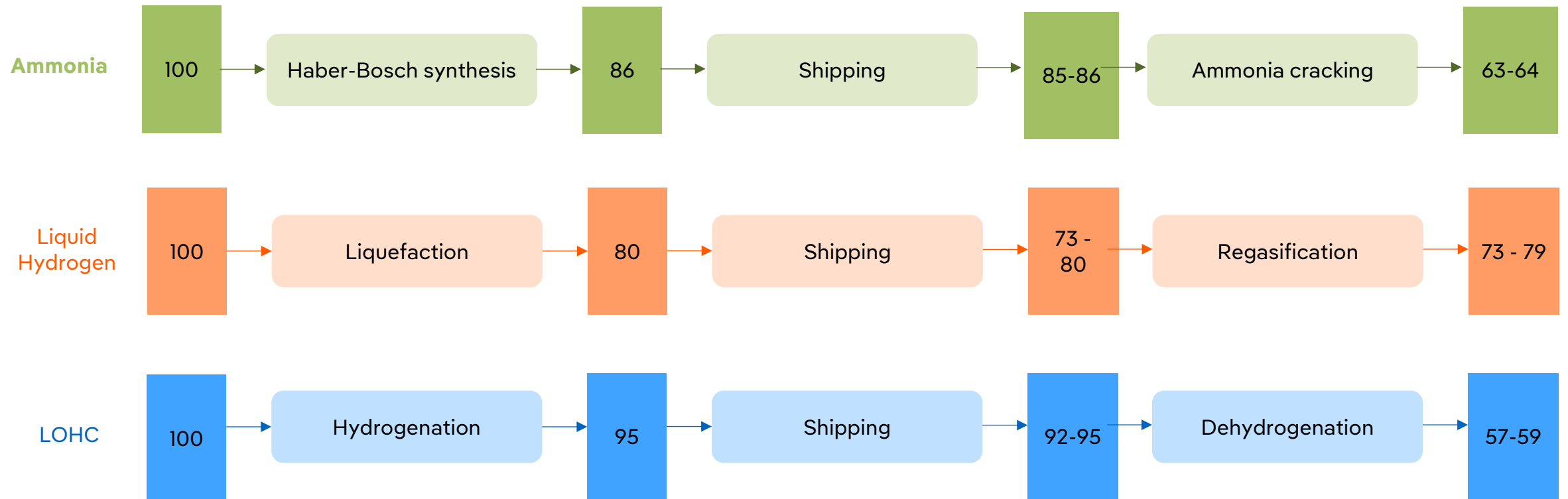
		MCH	NH3	LH2
H ₂ compaction rate		1/500	1/1.300	1/800
Liquid Phase		Ambient	- 33°C	- 253°C
Safety	Flamamability	Flammable	Non Flammable	Explosive
	Health Hazard	Slightly Hazardous	Extreme Danger (toxicity)	Extreme Danger
Technology readiness		Ready	Ready (Fuel NH3) After 2030 (Crack NH3)	2030-35 (Large scale)
Direct use		Not possible, only as carrier	Direct use of NH₃ in fertilizers, chemical industry, co-firing	aerospace industry, fuel, cryogenic applications
Transport infrastructure		Existing petroleum infra.	Existing LPG/NH3 infra.	New dedicated LH2 infra.
Energy eff.		55-60%	55-60% (Fuel NH3) 45-50% (Crack NH3)	Less tan 50%

Energy carriers technical comparison

Carrier's comparison



Energy losses in hydrogen equivalent terms



Source: IEA Global Hydrogen Review 2022

Numbers show the remaining energy content of hydrogen along the supply chain relative to a starting value of 100, assuming that all energy needs of the steps would be covered by the hydrogen or hydrogen-derived fuel.

The Haber-Bosch synthesis process includes energy consumption in the air separation unit.

Boil-off losses from shipping are based on a distance of 8000 km.

For LH₂, dashed areas represent energy being recovered by using the boil-off gases as shipping fuel, corresponding to the upper range numbers.

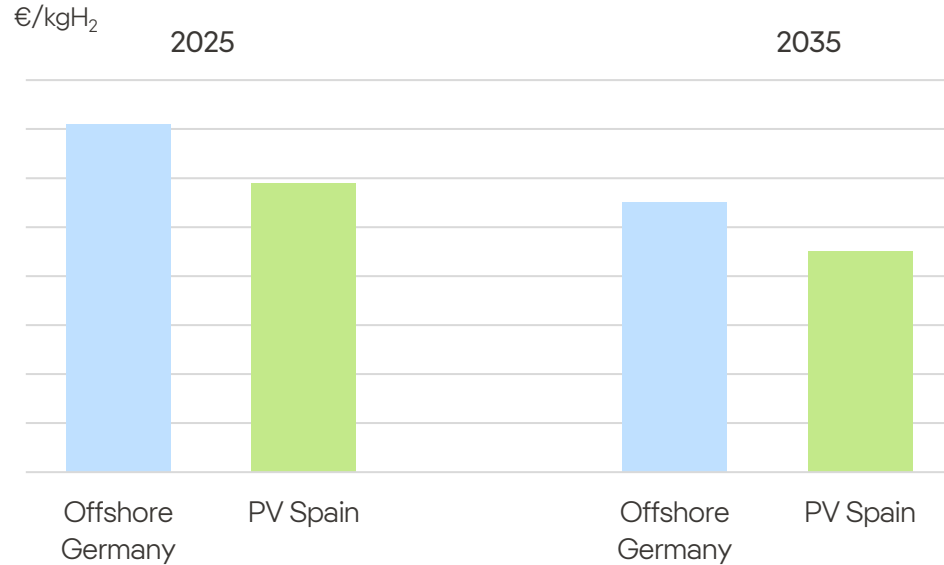
For NH₃ and LOHC, the dashed area represents the energy requirements for one-way shipping, which are included in the lower range numbers.

Local production vs exports



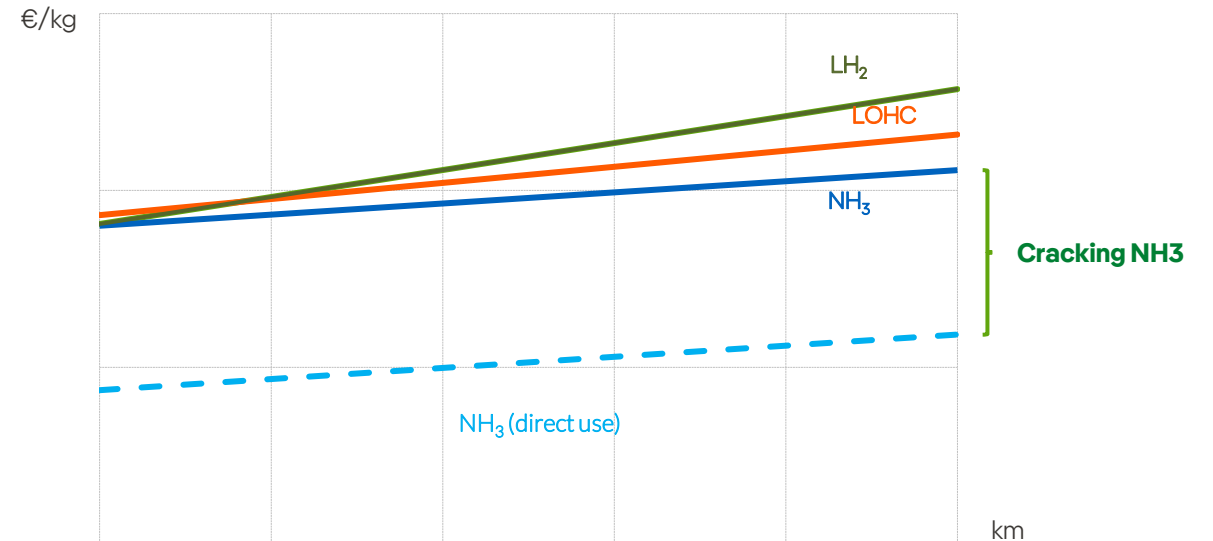
Production

H2 produced in Germany with offshore vs H2 production in Spain with PV



Carrier, Transport & Reconversion

Comparison maritime transport & H₂ reconversion: NH₃, liquid h₂ and LOHC



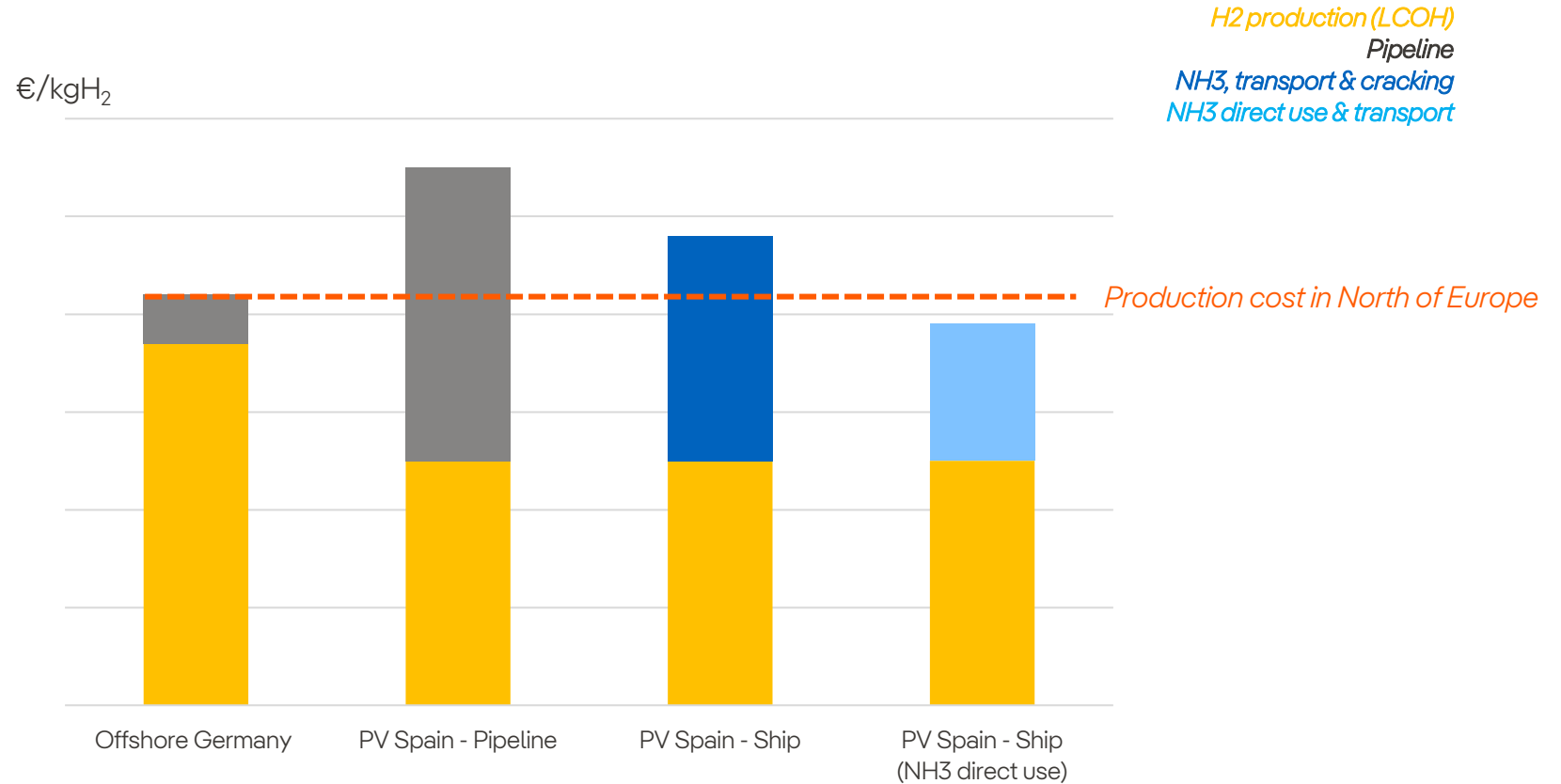
Estimation considering storage, transport and h₂ reconversion
Sources: Bloomberg, IEA, CSIRO

As the distance increases, transportation costs rise due to losses

Local production vs exports



Important constraints in Northern Europe for hydrogen production



Estimation considering storage, transport and h₂ reconversion Sources: Bloomberg, IEA, CSIRO

Consideration, final consumption in Germany

Significant room for economic and efficiency improvements → Need for new technological developments

Ammonia: Conventional & Sustainable Markets



	Conventional Ammonia
Market size	185 Mtpa
Demand	70% fertilizers, 30% other chemicals (acrylonitrile, caprolactam, explosives)
Production feedstock	72% Natural Gas, 26% Coal, 1% Oil
International trade	18 Mtpa (10%)
Players	China (29%), Russia, T&T, India, Saudi...
Contracts	Annual/short-term, fix quantity + Take or Pay, indexed
	Sustainable Ammonia (green&blue)
New Green Demand	<p>ARGUS: 87 Mtpa by 2040</p> <p>Traditional: 4.6 Mtpa NH3 as H2 carrier: 15.6 Mtpa Co-firing: 20.8 Mtpa Marine fuel: 45.6 Mtpa</p>
Production feedstock	Conventional process (Haber-Bosch) using green H2 as feedstock
Contracts	Financing of green ammonia plants requires long-term, fixed-price contracts. Creative formulas needed: flexibility, price review, indexation to new green indexes
Challenges	Nor incentives, neither mandates to move to green + lack of market (low WtP) Regulation advancing slowly

Green ammonia growth forecasts

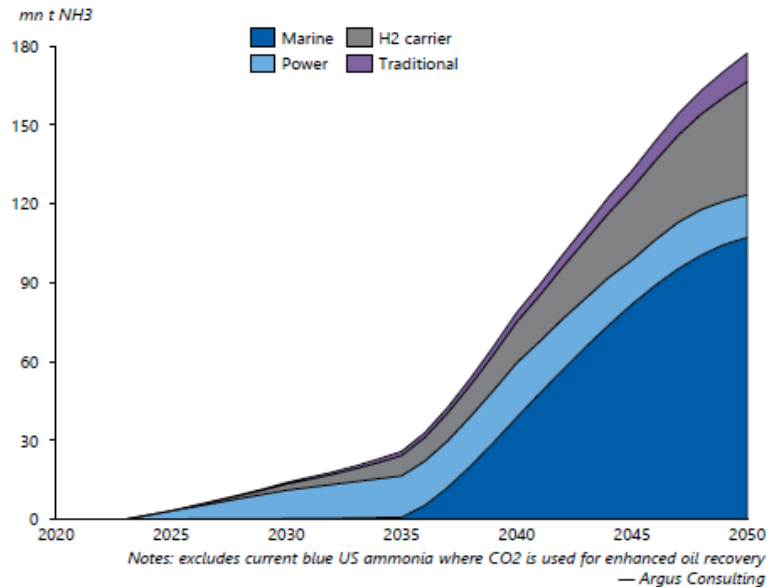


Global clean ammonia demand is forecast to reach 177 Mtpa by 2050

Niche traditional segments -agriculture & industrial- will be first movers, however new uses - bunkering and carrier- will be demand drivers from 2035 onwards.

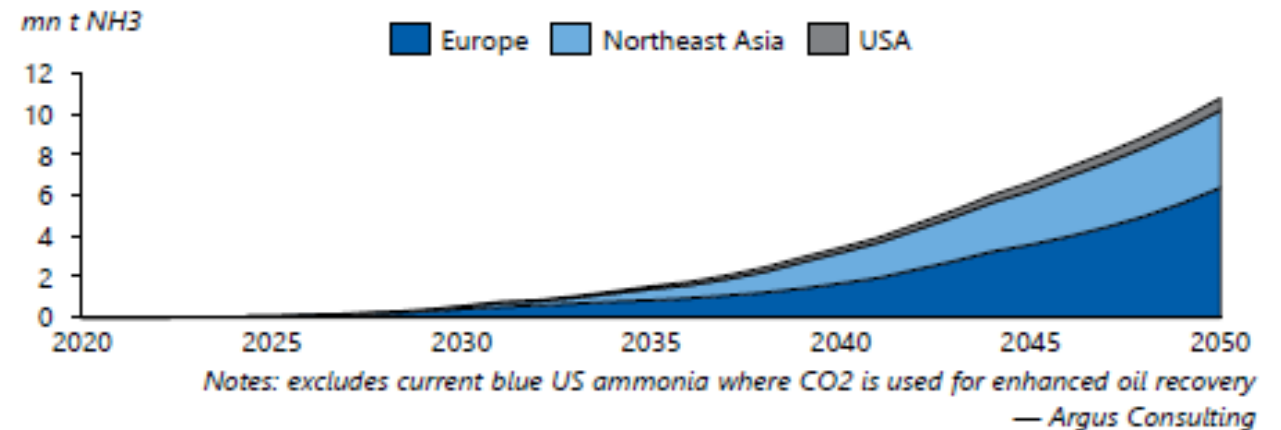
Clean ammonia or GREEN AMMONIA?

Estimated future low-carbon ammonia demand by segment



Low carbon forecast demand source: Argus Media, 2022

Demand outlook for green ammonia, traditional segment



Green ammonia demand for the traditional segment. Source: Argus Media, 2022

Green Ammonia needed to **reduce** ammonia's industry **GHG emissions** (~1% of global GHG emissions)



Green ammonia demand for traditional uses could grow up to 10.8 Mtpa in 2050

Ammonia carrier main challenges

Conventional ammonia production, Haber-Bosch

- Economics of scale benefit large production facilities but make small/medium projects uneconomic.
- Rigid production units, not modular solutions
- Low flexibility
- High temperature and pressure process

NH3 cracking systems

Ammonia cracking – dehydrogenation- is not well developed:

- Technology not required for the conventional ammonia uses:
 - **No existing technology at commercial scale**, crackers only 1-1.5 tpd of H₂ with 30-60% efficiency
- Energy and heat intensive process
 - 500-550°C with catalysis or hotter >850°C without it
 - 15-35% parasitic hydrogen consumption (if h₂ use to generate heat)
- Expensive materials for the catalyst – cobalt, iron, nickel or ruthenium
- Additional energy (and cost) for H₂ purification after the cracking
- The cracking reaction favours low pressures – H₂ compression needed afterwards
- Economics may depend on linkages with heat sources
- New additional infrastructure required – storage, h₂ pipelines- for the its commercial deployment and development as a feasible use for customers

Green Ammonia and Cracking Projects



Green NH3*

- More than **350 projects** under development
- More than **75% merchant projects**
- 40 projects with allocated funding

In operation

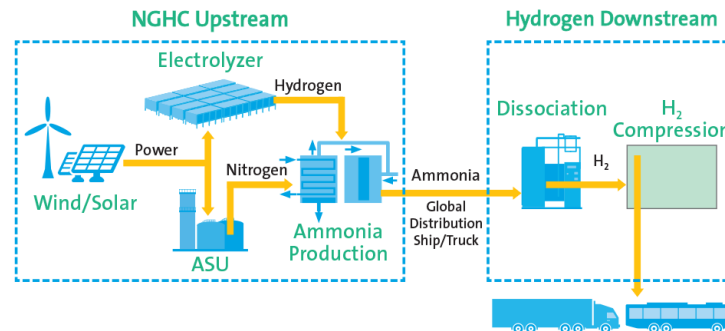
6 projects

NH3 cracking*

- **24 projects** announced
- **2 projects** under construction
- **Air Liquide (Antwerp) pilot ammonia cracker**, expected by Q1 2025

*Source: Argus, June 2025

NEOM Green Hydrogen Complex



- ✓ Joint Venture ACWA Power, Air Products & NEOM
- ✓ 4 GW Renewable Energy
- ✓ 2,2 GW Electrolyzer capacity
- ✓ 600 H2 t/day → 1,2 NH3 million t/year
- ✓ Dedicated jetty to transport green ammonia
- ✓ 80% construction completion
- ✓ Cracking system: Rotterdam / Hamburg

Europe as a catalyst



The stick: regulations & mandates

Transport (RED III¹⁾) - Decarbonization targets:

- a. **29 % of renewable energy** within final energy consumption
- b. **14,5 % CO2 intensity reduction** through renewable energies
- ✓ These targets can be met through EV charging, biofuels, or the use of green hydrogen (H2) and derivatives in the fuel production process
- ✓ **Specific sub-target of 1% green hydrogen RFNBO**, is established.

Industry (RED III)

42% grey H2 replacement with green H2 by 2030.

ReFuelEU Aviation

Progressive SAF and eSAF targets from 2025 and 2030, respectively

Maritime transport (FuelEU Maritime)

Gradual reduction of CO2 emissions in the maritime sector (2% in 2025 to 80% in 2050). Intention to promote RFNBO with multipliers

(1) Member States are required to transpose the RED III directive before May 2025.

(2) SAF: Sustainable aviation fuel produced from recycled oils and waste.

(3) e-SAF: Synthetic fuel obtained with green H2 and CO2.

The carrot: funding

INNOVATION FUND

Deploying innovative net-zero technologies for climate neutrality



Funded by the EU Emissions Trading System

- **Large projects** (approx. 100MW)
- **Available Budget:** approx 1.200 mill € per call
- **Capex financing**
- **Max. grant expected:** ~150 mill €
- Annual calls for decarbonization
- Innovative and CO2 reduction approach

European Hydrogen Bank

- No scale limitations
- **H2 production financing**
- **Lowest Price** criterion prevails
- **Available Budget:** 3.000 mill

Auction-as-a-Service

- National projects in the reserve list of the EHB
- EHB same criteria
- **Available funds:** 400 mil €

The Opportunity: Innovation

➔ Economic and efficiency technology improvements

➔ Energy security

➔ Boosting industrial competitiveness

➔ Sustainability

Thank you!

Carolina Pérez



Puertollano 20 MW Green H2 Plant