Argus Low Carbon Hydrogen Strategy Report Sample

Europe and Africa

Capturing opportunities with the Low-Carbon Hydrogen Strategy Report

This report helps market participants understand the challenges and opportunities of the emerging low-carbon hydrogen market by translating complex policies and incentives into 'firm' demand using policy-led methodologies

The low-carbon hydrogen market is developing slower than expected.

- **There is a lack of clarity around how EU policies designed to support hydrogen will be implemented.** This report unravels these complex policies and, using our policy-led methodologies, we forecast 'firm' demand potential for hydrogen across eight potential end-use segments.
- **Low-carbon hydrogen remains expensive.** This report incorporates the various subsidies (and penalties) that have been announced for the EU and in individual countries and sectors, generating break-even prices that indicate which sectors could be most promising for hydrogen and which require further incentives.
- **Few low-carbon hydrogen projects have taken a final investment decision (FID).** This report identifies 'firm supply' (more advanced projects), as well as tracks project announcements to evaluate the total supply potential across Europe and Africa.

There remains high potential to develop low-carbon hydrogen projects to meet demand in Europe.

- **Argus' analysis indicates firm demand exceeds firm supply and increases significantly over the long-term** led by EU mandates, specifically for marine and aviation.

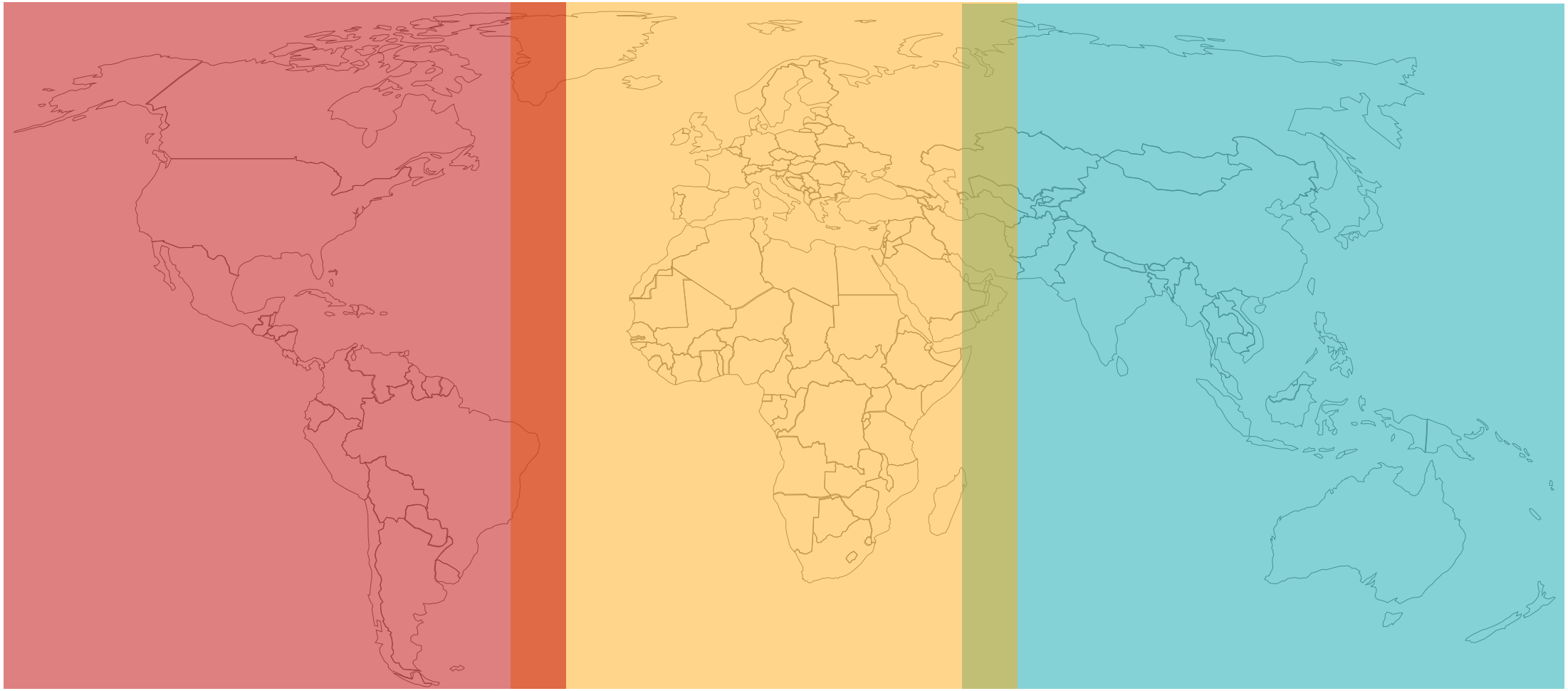
Europe will continue to drive low-carbon hydrogen developments globally. This report focuses on the main European countries pursuing hydrogen as a significant route for decarbonisation. Understanding the progression and opportunities for these first-movers serves as an invaluable example for companies considering their own investments in hydrogen.

Geographies covered under this study

Part 1: Asia-Pac and the Middle East

Part 2: Europe and Africa

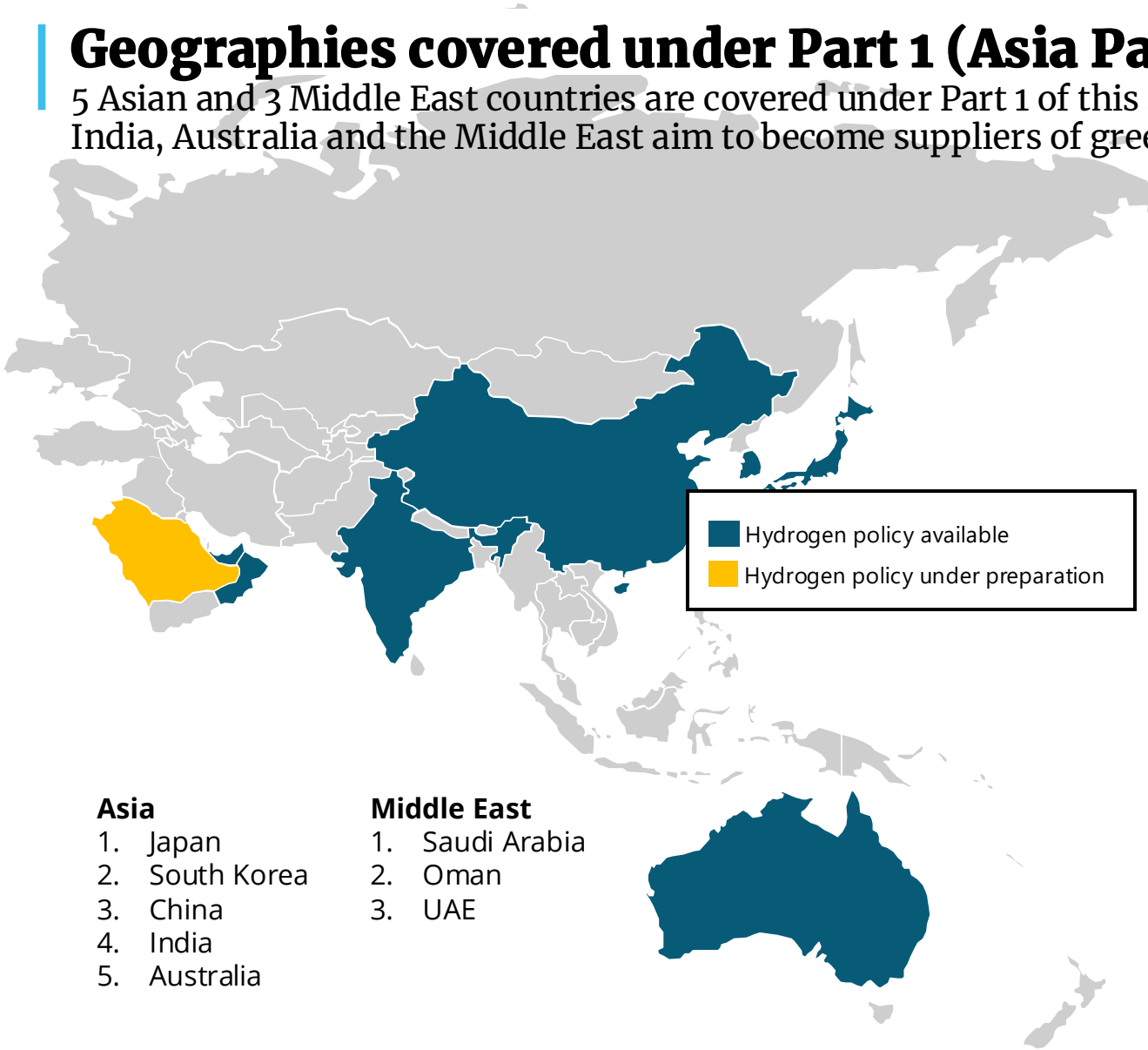
Part 3: Americas (coming early 2025)



Source: Argus Consulting

Geographies covered under Part 1 (Asia Pacific and Middle East)

5 Asian and 3 Middle East countries are covered under Part 1 of this study. Japan, Korea and China are demand-focused, while India, Australia and the Middle East aim to become suppliers of green hydrogen



Asia

1. Japan
2. South Korea
3. China
4. India
5. Australia

Middle East

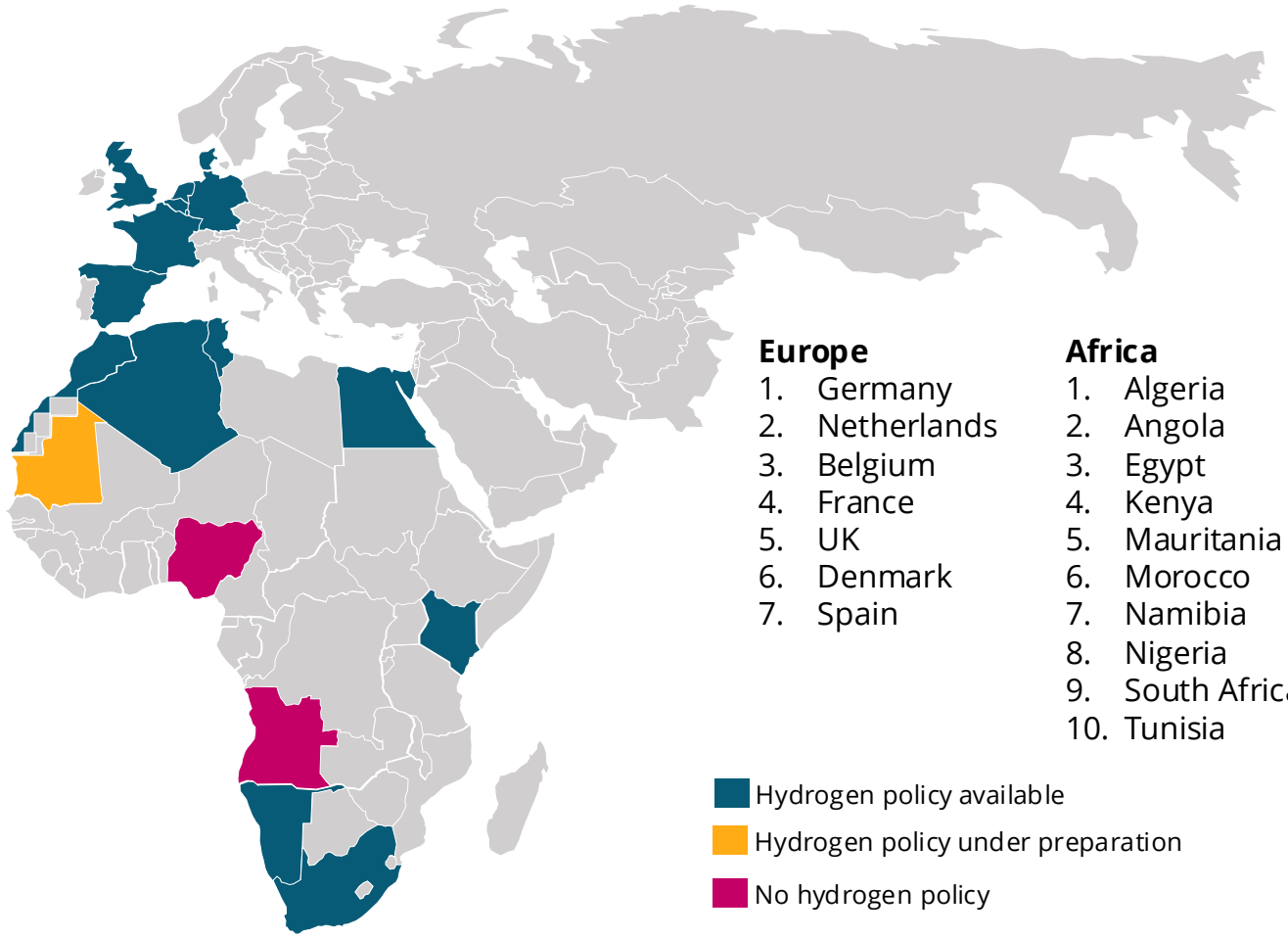
1. Saudi Arabia
2. Oman
3. UAE

- Part 1 of this study focuses on the hydrogen economy in the Asia Pacific and Middle East regions and is aimed at identifying the potential demand and export supply countries.
- The countries covered under this analysis include: Japan, South Korea, India, China, Australia and Middle East (Saudi Arabia, Oman and UAE).
- Of these, all countries have published their hydrogen roadmaps/strategies except Saudi Arabia, whose strategy is under development.
- Japan, South Korea and Australia were early movers in identifying hydrogen as a potential option for decarbonisation and announced their hydrogen strategies before the covid pandemic. Japan was the first country to do so.
- The remaining countries announced their strategies/roadmap after the pandemic, with the most recent being the UAE.
- Generally, each country's strategy is focused on either demand or supply.
- Japan, South Korea and China's hydrogen policies are mostly demand-focused in various sectors like transport, power generation and gas blending. China, though, has drafted its policy to generate both demand and supply.
- India, Australia and the Middle East all aim to become green hydrogen suppliers and export hydrogen globally.

Source: Argus Low Carbon Hydrogen Strategy Report

Geographies covered under Part 2 (Europe and Africa)

Seven European countries and 10 African countries are covered. Both supply and demand are assessed for Europe, while the Africa coverage is supply-focused as demand for low-carbon hydrogen is limited on that continent



Europe

1. Germany
2. Netherlands
3. Belgium
4. France
5. UK
6. Denmark
7. Spain

Africa

1. Algeria
2. Angola
3. Egypt
4. Kenya
5. Mauritania
6. Morocco
7. Namibia
8. Nigeria
9. South Africa
10. Tunisia

This study focuses on hydrogen supply and demand developments in Europe and Africa.

Supply

Argus assesses the potential supply for hydrogen in seven key European countries — Germany, the Netherlands, France, Belgium, Denmark, Spain and the UK — henceforth referred to as 'Europe' in this study. Hydrogen is expected to play a notable role in these countries, supported by specific mandates and legislation.

Spain, Belgium and Denmark are expected to become net exporters of low-carbon hydrogen, in addition to meeting their own demand needs.

Africa has the potential to leverage its natural resources — notably wind, solar and hydropower — to produce cost-competitive low-carbon hydrogen and become a significant supplier of hydrogen and its derivatives to Europe. Ten African nations are covered under this study — Algeria, Angola, Egypt, Kenya, Mauritania, Morocco, Namibia, Nigeria, South Africa and Tunisia. While not all have adopted a national hydrogen strategy, they have announced plans to develop low-carbon hydrogen projects.

Demand

Argus assesses firm demand in the European countries. Germany, France and the UK have the highest demand potential for low-carbon hydrogen.

An in-depth discussion on demand is excluded from Africa since there is limited demand for low-carbon hydrogen in these countries.

Source: Argus Consulting

Key features

Part 2 of 3

Part 1: Asia-Pacific and the Middle East

Part 2: Europe and Africa

Part 3: Americas

17 countries

Europe (7) and **Africa** (10)

600 slides

Containing comprehensive data and insight in the form of data, analysis, charts, tables, maps, infographics, and more

Databook

Key data for demand and breakeven prices by sector

Green and blue projects

Hydrogen project pipeline by country, including developers, capacity, timelines, renewable energy generation, electrolyser details, offtake agreements

8 demand sectors

Refining, fertiliser, power generation, gas blending, road transport, steel, maritime and aviation

Breakeven analysis

Breakeven price analysis of hydrogen technologies versus sector incumbents and alternative fuels

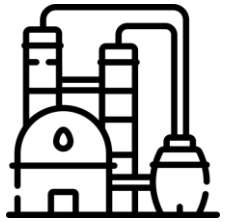
Access to market experts

Access to the experts behind the analysis to assist with onboarding

Source: Argus Consulting

Sectors covered under this study

Existing Hydrogen End-Uses



Refining

Hydrogen demand in the refining sector across various regions and breakeven price for green hydrogen

Fertiliser

Hydrogen demand in the fertiliser sector across various regions and breakeven price for green hydrogen

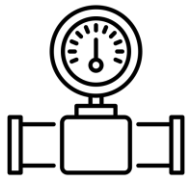
Steel

Hydrogen demand in the steel sector across various regions breakeven price for green hydrogen-based DRI technology against conventional steelmaking technology

New Hydrogen End-Uses

Power generation

Breakeven price for green hydrogen in CCGT against a conventional natural gas-based turbine



Gas network

Breakeven price for green hydrogen

Maritime and aviation

Hydrogen demand in the maritime sector and SAF and corresponding hydrogen demand in aviation sector across regions

Road transport

Hydrogen demand in the road transport (cars, buses and HGVs) across various regions and breakeven price for hydrogen powered vehicles against battery and conventional fuel vehicles

Source: Argus Low Carbon Hydrogen Strategy Report

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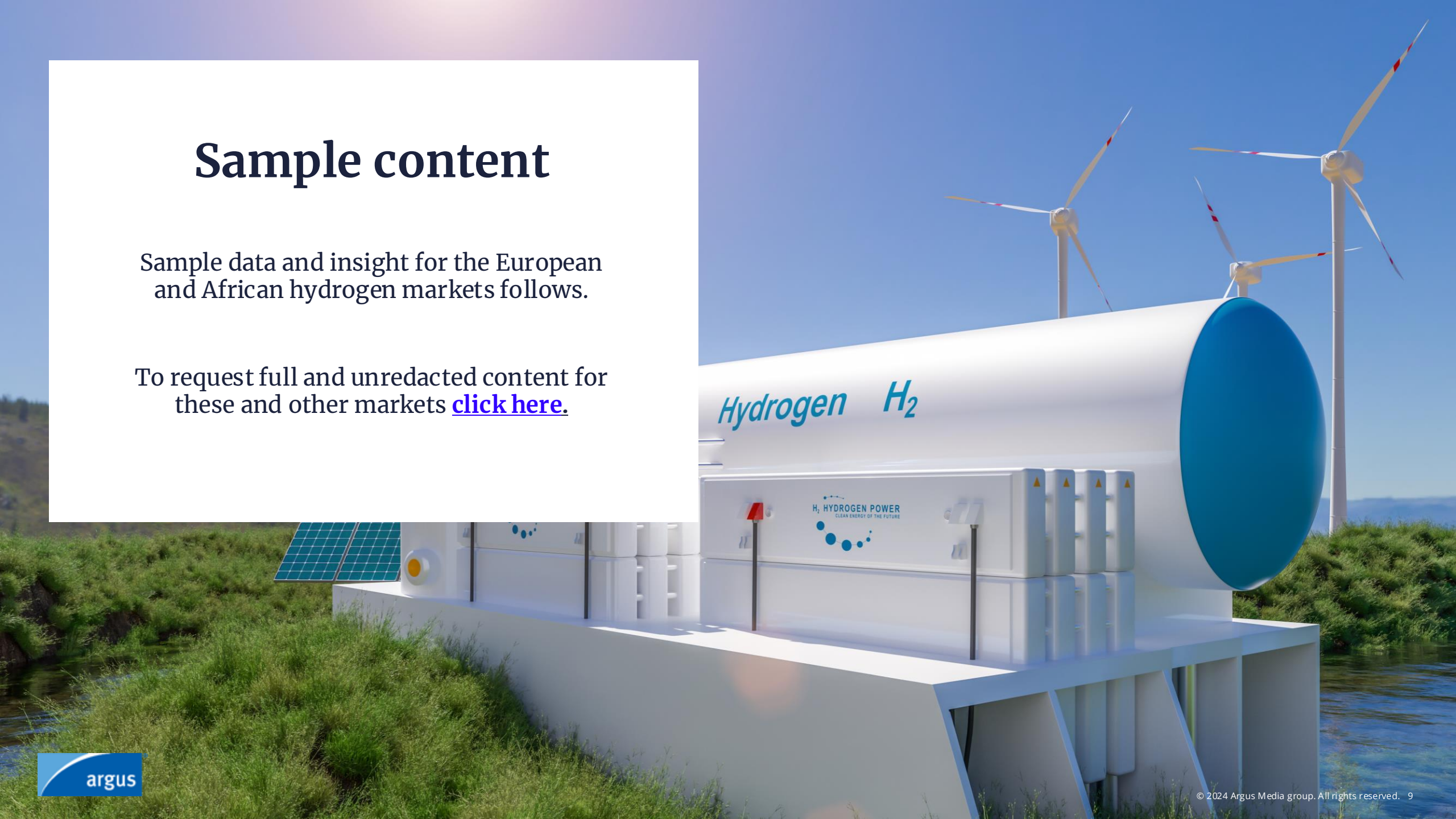
Sample content

Sample data and insight for the European and African hydrogen markets follows.

To request full and unredacted content for these and other markets click here.



Europe

Overview

Europe – Policies and impact on hydrogen

The EU introduced a number of policies and targets to drive hydrogen production and consumption in sectors, including industry, road transport, maritime and aviation

EU policies	Detailed in study	Description and implication on hydrogen
Fit for 55	**1**	• Package of policies aims to reduce 55pc of the GHG emissions (vs 1990 levels) by 2030. Several policies support hydrogen production, infrastructure and demand.
FuelEU Maritime		• Part of Fit for 55 legislative package, FuelEU Maritime promotes the use of renewable, low carbon fuels and clean energy technologies to decarbonise shipping • Sets maximum limit for annual average GHG intensity of ships calling at European ports. The limit decreases over time, from a 2pc reduction by 2025 to 80pc by 2050
ReFuelEU Aviation		• Part of Fit for 55 legislative package, ReFuelEU Aviation promotes the increased use of SAF to decarbonise aviation by setting requirements for aviation fuel suppliers to gradually increase the share of SAF blended into conventional aviation fuels supplied at EU airports. The share of synthetic aviation fuels in all EU airports rises from 1.2pc in 2030 to 35pc in 2050
RePowerEU	**2**	• Building on Fit for 55 package, RePowerEU is the EU's plan to reduce dependency on Russian fossil fuels and accelerate the green transition. RePowerEU does not have any legally binding legislative proposals (unlike the other policies covered on this slide) • Sets a target of 10mnt of domestic renewable hydrogen production and 10mnt of renewable hydrogen imports by 2030
Renewable Energy Directive, version III (REDIII)	**3**	• Legal framework for the development of clean energy across all sectors of the EU economy • Defines what is considered RFNBO (i.e. requirements for electricity used in electrolysers, CO2 sources for making synthetic fuels) • In 2023, mandates were confirmed for RFNBOs (green hydrogen) for existing industrial use of hydrogen
EU Emissions Trading Scheme (ETS)	**4**	• Set up in 2005, the EU ETS is the largest GHG emission trading scheme in the world • Emissions savings from carbon would allow low-carbon hydrogen producers to take advantage of (by selling) free allowances
Carbon Border Adjustment Mechanism (CBAM)	**5**	• A carbon border tax, CBAM will be phased in gradually for products at high risk of carbon leakage, including hydrogen, as free allowances, under EU ETS, are phased out. From 2026, importers will have to buy CBAM certificates corresponding to the carbon price that would have been paid under EU ETS • Low-carbon hydrogen whose emissions are below the ETS benchmark can monetise free allowances until they are phased out in 2034
Net Zero Industry Act		• Published as part of the Green Deal Industrial Plan. Aims to scale up the manufacturing of clean technologies in the EU, including electrolysers and fuel cells, solar, wind, biogas/biomethane, batteries and storage, carbon capture and storage, heat pumps and grid technologies • Introduced the European Hydrogen Bank
Gas Directive		• Defines low-carbon hydrogen, which meets a GHG emission reduction threshold of 70pc vs natural gas across full lifecycle • A methodology for assessing GHG emissions savings from low-carbon fuels will be set out in a delegated legislation by 31 December 2024 • **Hydrogen and Decarbonized Gas Market Package** includes a proposal to revise the earlier adopted Gas Regulation and Gas Directive to include hydrogen integration in the existing gas network. EU member states have until mid-2026 to write reforms into their national laws.
EU Taxonomy		• Classification system that defines criteria for economic activities aligned with a net zero trajectory by 2050 and broader environmental goals other than climate. In the most recent revision, the EU Commission set the threshold for sustainable hydrogen at 3t/CO_2e

Source: European Commission

Policy – Renewable Energy Directives (RED)

RED continues to evolve, with the third revision including targets for renewable fuels of non-biological origin (i.e. hydrogen) in industry and transport sectors

Summary of RED evolution

	REDI	REDII	REDIII
Key dates	2009 (introduced)	2018 (revised)	2023 (in force) May 2025 (deadline for Member States to transpose into national law)
Target share of renewables in EU's energy consumption	20pc by 2020	32pc by 2030	42.5pc by 2030
Target sectors		Transport Building, heating and cooling	Transport Building, heating and cooling Industry

REDIII sector targets

Transport

EU countries can either:

- Reduce their GHG intensity in transport by **14.5pc** by 2030, or
- Achieve a **29pc** share of renewables in the sector's final energy consumption by 2030

Introduces a **5.5pc** sub-target for RFNBO and advanced biofuels (combined) in the share of renewable energies supplied to the transport sector. Of this, there is a **1pc RFNBO** minimum requirement in 2030

Industry

- Industry to increase use of renewable energy by **1.6pc** per year
- **42pc** of hydrogen used in industry should come from renewable fuels of non-biological origin (RFNBO) by 2030 and **60pc** by 2035
- If the member state reaches their expected national contribution to the overall EU target and the share of fossil hydrogen consumed in member state is <23pc in 2030 and 20pc in 2035, then that member state could reduce their required contribution of RFNBOs in industry use by 20 pc.

Buildings, heating and cooling

In buildings, there is a minimum **49pc** renewable energy share in 2030

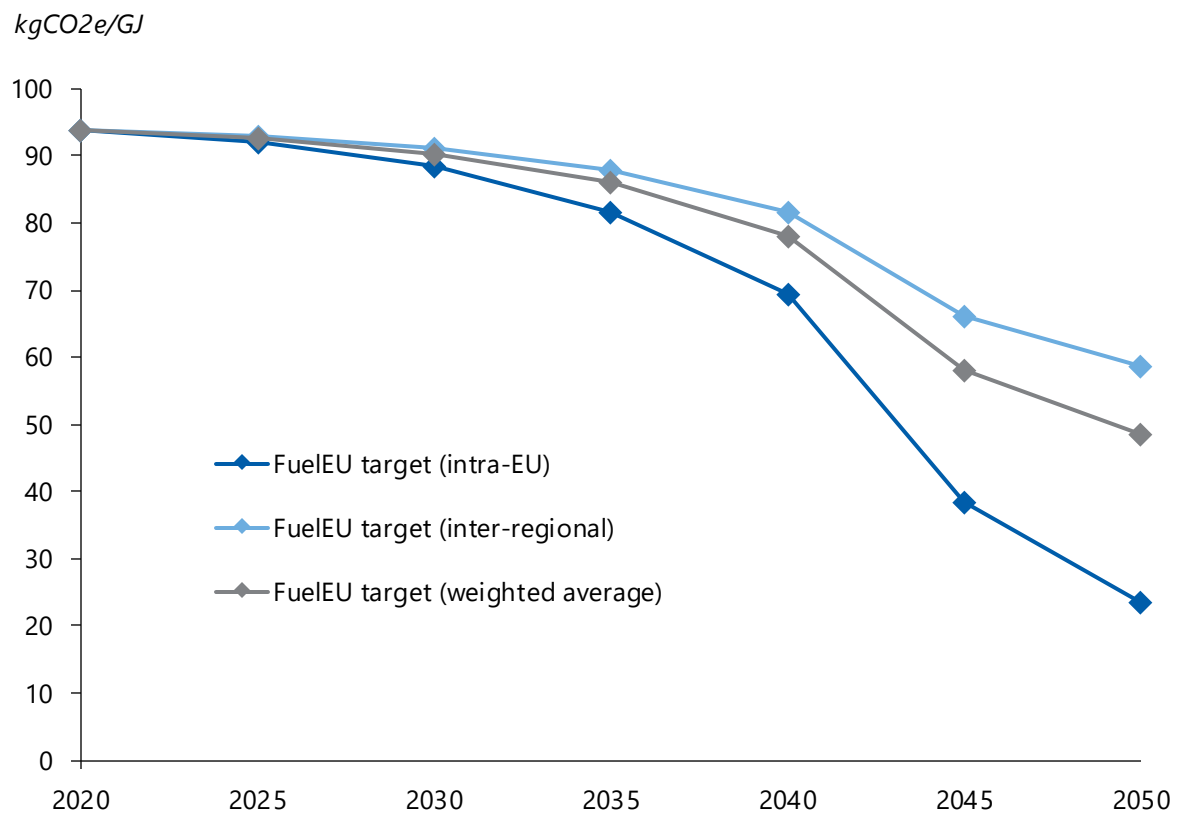
For heating and cooling, renewable targets gradually increase, with a binding increase of **0.8pc** per year at the national level until 2026 and **1.1pc** from 2026 to 2030

Source: European Commission

Policy – FuelEU Maritime

Shipping sector representing 3-4 pc of total EU's CO2 emissions

FuelEU Maritime fuel intensity targets



Notes: EU target emission intensity takes into account that only 50pc of international voyages are covered by targets

FuelEU Maritime

- The FuelEU Maritime legislative proposal aims at decreasing GHG emissions that arise from both domestic and international shipping. Most important measures are:
  i. Coverage: domestic voyages (incl. voyages between EU member states) and 50pc of international voyages (from or to EU port)
  ii. Target: GHG intensity reduction (emissions per unit of energy consumed) of 2pc in 2025, 6pc from 2030, 14.5pc from 2035, 31pc from 2040, 62pc from 2045 and 80pc from 2050, against 2020 baselines.
- Targets for GHG reduction will increase the demand for low carbon fuels but the fuel choices depend on the underlying vessel type, blending characteristics and overall market dynamics
- With the proposed fuel intensity pathway, the EU is planning a lower phase in of emission reductions in the marine sector but is more ambitious in the long-run, take note that it has different scope compared to IMO.

RFNBOs / Green Hydrogen

- In July 2023, the EU Parliament and Commission published new provisions on the use of renewable and low-carbon fuels in maritime transport, amending Directive 2009/16/EC.
- They stated that the regulation should "*provide for a combination of measures to ensure the support for the uptake of sustainable RFNBO, including the possibility to use a 'multiplier' until the end of 2033, allowing the energy from RFNBO to count twice*" – Hinting at double counting eligibility for RFNBOs in the maritime sector.
- Further to this, the amendment to Directive 2009/16/EC also highlighted a need for a "*2pc RFNBO sub target should apply as of 2034".* This sub-mandate would be subject to the penetration of RFNBOs being monitored in the EU market. If the share of RFNBO in the maritime bunker fuels used by ships (included under ReFuelEU) is less than 1pc by 2031, the sub-mandate should be introduced as of 2034

Source: Argus Consulting

Policy – Sustainable Aviation Fuels

Several countries have outlined plans for SAF mandates

There are currently applicable SAF mandates in Sweden (2pc), France (1pc) and Norway (0.5pc)

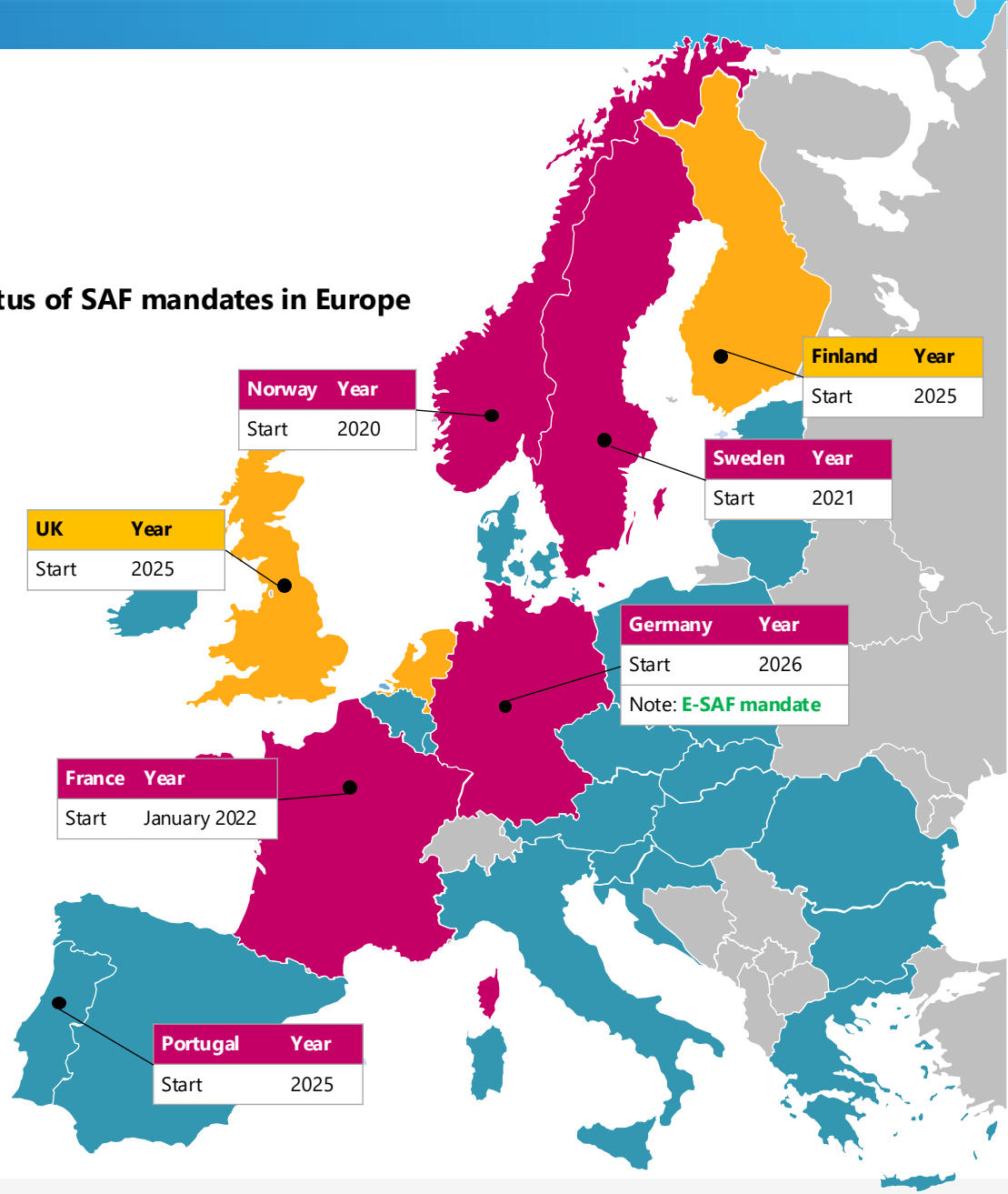
- **Sweden** is the only country with implemented mandates that has proposed a detailed plan for an exponentially increasing mandate basis before 2030
- **France** has proposed to increase mandates to 2pc in 2025 and 5pc in 2030, envisaging most mandate increases after 2030
- **Norway** has a mandate for SAF use and has proposed an increasing mandate pathway that would achieve 30pc in 2030, mandates are proposed to increase from 0.5pc to 2.0pc in July 2023
- **Germany** has introduced a synthetic SAF mandate of 0.5pc SAF from 2026 onwards, accelerating to 2pc in 2030
- **Portugal** has introduced a 2.5pc mandate of energy from renewable sources from 2025 in aviation and shipping, rising to 6pc in 2027 and 9pc in 2029

Discussed Targets:

- Finland is aiming at a mandate of 30pc in 2030, stating that initial smaller mandates should be introduced well in advance
- The UK is discussing a SAF mandate under various scenarios. 0.5pc mandate starting in 2025 and increasing to 65pc in 2050 is currently likely, consistent with the 'Late SAF Breakthrough' scenario from the SAF proposal
- Spain has discussed a 2pc mandate that could be introduced in 2025, but there has been little progress during the past three years

From 2025 member states national mandates will be superseded by ReFuelEU mandates as the EU aims to create a 'level playing field'

Status of SAF mandates in Europe



National mandate: Implemented
National mandate: Proposed/ discussed
No national mandate, covered under EU mandate

Source: Argus Consulting

Europe

Hydrogen strategy and assessment

Europe – Country assessment of hydrogen opportunity

Germany, the Netherlands, France and the UK have high domestic demand for hydrogen and have made some of the most significant strides towards developing their hydrogen economies

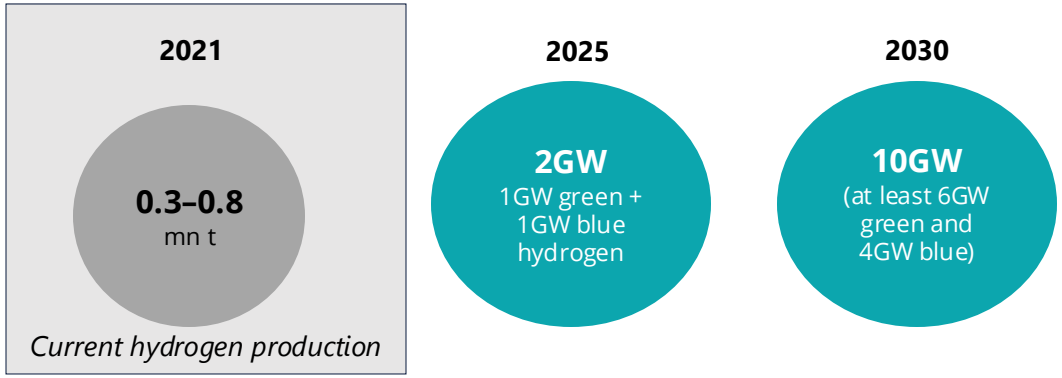
Country	Assessment	Opportunity
Germany		• Intends to phase out coal by 2030 and have renewables account for 80pc of its energy production • In 2023, the country doubled its 2030 hydrogen target to 10GW in an update to its strategy • Around [redacted] projects totalling [redacted] mn t/yr of low-carbon hydrogen production capacity announced, but only [redacted] pc at FID • Hydrogen strategy estimates 50-70pc of 2030 demand will be met through imports • H2Global pilot auction aiming to support imports launched in 2022; winners announced in 2024
Netherlands		• NECP's hydrogen programme outlines the development timeframe and targets for hydrogen, including 4GW of electrolyser capacity by 2030 and 8GW by 2032 • Port of Rotterdam to be hydrogen hub for production, imports, consumption and transport to northwest European countries. Aims aims to supply Europe with 4.6mn t/yr of hydrogen by 2030 • Committing €300mn in joint tender with Germany under H2Global initiative to support hydrogen imports
Belgium		• Targets 150MW of electrolysis capacity by 2026 • Aims to position itself as Europe's import and transit hub for hydrogen and derived fuels. Port of Antwerp targets 10mn t of green ammonia imports by 2030 • Potential to build more electrolysis capacity is limited due to constrains in developing renewable energy, most of which would be reserved for direct electrification • No operating support mechanisms announced
France		• Hydrogen strategy aims to produce 700,000 t/yr of low carbon hydrogen and 6.5GW of electrolyser capacity by 2030 • Around [redacted] low-carbon hydrogen projects announced, but only [redacted] pc reached FID • Investing €7.2bn in hydrogen, focusing on decarbonisation of its mobility and industrial sectors
UK		• One of the highest hydrogen targets in Europe – national strategy targets 10GW by 2030 (at least 6GW green and 4GW blue) • NZHF (£240mn fund) supports developmental and capital expenditure for blue and green hydrogen projects • The country benefits from abundant natural gas and offshore wind resources
Denmark		• Abundant wind resource and offshore wind expansion potential • Aims to be an exporter of green hydrogen production and Power-to-X technologies. Its strategy targets 4-6GW of electrolyser capacity by 2030 • Domestic demand for hydrogen is limited, but planned hydrogen pipeline connecting with Germany offers export opportunity
Spain		• National hydrogen strategy targets 12GW of electrolyser capacity by 2030, which was increased from 4GW • Three projects awarded funding from European Hydrogen Bank's pilot auction – totaling over €263.2mn and generating 56,000 t/yr of hydrogen production • Aims to use hydrogen in industry (replacing 25pc of hydrogen consumed in its domestic sector) and mobility

Source: Argus Consulting

United Kingdom – Low-carbon hydrogen targets

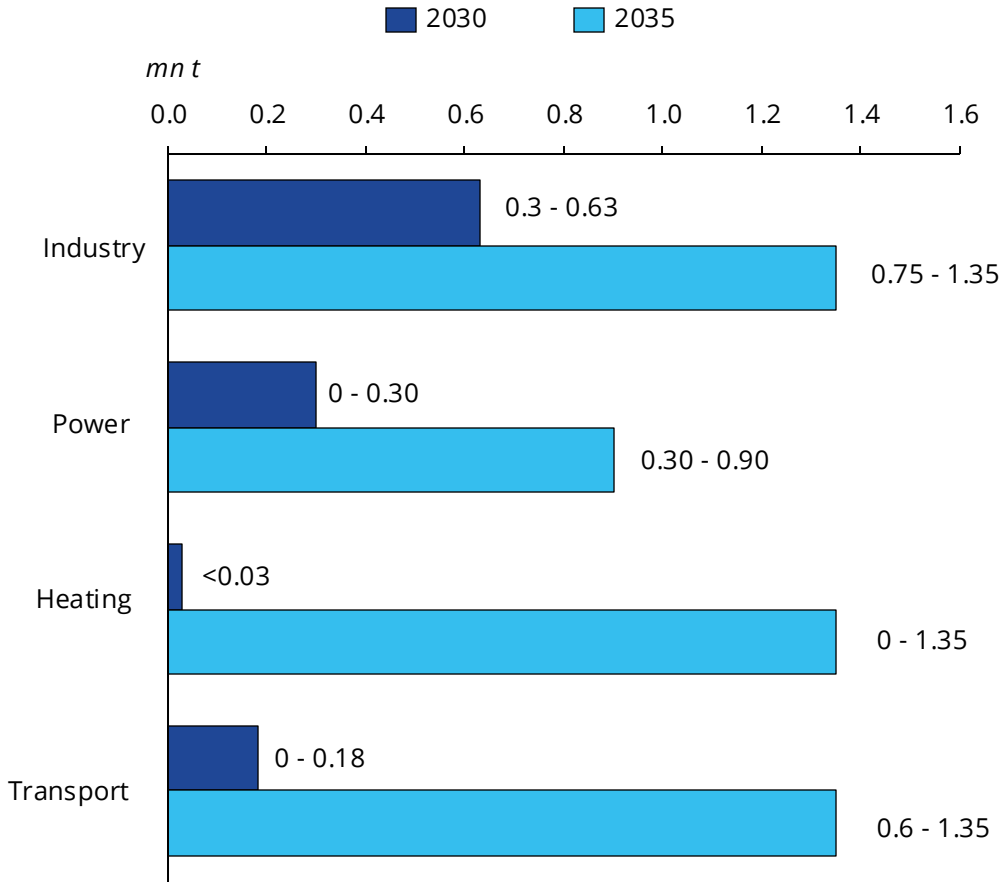
The country targets 2GW of hydrogen production by 2025 and 10GW by 2030. Its strategy estimates hydrogen could account for 20-35pc of final energy consumption in 2050, coming from industry, transport, heating (and power to a lesser extent)

United Kingdom's hydrogen production targets (2025 vs 2030)



- In its *Ten Point Plan for a Green Industrial Revolution*, the UK stated its aim to be a global leader in hydrogen by 2030.
- It targets 2GW of low carbon hydrogen (1GW green + 1GW blue) to be online or under construction by 2025. This target is likely to be missed.
- Initially, the UK aimed for 5GW of low carbon hydrogen production capacity by 2030. In April 2022, this target was doubled to 10GW (at least 6GW green and 4GW blue). following Russia's invasion of Ukraine and the resulting focus on energy security.
- The strategy anticipates low carbon hydrogen will be increasingly used in the 2020s and 2030s to decarbonise industry, power and transport sectors, and potentially heating.
- The UK aims to identify four low-carbon industrial clusters for implementation by 2030, which will serve as key centers of hydrogen demand.
- Its national hydrogen strategy estimates the UK would need 250-460 TWh (7.5-13.8 mn t) of hydrogen by 2050, accounting for 20-35pc of final energy consumption in 2050.

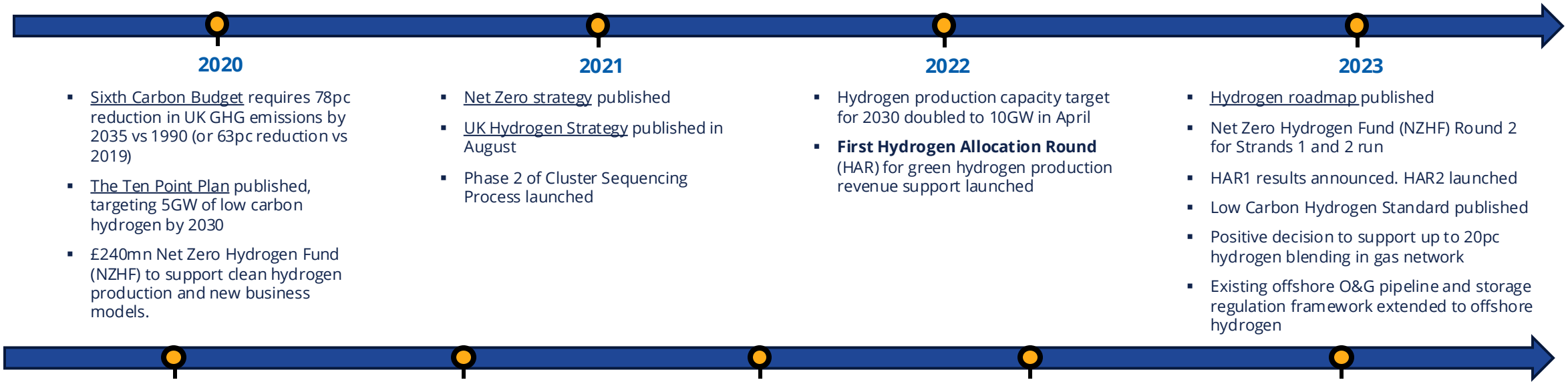
United Kingdom's hydrogen demand by sector (per its national strategy), 2030 vs 2035



Source: UK Hydrogen Strategy

United Kingdom – Hydrogen development timeline

The government has outlined a detailed plan of critical activities and milestones required to reach its 10GW target



Source: Department for Energy Security and Net Zero

Europe

Funding

European Hydrogen Bank (EHB)

The European Commission implemented the EHB to support domestic production and imports of renewable hydrogen through a fixed-premium auction

- The European Commission launched the European Hydrogen Bank (EHB) to accelerate investment in hydrogen production by bridging the investment gap for projects aimed at achieving domestic production targets.
- EHB is based on four pillars:
    i. Two financing mechanisms via fixed premium auctions to support production of renewable hydrogen within the EU and globally
    ii. Providing increased transparency on demand for hydrogen, supply, flows and prices by linking with off-takers and parallel member state initiatives
    iii. Co-ordinate and facilitate blending with existing financial instruments to support hydrogen projects
- A pilot auction was launched in autumn 2023, with winners announced in April 2024 (see next slide for details)
- A second auction will be launched in 2024. The commission is expected to tighten some of the eligibility criteria for the second round.

EHB auction summary

Form of Remuneration	Fixed Premium (€/kg of H2)
Source of Renumeration	Innovation Fund (revenue from the EU ETS)
Type of Remuneration	Output-based, payment is made upon delivery of certified and verified volumes of renewable hydrogen
Duration of Support	10 years
Bid Ranking / Award Criteria	Based on prices only (single-criteria auction)

EHB eligibility criteria – pilot auction

Budget	€800mn
Fixed premium cap	Up to €4.50/kg
Completion guarantee	4pc of requested subsidy
Timeline	• Launched autumn 2023 • Winners announced April 2024 • Projects to be commissioned within 5 years

EHB eligibility criteria (proposed) – second auction

Budget	€1.2bn (of which €200mn is for maritime)
Fixed premium cap	Up to €4.00/kg
Completion guarantee	8pc of requested subsidy
Timeline	• To be launched by end-24 • Projects to reach FID within 2.5 years of signing and be commissioned within 5 years

Source: European Commission

H2Global

The national hydrogen strategy estimates 50-70pc of its 2030 demand will be met through imports. H2Global aims to support imports in three tenders – Fertiglobe won the ammonia tender, while e-SAF tender is cancelled; methanol is ongoing

Summary of H2Global initiative

- Set up in March 2021 by the German government, H2Global represents the first international trading platform for green hydrogen and its derivatives – providing price and volume transparency
- The goal is to promote non-European imports of green hydrogen and support the global market ramp-up by bridging the gap between the cost for producing renewable hydrogen and its derivatives and the price buyers are willing to pay
- Berlin set aside €3.6bn in its 2023 draft budget to build hydrogen supply from abroad; funding can be used by H2Global. Announced it aims to increase to €4bn to support future rounds

H2Global consists of two separate auctions:

1. Determine which exporter is offering the lowest price for deliveries of green hydrogen
2. Purchase quantity is auctioned among interested buyers. Companies with the highest bid are awarded the deliveries. Hintco (Hydrogen Intermediary Network Company) compensates the difference between the purchase price and sales price

H2Global pilot auction

- Initial €900mn pilot auction launched in Dec-2022
- Launching three tenders – one each for ammonia, methanol and sustainable aviation fuel (e-SAF) – with Hintco committing to 10-year contracts

Ammonia Tender
Initial funding: €360mn
Total bids: 22
Amount Awarded: €397mn ($431mn)
Awardee: Fertiglobe
Price: €1,000/t green ammonia
(€811/t + transport, logistics, import duties)
Volume: 19.6kt/yr starting from 2027 (totalling 397kt/yr by 2033)

e-SAF Tender
Initial funding: €300mn
Total bids: 3. No final bids submitted
Amount Awarded: €0mn. Funds re-allocated to the ongoing methanol auction

Hintco stated uncertainty around GHG accounting rules on by-products from e-SAF production dissuaded interested developers from placing final bids.

Methanol Tender
Initial funding: €300mn
Current funding: €600mn (following re-allocation of funds from failed e-SAF tender)

Tender currently ongoing

Potential future joint tenders

The German government is also considering holding joint import tenders with other countries, whose governments have also agreed to providing funding under the H2Global initiative

 €600mn total

 €400mn total

 A$660mn total

 No details

Source: Argus Hydrogen Future Fuels, Argus Consulting

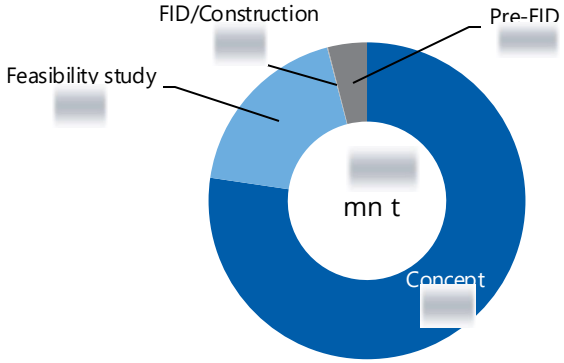
Europe

Supply

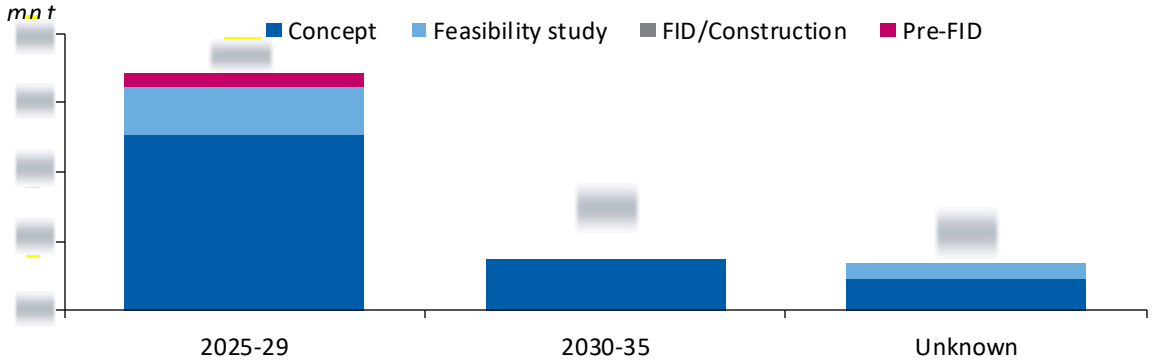
Spain – Announced low-carbon hydrogen production capacity

Around [redacted] projects totalling [redacted] mn t of low-carbon hydrogen production capacity has been announced in Spain but only around [redacted] pc of this is in FID or pre-FID stage

Spain's announced low-carbon hydrogen capacity by status



Spain's announced low-carbon hydrogen capacity by status and online date*



- In 2022, Spain had a total of 0.79mn t of hydrogen production capacity. Approximately 93pc of this total production capacity was from reforming process, with the rest produced as a by-product or from electrolysis.
- Spain announced around [redacted] renewable hydrogen projects totalling around [redacted] mn t of capacity. All are green hydrogen projects.
- However, only BP has thus far announced it has taken FID on a renewable hydrogen project to decarbonise operations at its Castellon refinery. Another [redacted] projects are expected to be nearing FID after having been awarded funding through IPCEI's Hy2Use programme or having been selected as winners from the European Hydrogen Bank's pilot auction. Together, these projects in FID or pre-FID stages make up just [redacted] pc of the total announced capacity.
- The remaining announced capacity remains in feasibility ([redacted] pc) or concept ([redacted] pc) stage, indicating there is a high degree of uncertainty around the commissioning dates.
- The Spain government targets 11GW of installed electrolyser capacity by 2030. The announced projects scheduled to come online prior to 2030 would be more than double this target.

**Excludes cancelled projects and projects with less than 10MW electrolyser capacity*

Source: Argus Consulting, European Hydrogen Observatory

Spain – Advanced low-carbon hydrogen projects

Only BP's Castellon refinery project has announced FID, although [redacted] projects totaling [redacted] kt/yr are nearing FID after having been awarded EU funding

	Project name	H2 capacity (000 t/yr)	Developer	Project Details
1	**BP Castellon refinery**	4.3	BP, Iberdrola	BP plans electrolysis capacity at its 108,000 b/d Castellon refinery. FID was announced in July 2024, but details of capacity and timeline remain unclear at the time of publication – BP previously said it aims to install 200MW of electrolysis capacity by 2027. The hydrogen is to be used to decarbonise its refinery operations but also supply other industrial consumers.
2	**Asturias H2 Valley**	17.3	EDP	Phase 1 consists of 150MW electrolysis capacity to be operational end-2025/start-2026. The hydrogen is be used to decarbonise a nearby coal-fired power plant at Aboño. There is potential to expand by another 350MW in Phase 2. FID on Phase 1 is pending.
3	**Bilbao Large Scale Electrolyser**	15.2	Petronor (Repsol)	100MW green hydrogen industrial hub planned at Repsol's existing refinery near Bilbao. The project was awarded IPCEI funding under Hy2Use. FID is pending.
4	**Cartagena Large Scale Electrolyser**	17.0	Repsol, Engie	100MW electrolyser to be built in Murcia in southeast Spain. The hydrogen would be consumed at Repsol's Cartagena refinery. The project was awarded IPCEI funding under Hy2Use. FID is pending.
5	**Catalina**	84	Renato PtX consortium (Enagás Renovable, Naturgy, Fertiberia and CIP)	Project aims to develop 504MW onshore wind and 571MW solar to power a 500MW electrolyser. The plant is to produce 84,000 t/yr of hydrogen and 247,000 t/yr of ammonia capacity. The hydrogen would be used for industry (mainly fertiliser) and gas grid injection. Potential to increase capacity to 2GW by 2030. The project was selected in the European Hydrogen Bank's pilot auction to receive €230mn.

Spain's total announced hydrogen capacity

Green

[redacted] mn t/yr

Note: table excludes projects with less than 20MW electrolyser capacity

Source: Argus Consulting

Europe

Demand and BEP

Europe – Country demand assessment

Methodology

Country's hydrogen policy/strategy

Is the policy ambitious? (Does it have any firm hydrogen production consumption targets?)

Does the policy address specific applications in specific sectors?

Does the policy/strategy set out sector-specific targets?

If all the above criteria is met

Hydrogen demand

Breakeven price

If a country has a policy with ambitious hydrogen production and consumption targets by a certain year and has sector-specific targets like fuel cell vehicle fleet deployment, hydrogen blending percentage in gas grid, hydrogen co-firing percentage et,c then both sector-specific hydrogen demand and breakeven prices are calculated

If all the above criteria is not met completely

Breakeven price

If a country has a policy that may or may not have hydrogen production or consumption numbers, no sector specific targets but identifies in the plan those sectors that it is willing to decarbonise, then only breakeven prices for hydrogen in that sector is provided

Based on the methodology, the following elements and sectors will be discussed in Europe's demand section

Hydrogen demand

- Refinery
- Ammonia/fertilisers
- Road transport
- Steel

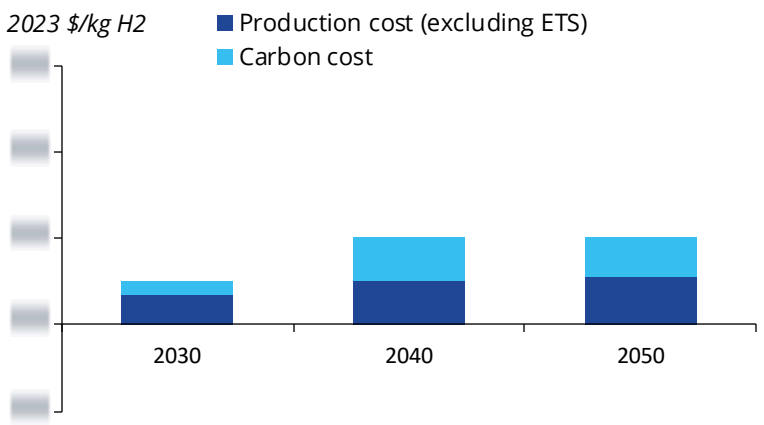
Breakeven price

- Refinery
- Ammonia/fertilisers
- Power generation
- Gas blending
- Road transport
- Steel

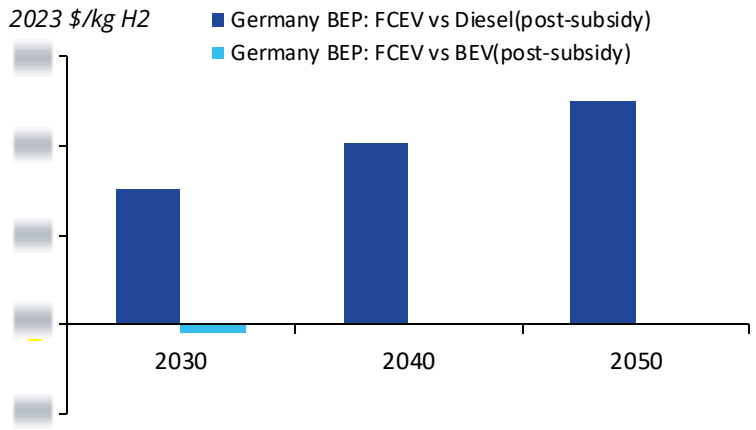
Comparison of breakeven prices across sectors

Argus' BEP analysis incorporates support mechanisms, such as EU ETS and subsides, to allow comparisons to be drawn across multiple sectors and countries

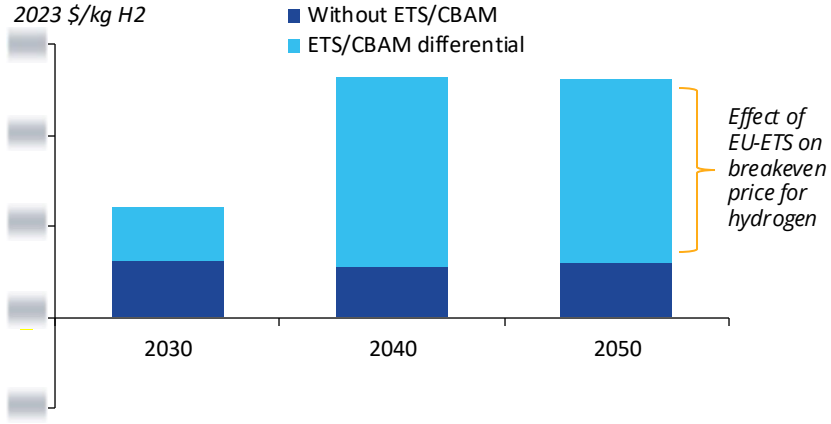
BEP refinery (Germany)



BEP road transport, buses (Germany)



BEP steel, H2-DRI vs BF-BOF (Germany)



- *Argus*' breakeven price analysis highlights the price at which hydrogen should be available such that it becomes cost-competitive to the incumbent fuel.
- In the above charts, we show a comparison of the breakeven prices in Germany's refinery, road transport and steel sectors for the years 2030, 2040 and 2050. In the case of refining, green hydrogen is compared to the price of grey hydrogen. For road transport, hydrogen is compared to a battery electric and petrol/diesel vehicle. For steel, hydrogen is compared to coal in a blast furnace.
- However, taxes and subsidies also act as important support mechanisms to encourage the deployment of hydrogen. For emissions intensive sectors, such as refining and steel, *Argus*' BEP analysis factors in the additional cost of carbon (EU ETS). For road transport, *Argus*' BEP analysis considers country-level incentives, such as purchase subsidies by vehicle type.
- The effect of these mechanisms can be seen in the charts. The relatively high BEP for buses and steel would suggest that these are two sectors where hydrogen has good potential in Germany.
- The benefit of *Argus*' BEP analysis is that comparisons can be drawn across multiple sectors and countries.

Source: Argus Consulting

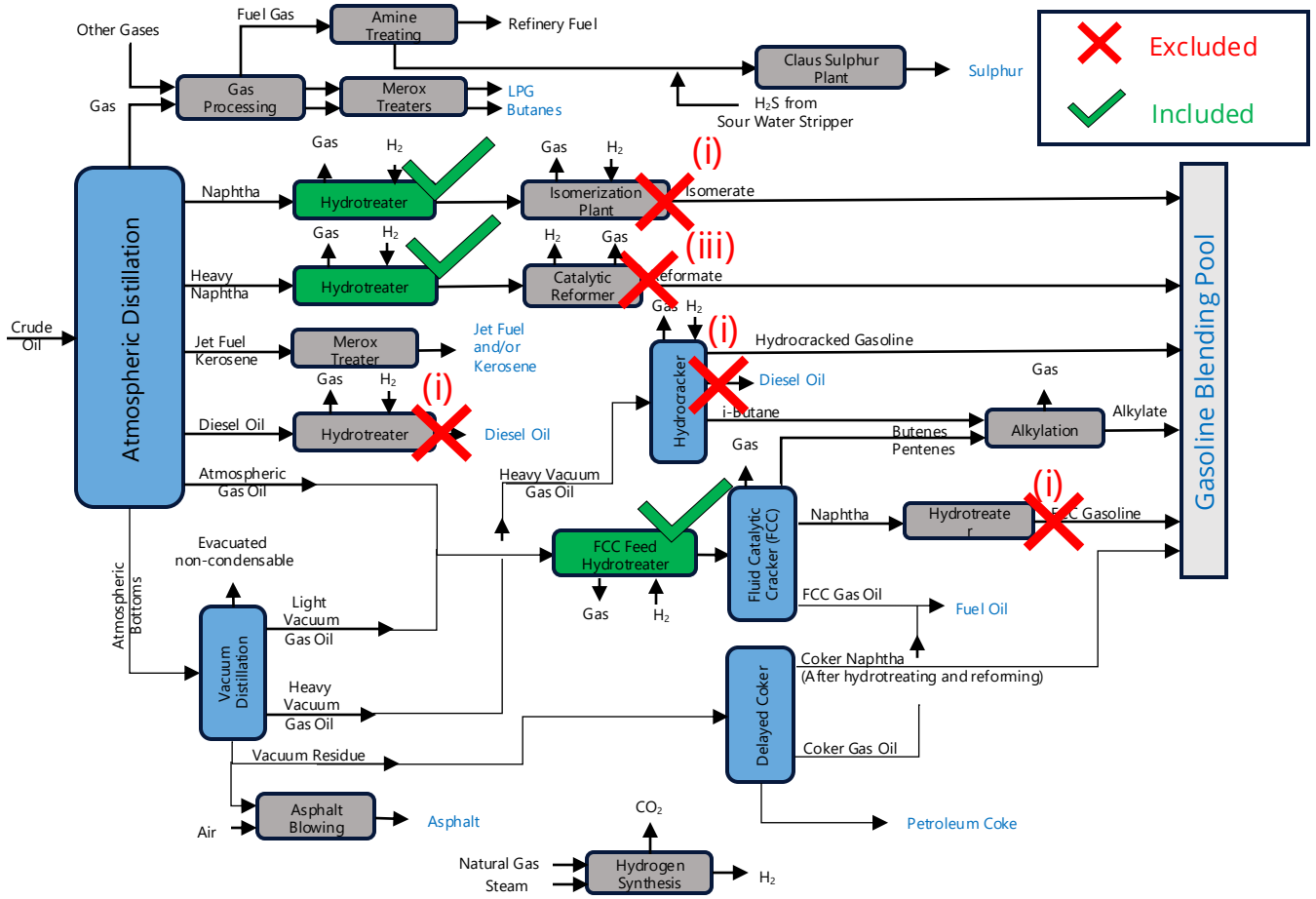
Europe

Demand – Refinery

Europe – Methodology for hydrogen demand in Europe's refining sector (method 1)

Method 1: calculation of refinery hydrogen demand based on EU's REDIII RFNBO policy guidelines

Hydrogen included and excluded in refining as per RFNBO guidelines



Industrial Green Hydrogen Mandate:

- The European Commission's REDIII mandates that at least 42pc of hydrogen used in **industry** must come from renewable fuels of non-biological origin (RFNBO) by 2030, increasing to 60pc by 2035.
- The policy provides guidelines for the calculation of hydrogen to be **excluded** under the RFNBO targets:
  - *i. **hydrogen used as intermediate products for the production of conventional transport fuels and biofuels***
  - *ii. **hydrogen that is produced by decarbonising industrial residual gas and that is used to replace the specific gas from which it is produced;***
  - *iii. **hydrogen produced as a by-product or derived from by-products in industrial installations***

Method 1

- This first method to calculate firm demand for green hydrogen in refineries takes into consideration the guidelines provided by the European Commission for calculating the hydrogen that is eligible under the REDIII industrial mandate.
- We leverage *Argus'* in-house refinery yield model, which tracks the production and consumption of green hydrogen within each of the refineries in the European countries covered under this report.
- From this model, we can identify the specific hydrogen consuming units that would be subject to the industrial mandate and, from this, estimate the green hydrogen that would be generated by these units.

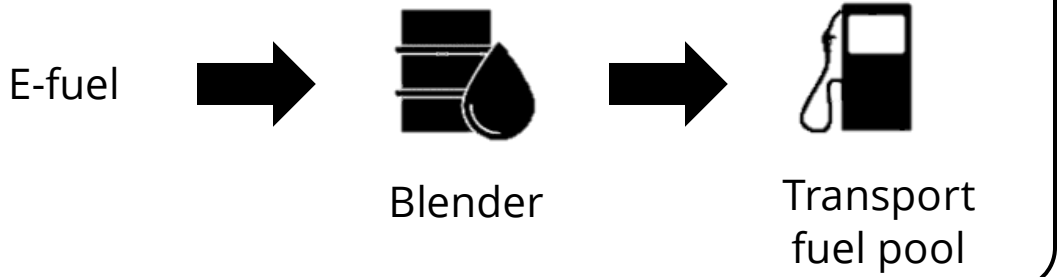
Source: Argus Consulting

Europe – REDIII's RFNBO sub-mandate compliance options (method 2)

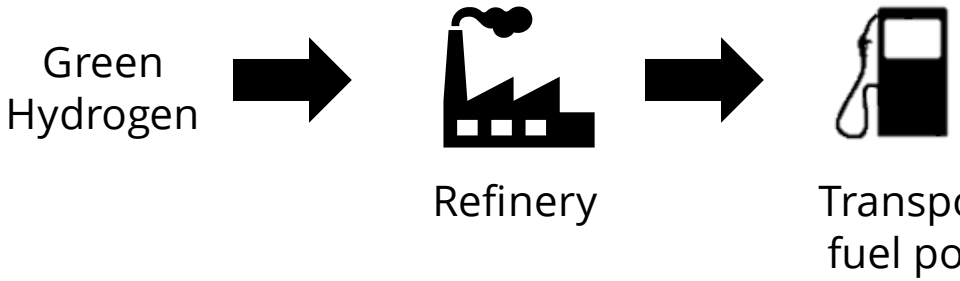
REDIII allows the RFNBO refinery route as a compliance option

RED III: RFNBO sub-mandate compliance options

1. E-fuel blending



2. Refinery intermediate fuels



Method 2 Rationale:

- Although refiners may not be incentivised to use notable volumes of green hydrogen on the back of the industrial mandate, the use of green hydrogen in refineries will be an eligible means of generating RFNBO tickets / meeting the transport mandate for RFNBOs under REDIII. Method 2 attempts to capture **firm** sources of green hydrogen consumption by refineries.

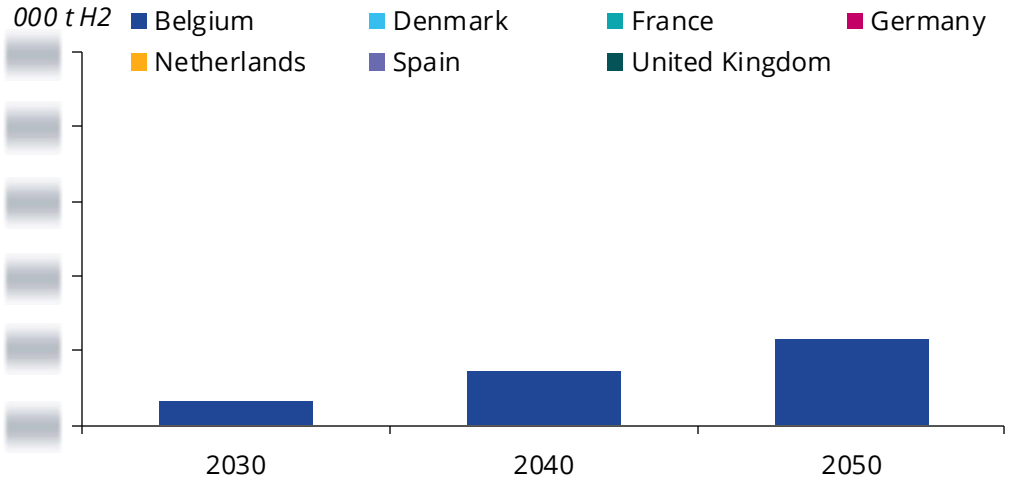
Source: Argus Consulting

Europe – Firm hydrogen demand in Europe's refining sector (summary)

Method 1 resulted in limited demand, so a production capacity-based method has been used to estimate green hydrogen consumption in refineries

Method 1: based on EU's REDIII RFNBO policy guidelines

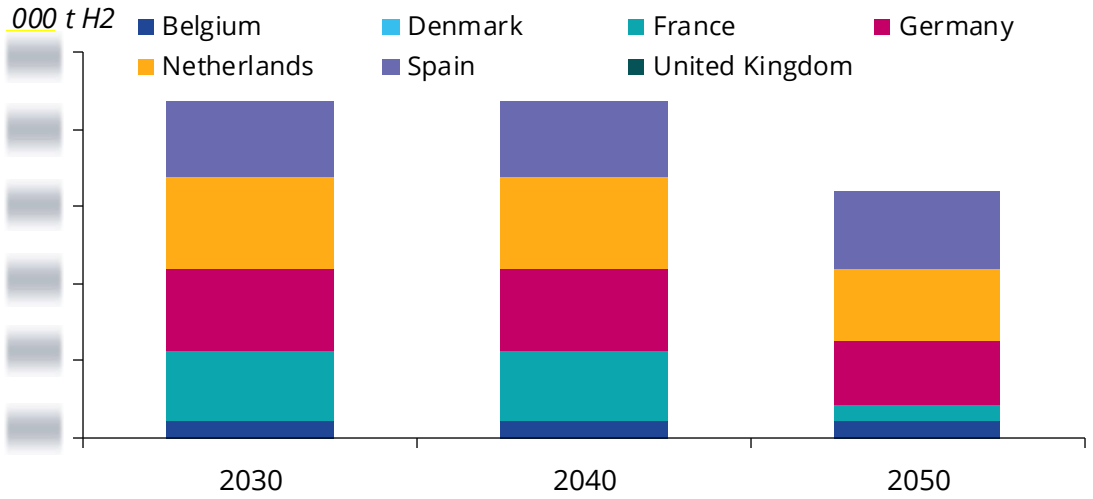
- European refineries are decarbonising their operations by displacing grey (fossil-based) hydrogen with green. While the green hydrogen would be consumed within the refinery, much of this is used to produce transport fuels.
- Therefore**, when green hydrogen is consumed in a refinery as an intermediate to produce transport fuel, it is counted towards REDIII's transport mandate for RFNBO, instead of industry**.
- This avoids double-counting demand for low-carbon hydrogen, but results in low 'apparent' demand for hydrogen in refining.
- (See following slide for further details on what is included in the calculation).



Notes: Firm green hydrogen demand only

Method 2: based on project announcements for green hydrogen use in refineries

- Firm demand under Method 2 includes all project announcements where green hydrogen is to be used in a refinery to displace existing grey hydrogen.
- This will likely be used to counted towards RFNBO ticket generation and meet the RED III RFNBO mandate.
- The chart shows cumulative green hydrogen capacities announced from refineries in the respective countries.
- For modelling purposes, we assume 100pc of the hydrogen capacity is captive (i.e. consumed in the refinery). Green hydrogen capacity = demand.



Source: Argus Consulting

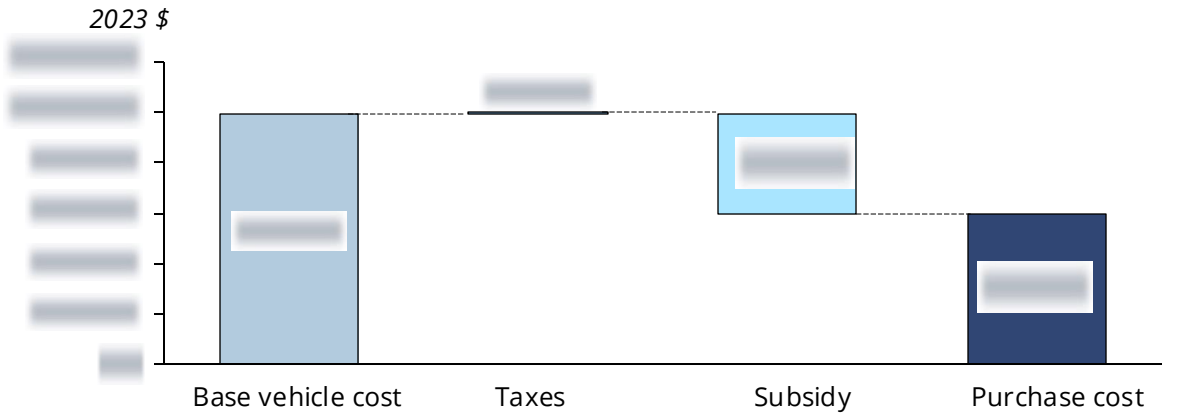
Europe

Demand – Transportation

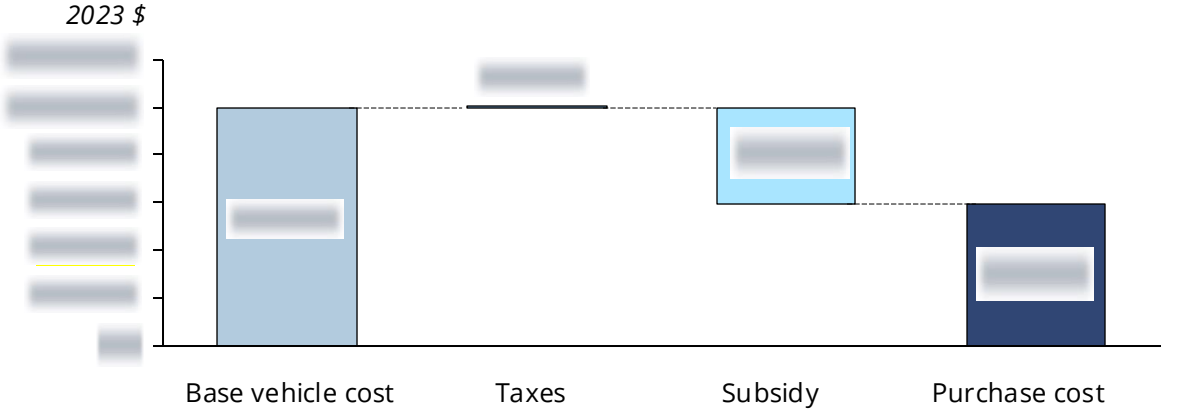
Impact of subsidies on hydrogen breakeven prices in road transport

Subsidies for FCEVs can increase competitiveness, but similar subsidy for BEVs makes it difficult for FCEVs to compete

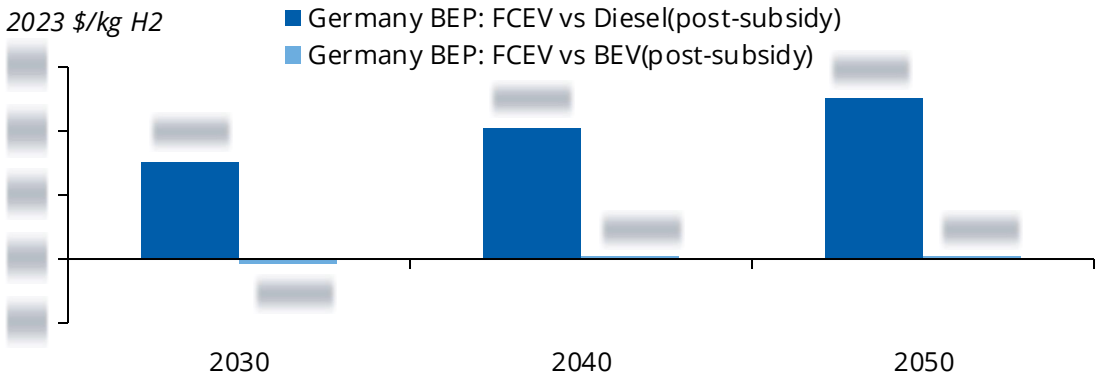
Purchase cost breakdown of FCEV buses, 2023



Purchase cost breakdown of BEV buses, 2023



BEP for buses in Germany



Note: subsidy incorporated till 2050 for our analysis, however it ended in February 2024

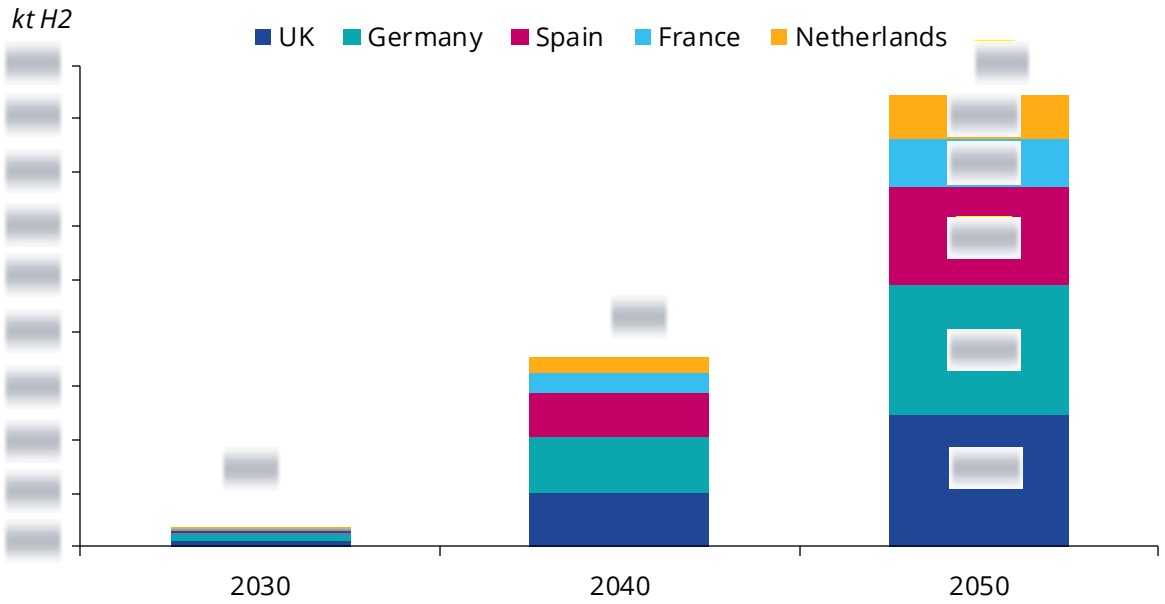
- Many countries in the EU recognise hydrogen's role in heavy vehicles, aviation and maritime, where battery alternatives are less viable, and therefore provide measures, such as taxes incentives and subsidies, to encourage adoption.
- Until Feb-2024, the German government was providing a subsidy for the purchase of zero emission buses (FCEV and BEV). However, since the same subsidy amount is provided for both technologies, it is more difficult for FCEVs to increase penetration over BEVs.
- The bottom-left chart shows the breakeven prices for hydrogen in Germany's bus fleet. With the subsidy, FCEVs become economical vs diesel; however, the analysis shows that FCEV's remain uneconomical vs BEVs. Factors, such as fast refuelling time and low-weight fuel, can make hydrogen vehicle a better option but this requires suitable infrastructure and subsidies to be in place.

Source: Argus Consulting

Low-carbon hydrogen demand in road transport in Europe

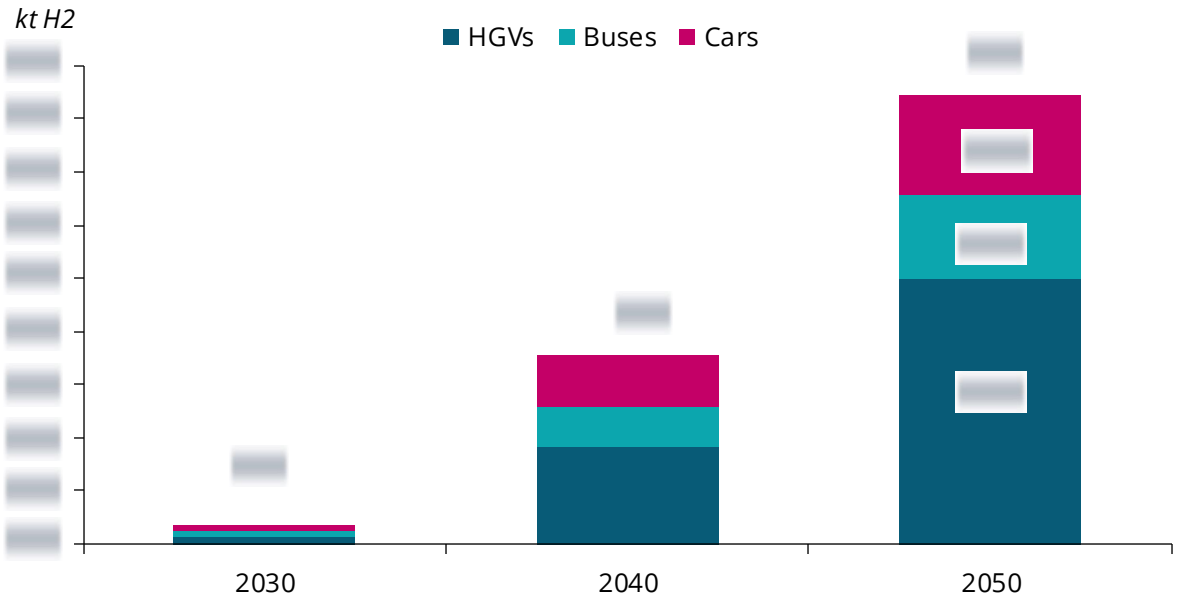
UK, Germany and Spain to account for over [redacted]kt of hydrogen demand in road transport in 2050. In the long-term, hydrogen is likely to play the largest role in HGV segment

Hydrogen demand in transport by country (kt/yr)



- Hydrogen demand in the European countries covered under this report is expected to grow at a faster pace from 2040 onwards.
- Argus estimates hydrogen demand to be around [redacted]kt in 2030, [redacted]kt in 2040 and [redacted]kt in 2050.
- UK, Germany and Spain are expected to account for the largest share of demand at [redacted]pc, [redacted]pc and [redacted]pc, respectively, by 2050.

Hydrogen demand in transport by vehicle type (kt/yr)



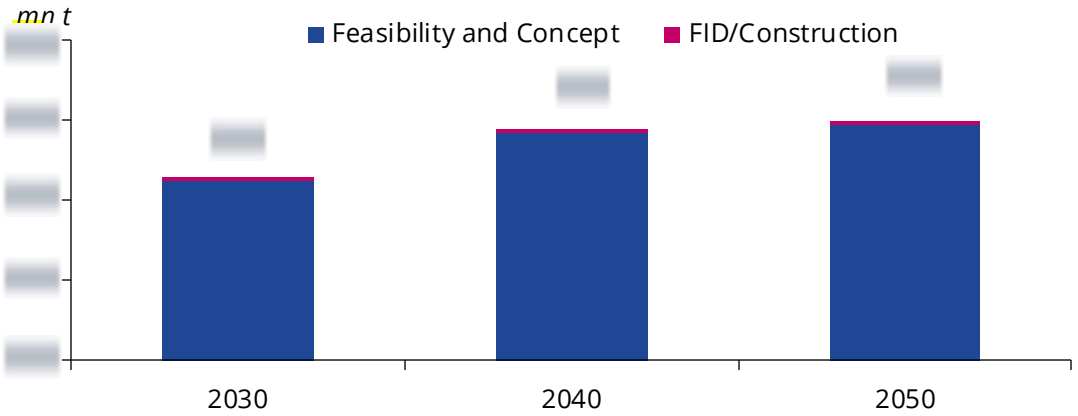
- FCEV HGVs are expected to contribute significantly to overall hydrogen demand because HGVs are used in long haul journeys and require less refuelling time, which is an advantage over BEV HGVs.
- *Argus* estimates more than half of demand is expected to come from HGVs, making up [redacted]pc in 2050.
- The share of hydrogen in buses and cars remains similar even with higher FCEV buses penetration is due to the fleet difference between the two with latter being significantly higher in numbers.

Source: Argus Consulting

Low-carbon hydrogen supply vs total transport demand in EU

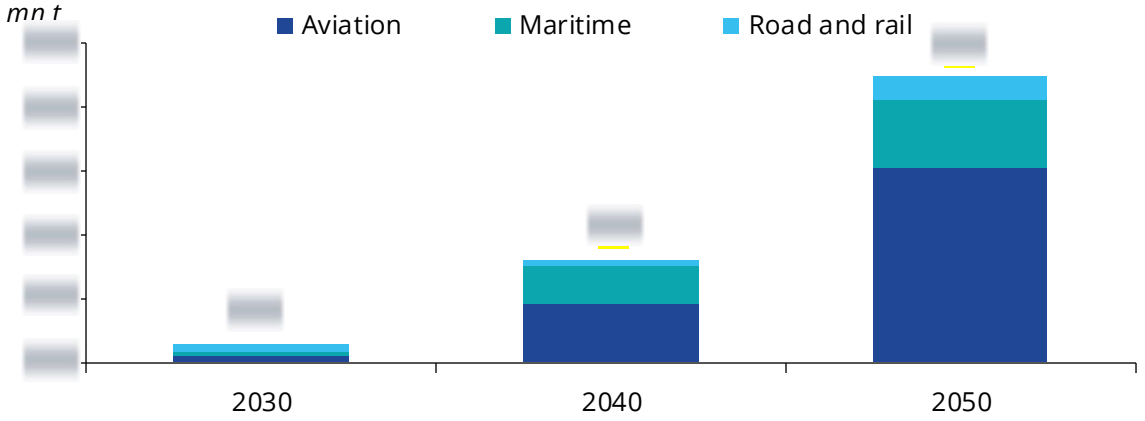
Argus estimates [redacted] mn t of firm demand in EU transport in 2030, rising to [redacted] mn t in 2050, led by aviation and maritime

Low-carbon hydrogen supply in EU (EU 27, UK and Norway)



- According to the IEA hydrogen project database, 23mn t/yr of low-carbon hydrogen capacity has been announced to come on line by 2030. But only 593,000 t/yr (2pc) of this is 'firm' (FID or under construction).
- The EU's demand-supply balance suggests firm demand in transport ([redacted] mn t) outstrips firm supply ([redacted] mn t) five-fold in 2030.
- [redacted] mn t/yr of low-carbon hydrogen capacity has been announced for launch by 2050. But this is still short of the [redacted] mn t/yr of firm demand that *Argus* forecasts from the transport sector alone by this time.
- ***Note:*** *the above chart shows the total low-carbon hydrogen project pipeline for EU 27 countries + the UK and Norway as reported in the IEA's hydrogen project database. Argus' analysis of the hydrogen projects in the countries covered in this study can be found in the country sections.*

Firm green hydrogen demand in transport in EU (EU 27, UK and Norway)



- *Argus* estimates that firm demand for green hydrogen in the transportt sector across the EU 27 + UK and Norway could reach [redacted] mn t/yr by 2030 and [redacted] mn t/yr by 2050.
- Argus classifies hydrogen demand in 2030 as 'firm' since it is driven by the EU's Renewable Energy Directive III (RED III) mandate, which states that at least 1pc of the total energy supplied to the EU's transport sector should come from RFNBOs (i.e. green hydrogen and e-fuels).
- After 2030, legislation for the aviation (ReFuelEU) and maritime (FuelEU Maritime) sectors come into force. Since no future increases to the RED III transport mandate have been announced, the proportion of green hydrogen demand into aviation and maritime increases significantly over time relative to hydrogen into road and rail.
- ***Note:*** *the above chart shows green hydrogen demand in the transport sector of the EU 27 + UK and Norway. Detailed analysis for hydrogen into other non-transport demand sectors can be found in the country sections.*

Source: Argus Consulting, IEA

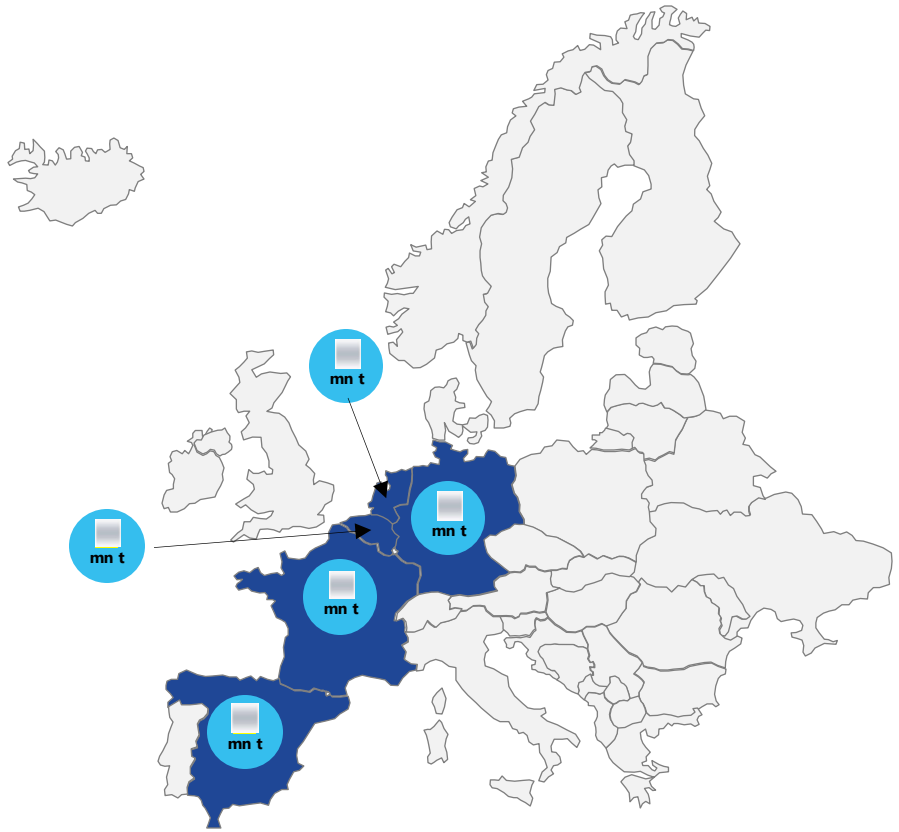
Europe

Demand – Steel

Planned green steel projects in Europe

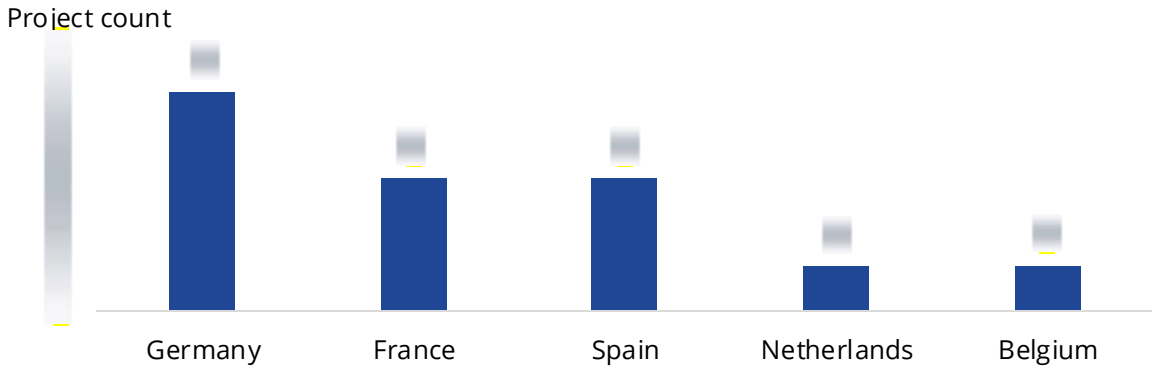
green steel projects have been announced in Europe, with around mn t/yr of capacity. Germany has the largest number of green steel projects and the highest planned capacity

Europe's green steel projects



Total planned capacity= mn t/yr

Europe's green hydrogen project count by country



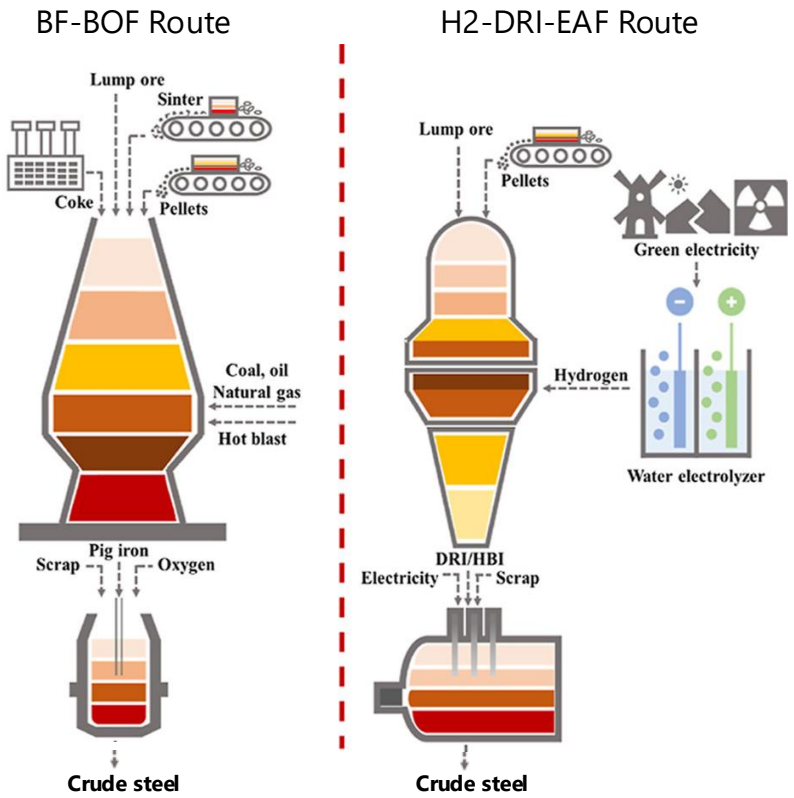
- Europe is one the early movers in green steel. REPowerEU specifies approximately 30pc of the EU's primary steel production is to be decarbonised using renewable hydrogen by 2030.
- Most of the green steel projects announced in Europe have announced online dates from the late 2020s. Therefore, we expect commercial-scale green steel production to come online from around 2030.
- Germany has announced the largest number of green steel projects, with total capacity of around mn t/yr.
- France announced green steel projects with a total capacity of mn t.
- Spain announced green steel projects with a total capacity of mn t.
- The Netherlands only has one steel plant - Tata's 7.5mn t/yr steel plant in Ijmuiden. The company plans to convert this blast furnace plant to DRI (2.5mn t/yr) by 2026.

Source: Argus Consulting

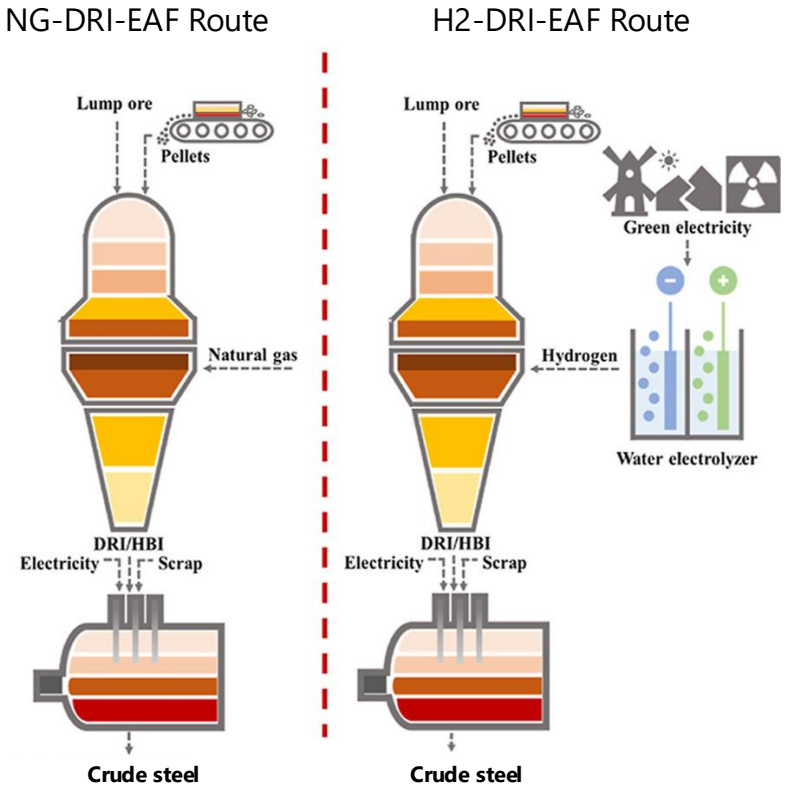
Breakeven price scenarios in steel

Argus has modelled the green hydrogen BEP comparing levelised cost of steel production using the BF-BOF, NG-DRI-EAF, and H2-DRI-EAF routes

Scenario 1: Comparing levelised cost of steel (LCOS) between a traditional BF-BOF steel plant and a hydrogen-based DRI-EAF steel plant



Scenario 2: Comparing levelised cost of steel (LCOS) between a natural gas DRI-EAF steel plant and a hydrogen-based DRI-EAF steel plant

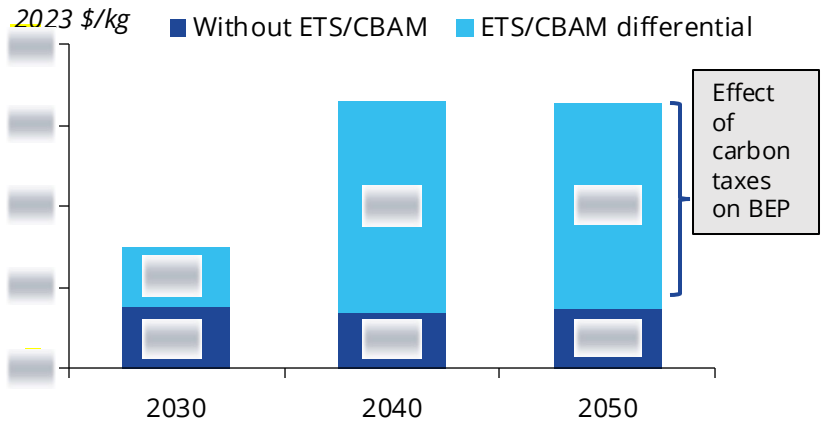


Source: Journal of Cleaner Production, Argus Consulting

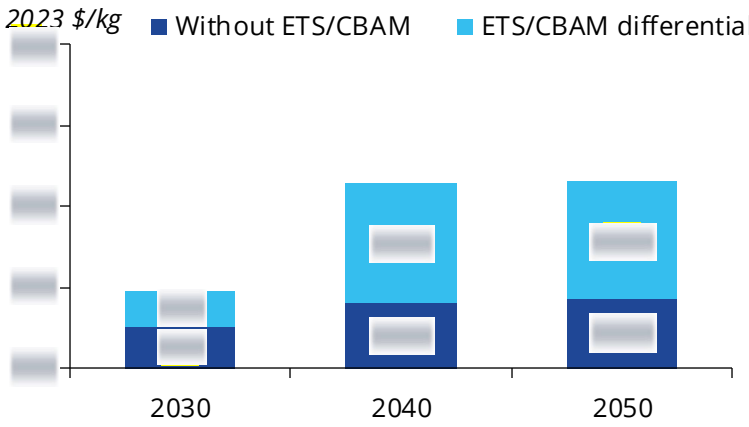
Germany – BEP and demand for hydrogen in steel

Argus' BEP analysis suggests that H2-DRI becomes economical with EU ETS in place. Firm demand for green hydrogen could reach around /yr from 2040 but total demand for hydrogen could reach mn t/yr if all Germany's BF-BOF production switched to H2-DRI

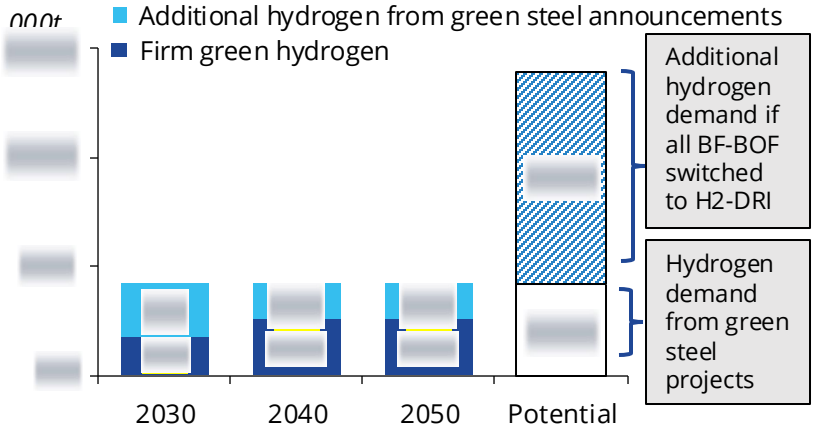
BEP analysis H2-DRI vs BF-BOF with carbon tax



BEP analysis H2-DRI vs NG-DRI with carbon tax



Hydrogen demand from Germany's steel sector



- The breakeven price (BEP) signifies the price hydrogen should be available such that the hydrogen technology (H2-DRI) becomes economically viable vs the traditional counterpart (BF-BOF or natural gas-DRI).
- The BEP calculation includes the raw material price and balances like iron ore lump, sinter and scrap, as well as fuel prices like coking coal, pulverized coal and natural gas etc.
- The BEP analysis incorporates the effect of EU ETS on the BF-BOF and natural gas-DRI processes. Carbon cost is the main driver of the high BEP in steel industry which is carbon intensive. EU ETS price is expected to double from its current level as free allowances are withdrawn from the market, which will further increase the carbon cost burden on BF-BOF and NG-DRI-EAF steel plants. The BEP analysis incorporates both the effect of EU ETS and CBAM.
- The positive BEP trend suggest that H2-DRI becomes economically competitive against the BF-BOF process with EU ETS in place if hydrogen is available at $ kg in 2030, $ /kg in 2040 and $ /kg in 2050. H2-DRI also becomes economically competitive against the natural gas-DRI process with EU ETS in place if hydrogen is available at $ kg in 2030 and $ /kg in both 2040 and 2050.

- mn t of crude steel production capacity via hydrogen has been announced to come onstream from 2026 onwards. Assuming 1t of crude steel requires 37.9kg hydrogen, the announced capacities would generate hydrogen demand of 'yr from 2030.
- For this analysis, *Argus* assumes steel producers comply with the REDIII industrial mandate. Thus, the demand for green hydrogen could reach yr in 2030, increasing to yr in 2040 and 2050.
- If all the mn t of steel produced from blast furnaces in Germany switched to H2-DRI, 'yr of potential hydrogen demand could be generated.

Source: Argus Consulting

Meet the team

Yu Kin Yeo

Senior Vice President (Singapore)

Yeo Yu Kin heads Argus Consulting Services in Asia & Middle East. He is responsible for Argus' advisory work in the region. Under his charge, Argus Consulting Services expanded rapidly in terms of bespoke study volume and industry coverage. Today, Argus Consulting carries out market and strategy studies in virtually all energy and chemicals spaces, including oil, refined products, petrochemicals, generation fuels, renewable energy, biofuels and biomass, fertilizer and metals.

Joyce Grigorey

Principal (London)

Joyce has 15+ years of experience in research and consulting, business development, strategy and project management roles gained across the natural resources sectors, including hydrogen, power & renewables, petrochemicals, plastics, refining, gas and shipping. She holds an MBA (Honours) from Imperial College London.

Dale Hazelton

Principal (Singapore)

Dale has 15+ years of experience in a variety of leadership and content specialist roles. His areas of expertise include hydrogen, generation fuels, power & renewables, and metals & mining. Dale holds a B.S. Mining Engineering from West Virginia University.

For more information including a full table of contents, click here.

