Argus Low Carbon Hydrogen Strategy Report Sample

Americas

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 potential demand.

Mandates for low-carbon hydrogen in Europe and Asia are driving demand globally; however, no similar mandates currently exist in the Americas. Thus, a different set of criteria needs to be considered to assess the region's demand potential.

The region's lack of mandates for the use of low-carbon hydrogen in specific sectors, coupled with uncertainty in regulatory policies and financial incentives, has been slowing the development of a hydrogen economy in many countries. Despite this, access to abundant, low-cost feedstocks, such as natural gas and renewables, holds much promise in supporting the region's ambitions to become a leader of hydrogen exports.

This third part of *Argus'* ***Low-Carbon Hydrogen Strategy Report*** provides insight into:

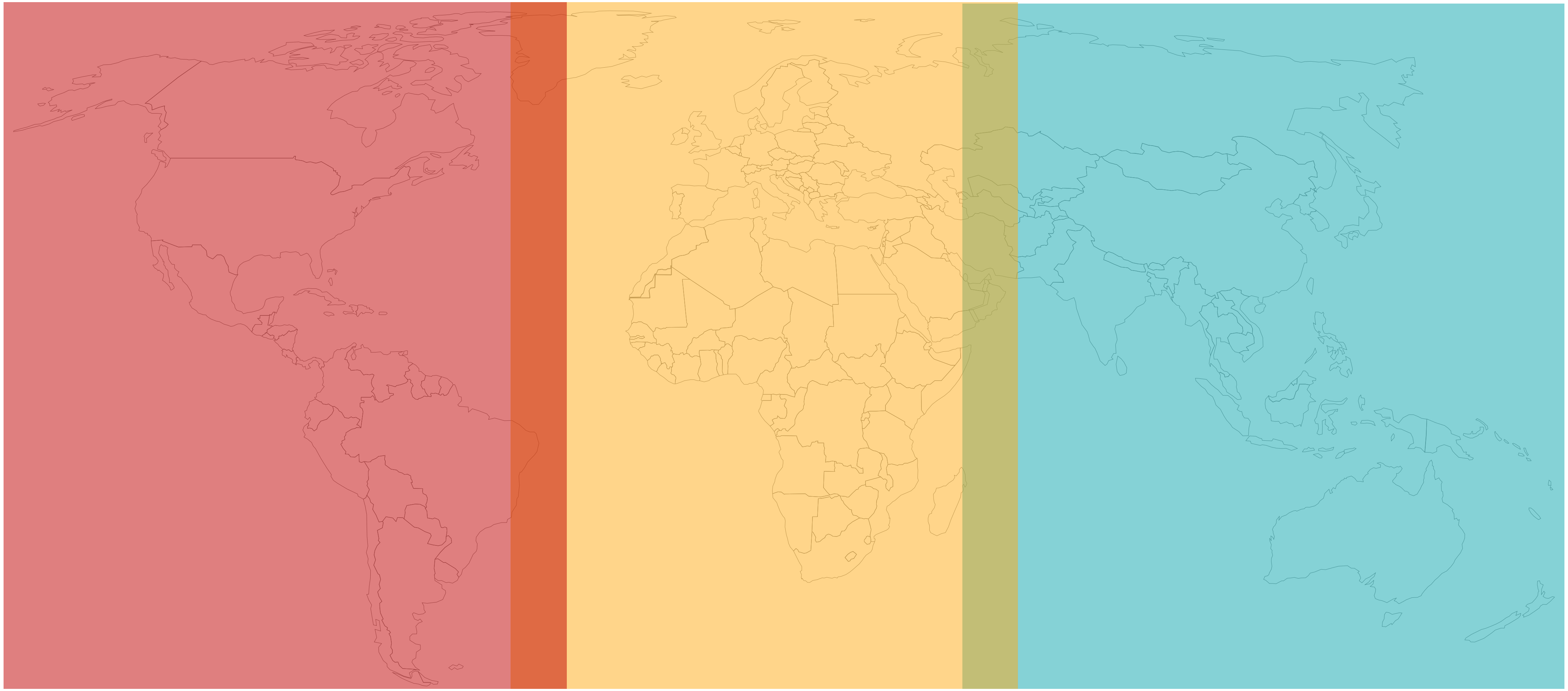
- what factors are driving hydrogen production and consumption in the Americas;
- when domestic low-carbon hydrogen demand could emerge and in what sectors;
- how much demand potential there could be in the Americas; and
- how large the export opportunity could be and what steps countries are taking to capitalise on this opportunity.

Geographies covered under this study

Part 1: Asia-Pac and the Middle East

Part 2: Europe and Africa

Part 3: Americas



illuminating the markets®

Source: Argus Consulting

Geographies covered under Part 3 (Americas)

Part 3 of this study provides insight into the hydrogen development in three North American countries and five Latin American countries. Given the lack of mandates for low-carbon hydrogen in the region, *Argus* has assessed the ***potential*** demand in these countries.

North America

1. US
2. Canada
3. Mexico

Latin America

1. Brazil
2. Chile
3. Argentina
4. Colombia
5. Uruguay

Hydrogen policy available

Hydrogen policy under preparation

No hydrogen policy

Part 3 of *Argus'* ***Low-Carbon Hydrogen Study*** study focuses on hydrogen supply and demand developments in North America and Latin America.

Given the lack of mandates for low-carbon hydrogen in any North American or Latin American country, *Argus* has assessed the ***potential*** demand for the countries covered under this report. It is worth noting that this methodology differs from Parts 1 and 2 of this study, where clear mandates, such as the EU's REDIII, have established specific targets for low-carbon hydrogen use in certain sectors, which we have used to inform our estimates of ***'firm' or mandate-led*** demand in those countries and regions.

Where possible, we have provided the assumptions and methodology used to determine the potential demand by country in this Part 3 of the study. For example, for the US we have referenced the US Department of Energy's industrial and transport decarbonisation strategies to inform our estimates of the possible penetration rate of low-carbon hydrogen among competing technologies in each sector.

We have only considered demand into sectors where a country's national hydrogen strategy indicates hydrogen will be used. Thus, demand projections are provided for the US, Canada, Brazil, Chile and Colombia.

A supply overview is provided for all countries covered under this Part 3 of the study.

Source: Argus Consulting

Key features

Part 3 of 3

Part 1: Asia-Pacific and the Middle East

Part 2: Europe and Africa

Part 3: Americas

8 countries

North America: US, Canada and Mexico

Latin America: Brazil, Chile, Argentina, Colombia and Uruguay

500 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

Table of Contents

argus

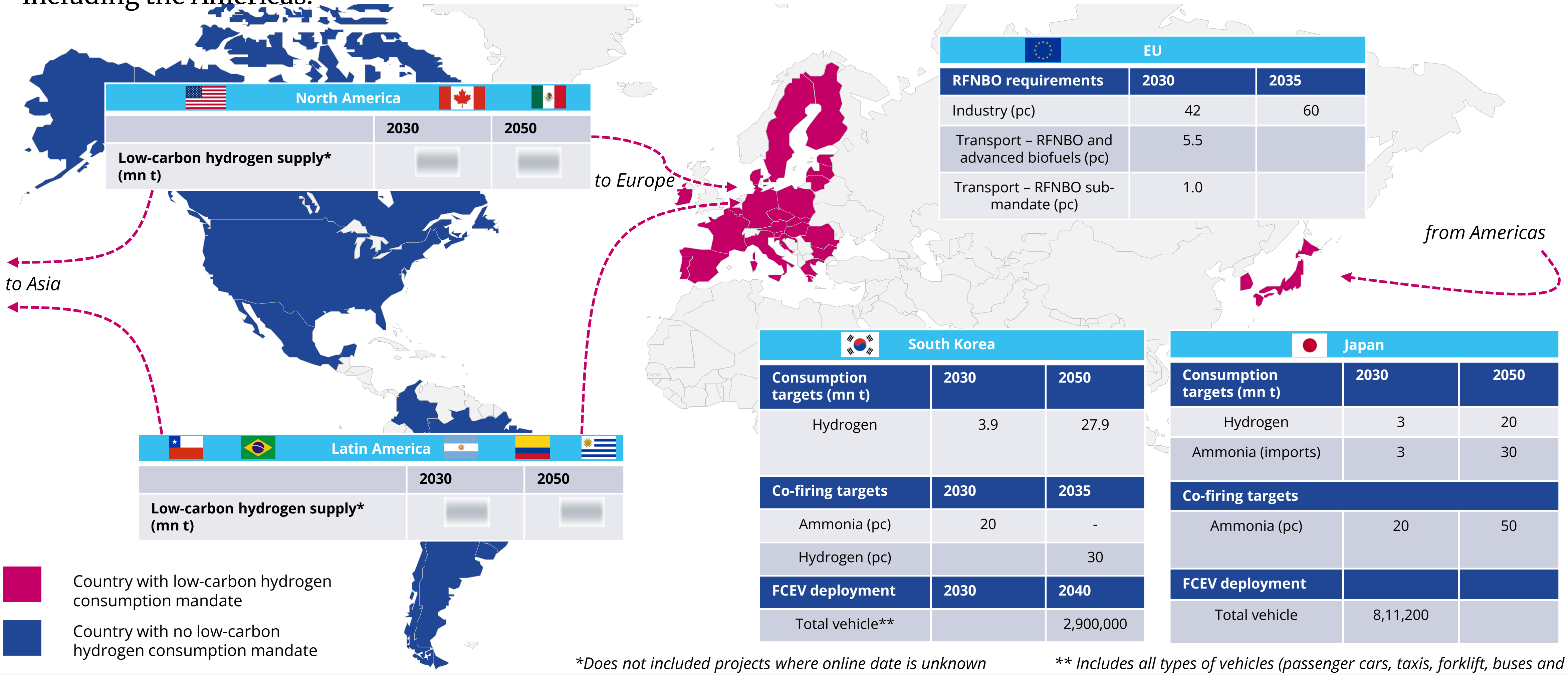
Sample content

Sample data and insight for the Americas hydrogen markets follows.

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

Executive Summary: Mandates for low-carbon hydrogen in Europe and Asia

Mandates in Europe and Asia are driving hydrogen demand globally - these regions are net short of production and are therefore reliant on lower-cost imports, which is prompting plans for large scale exports from regions with abundant, low-cost feedstocks, including the Americas.



North America

	2030	2050
Low-carbon hydrogen supply* (mn t)	[illegible]	[illegible]

Latin America

	2030	2050
Low-carbon hydrogen supply* (mn t)	[illegible]	[illegible]

EU

RFNBO requirements	2030	2035
Industry (pc)	42	60
Transport – RFNBO and advanced biofuels (pc)	5.5	
Transport – RFNBO sub-mandate (pc)	1.0	

South Korea

Consumption targets (mn t)	2030	2050
Hydrogen	3.9	27.9
Co-firing targets	**2030**	**2035**
Ammonia (pc)	20	-
Hydrogen (pc)		30
FCEV deployment	**2030**	**2040**
Total vehicle**		2,900,000

Japan

Consumption targets (mn t)	2030	2050
Hydrogen	3	20
Ammonia (imports)	3	30
Co-firing targets		
Ammonia (pc)	20	50
FCEV deployment		
Total vehicle	8,11,200	

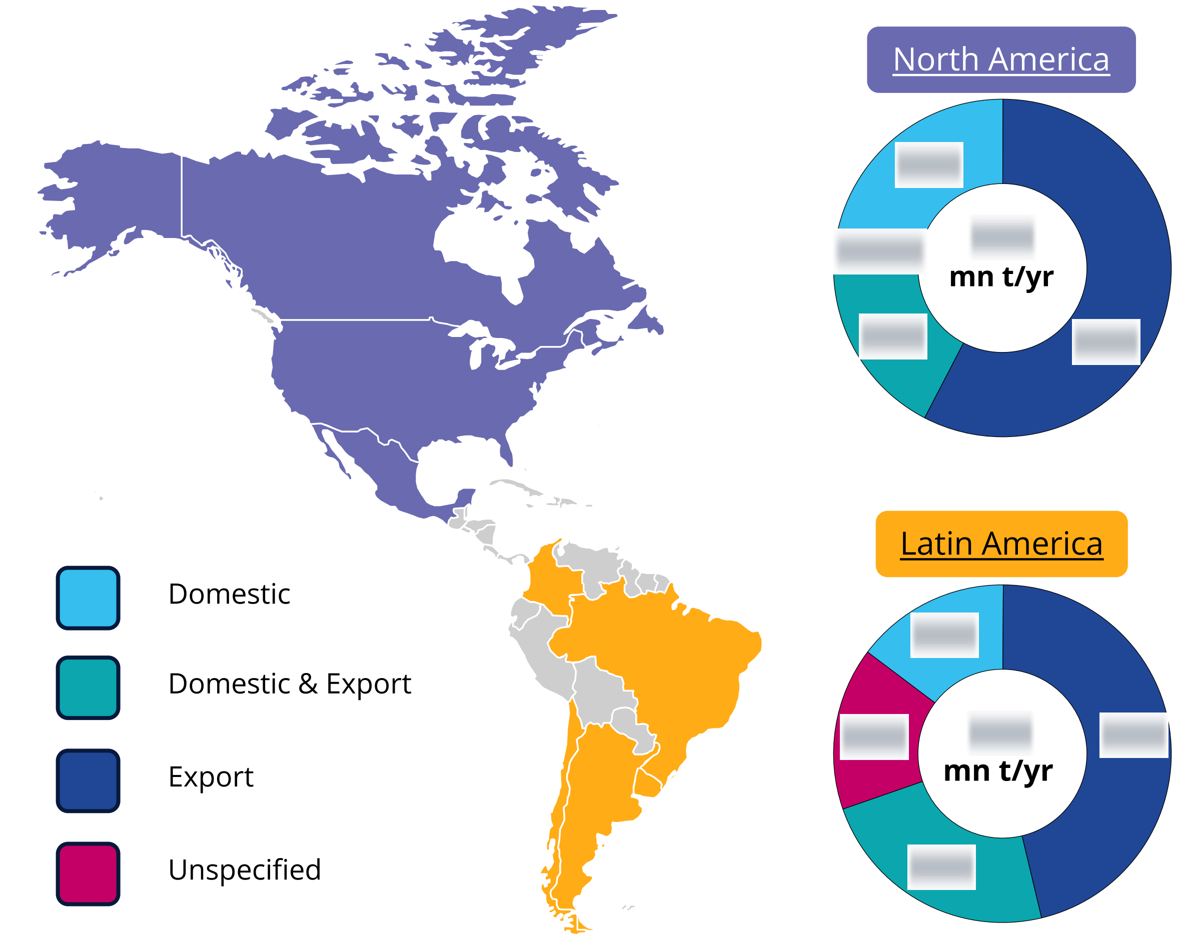
*Does not included projects where online date is unknown

** Includes all types of vehicles (passenger cars, taxis, forklift, buses and trucks)

Executive Summary: Americas low-carbon hydrogen target market

Argus estimates that over half of the announced low-carbon hydrogen production capacity it is tracking in the Americas is targeted for export.

The Americas low-carbon hydrogen supply* by target market



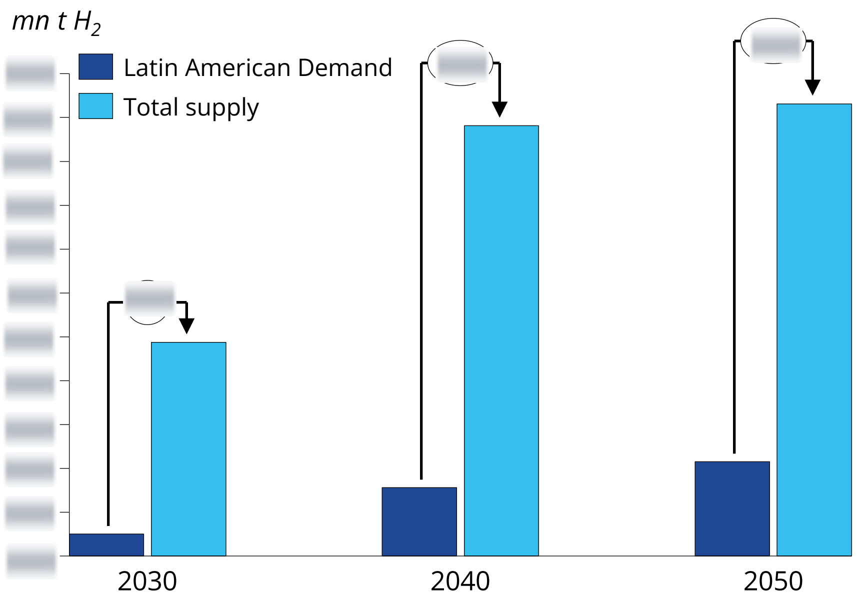
- *Argus* estimates that over 50pc (or [illegible] mn t/yr) of the announced low-carbon hydrogen production capacity it is tracking in the Americas is targeted for export.
- In the US, nearly [illegible] mn t/yr of low-carbon hydrogen production capacity is targeted at Asia (i.e. Japan and South Korea) – the majority of which is as blue hydrogen/ammonia. Exports to Asia represent around [illegible] pc of the country's total low-carbon hydrogen capacity slated for export.
- In Canada, around [illegible] t/yr of low-carbon hydrogen production capacity (or [illegible] pc of total announced capacity) is targeted for export. Of this, around two-thirds is to be exported to Europe as green hydrogen or its derivative, leveraging excellent wind resources in the country's east coast, as well as its proximity to the EU.
- In Latin America, just under half of the low-carbon hydrogen production capacity is targeted for export. Another [illegible] pc is targeting both the domestic and export markets – with further investment in export facilities, more of this share could shift to target solely export as offtakers in Europe and Asia have a higher willingness to pay than domestic markets.

**Does not included projects where online date is unknown*

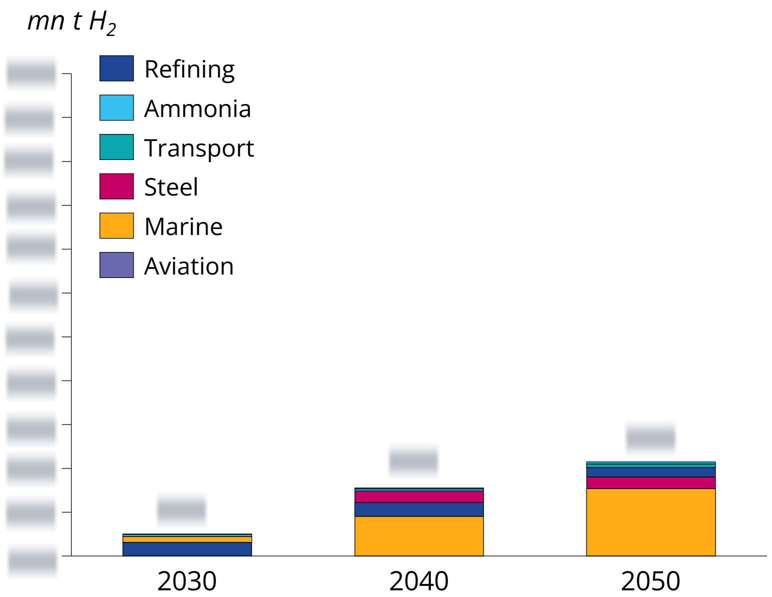
Executive Summary: Low-carbon hydrogen domestic demand – Latin America

In Latin America, growth in domestic demand for low-carbon hydrogen is limited, which *Argus* estimates could be around [illegible] mn t/yr by 2050, driven by the marine sector. The region's large renewables potential could make it a significant net exporter of hydrogen and its derivatives.

Latin America supply* vs demand**



Latin America demand by sector**



- *Argus* estimates low-carbon hydrogen demand in Latin America could reach [illegible] mn t/yr by 2030, [illegible] mn t/yr by 2040, and [illegible] mn t/yr by 2050.
- Demand for low-carbon hydrogen in Latin America is led by the marine sector, where demand could reach as high as [illegible] mn t/yr by 2050 (or [illegible] pc of total demand forecasted in the region). This is driven by the IMO's emission reduction targets for the international shipping sector, but national targets like those in Panama will also drive low-carbon hydrogen demand in the region's marine sector.
- Unlike North America, growth in domestic demand in Latin America is expected to be limited. Therefore, there is a significant supply surplus over the forecast. Assuming no further capacity is announced, the surplus could reach [illegible] mn t/yr by 2050. This surplus potential could make the region a large exporter of low-carbon hydrogen and its derivatives over the long-term.

**Does not included projects where online date is unknown*

***Marine demand is for the entire Latin American region not just highlighted countries*

US

Low carbon hydrogen/ammonia export opportunity

Overview
Hydrogen strategy and assessment
Low-carbon ammonia export opportunity
Funding
Infrastructure
Supply
Demand and BEP
Refinery
Ammonia/fertilisers
Power generation
Gas blending
Transportation
Steel

US – Key takeaways for the US clean ammonia export opportunity

Low-cost natural gas, coupled with the IRA tax credits make the US a favourable place to build low-carbon ammonia production, but uncertainty over BIL/IRA funding is likely to delay the commissioning of plants.

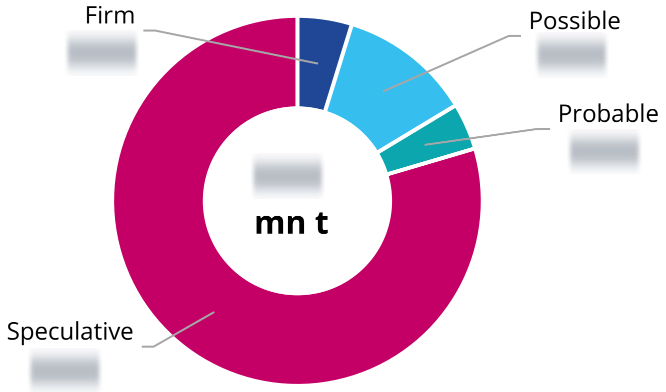
Factor	☑ Supportive of ammonia exports	☒ Not supportive of ammonia exports
Cost	• Low natural gas prices in the US make blue hydrogen cost competitive vs green hydrogen • Additionally, clean ammonia producers could be eligible to claim a tax credit under the IRA of up to $3/kg H_2 via the 45V or up to roughly $0.85 /kg H_2 via the 45Q • Finalised 45V rules mean blue hydrogen producers with low methane emissions could qualify for 45V, which offers a higher rate than 45Q (CO2 sequestration credit) • *Argus* believes the IRA's 45Q credit will likely remain unchanged and could result in more support for blue hydrogen/ammonia production	In Jan-2025, President Trump issued a number of executive orders aimed at rolling back efforts to tackle climate change, including halting any unspent funds under the IRA
Offtake agreements	• [redacted]pc of the US' announced low-carbon ammonia capacity is blue ammonia. Generally, blue ammonia produced in the US is targeting the export market, while green is targeting the domestic market. • Some green ammonia offtake agreements have already been signed	There have been no legally-binding offtake agreements for US blue ammonia
Exports	• Europe and Asia have consumption mandates for low-carbon hydrogen, which leads to countries in these regions having higher willingness to pay • Asia is more accepting of blue ammonia	In Europe, imports of blue ammonia will be subject to carbon tax on embedded emissions from 2026 under its Carbon Boarder Adjustment Mechanism (CBAM)
Project pipeline	[redacted] mn t/yr of low-carbon ammonia capacity has been announced in the US	• Only [redacted] of announced projects has reached FID • FID's will hinge on the outcome of the BIL funding and IRA's tax credits • Delays to project timelines are likely

Source: Argus Consulting

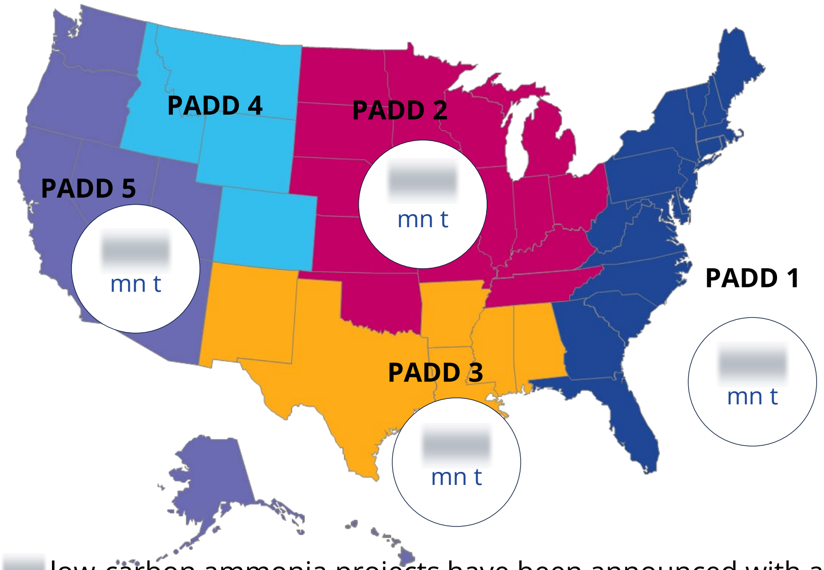
US – Announced low-carbon ammonia production capacity

Of the [redacted] mn t/yr of low-carbon ammonia projects that have been announced in the US, nearly [redacted] pc ([redacted] mn t/yr hydrogen equivalent) is targeting the export market; however, only [redacted] of the potential capacity has reached 'firm' or 'probable' status according to *Argus' Ammonia Analytics.*

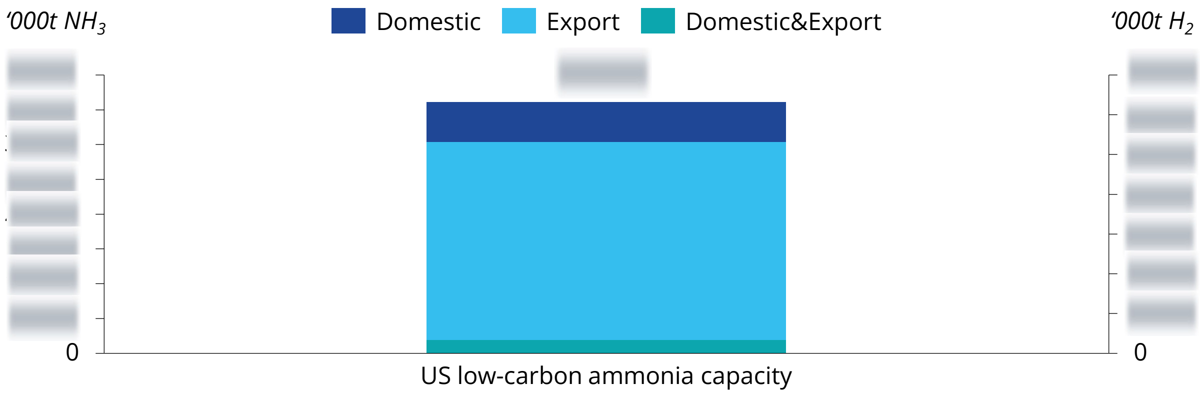
US announced low-carbon ammonia capacity by likelihood



US announced low-carbon ammonia capacity by PADD



US total announced low-carbon ammonia capacity by target market



- In the US, [redacted] low-carbon ammonia projects have been announced with a combined production capacity of [redacted] mn t. 85pc ([redacted] mn t) of this is in PADD 3.
- [redacted] pc of the US' announced low-carbon ammonia capacity is blue ammonia. Low natural gas prices in the US make blue hydrogen cost competitive vs green hydrogen.
- *Argus' Ammonia Analytics Service* suggests only [redacted] is currently in 'firm' or 'probable' status, illustrating the high-degree of uncertainty surrounding new projects.
- **Almost [redacted] pc of the announced capacity ([redacted] mn t/yr ammonia, equivalent to around [redacted] mn t/yr of hydrogen is targeting export markets)**, namely to Europe and Asia, where there is demand and a higher willingness to pay for low-carbon ammonia due to mandates for low-carbon hydrogen use in various sectors.

US – International offtake MoUs and agreements for US clean ammonia (green)

Some green ammonia offtake agreements have been signed and are for domestic consumption.

US green ammonia offtake agreements

Importer	Type of agreement	Companies involved	Ammonia end-use	Details
	Offtake agreement	[illegible]	Fertilisers	[illegible]
	Offtake agreement	[illegible]	Ammonia	[illegible]
	Memorandum of Understanding (MoU)	[illegible]	Fertilisers	[illegible]
Unknown	Offtake agreement	[illegible]	Unknown	[illegible]

Source: Argus Consulting, Individual company websites

US

Funding

US – Inflation Reduction Act (IRA)

The IRA's 45V tax credits provides incentives for clean hydrogen production, while the 45Q incentivises carbon capture, usage and storage

Inflation Reduction Act (IRA) explanation

- Signed into law in Aug-2022, the IRA is the most significant climate legislation in the country's history. It offers $369bn of investments, including tax incentives, grants, loans and other investments to encourage the use of clean energy and accelerate the net-zero transition. The law is expected to reduce energy costs for businesses and individuals, increase private investment in clean energy, strengthen supply chains and create good-paying, quality jobs for workers.
- It is also projected to lead to the reduction of GHG emissions by 40pc by 2030 versus 2005 levels, bringing the US one step closer to realising its ambition of lowering emissions by 50-52pc over the same period.

Evaluation of IRA production tax credits under Trump's presidency

- With the upcoming change in US government, there is some uncertainty about whether there will be any changes made to the IRA tax credits or possibly scrapped altogether.
- **Market participants are more confident that the 45Q credit will likely remain unchanged**. Since the 45Q tax credit is likely to generate jobs and economic growth in key Republican states, oil and gas companies are likely to lobby for the 45Q tax credit to remain.
- During his campaign, Trump pledged to boost US oil and gas production. This could lead to further **support deployment of blue hydrogen production** in the US.
- For these reasons, it is more **likely that blue ammonia will take priority over green** in the US, at least for this presidential term.

IRA incentives provision for clean hydrogen production/supply

The act includes provisions for clean hydrogen and fuel cell technologies, either extending existing tax credits, increasing existing federal tax credits or creating new federal tax credits.

Clean hydrogen production tax credit (45V) (1)

Provides incentives to hydrogen produced with methods emitting less than 4kgCO_2/kg of hydrogen. The incentives range from $0.6/kg - $3/kg of hydrogen, depending on carbon intensity (see next slide for further explanation)

Carbon capture and sequestration tax credit (45Q) (2)

12-year tax credit for carbon dioxide (also includes other carbon oxides, such as carbon monoxide) that is captured and stored or used, beginning on the date the carbon capture equipment was originally operational

Energy and storage credit (48) (3)

Extends the 30pc fuel cell investment tax credits

Advanced Energy Project credit (48C)

Extends 30pc investment tax credits for projects manufacturing FCEVs, electrolysers and hydrogen infrastructure

- Investment Tax Credit (ITC): Incentives in the form of percentage of the capital investment
- Production Tax Credit (PTC): Incentives per unit of product produced
- Additional detail covered on subsequent slides

US – ① IRA 45V final rules

More hydrogen projects may be eligible for the 45V tax credit as the US Treasury relaxes the rules, allowing nuclear and fossil-based power sources to be considered, while postponing the requirement for hourly matching by two years.

45V implications for green hydrogen

The 45V tax credit has three pillars that electrolytic-hydrogen producers must follow to claim the credit. When the rules were initially proposed, some proponents argued they were too strict and would limit eligible projects. After an extended consultation, the US treasury released the final rules in Jan-2025, relaxing some of the rules initially proposed.

Three pillars	Proposed guidance	Final rules	Implication
Additionality (to encourage build of clean capacity)	Hydrogen must be produced from clean generation capacity that was built at most 36 months prior	▪ Existing nuclear power plants at risk of retirement or closing can power electrolysis. Only merchant plants (sell <50pc of their power on the wholesale market) are eligible ▪ Existing gas or coal-based power plants retrofitted with CCS within 36-months of hydrogen production starting can power electrolysis ▪ States with renewable portfolio standards (RPS) can claim. Only applies to California and Washington currently, but more states could implement RPS	Hydrogen produced from more energy sources, including nuclear and fossil-fuels, can qualify
Temporal matching (to avoid increased grid emissions)	Hydrogen should be produced with electricity generated in the same hour	Annual matching will be allowed until 2027 and will transition to hourly matching from 2028. (EU rules allow monthly matching until 2030)	Hourly matching requirement postponed by two years to allow for a more gradual transition
Regional deliverability (to minimise inter-region grid congestion)	Electrolyser must source electricity from within the grid-region it operates (grid-region is defined by the DOE)	Electricity can be supplied cross grid-regions to produce hydrogen, provided the electricity can be tracked on an hour-to-hour (or more frequent) basis.	Adds some flexibility for electricity transfers

45V implications for blue hydrogen

US DOE's GREET* lifecycle emissions	GREET applies a fixed rate for upstream methane emissions (based on a national average) to calculate lifecycle emissions	Project-specific methane emissions to be accepted in calculating lifecycle emissions	Blue hydrogen producers with low methane emissions could qualify for 45V, which offers a higher rate than 45Q (CO2 sequestration credit)

**Greenhouse gases Regulated Emissions and Energy Use in Technology*

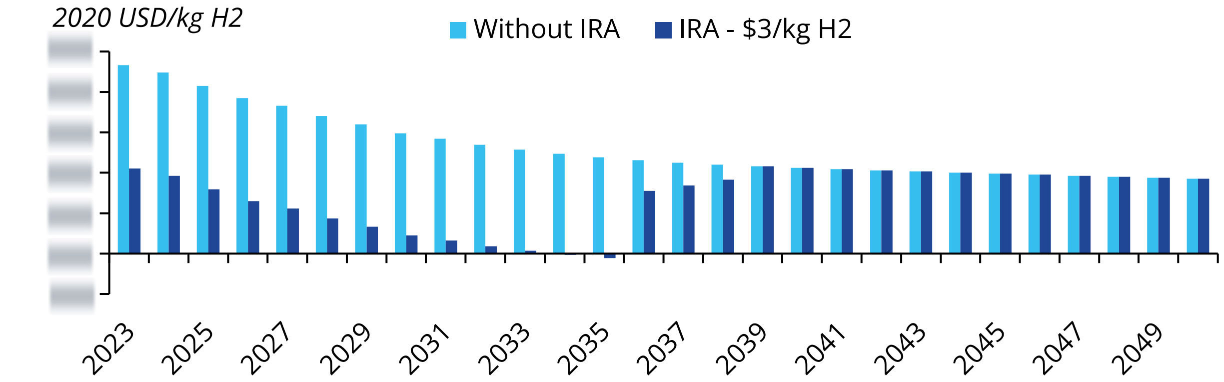
Source: Argus Consulting, US Department of the Treasury

US – Impact of IRA on green hydrogen production costs

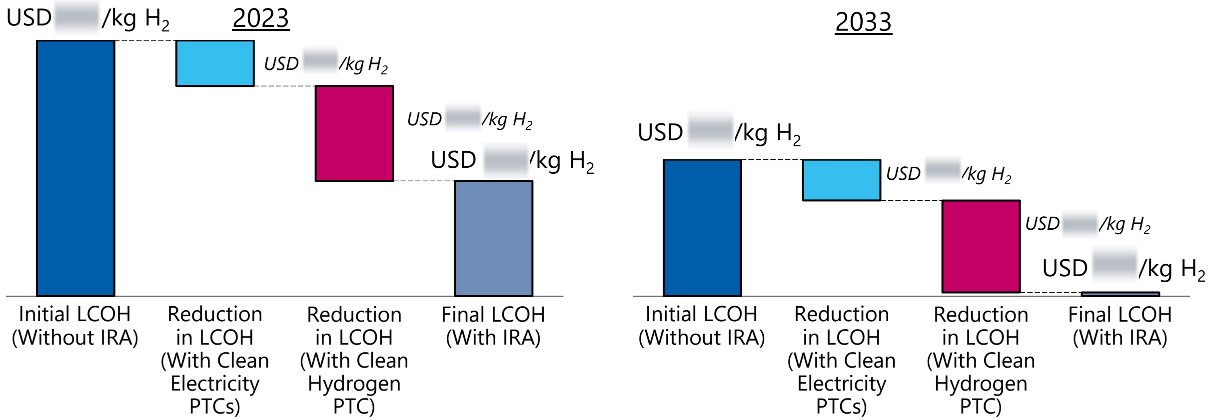
The Clean Electricity and Clean Hydrogen Production Tax Credits significantly reduce the cost of green hydrogen production.

- The chart shows the impact of the IRA on the levelised cost of green hydrogen produced via proton exchange membrane (PEM) electrolysis.
- The cost of green hydrogen production includes capital costs, fixed costs (labour costs, overhead costs, maintenance costs, amortised stack replacement cost), and utilities costs (electricity and water costs).
- Powered by captive renewable energy, the plant is assumed to qualify for both the Clean Electricity Production Tax Credit on solar and wind production and the Clean Hydrogen Production Tax Credit. It is assumed that the taxpayer meets the Prevailing Wage and Apprenticeship Requirements, and receives the Clean Electricity PTC of 1.5c/kWh and Clean Hydrogen PTC of USD 3/kg H_2.
- The results show that the IRA **reduces the production costs for green hydrogen from USD /kg H_2 to USD /kg H_2 for a hydrogen production plant in 2023**, increasing the competitiveness of green hydrogen production.
- The production costs dip negative with the IRA between 2034 and 2035, and revert to the production costs without IRA as the tax credits are phased out.

Impact of IRA on the levelised cost of green hydrogen production



Impact of IRA on the levelised cost of green hydrogen production, 2023 and 2033



Source: Argus Consulting

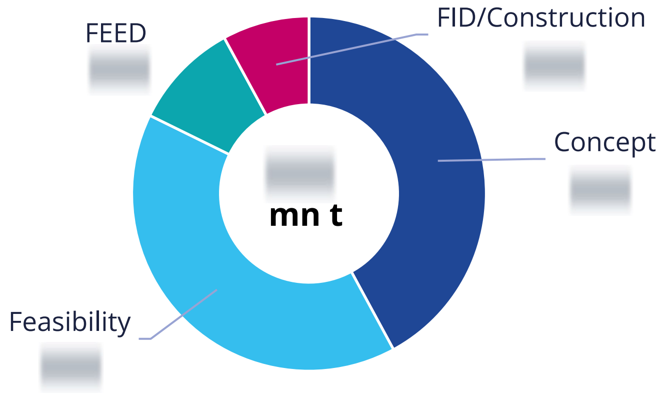
US

Supply

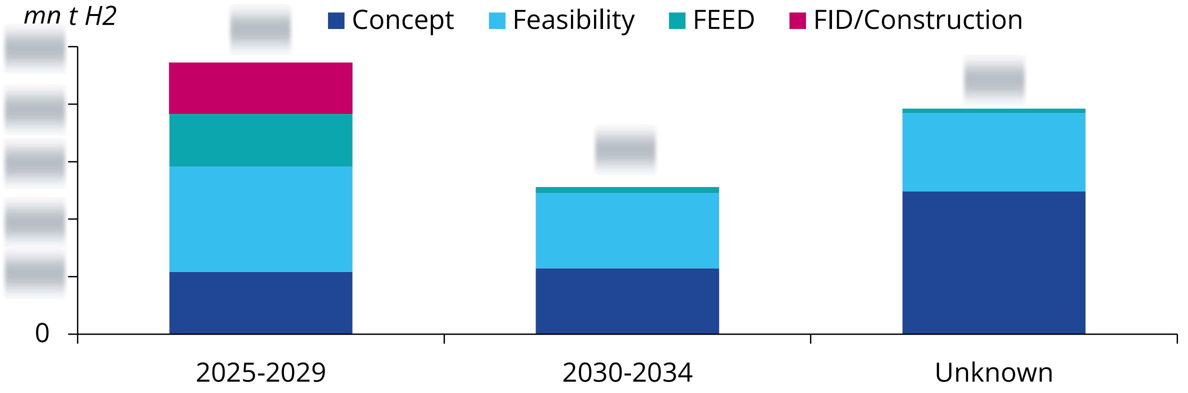
US – Announced low-carbon hydrogen production capacity

Over [illegible] projects totalling nearly [illegible] mn t of low-carbon hydrogen production capacity have been announced in the US, but only around [illegible] has reached FID/construction. [illegible] pc of the capacity targets blue hydrogen production.

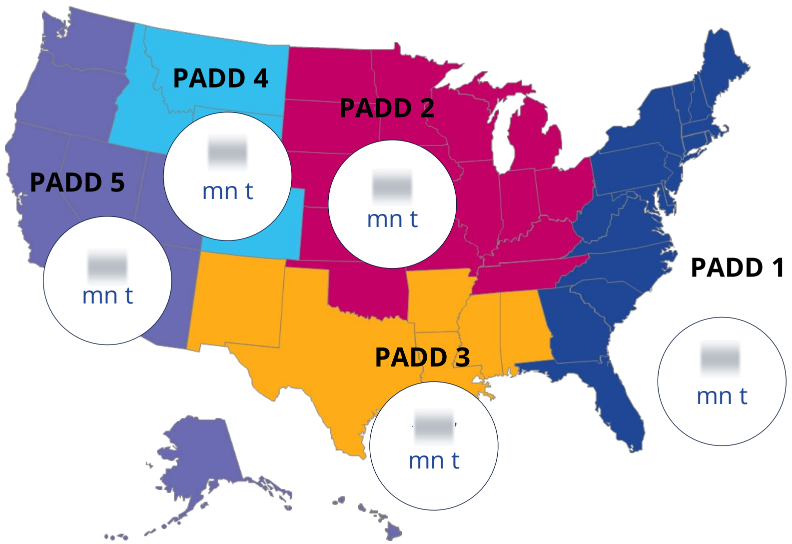
US announced low-carbon hydrogen capacity by status*



US announced low-carbon hydrogen capacity by status and online date*



US announced low-carbon hydrogen capacity by PADD (mn t H2)



- Over [illegible] low-carbon hydrogen projects, with a combined total hydrogen production capacity of [illegible] mn t, have been announced in the US. Of this, only [illegible] has reached FID/construction.
- Over [illegible] of the low-carbon hydrogen projects are either still in the feasibility or concept stage, illustrating the high-degree of uncertainty surrounding new projects.
- Almost [illegible] pc of the announced low-carbon hydrogen capacity ([illegible] mn t) and over 50pc of the projects are in PADD 3.
- [illegible] pc of the announced production capacity is targeting blue hydrogen. Low natural gas prices in the US make blue hydrogen cost competitive vs green hydrogen.

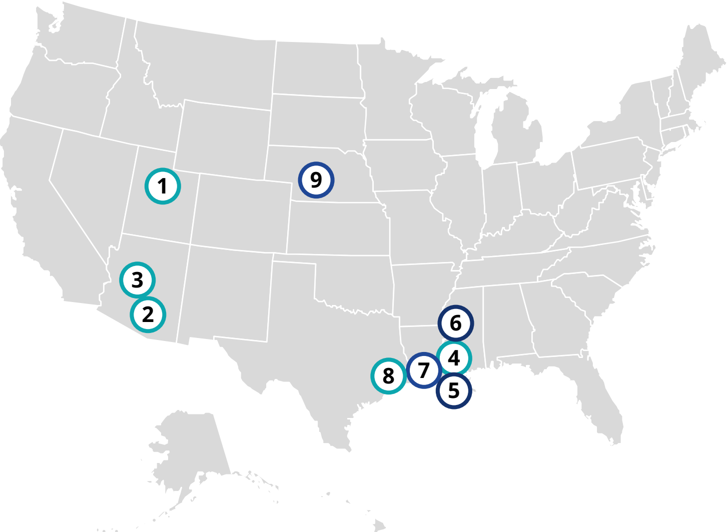
**Excludes cancelled projects and projects with less than 10MW electrolyser capacity*

US – Advanced low-carbon hydrogen projects

[illegible] projects with a total hydrogen capacity of ~[illegible] mn t/yr have progressed to FID/construction.

	Project name	Developer	Blue/ green	Electrolyser/Plant Capacity - MW	H2 capacity (000 t/yr)	Product	Offtake agreed	End-use
1	Advanced Clean Energy Storage	Advanced Clean Energy Storage		220	37	H_2	Yes	Power generation
2	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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



US total announced hydrogen capacity

Blue	Green
[illegible] mn t/yr	[illegible] mn t/yr

Source: Argus Consulting

US

Demand and BEP

US – Country demand assessment

While the US does not have mandates for low-carbon hydrogen use, the strategy indicates the US aims to pursue clean hydrogen use in transport and industry. Thus, this report assesses the long-term demand **potential** in these sectors.

Methodology

Country's hydrogen policy/strategy → *Is the policy ambitious? (mandated hydrogen production / consumption target)* → *Does the policy target specific applications in specific sectors?* → *Does the policy / strategy state sector-specific targets?*

If all the above criteria are met

Hydrogen demand | *Breakeven price*

If a country has a hydrogen policy which has an ambitious hydrogen production and consumption target by a certain year and has sector specific targets like fuel cell vehicle fleet deployment, mandate for hydrogen used in industry, hydrogen blending percentage in gas grid, hydrogen co-firing percentage etc then both the sector specific hydrogen demand and respective breakeven prices are calculated

If all the above criteria are not met completely

Breakeven price

If a country has a hydrogen policy which may or may not have hydrogen production or consumption numbers neither they have sector specific targets but have mentioned in the plan those sectors which they are willing to decarbonise then in that case only breakeven prices of hydrogen for the respective sector is provided

Based on the methodology, the following elements and sectors will be discussed in US demand section

Hydrogen demand
- *Refinery*
- *Ammonia/fertilisers*
- ***Road transport***
- *Steel*

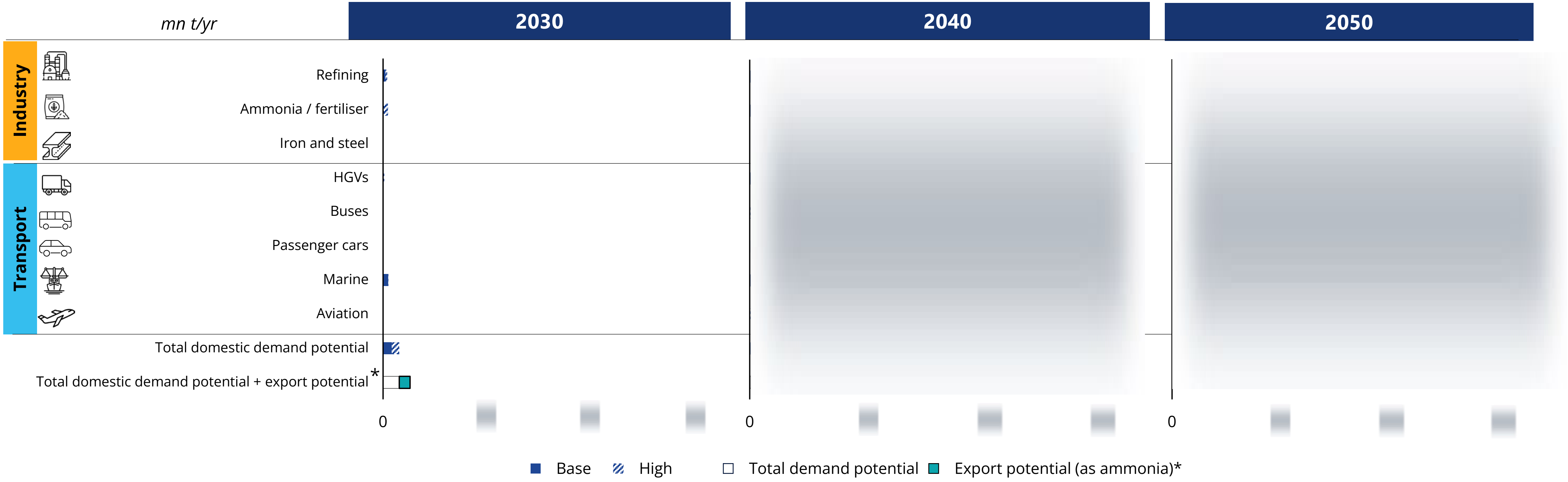
Breakeven price
- *Refinery*
- *Ammonia/fertilisers*
- ***Power generation***
- *Gas blending*
- *Road transport*
- *Steel*

Source: Argus Consulting

US – Low-carbon hydrogen demand potential

In the absence of mandates for low-carbon hydrogen use in the US, *Argus* estimates ***potential*** demand in the base case could reach nearly [illegible] t/yr by 2030, [illegible] mn t/yr by 2040 and [illegible] mn t/yr by 2050, led by marine fuels and road transport (HGVs)

While the US does not have any mandates for the use of low-carbon hydrogen in any sector, *Argus* assumes hydrogen will be used in some sectors, as indicated in its national hydrogen strategy and other key policy documents, such as the US DOE's *Industrial Decarbonisation Roadmap* and the *Blueprint for Transportation Decarbonisation*. Using these strategy documents as a point of reference, *Argus* estimates the demand **potential** for low-carbon hydrogen in industry and road transport. The slides that follow provide a high-level summary of the rationale used to forecast this demand potential, while full details can be found within the respective sector slides.



* **Export potential** assumes 100pc of the low-carbon ammonia capacity for export comes onstream and capacity = demand. No further capacities have been announced to start up beyond 2040; therefore, the export potential in 2050 remains the same as 2040. While more export capacity is likely to be announced in the future, we do not forecast this additional supply here.

US – Rationale for low-carbon hydrogen demand in transport

California is expected to lead FCEV deployment in road transport. Demand in maritime is expected to see significant growth in the long-term driven by IMO targets. Demand into aviation will be limited without mandates for its use

	Road Transport	Marine	Aviation
Reference source and policy (if applicable)	US DOE's *Blueprint for Transportation Decarbonisation*	Argus' marine fuel demand outlook	State-level SAF mandate policies
Selected scenario representing base case	State-by-state assessment of the policies supporting FCEV deployment in road transport	Base case scenario	
Assessment of low-carbon hydrogen potential and rationale			
2025-2030	LOW • Assume BEVs remain the dominant ZEV technology • *Argus*' BEP analysis indicates hydrogen use in road transport is negative across all vehicle types	LOW • No domestic regulatory mandates to decarbonise the US maritime sector • IMO's fuel carbon intensity reduction goals and vessel retirement will be driving the low-carbon fuel uptake	LOW • US aviation climate action plan envisages production of billions of tonnes for SAF however lacks regulatory actions for its uptake • There are no mandates for a nationwide SAF and synthetic SAF usage for the US aviation sector • States like California, Washington and Oregon have policies SAF adoption policies in place however together these could generate inconsiderable demand in 2050 compared to the fuel consumption in this sector today
2030-2040	MODERATE • Assume California ramps up FCEV deployment, particularly for heavy-duty trucks. California offers strong policies and financial incentives for FCEVs but is currently the only state to do so; hence, we assume FCEV adoption in other states is limited. • Assume The National Zero-Emission Freight Corridor expands, including hydrogen refuelling stations	MODERATE • Fossil fuel powered vessels are retired. A limited number of fossil-based vessel retrofitted to run on low-carbon alternative fuels • Newer vessels with alternate fuel drive train come in	
2040-2050	HIGH • *Argus*' BEP analysis indicates hydrogen use in road transport becomes positive for heavy-duty vehicles • Assume more US states follow California's lead and adopt policies and financial incentives for FCEV deployment • Assumes The National Zero-Emission Freight Corridor is successfully built out • *Argus* assumes BEVs are the dominant ZEV technology	HIGH • Low carbon fuel technology like ammonia matures and adoption of vessel running on these fuels becomes wide-spread	

Source: Argus Consulting

US

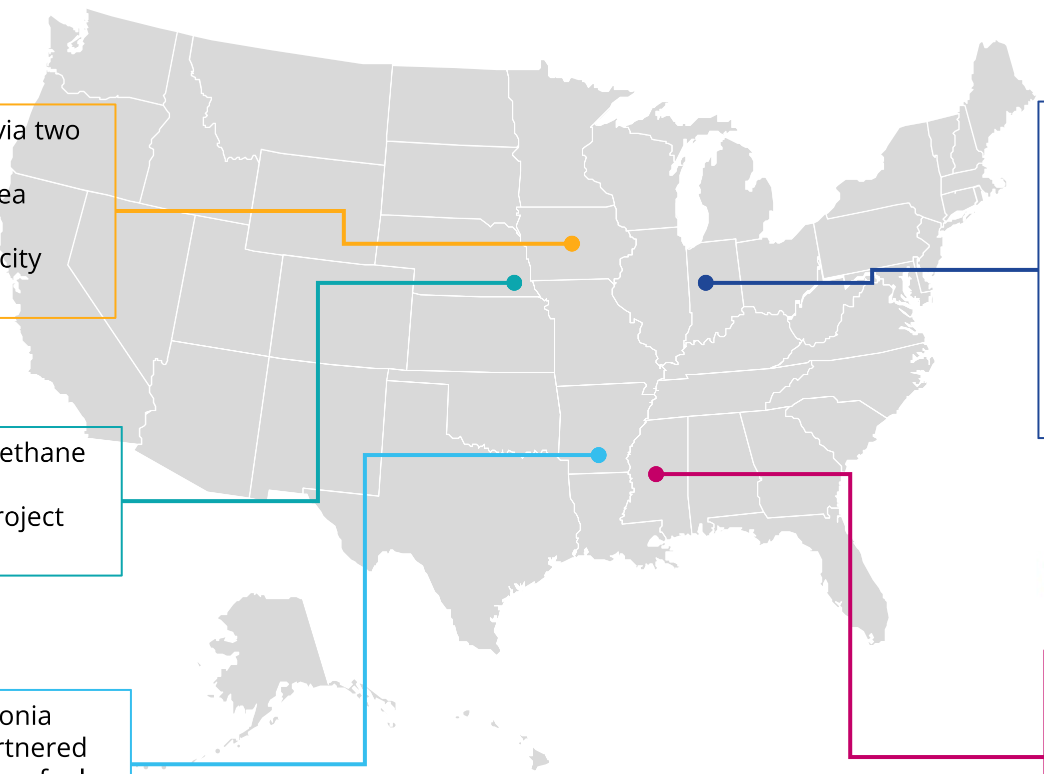
Demand – Ammonia/Fertilisers

- Overview
- Hydrogen strategy and assessment
- Low-carbon ammonia export opportunity
- Funding
- Infrastructure
- Supply
- Demand and BEP
  - Refinery
  - Ammonia/fertilisers
  - Power generation
  - Gas blending
  - Transportation
  - Steel

US – Decarbonisation projects for ammonia into domestic fertilisers

[redacted] low-carbon ammonia projects have been announced in the US, but only a handful of these target the domestic fertiliser market.

- [redacted] **low-carbon (blue and green)** ammonia projects with a combined capacity of almost [redacted] **mn t/yr** has been announced in the US. However, the majority of this production is likely to target the export market where there is a higher willingness to pay due to mandates for the use of low-carbon hydrogen and its derivatives (i.e. Europe and Asia).
- Only a small handful of these projects are planned for use in the domestic fertiliser market and have a combined capacity of [redacted] **mn t/yr**.



KOCH – AG & ENERGY SOLUTIONS

- Aiming to produce 565,000 t/yr of blue ammonia via two CCS projects at their Wever City plant
- Ammonia will be used to produce downstream urea products for domestic farms
- Koch Ag & Energy solutions purchased the Wever city facility in August 2024

monolith

- Aiming to produce 275,000 t/yr of ammonia via methane pyrolysis
- The US DOE granted a 20-year $1bn loan to the project
- The ammonia produced will be used domestically

LSB

- Aiming to produce over 375,000 t/yr of blue ammonia
- Alongside use as a domestic fertiliser, LSB has partnered with Amogy to promote low-carbon NH_3 as a marine fuel for inland US waterway

WABASH VALLEY RESOURCES

- Planning to produce 500,000t of low-carbon ammonia annually beginning in 2027 from the gasification of petcoke with CCS
- The US DOE's loan programme office (LPO) has loaned $1.6bn to the project
- The ammonia will be used in domestic fertiliser manufacture and predominantly serve farmers in the Corn Belt

CF

- Aiming to produce 250,000 t/yr of blue ammonia
- The addition of CCS to its existing complex will allow the facility to produce lower carbon upgraded nitrogen fertilisers such as urea ammonium nitrate

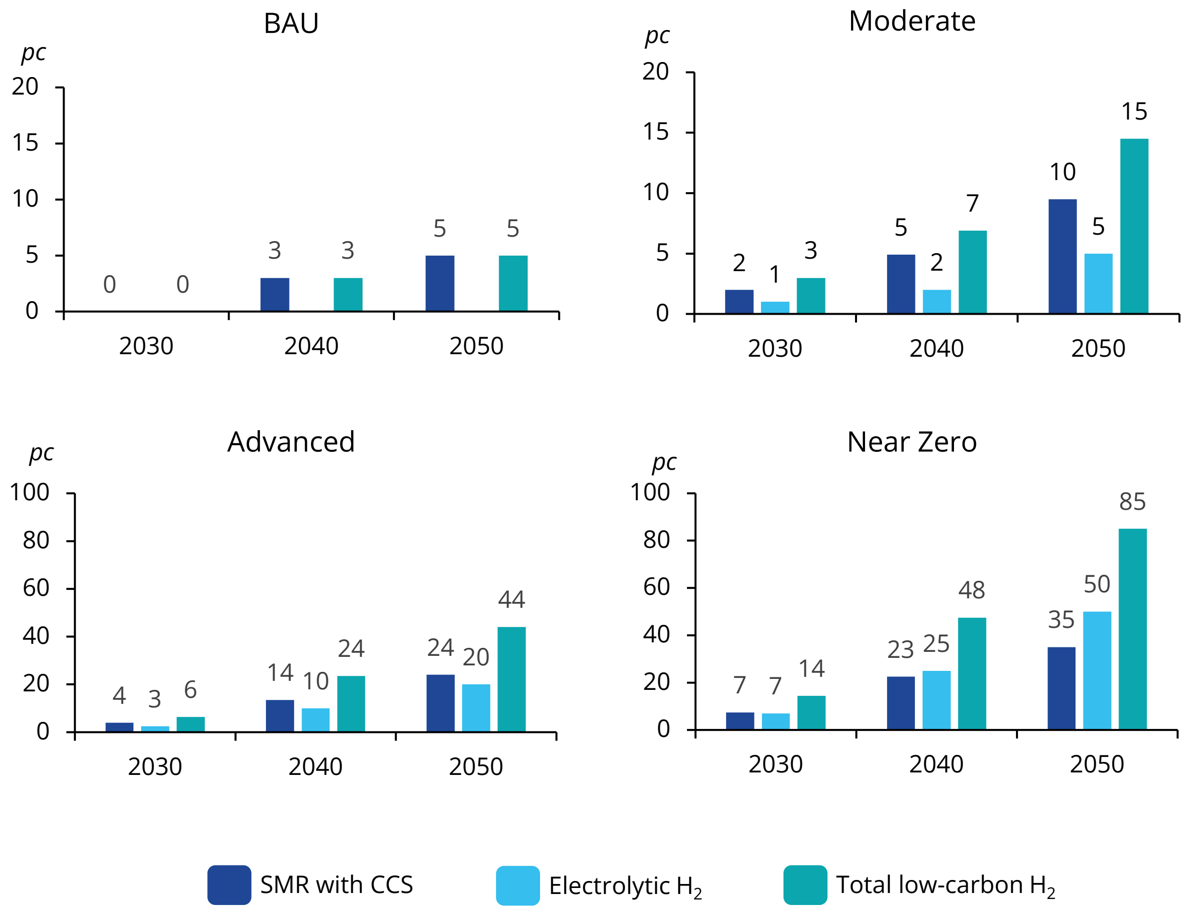
Source: Argus Consulting

US – Methodology forecasting low-carbon hydrogen demand scenarios in ammonia/fertiliser

The US DOE's *Industrial Decarbonisation Roadmap* estimates the proportion of low-carbon hydrogen in ammonia production for fertilisers can range between 5pc (under a BAU scenario) and 85pc (in a near net-zero scenario) by 2050.

- The US DOE's *Industrial Decarbonisation Roadmap* provides four scenarios for decarbonising the domestic ammonia sector through various technologies and the pillars (low-carbon fuels and CCUS) identified in the roadmap.
- The scenarios are BAU, Moderate, Advanced and Near Zero whose definition through DOE is given as:
  - i. Business as Usual (BAU) scenario: *assumes slow improvement in energy efficiency and fuel switching and slow adoption of CCUS technologies and reflects current business practices and current policies and regulations*
  - ii. Moderate scenario: *assumes higher energy efficiency improvement, more fuel switching to lower-carbon fuels compared to BAU. It also assumes low adoption of CCUS technologies, up to 10pc in 2050*
  - iii. Advanced scenario: *assumes significantly higher energy efficiency improvement using commercially available technologies, more aggressive fuel switching to lower-carbon fuels. It also assumes, in 2050, 30pc of CO_2 emitted from US chemical plants within the subsectors studied will be captured by CCS technologies*
  - iv. Near Zero scenario: *assumes the most aggressive energy efficiency improvement using commercially available technologies, more aggressive fuel switching to lower-carbon fuels compared to the Advanced scenario. It also assumes, in 2050, 70pc of CO_2 emitted after the adoption of energy efficiency and fuel switching technologies from US chemical plants within the subsectors studied will be captured by CCUS technologies.*
- The proportion of low-carbon hydrogen used in ammonia production in the four scenarios is calculated from the share of "electrolysis - H_2" (assumed to be low-carbon) and the CCS adoption rate the DOE assumes will be used in each scenario at a given point in time.

Proportion of low-carbon hydrogen under US DOE's decarbonisation scenarios for ammonia (pc)

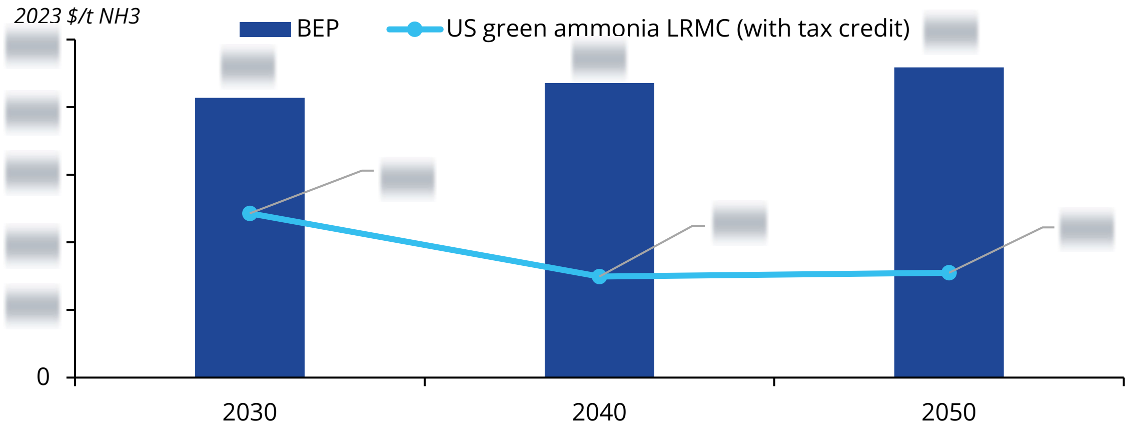


Source: US Department of Energy, Argus Consulting

US – Low-carbon hydrogen BEP and demand scenarios in ammonia/fertilisers

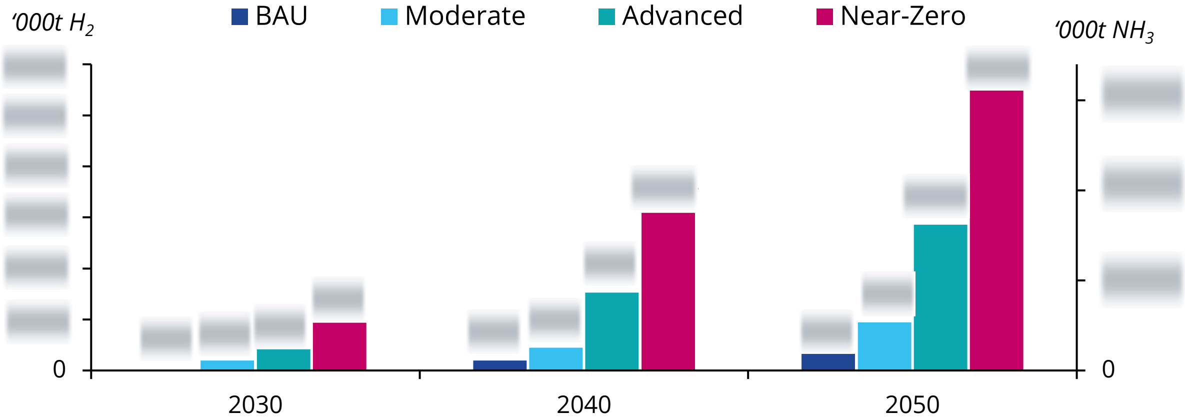
The BEP is higher than the long-run marginal cost of green ammonia, suggesting US producers would be incentivised (with the IRA tax credit) to produce green ammonia for use in the domestic fertiliser sector from as early as 2030.

BEP for hydrogen in the US ammonia/fertiliser sector



- The BEP for ammonia is the price of low carbon ammonia at which producers would be indifferent between using low carbon ammonia and grey ammonia (the extant technology).
- The benchmark grey ammonia price for the US is used to represent the maximum price that fertiliser producers are willing to pay for low carbon ammonia.
- The BEP is represented with *Argus'* benchmark forecast of grey ammonia CFR (cost and freight) Tampa.
- The BEP is $[illegible]/t NH_3 in 2030, $[illegible]/t NH_3 in 2040, and $[illegible]/t NH_3 in 2050.
- The BEP is higher than the long-run marginal cost of green ammonia in the US (with the inclusion of the 45V tax credit). This suggests US green ammonia producers would be incentivised to produce green ammonia for use in the domestic fertiliser sector from as early as 2030.

Low-carbon hydrogen demand under US DOE's decarbonisation scenarios for ammonia/fertiliser



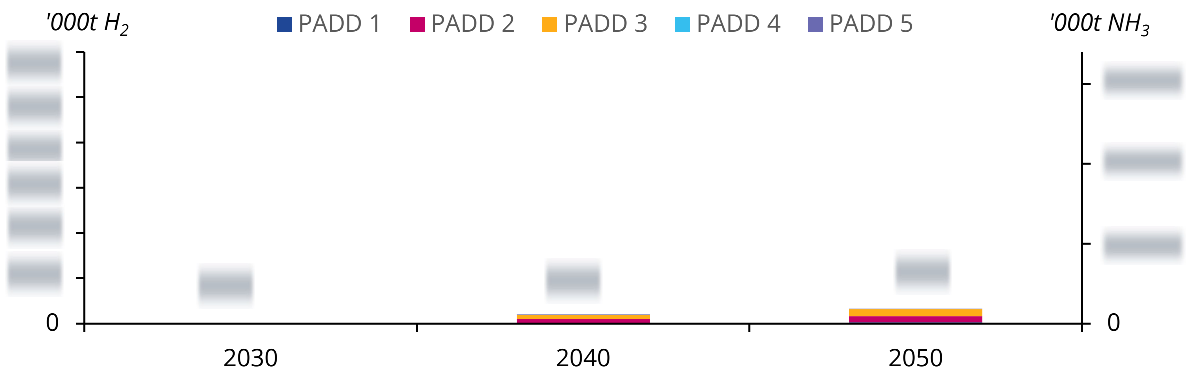
- The IRA's 45V and 45Q tax credits have the potential to make the economics of low-carbon ammonia production in the US attractive. Thus, there is could be high potential for market penetration by low-carbon ammonia.
- The above chart represents the demand potential for low-carbon hydrogen in US ammonia manufacture under the four decarbonisation scenarios as explained on the previous slide, applying the different penetration rates of low-carbon hydrogen to *Argus*' forecast for US ammonia production.
- Under the scenarios, by 2050, the potential demand for low-carbon hydrogen in ammonia could range from a low of [illegible] t/yr in the BAU scenario, up to a high of [illegible] mnt/yr (over [illegible] pc of current US hydrogen consumption) in the near zero scenario.

Source: US Department of Energy, Argus Consulting

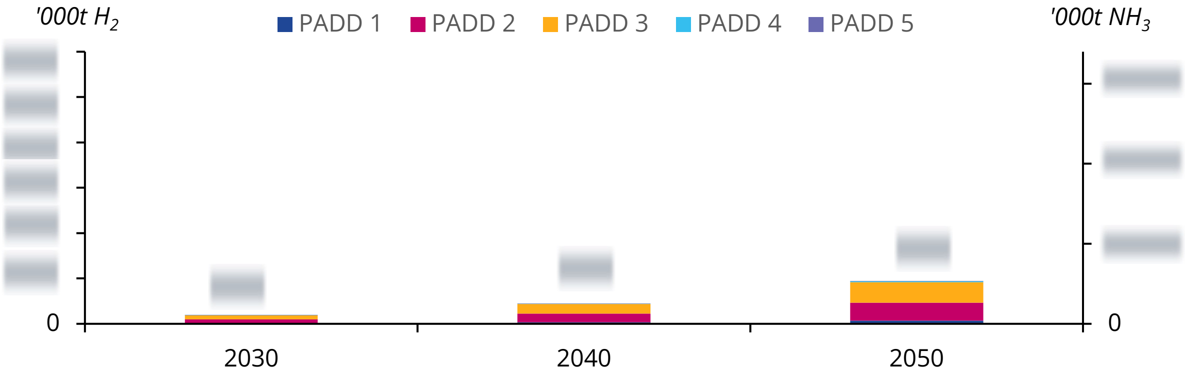
US – Low-carbon hydrogen demand scenarios in ammonia/fertilisers by PADD

Low-carbon hydrogen demand from ammonia into fertilisers will be predominantly in PADDs 2 and 3, where the majority of current capacity is located.

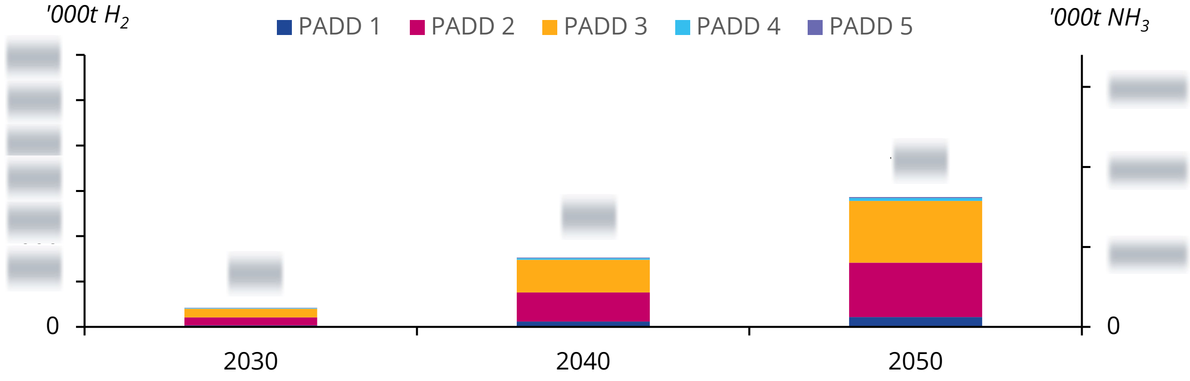
BAU



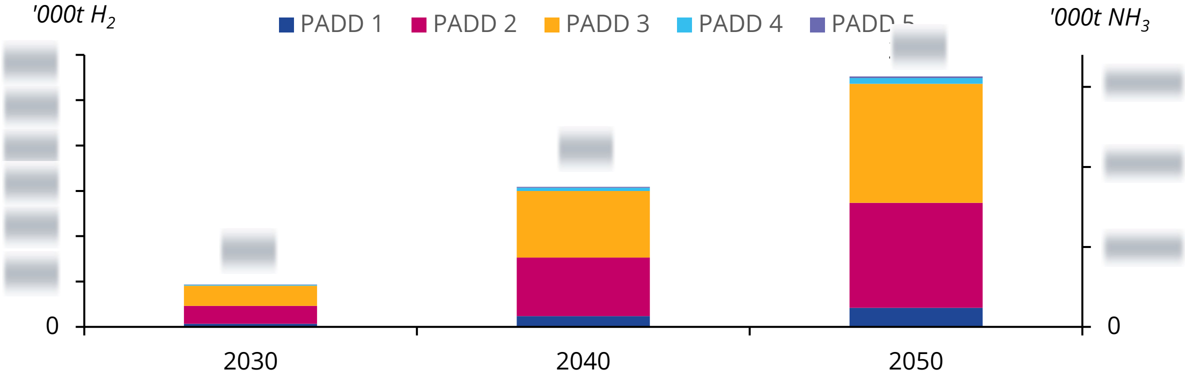
Moderate



Advanced



Near zero

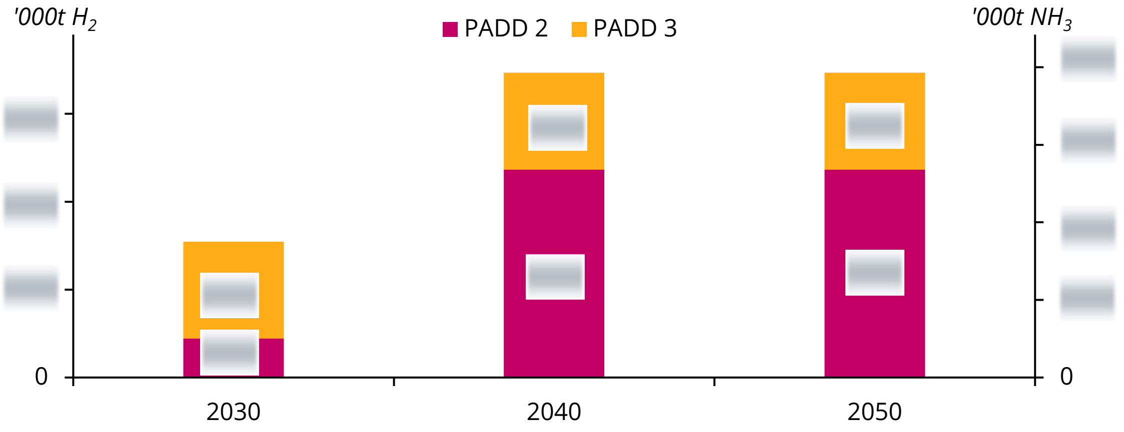


Source: Argus Consulting

US – Low-carbon hydrogen demand in ammonia/fertilisers (*Argus* base case)

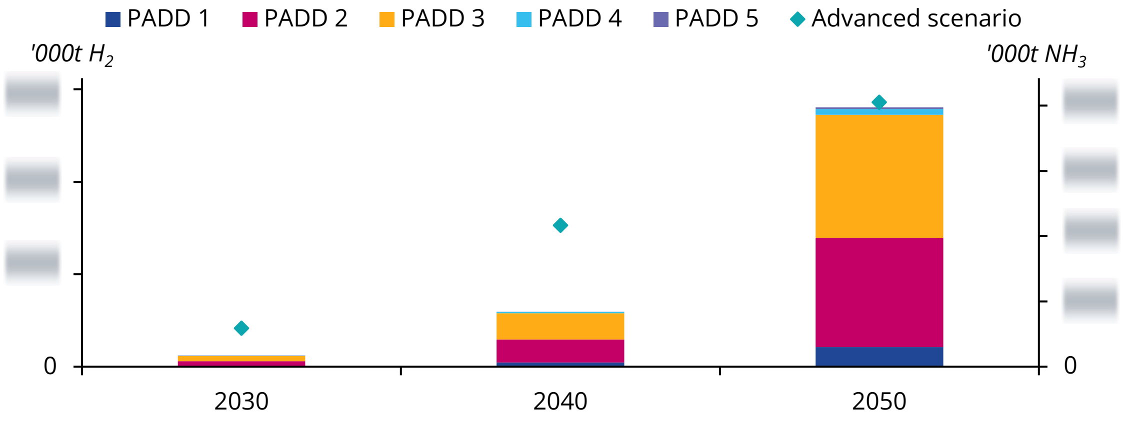
The base case for low-carbon hydrogen demand in fertilisers (from *Argus' Ammonia Analytics*) is more conservative vs the advanced decarbonisation scenario in the medium-term but hydrogen demand reaches over [illegible] mn t by 2050 under both cases.

Low-carbon hydrogen demand from low-carbon ammonia projects (firm, probable and possible)



- In addition to the four demand scenarios presented in the earlier slides which are linked to the penetration rates of low-carbon hydrogen in the US DOE's *Industrial Decarbonisation Roadmap*, this study also shares a base case demand forecast for low-carbon hydrogen and ammonia using analysis from *Argus' Ammonia Analytics* service.
- *Argus' Ammonia Analytics* tracks the announced low-carbon ammonia projects and assigns each a status, including operating, firm, probable, possible and speculative. The status is determined based on a project achieving certain milestones.
- The above chart calculates the low-carbon hydrogen demand that is required to meet *Argus'* firm, probable and possible low-carbon ammonia project capacity that is aimed for use in the domestic fertiliser market.

US low-carbon ammonia demand by PADD (*Argus* base case)



- Given there is no mandate for low-carbon ammonia use in the US, price will be a determining factor for driving demand. Assuming consumers will be unwilling to pay a premium for low-carbon ammonia, this view assumes demand will be limited to plants already announced which can claim the IRA tax credits.
- *Argus' Ammonia Analytics* forecasts low-carbon ammonia consumption will reach [illegible] mn t in 2030 and [illegible] mn t in 2050.
- Compared to the advanced decarbonisation scenario, *Argus*' base case demand forecast for low-carbon ammonia is more conservative in 2030 and 2040. However, by 2050, both demand views reach around [illegible] mn t/yr of demand ([illegible] mn t/yr of hydrogen equivalent).
- PADDs 2 and 3 account for the majority of the demand for low-carbon ammonia. Both PADDs benefit from proximity to US natural gas supply.

Source: Argus Ammonia Analytics, Argus Consulting

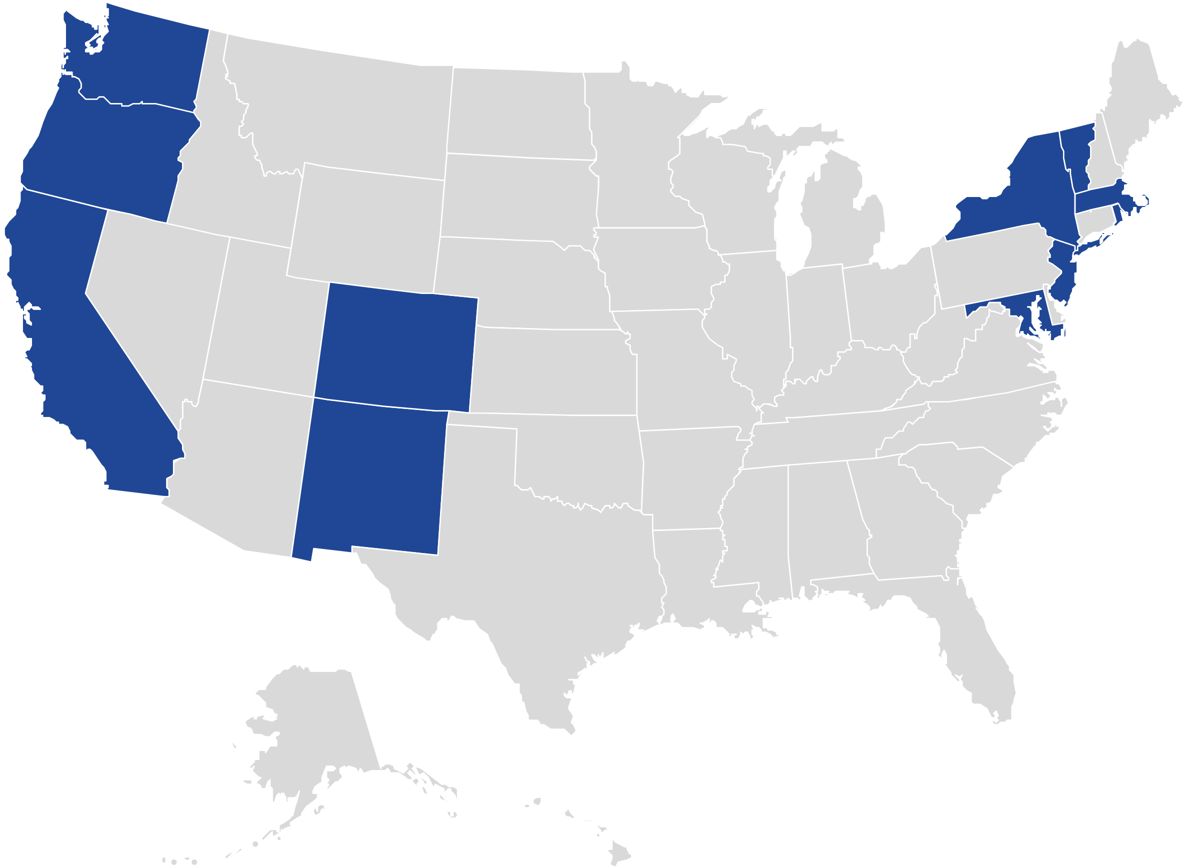
US

Demand – Transportation

US – State-level legislation for zero-emission MHDVs

California and 10 other states have targets for zero-emission truck sales. These states currently collectively account for around 25pc of new trucks registered in the US.

States adopting Advanced Clean Truck (ACT) legislation



- California approved implementation of its Advanced Clean Trucks (ACT) regulation in March 2021. The regulation aims to reduce emissions from MHDVs by requiring state and local governments to phase-in the use of ZEVs.
- Since then, ten other states have adopted the ACT regulation. Together, these states currently account for around 25pc of all new truck registrations in the US.
- Under the regulation, the share of zero-emission trucks which manufacturers sell (as a proportion of total truck sales) must increase each year in participating states.

ZEV sales targets by vehicle class

Vehicle model	Class 2b-3	Class 4-8	Class 7-8 tractors
2024	5pc	9pc	5pc
2030	30pc	50pc	30pc
2035 and later	55pc	75pc	40pc

- Large retailers and other enterprises are required to report on their shipments and shuttle services. Large fleet owners (>50 trucks) must report on their existing operations. This data will be used to identify future strategies for zero-emission truck deployment.

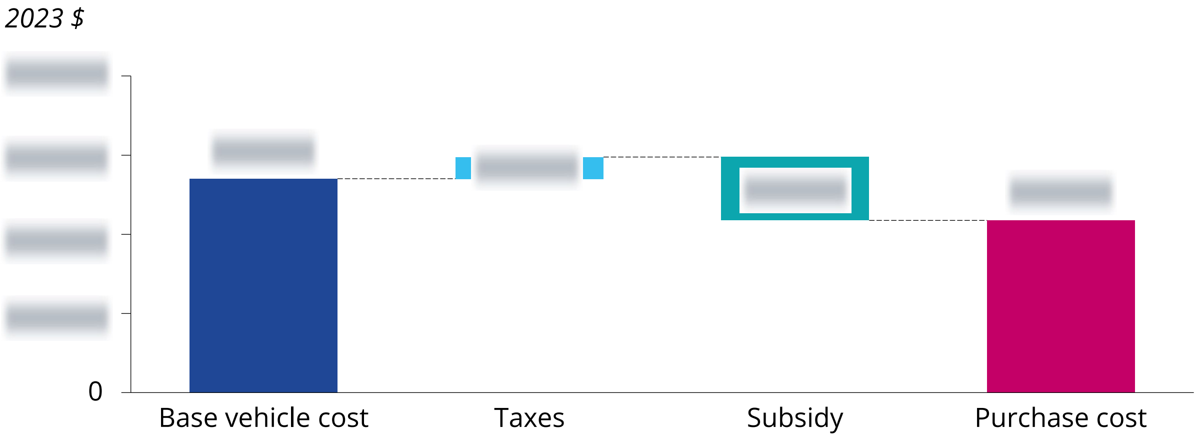
Source: Argus Consulting, CARB

US – FCEV HGV purchase cost and BEP for hydrogen

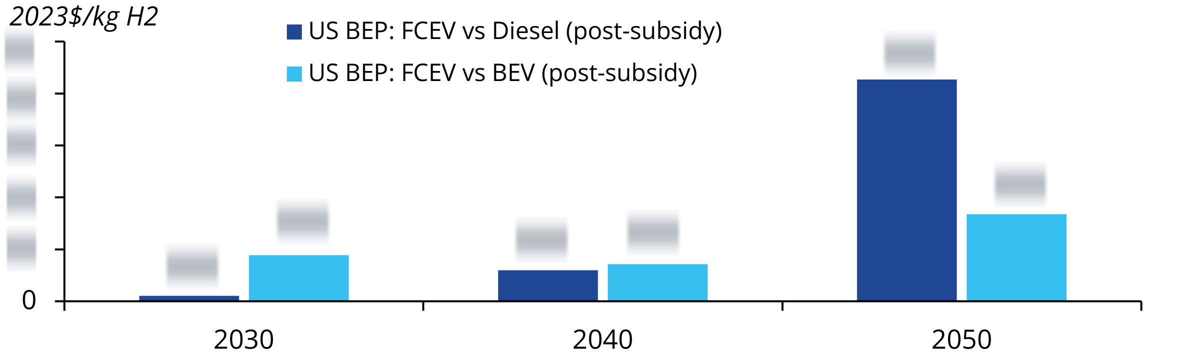
Heavy subsidies for FCEVs reduces the initial high purchase cost associated with FCEV HGV. The BEP is positive as early as 2030 for FCEVs vs both diesel and BEVs.

Purchase cost breakdown of FCEV HGVs, 2023

Purchase cost breakdown of BEV HGVs, 2023



BEP for HGVs in US



- The breakeven price (BEP) analysis estimates the price of hydrogen at which an FCEV would be competitive vs traditional (diesel) and competing technologies (battery electric) in California.
- At a federal level, the US is providing equal subsidies to FC-HGVs and BE-HGVs making it likely that BEVs will dominate the ZEV-HGV fleet to start with. However, states with a greater incentive for FCEVs vs. BEVs (e.g. California) will have a greater penetration of FC-HGVs.
- Positive breakeven price trend of FCEVs shows they can become price competitive by 2030. The declining capital expenditure of FCEV HGV and the purchase cost incentives are the major driving forces behind the increasing BEP trend of FCEV vs diesel.

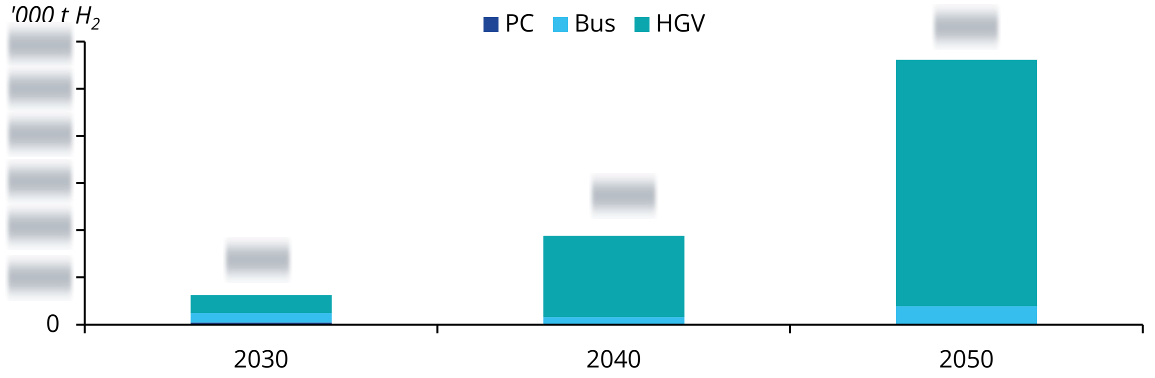
US – Hydrogen demand assumptions for road transportation scenarios

Argus' low and high-scenarios forecast hydrogen demand in the US road transport sector to be around [redacted] t/yr and [redacted]mn t/yr, respectively, by 2050. This depends on state-level policy, development of the National Zero-Emission Freight Corridor and successful deployment of the hydrogen hubs.

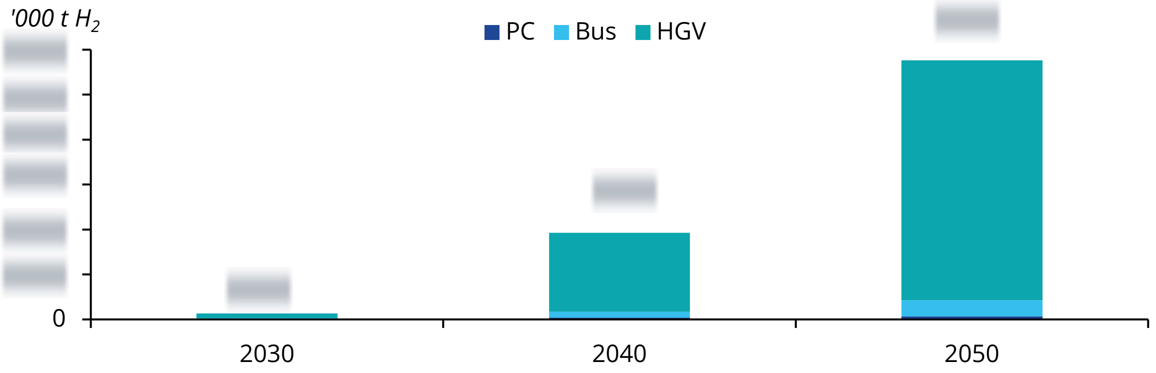
Hydrogen demand assumptions by scenario

Factor	Low scenario	Moderate scenario	High scenario
State-level FCEV policy support	• No US state receives policy support for FCEVs • Ambitions stated for the share of ZEVs in total vehicle sales are scrapped	• California offers strong policies and financial incentives for FCEVs and deployment is supported, particularly for heavy-duty trucks. • FCEV adoption in other states is limited	All US states receive significant policy support for FCEVs
National zero-emission freight corridor	Assume the national zero-emission freight corridor is scrapped	Assume the national zero-emission freight corridor expands as planned, including hydrogen refuelling stations	Assume the national zero-emission freight corridor is successfully deployed
Hydrogen hubs	US hydrogen hubs do not become operational	Some of the US hydrogen hubs targeting use in HGVs are implemented	The 6 US hydrogen hubs targeting use in HGVs are implemented

Low-case hydrogen demand in transport sector



High-case hydrogen demand in transport sector



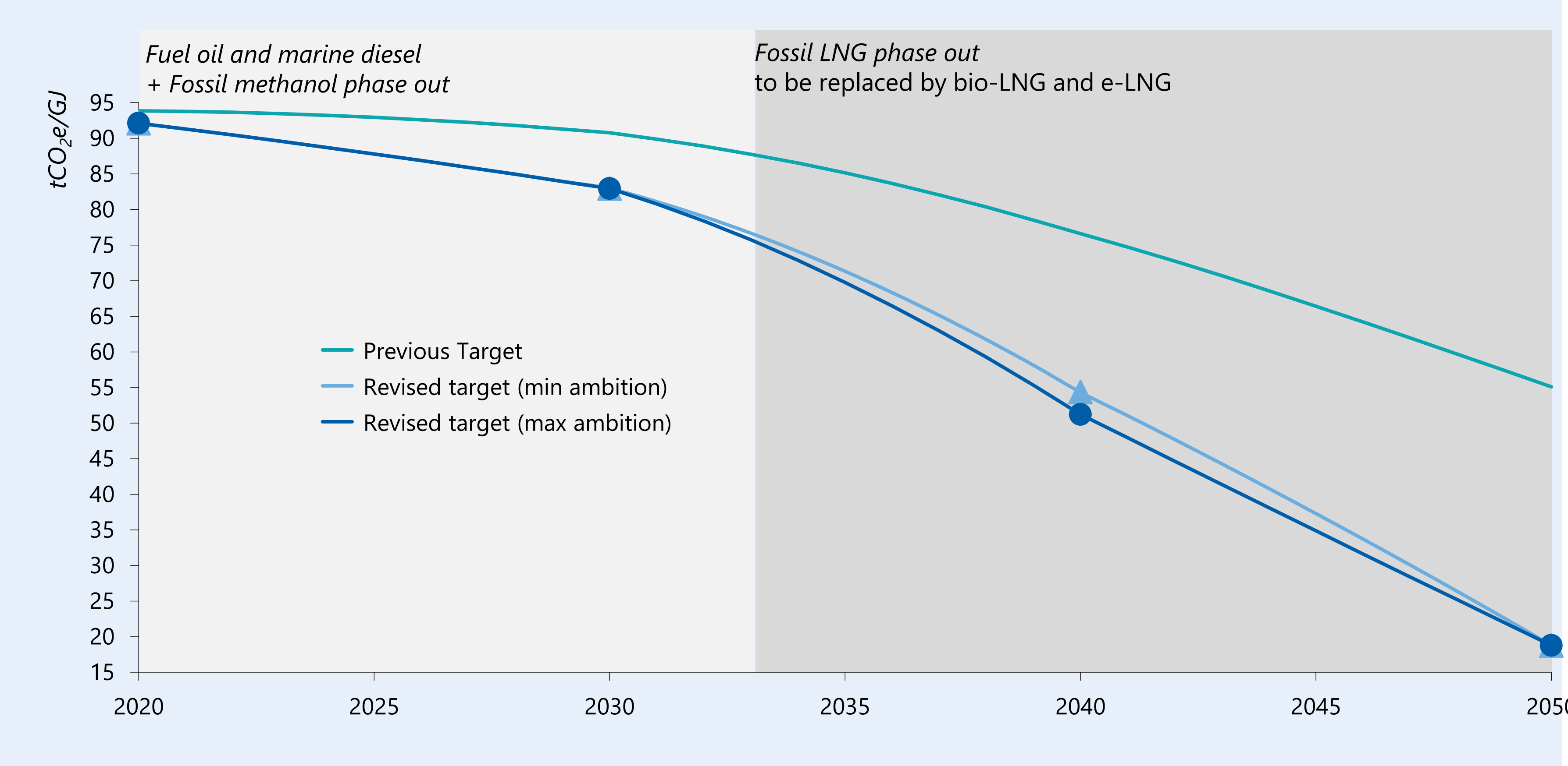
Source: Argus Consulting

Marine fuels

Marine fuels – 1 IMO (international targets)

Based on the IMO targets, specific fuels should be phased out.

Fuel Carbon Intensity: IMO Targets



Notes: EU targets adjusted for international voyages

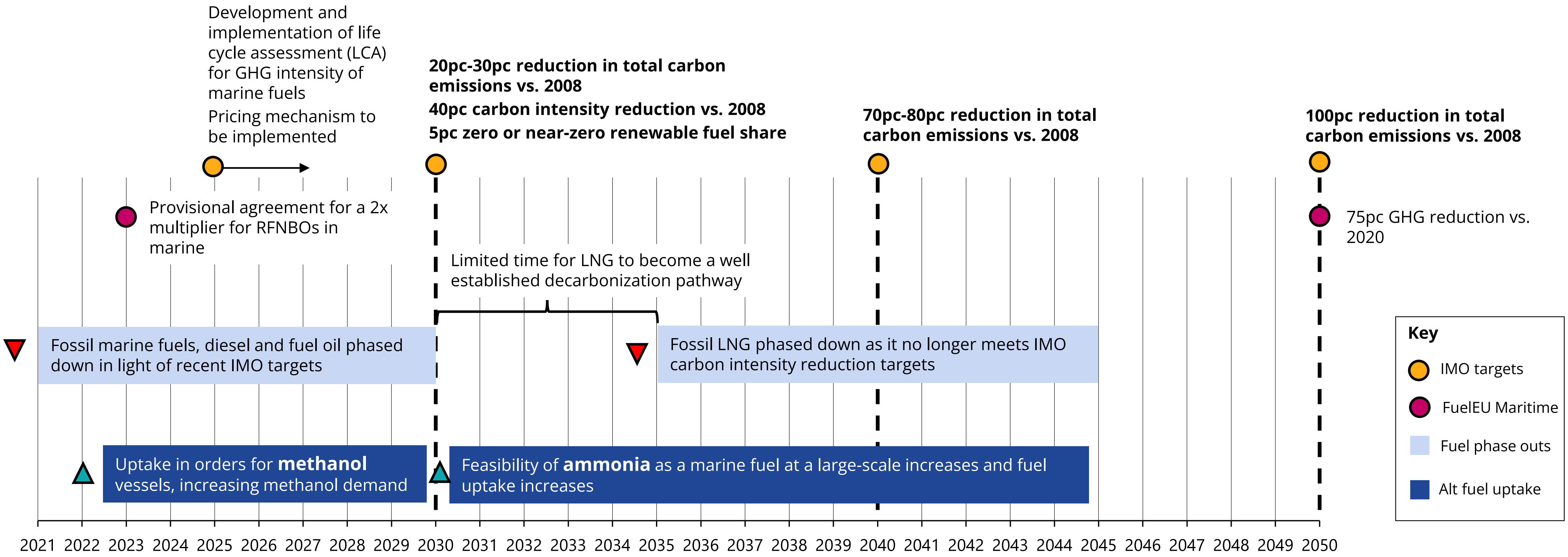
- Given the recent MEPC 80 revision to the IMO targets, the reduction in GHG emissions from international shipping can be summarised as follows:
    i. Average carbon intensity (CO_2 per tonne-mile) reduction target of 40pc by 2030 and a 5pc total fuel share of zero or near zero fuels.
    ii. Absolute reduction target of 20-30pc by 2030, 70-80pc by 2040 and 100pc by 2050 compared to 2008.
- Argus has evaluated the implication of the two separate targets for emissions and the potential reduction pathways of each. The absolute reduction targets are the most stringent of the targets.
- To meet these targets, specific fuels will need to be phased out. General fossil fuels from now and fossil LNG from around 2035.

Source: Argus Consulting

Marine fuels - Development timeline for alternative fuels

As IMO and FuelEU Maritime targets take effect, alternative fuels will be phased in as traditional fuels are phased out.

Timeline for various developments in the maritime sector



Source: Argus Consulting

Marine fuels - Methodology for zero-carbon fuels in maritime

Argus incorporates both a top-down and bottom-up approach to forecast demand for each low-carbon fuel to be used in the maritime sector.

Methodology summary

The forecast starts with a global growth outlook and subsequent global seaborne trade (1). This is then combined with our assumptions on vessel fuel efficiency (2) to global bunker demand on an energy basis (3). Next, we take a view on factors such as vessel retirements and retrofits to determine demand for New Tech Fuels (4). This is then further broken out into the individual low-carbon fuels based on each fuel's market maturity (5).

1

GDP → *Global correlation* → Seaborne Trade → *Global correlation* → Bunker Fuel Demand

2 Global fleet productivity and efficiency

Efficiency Improvements: IMO SEEMP and EEDI requirements factored in, alongside the impact of potential slow steaming across the fleet. Energy Efficiency Design Index (EEDI) stipulates the required energy efficiency of new vessels and mandates up to 30pc improvement in design performance depending on ship type and size

3 Global bunker demand

After accounting for efficiency improvements, the global forecast for seaborne trade and overall tonne miles in the sector is translated to a forecast for total bunker requirement on an energy basis (tonnes oil equivalent). There are clear changes in the relationship in 2008 (slow steaming) and ~2030 (EEDI SEEMP)

4 New Tech Fuel (NTF) demand

***Argus'* view is that factors such as vessel retirements, retrofitting and adoption of alternative fuel vessels will constrain the shipping industry's ability to reach the IMO targets.** After estimating global marine fuel demand, we estimate the age of the vessel fleet age and vessel retirements to determine the demand required to be filled by newer vessels capable of running on alternative fuels in the longer term. We then consider constraints such as the number of existing vessels that cannot be retrofitted to run on alternative fuels.

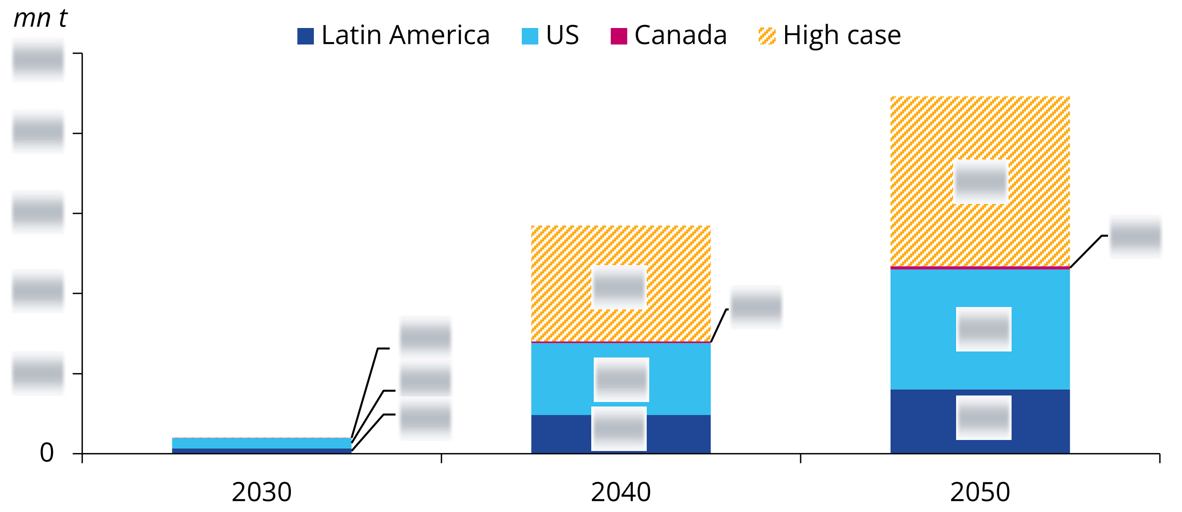
5 NTF Categorization

NTF or low-carbon fuel demand is then further categorized into LNG, methanol, ammonia and hydrogen based on market maturity of each fuel type. *Argus* forecasts methanol and ammonia fuels to post-2030, while LNG will be a transitional fuel during the shift from conventional to low-carbon fuels

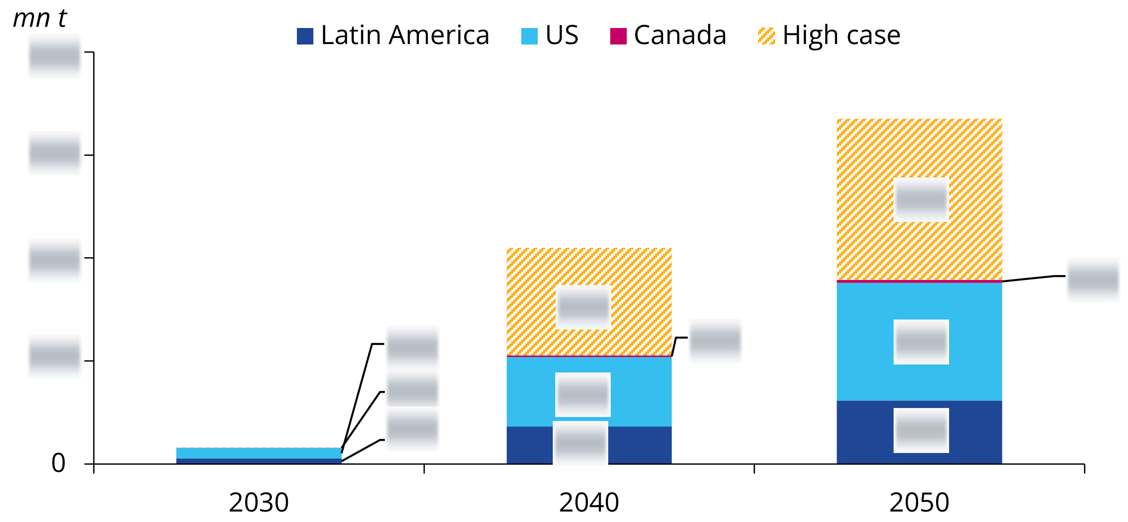
Marine fuels – Americas e-fuels and hydrogen demand in maritime

Argus estimates low-carbon hydrogen demand in the Americas' maritime sector could reach [illegible] mn t/yr by 2050 in the base case, and up to [illegible] mn t/yr in the high case. The US accounts for [illegible] pc of this demand.

E-fuel demand in maritime in Americas, 2030-50



Hydrogen demand in maritime in Americas, 2030-50



- *Argus* estimates demand for e-fuels in the Americas could grow from [illegible] mn t/yr in 2030 to [illegible] mn t/yr in 2050. The US represents around [illegible] pc of this demand as the largest consumer in the region with its massive international trade.
- Based on this forecast for e-fuel demand, *Argus* estimates low-carbon hydrogen demand using assumptions around the amount of hydrogen required for each fuel. In our **base case** (which assumes GHG reductions will be facilitated when newer vessels capable of running on alternative low-carbon fuels replace older vessels on their retirement), we estimate demand could reach up to [illegible] **mn t/yr in 2030,** [illegible] **mn t/yr in 2040 and** [illegible] **mn t/yr by 2050**.
- In the **high case** (which assumes IMO's fuel carbon intensity target for 2050 is achieved), we estimate low-carbon hydrogen demand could reach [illegible] **mn t/yr in 2030,** [illegible] **mn t/yr in 2040 and** [illegible] **mn t/yr by 2050**.
- Note: higher demand for e-fuels vs hydrogen demand is due to the low-energy density of e-fuels (compared to conventional fossil fuels) – that is, more fuel is required to achieve the same amount of energy on a per ton basis.
- There is currently less than [illegible] t of e-fuels used, which is primarily e-methanol from maritime industry leaders, such as Maersk and CMA CGM.

Source: Argus Consulting

Marine fuels – BEP scenarios

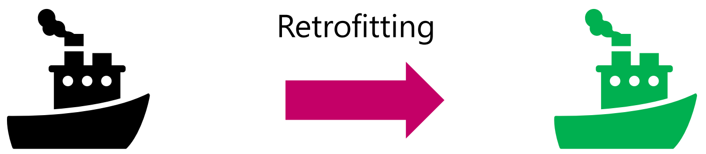
To generate the BEP for hydrogen in maritime, *Argus* analysed the levelised cost of VLSFO ship in comparison to investment in dual-fuel ships via two approaches: 1) retrofitting existing ships and 2) investing in new ships.

Argus modelled two scenarios for the BEP of marine fuels

- **Scenario 1**: Comparing the levelised cost of continuing to operate a 10-year-old VLSFO ship vs retrofitting it to an ammonia dual-fuel ship, both with a remaining lifetime of 15 years
- **Scenario 2:** Comparing the levelised cost of investing in a new VLSFO ship versus a new ammonia dual-fuel ship, both with a lifetime of 25 years
- In both scenarios, ammonia dual-fuel ship is assumed to run on 70pc ammonia which is the current operational limit, with the remaining being VLSFO as pilot fuels

Scenario 1: Continue operating a 10-year-old VLSFO ship vs retrofit to green ammonia dual fuel ship, both with a remaining 15-yr lifetime

10-year-old VLSFO ship | Green ammonia dual-fuel ship



Costs considered	10-year-old VLSFO ship	Retrofit dual-fuel ship
CAPEX	n/a	Yes
Fuel cost	VLSFO cost	10pc VLSFO cost
		90pc RFNBO cost (BEP)
Carbon cost	No	No

Scenario 2: Invest in a new VLSFO ship vs a new green ammonia dual-fuel ship, both with a 25-year lifetime

New VLSFO ship | Green ammonia new dual-fuel ship

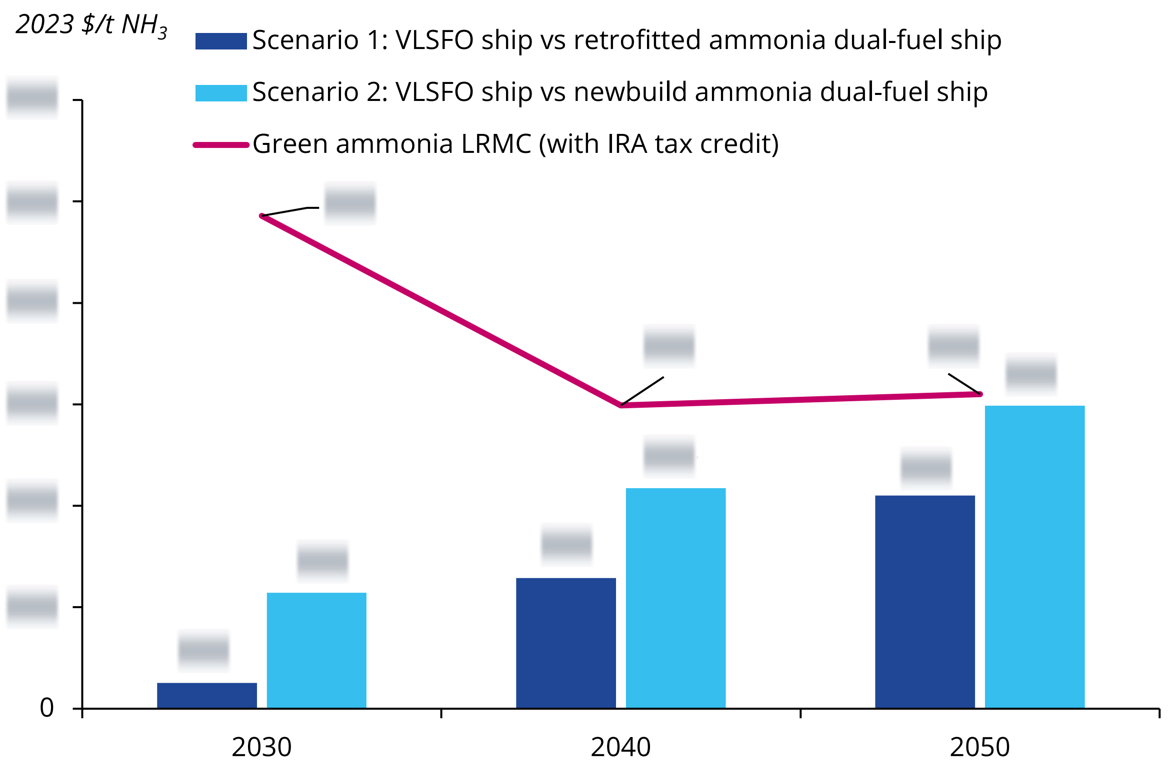
Costs considered	New VLSFO ship	New dual-fuel ship
CAPEX	Yes	Yes
Fuel cost	VLSFO cost	10pc VLSFO cost
		90pc RFNBO cost (BEP)
Carbon cost	No	No

Source: Argus Consulting

Marine fuels - BEP in US marine sector for duel-fuelled vessels using ammonia

In the absence of nation-wide regulatory policy for maritime sector, *Argus*' BEP analysis suggests green ammonia will remain economically unviable until the late-2040s.

BEP of green ammonia in maritime



- The BEP represents the price at which using green ammonia as a maritime fuel becomes economically viable, either in a retrofitted or newly-built ammonia dual-fuel ship (as per the two scenarios previously described).
- Unlike the EU, the US does not have any national regulatory policy that would levy a tax on emissions-intensive conventional fuel vessels that fail to comply with set emissions reduction targets.
- Therefore, increasing fuel oil costs account for the majority of the increase in BEP under both scenarios.
- When compared to the US long-run marginal cost of green ammonia (inclusive of the tax credit under the IRA), green ammonia as a marine fuel would only be economically viable towards the late-2040s.
- The US needs to adopt a maritime regulatory policy, such as the EU's FuelEU Maritime, which has legally binding targets incentivising vessels to switch to low-emission fuels.

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

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.

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.

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.