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The Ammonia Trifecta: A Comparative Analysis of Green, Blue and Grey*

Stephen B. Harrison, Managing Director, sbh4 consulting, Germany

European Green Ammonia Summit, Düsseldorf

14:00 to 14:30, 6th March 2025

*And in introduction to 'light-blue' ammonia – grey ammonia with sequestration of CO2 captured within the process

The competitiveness of Green Ammonia versus alternatives.

Grey ammonia is responsible for about 5% of global CO2 emissions. The CO2 emissions intensity of ammonia is high due to CO2 generated within the process being emitted to air.

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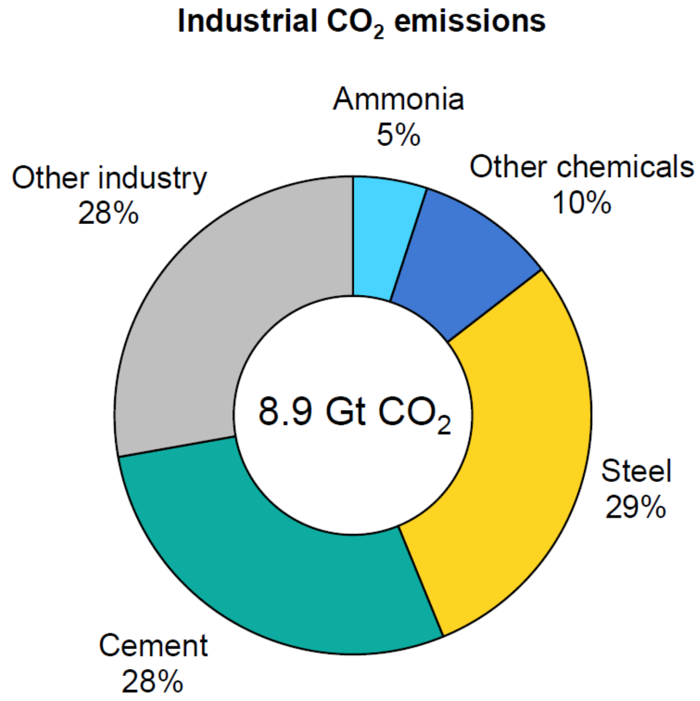
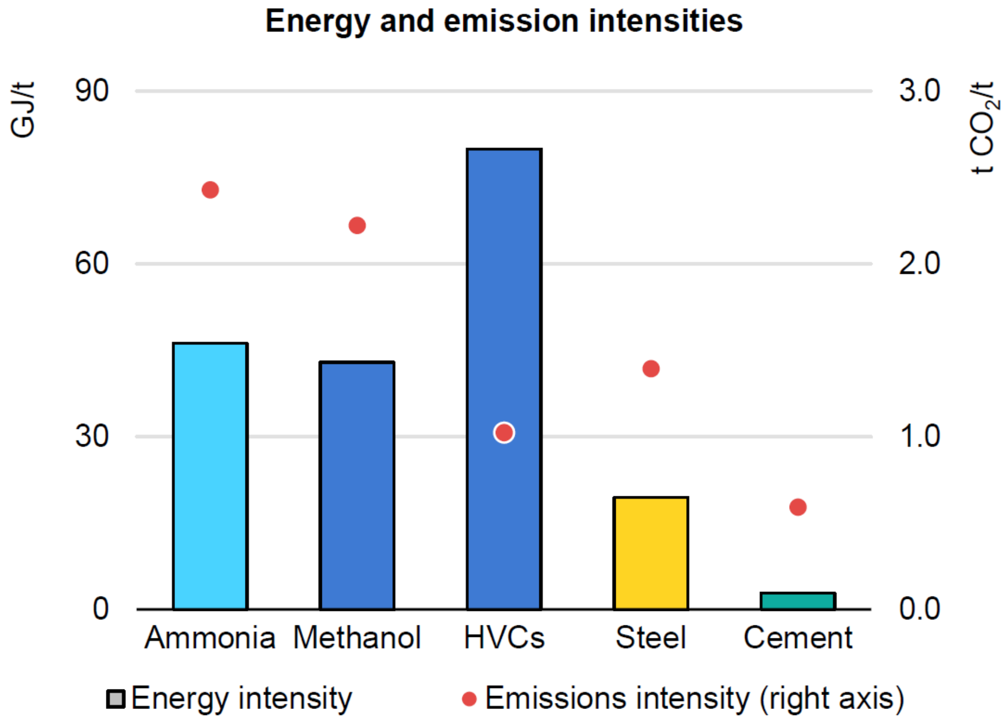
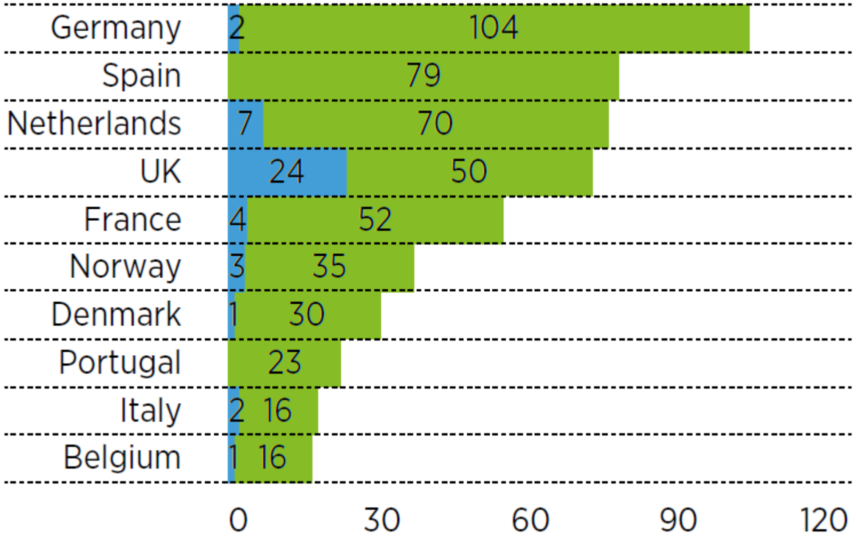




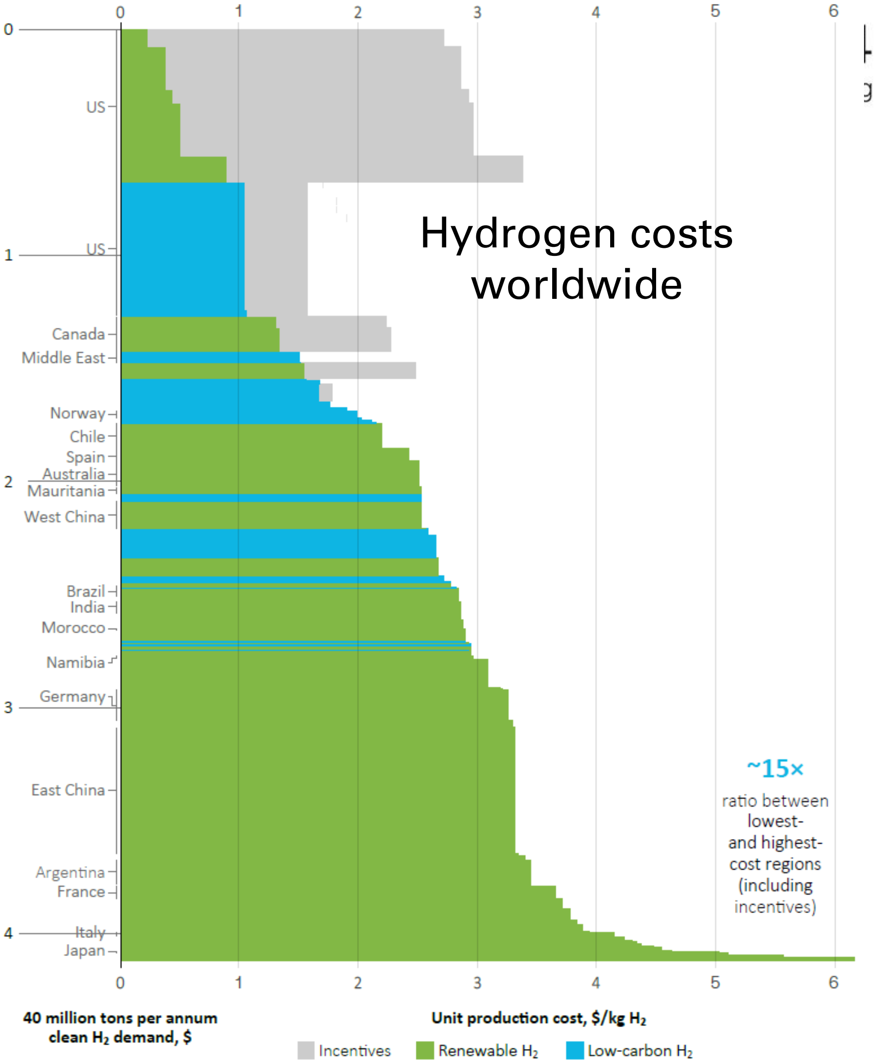

Grey falls out. But will green win the race?

At current gas / spark spread, green hydrogen and ammonia molecules are more expensive than blue molecules.

of projects in Europe



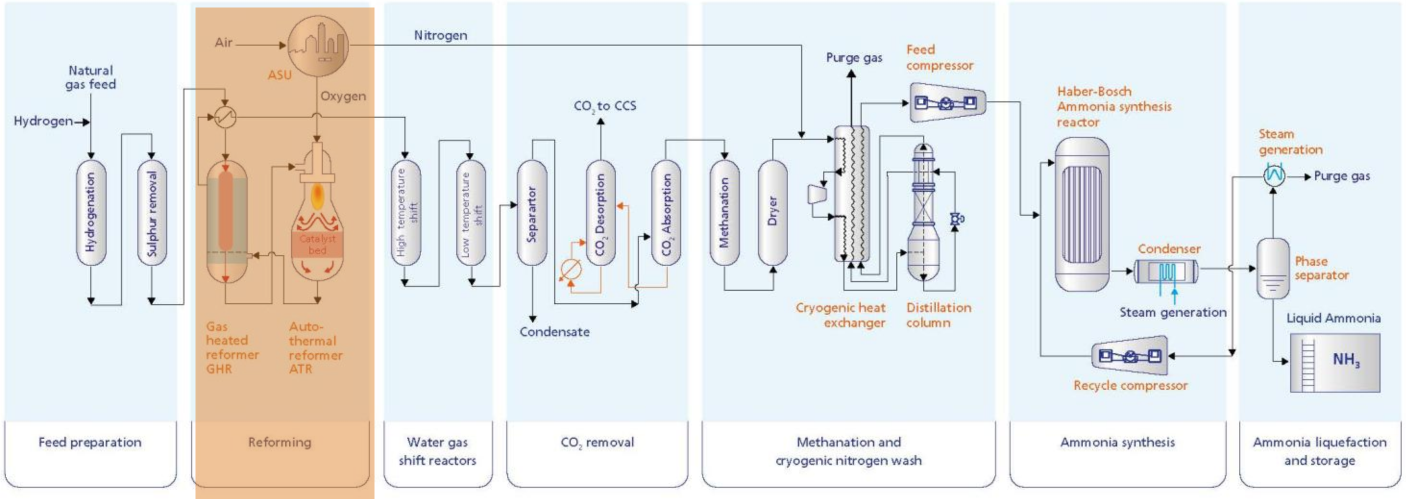
Hydrogen costs worldwide



Source: Hydrogen Council, McKinsey Global Hydrogen Flows 2023 Update
https://hydrogencouncil.com/wp-content/uploads/2023/11/Global-Hydrogen-Flows-2023-Update.pdf


Green looks expensive. What about blue?

Blue Ammonia Production Process with GHR / ATR



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On-purpose blue ammonia

- An air separation unit makes oxygen and nitrogen
- The power for the air separation unit can be from blue syngas
- Pure oxygen is introduced to the ATR to make hydrogen
- Nitrogen reacts with blue hydrogen to yield blue ammonia
- A GHR / ATR type process can be used to achieve a very high CO2 capture rate for ‘blue’ ammonia certification.
- CO2 emissions from the ATR are captured and can be sequestered to ensure blue hydrogen is produced
- Alternatively, some of the captured CO2 can be used to make urea

Do we need to prioritise new on-purpose blue ammonia capacity investment? Decarbonising with the world’s existing ammonia plants will reduce the capex burden and will minimise stranded assets. Ammonia plants can achieve >40 years of operation and about half of global capacity is <20 years old.

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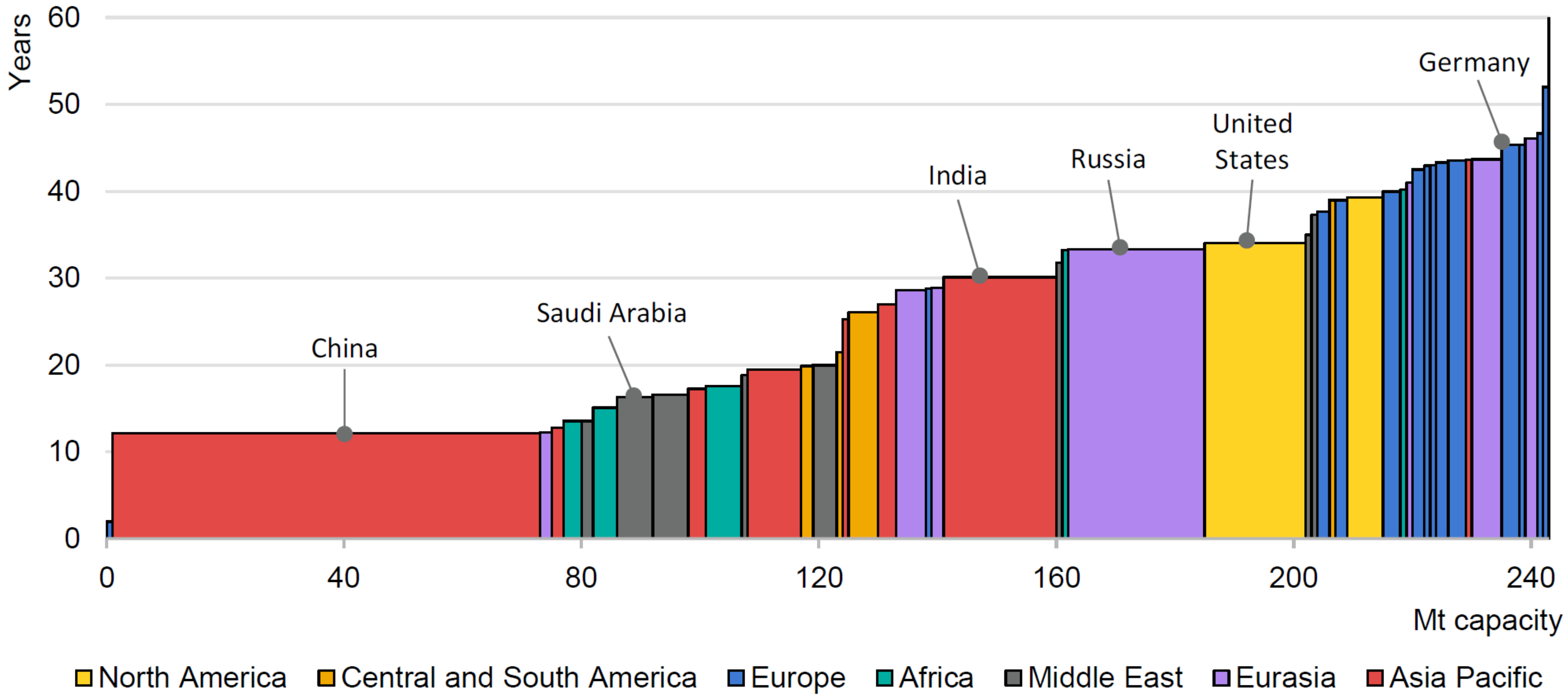
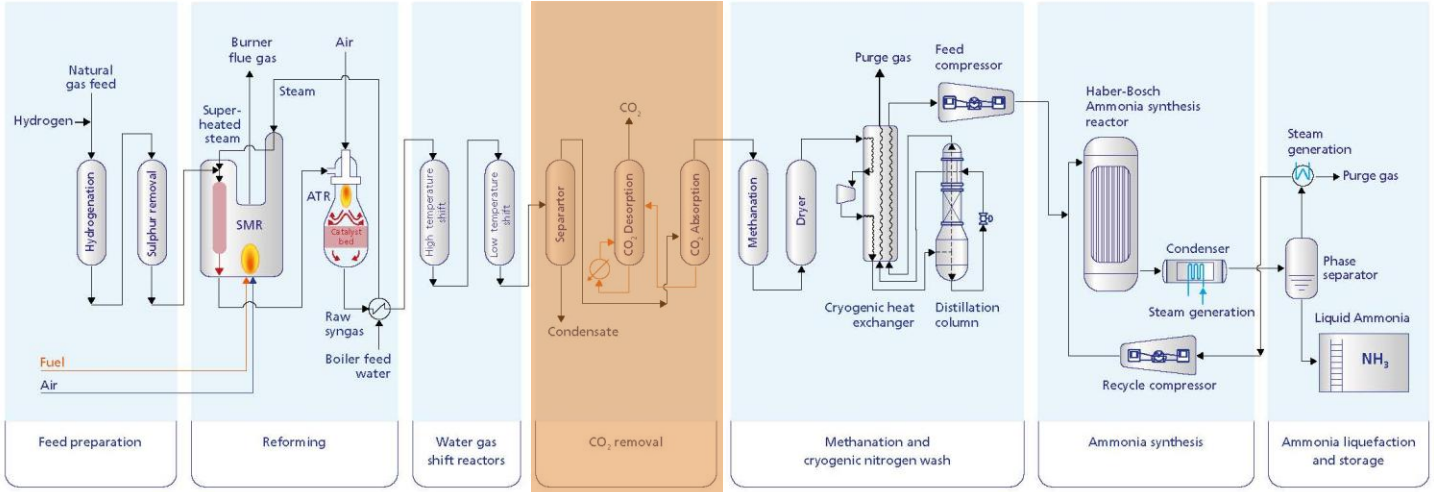


https://iea.blob.core.windows.net/assets/6ee41bb9-8e81-4b64-8701-2acc064ff6e4/AmmoniaTechnologyRoadmap.pdf

Blue is very capex intensive. Is there something between grey and blue?

Air-fed Ammonia Production Process



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Grey ammonia

- The reforming stages for grey ammonia can either be air- or oxygen-fed
- Use of an SMR is with the subsequent use of an ATR is common
- If the ATR is oxygen-fed, pure nitrogen must be added in the ammonia synthesis loop
- Pure oxygen is introduced to the ATR to make hydrogen
- CO2 emissions from reforming are removed to protect the ammonia synthesis catalyst
- Most of the CO2 is vented to atmosphere
- Some captured CO2 is used to make urea or used for food and beverage applications
- Alternatively, CO2 can be sequestered

Grey, Grey+CTS, On-purpose blue and Green Ammonia – a high-level, qualitative comparison*

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	Grey	Grey+CTS**	On-purpose blue	Green
Cost per tonne NH_3	5	5	5	1
CO_2 emissions	1	3	4	5
CO_2 capture energy penalty	–	5	3	5
Capex requirement to switch from grey	–	4	2	1
Location must be same bidding zone as renewable power	5	5	5	1
Needs CO_2 logistics access (ship, rail, pipeline)	5	1	1	5
Can use CO_2 for urea or F&B applications	5	5	5	1
Proven technology at scale	5	4	3	1
Total (unweighted)	**26**	**32**	**28**	**20**
Total (Cost / tonne NH_3 and CO_2 emissions weighted)	**27**	**35**	**32**	**25**

*High level, generic approach, based on sbh4 consulting's qualitative and quantitative experience and expertise. All projects are unique and must be evaluated across safety, environmental,operational, technical, financial, economic and risk aspects according to the project parameters. Concept and model can be adjusted by other experts to refine towards their perceptions and views.

**CTS refers to CO_2 transportation and storage (on grey ammonia facilities, the CO_2 capture aspect of the value chain is done by default within the process).

'Light blue' ammonia

- Grey ammonia with transportation and storage of already captured CO2.
- Drying, compression, liquefaction, transportation and sequestration for CO2 already captured in the ammonia process will be an incremental capital and operating cost on grey and would avoid the new investment capex of blue.


Would ‘light blue’ ever get a ‘green’ light?

Most industrial CO_2 emissions costs are calculated pro-rata, per tonne of CO_2 and the polluter pays. The price per tonne of CO_2 is either fixed, market driven or both.

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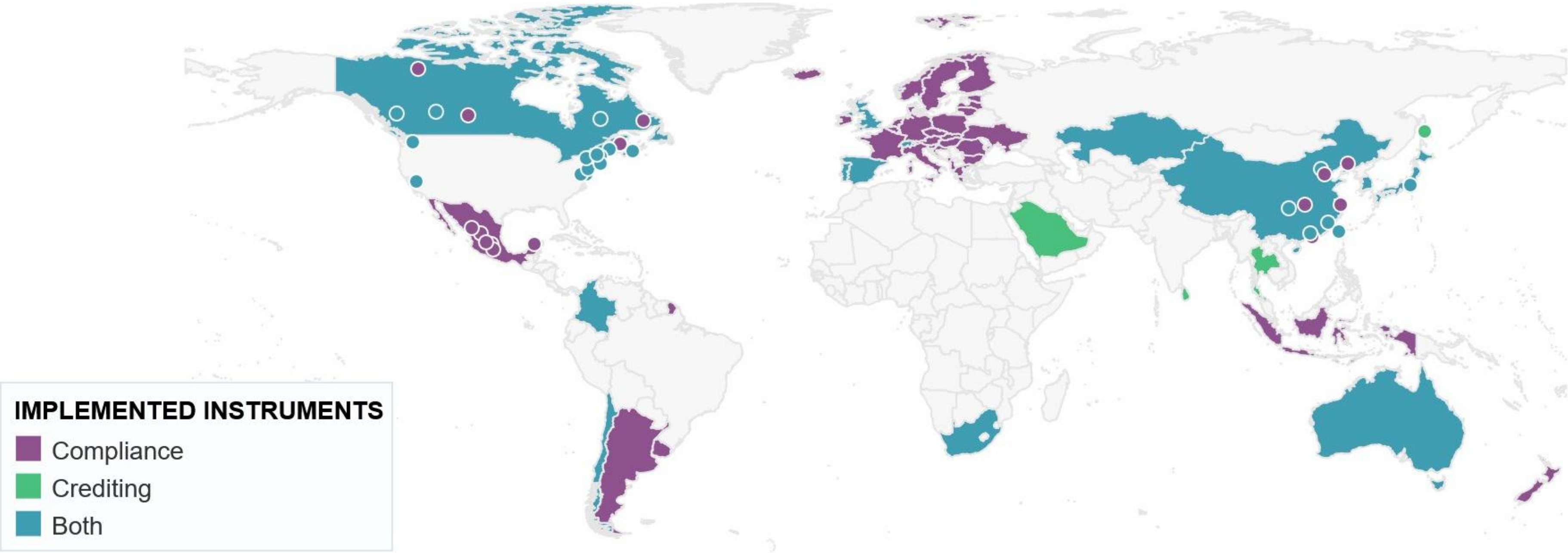

Blue and Green hydrogen (and by implication ammonia) attempt to do something different. Fixed thresholds (based on BAT, presumably?) determine the 'make or break' aiming points. It is not a sliding scale. Decarbonisation investment is therefore behind prior plans and pledges because the capex and risks to hit the thresholds are too high.

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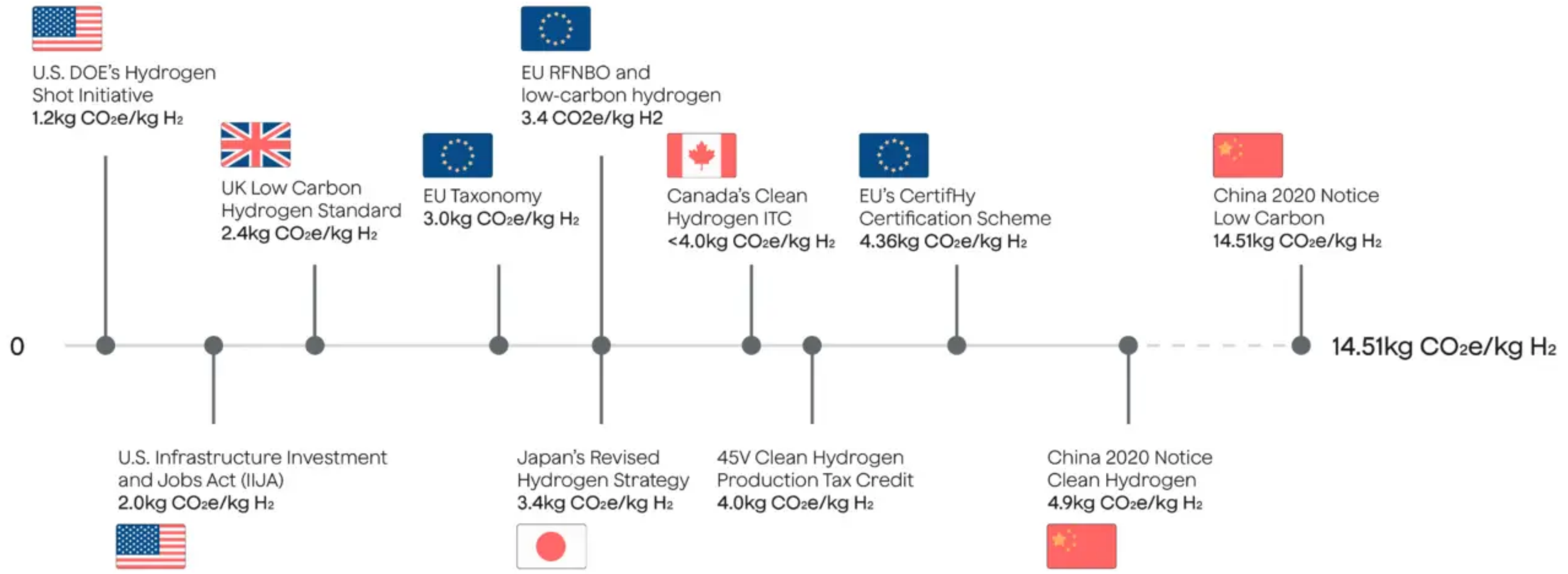

https://hycamite.com/articles/it-doesnt-matter-what-the-color-of-hydrogen-is-as-long-as-it-lowers-net-emissions/

Based on: EFI Foundation. "Hydrogen Market Formation: An Evaluation Framework." January 2024.

The EU is still discussing RED III blue hydrogen (and ammonia?) rules with clarity expected in 2025. If a pro-rata CO2 reduction approach, or 'Light-blue' ammonia are supported, green ammonia will struggle to secure a meaningful share of the market this decade.

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EPRS | European Parliamentary Research Service

Authors: Monika Dulian and Gregor Erbach; Graphics: Samy Chahri
Members' Research Service
PE 767.227 – February 2025

BRIEFING
Towards climate neutrality

European Parliament

Renewable and low-carbon hydrogen

State of play and outlook

The cost of **low-carbon hydrogen** includes the cost of carbon capture and storage (CCS). In 2023, the levelised cost of producing hydrogen through autothermal reforming with CCS (95 % CO_2 capture rate) in the EU-27 was estimated at €3.80/kg, which was 40 % lower than in 2022.

According to Hydrogen Europe, in 2023, the levelised production costs of hydrogen through **electrolysis with grid-mix electricity** varied from €4.1/kg (Finland) to €12.4 /kg (Poland), with an average of around €7.90/kg (compared to €9.80 in 2022).

https://www.europarl.europa.eu/RegData/etudes/BRIE/2025/767227/EPRS_BRI(2025)767227_EN.pdf

Green ammonia also has competition from other green e-molecules.

Attractiveness of green hydrogen derivatives – a high-level, qualitative comparison*

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	Green Ammonia	E-Methanol	E-SAF/ E-Diesel	E-LNG
CO_2 required to build molecule	5	1	1	1
Toxicity	1	4	3	5
Environmental impact of leak (land/sea)	1	3	3	5
Explosion risk of leak	4	5	5	1
GHG impact of leak	5	5	5	1
Gravimetric energy density (air)	1	1.5	5	4.5
Volumetric energy density (sea & land)	1	1.5	5	3
Maritime fuel readiness	1	3	5	4
Road/rail fuel readiness	1	2	5	2
Aviation fuel readiness	1	1	5	1
Existing (grey) infrastructure	3	3	5	4
Cost of production (green power/green H_2)	**5**	**3**	**1**	**2**
Cost vs fossil fuel equivalent	**5**	**4**	**1**	**2**
Demonstration project	1	5	2	2
Can process to E-SAF/E-diesel	1	3	–	2
Can build e-polymers and plastics	2	5	5	1
Can process to nitrogen e-fertilizer	5	1	1	2
Can be re-converted to green H_2	5	3	1	2
Suitable for low/reduced carbon thermal power generation	2	3	5	5
Fuel cell feedstock for low/reduced carbon heat and power	4	5	1	2
Total (unweighted)	**49**	**61**	**63**	**50.5**
Total (2 x cost elements weighted double)	**59**	**68**	**65**	**54.5**

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Green ammonia? Good luck!

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Introduction to Stephen B. Harrison and sbh4 consulting

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Stephen B. Harrison is the founder and managing director at sbh4 GmbH in Germany. His work focuses on decarbonisation and greenhouse gas emissions control through the provision of strategy consulting and technical / operational / commercial due diligence. Hydrogen, CCTUS, e-fuels and e-fertilizers are fundamental pillars of his consulting practice.

Stephen was the international hydrogen expert and team leader for two ADB projects related to renewable hydrogen deployment in Pakistan and Palau during which Stephen specified more than 2GW of electrolysers. In 2022, he supported the World Bank and the Government of Namibia with the Southern Corridor Development Initiative for green hydrogen and other synthetic fuels. Stephen also supported the IFC with a green hydrogen project in Pakistan. He also supports project developers in the private sector.

In support of the European Commission's CINEA he evaluated e-fuels, ammonia, hydrogen and CCS applications to the third innovation fund in 2023. He has also supported the European Investment Bank to execute three Project Development Assistance engagements in 2023 and 2024. His work with the EC also involves evaluation, due diligence and monitoring of hydrogen, hydrogen derivatives and CO2 management projects.

With a background in industrial gases, including 27 years at BOC Gases, The BOC Group and Linde Gas, Stephen has intimate knowledge of hydrogen from commercial, technical, operational and safety perspectives. For 14 years, he was a global business leader in these FTSE100 and DAX30 companies.

Stephen has extensive buy-side due diligence experience in the clean-tech sector. Private Equity firms, investment fund managers and green-tech start-ups are regular clients. Industrial corporations have often sought his guidance on their decarbonisation plans or growth strategies in the emerging hydrogen economy and CO2 management.

As a member of the H2 View and **gas**world editorial advisory boards, Stephen advises the direction for the leading hydrogen-focused international publications. He also served on the Technical Committee for the Green Hydrogen Summit in Oman in December 2022 and on the Advisory Board of the International Power Summit in Munich in September 2022.

Stephen was also session chair for the e-fuels and hydrogen propulsion track at the Hydrogen Technology Expo 2023 in Bremen and in Hamburg 2024. For this event in 2025, he is a member of the conference advisory board. Stephen also runs green and blue ammonia masterclasses for World Hydrogen Leaders events and has run similar courses online.