Developments in renewable ammonia production: Implications for the fertiliser industry

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Kevin Hendrik Reindert Rouwenhorst
Koolen Industries

International Fertiliser Society

DEVELOPMENTS IN RENEWABLE AMMONIA PRODUCTION: IMPLICATIONS FOR THE FERTILISER INDUSTRY

by

Kevin H. R. Rouwenhorst

Ammonia Energy Association, 77 Sands Street, 6th Floor, Brooklyn, NY 11201, U.S.A.

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SUMMARY.

Fertiliser manufacturers aim to decarbonise their production facilities, with some pledges made for full decarbonisation of fertiliser production within the timeframe 2035-2050. Since the last meeting of the International Fertiliser Society, various renewable ammonia projects have moved from announcement to construction or early operation. Furthermore, policy developments in Europe and the United States are likely to accelerate the deployment of renewable ammonia, and low carbon ammonia in general. This paper discusses how various fertiliser manufacturers plan to abate carbon emissions, with electrolyser capacities up to 24 MW. In addition, developments from new ammonia energy sectors are covered.

CONTENTS

Keywords: renewable ammonia, fertilisers, decarbonisation, ammonia energy.

1. INTRODUCTION.

Fertiliser manufacturers aim to decarbonise their production facilities, with some pledges made for full decarbonisation of fertiliser production within the timeframe 2035-2050. Since the last meeting of the International Fertiliser Society, various renewable ammonia projects have moved from announcement to construction or early operation. Furthermore, policy developments in Europe and the United States are likely to accelerate the deployment of renewable ammonia, and low carbon ammonia in general

2. RECENT POLICY DEVELOPMENTS.

Governmental action, such as the Inflation Reduction Act (IRA) in the United States will help to accelerate the implementation of renewable hydrogen capacity for renewable ammonia production. The IRA provides a 3 USD per kilogram hydrogen subsidy for new renewable hydrogen production capacity or other low carbon hydrogen production capacity with a carbon footprint below 0.45 kilogram CO_2 equivalent per kilogram hydrogen. This is equivalent to about 533 USD per tonne ammonia (or 29 USD per GJ), which may bridge the cost gap with fossil ammonia production and other fossil fuels, Figure 1.

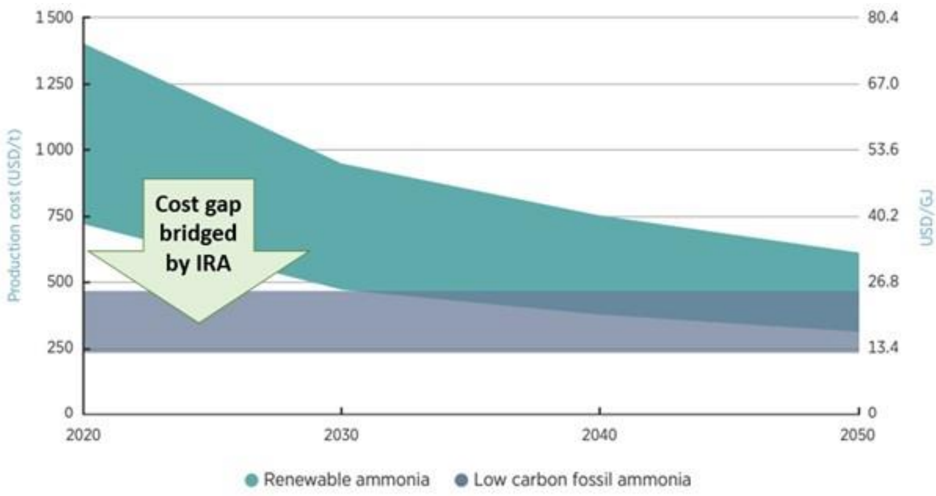

Figure 1: *Production cost projections for renewable ammonia and low carbon fossil ammonia. Source: IRENA (2022).*

In the European Union, policy packages have been proposed as well, e.g. the Fit for 55 and REPowerEU package. The Renewable Energy Directive (RED) of the European Commission aims for a 50% renewables share for hydrogen production by 2030, which is equivalent to 40 GW of electrolysers and 10 million tonnes of renewable hydrogen. Decarbonisation of existing ammonia production in ammonia is considered, as well as the importing of ammonia as zero-carbon fuel and as hydrogen feedstock.

3. DECARBONISING AMMONIA PRODUCTION.

The CO_2 emissions from ammonia production in fertiliser facilities can be minimised by replacing fossil-based hydrogen production with electrolysis-based hydrogen production fed with low carbon electricity.

The total announced low carbon ammonia capacity up till 2030 is shown in Figure 2. Renewable ammonia production is expected to take-off at a similar scale like fossil-based ammonia plants, e.g. 1 million tonnes per annum production, by 2025-2026. This coincides with new markets, such as ammonia as maritime fuel, and as a hydrogen carrier.

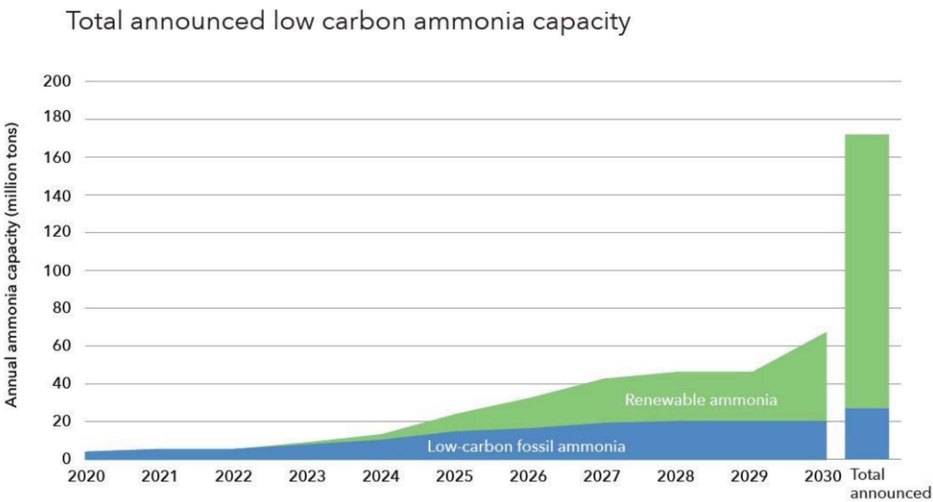

Figure 2: *Current and announced renewable ammonia production capacity. Source: Ammonia Energy Association (2022).*

4. RENEWABLE AMMONIA PRODUCTION.

By far, the largest capacity share of announced projects is for renewable ammonia plants. Currently operational projects and projects up to 2024 include (not intended as a complete list):

'Fertilizantes Cachimayo Cuzco', Cuzco (Peru), 1965.

The oldest electrolysis-based ammonia plant still in operation is located in Cuzco (Peru), starting operation in 1965. Enaex currently operates the grid-connected plant, which has a capacity of about 32 KTPA. The main application of this grid-connected electrolysis plant is nitrate production, for example for the mining industry (explosives).

Puertollano (Spain), 2022.

Iberdrola started initial tests for a facility that will produce 3 kilotonnes of renewable hydrogen per annum (17 KTPA renewable ammonia) from 100 MW solar PV with 5 MW battery storage capacity, coupled with a 20 MW PEM electrolyser (NEL), as well as 11 high pressure hydrogen storage tanks to account for fluctuations in renewable electricity. This renewable hydrogen is utilised by Fertiberia to produce 17 kilotonnes renewable ammonia per annum (8% the plant capacity). Fertiberia aims to fully decarbonise its fertiliser production by 2035.

'Egypt Green', Ain Sokhna (Egypt), 2022.

Fertiglobe recently commissioned the first PEM electrolysers (Plug Power) for its renewable ammonia plant in Ain Sokhna. EBIC operates an existing fossil-based ammonia plant with 660 KTPA and will offtake the renewable hydrogen from solar PV and wind energy. At completion of the project in 2024, the total renewable ammonia production is estimated to be 90 KTPA from 100 MW electrolyser capacity.

Porsgrunn (Norway), 2023.

Linde Engineering will install a 24 MW PEM electrolyser (ITM Power) at Yara's fertiliser production facility, which will be fed with grid electricity (mostly hydropower) to produce about 23 kilotonnes of renewable ammonia per annum. Yara aims to fully decarbonise its fertiliser value chain by 2050.

Donaldsonville (USA), 2023.

ThyssenKrupp will deliver a 20 MW alkaline electrolyser to the CF Industries fertiliser production facility. The grid-connected electrolyser will produce about 20 kilotonnes of renewable ammonia per annum. Next to this, various carbon capture and storage (CCS) projects are under development, and CF Industries aims to fully decarbonise its assets by 2050.

Chifeng City (China), 2023.

Envision Group is currently constructing renewable ammonia production based on dedicated solar PV and wind electricity in Chifeng City, China. The pilot plant will produce 20 KTPA of ammonia, starting from September 2023. The first proper phase with 100 KTPA ammonia production is planned for commissioning in December 2024.

'Camaçari Industrial Complex', Camaçari (Brazil), 2023.

Acrylic producer Unigel recently invested $120 million for 60 MW of alkaline electrolysers (ThyssenKrupp Nucera) to produce 60 KTPA of electrolysis-based ammonia in Camaçari, Brazil by 2023. The electrolysis-based ammonia production is set to quadruple by 2025.

‘Kapuni ‘green’ hydrogen project, Taranaki (New Zealand), 2023.

Balance Agri-Nutrients and Hiringa Energy are developing an electrolysis-based hydrogen plant from wind energy, which is set to produce 5 KTPA of renewable ammonia. This project partially revamps an existing fossil ammonia plant with a capacity of 150 KTPA.

Pryor (OK, USA), 2024.

LSB industries produces 246 KTPA ammonia in Pryor, Oklahoma (USA). It aims to decarbonise ammonia production via multiple electrolysis technologies: 20 MW alkaline electrolysis (ThyssenKrupp) and 10 MW solid oxide electrolysis (Bloom Energy), with the aim to produce 29 KTPA.

‘YURI’, Pilbara (Australia), 2024.

Yara’s existing natural gas-based 850 KTPA ammonia plant in Pilbara is export-oriented and represents 5% of global merchant ammonia supply. The plant aims to decarbonise via electrolysis addition (10 MW), operated by ENGIE (reached FID). The next steps include scale-up to 500 MW electrolysis capacity, as well as construction of a new 800 KTPA ammonia plant.

The project received AU$2 million from the West Australian state government, and AU$47.5 million from ARENA. Mitsui & Co. recently acquired a 28% interest stake in YURI, and Technip Energies will lead the EPCC.

5. LOW CARBON FOSSIL AMMONIA PRODUCTION.

Low carbon fossil ammonia production mainly occurs via two pathways: (1) SMR-based or ATR-based hydrogen production with CCS, or (2) methane pyrolysis.

‘Barents Blue Project’, Finnmark (Norway), 2025

Horisont Energi is developing a 1000 KTPA ammonia plant with CCS in Finnmark (Norway), to be operational by 2025. Future expansion to 3000 KTPA has been announced. A Memorandum of Understanding was recently signed with the Port of Rotterdam for its use as shipping fuel.

‘Olive Creek’, Hallam (Nebraska, USA), 2025

In Hallam, Nebraska (USA), Monolith Materials plans to build a low carbon 275 KTPA ammonia plant based on methane pyrolysis, to be operational by 2025 and with an ammonia synthesis loop from KBR. Next to hydrogen, carbon black is produced during methane pyrolysis. A letter of intent was signed with Goodyear Tire & Rubber for the use of carbon black in car tire manufacturing.

6. BEYOND COLOURS FOR AMMONIA PRODUCTION.

Ammonia can be produced along various pathways, as shown in Figure 3. The production pathways have a different range of CO_2 footprints. Discussions regarding decarbonising ammonia production, and therefore hydrogen production, are often based on colour-coding, which represents the pathways for producing ammonia. However, this only represents Scope 1 of key metrics, such as the carbon intensity and water footprint. Scope 2 and Scope 3 emissions are required to assess the full Life Cycle CO_2 equivalent footprint. Therefore, certification with transparent methodology is required for ammonia production and utilisation.

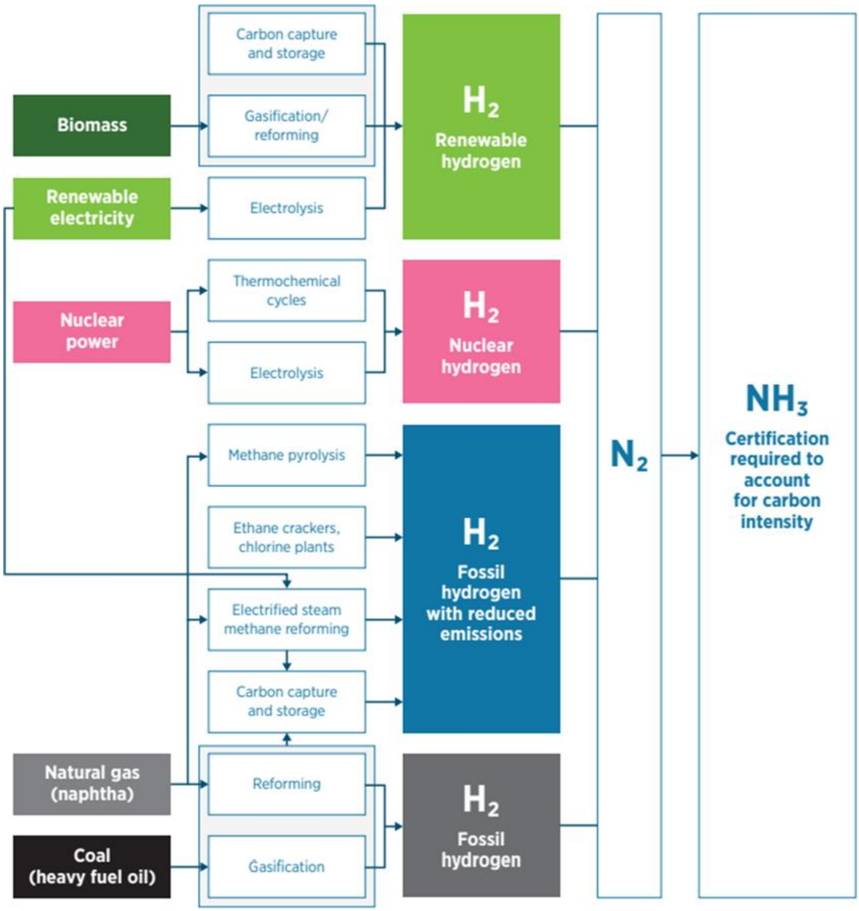

Figure 3: *Ammonia production pathways. Source: IRENA (2022).*

7. OTHER OPTIONS FOR DECARBONISING THE FERTILISER VALUE CHAIN.

Next to decarbonising hydrogen production, other decarbonisation options must be considered for fertiliser production and the fertiliser value chain. NOx emissions derived from downstream nitric acid and nitrate production can be abated with deNOx installations, such as selective catalytic reduction (SCR) technologies. NO_2 emissions have 298 times the global warming potential of CO_2 (!), and represents low hanging fruit for decarbonisation. Most European fertiliser producers are abating NOx emissions, whereas this is not yet the precedent around the globe. The estimated cost of SCR is below 5 USD/t-CO_2 equivalent.

It should be noted that fertiliser production only accounts for a portion of CO_2 equivalent emissions along the fertiliser value chain, with nitrogen leaching during fertilisation causing most emissions. Thus, more efficient fertiliser utilisation is key to decarbonise the food production. Utilising a value chain approach, full decarbonising of food production may be achieved by offsetting fertilisation emissions by carbon-negative ammonia production from biogas with carbon capture and storage (BECCS). Furthermore, biogas can be utilised to produce carbon-neutral urea, which currently accounts for 55% of global ammonia utilisation.

8. NEW MARKETS FOR AMMONIA AS A ZERO-CARBON FUEL AND HYDROGEN CARRIER.

Drivers for low carbon ammonia include new markets for ammonia, as well as high natural gas prices (in Europe). New markets for ammonia include its use as a transportation fuel, as a stationary fuel, and as a hydrogen carrier.

Ammonia is considered as one of the main alternatives to decarbonise the maritime sector. The first maritime engines able to operate on ammonia are expected to become commercially available in 2023-2024. The first 'ammonia-prepared' ships have been granted Approval in Principle.

Next to this, ammonia will find applications for stationary power and heat generation. For example, JERA and IHI aim to co-fire 20% ammonia in a 1 GW coal-fired power plant (Hekinan power plant, Unit 4) in 2024. Furthermore, ammonia-fed gas turbines are currently under development, with commercialisation of expected by the mid-2020s.

Ammonia can also be cracked and purified to hydrogen. Especially in Northern Europe, various large-scale ammonia crackers have been announced for hydrogen production, and subsequent transport inland via the existing natural gas grid.

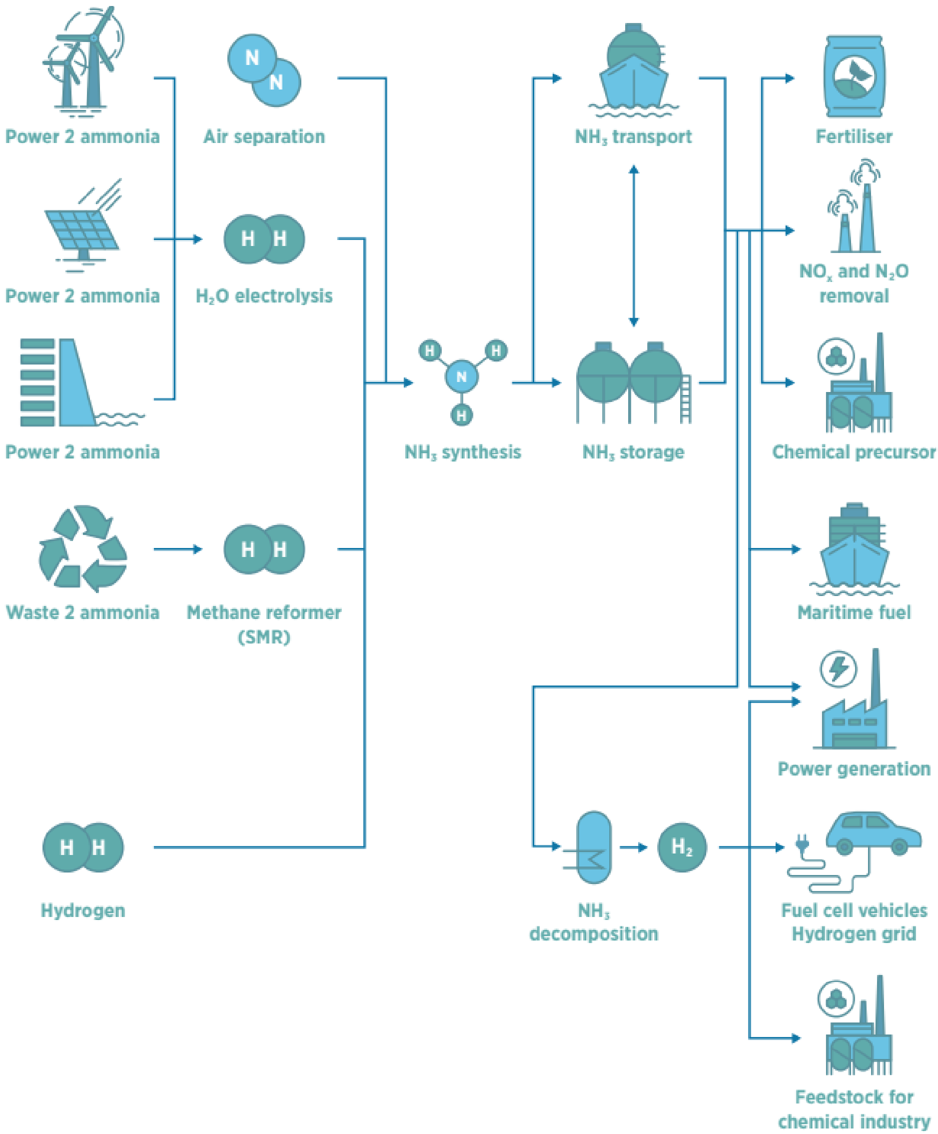

Figure 3: *Schematic of ammonia production and utilisation. Source: IRENA (2022).*

9. CONCLUSION.

With new markets for ammonia as a zero-carbon fuel and hydrogen carrier developing, food security is a key theme. In this context, various countries previously relying on fertiliser imports have moved towards their own renewable ammonia production plants. Examples include the 'Green Wolverine' plant in Northern Sweden (2027), and a renewable ammonia and calcium ammonium nitrate (CAN) plant in Kenya (2025).

In conclusion, ammonia as zero-carbon fuel and hydrogen carrier offers the energy sector and chemical sector a commodity that can be transported between continents. Substantial scale-up of low carbon ammonia production, e.g. fossil-based low carbon ammonia, renewable ammonia, and other low carbon ammonia production. Colour schemes should not be leading, but rather the carbon intensity of the ammonia produced, as well as other sustainability criteria. Most technologies along the value chain are commercial, while other technologies will become available around the mid-2020s, allowing ammonia to play a key role in decarbonising the energy landscape, without compromising food security.

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