Ammonia derivatives

Adding value to air gases and hydrogen

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As nitrogen fertilisers transition from grey ammonia to more costly green or blue ammonia, the question is how to absorb the clean premium?

The main cost driver for green and blue fertilisers is the increased production cost of clean hydrogen. However, as the amount of hydrogen in the fertiliser decreases, the impact of the higher cost for green or blue hydrogen diminishes. The reason is that the downstream stages to produce ammonia and ammonia derivatives remain un-altered, whatever colour hydrogen they are fed with.

Ammonia derivatives dilute the clean premium

Added-value ammonia derivatives such as urea, ammonium sulphate (AS), diammonium phosphate (DAP), ammonium nitrate (AN) and calcium ammonium nitrate (CAN) dilute the green or blue hydrogen cost to reduce the 'clean premium' to a more affordable level.

Hydrogen is 17.8% of the mass of ammonia, with nitrogen being the remainder. The hydrogen content in AN is reduced to 5%. And as the AN is converted to CAN, hydrogen falls to only 3.5% of the total mass.

As the mass of hydrogen in ammonia derivatives decreases, so does its cost within the product. In the case of DAP and CAN, hydrogen represents around 41% of the product value, whereas in ammonia it is 73%.

Additionally, DAP and CAN are inert solid fertilier granules which can be transported more easily than liquid ammonia, which is both toxic and flammable. For safety reasons, the use of AN as a fertiliser is prohibited, driving a high-value regulated European market for CAN.

Adding value to clean ammonia through ammonia derivatives significantly improves the business case for clean fertiliser value chains.

Air gases for ammonia derivatives

The Villeta Green Fertiliser Project is the flagship development of ATOME PLC. Villeta is an integrated complex, where green hydrogen will be produced using 110MW of electrolyser capacity fed with renewable electricity from the Itaipu dam.

Additionally, cryogenic air separation will produce gaseous nitrogen from the source of renewable electricity. This will be reacted with the green hydrogen in an ammonia synthesis plant. Conversion of the ammonia to nitric acid and the ammonia derivatives AN and CAN will also take place at the 30-hectare site.

In some nitric acid plants, oxygen facilitates process intensification in the absorber, where gaseous oxides of nitrogen are dissolved in dilute nitric acid to enrich the acid to the required commercial concentration.

In integrated sites where an air separation unit is included in the scheme to generate nitrogen for the ammonia production, or an electrolyser is present to generate hydrogen for ammonia synthesis, oxygen can beneficially be recovered as a co-product from these unit operations.

CAN and DAP production

Located in Puerto Sara, approximately 50 km south of Asunción, Villeta sits close to the east bank of the Paraguay River close to the Paraguay-Paraná waterway. This connects the site to several MERCOSUR countries through a regional river transport system.

Villeta is designed to produce CAN and will require circa 170 tonnes per day of dolomite. This rock will be sourced from local mines, integrating the facility into the Paraguayan economy.

Following Villeta, ATOME is planning a further ammonia derivatives development in Paraguay. The 300MW Yguazu project will diversify their product scope to DAP.

ATOME's Paraguayan projects are designed to reduce fertiliser imports to the MERCOSUR region and replace grey ammonia production from fossil fuel reforming with green ammonia production from 100% renewable electricity.

By producing green fertiliser at cost parity with the landed cost of gas-based grey hydrogen in South America, ATOME's projects in Paraguay serve climate goals and address the needs of the region's agricultural sector. And, by producing exportable added-value fertilisers such as CAN, the project will produce an internationally competitive ammonia derivative.

Bankability above all

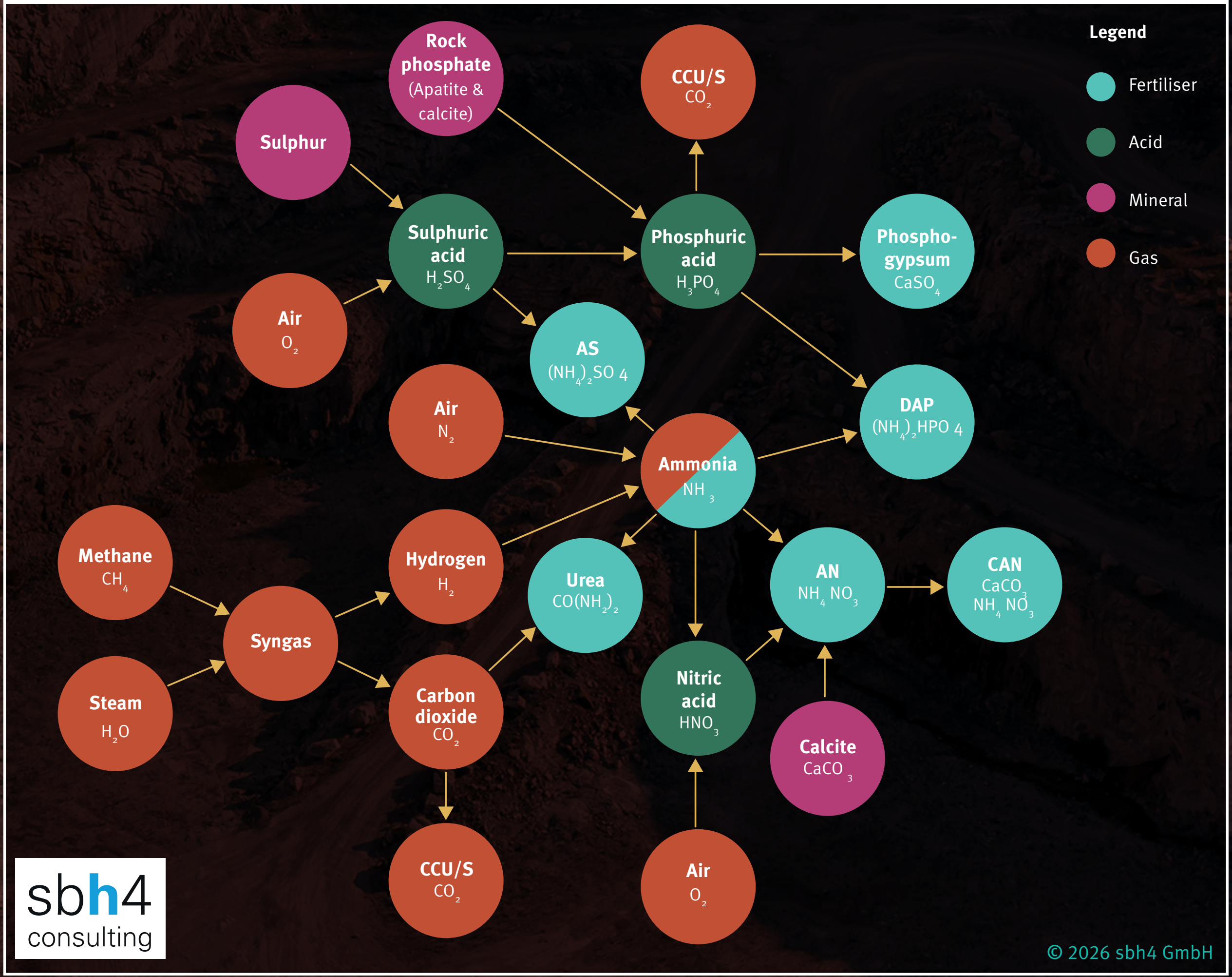
The economic viability of green hydrogen production is dependent on the availability and cost of renewable electricity, which constitutes 60% to 70% of the production cost. Unlike many green hydrogen projects that rely on non-programmable wind or solar power, Villeta will utilise the 14GW Itaipu dam as a firm supply of green electricity.

The Villeta project will utilise Casale's Flexigreen technology, which is optimised for renewable electricity-fed ammonia plants. While the hydropower source is remarkably firm, the Flexigreen design allows the process to turn down to 10% of nominal capacity. This allows the dam to supply other customers during periods of peak demand and ensures that the Villeta plant will be able to adapt to any potential future connection to integrated wind and solar renewable energy sources.

To de-risk the construction phase, in April 2025, ATOME and Casale signed a fixed-price, lump-sum EPC contract valued at $465m. The contract guarantees that production will commence within 38 months of the construction start date. The use of proven technologies and the experience that Casale has in the CAN value chain maximises the bankability for equity investors and creditors.

A significant commercial milestone for Villeta was closure of a 10-year offtake agreement with Yara International. The agreement, finalised in September

FIGURE 1. Ammonia at the Heart of Many Fertiliser Value Chains



2025, commits Yara to purchase the entire 260,000 tonne per year CAN production. This 'take-or-pay' structure will fully cover the costs of energy, operation and capital depreciation. It therefore serves as the foundation for the project's bankability.

Green hydrogen and CCS to combat CBAM tariffs

A benefit of producing green fertilisers is that they have a very low carbon dioxide (CO_2) intensity and are therefore not subject to the carbon border adjustment mechanism (CBAM) when they are imported to Europe. Blue ammonia and ammonia derivatives will have a similarly competitive position.

Due to the CBAM, some of the additional costs incurred when producing reduced CO_2 intensity products are neutralised once the product is landed in the EU and all taxes and tariffs have been paid. This supports the international competitiveness of decarbonised products and can help to build a business case for added-value clean ammonia and ammonia derivatives production.

When ammonia is made from steam methane reforming of natural gas, CO_2 leaving the reformer must be removed prior to the catalytic Haber Bosch ammonia synthesis reaction.

The active ammonia synthesis catalyst is iron. All molecules containing oxygen, such as water, carbon monoxide and CO_2 must be removed from the syngas before it is fed to the ammonia synthesis loop. Otherwise, the iron catalyst is oxidised and becomes ineffective. Therefore, every natural gas-fed ammonia facility integrates a CO_2 capture plant.

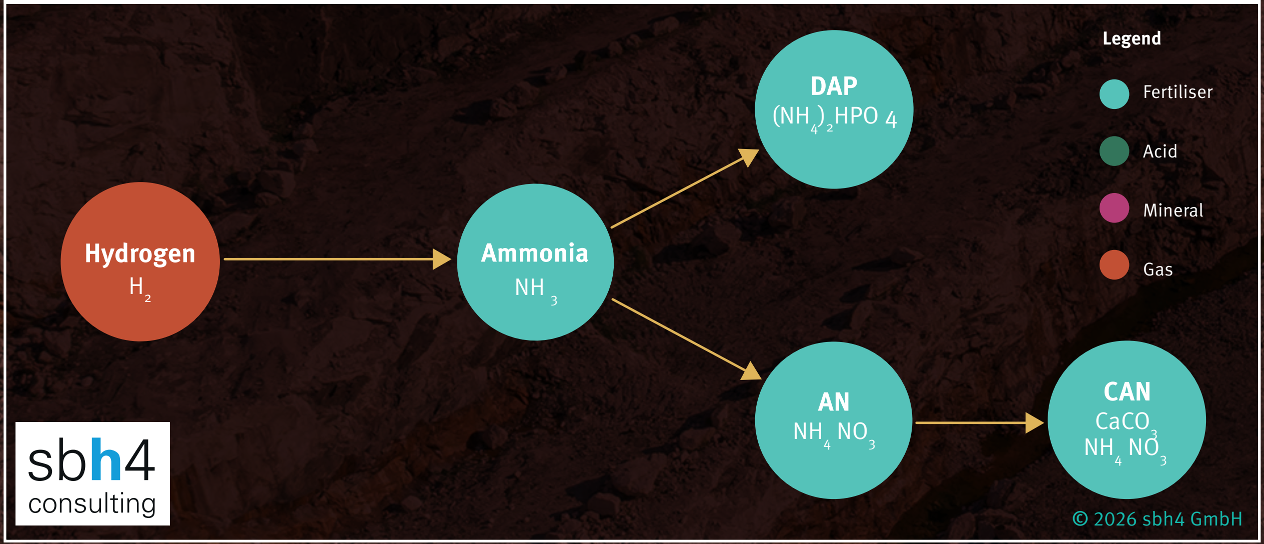
In some facilities, about 60% of the captured CO_2 is combined with ammonia to make urea. However, the residual 40% of the CO_2 from the SMR (and all of the CO_2 from ammonia plants that do produce urea) can be permanently sequestered.

Permanent CO_2 storage reduces the CO_2 intensity of their downstream nitrogen fertiliser products but add only a marginal incremental cost for CO_2 conditioning, transportation and geological storage.

FIGURE 2. Adding Value to Hydrogen with Ammonia and its Derivatives

Product	H_2 % in product	Grey H_2 value/ton	H_2% of value	Blue H_2 value/ton	H_2% of value	Green H_2 value/ton	H_2% of value	Green H_2 value/ton	H_2% of value
Hydrogen	100%	**$1,500**	100%	**$2,000**	100%	**$3,000**	100%	**$5,000**	100%
Ammonia	17.8%	$600	44.5%	$689	51.7%	$867	62%	$1,223	73%
AN	5.0%	$340	22.1%	$365	27.4%	$415	36%	$515	49%
CAN	3.5%	$300	17.5%	$318	22.0%	$353	30%	$423	41%
DAP	6.9%	$600	17.3%	$635	21.7%	$704	29%	$842	41%

FIGURE 3. Adding value to hydrogen with ammonia and its derivatives



Petrobras has operated geological CO_2 injection schemes linked to enhanced oil recovery for many years in the Santos Basin. They have sequestered more tonnes of CO_2 offshore than any other operator worldwide.

So, in addition to green ammonia being produced in South America, the continent has the potential to produce blue molecules also.

DAP and AS integration for value-added ammonia derivatives

CO_2 capture from DAP production will be implemented from 2027 at OCP's Jorf Lasfar industrial platform in Morocco. The initiative is part of OCP Group's decarbonisation roadmap, which aims to achieve carbon neutrality across Scope 1, 2 and 3 emissions by 2040. It also addresses international competitiveness by reducing the CO_2 intensity of DAP.

The captured CO_2 will be used by OCP Green Water for pH adjustment and re-mineralisation of drinking water in support of a local reverse osmosis desalination plant. This aligns to Morocco's goal of meeting all of the nation's water needs through unconventional water sources by 2027.

As an additional use case for the captured CO_2, INNOVX will build a facility that combines captured CO_2 and waste phosphogypsum to produce AS.

The Merseburg Process is the most common pathway to achieve this: it reacts aqueous ammonia with CO_2 to produce ammonium carbonate. Phosphogypsum is then reacted with ammonium carbonate to yield calcium carbonate and the target product ammonium sulphate.

Calcium carbonate is a recognised permanent sink for CO_2, so this pathway sequesters CO_2 emissions from the DAP process through mineralisation and enables integrated production of DAP and AS.

AS – ideal for sub-tropical climates

AS was the first commercially available nitrogen fertiliser but it was displaced in many markets by ammonia and urea because they have a higher nitrogen content by mass. However, AS is still used extensively in Brazil where it is suitable for the local soil, which contains very low levels of sulphur. Sulphur is essential to grow protein-rich crops such as soya beans, which are used locally for beef production and are exported.

Additionally, AS has a lower ammonia volatilisation rate than urea. This is important in the warm Brazilian climate and is a factor that leads to its use in South East Asia for growing wheat and rice. gw

FIGURE 4. Adding Value to Hydrogen with Ammonia and its Derivatives