argusmedia.com

July 2023

Argus White Paper

India's hydrogen strategy: Implications for its clean/ conventional ammonia and fertilizer industries

Defining realistic decarbonization targets

We often hear that replacing grey hydrogen with green hydrogen is the low-hanging fruit of the future hydrogen economy. But is it always the case? Let's look at one of the use cases that are often included in this category, nitrogen fertilizers, and focus on one of the biggest users globally: India.

The Indian government has ambitious plans to use green hydrogen to produce ammonia and replace natural gas-based domestic ammonia production and imports. To shed some light on the true potential of these plans we need to look in more detail at how ammonia is currently used in India.

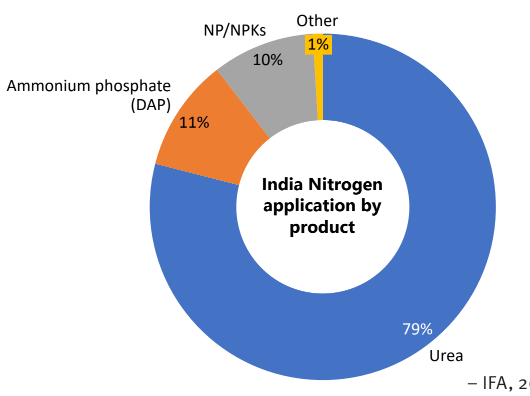
India currently consumes around 19 million tonnes of ammonia (equal to 3.35 million tonnes of grey hydrogen), 89% of which is produced domestically. Over 90% of domestically produced ammonia goes into the production of urea on site. Urea is by far the main source of nitrogen for India's agriculture, accounting for 80% of the total. The dominance of urea is historically explained by its high nitrogen content and ease of storage and transportation.

Fertilizers are considered vital for food security and delivery of urea at an affordable price has been a long-running and costly policy of the Indian government. India has a substantial fertilizer subsidy bill, which in FY23, ending March 2023, amounted to an estimated $27 billion, amid fertilizer prices at historical highs due to the disruptions caused by the war in Ukraine. Urea currently accounts for most of India's overall fertiliser subsidy.

The policy goal of securing urea to the farmer has also driven the huge investments into the domestic production of this key fertilizer input in recent years, whilst at the same time retaining its position as one of the of the world's largest urea importers.

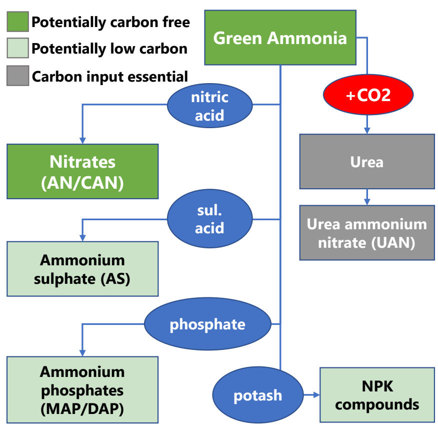
But in terms of green ammonia adoption that is problematic: urea requires a source of carbon to be produced, which would have to come from very expensive direct air capture, or CCS applied to bioenergy or fossil emissions. Adding CO_2 to decarbonised ammonia, only to see that CO_2 fully released back in the atmosphere once urea is applied to the soil would be a rather questionable practice (as *Argus* flagged a while back).

India nitrogen fertilizer application by product



– IFA, 2020 data

Green ammonia derivatives' production routes



To highlight the strategic importance of urea for India's fertilizer sector, and therefore for the country's food security, it is important to note that India is still investing in new domestic urea capacity, all based on hydrogen and ammonia that are very much "grey". Including these new plants, by 2025 we will have a total of 17.5 million tonnes of grey ammonia consumption for urea production, tonnage that would be difficult to decarbonize with the use of green hydrogen/ ammonia.

Straight nitrates would be the only truly carbon-free products for using green ammonia to produce a downstream nitrogen fertilizer but are effectively banned in India due to safety concerns. The remaining options for producing a low-carbon fertilizer at scale in India would be ammoniated phosphates (DAP) and NP/NPK products. That's perhaps the biggest opportunity for green ammonia in India: a large share of DAP/NP/NPK produced in India currently relies on imported ammonia (over 2 million tonnes annually), which could be theoretically fully replaced with domestically produced green ammonia.

A further 400,000 tonnes of ammonia are imported for a range of other industrial applications, which could also be replaced by domestic green ammonia production.

Note that these assumptions do not take into account the costs involved however, which would be significant and will be analysed in the second part of this analysis.

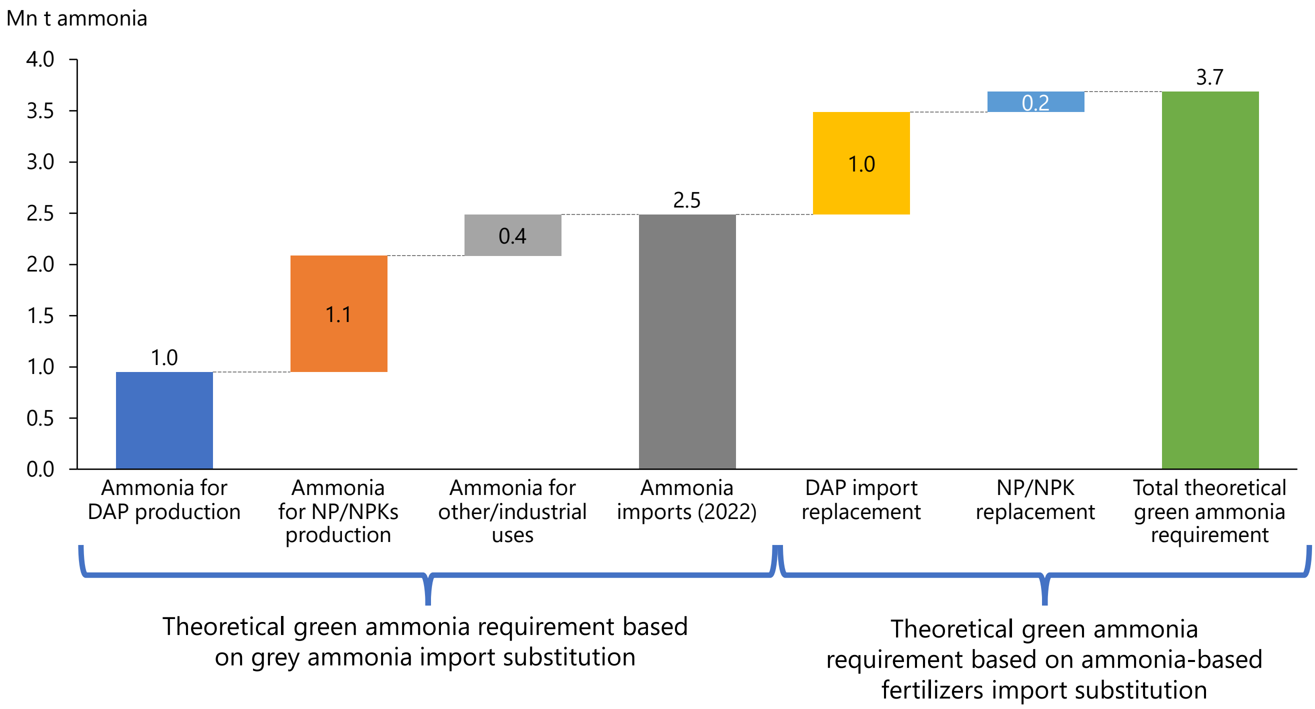
In a more far-fetched scenario, which we consider highly unlikely, India could also aim to replace its sizeable DAP and NP/NPK imports with domestically produced, green ammonia-based equivalents. The current 4.9 million tonnes of imported DAP would require more than 1 million tonnes of green ammonia production. We estimate that the 1.1 mn t of NP/NPK currently imported would require a conservative 200,000t of ammonia production, if those volumes were onshored. It is reasonable to assume that the cost of substituting grey to green ammonia-based complex fertilizers imports would provide a further rocket-boost to the already huge subsidy bill on fertilizers in India.

To summarise:

1) **Using green ammonia to decarbonise India's fertilizer industry can only be partially achieved** due to the structure of the market and of India's current fertilizer production base, unless we envisage a future in which a large portion of India's urea domestic production capacity will be mothballed and/ or repurposed at great cost, and a significant regulatory change will be implemented to move away from urea. Both assumptions are considered highly unlikely.

2) Purely theoretically, and **in a very optimistic scenario, only around 2.5 million tonnes (or 11%) of India's current grey ammonia consumption can be decarbonised with green hydrogen/ammonia**. This could grow to 3.7 million tonnes with a very drastic import substitution plan that includes

India green ammonia theoretical potential as a fertilizer raw material

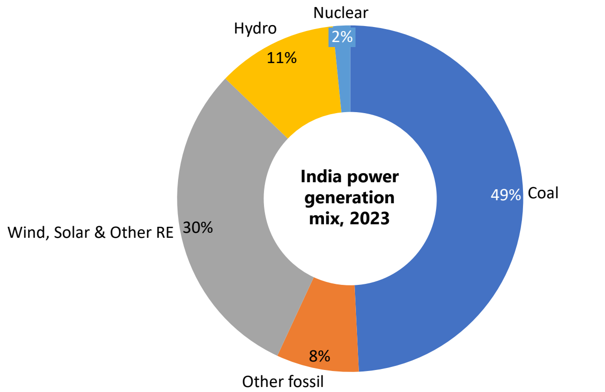


downstream products such as DAP and NP/NPKs. This would roughly be the equivalent of 3 world-scale ammonia plants.

We note however that **due to the high costs involved**, and the potential burden on India's already contentious domestic fertilizer subsidy budget, we consider these numbers highly speculative, and **the *Argus* view is that the achievable volumes of green ammonia production and consumption as a fertilizer raw material in India will be much lower in the short-term (within this decade)**.

In addition to the decarbonization of the domestic fertilizer sector, we also notice that several announced green ammonia projects are aiming to supply export markets, targeting for instance fuel applications, and far-flung markets. A more philosophical consideration should be made about the appropriate use of potentially vast amounts of renewable power for the production of green hydrogen/ammonia destined to export markets when at the same time the real low-hanging fruit could be the decarbonization of India's electricity grid, which as of 2022 was still largely dominated by coal, as shown below. This perhaps deserves a separate analysis.

India power generation mix, 2023



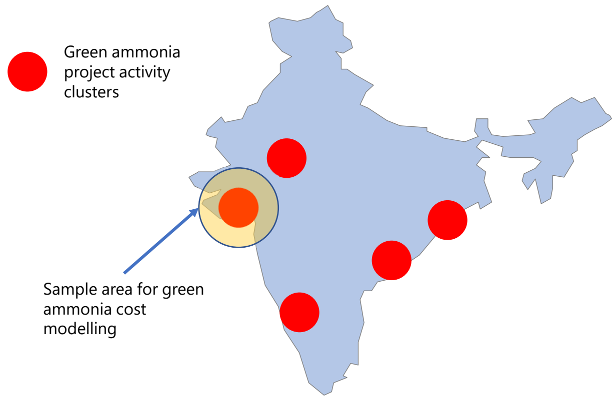
– India Ministry of Power

The cost of decarbonization: scenarios and implications

In the second part of our analysis, we are going to look in more detail are the costs involved in rolling out a large-scale replacement of grey ammonia with green ammonia in India, with focus on the cost implications for India's large fertilizer market.

While green hydrogen projects in the country are still at a speculative stage, we are seeing plans of renewable setups that are dominated by solar PV with a small share of onshore wind capacity. Accordingly, in our Ammonia Analytics' green ammonia model we have assigned India a power mix split of 75pc and 25pc of solar and onshore wind respectively. Our generic location for the country is the state of Gujarat, which could become a key location for green ammonia production and trade in the future, although we are aware that green hydrogen/ammonia project activity is distributed across various parts of India, as shown below.

India's green ammonia project activity by location



Renewable power costs in India are estimated to be among the cheapest in the world. Power purchase agreements for some solar plants have recently been set at as low as $26/MWh. Capital costs for onshore wind plants and ammonia building units are similarly competitive. However, India suffers from a country risk premium of 2.2pc and a WACC based on the fertilizer industry, which is the target end use examined in this article. Its risked WACC is calculated as 11pc, and after adjusting for inflation, falls to 9pc. Higher financing costs relative to other countries offsets some of the benefits from cheap renewables and ammonia plants for India.

Renewable power availability in the sample location in Gujarat lacks the potential we see in other locations for countries like Chile and Saudi Arabia. While solar power in India has an annual average capacity factor of 20pc, it varies considerably across the year going as low as 12pc in the monsoon months of July and August. The average capacity factor for onshore wind is estimated to be 29pc which is lower than what we observe in locations with high wind potential. Based on the 75-25 power mix of solar and wind, the generator in our location achieves an aggregate capacity factor of 22pc.

It is important to model different configurations for power supply. *Argus* provides the following scenarios:

1. **Island model:** this setup has captive renewable capacity which is the only source of power for the ammonia plant's electrolyser. This places a constraint on the electrolyser's operating rate

2. **Island with battery model:** this setup adds a battery to the island model so that any excess power generated can be stored and fed to the electrolyser during low power generation hours.

3. **Grid banking model:** in this production model the facility is connected to the local power grid and the renewable generator can send power to the grid during its peak production hours. This way production can remain green even though the local grid itself is not.

4. **Grid banking model with battery:** this configuration adds a battery to the grid banking model so that any excess power generated is first stored in the battery before it is sent to the grid.

5. **Grid banking without net zero grid condition:** the facility has captive renewable generation and balances its power requirements from the local grid to operate the electrolyser at 100pc capacity. Power is only drawn from the grid (and not sent back) as there is no requirement for net zero grid draw.

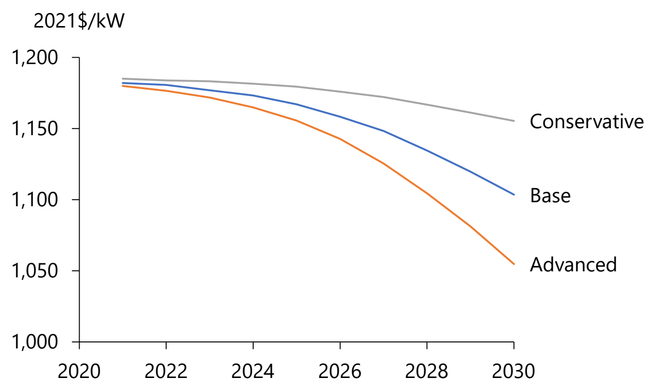
6. **Grid-based:** in this setup we assume that the facility takes 100pc of the electricity to run the electrolyser at maximum load from the local power.

Assuming that most of the projects under consideration in the short term will be based on alkaline electrolysers, since they are the most readily available on a commercial scale, we can build different scenarios for the levelized cost of green hydrogen and ammonia in India.

We are going to focus on the costs achievable within the most immediate investment cycle (i.e. for a green ammonia plant to be commissioned by 2027), since the costs associated with such facility would shape the prices needed by the project developers to produce desirable returns for the lifetime of the plant, and therefore until well beyond 2035.

Electrolyser capital cost is the key cost uncertainty at the moment, given the current high cost of electrolysers and the wide range of expectations over the trajectory of cost improvements. The other equipment, such as the ammonia synthesis loop, is based on mature technologies with no expected cost improvements over the forecast period.

Alkaline electrolyser cost forecast



Alkaline electrolyser capital intensity is based on our "Base" scenario illustrated below, in which by 2027 the cost is expected to be 1,048 2021$/kW. Note that the future rate of improvement for electrolyser costs will rely on the rate of investment in electrolyser capacity and technology, and therefore any delay in the adoption of green hydrogen and derivatives is likely to result is a slower rate of improvement for costs.

It is important to note that if we based our cost estimates on PEM electrolysers, the resulting costs within the timeframe under consideration are likely to be higher (even though PEM electrolysis theoretically has a greater potential for cost reductions over the very long term).

Argus forecasts that for a project commissioned in 2027 the Levelised Cost Of Ammonia (LCOA) in India will range between \$669/t for a grid based configuration to \$927/t for a green ammonia plant based on an island configuration, using alkaline electrolysers as mentioned above. These costs are based on a chemical industry-specific WACC, adjusted by country risk. Note that all costs are expressed in constant 2021 US Dollars, and therefore so not take into account inflation.

The island setup is the most expensive, even more costly than the grid banking without net zero grid setup which includes power costs charged at wholesale rates. The reason for the costliness of captive setups in India is twofold. India has high financing costs, and these are aggravated under the captive setups which are more capital intensive than other configurations.

Second, required electrolyser capacity for India is even larger because of a low aggregate generator capacity factor of only 22pc. The electrolyser operating rate for example under the island setup is only 38pc, reflecting the need for a larger electrolyser to produce at the target scale. As electrolyser costs are expected fall though, and renewables get more efficient in power capture, these setups could start performing better than the configurations that involve power costs purchased at grid wholesale rates.

Our base configuration representing the grid banking setup is one of the most economical. We can attribute the low costs under this setup to the cheap LCOE from renewables in India and lower electrolyser capital costs since we can run the electrolyser at maximum capacity.

Once we have this cost estimate, we can start thinking about the implications for the green ammonia-based nitrogen fertilizer production and import substitution scenarios we outlined in the previous part of the white paper. India has a substantial fertilizer subsidy bill, which in the 2022-23 financial year (ended March 2023) amounted to an estimated \$27 billion, amid fertilizer prices at record highs due to the disruptions caused by the war in Ukraine. This was 40% higher year-on-year, and almost 70% higher than in FY2020-21. The magnitude of the subsidy bill is invariably a contentious topic in the Indian political debate, with frequent calls for reform.

Some of the recent analysis of the grey hydrogen/ammonia replacement potential with green have been based on the comparison between 2022 gas prices, which were driven to all-time highs due to the war in Ukraine, and green hydrogen/ammonia production costs. Now that gas prices seem to have stabilized, and ammonia prices have followed suit, plummeting back to normal levels, the picture is quite different.

The chart below shows *Argus*' medium-term grey ammonia price forecast on a cfr India basis, compared with our forecast range for green ammonia produced in India over the same period.

Based on the green ammonia cost ranges shown above, **replacing the current level of grey ammonia imports into India (2.5 million tonnes) with green ammonia produced domestically, would imply an extra cost ranging between $537 million and $1.2 billion in 2027.** This is based on a forecast price of grey ammonia of $474/t in 2027.

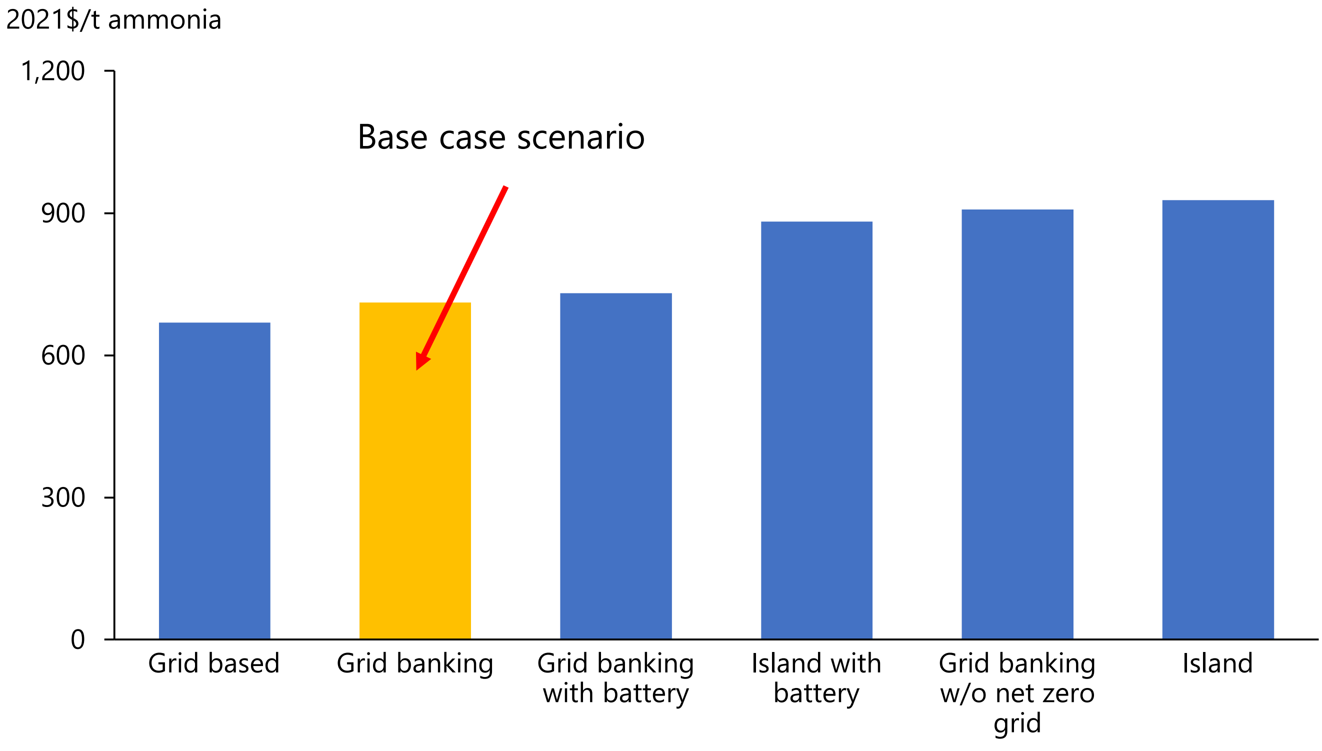
A full substitution of ammonia-based fertilizer products (imported DAP, NP/NPKs) would imply an additional bill ranging from $1.3 billion and $2.3 billion in 2027 (based on a total of 3.7 million tonnes of green ammonia produced domestically).

However, it is over the longer term that the magnitude of these costs becomes quite alarming. If we take into consideration our base green ammonia plant configuration, its levelized cost of ammonia based on a 2027 commissioning would be around $710/t. This means that the project would have to achieve an average sales price of $710/t over the lifetime of the project to ensure an NPV above zero (i.e. to ensure that the project does not destroy value for the investors). **Over a 10-year period, if we compare this levelized cost with Argus' longer term grey ammonia price forecast, this would translate into a cumulative $6.7-10 billion cost of grey ammonia substitution.**

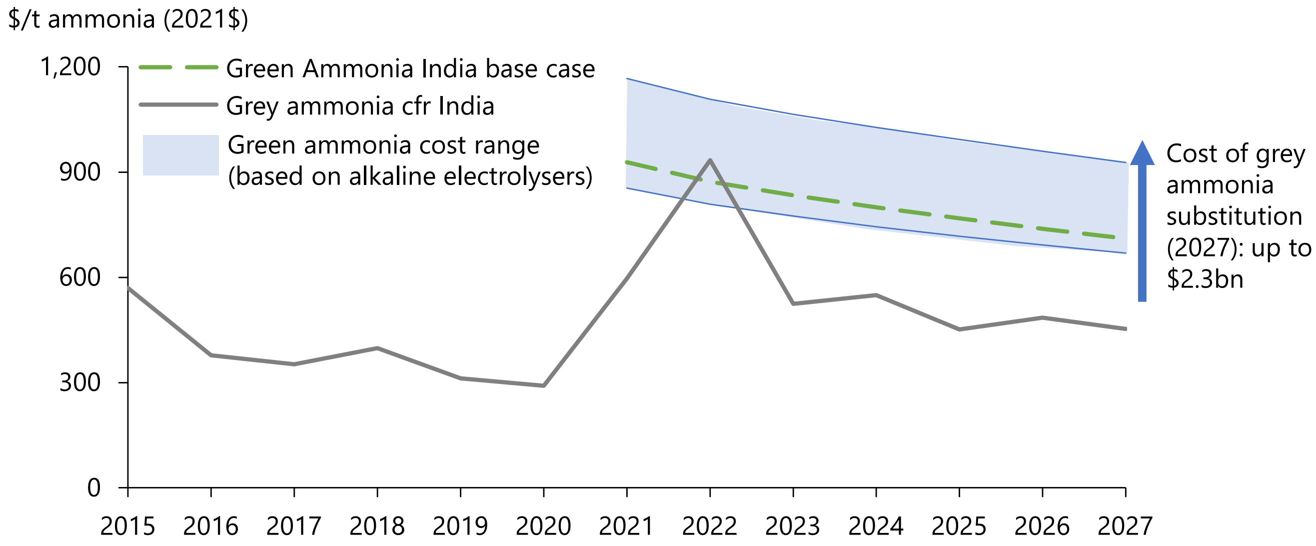
These additional costs would inevitably be reflected in a higher fertilizer subsidy bill, since India's Nutrient Based Subsidy (or NBS, the official name of India's fertilizer subsidy scheme) includes the product categories that would be produced with this green ammonia. Although the future budget allocated to fertilizers by the time domestic green ammonia plants become operational cannot be determined at present, it is likely that a significant percentage of the additional costs calculated above will be partly reflected in the NBS scheme, and partly in any support measure that the Indian government will put in place to incentivise domestic green hydrogen production.

An example of these support measures is the announced green hydrogen subsidy fund, which will provide very limited support to the industry, with average support limited to 40 rupees/kg ($0.49/kg) for three years.

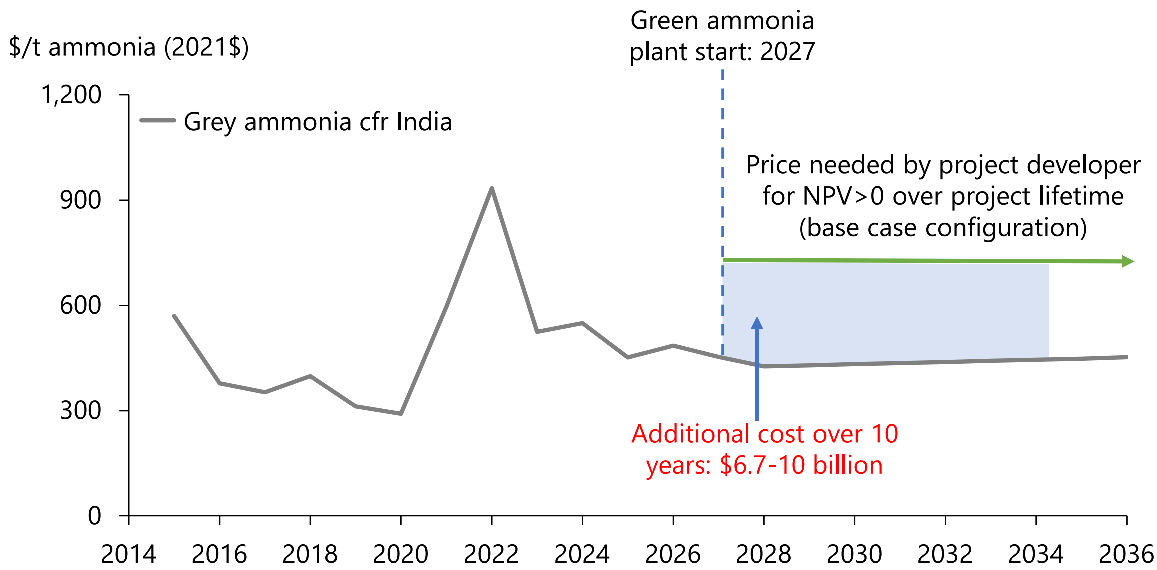
Green ammonia LCOA under base case and various production setups for India (2027 forecast)



Green ammonia LCOA vs grey ammonia prices



Cumulative cost of grey ammonia substitution over 10 years



For this reason, the Argus view is that only a small portion of current grey ammonia consumption and imports will realistically be replaced by domestic green ammonia production within the timeline indicated by the Indian government.

For a level-headed view on the decarbonation prospects for grey ammonia, *Argus* offers an unbiased and facts-based analysis in the *Argus* Ammonia Analytics service.

by Andrea Valentini, VP, Business Development - Ammonia, Argus

Argus services analysing clean and conventional ammonia markets

Argus Ammonia

The Argus Ammonia price reporting service provides accurate and reliable daily and weekly price assessments, alongside news and market commentary direct from our expert global editorial team. Includes the underlying data in Excel.

Clean ammonia coverage includes: Modelled weekly price for green ammonia, fuel equivalent pricing, carbon-adjusted price of ammonia, market developments, downloadable projects datasets, MoU's, offtake and vessel tracker.

Argus Monthly Ammonia Outlook

The Argus Monthly Ammonia Outlook service delivers focused short-term outlook market intelligence, including 12-month forecasts for prices and trade balances. Includes clean ammonia news and insights, and the underlying data in Excel.

Argus Ammonia Analytics

The Argus Ammonia Analytics quarterly service connects you with industry-leading clean and conventional ammonia market intelligence - offering essential medium to long-term analysis and outlooks.

Includes quarterly reports and data with 15-year forecasts, and one longer-term annual report with forecasts to 2050 (based on Long Run Marginal Cost analysis).

Argus Consulting services

Argus' bespoke consulting division have a proven track record of delivering best-in-class fully bespoke conventional and clean ammonia solutions, including market-specific research and analysis.

Interested in other fertilizer markets, or the hydrogen market?

Learn more about Argus fertilizer market coverage, and hydrogen market coverage.

For more information:

ammonia-m@argusmedia.com +44 20 7780 4200 www.argusmedia.com @argusmedia