German-Dutch Green Ammonia Supply Chains:

Current State, Opportunities, and Challenges

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Executive Summary

The potential of imported (green) ammonia as one of the key contributors to achieving climate neutrality by 2050 is increasingly being recognized by relevant stakeholders, such as infrastructure providers, including storage terminal and power station operators, energy-intense industrial sectors as well as political decision-makers. Especially the availability of affordable renewable energy outside Europe in contrast to the EU's limited production capacity significantly contributes to the support for importing green ammonia.

The potential of green ammonia, especially with regard to reducing CO2 emissions in the short term (2030-35), is based on the following factors:

- (Green) ammonia can be utilised in various ways: as energy storage, as fuel, as feedstock.
- The transport, storage, and use of the product are an established practice. Comprehensive safety standards have been developed and are, accordingly, very high. Risks are therefore well-managed.
- Transport infrastructure is also varied: ammonia can be transported by inland barge, by railcar, by pipeline, and even by truck. Large industrial customers can potentially be supplied by repurposed pipelines.
- Green ammonia has a comparatively high energy density: its energy density is higher than that of H2, green methanol, LOHC.
- Green ammonia is priced competitively.

Given the potential of (green) ammonia to support the sustainable transition of energy-intense industrial sectors, political decision-makers in NRW should co-operate with industrial stakeholders more closely to establish more favourable framework conditions for the transport, storage, and use.

Despite green ammonia's advantages and potential, the green ammonia market still faces a classic chicken-and-egg problem: insufficient demand hampers supply growth, while lack of supply stifles demand. The most straightforward approach would be to kickstart the market by replacing the current use of grey ammonia with green ammonia, although this transition currently lacks a viable business case under existing support mechanisms. A facilitating role for blue ammonia should also be allowed during an initial transitionary phase. In general, building viable business cases for sustainable energy carriers will be challenging without additional support.

Policy recommendations emphasize the need for an interconnected EU hydrogen backbone, support for pilot projects, specific support for import and a balanced regulatory environment that supports sustainable, both green and blue variants.

Germany and the Netherlands have successfully co-operated regarding the supply of energy and feedstock for several decades, particularly supplying the key industrial regions of NRW. This co-operation can further be developed into an innovative and forward-looking partnership to develop supply chains for increasingly climate-neutral energy and feedstock. This means that cross-border cooperation between Germany and the Netherlands on shared infrastructure requirements is crucial. Given its location, the Netherlands is pivotal for the energy supply across North-Western Europe and to Germany and especially NRW. Utilising existing assets and harmonising safety standards will expedite the transition process whilst ensuring a competitive market landscape.

1. Preamble

The interest in increasing the use of green ammonia is driven by efforts to meet the European climate targets for reaching climate neutrality by 2050. Due to its characteristics such as easy transportability, imported green ammonia has the potential to make a significant contribution to reaching climate targets, especially in the short term up to 2030-2035. Green hydrogen derivatives, especially green ammonia is expected to hit the market earlier than green hydrogen, also because green ammonia cannot only be used as an energy carrier but also as feedstock and shipping fuel. This means that there are various ways of using ammonia, each associated with different market conditions, infrastructure requirements, and market participants:

- **Direct cracking of ammonia after import**: This involves processing ammonia in ports and further transportation as hydrogen via pipelines. This involves additional energy which increases costs and, potentially, its environmental impact.
- **Local cracking of ammonia at the point of use**: This involves importing and forwarding ammonia, then cracking it on-site. This involves additional energy which increases costs and, potentially, its environmental impact.
- **Direct use as a fuel or feedstock**: Ammonia can be used directly as feedstock or fuel in the energy industry/energy generation without cracking, so no extra energy and costs involved.

Recent policy decisions by the German Federal and NRW State Government highlight the importance of green ammonia with major policy steps:

- Mentioned in National Hydrogen Strategy
- Included in the Hydrogen Import Strategy
- Defined as “of overriding public interest” under the drafted Hydrogen Acceleration Act
- Recently awarded a contract at the first H2 Global auction
- Recognised in NRW Import Concept

Equally, the importance of green ammonia has been recognized in Dutch strategies related to green hydrogen as well as various government announcements, e. g. on costs (April 2024), the hydrogen network (July 2023), and energy diplomacy (June 2023).
It is also reflected in already signed MoUs on green hydrogen, e.g. between the Netherlands and Australia (January 2023) and between the Netherlands and South Africa (June 2023).

These steps clearly demonstrate that political decision-makers have recognised the potential of green ammonia which, in turn, supports its market ramp-up.

<u>German-Dutch stakeholders jointly strive for a common understanding of green ammonia</u>

Germany and the Netherlands share common objectives regarding the energy transition and industrial transformation. Given the interconnectedness of their industries, their energy and

feedstock supply, both countries have been closely working together to support the required industrial transformation of their respective industrial sectors.

Key players from both sides of the border have been brought together by VOTOB, the Dutch tank storage association, Rhein Ruhr Power, a think tank and industrial stakeholder association aimed at strengthening the technological and innovative capabilities in the Ruhr metropolis, and the strategic consultancy von Beust & Colleagues. In a workshop of 3rd July 2024, held at the GWI in Essen, a wide range of industrial, academic and political stakeholders have addressed the issues associated with strengthening and extending the supply chains for green ammonia between the Netherlands and the industrial offtakers in NRW.

In particular, the attendees of the workshop which was supported by Hydrogen Metropole Ruhr (HyMR), discussed the current market, possible market developments and, crucially, current challenges and approaches to overcome them.

Agreement on common infrastructure needs, such as pipelines or railway lines, to enable seamless cross-border transport was identified as a particularly relevant topic.

Discussions among industry and governmental stakeholders have demonstrated that there are varying concerns about the suitable supply of ammonia. Whereas Dutch stakeholders from federal and municipal government prefer pipeline transport due to safety and emission reasons, German stakeholders are more hesitant concerning pipelines and seems to prefer rail transport for ammonia. This discrepancy needs addressing to create a unified approach to strengthening and extending supply chains for green ammonia.

2. Market

There has been a market for fossil ammonia for decades, particularly to produce fertilisers, which is therefore an appropriate starting point for the replacement of fossil ammonia with increasingly more climate-neutral ammonia, i.e. blue and green ammonia. Although initial steps have been taken with H2Global as a German initiative with Dutch support, new use cases are economically challenging. Replacing grey with green ammonia is at least technically a low-hanging fruit, but there are still obstacles to further market development.

How and Shere to Start with Market Ramp-Up

First Step Taken: Purchasing Green Ammonia with H2Global

As part of the first H2Global tender round, the German Ministry of Economic Affairs and Climate Action (BMWK) auctioned a bid in July 2024 that will import at least 259.000 tonnes of green ammonia worth around 400 million euros to Germany via the port of Rotterdam between 2027 and 2033. In total, this would correspond to more than ten per cent of Germany's annual ammonia production. The production price would be 811 euros per tonne of ammonia. According to the BMWK, this translates into a price of less than 4.50 euro/kg of green hydrogen.

Replacement of Grey by Blue (and later Green) Ammonia

The most straightforward approach to kickstart the ammonia market is by replacing grey ammonia with blue and later green ammonia. However, this transition lacks a viable business case under current support mechanisms. For instance, Climate Protection Contracts are designed for new technologies and do not apply. Similarly, the Carbon Border Adjustment Mechanism (CBAM) only compensates for the competitive disadvantage on the European market compared to imports, but it does not help to make more sustainable but more expensive European products competitive in the global market - the switch to sustainable energy sources such as green ammonia is therefore not economically viable.

Possible Short-to-Medium-Term Use Cases

While there are limited additional new use cases identified up to 2040, several existing applications have high Technical Readiness Levels (TRL) but lack robust business cases:

- **Ship Engines**: ship engines have a high TRL for using ammonia as fuel, accordingly, two-stroke dual-fuel engines are currently in advanced development. For example, engine designer MAN Energy Solutions expects ammonia-fuelled ships to be sailing by 2026/27, to be followed by a considerable market ramp-up so that by 2030 ammonia is one of the biggest marine fuels for ship newbuilds.
- **Industries without Global Competition**: Sectors like cement and glass manufacturing can afford more expensive feedstock due to their lack of global competition.

Possible Long-Term Use Cases

Future applications of ammonia present both opportunities and challenges:

- **Large-Scale Generation**: Not yet foreseen due to the need for deNOx facilities which add costs.
- **Smaller Scale Generation**: Up to 50MW is possible since ammonia is easy to store on-site.
- **Mixing Ammonia with Gas/Gasified Biomass:** research is needed to determine optimal mixing percentages.

Major Challenges

Hesitancy Among Companies

Some companies in NRW have recently switched from coal to natural gas at significant cost, albeit subsidised. These companies are hesitant to switch again to ammonia/H2 in the near future due to the financial burden and operational disruptions involved.

Addressing Market Transparency and Predictability

There is a significant lack of market transparency regarding the cost structure of green ammonia at the desired scale. This opacity creates problems in predicting business cases and hinders investment decisions. To support market ramp-up effectively, incentives for substituting fossil gas must be strengthened.

3. Use and Transport Infrastructure

Whilst the final objective is the widespread use of green ammonia and other carriers, in the short-term the important role of blue ammonia for decarbonisation needs to be taken into account. An integrated approach that includes both variants and therefore includes the transformation of existing business cases and the creation of new business cases will facilitate a smoother transition towards increasingly climate-neutral energy and feedstock supply. Additionally, leveraging existing infrastructure will play a crucial role in determining whether green hydrogen or green ammonia become the preferred choice for various industrial applications.

An integrated Approach: Blue Ammonia as a Facilitator

Why Blue Ammonia is Needed

The arguments supporting the faciliatory role of blue hydrogen also apply to blue ammonia: blue ammonia serves as a transition technology, enabling immediate reductions in CO2 emissions while the infrastructure for green ammonia is being developed. Both green and blue variants are necessary to meet current and future demand, making concerns about lock-ins unfounded. Putting CO2 abatement costs into perspective, blue ammonia is more cost-competitive – thus making it a more viable option in the short term.

Competition and Market Dynamics

Excluding blue hydrogen/ammonia from the market would reduce competition among countries and companies. Not all regions have the capability to produce green energy carriers, so allowing both blue and green variants ensures a more competitive and diverse market landscape.

Regulatory Challenges

The regulatory environment significantly influences the adoption of both green and blue ammonia. While regulations generally support green carriers, blue variants at most receive indirect support through CO2 pricing mechanisms. This disparity needs addressing to create a balanced market. Current regulations like the EU-Renewable Energy Directive (RED III), especially the RFNBO industry quota creates an ‘incentive trap’ by requiring additional green hydrogen if switching from grey fossils to blue hydrogen.

Ammonia as Viable Option to Overcome Infrastructure Limitations

Demand Industry Options

Industrial sectors are currently exploring multiple options, including both hydrogen and ammonia, depending on supply options, product needs, quantity, geographical location and *Kernnetz*/*Hynetwork* connections. This flexibility allows industries to adapt based on availability and logistical considerations. For SMEs in particular, which will not be connected to the hydrogen core networks in the medium term, the use of ammonia and a local cracker offers the opportunity to convert to hydrogen-based technologies without having to wait for pipeline-based hydrogen to become available.

Clear Industry Signals Needed

For political and industrial stakeholders to effectively co-operate and work towards improving the framework conditions for the transport, storage, and use of green ammonia, it is now key for potential industrial users to provide clear signals about their specific infrastructural needs. Currently, there is a lack of detailed input from industry players which hampers coordinated planning efforts.

Leveraging Existing Infrastructure and Transport Modalities

Utilising existing infrastructure and transport modalities, such as storage tanks, pipelines, railcars, barges, trucks, and canal networks can significantly reduce initial investment costs. Ammonia can leverage existing infrastructure more effectively than hydrogen: the potential for ammonia transportation by barge or rail is significant due to its higher energy density. The existing rail and inland waterways infrastructure can already provide efficient supply solutions in the short- and medium-term. However, in longer-term the existing infrastructure will need to be extended.

4. Social Acceptance

The use of technologies associated with risks and potential harm to people, nature and the environment depends on the understanding and subsequent acceptance of the technology employed and its potential impact by local/neighbouring communities, NGOs, civic groups, and other key societal stakeholders. Given its noxious properties, this also applies to ammonia. Early provision of information about the product, its handling and safety measures as well as early public participation and transparency throughout about existing (and new and extended) laws, regulations, and extra training will be necessary to reduce existing fears and insecurities and obtain the required understanding, trust, and acceptance.

In all these endeavours the message must be clear: ammonia has been safely used for decades under strict safety requirements for the transport, storage, handling, and use. This means that the relevant expertise and experience does exist to handle greater volumes and more users of (green) ammonia.

5. Policy Recommendations

- **Prioritising the EU hydrogen backbone:** this infrastructure is crucial for facilitating the widespread adoption of green hydrogen and green ammonia as energy carriers across Europe.
- **Political support for small-scale projects:** these projects can serve as scalable examples for larger initiatives and help build a track record that demonstrates feasibility and reliability.
- **Level-playing-field for all low-carbon carriers:** the regulatory environment must be balanced to directly support not only green but also blue ammonia as a facilitator for green ammonia projects.
- **Revising RFNBO-Quota:** the current RED III creates an incentive trap by requiring additional green hydrogen when switching energy supply. Adjustments are needed to make this regulation more flexible and supportive of blue transitions.

- **Fostering Dutch-German collaboration:** governments of both countries should collaborate on infrastructure developments to strengthen, extend, and create new relevant supply chains. This includes agreeing on shared requirements and safety standards for pipelines or train routes to facilitate seamless transportation across borders.
- **Strengthening current infrastructure and transport modalities:** policies should encourage the utilisation of existing infrastructure such as storage tanks, pipelines, railcars, trucks, and canal networks. This approach can significantly reduce initial investment costs and expedite the transition process.
- **Buffering capabilities:** regulations should mandate buffering capabilities like tanks and caverns at entry points and along logistical chains to maintain a constant supply flow. These buffers are essential for managing supply fluctuations effectively.

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