



Barents Blue Ammonia Project: a landmark towards sustainability

BJØRGULF HAUKELIDSÆTER EIDEN

Horisont Energi

Sandnes, Norway

ANDREA ZAMBIANCO, MASSIMILIANO SALA

Saipem S.p.A.

Milan, Italy

Limiting global warming will require the implementation of solutions to drastically reduce the carbon footprint, such as low carbon ammonia.

Blue ammonia plays a key role to convert natural gas into a clean product by means of state-of-the-art technologies, such as Syncor™ by Topsoe, properly integrated with utilities and offsites to ensure superior energy efficiency and a very high level of CO₂ capture for the overall complex.

A new market for low carbon ammonia as energy carrier is expected to develop over the next years leveraging on existing infrastructure and knowledge for ammonia management gained over one century; blue ammonia relies on proven technologies available at scale and generates sustainable economics.

Horisont Energi has an ambitious plan to develop a large-scale blue ammonia complex in Finnmark, Norway exploiting the favorable combination of feedstock gas availability, high reliability of renewable electric power in the grid, cold climate conditions which allow higher process efficiency, and proximity to offshore CO₂ storage. Saipem's consolidated background in the execution of ammonia projects worldwide is supporting Horisont Energi's vision with project tailor made solutions.

This article describes the main Barents Blue Ammonia Project features such as 99% carbon capture rate target, high degree of modularization, winterization, infrastructure for ammonia and CO₂ management and provision for future expansion.

1. INTRODUCTION

Horisont Energi is a Norwegian, independent energy company with the mind and heart of a start-up. Horisont Energi's ambition is to become a leading clean energy company offering cost-effective clean ammonia and carbon storage services. Horisont Energi's mission is accelerating the energy transition to carbon neutrality through pioneering projects.

Saipem is an advanced technological and engineering platform for the design, construction and operation of complex, safe and sustainable infrastructures and plants with strong track record in ammonia projects. Always oriented towards technological innovation, Saipem is committed to supporting its clients on the frontier of the energy transition with assets, technologies and processes that are increasingly digital and oriented towards environmental sustainability.

Horisont Energi has the aspiration to develop the most carbon and energy efficient blue ammonia plant in the world, an environmentally friendly plant with focus on sustainable solutions.

In 2021 Saipem started to work for the concept study of Barents Blue Ammonia (BBA) Project and subsequently was awarded for the extension of the engineering services currently on going, to optimize the overall complex, integrating process, utilities and offsites.

2 FOREWORD

Ammonia is one of the most important chemicals, for its use as feedstock in the fertilizer industry; it is produced in many countries and traded across the world. The current production of ammonia is energy-intensive, and it is responsible for more than 1% of the global carbon dioxide and overall Green House Gases, considering that for each ton of ammonia nearly 2 tons of CO₂ are generated. It is therefore imperative to change to a more sustainable way to produce ammonia to replace grey ammonia and provide a sustainable alternative to ensure world's food production.

Clean ammonia is expected to become a solution to tackle the climate change also in other ways: ammonia is a perfect molecule for transportation of hydrogen and thus energy. It is now widely recognized that hydrogen will be a very important energy carrier in the near future and the hydrogen content per unit of volume is indeed even higher for ammonia than for hydrogen molecule itself. Already relatively simple infrastructure for ammonia liquefaction, storage and shipping exists making ammonia the perfect choice for H₂ transportation. In addition to the use of ammonia as hydrogen carrier, which is expected to be widely developed in the short term, the use of ammonia as direct fuel (for example for marine engines and for electric power generation) may unlock further potential of clean ammonia market.

Amongst different ways to produce clean ammonia, the so-called blue ammonia, which is based on reforming of natural gas coupled with carbon capture and storage, offers immediate advantages since it is based on the process schemes already adopted by the current industry and minimizes the cost especially in areas where it is possible to safely store CO₂.

Blue ammonia concept is based on the well-consolidated process scheme for production of ammonia which expands the CO₂ capture already included in the syngas purification to the full Carbon Capture Utilization and Storage (CCUS) value chain. The concept is essentially made of end-of-pipe blocks that do not affect the main process; however, minor adjustments may be required to improve the CO₂ capture rate. Despite the lack of a standard, it is generally recognized as a "blue" concept if most of the CO₂ (typically > 80%) is captured.

This article describes the main Barents Blue Ammonia Project features such as 99% carbon capture rate target, high degree of modularization, winterization, infrastructure for ammonia and CO₂ management and provision for future expansion.

3 BARENTS BLUE AMMONIA PROJECT

Horisont Energi is planning to develop a large-scale blue ammonia complex in Finnmark, Norway, figure 1, exploiting the favorable combination of feedstock gas availability, cold climate conditions which allow higher process efficiency, and proximity to offshore CO₂ storage.

Saipem's consolidated background in the execution of ammonia projects worldwide and the strong experience with Topsoe's technologies is supporting Horisont Energi's vision with project tailor made solutions.



Fig. 1: Plant location

2.1 The Plant

The selected technology for Barents Blue Ammonia is SynCOR Ammonia™ licensed by Topsoe which is based on Autothermal Reforming (ATR).

ATR is emerging as a promising application for the new generation of large-scale ammonia plants. ATR is well-referenced in other syngas applications, such as methanol and Gas-to-Liquids, and the first large-scale ammonia project based on SynCOR Ammonia™ is currently under execution by Saipem. For blue ammonia there is an inherent advantage in the use of ATR; most of the natural gas is used as feedstock and the CO₂ generated during reforming section can therefore easily be captured in the conventional CO₂ Removal Unit, while only a small portion is used directly as fuel, eventually resulting in reduced CO₂ emissions to the atmosphere. As a consequence, the CO₂ capture rate achievable without modifications to the process scheme (i.e. simply conditioning and storing the captured CO₂) is higher for the ATR than for the SMR which is in the range of typically 80-88%. Taking into consideration the capture

rate, an ATR based plant is inherently a Blue Ammonia plant and it does not require the introduction of post-combustion CO₂ capture from the flue gas as SMR typically would do. To further improve the capture rate, among various alternatives, it is convenient to use off-gas from the syngas purification along with purified syngas recycled as fuel in the fired heater, without excessive oversize of the front end, as depicted in Fig.2.

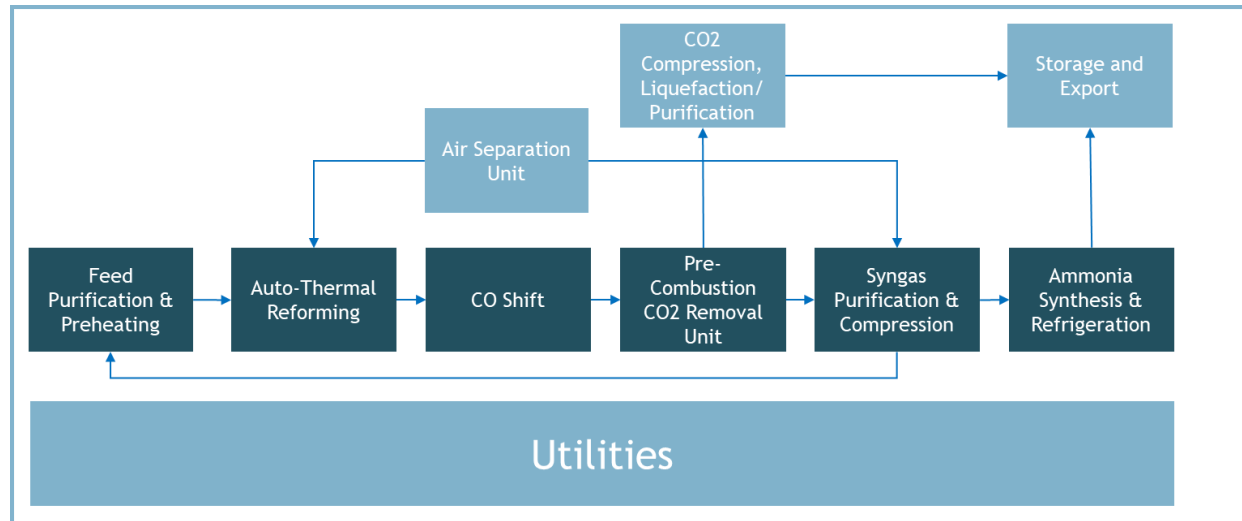


Fig. 2: Ammonia Plant scheme

The integration of the utilities with the ammonia plant, and in particular the optimization of the steam and power network, is a key element in the design of the overall complex [Ref. 1].

Extensive use of electrical over direct steam turbine drivers increases the overall efficiency of the complex. The plant electrical power requirements are mainly satisfied by the internal power generation by means of Steam Turbine Generator (STG) with a limited renewable electricity from the grid.

The STG efficiency is maximised thanks to the use of Very Pressure Steam (115 bar and 510°C) and minimum vacuum pressure allowed by cold water at condenser.

Sea water is used for direct cooling of major condensers and closed cooling water circuit.

A thorough value engineering exercise has been carried out to identify all the possible opportunities to increase the efficiency in normal operation: for instance, excess syngas generated in the ammonia front end section for fuel is expanded to generate 3-4 MW electric power.

However, the optimization of the efficiency shall be evaluated in conjunction with other key design parameters such as the reliability and operability; therefore, the plant is designed also to operate without some of the energy recovery features.

In addition, low steam to carbon ratio enables large scale capacity; in fact, all the units in the plant do have equipment which is within referenced size of operating plants or generally requiring minimum scale up.

BBA is a fully automated plant with integrated energy management; one of the advantages of ATR is that it is possible to maximise the automation with inherently efficient and safe operation. It is reducing significantly the risk of human error resulting in less lost time accidents, increasing plant availability and reducing the environmental impact –of flaring caused by erroneous upset situations. [Ref. 2]

In addition to the CO₂ emission, the plant is designed to minimize the overall impact to the environment with main focus on noise, effluents and emissions (e.g. mitigation measures implemented after a dedicated noise study, DeNox system implemented, etc.).

2.2 Carbon Capture rate: 99% target

Barents Blue Ammonia Project captures and permanently stores approximately 2 million tons per annum of CO₂ per each ammonia train, which corresponds to the CO₂ emissions generated from more than 400.000 cars.

As described in the previous paragraph, the CO₂ is captured from the synthesis gas with the standard capture technology already included in conventional plants; therefore, proven precombustion CO₂ capture technologies can be

applied also for the blue concept. For BBA it has been implemented a high efficiency scheme fully integrated with the process.

The emission of CO₂ from fired heater upstream the ATR are minimized thanks to the hydrogen rich gas from front end. The proper increase of front-end size has been evaluated to be more economical and efficient than the implementation of a post combustion CO₂ capture unit in the fired heater exhaust [Ref. 3].

The selection of the most adequate process scheme is driven by both plant operating conditions and/or the opportune use of the available utilities at site.

It is important to recognize the 99% target includes, the contribution of all the other sections of the complex: utilities and offsites.

The steam generated by process heat recovery is used to drive the major compressors and to generate electric power by means of STG. With the minimum supplementary steam generated by the Auxiliary boiler, which is using hydrogen rich gas as fuel during normal operation, it is possible to close the steam and power balance avoiding additional CO₂ emission in the utilities section.

Design is tailored to reduce CO₂ emission also during the commissioning and start up phases; for BBA, dedicated studies have been carried out to identify the suitable design and features to minimize CO₂ emission also during transient scenarios (e.g. minimizing the flaring and the use of natural gas as fuel in the auxiliary boiler).

The capture rate is not the only parameter to measure the environmental sustainability of a blue ammonia project: another important parameter is the carbon intensity which takes into account not only the emissions generated in the process but also the emissions associated to the imported electricity. The maximization of the efficiency reduces the natural gas consumption and the relevant contribution to the carbon intensity, while the availability of renewable energy from grid is essential to maintain low the overall index. According to the dedicated study performed by Saipem, BBA carbon intensity (tCO₂eq/t product) for scope 1 and 2 is 0.0169 while the benchmark for a modern grey ammonia plant in Europe is 1.694 [Ref.4].

2.3 Winterization

The cold climate in the region represents a challenge to be addressed with specific solutions. However, it also represents an opportunity for the project to improve the plant's efficiency. For example, the utilities scheme is involving the use of cold sea water (8°C) as direct cooling media for STG condensers and a close cooling water loop (13°C) provides robust plant cooling with high thermal efficiency.

The building heating is performed by hot water while process winterization is done by electrical tracing.

When possible, the use of waste heat from the plant has been applied to improve the efficiency and further CO₂ emission reduction. As an example, Heat Pump circuit has been integrated with process streams for winterization purposes.

Winterization shall take under consideration both the safety of people as well as integrity of the facility.

2.4 High degree of modularization

The modularization of blue ammonia plants has been extensively studied by Saipem starting from the experience of recent and on-going projects. Modularization offers several advantages in terms of safety and costs for location where mobilization of huge construction manpower is not possible and/or access at site is difficult or not possible for a prolonged period such as Finnmark.

A deep analysis of the optimum size of the modules considering logistic constraints, cost and time-effectiveness and availability of yards has been performed to optimize the strategy. As result of the investigations, the overall complex has been modularized to a large extent (>90% on total equipment count).

The process sub-units fit within single big modules to minimize the hook-ups and pre-commissioning works at site. An overview of the modularized blue ammonia plant is depicted in Fig. 3.

An advantage of this project is represented by the location, with direct access from the sea which allows the offloading of large modules, with more than 5000 tons per module and maximum dimension of approximately 100 x 30 x 36 m (LxWxH)per module.

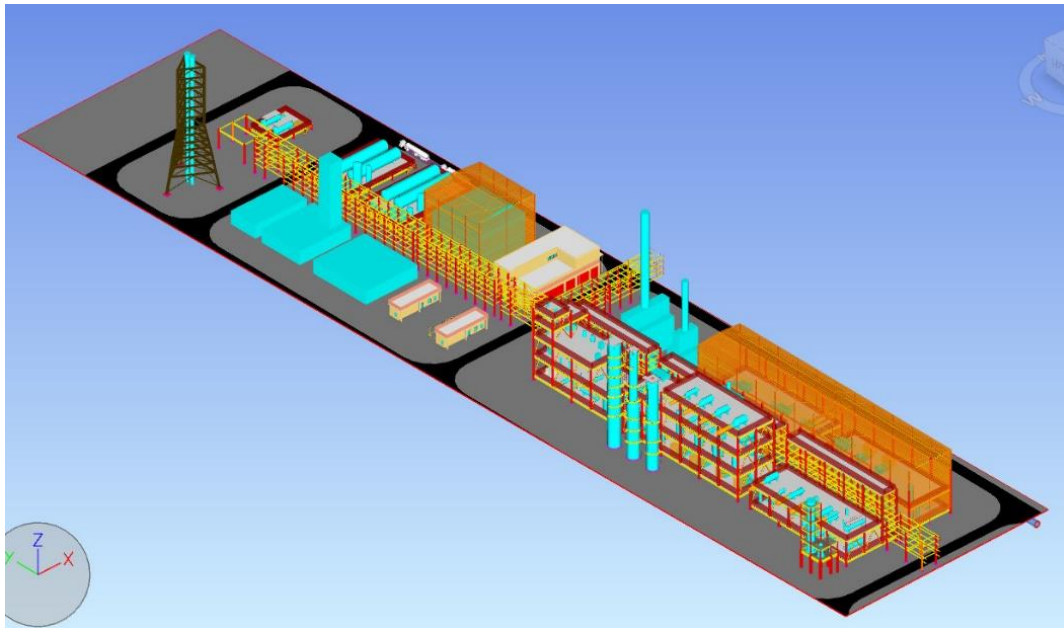


Figure 3 – Modularized Blue Ammonia Process Train

2.5 Infrastructure for Ammonia and CO₂ Management

The Ammonia is stored in a rock cavern physically located under the site thus enhancing safety, reducing the thermal dispersion and minimising the boil off refrigeration energy consumption associated. This is a very efficient solution from the energy point of view. The capacity is 120,000 m³.

CO₂ management is currently under optimization. Among the possible solutions, a permanent CO₂ storage offshore which can be reached by a pipeline or by ship. In the latter case, an intermediate CO₂ storage is required.

Depending on the CO₂ purity target, a purification and chilling section might be required and somewhat affect the overall energy plant consumption.

2.6 Provision for future expansion

Since the early stage of the project, constructability aspects related to the possible future expansions have been duly considered. Proper design allows safe and efficient expansion even when the first train is already in operation.

The optimized choice for the common utilities and offsites allows the overall cost minimization in the project life.

Modularization offers significant advantages for the possibility to replicate the modules for the additional train and utility modules already designed for future expansion.

Site preparation, sea water intake, raw water tank, fire tank, main electrical substation, main control room, ammonia storage, jetty and its loading system shall take already into consideration the expected overall expansion.

SAIPEM has already executed plant expansion in phases which could provide benefits in term of shorter overall execution schedule, reduced costs and improved quality [Ref. 5].

2. SAIPEM EXPERIENCE

SAIPEM is one of the world leaders in the execution of fertilizer projects. Today, SAIPEM has available the design for integrated facilities producing 3500+ TPD of ammonia and 5000+ TPD of urea. This experience is complemented by a broad portfolio of various syngas projects, such as methanol and hydrogen. Specific experience has been developed on the ATR based complex with optimized and integrated solution developed with Licensor [Ref. 6]. In more than 60 years, Saipem has designed nearly 100 syngas units, 65 of which are also built as EPC contractor. Table 1 shows the recent Blue Hydrogen/Ammonia projects executed by Saipem.

Table 1
Blue Hydrogen/Ammonia projects recently executed/under execution by SAIPEM

Company (Location)	Product	Capacity
Major Oil&Gas (Undisclosed)	Blue Ammonia	2x3,450 TPD with 95% CO ₂ capture
Major Oil&Gas (Undisclosed)	Blue Hydrogen	235,000 Nm ³ /h with 95% CO ₂ capture
Major Petrochemical (Europe)	Blue Hydrogen	280,000 Nm ³ /h with 95% CO ₂ capture
Horisont Energi (Norway)	Blue Ammonia	3,000 TPD with 99% CO ₂ capture

In addition, Saipem's references on ammonia storage tanks are generally part of larger scope of supply on LSTK basis that includes ammonia process production units; Saipem has in-house engineering capability to autonomously design and built ammonia storage tanks. In this field, Saipem can also draw on its vast experience in the design and construction of a large part of world LNG storage tanks, over the last 40 years. Also, the EPC experience with Gravity Based Structure foundation increase the possible alternative solutions.

Saipem can leverage on the EPC execution of more that 130,000 km of pipelines and the expertise gained in the development of studies with gaseous hydrogen and liquid ammonia. Saipem is one of the major players also in the offshore and drilling sector, with its own assets including floaters and ship.

The above expertise is particularly important to complete the value chain of the ammonia from production to distribution.

The value proposition for low carbon ammonia (see as example the "Clean energy Hubs") can be tuned based on the specific client needs, developing ammonia and CO₂ terminals, ref. figure 4.

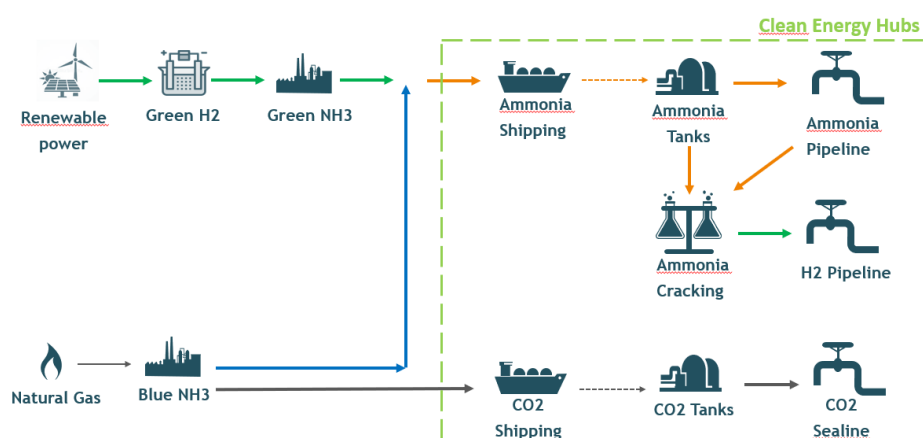


Figure 4– SAIPEM Clean Energy Hubs value proposition

The experience as EPC contractor in ammonia industry in combination with the track-record of more than 70 CO₂ removal units designed and built for various processing plants, and the development of a proprietary post-combustion capture technology, the experience with transportation by pipelines and ship, and reinjection/reuse, makes Saipem the partner of choice to develop "blue" ammonia/hydrogen projects and associated facilities such as CO₂ Hubs, ref. figure 5 and 6.

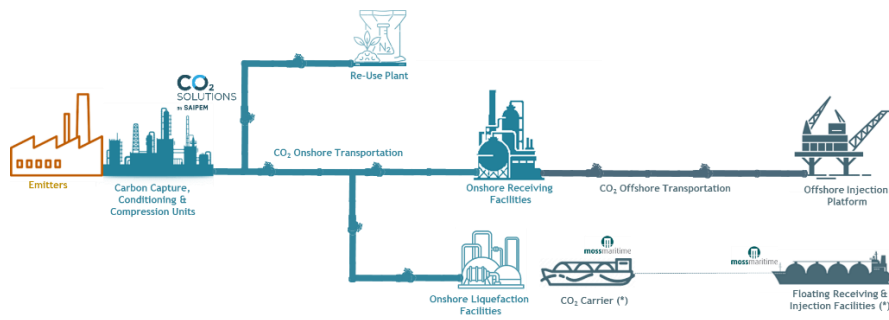


Figure 5– SAIPEM CCUS value proposition

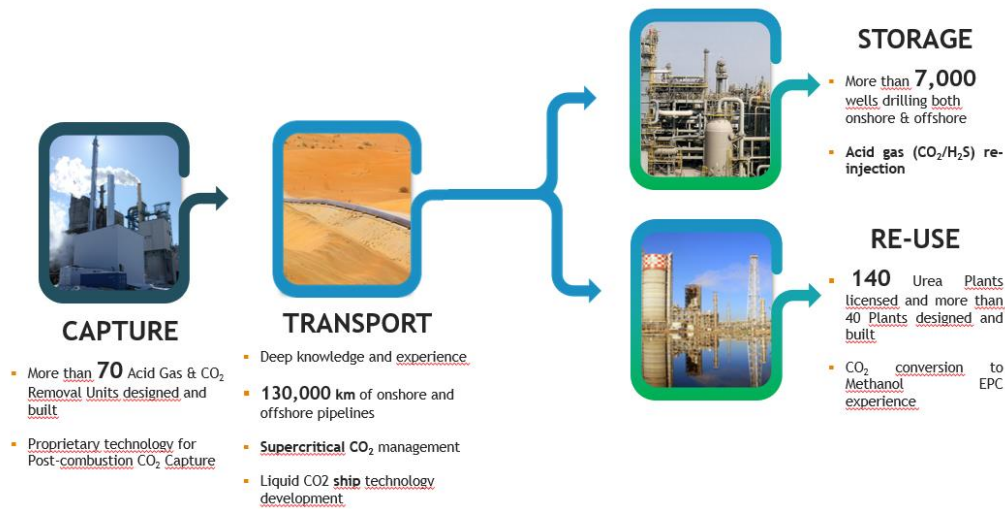


Figure 6– SAIPEM CCUS experience

3. CONCLUSIONS

The Barents Blue Ammonia Project represent a milestone in the large-scale low carbon ammonia production industry, the first world scale blue ammonia plant in Europe, a reference for the optimized solutions identified to address the many challenges posed by the stringent requirements.

It is possible to achieve 99% CO₂ capture target with proper design aimed at minimizing the CO₂ emissions taking into consideration the whole life of the project.

The remote location of Finnmark, offers challenges which can be considered also as opportunities. The cold climate allows high efficiency solutions. The remote location obliges the maximization of modularization and the easy access to the site by sea accomodates huge modules size which in turn represents an opportunity to increase safety and construction productivity resulting in cost control during the execution. Integration of utilities offers waste heat recovery and reduced CO₂ emissions. The high degree of automation grants safer and more efficient operation.

Horisont Energi's ambition has been continuously pushing Saipem to go beyond the standard practice and find innovative solutions for low carbon ammonia, embedded in the industry experience.

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