# GO GREEN (AMMONIA)!

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## INTRODUCTION

Ammonia is a key component utilized in most fertilizers for agriculture. The conventional production of ammonia via the Haber-Bosch process produces vast amounts of carbon emissions, contributing to 12% of global industrial carbon emissions (Nayak-Luke, 2018). Traditional ammonia production also contributes to roughly 2% of the world's energy consumption (Baltrusaitis, 2017). Team 20 presents a cleaner, more energy efficient solution to these issues by designing a green ammonia processing plant. This project is focused on utilizing offshore wind energy and the biochemical enzyme nitrogenase as a catalyst. Nitrogenase possesses the ability to naturally fixate nitrogen, producing ammonia at room temperature and pressure. Since this is a first-of-a-kind process, it is anticipated that a pilot study will be completed in order to inform the design of a full-scale plant that would produce 100 tons of $NH_3$ per day. Green ammonia production is an emerging market where investments in green fuel and large-scale green energy plants are rapidly increasing.

## OBJECTIVES

- Design a green ammonia plant that generates no $CO_2$ emissions
- Power the plant with offshore wind energy
- Develop a solution that is more energy-efficient than current ammonia manufacturing plants by using nitrogenase as a catalyst
- Hold safety paramount in the design of the ammonia plant

## REFERENCES

Baltrusaitis, J. (2017). Sustainable ammonia production. *ACS Sustainable Chemistry & Engineering*, 5(11), 9527–9527. https://doi.org/10.1021/acssuschemeng.7b03719

Nayak-Luke, R. (2018, October). (PDF) 'green' ammonia: Impact of renewable energy intermittency on plant sizing and Levelized cost of ammonia (LCOA). ResearchGate. Retrieved September 24, 2021, from https://www.researchgate.net/publication/328166595_%27Green%27_ammonia_Impact_of_renewable_energy_intermittency_on_plant_sizing_and_levelised_cost_of_ammonia_LCO

## OUR DESIGN

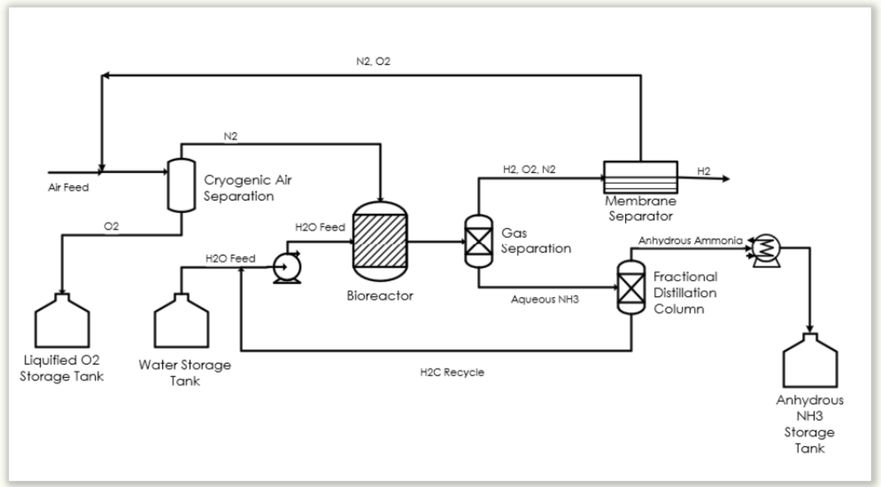
Team 20 designed a green ammonia processing plant that utilizes nitrogenase as a biochemical catalyst. The nitrogenase protein consists of an FeS and a MoFe complex. The FeS cluster donates electrons to the MoFe complex, which requires the hydrolysis of ATP to form ADP and inorganic phosphates. The MoFe-cofactor is activated and undergoes reductive elimination of $H_2$, then cleavage of the $N_2$ triple bond. This results in products of ammonia and hydrogen. In order to develop a material balance, the team introduced an additional reaction to reproduce ATP and maintain catalyst regeneration.

$$N_2 + 16\,ATP + 20\,H_2O \longrightarrow 2\,NH_3 + H + 16\,ADP + 16\,H_2PO_4^-$$

$$16\,ADP + 16\,H_2PO_4^- \longrightarrow 16\,ATP + 16\,H_2O$$

$$\mathbf{N_2 + 4\,H_2O \longrightarrow 2\,NH_3 + H_2 + 2O_2}$$

The process contains a cryogenic air separation unit, where air is split into oxygen and nitrogen. Nitrogen and water are fed to a bioreactor, filled with the nitrogenase protein, where the reaction happens. Nitrogen and oxygen are separated from aqueous $NH_3$ and recycled back into the air stream, while hydrogen is separated via a membrane separator. Ammonia is distilled from the water and stored as condensed anhydrous ammonia.




The plant will run on offshore wind energy sourced from a wind farm off the coast of Rhode Island. This design allows for the production of ammonia at mild temperatures and pressures, with no production of $CO_2$ within the process.

Corrosion compatibility studies, various engineering controls, and reactivity and flammability data for all chemicals within the process were assessed to develop a process safety plan.

## THE TEAM

*Left to Right:* Anna O'Keefe, Tori-Ann Brown
*Chemical Engineering*

## FUTURE RESEARCH & CONCLUSION

This project serves as a good first step into the use of nitrogenase for industrial scale ammonia production; however, more research must be done for application. A pilot plant in the form of a research team would be necessary to optimize nitrogenase performance. The use of nitrogenase without ATP hydrolysis could potentially be the breakthrough necessary for this process.

Green ammonia production using nitrogenase is a new and developing method for ammonia manufacturing which could play a momentous role in reducing greenhouse gas emissions and tackling the issue of climate change.

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