Team 7: Green Ammonia in Maryland (GAM)

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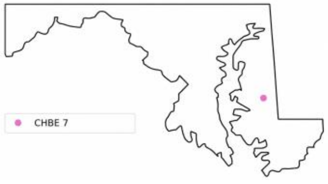
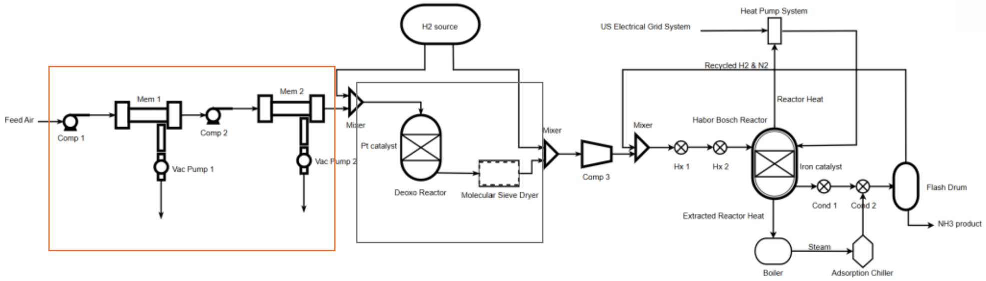




Background:

Maryland currently relies on fossil-fuel-based ammonia production, which generates significant greenhouse gas emissions despite steady fertilizer demand, while regional wind and solar resources are growing but remain underused for industrial manufacturing. The purpose of this process is to modernize the Haber-Bosch ammonia production with these technologic advances

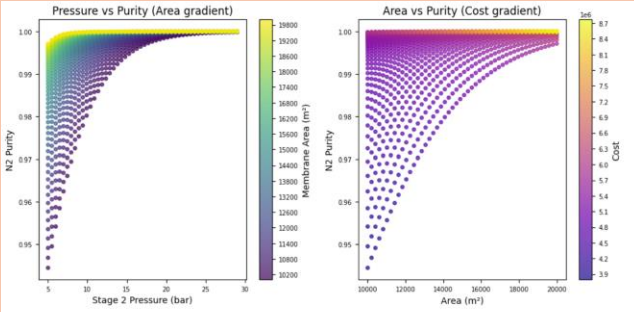
Goals:

- Ammonia Requirement per Acre = 76.66 kg/yr
- Harvested Farmland in Maryland 2022: 1,274,673 acres
- Total Ammonia needs of Maryland: 97,713 tons/yr
- Ammonia Purity: 99%
- MAX CO2 Emissions: 25,000 tons/yr
- IRR: 5-10%

Stakeholders:

Stakeholder	Concerns	Needs	Wants
Investors	Not Losing Money	Rate of Return > Cost of Capital	10% Rate of Return
Customers	Product Purity, Quantity	High Product Purity	Consistent Large Supply of Ammonia
Operating Engineers	Safety and Operability	Design Within OSHA Regulations	Minimal Risk and Ease of Use.
Environmental Organizations	Environmental Impacts of Plant	Environmental Impact Within Regulations	Sustainable, Low Footprint Design
General Populace	Pollution	Minimal Impact to Local Environment	No Change to Daily Life

Membrane Separators:



Post Oxygen Removal:

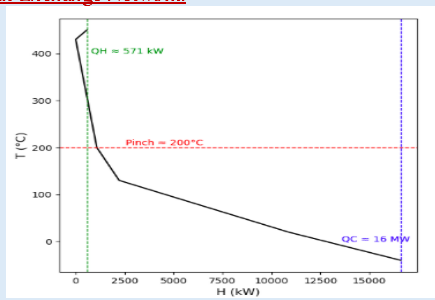
N_2 : 99.998527261 %
Ar : 0.0004208669 %
CO_2 : 0.0000002854 %
O_2 : 0.0000000000 %
H_2 : 0.0009515677 %
H_2O : 0.0001000189 %

Flow rate: 93.00 mol/s
Temperature: 300.79 K
Pressure: 28.01 bar

Haber-Bosch Reactor:

	Reactor	Condensers	HXs	Compressor
Temperature (°C)	450	450 → -20	94 → 450	37 → 304
Pressure (bar)	150	150	150	28 → 150
Heat/Work Duty (kW)	-9978.8	-16256.1	10195.7	2959.2

Heat Exchange Network:



Economic Analysis:

Total Cost of System: $160.6 million
- Reactor: $19.9 million
- Nitrogen Separator: $2 million
- Storage Tanks: $35.2 million
- Compressor: $7.5 million
- Heat Exchangers: $700k
- Heat Pump: $2.8 million
- Absorption Chiller System: $4.4 million
- Piping and Infrastructure: $58.4 million
- OSBL investment: $29.2 million

Operating Cost: $50.8 million/year
- Nitrogen Separator: $6.3 million/year
- Hydrogen: $35.1 million/year @ $2/kg
- Electricity: $3.1 million/year
- Personnel: $469k/year
- Property Tax & Insurance: $1.5 mil/year
- Rent of Land: $2 million/year

Earnings:
- Revenue: $77.5 million/year @ $0.78/kg
- Post-Tax Profit: 18.9 million/year @ 29.25%
- Payback Period: 8.5 years

Major Findings:

- Ammonia Production: 99,319 tons/yr at 99.5% purity
- Only 338 metric tons CO_2 emissions per year.
- IRR: 10% over 20 years
- Heat Delivered via Heat Pump: 571 kW

Sustainability Assessment:

- 489 metric tons CO_2 emissions saved from heating. The equivalent of 2.42 tractor trailers!
- 84566.7 m^3 water saved. Equivalent of 33.8 Olympic swimming pools!

Conclusion/Recommendation:

- Membrane Separation is feasible for industrial N_2 separation but suffers diminishing returns with scale up
- In the future, with green hydrogen production and renewable energy scale up, this system will become both more economically and environmentally viable.
- Explore possible use cases for system waste heat
- Perform cost analysis of liquid H_2 storage over gaseous H_2

Reference:

- Towler, G.; Sinnott, R. Chemical Engineering Design: Principles, Practice and Economics of Plant and Process Design, 3rd ed.; Butterworth-Heinemann/Elsevier: Amsterdam, 2022. ISBN 978-0-12-821179-3.
- Erfani, N.; Baharudin, L.; Watson, M. Recent Advances and Intensifications in Haber-Bosch Ammonia Synthesis Process. *Chemical Engineering and Processing - Process Intensification* 2024, *204*, 109962. https://doi.org/10.1016/j.cep.2024.109962 (accessed April 29, 2026).
- Marcos Da Conceicao; Nemetz, L. R.; Rivero, J.; Hornbostel, K.; G. Glenn Lipscomb. Gas Separation Membrane Module Modeling: A Comprehensive Review. Membranes 2023, 13 (7), 639–639. https://doi.org/10.3390/membranes13070639.
- Sadighian, A. Mass Transfer between Pentane and Heavy Hydrocarbons; 2009. https://www.ualberta.ca/en/engineering/media-library/research/petroleum-thermodynamics/publications/thesis/2009ardalanmscmasstransferbetweenpentanceandheavyhydrocarbons.pdf (accessed 2026-04-30).