AMMONIA PRODUCTION USING RENEWABLE ENERGY

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Introduction

Motivation & Scope

- Ammonia is conventionally produced by the Haber-Bosch process which is powered by fossil fuels.
- The Haber-Bosch process produces 1.87 tons of CO2 for every ton of ammonia produced, accounting for approximately 1.2% of global CO_2 emissions.
- This project uses wind energy to produce renewable hydrogen (H_2)and nitrogen (N_2) for ammonia (NH_3) synthesis..

Objectives

- Identify the availability and cost of renewable H_2 and N_2 in Nova Scotia.
- Identify the feasibility of ammonia production using the low-pressure route versus the conventional high-pressure route.
- Selection of a scale for the proposed ammonia plant that is suitable for Nova Scotia.
- Perform an economic analysis to estimate the production cost of ammonia.

Location

- The proposed project will be located at Baccaro Point, NS.

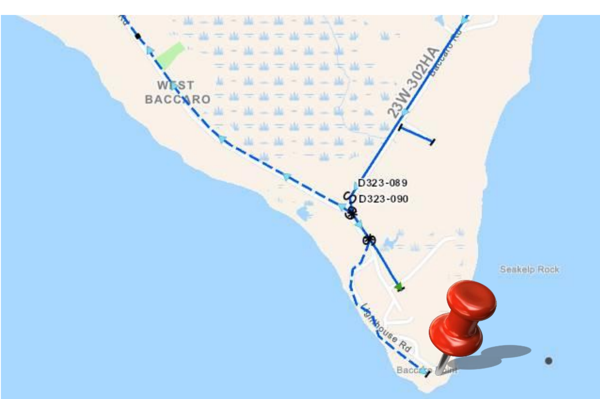

Figure 1: Map of facility location and available power distribution network

Design Process

➢ **Why wind Energy?**

- In Nova Scotia, wind energy is the most suitable renewable energy source as wind turbines are widely used and available in the province

➢ **Why Baccaro Point?**

- Climate data maps were assessed to determine a location with strong wind resource
- Land availability maps were assessed to determine a location with sufficient land availability
- Baccaro Point has a suitable power distribution network (Fig. 1)
- Baccaro Point is suitable in terms of wind resource, land availability, and power distribution network

➢ **Why high-pressure route for ammonia synthesis?**

- Ammonia synthesis through the low-pressure methods such as electrochemical, non-thermal plasma and thermochemical looping were investigated
- High pressure synthesis through the Haber-Bosch process was selected due to superior technological maturity, scaling potential and the higher quality and volume of available literature.

Details of Design

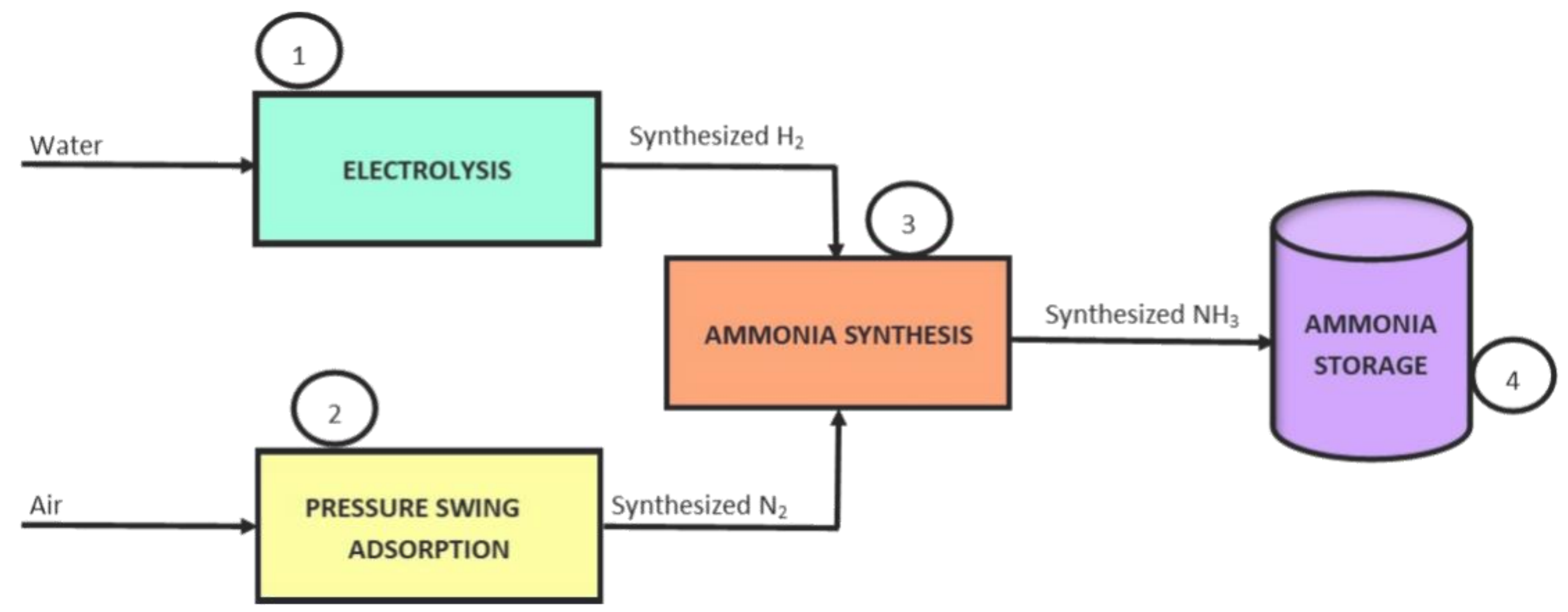

Figure 2: Process Flow Chart for the design process

1) Electrolysis

- The renewable H_2 used for ammonia synthesis is generated from water.
- An alkaline electrolyzer will be used to separate H_2 from water.
- An alkaline electrolyzer was selected because it is cost-effective, efficient, and can produce a H_2 purity of at least 99.8%[3].
- In this project, H2 is produced at 79.98 kg/hr with a purity of 99.98%.

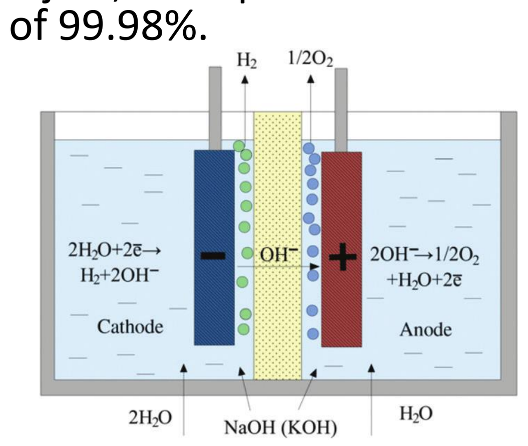

Figure 3: H_2 production using alkaline electrolysis

2) Pressure Swing Adsorption

- The renewable N_2 used for ammonia synthesis is generated from air.
- Pressure swing adsorption (PSA) will be used to separate N_2 from air.
- PSA was selected because it is a cost-effective method for onsite N_2 generation for a wide range of purity and flow requirements[2].
- In this project, N_2 is produced at 376.9 kg/hr with a 99.99% purity

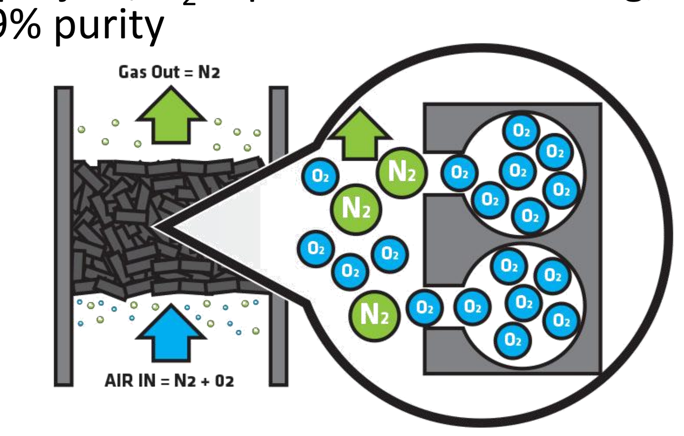

Figure 4: N_2 production using pressure swing adsorption

3) Ammonia Synthesis

- Synthesis occurs in an adiabatic, two bed, indirectly steam cooled reactor.
- Beds are 0.7 m^3 and 1.7 m^3, packed with 3mm diameter activated iron catalyst.
- Reactor constructed from nickel alloy stainless steels, to prevent hydrogen attack.
- Reactor operates at 200 Bar and 340-475 °C.
- Single pass conversion of 32.77 %, produces 451 kg/h of ammonia.

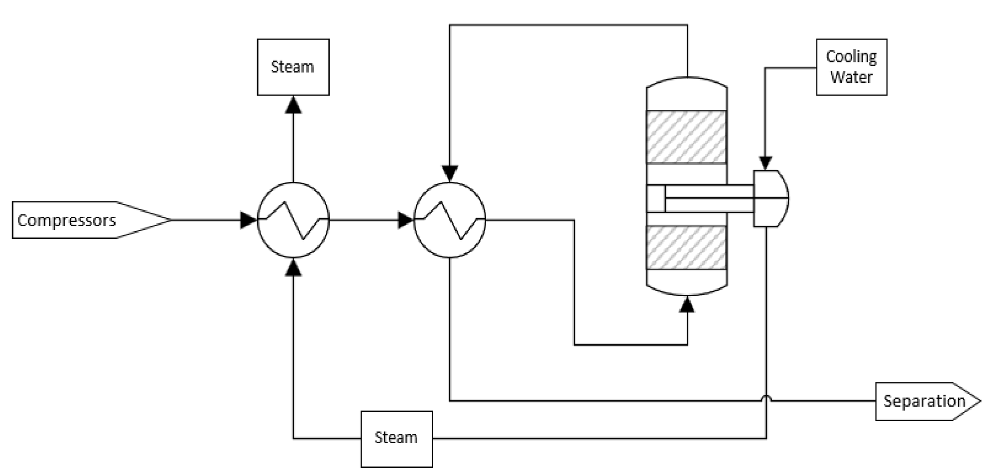

Figure 5: Reactor configuration in ammonia synthesis loop.

4) Ammonia Storage

- Chilling loop uses on site NH3 as refrigerant.
- Cooler heat exchangers utilized cooling water.
- Separators produce ammonia purity of 99.92%.
- Ambient temperature allows for seven-day storage periods.

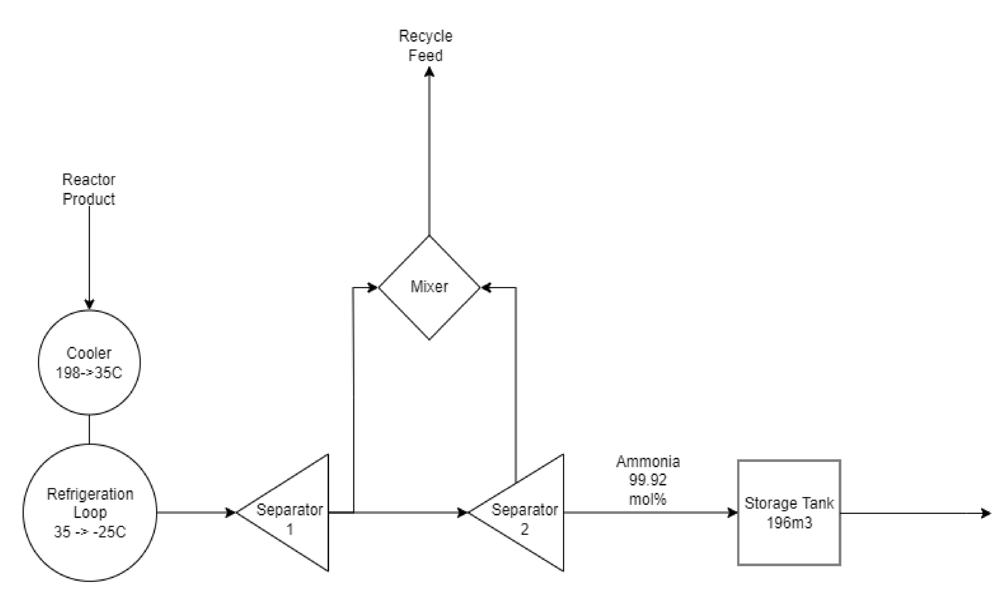

Figure 6: Ammonia condensation, separation and storage configuration.

Energy & Economic Analysis

Energy

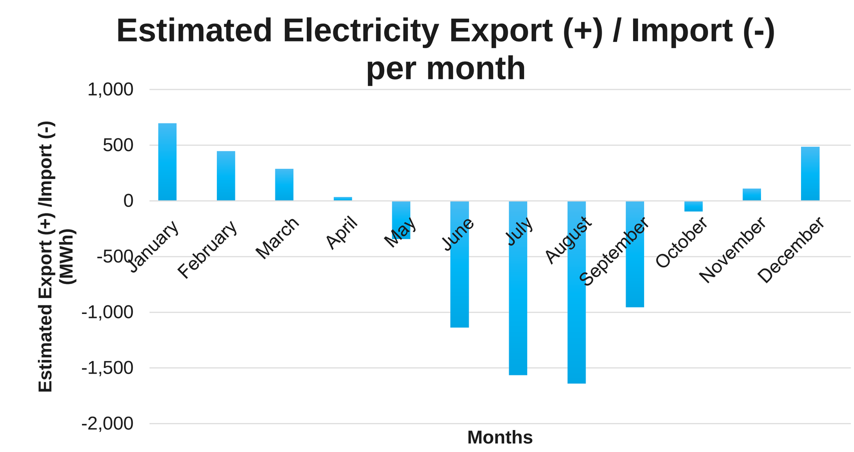

Figure 7: Graph of estimated electricity export (+)/ import (-) per month

➢ Annual Electricity Exported = 2054 Mwh

➢ Annual Electricity Imported= 5726 Mwh

➢ Due to electricity imported from the Nova Scotia Power Inc. grid 4065 tonnes of CO_2 is emitted annually

Cost

- Total grass roots operating, and capital cost investment estimated at $22.3 million

Table 1: Cost Breakdown

	USD
Total Grass Roots Cost	$22,370,000.00
Total Module Cost	$20,340,000.00
Total Equipment Cost (annual)	$9,794,500.00
Raw Materials Cost (annual)	$3,803,592.00
Operating Cost	$622,300.00
Utilities Cost	$199,000.00

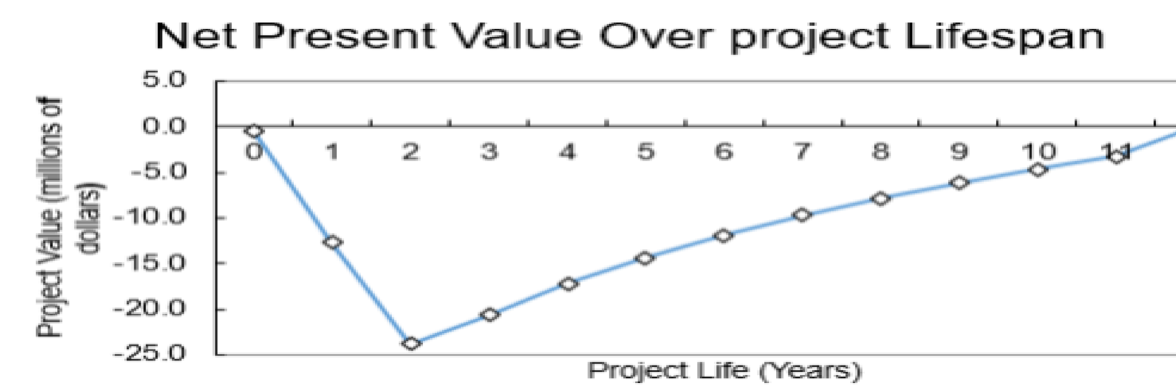

Figure 8: Graph of net present value over project lifespan

Conclusion and Recommendation

- Minimum ammonia sale price is 4.08$/kg USD to ensure NPV of zero at the end of project life.
- Currently, the minimum price of ammonia produced by this project is not competitive with market prices worldwide.
- Investigation into potential government subsidies could allow this project to be viable.
- Explore the feasibility of using some of the ammonia produced as fuel for other processes.
- Investigate the applicability of different plant equipment to reduce equipment count and cost.

References

- [1]Appl, M. (1999*). Ammonia: Principles and Industrial* Practice. Weinheim: Wiley-VCH.
- [2]Ivanova, S., & Lewis, R. (2012). Producing nitrogen via pressure swing adsorption. *Chemical Engineering Progress*, 108(6), 38-42. cryogenic air separation plants. *Industrial & engineering chemistry research*, 47(2), 394-404.
- [3]Brauns, J., & Turek, T. (2020, February 21). *Alkaline water electrolysis powered by Renewable Energy: A Review*. MDPI.