Design of a Natural Gas-fed Blue Hydrogen Production Facility

An Analysis of the Ammonia Production Facility in Point Tupper, Nova Scotia

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

Climate change is a crucial issue that has shaped our generation and threatens our existence. Humans have had a profound impact by increasing carbon footprint and emissions. It requires both social and technical solutions. However, our carbon footprint has increased because of our industrialization and the desire of all peoples to have a higher standard of living and to provide greater opportunities for everyone. Sustainable must have a dual meaning in both economic and social practice. Socially, businesses must be renewable by not overusing or exploiting the Earth’s resources and limiting emissions. Economically, business must engage in practices that may be sustained for the long-term and generate revenue that outweighs its production costs. Government regulation has a deep effect on the sustainability of businesses as outlined, but that will not be the focus of the projects outlined in this paper. The technical project proposed provides both economic and technical matters for a proposed renewable process, while the social project outlines the importance of branding and outreach to emphasize the greater and long-term goals of the project. The technology aspect is critical to provide scientific credibility to the process to prove it can function in the proposed manner. The social aspect is critical because any large technological project will have to interact with the surrounding community and society. The technical project outlined focuses on the design of a Blue Hydrogen production facility that uses novel technologies to transform natural gas into hydrogen fuel. The STS project focuses on a case study about a planned Green Hydrogen Ammonia production facility that has received pushback because of its non-renewable elements. The technical project will look to design a process that is low in emissions while also attempting to be economically viable so that it may be adopted in industry therefore being sustainable in both senses. The social project explores the effect that human behavior and societies pressures might have on the outlook of trying to implement this technology into communities across the world. Both projects will explore avenues to develop sustainable practices to reduce our carbon footprint and therefore slow climate change.

Technical Project Proposal

Hydrogen has seen growing potential in recent years as an energy source for electricity production in homes and vehicles, as the development of other renewable sources and biofuels remains slow in many regions. Hydrogen is not abundantly available in nature however and instead has to be produced from other energy sources (Nikolaidis et al., 2016). Traditional hydrogen production, often called 'gray hydrogen,' consists of reforming fossil fuels like coal and natural gas to create hydrogen gas and other emissions, including Carbon Dioxide (CO_2), a significant greenhouse gas. Steam methane reforming (SMR) is the most common strategy deployed in this production (Yu et al., 2021). In SMR, a high energy reformer converts hydrocarbons and steam into syngas which is reacted to produce hydrogen and CO_2, but the CO_2 is not captured and stored. (Nikolaidis et al., 2016). While this process has been widely used in industry, its large energy requirements and considerable CO_2 emissions make it unattractive for continued widespread use in producing hydrogen for a cleaner energy future.

The process we propose will instead produce blue hydrogen. This can be made in the same ways as gray hydrogen; however, the CO_2 produced during the reformation of methane is captured and stored, lowering the overall carbon emissions of the hydrogen plant. In a society whose concern over the effect our emissions are having on the environment is growing, this is a major step towards emissionless energy production (Hydrogen Benefits and Considerations). However, carbon capture requires energy, lowering the plant's efficiency and increasing costs of production. One way in which we are mitigating these effects is by using autothermal steam methane reforming (ATR). This method involves reacting pure oxygen and steam with methane to produce carbon monoxide and hydrogen, an exothermic reaction (Lamb et al., 2020). Therefore, the heat generated through this reaction can be used to sustain the process with far less energy input than a typical SMR reactor, decreasing costs and overall carbon footprint. Oni *et al.* (2022) outline a generalized process flow for ATR, displayed in Fig. 1.

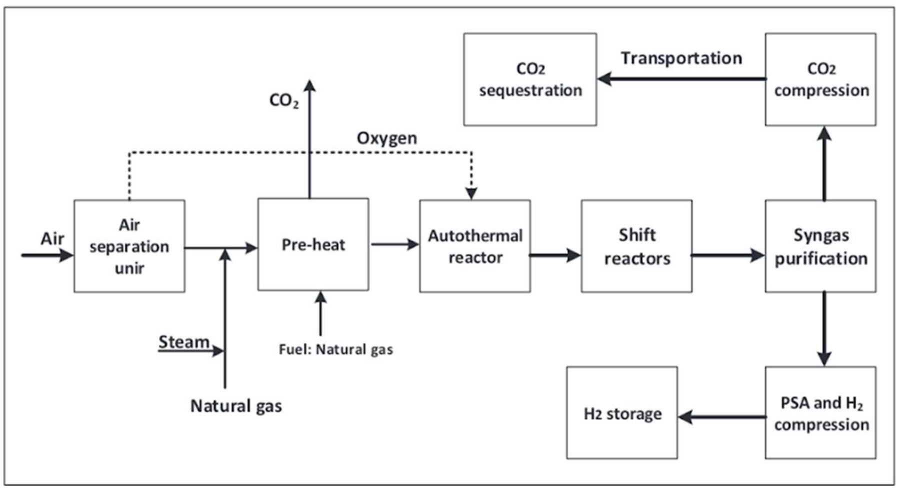

Fig. 1- Block Flow Diagram for Autothermal Reforming (ATR)

To perform autothermal reforming at the optimal reaction conditions, pure oxygen must be fed to the ATR unit to increase the efficiency and yield. For this project, industrial grade oxygen will be supplied from a third party, rather than building an on-site air separation, saving on capital cost and slightly operational costs (PPI Industry Data, 2022). After the materials flow through the ATR, a water-gas shift (WGS) reactor will be used to convert the carbon monoxide produced into additional hydrogen gas and CO_2. Amine scrubbing will be used to remove sulfides from the feed and to separate CO_2 and H_2 in the product streams (Carver Pump, 2021). The CO_2 produced from the reactor will be refined to be sold for enhanced oil recovery (EOR).

Although EOR is not the most environmentally conscious route for use of captured CO_2, it is currently the most profitable. 88% of total CO_2 use across the world in 2017 was "gaseous," meaning that it was directly used for fossil fuel recovery (Roberts, 2019). Keeping the captured CO_2 as a gas instead of liquefying or solidifying it is also more cost effective, as it eliminates the need for additional condensers and pumps.

We plan to use Aspen Plus to simulate the complex chemical behavior and unit operations within our designed plant. Additionally, we plan to incorporate Microsoft Excel and Powerpoint for presenting and processing data. Design data will come from papers that have already performed basic economic analysis and conceptualized the entire process down to the unit operations (Oni et al., 2022). Economic analysis is crucial to determining the project's feasibility, and influences several design choices. (Ali et al., 2021). This project will be completed as a team of five students over the course of two semesters in the classes CHE 4474 and CHE 4476. Gantt charts will be used to organize our workflow and establish deadlines, and work will be divided equally amongst teammates.

STS Project Proposal

In May 2022, EverWind Fuels ("EverWind"), a private green hydrogen and ammonia developer, announced that they intend to develop green hydrogen and ammonia production facility in Point Tupper, Nova Scotia. EverWind claims the plant will create billions of dollars in new investment, attract new jobs, reduce Nova Scotia's emissions targets, and establish Nova Scotia as a leader in green hydrogen production for both the Canadian and global markets (EverWind, 2022). The production of the green ammonia will be powered by a combination of the green hydrogen production and offshore wind farms in the Nova Scotia region.

However, several concerns have been raised about how the plant will be powered. EverWind's environmental affairs advisor, Ken Summers, reports that the project would not initially be powered by wind farms. The energy required for the first phase will come from "just the Nova Scotia grid" according to EverWind CEO Trent Vichie However, Vichie stated that EverWind would be adding wind power to the Nova Scotia Power ("NSP") grid in phase one, which would "[touch] the Nova Scotia grid" and then go to the EverWind facility (Baxter, 2022). Vichie did not confirm the specifics of the wind project, or if it was from five new wind projects in Nova Scotia which would be equivalent to 12% of the province's electricity consumption (Beer, 2022).

Additionally, several questions have been raised about the renewability of the NSP grid when the project comes online. Jacqueline Foster, a spokesperson from NSP, reports that the five new wind projects will be online by 2025 and capable of powering 30% of the energy demands of the province. However, NSP expects that 20% of its power will still come from renewable energy in 2030. Additionally, NSP intends to double its use of biomass at boilers in Port Hawkesbury Paper and Brooklyn Energy. However, the jury is still out on biomass' status as a carbon-neutral fuel source. Ray Plourde of the Ecology Action Center has described burning biomass as "a willful act of ecocide" due to the "fraudulent categorization of biomass by the Nova Scotia government as 'carbon neutral'" (Henderson, 2022). Additionally, NSP will rely on its four coal-fired plants for the foreseeable future, resulting in the hydrogen and ammonia at the EverWind plant being produced with NSP power in 2025 relying on a mix of coal and 30% wind energy, calling the green status of the hydrogen and ammonia into question (Baxter, 2022).

Social construction of technology (SCOT) will be the STS framework used to analyze this plant. The premise of SCOT is that human behavior shapes technology. Additionally, technology cannot be understood without examining how it is placed in society. Proponents of SCOT argue that the success of a technology can only be determined by examining it through the lens of which stakeholders evaluated the technology and what metrics they used to determine its success (Bijker et al,. 1989).

Based on the amount of the reporting on this issue done by local sources rather than large news outlets, it seems that the local populace is very invested in the development of the Point Tupper plant. Based on this observation, it is reasonable to say many local lawmakers will be very invested in making sure this plant is both economically and environmentally sustainable. Therefore, society is empowered to shape the design, construction, and introduction of this green ammonia plant. Based on this framework, the modifications from existing “grey” and “blue” hydrogen plants will be interpreted through the context of societal pressure and influence. Grey and blue hydrogen are both produced with unsustainable fossil fuels, but blue hydrogen plants capture the carbon emissions for storage or processing (Baxter, 2022).

Because this is an ongoing project, it presents an interesting opportunity to utilize the SCOT framework over time as new developments occur in the design and construction of the Point Tupper plant. If new legislative or societal reactions are published, they will contribute both as an in-depth view into how society specifically effects technology and to the analysis.

Conclusion

The technical project discussed in this project engages in designing a Auto-thermal Steam Methane Reforming (ATR) plant that converts natural gas into hydrogen fuel utilizing Carbon Capture technology to formulate Blue Hydrogen. The STS research project outlined will investigate the pushback to the planned EverWind Green Hydrogen plant in Point Tupper, Novia Scotia. This research paper will investigate the impact of journalists, as a part of society, whose angry response, on the future of planned Green Hydrogen plant. Insights from this research paper will help inform the technical project by promoting language and exposure that promotes long-term effects and the beneficial outcomes of the design project. Ultimately, both the STS and design project will attempt to address the need for humanity to reduce our carbon footprint with practices that is renewable, economic, and sustainable.

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