Thesis Project Portfolio

Carbon-Neutral Production of Methanol Via Direct Air Carbon Capture and Blue Hydrogen

(Technical Report)

The Use of Direct Air Capture to Reduce Carbon Emissions for Process Plants

(STS Research Paper)

An Undergraduate Thesis

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Sociotechnical Synthesis

As our society continues to evolve and change with the progression of technology, the long-term effects that technology and society both have on the environment needs to be addressed. My STS Research Paper provides a case study of a real-world example of my capstone project, a process that utilizes Direct Air Capture in order to produce a profitable chemical, methanol, being implemented and put into production to some degree of success. Ultimately, the case study proved that in that particular instance, the project was a failure, but by analyzing the key factors that steered the case study through the lens of Actor-Network Theory, we are able to identify what must be done in order to have lasting success going forward with a real-world, large-scale implementation of my capstone project.

My capstone project is a Direct Air Capture Process that harvests CO_2 from the air and converts it through multiple chemical reactions to produce methanol, a valuable product in many different industries. Essentially, this project takes harmful carbon emissions out of the atmosphere and then converts that into an important, profitable material rather than just finding some other way to dispose of the harmful gases. My capstone project involved designing a process that would separate out the CO_2 from the air via large fans that vent air directly to an air contactor that reacts any CO_2 with potassium hydroxide (KOH), which produces water and potassium carbonate (H_2O and K_2CO_3). The K_2CO_3 is then sent to a pellet reactor where it reacts with calcium hydroxide ($Ca(OH)_2$) to produce potassium hydroxide and calcium carbonate (KOH and $CaCO_3$). Finally, the $CaCO_3$ is sent to the calciner, which allows the $CaCO_3$ to undergo a decomposition reaction, forming calcium oxide (CaO) and regenerating a pure CO_2 stream.

Following this process, the next step in my capstone project involved designing a second process that takes the CO_2 from the Direct Air Capture process and produces methanol. This was

done by first having the CO_2 go through a reverse water gas shift reactor, where hydrogen can react with CO_2 to produce water and carbon monoxide (H_2O and CO). The carbon monoxide would then be sent to a hydrogenation reactor where it reacts with H_2 again to produce methanol (CH_3OH). While there were a lot more steps involved in designing this process, this was the general big picture idea; turning greenhouse gases that existed in the atmosphere and converting it into a valuable chemical that can be sold for profit. Through this project, a potential design for a chemical plant that has a positive environmental impact while producing a valuable product was made.

The research paper analyzed the Gorgon Carbon Capture, Storage, and Sequestration Project located in Burrow Island, Australia. This project was developed and constructed by Chevron Australia in partnership with Shell and ExxonMobil, as well as some other Japanese oil and gas companies. Numerous technical difficulties and failures delayed the project from meeting government expected progress points in terms of the amount of CO_2 taken out of the atmosphere and stored. However, this was only a small factor compared to the societal and political factors that ultimately perpetuated these technical delays into preemptively calling the project a failure. The amount of media coverage, specifically negative media coverage, by outlets like The Guardian, as well as the lack of information that was made available to the public about the project caused discomfort and eventually a condemnation of the project. My research paper analyzes each of the different factors that were involved in the downfall of this project. Everything from tax incentives for oil and gas companies to government funding for new technologies had a significant socio-political influence on something that would seem like a mere technical failure. After a deeper observation, it becomes clear that society has a clear influence on the success of new projects like the Gorgon Project.

A transition to more sustainable technologies like the one deployed at Burrow Island as well as my capstone project requires far more than just making technological advancements. It requires societal acceptance and transparency with the information, both information about the technology itself as well as developments with any project that may be being built. In addition, governments play a very important role in these projects as well. Government funding is great in order to help with the capital investment costs of some of these projects, but without having similar strong tax incentives like oil and gas have in numerous world governments, these new sustainable technologies will not be able to have the same success or even hope to replace the current dependence our society has on fossil fuels. Ultimately, the most important takeaway that I learned from being able to work on both these projects simultaneously was that technological advancements can only do so much. It is so much more important to have proper support from society as well as the government in order for new sustainable technology projects to be successful. This is something that, at first glance, would not have been obvious to me. If a new technology was developed, surely as long as it worked well and was profitable there would be no repercussions in investing into these projects. However, after working on both these papers, it is clear that good ideas can still fail under negative social spotlights.