Thesis Project Portfolio

Design of an Autothermal Blue Hydrogen Production Plant

(Technical Report)

The Effect of *Chernobyl* (2019) on the Perception, Development, and Current Implementation of Nuclear Energy in the United States

(STS Research Paper)

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Introduction

This thesis portfolio contains a technical capstone project and an STS research paper, both of which feature technologies that have been developed in part to combat global warming and climate change. For the technical project this is carbon capture and storage (CCS), and for the STS research paper it is nuclear energy. Specifically, the technical project involved designing a blue hydrogen plant utilizing autothermal reforming, which minimizes carbon dioxide (CO_2) emissions by capturing the greenhouse gas and liquifying it for enhanced oil recovery. Looking at the STS research paper, I analyzed the impacts HBO's *Chernobyl* (2019) had on the perception, development, and current implementation of nuclear energy in the United States. While nuclear energy can be seen as a solution to burning fossil fuels for electricity, since CO_2 is not produced during the fission process, its history and perception is controversial to say the least. Despite the many challenges both technologies present, the appeal is understandable: CCS technologies can be retrofitted to existing processes, and nuclear energy has plenty of existing infrastructure in the US.

Summary of Capstone Project

Hydrogen production from natural gas is an extremely CO_2 emission-heavy process; however, utilizing carbon capture techniques, this important resource can be produced with a much lower environmental impact. We propose an autothermal methane reforming plant as a relatively low-energy intensive process for the purpose of producing hydrogen and capturing the generated carbon dioxide. Hydrogen will be produced through a series of reactions combining either steam and methane or steam and carbon monoxide to produce hydrogen and carbon dioxide via steam methane reforming reactions or water gas shift reactions, respectively. Carbon dioxide will be captured and sold for use in enhanced oil recovery while hydrogen will be

purified via pressure swing adsorption and then sold and piped to an adjacent ammonia production facility.

The plant is expected to run for about 20 years at an average production capacity of 254 kT hydrogen per year. Using Aspen Plus simulations, each unit was designed, and reactions and separations were modeled. From these designs, the overall calculated capital cost of plant installation was estimated at $1.3 billion and operational costs of $567 million. The majority of these operational costs come from raw materials, such as natural gas and oxygen, with labor and utility costs making up a small portion. In total, the yearly revenue of the plant is estimated to be $1.4 billion, made primarily from the sale of hydrogen at $5 per kg and carbon dioxide at $34 per tonne. Based on our analyses of our costs and revenue streams, we have found this to be a feasible and profitable investment that, with proper monetary aid, can begin to move forward with construction. Future blue hydrogen processes could work to further optimize reactor systems towards methane conversion and minimize energy costs associated with carbon capture, and assumptions around unit outputs could also be reevaluated in more detail. Overall, we believe that our study and design will contribute knowledge to the blue hydrogen space and draw potential investors to its market, leading to a more environmentally friendly hydrogen market.

Summary of STS Research Paper

Contrary to past media on nuclear power risks, *Chernobyl* is having a more ambivalent impact on the perception, development, and implementation of US nuclear energy. A review of literature shows that nuclear energy perceptions don't usually match their accident occurrence rates, and media can affect how people view technology, especially nuclear energy. Data gathered for investigating and supporting this paper's claim include national polls, various datasets, critic and audience reviews, and academic papers looking at the sociotechnical impacts

of the show. In my review of this evidence, I will examine the social, political, and economic impacts of *Chernobyl* on America's nuclear industry, with a particular emphasis on the alteration or lack thereof of the country's sociotechnical imaginaries regarding future energy production. Doing this points to Chernobyl having a negative effect on the US nuclear industry purely in a correlational sense, not directly, and that this evidence isn't particularly strong. Further, there are many critic and audience reviews stressing the show's key message that it wasn't primarily the technology that caused Chernobyl, but the inadequately trained personnel and Soviet Union's administrative culture of secrecy and lies. Understanding this message, broadly speaking, points to an American sociotechnical imaginary where nuclear energy will be utilized in some degree to address our energy needs amidst the climate crisis.

Reflection

By working on both the capstone project and STS research paper simultaneously, I gained a broader insight to each topic that otherwise would not have been possible had the projects been completed separately and in isolation. One major insight was the technical challenges of each technology. Researching nuclear energy taught me so much about process safety, a vital component of designing a blue hydrogen plant, and in making that plant I acquired a better appreciation for the scale of nuclear power plants and how that may affect perceptions. Completing both projects also opened the door to understanding why the climate crisis is so challenging to deal with. While both nuclear energy and blue hydrogen mostly succeed in minimally contributing to global warming and climate change, naturally there are roadblocks that traditional processes don't have to address. Designing gray hydrogen plants is easier than blue hydrogen ones since the generated CO_2 gas can just be released into the atmosphere, and using natural gas for electricity generation is less controversial than using nuclear sources. All that

being said, making the fundamental changes to decrease the total amount of greenhouse gases in our atmosphere is worth the added challenges, as it is easier to keep a world livable than to make it livable again. I'm incredibly grateful to have been able to research and create this thesis portfolio, and I hope its findings will lead to a better, more knowledgeable world.