Thesis Project Portfolio

Design of an Autothermal Blue Hydrogen Production Plant

(Technical Report)

Green Energy in Developing Countries

(STS Research Paper)

An Undergraduate Thesis

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Executive Summary

Technical Capstone Project- Blue Hydrogen

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 253,881,360 kg 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 and carbon dioxide. 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.

STS Paper- Green Energy in Developing Countries

The STS research paper explores the topic of green energy policy and programs in developing countries. As the world faces a global climate crisis, many countries are beginning to transition from fossil fuels to cleaner energy sources, including renewable green energy. However, financial, geopolitical, and environmental obstacles hamper the transition of developing nations to cleaner energy. Populations are rapidly increasing in many developing nations, and the resultant energy demand could increase CO_2 emissions if these countries are not able to generate sufficient clean power. This paper analyzes the obstacles facing developing nations when implementing green energy programs, including financial needs, socioeconomics, external influence from foreign investment, and local geography & resources. Countries like Morocco are analyzed to determine what a green energy program might look like, if adapted to the local climate. Existing programs are also discussed, including a program in South Africa to sustain a remote island with off-grid clean energy.

STS frameworks are also implemented to analyze these programs through different perspectives. One framework that is used is Social Construction of Technology (SCOT). This STS framework focuses on the relationships between a certain piece of technology and different relevant social groups, looking at how these groups can influence and affect each other. The framework also introduces the concept of interpretive flexibility, or how a technological artifact has the capacity to sustain multiple meanings for different people and can have multiple uses outside of its original design. SCOT is utilized in the STS paper to identify how green energy programs differ in their implementation from country to country, and how influences of several groups can impact the effectiveness of these programs.

The other framework used to enhance analysis of this issue is diffusion of innovation analysis. This framework identifies several stages of adoption regarding a particular technology and outlines different groups of adopters. The focus of this paper will be on the "early adopters" group, who are the first major group of people to implement a piece of technology such as green energy. This group can accelerate the diffusion of green energy programs in developing countries, leading to the widespread adoption of the technology and the reduction of hazardous emissions from pollution and dirty cooking fuels.

The paper concludes by creating three general principles for green energy program implementation, including avoidance of financial jeopardy from foreign investment, direct investment into capital costs of projects instead of distributed investment, and that the program should adapt to the local climate, choosing the best possible energy resource available. These general principles are broad to leave room for adaptability due to the large variance between countries, as discussed in the paper. Overall, these principles can be used to guide a policymaker or investment firm into making ethical and effective programs that reduce global emissions while improving quality of life for millions.

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