Thesis Project Portfolio

Green Production of Microelectronics-Grade Hydrogen and Research-Grade Oxygen

(Technical Report)

Pathway Towards Integration of Green Hydrogen Into Society

(STS Research Paper)

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Executive Summary

To combat climate change, it is increasingly important to transition away from modem reliance on fossil fuels. Within the chemical synthesis industry specifically, fossil fuels are used heavily in the production of hydrogen gas, both as an energy source and method of production. Therefore, the technical research component of this paper will discuss a profitable, carbon-neutral "green" method of producing hydrogen, ultimately designed to be sold at a high purity level to the microelectronics industry. Although this hydrogen is not designed for fuel cell usage, there is great potential for green hydrogen to be used as an energy source, with valuable qualities such as a high energy content, as well as being entirely carbon-neutral in both generation and consumption. The sociotechnical component will analyze how green hydrogen should be integrated into society as a clean energy source, as a replacement for polluting fossil fuels. Overall, both the sociotechnical and technical research components aim to understand and create feasible solutions towards global decarbonization through the use of green hydrogen.

Production of green hydrogen, as opposed to the traditional carbon-emitting method known as gray hydrogen, is rarely executed due to higher prices associated with clean production. These higher prices are a consequence of the usage of renewable energy as an electricity source, as well as the expensive equipment required for green hydrogen production. To solve this problem, this technical research paper lays out a green hydrogen production system which is entirely carbon-neutral and economically viable. To achieve this, the microelectronics industry was selected as the targeted market because it is the highest-valued hydrogen consumer. The renewable energy method and location for our chemical plant siting were optimized to minimize costs associated with renewable energy. Additionally, to ensure feasibility, this process will be selling a generated byproduct, oxygen, at research-grade purity to further subsidize higher costs associated with green production methods. Design of this process was ultimately

performed in aspirations of decarbonizing the chemical, specifically hydrogen, synthesis industry.

This process begins with the intake and purification of river water from the Torne River in Abisko, Sweden, where the plant will be located. This water is pretreated and sent into an electrolysis unit, where it is reacted into hydrogen product and oxygen byproduct. Each of these materials are then purified to the levels specified with their respective markets (each 99.999% purity), compressed to bottling pressures, and sold at high price points. As onshore wind electricity is exclusively used as the energy source and water is the only raw material consumed, this process is entirely carbon-neutral. An economic analysis confirms that this process is extremely profitable, generating around $6.6 billion dollars within a 20-year plant lifetime. It is, therefore, recommended that this process is executed for as it is expected to be a success both financially and environmentally.

As described earlier in this executive summary, green hydrogen is very lucrative as an energy source due to its nature as both carbon-neutral in production and consumption within a fuel cell. However, green hydrogen faces significant obstacles before it can be implemented as an energy source globally as a replacement for fossil fuels. Primarily, these are a lack of legislature and policies surrounding green hydrogen production, lack of infrastructure, and an unfavorable public opinion towards green hydrogen as a whole. This sociotechnical paper will therefore answer the question of how best to implement green hydrogen as an energy source into society through the lenses of the “Technological Momentum”, “Diffusion of Innovation”, “Relational View” and “Cultural Lag” frameworks, in conjunction with various case studies and literature reviews.

Through these analyses, it was concluded that it is feasible for green hydrogen to be adopted as an energy solution. Existing infrastructure, originally meant for gray hydrogen facilities, should be repurposed for green hydrogen production sites. To transition away from traditional energy generation methods, green hydrogen must first become the standard production method (over gray) in the chemical synthesis industry. Over time, this will promote decreases in green hydrogen production costs and improvements in production techniques, resulting in integration of green hydrogen into the power sector as a fuel. China is the most probable pioneer country for pushing out green hydrogen legislation, however pioneer adoption locations include the Middle East, Africa, Russia, China, the US and Australia. Adoption of this technology requires support of the public, which can be improved through educating the public on social media to increase awareness and understanding of hydrogen as a whole.

Together, these papers hope to demonstrate the potential of green hydrogen as a solution for improving climate change, as well as paving a realistic, yet optimistic, pathway towards its adoption. By designing a successful process for decarbonization of the chemical synthesis industry, it is hoped that this project will increase investment in green hydrogen in a whole, ultimately facilitating integration into the power sector, and decarbonizing the world.