Thesis Project Portfolio

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

(Technical Report)

The "Holy Grail" of Energy: Assessing the Origins and Implications of Discourse Championing Singular Technical Solutions to Electricity Distribution as a Tool to Better Inform the Social Consequences of These Innovations

(STS Research Paper)

An Undergraduate Thesis

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In Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

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Sociotechnical Synthesis
(Executive Summary)

Understanding the Multidimensional Nature of Solutions to Climate Change

"For every complex problem there is an answer that is clear, simple, and wrong."
– H. L. Mencken

Climate change will prove to be one of the greatest challenges to humanity this century, not because of technical difficulty but because of our inability to adopt systems-level thinking to a problem that demands it. 81% of our energy today comes from fossil fuel sources, indicating our society's heavy reliance on these cornerstone chemicals. However, these fuels are simply unsustainable long-term, which is why my technical thesis is a proposal for green production of microelectronics-grade hydrogen and research-grade oxygen. Hydrogen has been identified as a potential clean substitute to these fossil fuels, but production processes today are either carbon-intensive or prohibitively expensive. My team's technical proposal aims to create a commercially viable hydrogen production facility that uses renewable energy from Sweden to improve economic and environmental prospects of the process. However, clean hydrogen will not solve all of climate change; clean electricity will represent the other half of sustainable efforts. My STS topic examines how public visions of the electricity grid compare with the discourse used by power distribution startups and argues that a single, "holy grail" solution is the inappropriate perspective to tackling this incredible challenge of decarbonization.

The technical portion of my thesis produced a complete plant design for a green hydrogen facility based in Sweden. The key principle behind the process is proton-exchange membrane (PEM) water electrolysis using water from the Torne river to produce 1,864,000 kg of hydrogen per year and 15,334,000 kg of oxygen per year. We designed the pre-electrolysis reverse osmosis membrane and post-electrolysis separation filters using AspenPlus under a design basis of 1,500,000 kg of hydrogen per year. The total capital cost of the plant is $34 million, and the yearly operating cost is $15 million. Using standard market rates, our production would yield a yearly hydrogen revenue of $394,413,880.66 and an oxygen revenue of $45,109,684.35. A 20-year lifecycle assessment with a 10-year straight-line depreciation gives a total revenue of $6.6 billion and an internal rate of return of 64%. With these findings, we recommend that green hydrogen proposals be pursued in areas with steady, cheap, renewable energy as our assessment using novel PEM electrolyzers demonstrates commercial viability.

In my STS research, I focused on the origins and implications of the “holy grail” metaphor in electricity transmission startups in the context of public visions of the grid. I used a discourse analysis to study the analogies made by the public regarding their imaginations of the future of electricity distribution. I also assessed the “holy grail” analogies used by power distribution companies to understand the implications of their language on funding and overall grid strategy. My analysis revealed that differences in the public visions of the grid are due to a difference in the prioritization of cultural values under different geographical and socioeconomic contexts, meaning a single solution to the electricity transmission problem is infeasible. Furthermore, the funding study illustrated that companies who market their solutions as the “holy grail” receive a disproportionate amount of funding to pursue their innovations–money that would otherwise go to local projects that may have better public acceptance. These findings recommend that more research should be done regarding how to better allocate funding resources to address a complex problem in transmission that does not have a single solution.

Doing these two projects together revealed to me the true complexity of climate change and how we will almost certainly require a multidisciplinary approach moving forward. Singular solutions may work under certain contexts, but climate change as a whole is a complex sociotechnical system with many underlying, conflicting forces. My technical topic showed how green hydrogen may not be viable everywhere yet, but it should be pursued in areas with favorable renewable resources that can make the product cost-competitive. Our technical results were extremely sensitive to the initial conditions, indicating that green hydrogen is not a silver bullet solution to replacing fossil fuels. This realization supplements my STS research, where my discourse analysis showed a fundamental disconnect between the cultural values people hold regarding clean electricity and how technical innovations are approaching the problem. This conclusion shows that even if a technical innovation is feasible, cultural and organizational actors will determine if the technical actor is productive.

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