Thesis Project Portfolio

Power Plant Design Using Allam Cycle CCS

(Technical Report)

Dysfunctional Modeling: A Combined Method to Improve Sociotechnical Energy System Analysis

(STS Research Paper)

An Undergraduate Thesis

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

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Spring, 2021

Department of Chemical Engineering

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Sociotechnical Synthesis

(Executive Summary)

Unexpected Results: Carbon Capture and Sequestration Technology and Sociotechnical Frameworks

In ExxonMobil's 20-year international energy outlook released last year, 76% of the world's energy is predicted to still be supplied by fossil fuels in the year 2040. It is currently estimated that 36.6 gigatons of carbon dioxide are released into the atmosphere annually, and one-third of that is from electricity production. I learned these things in my Energy Science and Technologies course in the fall of my 4th year, and they scare me. Four other students and myself were inspired by this course to use our final capstone design to create a bridge power technology that would conceivably help break this trend by giving renewable energy time to develop. We designed a natural gas power facility that utilizes oxyfuel combustion and CO_2 as a working fluid to produce electricity with zero carbon emissions and pure water as a byproduct. In the conception of this design, and as a relatively new member of the engineering field, I naturally had to ask myself, why doesn't this already exist at a large scale? This question was the spark that ignited a wildfire of possible STS research questions. Just like a wildfire, addressing this problem head on and all at one time was overwhelming, so I had to search for my opening to attack. The tactical approach I finally came upon was one based deeply in sociotechnical framework theory and its application to energy technology systems.

As stated earlier, over the course of a year I designed and modeled a natural gas power facility achieving a net electricity output of 600 MW and zero atmospheric carbon emissions. I used the Allam Cycle as a guide which utilizes oxyfuel combustion removing the existence of toxic byproducts such as NO_x and producing only water and CO_2, which are easily separated. While this design reached efficiencies above 50%, something impressive for most power cycles when actually executed, it lost overall $31 million each year from the costs of manufacturing. After countless hours of work from our enthusiastic team of soon-to-be engineers, we had to recommend in our final presentation not to move forward with our project as designed. While this was disappointing in a way, I do not see this as a failure. Upon this finding being revealed, our team ran multiple economic scenarios where slight resource price changes and other optimizations made all the difference. I believe that the success of this technology, meaning mainstream adoption, is greatly based on the energy technology system it resides in, and as I discovered, those systems are very complex and dynamic.

In my valiant but ultimately Sisyphean attempt to answer the massive quandary of why RET isn't in widespread use in the US already, I became familiar with two sociotechnical frameworks: Geels' multi level perspective (MLP) and Grübler and Wilson's energy technology innovation system (ETIS). The MLP and ETIS use theories based on technology transitions and lifecycles respectively to map the progress of RET technology from small scale

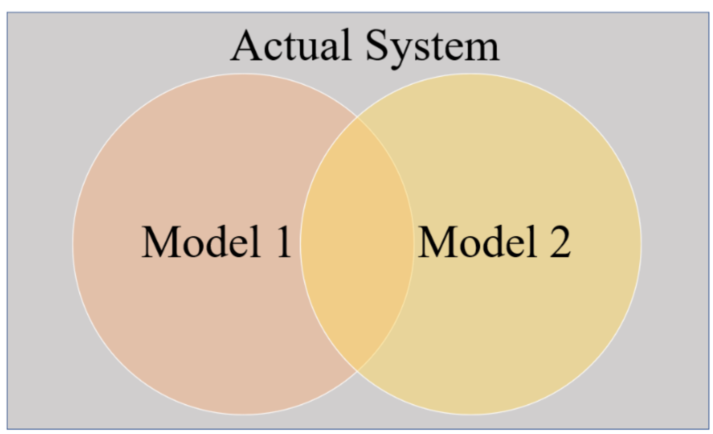

Figure 1 - *Illustration of multiple sociotechnical framework model utilization providing greater yet still incomplete mapping of a real system*

design to mainstream use. I found that the frameworks provided valuable insight into how the networks operate, but ultimately still were inadequate in overall mapping. Using this and my other research, I inferred that applying both frameworks and using one to explain the other provided a better overall view of the system in question – I called this the combined method. When I discovered this, my STS research shifted to something more based in sociotechnical systems theory. I learned when it comes to sociotechnical framework theory, because the systems that we try to analyze are so complex and layered, the best that can be done is to combine our resources (frameworks) to have as many pieces of the puzzle as possible.

If you had told me at the beginning of my STS problem definition process that not only would I would discover something so fundamental to sociotechincal theory, but it would also truly impact my perception of my technical project, I wouldn’t have believed you. I came into this project certain that I would simply design a power plant and look up some information about expensive new technology that I already knew, and I was wrong. I designed a facility that lost money and didn’t bat an eye at it. My STS research totally shifted my view on RET, and it gave me a much more full understnading of just how tempermental and complex systems like these are, and how the smallest changes to them can have the biggest impact.

My completion of this thesis project as a whole would not have been possible without a team of enthuastic professionals behind me. Thanks are deserved to Professor Kathryn Neeley for assistance with the in depth analysis of sociotechnical energy frameworks and their applications, and to Professors Eric Anderson, William Epling, and Ron Unnerstall for everything from project inspiration to detailed technical consulting.