Designing a pragmatic system requires the ability to establish an outlook of what the final system will look like, as well as validating the system’s individual components. The big picture of the proposed system is to integrate nuclear and renewable energy systems to provide clean energy to the electrical grid. ( See Round 3 for details on the problem space.) Addressing this objective has further progressed as some of the following areas were explored: Methods and Materials, Technical literature analysis, intellectual property strategies, marketing, and ethics.

Intellectual Property

There are several already filled patents relating the use of various energy generating sources coupled with a secondary industry process like methanol production. These patents, mostly from big industry leaders like General Electric, Hitachi, Mitsubishi and Toshiba, mostly differ in interconnection designs, energy generating sources and the method in which energy is transferred from the generating source to the industry process. Furthermore, another patentable field of special interested is the energy network itself. Energy network being the plurality of power stations and a variety of loads interconnected by an electricity grid. It is clear, by the accelerating number of patents filed in this industry area in the last years, that there is a great possibility for value. These systems are not only design for better energetic efficiency but also to have a huge economical advantage versus conventional systems. If an efficient overall system can be design, patenting this design(s) can offer a competitive advantage versus other similar systems with less efficiency and capabilities. Once filed it would be beneficial for the world to have these ideas be public domain as global warming and pollution is a challenge that we are all facing together. If these efficient designs are not patented, the competition might do it without any intent of opening the patents to public domain. These types of IP’s may generate revenue in a variety of ways mainly either licensing the design or by offering to build and operate these types of systems to clients be it counties to states.

Ethics

The National Society of Professional Engineers Code of Ethics requires all projects to be done with “honesty, impartiality, fairness, and equity, and must be dedicated to the protection of the public health, safety, and welfare”. One the main purposes of developing this type of technologies and electrical networks is to help tackle the global warming issue while improving reliability, safety, and cost-effectiveness. As with any other technology there are many possible unintended consequences, especially when the technology has only been developed theoretically and prototypes do not exist. The work being done in every stage of the project is set around minimizing these possible consequences. Some of examples of possible consequences for every stage of the project are listed as follow:

Table X. Possible Unintended Consequences

|  |  |  |  |
| --- | --- | --- | --- |
| Stage 1: Design and Virtual Simulation | Stage 2: Test | Stage 3: Build | Stage 4: Use |
| Failure to correctly design certain components of a complex system. | Prototype does not work as intended. | Theoretical designs and tests slightly different from reality causing redesign. | Hydrogen Production Malfunction |
| Goals not reachable due to shortness in team members, time and expertise. | Regulatory bodies request additional information causing unexpected delays. | Project acceptance problems by the local community of the selected location. | Radioactive Contamination of secondary loops. |

Each of these possible unintended consequences probability will be minimized as much as possible as per the Code of Ethics for Engineers, “holding paramount the safety, health, and welfare of the public”. In any stage of the process, all engineer members “shall avoid all conduct or practice that deceives the public” by providing public statements in an objective and truthful manner.

Marketing

· What is the relationship between your technology and the possible commercial application?

The technology that we are proposing is a multifaceted development- integrating a Nuclear Power Plant, a Hydrogen Production Plant, and Renewable Energy Resources. In order for the integration process to combine efficiently, each major component needs to be taken in account, and further broken into subcomponents.

The first major component taken into account is the Nuclear Power Plant; the NPP will provide base load energy needed to corroborate the other components. The NPP design used for this system is based off the ThorCon molten salt reactor. While progress is being made to develop the first model, the model is still undergoing development and has not yet been commercialized.

When coupled with renewable energy sources such as wind and solar energy, it is projected that the NPP will run continuously. While this is useful during the off peak periods of the renewables, excess energy is generated when these systems are being utilized. Furthermore, a secondary system is developed to defer the excess energy to- in this case the secondary system is the Hydrogen production plant.

A number of Hydrogen production cycles were considered, the final decision being settled using the 4-step CuCl cycle. This cycle was chosen because it couples well with the amount of energy the NPP produces and the amount of energy needed to efficiently run the hydrogen plant. While much research has been dedicated to investigating this cycle, it has primarily been tested in a laboratory and modeling framework, and has yet to be commercialized. Conventional forms of hydrogen production is difficult to couple because it requires more energy input than the NPP produces.

Along with these considerations, it is important to examine geographically where the plant would be located. For example, California is a major consideration because it has a deep penetration of renewables. While the NPP, and renewables do not need to be located on the same site, they do need to be in close enough proximity to operate within the same electrical grid. Unlike, the renewables, the hydrogen plant does need to be located on the same site as the NPP because it will be powered directly from the energy of the NPP.

Assessing the energy customer base should not be a difficult task, as we are providing a large amount of clean energy to the grid, however, it may take a little market research to acquire long term customers for hydrogen.

Taking all of this into account, the relationship between this technology and commercialization lies within the ability to individually commercialize the NPP, and further the 4-step CuCl cycle of the hydrogen plant. Once these tasks have been done, finding a suitable location to place our technology is another consideration to be assessed.

( include something about engineering the integration between the systems will need to be assessed on a larger scale )

Technical Literature Review

· What’s the body of work relevant to your technology?

During the preliminary stages of conducting a literature review for our technological development, the primary areas that were important to categorize were the types of nuclear reactor we would use, and the type of secondary process that would be best to couple with our chosen NPP.

After researching different types of generation IV nuclear reactors, we specified the use of a molten salt nuclear reactor. Following this was an analysis of the companies that were designing molten salt reactors. Some of the things we considered are the following: What type of molten salt reactor is this company using? Will there be enough information regarding their design for us to develop a system from? What key parameters from this design will help moving with integrating into the secondary system? These considerations help us to our final decision of the ThorCon molten salt reactor design.

Following research on the reactor design was the analysis of secondary process that couple well with the NPP. Some of the processes we considered included the following: desalination plant, methanol plant, and hydrogen plant. After further analysis, the final decision was to use hydrogen production because there was a good market size available, and the input energy needed to was perfectly suited.

· How does your project build upon, contribute to, and/or differs from previous research, studies, product development strategy

Much of the work we have done builds on work that has already been done. Research is currently available of the different types of Nuclear Hybrid systems, while our work fits within this category, it differs because of the systems that we have chosen to couple together. The would we have done is also more technically designed for the integration on the system to take on a more realistic approach. Developing the base work of the ThorCon system to couple with the Hydrogen plant and vice-versa.

· What are pertinent insights from journal articles, conference papers, and books?

When looking for resources, many different areas were explored, such as thesis papers, books, conference papers, and journal articles. The most valuable insights from these sources came in the form of equations, values, graphs, and basic information on how the process works. While it was important for use to pick and choose what information was most closely associated with out project, we had to manipulate some of the work to fit within the confines that was needed.

Methods and Materials

By bringing the information from the aforementioned papers and resources together, we are aiming to create a skeletal model of a hybrid nuclear power system that is able to load follow in accordance to a given energy demand. This model will give us unique insight into the effectiveness of the plant and estimate how quickly load following can be achieved and the cost effectiveness of such an endeavor. The first step to creating this model was to lay out a skeleton of our system by characterizing the aspects of our hybrid plant. While there are countless permutations to create a hybrid plant, we slowly honed in on the design we wanted by performing cost benefit analysis on each block of the plant.

This step by step selection process benefited from the fact that each selection put restrictions on other components. For example, we chose a supercritical rankine cycle which limited the options for the heat exchanger. In most components or systems, there doesn’t exist a best technology so a decision was made based on the aspects the team considered the most important. For example, passive safety and extensive documentation were the most important aspects for choosing a nuclear power system while economic benefits and potential for scaling were considered the most important aspects of our secondary process.

With this skeletal model set up, numbers and formulas can be combined to estimate the values that we actually care about. These equations come from a mix of fundamental thermodynamic laws and an experimentally identified expressions for the various components we chose. They are implemented into a code that iteratively solves for system values that ultimately satisfies all the equations and boundary conditions. These boundary conditions come from the temperature, mass flow rate, and pressure values given by Thorcon’s MSR at 100% energy production as shown in ***FIGURE***. Once the system’s temperature characteristics and energy output can be identified for any required electrical load (from 0 to 100%) by our MATLAB code, we will identify how much hydrogen we can produce. Incrementally, we will build upon our previous findings in our given system until the model is complete.

As a quick overview, the way our hybrid system works is that molten salt travels through the secondary system and then to the power generation system as shown in ***FIGURE***. Heat can be extracted to the hydrogen production system which means that the molten salt going to the the energy generation loop comes in at a lower temperature and thus the water comes out at a lower temperature. While the total heat extracted from the molten salt between the two systems stays constant, the efficiency of electricity generation decreases at lower steam temperatures. This means that putting 70% of the heat from the molten salt into the energy generation system will generate less than 70% of the total electricity generation potential. Using this information we can ident