ChemE Lab Final Assessment

One of the most interesting labs, and perhaps most relevant to contemporary global issues, we had this semester was the efficiency and optimization lab for a solar to fuel system. In lab, we tried to optimize the operating conditions for a photovoltaic panel, an electrolyzer and a fuel cell, in order to determine the solar-to-fuel, more specifically solar-to-hydrogen, efficiency when putting all of these together. The purpose of this system is to make hydrogen and oxygen from electrolysis of water powered by solar energy collected from the PV cell, and then use this hydrogen and oxygen in a fuel cell to generate electricity. A technology like this is clearly of interest and sounds like a promising sustainable solution as it has potential to disrupt conventional fossil fuel energy industries like domestic and commercial electricity, transportation, and even the chemical industry. Unlike traditional fuels that not only produce carbon dioxide but also contain impurities that release harmful and poisonous gases like NOx, SOx, and carbon monoxide, which then requires pollution mitigation systems like catalytic converters, the solar-to-hydrogen system only involves water, hydrogen and oxygen species. Thus, using solar energy to split water into hydrogen and water essentially presents a sustainable, carbon neutral energy source that can be produced from readily abundant raw materials – sunlight and water. Moreover, a solar-to-hydrogen system also presents a solution to one of the biggest problems that solar energy presents, intermittency. For example, if we consider a residential building equipped with solar panels and the ability to store solar energy in a hydrogen fuel form, energy will be stored throughout the sunny day when people are away at work and then used at night when they are back in their homes. For the consumer, this means they can be one step closer to becoming independent from the power grid, and introduces the potential to offset their expenditure in utilities, provided the solar-to-hydrogen technologies are affordable enough and competitively priced.

In our experiment, we determined the energy efficiency for the whole solar-to-hydrogen system to be 3.2%. The energy efficiencies for the PV cell, the electrolyzer and the fuel cell were determined to be 8%, 99% and 40%, respectively. To offer some comparison to conventional technologies, internal combustion engines used in cars show a thermal efficiency of approximately 20-30%. It would be interesting to find how energy efficient gasoline is when the amount of energy required to extract oil, refine it, transport it and pump it into a car's gas tank is taken into consideration, as this would offer a more comparable result to our 3.2% efficiency. Moreover, it would also be interesting to compare the carbon footprints of making the infrastructure for fossil fuels versus renewable fuels. For example, wind energy is largely considered to be a green renewable energy source, but wind turbines require a lot of steel, and making steel requires a lot of carbon. This finding really highlights the importance of optimizing the individual components of the solar-to-hydrogen system in order to have an efficient system. While the electrolyzer was almost perfect and the fuel cell was fairly efficient, the PV cell presented the lowest efficiency out of them. Then, we conducted a modeling analysis where we considered a simplified scenario to see if a required system load of 300kWh can be supplied by the solar-to-hydrogen technology year-round, allowing for solar irradiation fluctuations. It was found that an initial amount of approximately 1600m^3 of hydrogen gas would have to be stored beforehand if the system load of 300kWh was to be met year-round.In this case, the solar-to-hydrogen technology would not able to meet it from electrolyzing water powered by solar energy, additional hydrogen would be required for the fuel cell to supply more energy. Therefore, from our lab experiment, it seems like the solar-to-hydrogen technology is not feasible for large scale commercialization, for now. More work has to go into optimizing the individual components such that more promising results can be found in lab, that will then allow for the scale up and commercialization of a new sustainable energy technology.