4 Design

4.1 Design Context

4.1.1 Broader Context

Describe the broader context in which your design problem is situated. What communities are you designing for? What communities are affected by your design? What societal needs does your project address?

Our project is designing for communities with utilities that are trying to move to more environmentally friendly practices. Utilities and the communities connected to the utility are affected by our design. It addresses the need to be more environmentally friendly and to increase the amount of renewable energy that is used in the power sector.

Adding a system like ours would also increase the reliability of the power grid as much of the infrastructure is approaching end of life and will be experiencing more power failures in the years to come. Adding more systems like this would increase the reliability of power delivery to the affected communities as well as lessen the environmental impact due to power generation described above.

List relevant considerations related to your project in each of the following areas:

Area	**Description**	**Examples**
Public health, safety, and welfare	This project affects the general well-being of communities where the solar farm is placed. Having a solar farm in a neighborhood instead of a coal power plant helps the welfare of families during natural disasters.	Solar panels reduce exposure to air pollutants because solar panels do not rely on fuel that emits carbon dioxide. Building the solar farm will create job opportunities.
Global, cultural, and social	This project reflects the positive values of green energy and reducing climate change. One consideration is the public perception of solar and the number of people who do not want it in their communities.	Development and design of the solar field and substation will not violate any code of ethics and will not force any of the community users to change their typical practices. It will affect how the community views renewable energy as it will positively effect their utility bill. Public perception of solar is important as these systems will likely become visible parts of their communities, and many are not open to this becoming a part of their community even if they are not against the idea of clean energy itself. Working with communities is necessary to ensure these projects can get off of the ground and can go into development.

Environmental	This project will increase the amount of renewable energy, therefore creating a more green way of producing electricity.	Increasing use of renewable energy, therefore making the electricity production in the area more environmentally friendly. The use of solar power also reduces the amount of oil and natural gas extraction necessary to reach the same power output. Less oil and gas extraction reduces harm to local flora and fauna and lessens disruptions to local wildlife.
Economic	Lower consumer expenses, more affordable energy generation for utilities	Overall design of the solar field and substation must be cost friendly as the utility is focused on the cost benefit of adding more renewable energy.

4.1.2 Prior Work/Solutions

Include relevant background/literature review for the project

– If similar products exist in the market, describe what has already been done

Solar farms are a growing source of renewable energy for the power grid. Our project of creating a utility scale solar farm has been done before and exists in the market. These projects are 20 MW or larger. The farm that we are creating is going to be 60 MW. These renewable energy resources compete in the market by offsetting retail electricity rates.

There are several ways to ensure that a solar farm is successful. Location and orientation is key as well as being able to compete with organized electricity markets that can be traded and sold in order to benefit both the consumer and utility companies.

– If you are following previous work, cite that and discuss the **advantages/shortcomings**

One of the main advantages of solar power is the fact that it is a clean energy source. In addition it is a reliable source of electricity during daytime hours because the sun is not going anywhere. Unfortunately, the construction of solar farms has associated emissions, and is not an entirely emissions free project. However conventional energy sources emissions are much worse than those of solar farm construction projects. Another benefit of solar farms is it can be used by livestock to graze or for growing crops. According to 'innovative solar systems' agrovoltatics the practice of co-locating farmland and solar farms has shown to be very beneficial. Another way to increase the positive impact environmentally from the solar farms is by restoring the ground coverage to the natural vegetation within the reasonable limits of maintaining the PV system. One such example of this ground vegetation restoration would be the Solar Farm set up in Ames. During the project they decided to also work to restore the ground coverage within the PV system to native grasses. In a study by the Department of Energy in 2012, they estimated that 14% of the power generated in the US would be Solar, and a total of 329 GW output. Of that output 37% could be output from rooftop installations, but the rest would be in a more traditional solar farm set up. The estimated land use for these projects would total 1.8 million acres (Beatty, et. al). Setting up PV systems in integrated fashions such as the mixed land use with farmers or land restoration, increases the productive output and positive impact from these projects.

While there are several advantages to solar energy there are also additional cons of using this type of energy. There are three main issues with solar farms; land use, output is based on weather patterns, and cost. The extensive land use can be cut by setting systems to incorporate agrovoltaic practices to combine land uses. The only way to mitigate the effect of weather on output is choosing a location in which the weather would have minimal impact, such as an area with minimal rain and cloud coverage throughout the year. Finally, solar farms are very expensive which is not always feasible. Based on our price analysis calculations, our solar farm is looking at being around $80 million. Many utilities could not justify spending that amount of money on a power generation project that cannot operate at all hours a day.

– Note that while you are not expected to "compete" with other existing products / research groups, you should be able to differentiate your project from what is available. Thus, provide a list of pros and cons of your target solution compared to all other related products/systems.

Detail any similar products or research done on this topic previously. Please cite your sources and include them in your references. All figures must be captioned and referenced in your text.

4.1.3 Technical Complexity

Provide evidence that your project is of sufficient technical complexity. Use the following metric or argue for one of your own. Justify your statements (e.g., list the components/subsystems and describe the applicable scientific, mathematical, or engineering principles)

1. The design consists of multiple components/subsystems that each utilize distinct scientific, mathematical, or engineering principles –AND–
2. The problem scope contains multiple challenging requirements that match or exceed current solutions or industry standards.

- Two parts, solar field design and substation design
- Client meetings with agendas and minutes
- Solar field design
    - Multiple CAD Designs
        - Array design
        - Rack and string detail
        - Array component layout
        - Electrical detail and line diagram
    - Array Parameter Tool calculations
    - Voltage Drop Calculations
    - Cost Analysis
    - Trench Fill calculations
- Substation Design

- One line and three line diagrams, grounding, equipment, and bus layout
- Grounding, bus, AC, DC, voltage drop, and lightning calculations
- Equipment selection

4.2 Design Exploration

4.2.1 Design Decisions

List key design decisions (at least three) that you have made or will need to make in relation to your proposed solution. These can include, but are not limited to, materials, subsystems, physical components, sensors/chips/devices, physical layout, features, etc. Describe why these decisions are important to project success.

Our first main decision was deciding on the exact components we were going to use in the solar farm. These three components are the solar panels, inverters, and combiner boxes. These components ensure that the farms work to its best ability making this decision very important.

The second big decision we made was choosing what location we should use. The two locations that we were looking at were Roswell New Mexico and Ames Iowa. We looked into these two locations: price of land, hours of sunlight a year, and success stories in each location. This decision is important because location is one of the main factors that goes into whether or not the solar farm is able to compete in the market based on the amount of power and electricity it can make.

The third decision we have been making as we have been drafting up our CAD drawings is the design layout. Again orientation of a solar farm can have major effects on the overall output of the system making it a very important decision to be made. In addition certain set ups compared to others are limited based on the voltage drop calculations we have been doing simultaneously.

4.2.2 Ideation

For at least one design decision, describe how you ideated or identified potential options (e.g., lotus blossom technique). Describe at least five options that you considered.

In order to make our design decisions we have had to do a lot of research on the different components within a solar farm. We decided to research three different brands for each of the main components: solar panels, inverters, and combiner boxes. After finding our top three for each of these components we paired them in different combinations together creating six different options that we considered.

4.2.3 Decision-Making and Trade-Off

Demonstrate the process you used to identify the pros and cons or trade-offs between each of your ideated options. You may wish you include a weighted decision matrix or other relevant tool. Describe the option you chose and why you chose it.

We used a spreadsheet to compare all the data generated for the six different combinations that we came up with. The main thing that we compared was the inverter capacity and the industry standard ILR. We needed our ILR to be 1.3 per the standard so we could immediately rule out decision number three. Next we wanted to use the highest inverter capacity while still achieving an ILR of 1.3. The design that had the highest inverter capacity of 5000 kW was decision number two so we decided to go with this one since the other designs' capacities ranged from 3000 kW to 4700 kW.

4.2.4 References

https://vittana.org/11-prevailing-solar-farms-pros-and-cons
https://innovativesolarsystemsllc.com/2019/08/why-solar-benefits-of-solar-farms/
https://www.nrel.gov/docs/fy17osti/66218.pdf (Solar Farm and Native Vegetation Restoration, Beatty, et. al)