Student C, Student E
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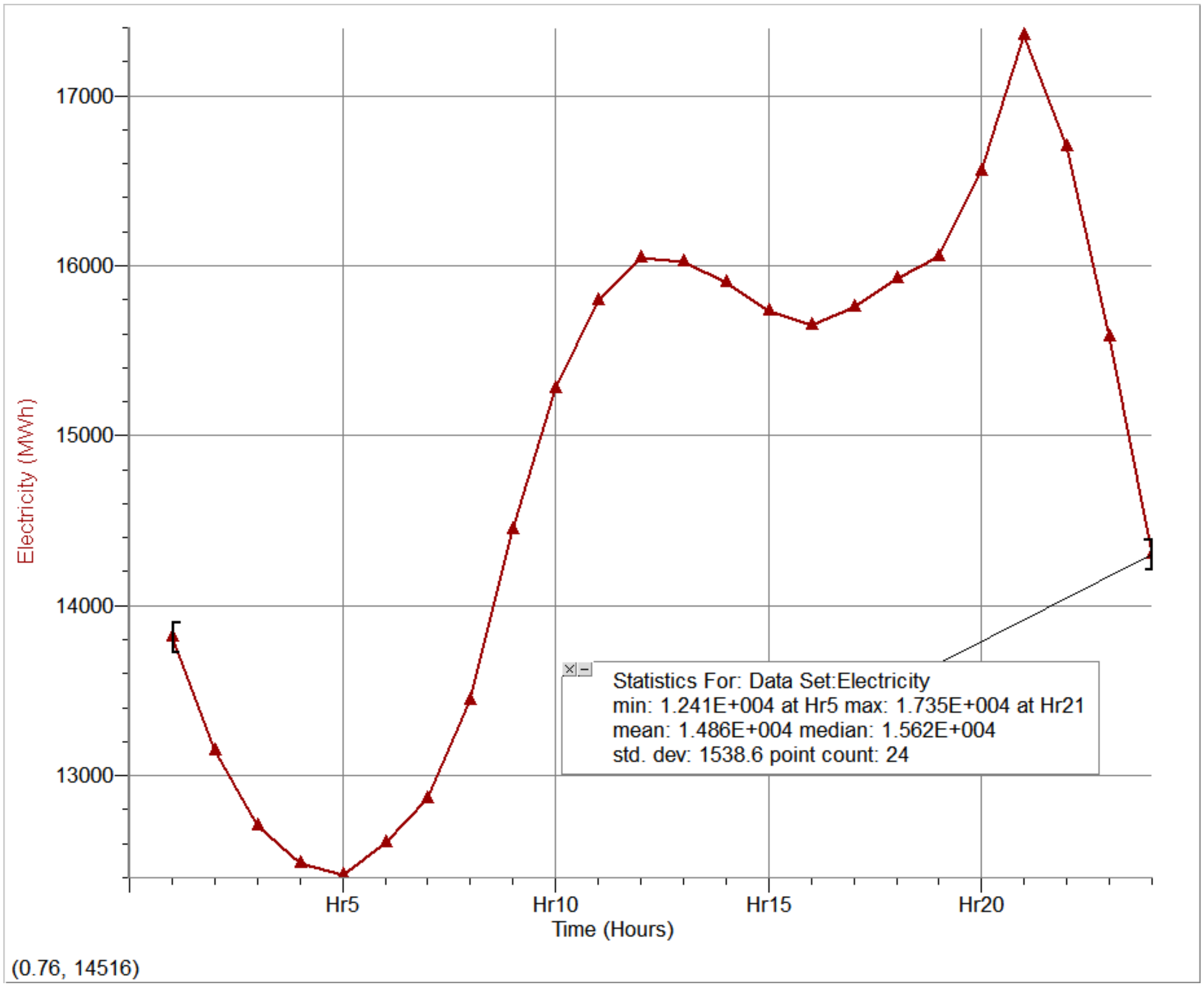
Project 1A: Problem and Constraint Definition

The United States generates over 4,110 million MWh of electricity each year, costing $400 billion and emitting 2.5 billion metric tons of carbon dioxide (Yildiz, 2010). Additionally, the United States' total electricity consumption has increased annually by an average of one percent over the past ten years (U.S. Total Electricity Consumption, 2010). This presents a major problem for the United States as the costs and environmental impacts of fossil fuels continue to increase. Solar power generation presents a unique opportunity to alleviate the United States' energy problem. Once solar cells are manufactured, they produce no waste emissions and utilize abundant solar energy. Current crystalline silicon cells take about four years to collect enough energy payback, while newer thin film cells will be able to reduce the energy payback period to a year or less (Learning About PV: The Myths of Solar Electricity, 2008). After this payback period, solar cells become net positive and can offset the pollution and carbon emissions produced by fossil fuels. Photovoltaic cells also can reduce transmission losses through local power generation. Installing solar cells on rooftops puts electricity generation right next to consumers, as opposed to centralized power plants that must transmit electricity over long distances. The problem that we face is how to properly implement solar energy in the United States in a way that minimizes costs and promotes sustainable growth in the future.

One of the most prominent constraints to solar power is its ability to only collect energy during the day. Without storage systems or backup generators, the United States cannot rely on solar energy for a large share of its power generation. However, solar power can be used for peak leveling, since grid loads tend to peak during the daytime. Conventional peak generation by natural gas is also typically expensive, so solar energy would be competitive for this application. A graph of the grid load for the NYC/Long Island area on April 18, 2010 shows how there is a peak during the day time at around noon (NYISO Hourly Loads, 2010).



While electricity from photovoltaics costs between 15 to 25 cents per KWh (Learning About PV: The Myths of Solar Electricity, 2008), in a city like New York City, where the grid is strained and cannot transmit much more electricity from outside, photovoltaics provide an opportunity for local power generation. In such cases, consumers can also invest in expensive, high-efficiency solar modules to produce more electricity with smaller roof/land usage.

Extrapolating from the New York City data, the difference between the peak load and base load (minimum load) is about 30 to 40 percent of the peak load. However, since much of the peak load occurs after sunset, let us limit the deployment of photovoltaics to 15 percent of the peak load to reduce the need for energy storage or backup generators. The United States summer peak load was 752,420 MW in 2008 (Yildiz, 2010). 15 percent of this would be 112,870 MW. If we use the cheapest photovoltaic cell technology, Cadmium Telluride, the total costs for installation would be $110 billion at 98 cents per watt. The total land usage would 1,505 square km at 75 watts per meter (Rosenblat, 2009). Land usage should not be a problem since there is much available space on rooftops and parking lots. Alternatively, solar panels can be installed in the estimated 20,000 square kilometers of "brownfields", or abandoned industrial sites in the U.S. (Learning About PV: The Myths of Solar Electricity, 2008).

Another constraint for the implementation of solar energy is the need for local inverters. Since solar panels only produce DC current, solar panels need inverters to convert the current to AC before it can be used in the grid. This produces an engineering obstacle for designing a safe and efficient power grid if every household in the United States generated power for the grid. Local power generation creates "island" hazards for maintenance workers, as rooftop panels continue to input power to the grid when utility companies shut down a section for repair. Thus, local solar panels must have smart grid connections to detect when grid power is disconnected for repairs or maintenance. The panels themselves must also be cleaned once in a while to maintain efficiency. While looking at the possible construction of solar farms in desert regions, engineers must take into consideration the amount of water and resources it takes to clean dust off panels.

In the end, cost is the main constraint to solar power. Solar power generated by photovoltaics is more expensive than most conventional power generation and requires large upfront costs to consumers. However, if utility companies implement payback programs for excess power generation by home rooftop panels, homeowners can easily pay back their initial investments and even earn profits. For example, if homeowners were to install a standard 1 kW Cadmium Telluride module, they will be able to completely pay off the initial costs in three and a half years, assuming that the sun shines brightly eight hours a day and using the 2008 average retail price per kWh of 9.74 cents (Yildiz, 2010). Since a Cadmium Telluride cell should last at least 15 years, a 1 kW module should be able to make a net profit of $3286.

In implementing solar photovoltaics in United States power generation, we still have many obstacles to overcome. Nevertheless, with decreasing costs and improving efficiencies, the solar power industry is growing by more than 35% a year (Learning About PV: The Myths of Solar Electricity, 2008) and will become a major player in energy generation.

Works Cited

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