Electrical Engineering Department Project, 2018
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Design

System Overview:

Columbia secondary school has requested a solar panel system that will accommodate the needs of their school garden. Our solar panel system will be located in front of Pupin Hall and consists of 12 solar panels with dimensions 39.7 x 26.7 x 1.4 inches. Students from the secondary school will come daily to collect their Windy Nation 12V charged battery. They will also bring back their uncharged battery from the previous day to be recharged.

Our design has been greatly simplified to accomodate to the available materials and simplifying the design process. However, an overview of our calculations regarding the the materials can be found in the calculations section. Our goal is to be able to power the Garden AC System for 2 hours at 120V and 20 amps.

The Solar Panel:

We narrowed our panels down to two candidates:

Renogy 100 Watt 12 Volt Polycrystalline Solar Panel

Maximum Power	100W
Optimum Operating Voltage	17.8 V
Optimum Operating Current	5.62 A
Weight: 16.5 lbs	Dimensions: 39.7 x 26.7 x 1.4 inches
Cost	$105

100 Watt Flexible Solar Panel with SunPower Solar Cells from Windy Nation

Maximum Power	100W
Optimum Operating Voltage	17.8V
Maximum Power Point	5.62A
Weight 4.1 lbs (1.85 kg)	Module Dimension (L x W x H) (41.7" x 21.3" x 0.1")
Cost	$179.99

We can see from these two tables that the performance ratings of the two are similar but the monocrystalline 100 Watt Solar Panel is flexible, thinner and lighter. It also costs a lot more (179 vs 105). Due to our needs for a long term power solution that will probably be mounted permanently. We chose the polycrystalline solar panel to save on costs.

Other Materials and Setup:

As for other materials, we choose the following for simplicity and compatibility after careful research. Batteries are chosen to 1) have deep cycling compatibility, 2) be able to hold the necessary 4800 WHr energy needed to power the garden AC system.

Table 1: Other parts

Batteries	12V 100 Amp-Hour Deep Cycle AGM Sealed Lead Acid BatteryX6	\$185x6=\$1110
Inverter	VertaMax 3000 Watt 12V Pure Sine Wave Power Inverter DC to AC	\$416
Regulator	TrakMax 30L LCD MPPT 30A Solar Charge Controller Regulator	\$200

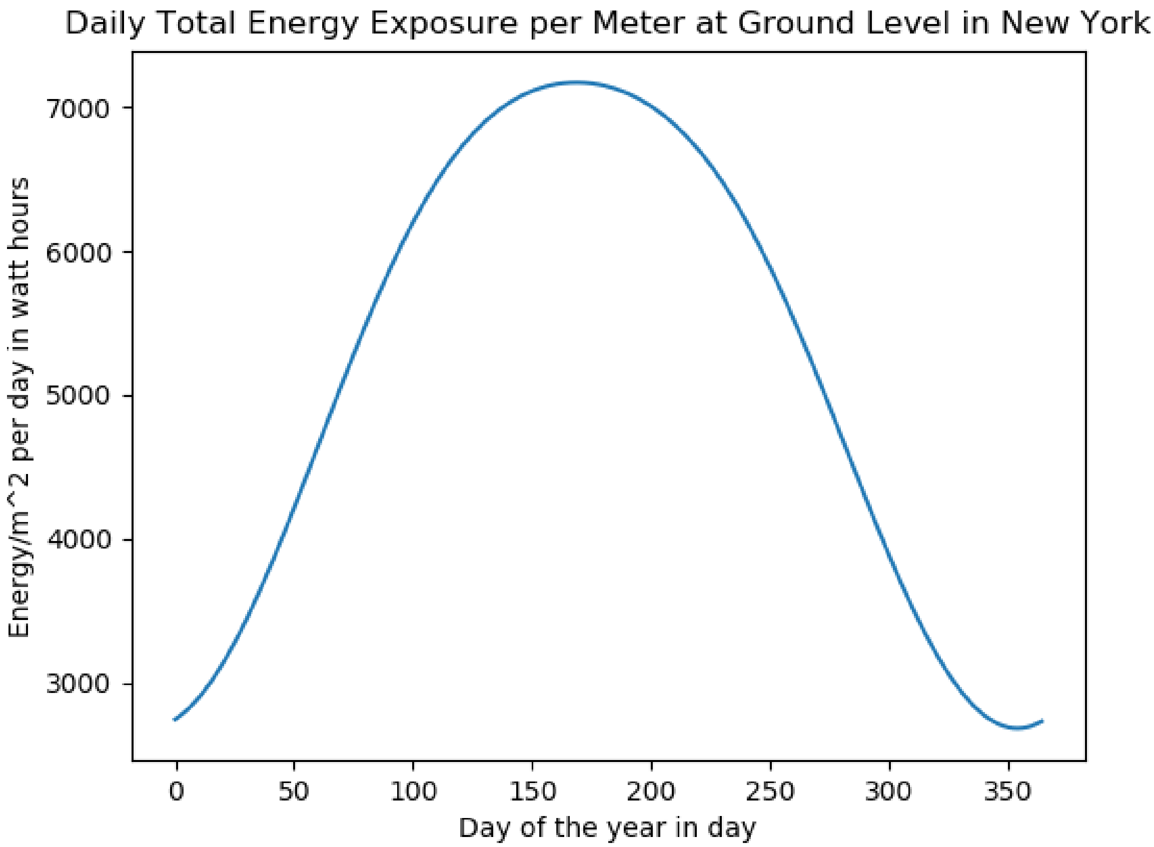
The batteries will be connected in parallel. During charging, it will be connected to the regulator which utilizes MPPT algorithm to maxmize the power output of the solar cell array. The regulator will be connected to the solar cells. The solar cells will be connected in parallel as there will be very little distance between the regulator and the cells: loss due to high amperage energy transfer is minimized. The system is also more immune to the shading problem - one panel shaded will not affect the whole string, a problem worth considering as our system will be surrounded by buildings. 6 batteries will be able to store a total of 7200 WHr of energy. Even though technically only 4 batteries are needed for our need of 4800 WHr, the extra two batteries should be able to hold excess charge in times when the sun has more available energy and can be used as backup power for rainly and the winte days.

When discharging, the batteries will be hooked up to the power inverter which boosts the 12V battery voltage to 120V, allowing the garden AC system to draw the power.

Calculations:

We calculated the amount of Solar Energy expected per square meter in New York with Python. We first calculated the distance of Earth from the Sun as a function. We then took into account of New York's location and Earth's declination angle. Python source code of our calculation is available on github [1] The permittivity of the atmosphere to solar radiation was adjusted to be 0.75 to fit the lowerbound of our model to available official data [2]. A quick reference to other resources finds our assumption rational [3]. We assumed that we are able to obtain around 6 hours of perfect sunlight everyday as our conservative estimate. The advantage of using a model like ours is that we can not only predict how many solar panels we would need to charge our batteries to 4800 watt-hours, we can effectively predict how much solar energy we can expect from the sun each and everyday of the year.

Figure 1: Our solar energy graph for an entire year



Taking the lowest of the year: 2700 Watt-Hours/m^2, which roughly occurs at the 350th day mark, and assuming the efficiency coefficient of the solar panels to be 0.2 and taking into account each solar panel's area: $0.687m^2$, we can roughly approximate how many solar panels we would need.

Each panel output during the day of lowest sun exposure:

$$0.687m^2 \times 0.2 \times 2700WHr/m^2 = 370.98WHr$$

$$4800WHr/370.98WHr = 12.938Panels$$

Since our estimate is extremely conservative (we did not take into account of the left over charge we may have from the previous day or any other time of the year and we have vastly underestimated daylight time), we should be able to round down our estimation and 12 solar panels should be sufficient to run our garden.

A few select points of our data is calculated here and put onto a table:

Table 2: Select Data Points

Day	Total Energy in WHr	# of hours of garden power
1	4719	1.96
50	6875	2.86
100	10173	4.23
150	11716	4.88
200	11569	4.82
250	9755	4.06
300	6459	2.69
350	4436	1.84

Cost

As for total cost Solar panels:

$$105 \times 12 = \$1260$$

We add everything above together, obtaining:

$$1260 + 416 + 200 + 1110 = \$2986$$

Along with installation fees and such, we are estimating a budget proposal of around $3500 for a relatively robust system.

References

[1] https://github.com/billchen99/AOE_SolarPanel/blob/master/solar_alex1.py
[2] *Solar Energy Resource Throughout New York*, http://www.asrc.cestm.albany.edu/perez/publications/
[3] *Solar Energy To Earth http://energyeducation.ca/encyclopedia/Solar_energy_to_the_Earth*