Additional Solar System Information and Resources

Background information

a. Roughly 400 schools in NJ already have solar systems, producing more than 91 MW, out of approximately 2500 K-12 schools in NJ.
b. The median size of K-12 PV systems in NJ is 89kW (equivalent to 10-20 residential systems).
c. The largest one is Lawrenceville School's 6.1 MW system. All 7 schools in Lawrence Township have solar systems.

Resources:

d. Case studies
e. How-to guides
    i. https://www.youtube.com/watch?v=QbIuB7Ojp1A
    ii. http://www.affordable-solar.com/Learning-Center/Building-a-System/Calculating-Tilted-Array-Spacing
    iii. http://www.affordable-solar.com/Learning-Center/Building-a-System/Sizing-Grid-Tied-Solar-Arrays
f. Other potential Calculators (optional):
    i. http://www.valentin-software.com/en/products/photovoltaics/0/pvsol-online-calculation (PVSol - Free online tool)
    ii. http://www.pvsyst.com/ (PVSyst)
    (Each of these has a 30-day free trial)
    iii. http://www.pvlighthouse.com.au/calculators/calculators.aspx
g. http://www.njcleanenergy.com/renewable-energy/programs/srec-registration-program/pvwatts-instructions
h. http://www.njcleanenergy.com/renewable-energy/programs/net-metering-and-interconnection
i. http://www.njcleanenergy.com/renewable-energy/program-updates/solar-act/solar-act-proceedings-archive

j. EIRC — NJ Sustainable Schools Consortium

The following is from http://www.affordable-solar.com/Learning-Center/Building-a-System/:

Sizing a Grid-Tied System

Correctly sizing grid tied solar arrays is critical in today's solar market. Most utility rebate programs only pay back for the total amount of energy used at the site, and money that could have been earned from over-producing is lost. Because of this, the penalty for over-sizing a solar array is a less cost-effective system and a longer payback. In an industry where every penny per watt is important, it is very important that the solar array be sized accurately to the site-specific electric usage, array orientation, and the type of equipment used.

There are three variables in a basic array sizing calculation, the equation is:

$$\text{System Size (Watts)} = \frac{(\text{Watt hours}) * \eta}{(\text{sun hours})}$$

Where η is the DC to AC system efficiency, Watt hours are obtained from your utility bill, and sun hours are found using an online calculator from the National Renewable Energy Laboratory (NREL). All of these factors are described and expanded on, so there is a clear understanding of everything that affects the size of the solar array, and more accurate system sizes can be calculated. Once values for all three are obtained, it's a simple matter of plugging and playing to get the solar array size in watts.

(Read the rest here: http://www.affordable-solar.com/Learning-Center/Building-a-System/Sizing-Grid-Tied-Solar-Arrays)

The Inverter

The inverter is one of the most important and most complex components in an independent energy system. To choose an inverter, you don't have to understand its inner workings, but you should know some basic functions, capabilities, and limitations. This article gives you some of the information you'll need to choose the right inverter and use it wisely. (Read the rest here: http://www.affordable-solar.com/Learning-Center/Building-a-System/choosing-inverter

More at http://www.affordable-solar.com/Learning-Center/Solar-Basics

Here is a somewhat differently worded set of instructions if any of the above seem insufficient or difficult to follow, with examples provided:

Major system components

Solar PV system includes different components that should be selected according to your system type, site location and applications. The major components for solar PV system are solar charge controller, inverter, battery bank, auxiliary energy sources and loads (appliances). For further details you can visit http://www.wholesalesolar.com/gridtie.html for examples of components

- **PV module** – converts sunlight into DC electricity.
- **Solar charge controller** – regulates the voltage and current coming from the PV panels going to battery and prevents battery overcharging and prolongs the battery life.
- **Inverter** – converts DC output of PV panels or wind turbine into a clean AC current for AC appliances or fed back into grid line.
- **Battery** – stores energy for supplying to electrical appliances when there is a demand.
- **Load** – electrical appliances that connected to solar PV system such as lights, radio, TV, computer, refrigerator, etc.
- **Auxiliary energy sources** – diesel generator or other renewable energy sources.

Solar PV system sizing

1. **Determine power consumption demands**

The first step in designing a solar PV system is to find out the total power and energy consumption of all loads that need to be supplied by the solar PV system as follows:

1.1 Calculate total Watt-hours per day for each appliance used.

Add the Watt-hours needed for all appliances together to get the total Watt-hours per day which must be delivered to the appliances.

1.2 Calculate total Watt-hours per day needed from the PV modules.

Multiply the total appliances Watt-hours per day times 1.3 (the energy lost in the system) to get the total Watt-hours per day which must be provided by the panels.

2. Size the PV modules

Different size of PV modules will produce different amount of power. To find out the sizing of PV module, the total peak watt produced needs. The peak watt (Wp) produced depends on size of the PV module and climate of site location. We have to consider "panel generation factor" which is different in each site location. To determine the sizing of PV modules, calculate as follows:

2.1 Calculate the total Watt-peak rating needed for PV modules

Divide the total Watt-hours per day needed from the PV modules (from item 1.2) by 3.43 to get the total Watt-peak rating needed for the PV panels needed to operate the appliances.

2.2 Calculate the number of PV panels for the system

Divide the answer obtained in item 2.1 by the rated output Watt-peak of the PV modules available to you. Increase any fractional part of result to the next highest full number and that will be the number of PV modules required. Result of the calculation is the minimum number of PV panels. If more PV modules are installed, the system will perform better and battery life will be improved. If fewer PV modules are used, the system may not work at all during cloudy periods and battery life will be shortened.

3. Inverter sizing

An inverter is used in the system where AC power output is needed. The input rating of the inverter should never be lower than the total watt of appliances. The inverter must have the same nominal voltage as your battery.

For stand-alone systems, the inverter must be large enough to handle the total amount of Watts you will be using at one time. The inverter size should be 25-30% bigger than total Watts of appliances. In case of appliance type is motor or compressor then inverter size should be minimum 3 times the capacity of those appliances and must be added to the inverter capacity to handle surge current during starting.

For grid tie systems or grid connected systems, the input rating of the inverter should be same as PV array rating to allow for safe and efficient operation.

4. Battery sizing

The battery type recommended for using in solar PV system is deep cycle battery. Deep cycle battery is specifically designed for to be discharged to low energy level and rapid recharged or cycle charged and discharged day after day for years. The battery should be large enough to store sufficient energy to operate the appliances at night and cloudy days. To find out the size of battery, calculate as follows:

4.1 Calculate total Watt-hours per day used by appliances.

4.2 Divide the total Watt-hours per day used by 0.85 for battery loss.

4.3 Divide the answer obtained in item 4.2 by 0.6 for depth of discharge.

4.4 Divide the answer obtained in item 4.3 by the nominal battery voltage.

4.5 Multiply the answer obtained in item 4.4 with days of autonomy (the number of days that you need the system to operate when there is no power produced by PV panels) to get the required Ampere-hour capacity of deep-cycle battery: Battery Capacity (Ah) = Total Watt-hours per day used by appliances x Days of autonomy (0.85 x 0.6 x nominal battery voltage)

5. Solar charge controller sizing

The solar charge controller is typically rated against Amperage and Voltage capacities. Select the solar charge controller to match the voltage of PV array and batteries and then identify which type of solar charge controller is right for your application. Make sure that solar charge controller has enough capacity to handle the current from PV array. For the series charge controller type, the sizing of controller depends on the total PV input current which is delivered to the controller and also depends on PV panel configuration (series or parallel configuration). According to standard practice, the sizing of solar charge controller is to take the short circuit current (Isc) of the PV array, and multiply it by 1.3 Solar charge controller rating = Total short circuit current of PV array x 1.3 **Remark**: For MPPT charge controller sizing will be different. (See Basics of MPPT Charge Controller)

Example: A house has the following electrical appliance usage:

- One 18 Watt fluorescent lamp with electronic ballast used 4 hours per day.
- One 60 Watt fan used for 2 hours per day.
- One 75 Watt refrigerator that runs 24 hours per day with compressor run 12 hours and off 12 hours.

The system will be powered by 12 Vdc, 110 Wp PV module.

a. Determine power consumption demands

Total appliance use = (18 W x 4 hours) + (60 W x 2 hours) + (75 W x 24 x 0.5 hours)

= 1,092 Wh/day

Total PV panels energy = 1,092 x 1.3

needed	
	= 1,419.6 Wh/day.
b. Size the PV panel	
2.1 Total Wp of PV panel capacity needed	= 1,419.6 / 3.4
	= 413.9 Wp
2.2 Number of PV panels needed	= 413.9 / 110
	= 3.76 modules

Actual requirement = 4 modules

So this system should be powered by at least 4 modules of 110 Wp PV module.

6. Inverter sizing

Total Watt of all appliances = 18 + 60 + 75 = 153 W. For safety, the inverter should be considered 25-30% bigger size. **The inverter size should be about 190 W or greater.**

7. Battery sizing

Total appliances use = (18 W x 4 hours) + (60 W x 2 hours) + (75 W x 12 hours)
Nominal battery voltage = 12 V
Days of autonomy = 3 days
Battery capacity = [(18 W x 4 hours) + (60 W x 2 hours) + (75 W x 12 hours)] x 3 (0.85 x 0.6 x 12)
Total Ampere-hours required 535.29 Ah
So the battery should be rated 12 V 600 Ah for 3 day autonomy.

8. Solar charge controller sizing

PV module specification
Pm = 110 Wp
Vm = 16.7 Vdc
Im = 6.6 A
Voc = 20.7 A
Isc = 7.5 A
Solar charge controller rating = (4 strings x 7.5 A) x 1.3 = 39 A. **So the solar charge controller should be rated 40 A at 12 V or greater.**

Suggest standard panels — size, capacity, & efficiency?

In addition, there is a 60-page design guide created by HeatSpring. Here’s the table of contents:

Here's where students and teachers can download it: http://blog.heatspring.com/solar-basics/