CDFS-4102-14

## Farm Energy Fact Sheet Series

# Estimating the Size of Your Solar Electric System

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## Introduction

Farms have many energy demands to perform daily tasks. Electric power is a simple and clean option to complete many of the energy demanding jobs. Generating on-farm renewable energy with solar electric systems has the potential to stabilize and reduce the annual energy costs for the farm. Before making an investment in a system, it is important to understand the scope and scale of a solar electric system that will be required to meet your goals. Proper sizing will match the electric needs of the farm to an efficiently sized and priced solar electric system. When considering an on-farm solar electric system, the first goal is to accurately estimate your electric usage and determine what size solar electric generation can be developed to meet some or all of the usage. Most solar electric developers/installers offer a service to size a system for your farm based on their experience and on-site measurements. You can use the following information to understand the developer's approach and/or conduct a sizing estimate of your own.

## Consider a Energy Audit

On-farm solar electric generation is about reducing the amount of electricity you purchase from the utility. Before investing in an on-farm solar electric system, you should conduct an energy assessment to identify strategies to reduce your energy use and integrate energy efficiency practices. A farm or agricultural business energy audit should be considered as part of the process. An energy audit can typically be done by your local electric provider or a recommended consulting firm. In some cases, the cost of the energy audit can be reimbursed by your local provider as many are supportive of reducing peak electric demands of their customers. Energy audits identify inefficient uses of energy and/or the timing of peak demand operations in the business. Both approaches can yield some energy cost savings.

## Understanding Your Usage

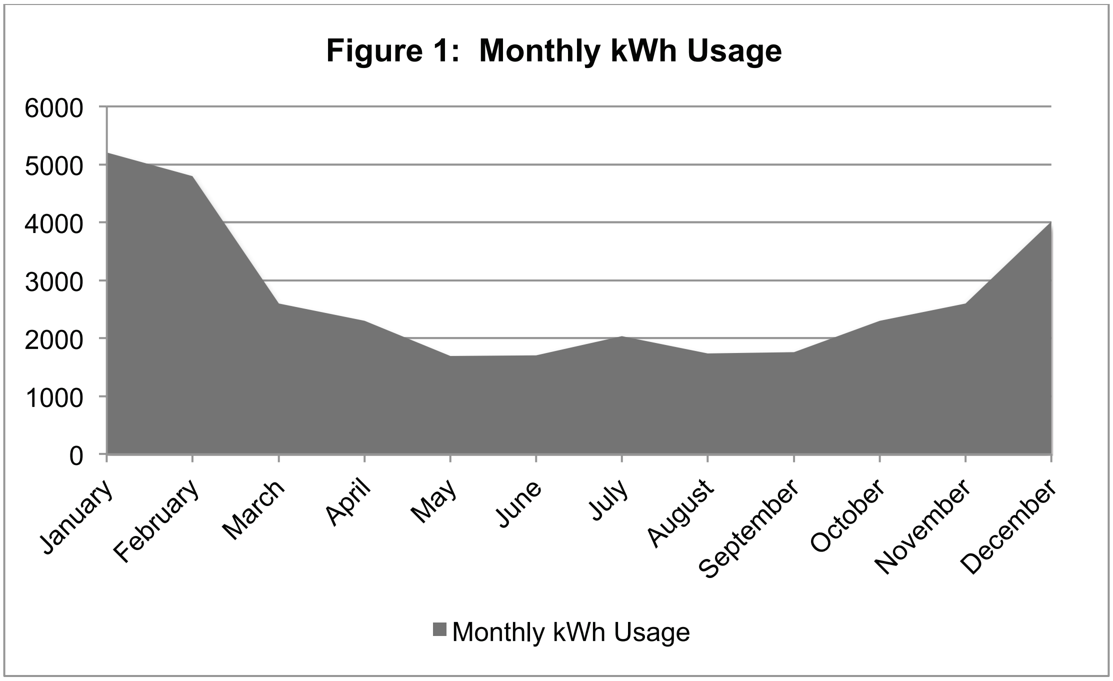
Collecting data is important to knowing where to begin. Your own data about electric usage is the most valuable because the specifics of your farm are unique to a proper sizing of solar electric generation. Gather all of your electric bills for the past 12 months and assess each one. You may have a bill that has specific electric meter data for different parts of the home, farm or agriculture business. Locate the section of the bill that gives the number of kilowatt-hours (kWh) used. Write down on a piece of paper or a spreadsheet the name of the first month and the kWh used during that month. Do this for the previous 12 months, up to the current month. You may begin to see trends and relationships specific to your business related to your electric usage. Add up the total kWh for those 12 months to calculate the number of kilowatt-hours you used during that 12-month period. Once you have the total, divide it by 12. This will give you the average monthly kWh usage on an annual basis for that electric meter.

For example, figure 1 illustrates the monthly kWh usage on a small swine and goat operation in southern Ohio with a farrowing house, nursery, and kidding facility. In this example, the average monthly usage over a 12-month period is 2,705 kWh. Ventilation fans are used throughout the year, heaters in each barn, and several heat lamps in the fall and winter that contribute to a peak electrical usage of 5,200 kWh in January.

If you don't have your electric bills for the past 12 months, you may contact your electricity provider and they can help determine your monthly and annual kWh usage.

## Farm Energy Log

Another approach to understanding your electricity usage is to keep an energy log. An energy log is a record of the amount of energy used on your farm or business




during a specific period of time. A farm energy log is no different than tracking your spending to increase savings or counting calories to lose weight. It is a record of the electric devices you use, how long you use them, and the rate the device uses electricity. An electric motor or equipment typically is rated as to how many watts of power it uses. A simple equation is used to determine the watt-hours even if the watts are not rated on the device. The device runs using a determined number of amps. The equation **amps X volts = watts** can be used. If the device runs on 5 amps and is on a 120 volt electric circuit, the watts are 600. If the 600 watt device is used for 125 hours per year, the annual usage is 75 kWh (600 watts X 125 hours/1000 = 75 kWh). There also are many simple low-cost devices that can be used to measure energy usage directly at the receptacle or circuit.

The energy log would be used to record multiple devices used on the farm or agricultural business. It is important that the amount of energy used is tracked in addition to the cost per energy unit. Cost per energy unit can be determined from the monthly electric bill by dividing the amount of the bill by the kWh used during the billing period or by contacting the electric provider. The farm energy log is a simple procedure. You can start now or consider gathering past bills and entering old data. Attachment A provides a sample energy log modified from the *E3A Exploring Energy Efficiency and Alternatives Educators Toolkit* that you can use with your farm or business (University of Wyoming and Montana State University, 2011). An energy log can also help you account for future expansions in your farming operations that may increase electric usage. Proposed expansions may include the addition of electricity demanding equipment that may have specifications describing the electricity usage per device.

## How much electric usage do you want to offset?

When developing an on-farm solar electric system, the goal is to offset a portion or all of your farm's annual electric demand. In Ohio, a policy tool called net metering supports the development of on-farm energy systems. Net metering is a billing arrangement where customers who produce their own electricity can receive a credit on their electric utility bills for any extra electricity produced by the customer that flows back onto the electric utility's distribution system. The excess generation credits are allowed to accumulate until applied against future charges on the customer's electric bill. As of 2013, 43 states have incorporated some type of net metering policy. Ohio's net metering policy applies to the states' investor-owned utilities and has no specified capacity limit. According to Ohio Administrative Code (OAC 4901: 10-28) a net-metered system should be designed to offset part of or all of the customer's electric requirements, but not exceed usage on a 12-month basis. Rural electric cooperatives and municipal electric utilities are not required to offer net metering (The Public Utilities Commission of Ohio, 2014). While not required by law, many of Ohio's rural electric cooperatives and municipal utilities do offer net metering, but may have capacity limits on the system size. A capacity limit would limit the amount of electricity a consumer is allowed to produce and flow back to the utility's distribution system. Contact your rural electric cooperative or municipal utility to find out specific details on their programs.

Several factors should be considered when deciding how much electricity to produce for offsetting electric demand. For example, some farms may have a goal of offsetting 100% of their electric needs with an on-site generation system. However, a goal of offsetting 100% may be limited by factors such as the capital investment required or the development space available for solar electric panels. Another consideration that could impact your offset goals is the variability of your electric demands. Think about grain drying and how some years we dry a lot of grain for proper storage, while other years we may not need to dry as much because of crop rotation or natural drying that occurred pre-harvest in the field. Furthermore, as net metering is applied in Ohio, you will get less for electricity that is put onto the grid and taken off in later months than for electricity generated and used when it is produced. For example, a solar energy system used to offset grain drying in one month may not be as economical as solar electricity used to offset a constant baseload such as ventilation fans, lighting or refrigeration. To account for this variability, be sure to look at your current bills and note the peaks and valleys. A summary of factors that could impact the size of your solar electric system include:

- How much money do I have to invest in a solar electric system?
- How much space do I have available for development?
- Does my utility provider have capacity limits restricting the size of my system?
- Do I have future plans for expansion on the farm that will add electric demanding equipment or buildings?
- Is my electric usage fairly consistent or variable?

Although you may want to generate all of your electricity with the sun, many solar electric system owners begin with a small system to supplement their main supply of electricity. A small system means fewer upfront costs and the ability to gauge how much generating capacity is necessary (National Renewable Energy Laboratory, 2002). In addition, generating a fraction of your usage is more economical on a kWh basis than generating closer to 100% of your usage.

## Daily Solar Radiation

There are several factors that determine the solar radiation for your location. Major factors are location on the earth (latitude and longitude), season, time of day, the climate (weather conditions), and air pollution. The unit of measure for solar radiation is $kWh/m^2/day$.

Within Ohio, the maximum June radiation ($kWh/m^2/day$) for flat-plate collectors facing south on a latitude tilt at various locations are: 5.7 (Toledo), 5.3 (Youngstown), 5.5 (Akron), 5.5 (Mansfield), 5.5 (Cleveland), 5.4 (Columbus), and 5.6 (Dayton). June experiences the maximum radiation rate due to the length of daylight and the orientation of the sun to the earth's surface. Radiation rates for Toledo in December and January are 2.2 and 2.8, respectively. Toledo's annual average radiation rate for the mentioned collector is 4.4. Based on some examples in Ohio, a good estimate is that you can expect 1,100 kWh per installed kW of solar per year in Ohio.

## Steps to Estimating System Size

The size of the solar electric system can be estimated by using the data collected about the proposed site, monthly kWh usage, and the output of a solar panel. The following steps have been modified from the U.S. Department of Energy fact sheet titled *How to Size a Grid-Connected Solar Electric System* and will organize your data into calculations to estimate the size of the solar electric system.

1. Identify annual energy use from your utility bill (kWh).
2. Subtract kWh you will eliminate with conservation and energy efficiency (kWh).
3. Divide by 1100 kWh/yr per installed kW. This represents a system providing 100% of your electricity (kW).
4. Multiply by the percent of your electricity you would like to provide using solar energy (kW).
5. Multiply by 1000 to give the size in Watts (W).
6. Multiply by 1.2 for system inefficiency (W).
7. Divide this number by the peak energy production from the solar panels you are considering (e.g. 250 W).

Using the small swine and goat operation example in southern Ohio, chart 1 demonstrates the 7 step process to estimate a solar electric system size in Ohio. As identified in figure 1, the average monthly kWh used over a 12-month period on this farm is 2,705 kWh, with a total of 32,460 kWh annually.

By using the right column, you can use the calculations of the example with your specific data. Once you have the estimated size of your system as identified in step 4 above (22.4 kW), you can use online calculators to further estimate the system's performance. The National Renewable Energy Laboratory (NREL) has developed an electronic design tool called the PVWatts Calculator (**pvwatts.nrel.gov**). The PV Watts Calculator uses satellite images of your street address and allows you to overlay a potential solar energy system on the site. The calculator also provides a monthly estimate of kWh that

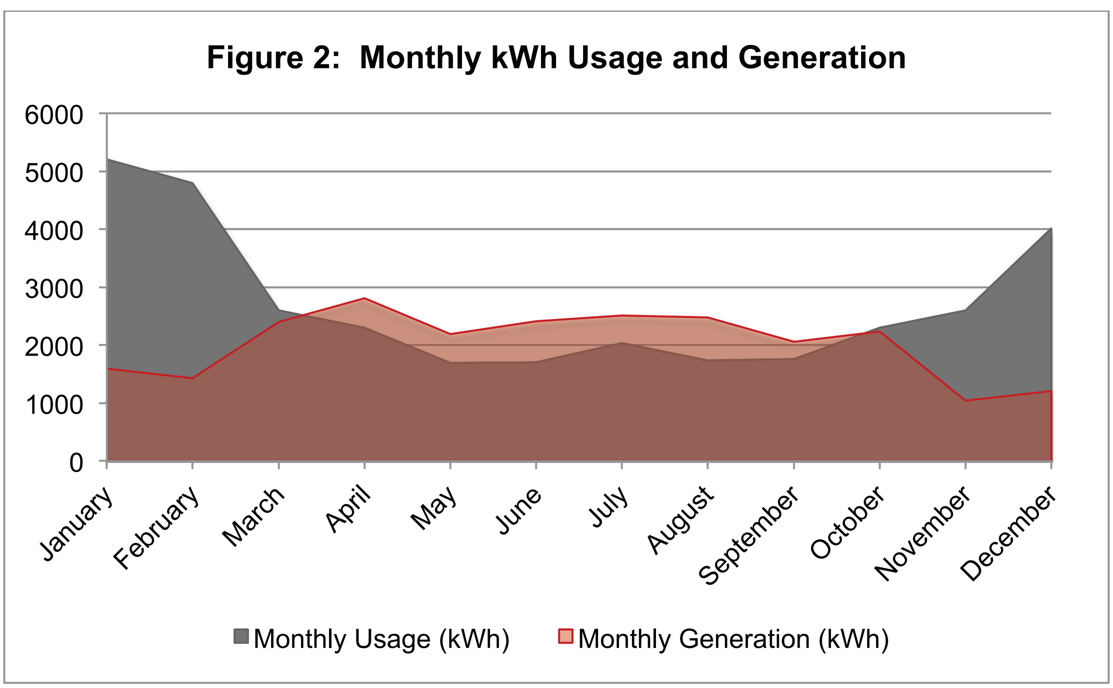
**Chart 1: How to Estimate System Size**

| Step | Data | Ohio Farm Example | Your Farm/Business |
|---|---|---|---|
| 1 | Identify annual kWh used | 32,460 kWh/y | |
| 2 | Subtract kWh reduced by conducting an Energy Audit | 32,460 – 5,000 = 27,460 kWh/y | |
| 3 | Divide by 1100 kWh/y per kW | 27,460 (kWh/y) / 1100 (kWh/y/kW) = 24.9 kW | |
| 4 | Multiply by percent of electricity to offset (90%) | 0.9 x 24.9 = 22.4 kW | |
| 5 | Multiply by 1000 to give the size in Watts | 22.4 kW x 1000 W/kW = 22,400 W | |
| 6 | Multiply by 1.2 to cover system inefficiencies | 22,400 x 1.2 = 26,880 W | |
| 7 | Divide by the kW size of each solar panel | 26,880 W / 250 W = 107 panels | |

your system will generate. Figure 2 provides an overlay view of the electricity used and electricity generated for the small swine and goat barn example as estimated by the PVWatts Calculator. This helps to illustrate how net metering works as the system would generate more electricity than the barn uses in the summer months, and would receive credit for excess generation that can be recovered in the winter months when usage is higher. However, it is important to remember that at the end of a 12-month period, you must be a net user of electricity, not a producer.

## How Much Space Will I Need?

As discussed earlier, one factor that could limit the amount of electricity offset by an on-farm solar electric system is the amount of space available for development. To calculate the area of a solar electric system needed, multiply the number of panels calculated above by the area of each panel (length x width). Multiply this number by 1.05 to account for spacing between panels. This is the roof area or ground area that would be needed for the number of panels calculated above. As a general guide, a solar electric system will require 100 square



feet of rooftop (or yard space) for every kilowatt (kW) of electricity produced (National Renewable Energy Laboratory, 2009). By familiarizing yourself with the data and the steps to estimate a system size, you can more accurately visualize how different size panels will impact the overall footprint required for development.

For instance, step 7 in the example recommends you divide the total system watts by the peak wattage rating of the solar electric panel. In this example we used 250-peak watt panels, which suggests the system would require 107 panels. In comparison, as illustrated in chart 2, if you were to substitute 140-peak watt panels in this example, the system would require 192 panels. As discussed in this example, if space is a potential limiting factor to the size of your system, you can decrease the system footprint by increasing the efficiency of your panels or revising the percent of electricity (step 5) to offset with on-farm system.

**Chart 2: Space Requirement**

| Panel Type | Size (L x W) | Sq. Ft. Per Panel x Panels Required | | Total Space Required |
|---|---|---|---|---|
| 140 watt | 59" x 26" | 10.6 | 192 | 2,035 sq. ft. |
| 250 watt | 65" x 39" | 17.6 | 107 | 1,883 sq. ft. |

## Summary

Using the steps outlined in this fact sheet will provide you with a general estimate of the solar electric system size that is required to meet your needs. The steps are designed to help you better understand the factors that impact system size but should not be the only source used to size a system. Many online tools and system calculators can be used to confirm your projections. Ultimately the solar electric developer/installer can conduct an analysis that will take into account more details and generate a more comprehensive system design.

## Additional Resources

E3A Exploring Energy Efficiency and Alternatives Educators Toolkit—**e3a4u.info**

Energize Ohio: On-Farm Renewable Energy Tools—**energizeohio.osu.edu/farm-renewable-energy-development**

NREL PV Watts Calculator—**pvwatts.nrel.gov**

NREL Cost of Renewable Energy Spreadsheet Tool (CREST)—**financere.nrel.gov/finance/content/crest-cost-energy-models**

## References


National Renewable Energy Laboratory. (2002, August). *How to Size a Grid-Connected Solar Electric System*. Produced for the U.S. Department of Energy. DOE/GO-102002-1607.

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## Attachment A: Electric Use Worksheet

### Electricity Use Worksheet

**Address:** **Calculated by:** **Date:**

| Electrical Device | *Wattage (Volts x Amps = Watts) | X | # of Hours Used Per Day (when used) | X | # of Days Used Per Year | = | Watt-hours Used Per Year | Divide by 1,000 = kWh | Kilowatt-hours (kWh) Used Per Year |
|---|---|---|---|---|---|---|---|---|---|
| Electric Motor | 600 watts | X | 2 | X | 62 | = | 124 | 74,400 / 1,000 | 74.4 kWh |
| | | X | | X | | = | | 1,000 | |
| | | X | | X | | = | | 1,000 | |
| | | X | | X | | = | | 1,000 | |
| | | X | | X | | = | | 1,000 | |
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| | | X | | X | | = | | 1,000 | |
| | | X | | X | | = | | 1,000 | |
| | | X | | X | | = | | 1,000 | |
| **Electrical Device** | ***Wattage (Volts x Amps = Watts)** | **X** | **# of Hours Used Per Day (when used)** | **X** | **# of Days Used Per Year** | **=** | **Watt-hours Used Per Year** | **Divide by 1,000 = kWh** | **Kilowatt-hours (kWh) Used Per Year** |
| | | X | | X | | = | | 1,000 | |
| | | X | | X | | = | | 1,000 | |
| | | X | | X | | = | | 1,000 | |
| | | X | | X | | = | | 1,000 | |
| | | X | | X | | = | | 1,000 | |
| | | | | | | | | 1,000 | |
| | | X | | X | | = | | 1,000 | |
| | | X | | X | | = | | 1,000 | |
| **Total Kilowatt-hours(kWh) used per year** | | | | | | | | | |
| **Divide by 12 for Average kWh Used per Month** Use this number for the solar system sizing worksheet | | | | | | | | | |

* An electrical device has a metal plate/sticker showing **wattage** on or near the back or side. If not shown, use the amperes (amps) number times the voltage to get wattage. Most U.S. appliances use 120 volts. Larger appliances (electric clothes dryers and cooktops) use 240 volts.

- **Refrigerators:** Because they cycle on and off to maintain a set temperature, divide the total time the refrigerator is plugged in by 3.
- **Phantom loads** are electrical loads used by devices even when they are turned "off." These loads can increase a device's consumption by up to 15 watts. Avoid this unnecessary "stand-by" consumption by unplugging electronics and appliances when not in use or by plugging them into a power strip (or surge protector) and using its on/off switch.