Solar and Wind Energy for Greenhouses

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Introduction

You know the story: energy prices are rising rapidly and fuel oil prices are breaking records on an almost daily basis. As our economy is slowing down, consumers are spending less on non-essentials, including ornamental plants. It is no surprise that many greenhouse growers are wondering how they will survive. One strategy is to lower energy consumption, for example by becoming more energy efficient, or by using alternative energy sources. Though a lot of attention has been given to biomass as an alternative fuel source (e.g., wood, corn, switchgrass), this article will focus on solar and wind energy.

Solar Energy

Plants need sunlight for photosynthesis, so typical greenhouse glazing materials are designed for maximum light transmission. However, since sunlight can become too bright for optimum plant production, shade curtains are used to control the light intensity at crop level. The glazing material and the shade curtain have a significant impact on the heat loss (and gain) of a greenhouse, so designers compromise between light transmission and energy management. While plants convert sunlight into biomass production, photovoltaic (PV) panels convert it into electricity. The conversion efficiencies of PV panels have increased over the years to as high as 17% at maximum light intensity. Some experimental PV cells have achieved efficiencies of 40%. PV panels should be mounted for maximum light interception. In the Northern hemisphere, panels can be attached to south-facing roofs or other support structures (Photo 1), or on a tracking device that follows the position of the sun across the sky. Typical PV panels do not transmit sunlight, so installation on greenhouse roofs is not recommended. PV panels generate DC power that can be converted to AC power to operate greenhouse equipment. PV systems can be interconnected with the local electrical grid, ensuring that electrical power is available unless there are local power outages. In a grid-connected system, excess power from the solar installation can be sent to the grid. Interconnection requirements vary from state to state and utility to utility. Off-grid PV systems require some form of electrical storage to provide power during periods of little or no sun. Typically, banks of batteries are installed for this purpose. Off-grid systems are best suited to applications where there is no nearby electrical grid and electrical loads are fairly consistent.

A significant portion of sunlight reaches the surface of the Earth as heat radiation. We can use this energy to heat water. Typically, not much water is needed for washing and cleaning purposes, but growers can use warm water to heat the greenhouse. The most solar energy can be collected during the middle of the day, so storing the warm water for use during the night is a good strategy to reduce the use of heating fuel. The rising heating fuel prices make long term storage of warm water more attractive. This strategy would allow for energy collection during the sunnier months of the year, to be used during the darker (and colder) months. Long term storage requires large insulated holding tanks or other means (e.g., underground aquifers) to contain the energy. In some cases both warm and cold water storage systems are used allowing for heating as well as cooling of the greenhouse environment. In that case, the use of a heat pump (a reversible refrigerator that can be operated in heating or cooling mode) can prove economical.

There are many technologies for converting incoming solar radiation into heat. The most common systems are flat plate collectors, in which water or other fluids flow through a panel that is oriented toward the sun. Very simple flat plate collectors are often used for heating swimming pools. Slightly more complex systems that may incorporate water storage, insulation behind the panels, and transparent covers in front of the panels are used around the world for heating hot water for domestic use. Flat plate collectors work most efficiently at lower water temperatures. Other systems for converting sunlight into heat include evacuated tube collectors and parabolic reflectors. These products are capable of generating higher temperatures, but are significantly more expensive and often depend on using tracking systems to maintain an optimal orientation. The American Solar Energy Society provides additional information on their web site (http://www.ases.org/).

Wind Energy

Using wind to pump water and generate power is not a new idea. Before the start of rural electrification in 1936, wind energy was widely used across the US. During the last ten years, technology improvements and rising energy prices have significantly increased the number of wind energy installations. In many cases, (large) installations occurred on farmland, but often the farmers are not the main users of the generated energy, nor do they own the equipment. Many farmers only receive a land lease payment for land area used by wind turbines. Today most new wind installations are used to generate electric power.

Obviously, the success of wind energy installations depends on site-specific wind conditions. Coastal and mountainous areas and the Central Plains typically experience higher average wind speeds and are thus more attractive as generating sites. Wind maps have been compiled for all regions of the US and these maps are useful for a first approximation of the average wind speed at a given location (e.g., http://www.nrel.gov/gis/wind.html). However, local topology, vegetation, and building structures significantly affect the average wind speed. Where possible, use local wind speed measurements to determine whether a site is appropriate for wind generation. Currently, an average wind speed of 9 mph for small wind generators and 13 mph for large generators (measured at 100 ft above the ground) is considered necessary for the economical use of wind power (Photo 2).

So what are the options if you want to power your greenhouse with a wind generator? Small wind generators (up to 100 kW in generating capacity) can be used to operate much of the greenhouse equipment, except for possibly a supplemental lighting array simply because of its rather significant power consumption. Such a system can be operated off-grid, but a connection to the grid is preferable. Grid connected systems have the advantage of having power available when the wind system is not functioning at full capacity, and do not require batteries for electrical storage. Large wind installations require a significant investment, are subject to environmental impact reviews, and have not always been embraced by local communities. In some cases, farmers have formed cooperatives to finance such projects, gain community approval, and reduce investment risks. The American Wind Energy Association provides additional information on their web site (http://www.awea.org/).

Grid Connection

Depending on local regulations and laws, so-called net-metering systems can be installed that allow your electricity meter to run 'backwards' when your power generator is producing more than you need. Often, net-metering arrangements allow a producer to deliver to the grid up to their typical use determined over a period of a year. Any excess power delivered to the grid will not result in additional reimbursements. Therefore, larger generating systems that plan to export significant quantities of electricity to the grid require special arrangements with the local electric utility. In many states, electrical utilities are mandated to purchase a specific percentage of their energy from 'green' or renewable sources and could very well be interested in making special arrangements with larger energy producers.

Grant, Loan and Rebate Programs

Local utilities, state and federal organizations offer a variety of grant, loan and rebate programs for alternative energy installations. Each of these programs comes with its own set of requirements and often require cost-sharing. Nevertheless, these programs can reduce the investment costs and/or reduce the pay-back period. Many of these programs are announced on web sites requiring some effort to learn about them. In some states, energy regulating commissions such as a Board of Public Utilities or state energy agencies have programs for renewable energy systems. Your local Extension service, state departments of agriculture, the USDA and the NRCS are good places to start investigating the various opportunities. And don't forget to talk to your local utility.

Renewable Energy Certificates

Some states administer renewable energy certificate (REC) programs that allow certified producers of eligible renewable energy to sell these certificates that represent proof that 1,000 kWh of electricity was produced. Thus, in addition to reducing your electric power consumption from the utility grid (i.e., by lowering your monthly electricity bill or receiving payment for excess electricity you exported to the grid), the RECs generated by your system can provide additional income when sold (e.g., to a power company that was mandated to deliver a certain percentage of its total output as renewable energy). While prices for RECs fluctuate, REC programs provide additional financial incentives for renewable energy production (http://www.eere.energy.gov/greenpower/markets/).

Energy Conservation

But before you consider a solar or wind system for your greenhouse operation, the first step in any renewable energy project is ensuring that the existing system is functioning efficiently. The reason is quite simple: the cost of implementing energy efficiency measures is less than the cost of installing renewable energy technologies to compensate for inefficient use of conventional energy sources. Some of the many ways to achieve better energy performance in greenhouses include using thermal curtains where possible and checking that they seal properly (i.e., form a continuous barrier), verifying that environmental control systems are doing what they are supposed to, and sealing glazing leaks through unintended openings in walls and roofs. Additional energy conservation ideas and techniques can be found at http://www.ofa.org/energy.aspx. A useful reference source is the book titled 'Energy Conservation for Commercial Greenhouses', published by NRAES (http://www.nraes.org).

Photo 1. Solar array at the Blew Family Farm (Oak Grove Plantation) in Pittstown, NJ. The 62 kW system consist of nine racks containing 63 panels each. Each rack has lightning protection and its own power inverter so that the loss of one rack does not affect the others. Similarly, the loss of a single panel does not affect the rest of the panels within a rack. The array was installed in 2006 at a total cost of approximately $10.00 per Watt. The installation was partially financed with federal and state incentives and rebates. The remaining investment cost of approximately $3.00 per Watt is projected to be paid off over a 15-20 year period. Photo by Jack Rabin, New Jersey Agricultural Experiment Station.

Photo 2. Wind turbine. Currently, an average wind speed of 9 mph for small wind generators (up to 100 kW in generating capacity) and 13 mph for large generators (measured at 100 ft above the ground) is considered necessary for the economical use of wind power. Photo by A.J. Both, New Jersey Agricultural Experiment Station.