ENERGY CONSERVATION SERIES:

Renewable Energy in Agricultural Operations

New Jersey

INTRODUCTION

Many alternatives to using conventional fuels and electrical generation can be implemented in agricultural operations. This fact sheet discusses the potential for use of energy from biomass, solar, wind, geothermal and water power. The general concerns that apply to all forms of locally produced energy include capital and ongoing costs, on-site and off-site uses and the specific applicability of different forms of renewable energy to particular farming operations. The viability of any particular form of locally produced energy often depends on current and projected energy pricing as well as the ability to transport excess energy off-site and to import energy when on-site production does not meet current needs.

BASICS OF RENEWABLE ENERGY

The practical and economic viability of renewable energy resources is closely tied to considerations of energy storage and transport. As a rule, excess energy produced on the farm can be either be stored, conveyed elsewhere or consumed on premises. On-site consumption of excess production may not be a cost-effective use of capital resources.

Some energy products are relatively easy to store. Storage of solid fuels (wood, coal, various forms of biomass) is fairly straightforward. Problems in storing solid fuels are mostly related to keeping fuel dry, free of pests (e.g. termites) and ease of handling. Storage of liquid fuels is generally more complex. It is more important to prevent water incursion in liquid fuels. Additionally, liquid storage facilities must address concerns about the consequences of leaks and volatile emissions. Flammability of certain liquid fuels can also be a concern. Storage of significant quantities of gaseous fuels is even more complex. Although water incursion and leakage into soil are not issues, flammability and the potential for explosion may be greater concerns. Large scale storage of gaseous fuels typically requires compression, with attendant energy costs and additional concerns about safety.

Electricity is particularly difficult to store. Batteries are the most common form of electrical storage, although compressed air, pumped water, capacitors and conversion to other forms of energy may be options in some circumstances. Long term storage of large amounts of electrical energy is often too expensive to be financially viable.

Although electricity is difficult to store it is typically the most transportable form of energy, since most electrical users are connected to a large scale electric distribution grid. Other forms of energy are often much more complicated to transport from the farm than electricity. Natural gas pipelines represent another extensive energy supply grid, but issues of quality and quantity as well as legal and logistical obstacles generally preclude moving methane from the farm to other potential users via the natural gas grid. Most other transport from the farm will be in bulk, typically by truck or rail.

Whenever energy is transported to other users, the quality of the energy becomes an issue. For export of electricity, utilities have specific interconnect requirements to ensure that locally generated electricity will not create quality or safety problems. Because locally produced electricity must be compatible with available electrical equipment and, in most cases, with the electrical grid, it is essentially indistinguishable from grid power. This compatibility is not always the case for other site-produced energy. This is most important for energy that is difficult to store, notably gaseous fuels. Site produced methane (biogas) has a significantly lower energy content than pipeline gas and may have a number of contaminants. These characteristics often limit the potential for exporting biogas when there is an excess produced on site. Although solid and liquid fuels are relatively easy to transport and often compatible with off-site uses without further processing, the cost of transportation relative to the cost of on-site storage may favor local use and storage of the energy.

Farm-Scale Wind Turbine
PHOTO: ADAPTED FROM USDA

The issues of energy storage and exportation are important because they have consequences that vary according to the form of renewable energy production on the farm. In particular, when energy export is inexpensive and straightforward, local concerns such as the cycle of demand, cost of storage and ability to expend excess energy at little cost are not very important.

Electrical generation is one of the most common applications of renewable energy, particularly from solar and wind resources. The simplest and often most practical application is to connect the electrical generation system to the local electrical grid. As noted above, this requires generation that is compatible with the electric supply (in the United States, alternating current at 60 Hertz). In many respects, other than their lower carbon footprint, solar, wind and hydro electrical generation look like extensions of the regional electrical generation infrastructure that happen to be situated, operated and maintained on the farm. By contrast, other local energy production, for example, an on-site digester producing methane from animal manures, is a substitute for off premise energy resources that will require various adaptions of both farm infrastructure and operations to make optimum use of the local energy source. For a complete discussion of the use of biomass within American agriculture, as well as a discussion of the difficulties of integrating renewable sources into the grid, see the USDA Rural Development publication "Linking Distributed Electricity Production" (4).

Other than issues of the suitability of a site for a renewable energy facility (solar orientation, wind speeds, etc.) grid-connected electrical generation from solar, wind or hydropower is not substantively different from these forms of power production when situated anywhere else. In most cases, electricity can be exported to the regional grid at the same rates as imported power would cost the consumer. This arrangement, often referred to as net metering, is discussed in more detail below. On the other hand, the viability of biofuels, solar, thermal power, and geothermal energy on a farm depend greatly on the specific characteristics of the farming operation and the design and implementation of the renewable energy technology.

Solar Electricity for Remote Water Supply
PHOTO: NRCS OHIO

SOLAR ENERGY

The variable nature of solar energy (night/day cycles, cloud cover and seasonal variation) affects the design process for solar energy installations, whether thermal or photovoltaic (PV). The relatively high capital costs encourage optimal use of solar energy when it is available. Orientation of solar arrays is the most important aspect of optimal solar energy production. In the northern hemisphere, fixed solar arrays should generally be oriented to face south as closely as possible. The optimum tilt angle for a fixed solar array depends on a variety of factors; most importantly latitude, but also seasonal variability in demand and local climate characteristics. Solar energy equipment typically requires relatively little maintenance, but periodic cleaning, control of nearby vegetation and replacement of ancillary components such as inverters and pumps are part of the maintenance required for optimal performance. Appropriate sizing of solar facilities will ensure quicker payback and may help reduce initial costs. Sizing requirements are different for PV and thermal systems.

Most installations of solar technology are likely to be subject to a variety of permitting requirements. For all types of solar installations building codes and other local, state and federal requirements may influence the design, capacity and location of the facility. PV arrays will typically have to comply with current electrical codes. Grid-tied PV systems generally must conform with the requirements of the electrical utility and often with the requirements of the regional electrical grid operator.

Solar photovoltaic panels produce electricity directly from the radiant energy of the sun. The efficiency of conversion from solar energy to electricity is 15% or better with quality crystalline silicon photocells. PV panels produce direct current (DC), which must be transformed through an inverter into AC power at appropriate voltages (most often 240 or 480 volts). PV panels are characterized by their electrical output at peak sunlight, so a 50 watt panel (about 3.5 square feet) should produce around 50 watts on a clear day when the incoming sunlight is perpendicular to the panel. In practice, this means that average output will be much less than the rated output because of the changing amount of available light at different times and the changing angle of incidence of sunlight on the panel. The ratio of average output during a year to the power rating (capacity factor) varies for different locations. The capacity factor for New Jersey is around 15%, and diminishes slightly for northern portions of New England (1). Panel mounting equipment which allows for moving the panel through changes in season and time of day will allow for maximization of the capacity factor. For large installations, computerized, automated equipment can be used to automatically move panels throughout the day; while for smaller installations manual adjustments following changes in season are practical. Panel efficiency typically declines over time, and although the rate of degradation is slow it may become noticeable over a panel life of 20 or 30 years.

Electrical rates for most commercial operations, including many farms, include costs for both consumption (kilowatt-hours) and peak demand (kilowatts) during the billing period. Solar electric may not have a significant impact on peak demand and the associated charges. In most locations, electricity produced from solar energy and other renewable sources can be used to generate renewable energy credits (RECs). These credits are based on the total amount of electricity produced, whether or not the power is used on-site. The value of RECs may depend on the source of renewable energy used and market pricing for credits.

Sizing PV arrays depends on site characteristics, the extent of the local electrical demand, and the local regulations that apply to the export of power. Most areas allow net metering of photovoltaic and other renewable electrical energy sources in interconnections with the regional electrical grid. With a typical net metering arrangement the customer receives credit at retail rates for some portion of the electricity generated on site. These arrangements usually require that the on-site generation not exceed on-site consumption on an annual basis. In some circumstances, PV arrays sized to closely match the energy consumption of an operation on an annual basis may create a disincentive to future energy efficiency. Any conservation measures that reduce on-site annual electrical use below the total PV output may have to pay for themselves based on wholesale (significantly lower than retail) prices for electricity plus the value of the corresponding RECs.

Off-grid PV installations typically require some amount of electrical storage, usually in the form of battery banks. The initial and ongoing cost of storage along with the fact that off-grid applications are not generally eligible for solar RECs significantly increases the cost of PV systems not tied to the grid. However, such systems can be of great value for purposes other than attainment of renewable energy goals. Remote solar installations can allow the use of electric power where extension of grid infrastructure to a specific location would be impractical, such as electric fence chargers, weather monitoring stations, pastures, and small, remote outbuildings.

There are several technologies that use solar energy to produce heat. The two most common collectors for solar thermal energy are flat-plate (insulated or uninsulated) and evacuated tube collectors. Concentrating collectors, usually more suited to larger scale systems, include parabolic troughs and dishes, and typically generate energy at much higher temperatures than flat-plates and evacuated tubes.

Solar thermal energy can be used for heating hot water or space heating. For a variety of reasons, water and water-glycol mixtures are generally the preferred fluids for distributing and storing solar heat. Whether the system uses liquid or air as the working fluid, most installations will require some form of storage. The storage capacity is usually designed to meet shorter term needs, to compensate for the lack of solar energy at night or during cloudy periods. Longer term (seasonal) storage is technically feasible but often not economically viable. Often there is a mismatch between the available solar energy and the heat demand that cannot be addressed by short term storage. For example, a greenhouse that operates year round will have the highest energy needs during periods of low light. Often the best solution is to size solar systems to supplement rather than supplant other sources of heat.

WIND ENERGY

As with solar energy, wind energy is a variable source of power that is most commonly used to generate electricity in wind turbines. Wind has been used for hundreds of years to provide mechanical power, most frequently for pumping water, milling, and transportation. In new installations, water pumping may be the most practical of these because of the relatively low cost of storing water. The amount of wind energy available at any particular location is very dependent on local and regional conditions. A site assessment is a vital step in determining whether wind energy is economically viable at a particular location. The average electrical output of a wind turbine depends on the long term wind profile at the location, height of the tower, and the capacity of the turbine. The electrical output rating of wind generators is typically determined at the turbine's rated speed. Most wind turbines will shut down at wind velocities above the rated speed to prevent damage to the equipment. Below the rated speed, the output of the turbine will decline; the rate of decline is proportional to the square of the wind speed. Below a wind speed threshold that is specific for each turbine there will be no electrical output.

Site selection is an exceedingly important consideration in installing wind energy equipment. Sites are selected based on local wind conditions, as well as suitability for construction of tall towers. Generally, towers are most efficient when placed at least two blade radii above the highest topography within one mile. On many farm sites in New Jersey, local rules may prohibit erection of any structure of this height. Wind power is therefore much less practical in suburban or otherwise highly-populated areas. USDA Rural Development provides a good framework for making site selections in its publication "Small Wind" (2).

There are significant economies of scale for wind turbines used to generate electricity, and wind energy may not be a viable option for many smaller operations even when there is an adequate wind resource. Most regulatory and economic issues related to PV installations and grid interconnections apply to wind turbines. Additionally, various zoning and environmental concerns, local, state and federal; may impact wind system design and installation. Issues that may arise with respect to wind turbines include threats to wildlife (particularly birds and bats), noise, and visual impact on the landscape.

Micro-Hydro Dam
PHOTO: USDA FOREST SERVICE

HYDRO POWER

Like wind, water has been used as a source of power for centuries. Hydro power has been used to generate electricity as well as for mechanical uses, such as pumping water and milling (grains and other materials). There are significant economies of scale with hydroelectric power generation, and hydro power in its various forms is only appropriate in locations with very specific water resource characteristics. Many issues of economics, permitting and grid interconnection are similar to those of solar and wind power. Because hydropower usually requires modifications to waterways there are likely to be permitting requirements related to stream encroachment. There are several off-the-shelf products available which allow the generation of 1,000-10,000 watts of power from small streams, known as "micro-hydro" systems (3).

GEOTHERMAL

Geothermal energy is based on the extraction of heat from the earth. Higher temperature geothermal energy is only available at very specific locations, most commonly in regions with active volcanic activity. In the northeastern United States, ground earth and water temperatures are usually warmer than the air in the winter and cooler than the air in the summer. This temperature difference can be used to provide heating and cooling.

The most practical application of geothermal energy in the Northeast is the use of heat pumps to provide heating, cooling or both. Pipes buried in soil, either in horizontal or vertical configurations, delivers water at temperatures close to the deep ground water temperature. In wintertime a heat pump can extract heat from this water, returning colder water to the ground loop, to provide space or water heating. In the summertime the process is reversed, and the heat pump returns warmer water to the ground loop while providing cooling for buildings, or other applications.

The viability of ground loop geothermal systems is very dependent on the specifics of an operation. Heat pump efficiency varies depending on the temperature of both input and output fluids. System design must take into consideration the site conditions, the costs of conventional heating and cooling, and the operating characteristics of the farm. Although the capital investment for ground loop heat pump systems is likely to be high, ongoing maintenance costs are relatively low. Ground-loop geothermal heat pumps involve the installation of many hundreds of feet of pipes underneath the frost line, in either soil or a deep body of water. See the US Department of Energy Geothermal Heat Pumps portal (6) for more information and a video on this energy option.

Switchgrass at End of Season
PHOTO: NRCS

BIOMASS

There are many ways to derive energy from biomass. Agricultural crops, by-products and waste can often be burned directly, gasified for combustion, or converted to liquid or gaseous fuels. The most efficient solution for small operations is direct combustion, whereby plant material is burned on the farm.

Biomass can also be converted to liquid fuels, most often ethanol or biodiesel. Better feedstocks are high in sugars or starches, however, cheaper, low-quality feedstocks composed of cellulose may be used. Any conversion of biomass to ethanol benefits from economies of scale, so production of ethanol is usually most appropriate for regional rather than on-farm production facilities. For more information on biomass energy production and use, see the fact sheet in this series "Biomass for On-Farm Energy" (5).

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