The Farmer's Handbook for Energy Self-Reliance

A Guide to Using Energy Efficiency, Biomass, and Renewable Energy on the Farm

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Institute for Energy and the Environment
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Summary

The following handbook is a guide to help farmers use energy more efficiently. First, by implementing energy efficiency measures and second by using biomass and renewable energy farmers may reduce operating costs, while also decreasing some of the potential environmental effects of farming.

This handbook is divided into various chapters. Chapter 1 offers an introduction to energy self-reliance on a farm. The next nine chapters of this book describe various energy management solutions that farmers can use to address these problems. The first three chapters detail how energy efficiency can be incorporated into a small farm operation. The next three chapters describe the use of energy created from biomass. The final energy management chapters depict the use of renewable energy sources on farms. Throughout these sections vignettes and stories of success have been added whenever possible to describe how farmers have been using these energy management tools to achieve energy self-reliance and improve their bottom line.

How to Use This Handbook

The pages that follow are a guide to managing energy on small farms. Whenever possible, examples have been included to demonstrate how other farms have adopted various energy saving and energy producing measures. This handbook does not cover every aspect of energy use but rather, serves as a starting point for those farmers interested in energy efficiency and greater energy self-reliance. The technologies and strategies suggested in this handbook in most cases, require energy expertise that can be provided by specialists. Although energy management is not always simple there are many benefits to it and we hope that this guide will serve as a resource to put farmers on a path to energy efficiency and self-reliance.

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Chapter 1: Energy Self-Reliance

The Need for Energy Self-Reliance

The American farmer is facing a crisis of historic proportions. Oil prices are at an all-time high. Electricity costs in most states are growing at unimaginable rates. Transportation costs are increasing. This energy squeeze comes at a time when shrinking profit margins and increased competition threaten the very existence of small farms. Incorporating the use of energy efficiency, biomass, and renewable energy sources can help make farms more profitable and robust.

Energy Self-Reliance

Farmers benefit from supplying some of their own energy—becoming more self-reliant and less dependent on utility companies—for a number of reasons. Three benefits of energy self-reliance are highlighted and explained below.

1. *Financial Viability and Cost Savings*
   First, the more farmers can produce their own energy, the less vulnerable they will be to the global fluctuations in energy prices. The Association for the Study of Peak Oil and Gas estimates that global reserves of oil and gas will peak around 2010 after which prices will continually climb. As farmers know, agriculture requires substantial energy use. If farmers can insulate themselves from energy price fluctuations, they will reduce their financial risks. Furthermore, many farmers may have the potential to turn their farms into net-producers of energy, meaning that they can sell their electricity or bio-fuel for a profit.

2. *Limiting Environmental Externalities*
   Producing energy from fossil fuels has many negative effects on the environment. In particular, coal fired power plants are a major source of local and world wide air pollution as well as a significant contributor to global warming. In addition, ozone, a by-product of fossil fuels, damages crops and reduces yields. Thus, reduced energy use means better environmental protection that will help farmers in the long run.

3. *Food Security & Operational Independence*
   A farmer's ability to produce their own electricity or tractor fuel and thus reduce their dependence on external sources of power means that their farming operations are more independent and less subject to global politics. For example, America's food supply is highly dependent upon imported oil for fuel. Greater energy self-reliance could mean that, should oil become less available from other countries, agricultural production would not be interrupted.

An Energy Management Plan

The optimal path to energy self-reliance for farmers is to implement an energy strategy. Synergies occur when several energy-saving and energy producing efforts are used simultaneously. In short, it is the combination of efficiency measures, biomass and renewable energy that help a farmer reach energy self-reliance. Implementing all of the strategies creates more benefits than each factor could alone.

Energy Efficiency

Energy efficiency means accomplishing the same tasks (i.e., lighting, powering motors) but using less energy to do it. There is a range of ways to use energy more efficiently, although some require more effort than others. One simple way is to replace incandescent light bulbs with efficient fluorescent lights. On the more difficult side, farmers could save significant energy by installing combined heat and power (CHP) units on farms. Energy can also be saved by changing production practices. For

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example, a farmer can reduce tractor diesel consumption by shifting from more traditional tillage methods to conservation tillage. In fact, there are many methods that farmers can use to reduce energy consumption in order to save money, protect the environment, and meet some of their own energy needs.

Biomass

Biomass is organic material made from plants and animals that contains stored energy from the sun. Plants absorb the sun's energy through photosynthesis and then convert the energy into chemical energy that is stored in plants. When biomass is burned, the chemical energy is released as heat so that burning wood waste or garbage can produce steam for making electricity or for providing heat to industries and homes. Unlike fossil fuels, biomass can be quickly replenished and is a renewable form of energy because we can grow more plants.

Renewable Energy

Renewable energy refers to non-fossil fuel sources of energy. Fossil fuels, or coal, oil and gas, are not renewable because they take millions of years to form and there are limited amounts of each stored in the earth. Wind and solar energy are both considered renewable energy sources because humans will never exhaust their ability to harness wind and solar energy. To encourage the use of renewable energy, a number of states allow "net metering," a process where farmers can sell excess electricity that they generate on their farm (using biomass, solar or wind energy) to a utility.

Energy Management: The Dairy Farm

If a farm both reduces energy use and creates energy, it can reduce the percentage of power purchased from utilities. The following scenario shows how a typical small to medium size farm that has 300 dairy cattle, 160 acres of corn/soybeans (in rotation), 40 acres of wheat, and 30 acres of alfalfa can maximize energy savings and become more energy independent using the synergistic effects of combined energy strategies.

Base Year 1: Energy Efficiency

For our hypothetical farm, let's assume that it is the first year the farmer adopts energy efficiency measures. While energy savings can vary depending on the particular energy use of a farm, it is reasonable to assume that a typical farm could save up to 30 percent of its energy costs by, among other things, installing energy efficient lighting and new efficient motor pumps. These energy efficiency measures can lower energy consumption. These measures can be combined with insulation in the home and workshop, which decreases heating oil consumption.[1] In addition, the federal government reduces the cost of the efficiency measures by offering the farm tax credits on each efficiency up-grade installed.

Base Year 2: Biomass

Manure is another biomass product found on farms that is a potential renewable energy source. Diary farming uses a lot of electricity to run the pumps that milk the cattle, to refrigerate

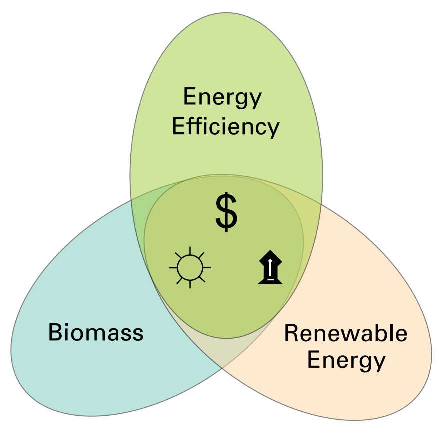

FIGURE ONE: The relationship between each energy management strategy amplifies the effects of the others.

the milk once collected, and to heat and cool farm buildings. Using manure to generate electricity can achieve several important goals. It can be used to generate the energy that the farm needs, reducing the amount purchased from a utility. It can solve odor and water pollution problems, as well as produce useful by-products that save money.

Continuing the hypothetical steps to energy self-reliance, let's assume that in the second year, a farmer applies for and receives a grant from the state government office of natural resource management to build an anaerobic digester. The grant provides matching funds for the digester up to 25 percent of the capital costs.[2] An anaerobic digester converts manure (volatile solids) into methane gas which is captured and burned in a generator to create electricity. A 300 cow diary operation could produce enough manure for roughly 50 kilowatts (kW) of electricity capacity. After the manure goes through anaerobic digesting there are solids that remain, which can be used both as fertilizer and also bedding for animals, saving the farmer from having to purchase those products. In some cases, farmers have saved over $60,000 a year in animal bedding alone.

A Synergy Is Created

In our example, there is a synergy created between the efficiency measures adopted in the first year and the digester installed in the second year. The efficiency measures lowered the farm's annual rate of consumption of electricity by 30 percent. This means that the electricity being generated by the digester is now providing a higher percentage of the amount of the electricity that the farm consumes. In that way, the energy efficiency measures amplify the net benefit of installing the digester by reducing the total consumption of electricity from off-farm sources. Thus, by implementing both energy management strategies, as well as digesting and efficiency measures, this farm has reduced its total energy costs. It also is now less dependent on outside sources of power to operate the farm. The farm has accomplished the goals of decreasing dependence on outside sources of power and reduced environmental harm.

Base Year 3: Renewable Energy

During the third year, our hypothetical farm signs a contract with the local power utility to install a net-metering device on the farm. Net-metering allows a farm to sell the electricity it generates on the farm to its electrical utility. At night when the farm's electricity consumption is low, the digester is still generating electricity. Since the farm does not use all the electricity the digester is generating, the excess power can be used to off-set or reduce the cost of future electricity use. The power 'credit' earned by the farm at night literally turns the electrical meter backward thereby showing a negative consumption of electricity and earning energy credits that can be used for power that the farm will use later.

If the farmer should also opt to install photovoltaic (PV) cells on the roof of the barn, the farm can apply for and receive a grant to reduce the initial capital costs of the solar panels. The farm is also eligible for federal and state tax credits that reduce installation costs. The solar panels are connected directly to the circuit breaker in the barn so that during the day, while electricity consumption is at a high level, the solar panels are providing electricity directly to where it is needed. This is in addition to the power that the anaerobic digester is already generating. The additional power further reduces the farm's daily consumption of outside energy, producing the financial, environmental and operational benefits that self-reliance can provide.

Achieving Self-Reliance

The hypothetical farm in our example implemented a separate energy management tool in three succeeding years; energy efficiency in Year 1, biomass in Year 2, and renewable energy in Year 3. Figure Two shows how using the "Percent of Electricity Produced on Farm" can lead to greater self-reliance. Each line represents one of the three energy management strategies used by the farm in the preceding example. The increasing green line is the cumulative effect of all three strategies. Notice that alone, each only contributes a limited amount of energy to reduce the amount of off-farm energy needed. However, combined, these individual strategies can significantly decrease the dependence on off-farm energy.

In Figure Two the farm has an increase in on-farm electricity production in Year 4. The increase in on-farm electricity is due to the synergy created by employing the digester and solar panels with the net-metering device on the farm. Under most net-metering rules, utilities must credit the farm account for kilowatt hours that the farm produced in excess of what the farm consumed during a month. Some states require the utility to pay the farm for the excess power it generates. Therefore, in months in which the farm generates more power than it needs, it can earn income from generating electricity. While this may not be a significant amount, it is an additional benefit worth highlighting.

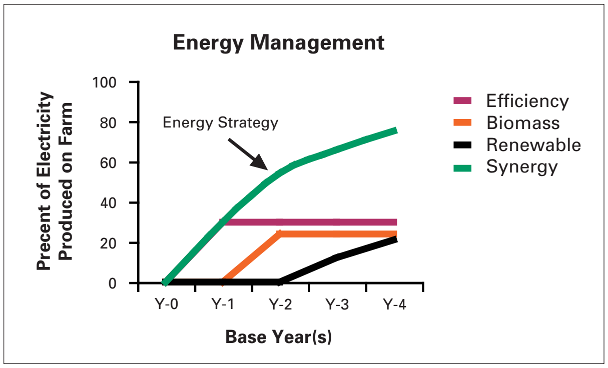

FIGURE TWO: DAIRY FARM. The potential energy savings of implementing each strategy on a hypothetical dairy farm.

Note: Efficiency in this case is not a net producer of electricity, but a net reducer of electricity use. However, in this example it is treated as an element in on-farm production of electricity to demonstrate the cumulative gains for the farm compared to base Year 0.

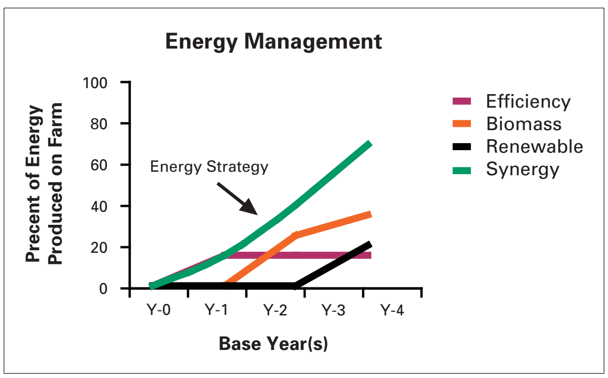

FIGURE THREE: ORCHARD FARM. The potential benefits of implementing an energy management plan on a hypothetical orchard farm.

Note: Efficiency in this case is not a net producer of electricity, but a net reducer of electricity. However, in this example it is treated as an element in on-farm production of electricity to demonstrate the cumulative gains for the farm compared to base Year 0.

The efficiency measures implemented in the first year lowered the energy consumption of electricity from the grid. In addition, by adding biomass and renewable energy in the second and third year, the farm becomes a net producer of electricity during some months instead of a net consumer. This creates the potential for the farm to sell electricity to the local utility. While energy has been an expense, it now has the potential, at times, to provide income.

Energy self-reliance for this farm has other benefits as well. By creating its own electricity, the farm has reduced the demand on the power grid, freeing up electricity for neighboring businesses and residential consumers. Decreasing overall demand on the power grid during periods of high demand, like the summer when air conditioners test the grid's limits, reduces the likelihood of power outages and the need for new generation. The solar panels will be most productive during the "peak" period of electricity consumption, which is during the middle of the day. Moreover, any reduction in kilowatt hours used reduces the likelihood that new fossil fuel or nuclear power plants would need to be built.

Renewable Scenario: The Orchard and Vegetable Farm

The previous example is meant to encourage the reader to think about the possible synergies between the different energy management measures.[3] The principle of combined energy strategies could work for a variety of farm operations, including ones that might not produce manure. To demonstrate how an energy management strategy might work on a different agricultural operation, imagine a farm that bases its production on five acres of vegetables, 30 acres of prairie hay, and a 20 acre apple orchard (Figure Three). Energy use includes heating oil for a greenhouse where plants are started before being planted and diesel to run the tractors used to care for the orchard and bale the hay.

Base Year 1: Energy Efficiency

In Year 1 the farm could invest money in energy efficiency measures. By adding insulation in the workshop and residence, placing fans with new models that have energy efficient motors, installing compact fluorescent lighting and replacing old appliances with Energy Star rated models, the farm would realize impressive savings in energy costs over a relatively short time period.

Base Year 2: Biomass

In the Year 2, the farmer decides to make biodiesel on the farm. In the spring, the farmer converts his 30 acres of prairie hay into rapeseed. Rapeseed can produce approximately 120 gallons of biodiesel per acre. Therefore, the 30 acres of rapeseed will net about 3,600 gallons of biodiesel for on-farm use. The farm also installs a rapeseed press to make the bio-diesel. The biodiesel produced on the farm is then used to run the tractors that harvest the apples and the trucks that transport them to market. The farm is able to produce enough biodiesel to reduce the farm's diesel consumption by 50 percent.

Base Year 3: Renewable Energy

During base Year 3 the farm installs a windmill to generate electricity on the farm. The farm also installs a net-metering device after contacting the local power utility. The windmill is connected to the net metering device. The new windmill is able to provide on-farm electricity for the residence, the greenhouse and the workshop. Any excess electricity that the windmill generates is sold back to the power utility to offset future energy needs.

Synergies Created on the Orchard and Vegetable Farm

If this hypothetical farm were to implement each energy strategy, it would realize energy savings. Energy efficiency measures lowered the total consumption of energy thereby amplifying the proportional effect of generating energy through biodiesel and wind power. Furthermore, together all three areas maximize the potential to save money by creating energy on the farm. The biodiesel and windmill not only reduce environmental degradation by replacing fossil fuels and reducing the air and water pollution, but also grant the farmer a degree of control over his or her energy choices.

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1. Elizabeth Brown & R. Neal Elliott, AM. Council for an Energy-Efficient Econ., Potential Energy Efficiency Savings in the Agriculture Sector 4 (2005).
2. For example, see California Legislative Enactment SB 5x (Section 5(b)(5)(C)(i)) that provides California farmers with a grant for anaerobic digesters.
3. In this example we do not go into the descriptive analysis of the synergies created at each stage. Rather, we use this example to demonstrate how these principles might work on a farm where the energy costs are from petrol-based fuel.

Chapter 2: Energy Efficiency in Home and Farm Buildings

The least expensive, quickest, and easiest way to save money on your farm is by using energy efficiency. Farms can become more energy efficient in a variety of ways, from demand side management programs—such as replacing incandescent light bulbs with fluorescent lights—to installing distributive generation technologies like CHP. None of these efficiency improvements will decrease energy demands by themselves. However, the synergies created by implementing a variable mix of efficiency improvements can work together to reduce a farm's energy demand substantially.

When a farmer decides to make plans for new buildings or make renovations to current buildings, efficiency should always be an important consideration. The following efficient building principles should be used to help guide farmers with their decisions, keeping in mind there is no single solution that applies in every instance:[4]

- Minimize operating energy.
- Incorporate renewable energy wherever possible.
- Optimize material use with the fewest, best materials.
- Design for local conditions; build with local materials.
- Conserve resources in design, construction, and operation.

Lighting

Lighting presents one of the biggest opportunities for savings, both in the home and on the farm. According to researchers from the American Council for an Energy Efficient Economy (ACEEE), lighting amounts to 1 percent of the total known energy budget of the farm.[5] In addition, it is estimated that, through the adoption of a combination of lighting measures in and outside of farm buildings and residence, such measures will produce a savings estimate of between 40 and 70 percent.[6] Lighting measures come in various forms, including compact fluorescent light bulbs, high intensity discharge retrofits, occupancy sensors, day lighting controls, and timer controls.[7]

It is important to remember that these measures described as on-farm lighting includes residential lighting, as well as larger-scale lighting in barns, and area lighting for the farm yard.[8]

Simple Tips for Everyday Farm Living and Working

Some important common sense measures that are often forgotten, but that should always be in practice, include simply remembering to turn the lights off, or using appropriate lighting based on the type of task. Also, remember to draw the shades on farm-buildings, or install shades on farm buildings to keep heat from penetrating indoors during summer months or escaping during winter months. Another strategy to consider when building a new farm building is to orient it strategically in a direction to get the most benefits of light from the sun.[9] By incorporating these techniques into your operation, you make your assets inherently more valuable because they can do the same amount of work with lower energy costs.[10] The U.S. Department of Energy (DOE) provides great advice to farmers to lower their energy costs through more efficient lighting techniques both indoors and outdoors.[11]

Indoor vs Outdoor Lighting

Here are some basic things to think about for achieving energy-efficient outdoor lighting:

- Security and utility lighting does not need to be bright to be effective.
- Use fluorescent, high-intensity discharge, or low-pressure sodium lights unless incandescent lights are automatically controlled to be on for just a few minutes each day.
- Consider incandescent flood lights with combined photo-sensors and motion sensors in the place of other security lighting options.
- Use photosensors with fluorescent, high-intensity discharge, or low-pressure sodium lights.

- Make sure outdoor light fixtures have reflectors, deflectors, or covers to ensure more efficient use of the light source and help reduce light pollution.
- Use timers and other controls to turn decorative lighting on and off.
- Use outdoor solar lighting where and if applicable.[12]

Lighting the Barn

Replacing all of the incandescent lights in the barn with energy efficient fluorescent lights can save up to 75 percent on the costs of energy for lighting. Moreover, the use of motion sensors, instead of timers, can be even more effective in lighting areas when you need them. Another important efficiency tactic is to design your lighting so that it only illuminates the area that you will be working in. For example, there is no need to light up your entire barn when you are only doing something on the work bench. Energy-efficient lighting in these applications, however, must be carefully tested and designed for adequacy.

Compact Fluorescent Lighting

One of the easiest ways to increase energy efficiency is to replace the old incandescent light bulbs that might be currently used and install compact fluorescent light bulbs (often referred to as CFLs).[14] CFLs can be installed in regular incandescent fixtures, and they consume less than one-third as much electricity as incandescent lamps.[15] For instance, a farmer can expect savings of almost $60 over the life of a 100-watt equivalent CFL. Replacing a 100-watt incandescent bulb with an equivalent 25-watt CFL can save a farm $2 per lamp each month in energy costs, assuming a 100-watt bulb is used for ten hours per day at $0.085 kilowatt hours (kWh). Thus, replacing ten 100-watt bulbs can save $20 a month.[16] CFLs are most applicable in low moisture, low dust environments such as utility rooms, office spaces, machine sheds and residences.[17] They can also be used in feed rooms and animal housing if you install fixtures that are approved for use in wet locations.[18] However, you should consider many factors when selecting the appropriate CFL for your farm needs. Again, it is important to choose the appropriate lamp based on the type of lighting activity. Some other factors to consider are whether the lamp will be used indoors versus outdoors, as floodlighting versus decorative, where there is moisture potential, in cool or warm temperatures, and whether the lamp will be enclosed.[19]

Finally, most utilities offer their customers discounts on or even provide free CFLs. Check your utility bill or contact your local utility for more information about your utility's incentive programs.

High Intensity Discharge Retrofits

High-intensity discharge (HID) lamps provide the highest efficiency and longest service life of any lighting type.[20] They can save 75 to 90 percent of lighting energy when they replace incandescent lamps. Because of the intense light they produce at a high efficiency, HID lamps are commonly used for outdoor lighting and in large indoor arenas. Since the lamps take awhile to establish, they are most suitable for applications where they stay on for hours at a time. They are not suitable for use with motion detectors.[21]

Occupancy Sensors

Sensors turn lights on only when they are needed, but are more precise than timers as they respond to actual conditions. Ultrasonic motion sensors turn lights on and off in response to movement. Infrared sensors turn lights on and off in response to body heat; and photosensors turn lights on and off when ambient light levels fall below or rise above certain levels. There also are many solar powered outdoor lights available. These lights have zero operating cost as they store solar energy all day and use it at night. This technology has been proven successful for many years, even in cloudy conditions.[22] Occupancy sensors—indoor lighting controls—detect activity within a certain area. They provide convenience by turning lights on automatically when someone enters a room. They reduce lighting energy use by turning lights off soon after the last occupant has left the room.[23]

Occupancy sensors must be located where they will detect occupants or occupant activity in all parts of the room. There are two types of occupancy sensors: ultrasonic and infrared. Ultrasonic sensors detect sound, while infrared sensors detect heat and motion. In addition to controlling ambient lighting in a room, they are useful for task lighting applications, such as over kitchen counters. In such applications, task lights are turned on by the motion of a person washing dishes, for instance, and automatically turn off a few minutes after the person stops.[24]

Day Lighting Controls

High-quality day lighting requires a design that eliminates glare and unwanted solar gain, and distributes the light evenly and effectively. Natural daylight actually produces less heat per unit of illumination than electric lights, reducing cooling bills as well as the demand for electricity. Also, windows incorporating spectrally selective glazing and tints, or low-coatings, make day lighting compatible with the cooling and heating requirements of any given climate. If replacing your windows is not an option, you can add films to your existing windows to allow the desired amount of light and heat into and out of your home.[25] Depending on your lighting needs, another alternative to artificial lighting is a lightshelf. Lightshelves are flat surfaces attached to the exteriors of buildings that bounce natural light through windows and deep into the building; they also reduce glare. In addition, light pipes, also known as solar pipes or tubes, are a simple type of alternative lighting technology and are available for under $400. These pipes last for years, require no maintenance, have a proven performance, and, of course, use no electricity. Light pipes have been used in homes to funnel light into dark hallways, bathrooms, kitchens, and living spaces with few or no windows.[26] These might also be helpful to include in barns or other farm buildings.

Day lighting has been found to be particularly cost-effective in dairy farming. The animals respond favorably to a rigid schedule of continuous light followed by a number of hours of continuous darkness.[27] The benefits of such practice mean farmers can save money while increasing milk production. Some tips and cost benefits include:

- Converting from eight foot T12 to T8 fluorescent lights will save approximately 400 kWh, or $40 per year, per fixture! Install 25 fixtures and save $1,000 per year.
- Install pulse start metal halide fixtures instead of mercury vapor fixtures. Each pulse start metal halide fixture puts out roughly twice as much light as the same wattage mercury vapor lamp. This means you can use fewer fixtures and save energy.
- Use a 150 watt pulse start metal halide lamp in place of a 250 watt mercury vapor lamp. You will get more light, save 736 kWh each year and save $74 per year per fixture. Install 25 fixtures and save $1,850 per year.
- Installing pulse start metal halide versus a standard fixture results in approximately 360 kWh savings, or $36 per year per fixture! Install 20 fixtures and save $720 per year.[28]

Timer Controls

Lighting controls such as dimmers, timers, and sensors ensure that lights are turned on when they are needed; they can also adjust light output to the desired luminosity. These controls can save a lot of energy if used properly.[29]

- *Dimmers:* Dimmers actually extend the life of the bulb while saving you energy. Compact and tube fluorescents are available in dimmable fixtures.

- *Timers:* Timers save energy simply by turning lights on and off at pre-designated times.

Simple timers are not often used alone for outdoor lighting because the timer may have to be reset often with the seasonal variation in the length of night. However, they can be used effectively in combinations with other controls. For example, the best combination for aesthetic (decorative) lighting may be a photosensor that turns lights on in the evening and a timer that turns the lights off at a certain hour of the night (e.g., 11 P.M.).[30] For indoor lighting, timers are sometimes used to give unoccupied houses a lived in look. However, they are an ineffective control for an occupied home because they do not respond to changes in occupant behavior, like occupancy sensors.[31]

Space Conditioning: Heating Ventilation Air Conditioning, Insulation, Weatherizing, and Air Leaks

The Building Envelope

The term "building envelope" refers to your farm buildings' walls, roof, windows, and foundation, which shield your living space or farm building from the elements.[32] Making sure that the building envelopes of the farm are as energy efficient as possible is a must on the modern farm. Because of the diverse climatic regions that the agricultural sector covers and the varying requirement of different operations, heating and cooling systems, different efficiency strategies performed on the building envelope will apply. For instance, hog and pig, poultry, and greenhouse farm-types have large cooling and heating loads.[33] Thus, these types of farms might want to consider focusing on space conditioning as their first priority in attaining more energy efficiency. Accordingly, because the workshop area has different purposes than your home, an unheated storage building, or a barn, different building envelope efficiency strategies will apply. The three main areas where efficiency improvements can be made to the envelope of your farm buildings, including the home, are in insulation, heating and cooling systems, and weatherizing.

Heating Ventilation Air Conditioning

Although there is little agricultural-specific information available for heating and cooling measures and their energy savings, they are well known in others sectors to be areas of large potential savings.[34] Based on Heating Ventilation Air Conditioning (HVAC) energy savings from the residential and commercial sectors, the combination of a variety of heating and cooling measures estimates savings at 30 percent.[35] Because of the diverse climatic regions that the agricultural sector covers and the varying requirements of different operations, heating and cooling systems should be researched based on the unique characteristics of the farm's location, the type of farm building, the type of use of the farm building, etc.

HVAC systems account for 40 to 60 percent of the energy used in U.S. commercial and residential buildings. Proven technologies and design concepts, along with energy efficient HVAC technologies, now allow these services to be provided with significant energy savings and lower lifecycle costs. Useful guidelines are available for evaluating the relative efficiency of many appliances and of equipment like furnaces. One standard is the Energy Star certification. In addition to selecting the most energy efficient heating and cooling system, by burning bio-mass on the farm to heat the barn or home, planting trees around your home to provide shade during summer months and act as insulation during the winter months, or by wrapping your water heater(s), you can dramatically reduce your energy costs. The use of all of these smaller improvements can quickly add up to large energy savings.[36]

Radiant Heating

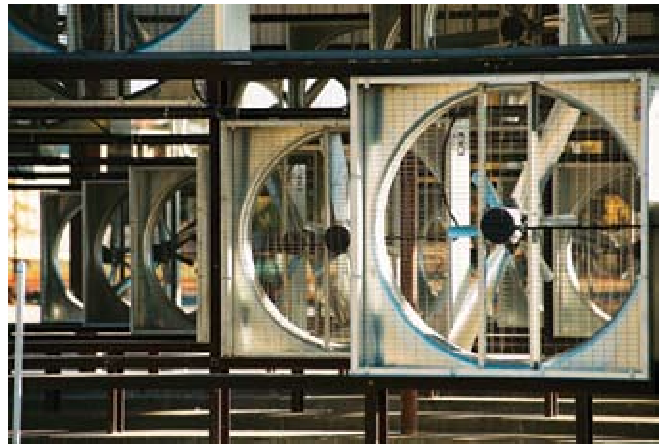
Instead of warming air and then circulating it throughout your work area using ducts and vents, a radiant heating system can be embedded under your work shop floor. The installation of electric heat coils or warm water pipes under the entire floor can evenly distribute low-temperature heat. Radiant heating systems generally require more up front expense than other heating sources, but they also offer several advantages.[37] For example, radiant heating systems are very efficient at low shop temperatures because the radiation heat warms the surfaces it strikes, providing comfortable equipment and surface temperatures.[38] Also, radiant heat sources lower heat loss when large entry-doors are opened since it is not the air in the work shop that is doing the heating, but the workshop itself.[39] Finally, radiant heating systems can provide about the same comfort level as forced air heaters at a 10 degree Fahrenheit lower shop temperature.[40] This means lower energy use by you, and increased savings on your energy bills!

Energy Efficient Fans

High volume, low speed fans are an efficient way to move large amounts of air and make less noise than standard low volume fans. Generally, try to install fans that have an efficiency rating of 20 cubic feet per minute, per watt used. Furthermore, check to make sure that your fans are clean. Dirt and grime can lower fan efficiency by 20 percent or more. Finally, when the fan is operating, open a door or window slightly (preferably one across the room from the fan) in order to supply fresh air.[41] Particularly, in the summer, provide a cross-flow of air to cool the work space by opening both the endwall and sidewall doors.[42] These simple practices can increase the fan's effectiveness and allows you to run the fan less, which ultimately saves you money on your energy bill.[43]

Some of the most important parameters and selection tips to keep in mind when determining the size and number of fans required for ventilation of the operation include:[44]

- Generally, larger diameter fans will be more efficient than smaller fans.
- Fans with a discharge cone will be more efficient than those without.
- Motor efficiency will affect energy use and the motor's speed can affect efficiency and noise levels.



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- Fan blade tip speeds greater than 4,500 feet per minute will create excessive noise levels. To keep noise levels low, fan revolutions per minute (rpm) should be less than 720, 480, 360 and 320 rpm for fan sizes of 24", 36", 48", and 54", respectively.
- Machete or straight and teardrop blade designs are more efficient and accumulate less dust than cloverleaf shaped fan blades.
- The clearance between the fan blade and the housing will affect efficiency and the static pressure at which the fan is capable of operating. Large clearances will allow air to leak back past the fan blade and housing. If the entrance of the housing to the blade is smooth and rounded, it will reduce the turbulence and drag of the air as it enters the fan blade air foil.

Maintaining the Heating System

When fuel costs are high, it is easy to overlook the value of maintenance. However, a problem in the heating system simply adds to these costs. Change the filter regularly and have the system serviced to make sure it is operating efficiently. In addition, keep a record of all services performed.[45]

Greenhouses

Greenhouse heating costs can have a major effect on the livelihood of greenhouse growers. In order to reduce these energy costs, and increase the viability of your greenhouse farm, consider the following ten tips when heating the space:[46]

1. *Infrared (IR) plus anti-condensation treated films*
   IR film should be installed to the inside of the greenhouse with a standard film on the outside. This duo reduces space heating energy use by 10 to 20 percent without condensation problems, and the costs are quite low—typically as little as an additional 2 cents per square foot or about $60 for a 30 foot by 96 foot greenhouse. This puts payback at less than one heating season in certain climates, even if you only heat your greenhouse for a few months of the year.

2. *Insulated side walls*
   With a bench system energy savings can be achieved by insulating side walls, end walls and perimeter with one inch or two inch foam insulation board. Insulation should be dug in 12 to 24 inch deep and can extend up to plant height. The foam should have a protective cover such as aluminum foil to prevent ultraviolet deterioration and reduce fire hazards. Spray-on foam on framed walls are another good option, but also need to be protected. If foam is placed on the inside of the greenhouse, make sure it's topped with a reflective coating aimed toward the inside. This will reflect direct solar radiation back to the crop canopy and aid in plant growth. Energy savings can be substantial: just two inches of foam insulation around the knee wall of a 28 by 100 foot greenhouse will save about 400 gallons of fuel oil, 610 gallons of propane or 558 therms of natural gas annually if your greenhouse is heated throughout the year.

3. *Night curtains*
   Greenhouses tend to peak in energy use during the night: research indicates that a greenhouse uses 80 percent or more of its heating energy after dark. Consequently, greenhouse owners should focus on limiting nighttime heat loss whenever possible, and one excellent way is with a movable insulated curtain. There are several types of curtain materials: porous curtains cut heat loss by about 20 to 30 percent when closed, can be used for shade in the summer, and allow water to drain through. Non-porous aluminized materials provide shading in summer and heat retention in winter by up to 70 percent, but hold water which can cause the curtain system to fail from the water weight. Semi-porous aluminized materials do the best job of cutting heat loss—up to 65 percent when closed—provide summer shade and drainage of condensation.

INFILTRATION LOSSES

4. *Close the gaps*
   Holes, cracks and gaps in the greenhouse result in unwanted leaks. A 36 inch entrance door with an 1/8 inch wide crack around it will allow about 500 cubic feet per minute of infiltration requiring about 25,000 British Thermal Units (BTU) per hour of additional heat. At $2.40 per gallon of propane, the cost is about $0.60 per hour.

5. *Poly film coverings on glass houses*
   Double poly cover can reduce heat losses by up to 50 percent, but can also reduce light levels by as much as 18 percent, and might require mechanical ventilation to control humidity and replace carbon dioxide. Weigh the trade-offs and determine which options make the most sense for your greenhouse.

6. *Wind breaks*
   If your greenhouse is located in an open, windy area, a wind break in the path of the prevailing winter wind will help to reduce infiltration losses. A permanent wind break can be created with four or five rows of deciduous and evergreen trees planted four-to six mature tree heights upwind of the greenhouse. Plant a mix of tree species to guard against losing the entire windbreak from disease or insects.

HEATING SYSTEMS

7. *Thermostats*
   Clean thermostats regularly—a dirty thermostat will not read temperature correctly—and calibrate them annually to ensure accuracy.

8. *Furnace checkup*
   Furnaces and unit heaters should be serviced and tested yearly by a professional. This helps to ensure furnace safety and energy efficiency, and the increased efficiency will easily pay for the cost of the inspection and tune-up. A 2 percent increase in efficiency will save an estimated 179 gallons of fuel oil, 259 gallons of propane or 250 therms of natural gas per year for a 30 by 96 foot greenhouse that is used year round. Replace older deteriorating unit heaters, or gravity-vented unit heaters, with either power-vented unit heaters or with 90 percent efficiency condensing type unit heaters. The power-vented unit heater will pay for itself in 36 days versus purchasing a gravity-vented unit heater, while a high efficiency condensing unit heater could provide a simple payback of approximately two years. There are particular maintenance tips to be aware of depending on whether gas burners or oil burners are used and for chimneys.

9. *Central heating systems*
   Each uninsulated linear foot of two-inch heating supply pipe will lose an estimated $4 worth of heat during the winter. Eliminate this waste and expense by properly insulating the heating pipes and air ducts in headhouses and boiler rooms. Insulation is simple to install and usually has a payback of less than two years. It's also important to have the heating system serviced regularly. This includes changing fuel filters, cleaning nozzles, checking valves and controls, checking and aligning belts, lubricating bearings, testing combustion efficiency and removing soot from inside the firebox. Soot removal is especially critical. For instance, just an 1/8 inch of soot can increase fuel consumption by 10 percent or more.

10. *Bottom heating*
Move heating pipes and air distribution systems from overhead to either under bench, on floor or in floor, and you can save 20 to 25 percent in heating costs and have the added bonus of faster plant growth.

Insulation

Insulation is the first line of defense for heated or cooled buildings. Insulation increases the resistance of the building to heat flow, helping to keep heated or cooled air from escaping.[47] Determining adequate insulation depends on several factors: what kind and how much insulation is currently installed, the geographic location of the farm, the benefit of adding more insulation, where the insulation is installed, and, how it is installed.[48] In addition, building envelopes on the farm have different functions, which should be factored into insulation choices. Also, the fire resistance of the insulation material should be considered. The most common types of building insulation today are fiberglass, cellulose, or petroleum-based foam, though many specialty types of insulation are commercially available, including cementitious foam, straw and mineral fiber.[49] Several building-energy calculators are available for farmers to use in order to help them make the best insulation decisions.[50] Once basic levels of insulation have been achieved in the walls, roof, and floor, the farmer should focus on preventing energy loss in other parts of the building such as weatherizing and air leaks around windows and doors.[51]

Farm Shop

Normally a work shop does not need to be kept at the same temperature as a home. In warm-weather climates, moderate amounts of insulation in the ceiling, roof, and walls surrounding the workshop can go a long way toward providing some heat relief in the summer and reducing condensation in the winter.[52] However, in cold-weather climates where the farm shop is heated, the building envelope should be well insulated, including the foundation, sidewalls and ceiling to avoid running heaters longer than needed.[53] An important tip is that insulating the ceiling takes 15 percent less insulation and gives 15 percent better heat loss protection than insulating the roof area.[54] Regardless, the farm shop should always be insulated, with foam or fiber-glass insulation applied to the sidewall, foundation, and ceiling.

Another suggestion is that the typical heated farm shop should have sidewalls insulated to a level of R=13 and a ceiling insulated to R=20.[55] "R" or "R-value" is a measure of a material's resistance to heat transfer by conduction (the transfer of heat through a solid object, from its warmer side to its cooler side), with the higher "R" levels corresponding to better insulating properties and, consequently, more resistance to heat flow.[56] For safety reasons, always make sure to cover insulation material with a fire-resistant lining on sidewall.[57] Finally, insulating the perimeter of the building foundation is recommended in heated shops to make the floor warmer around work benches and more comfortable for winter use.[58]

Livestock and Other Farm Buildings

When it comes to livestock structures, conserving energy means doing those things that reduce or eliminate wasted heat during winter and excessive heat build-up during summer. The most effective conservation measure is proper insulation.[59] Of the many advantages to insulating livestock buildings, including a lower heating bill, you might be surprised to know that proper insulation increases meat, milk, or egg production.Insulation also provides better general animal health and more comfortable working conditions.[60] It has been estimated that, with high and rising fuel costs, an insulation investment with a 20 to 30 year useful life can pay for itself in 2 to 3 years, depending on the building's present condition and intended use![61]

Adding insulation (R-19 or 6 inches for walls and floors, R-38 or 12 inches in attics) is an important step to make, if current insulation is not sufficient.[62] In addition, increasing attic insulation from R-19 to R-38 reduces heat loss through the attic by up to 50 percent.[63]

Farm Residence (Home)

A significant amount of information is available to consumers regarding home insulation. It is well known that proper insulation of the home not only lowers your energy bills, but also increases the comfort of the living space. The DOE provides helpful tips to consumers when either choosing insulation for a new home, or updating the insulation in an existing home.[64] The folks at the DOE recommend consumers hire a qualified home energy auditor to determine the specifics. However, they guide consumers through the process if they choose to complete the process on their own.[65] Also, an energy auditor can be used to determine the efficiency of other buildings throughout the farm. Finally, in order to improve the effectiveness of the insulation, it is important to reduce air leakages as much as possible. In order to learn how to detect air leaks in the home, and to determine the amount of ventilation needed. The easiest way to repair air leaks is through caulking and weatherstripping. It is estimated that these two simple air sealing techniques will pay for themselves in energy savings within one year.[66]

Weatherizing and Airleaks

Whether in farm buildings, or in homes, air leaks are a major cause of heat loss. Windows, doors, and roofs are primary culprits. The total amount saved varies, but older structures usually realize the most savings. Caulking and weatherstripping around windows and doors can reduce heat loss up to 37 percent in those areas. Some older buildings may need to be modified if heat losses are great.[67]

Water Heating Systems

One final step a farmer should take to create the most energy efficient building envelope is an evaluation of their water heating systems. This should be done both for the home and other farm buildings. Like HVAC measures, there is very little data available for agriculture-specific water heating end uses and savings. Accordingly, available data in the residential and commercial sectors indicate a potential savings of approximately 20 percent in the agriculture sector.[68]

One unique option to consider is to include a solar water-heating system on the farm. These systems range from the simple and homemade to the complex and expensive. Generally, they serve to preheat water before it reaches a conventional water heater, minimizing the energy that the water heater then uses to boost the water to its final temperature.[69] For seasonally occupied or warm-climate agricultural buildings, even a simple solar water heater may bring the water to full temperature without supplementary heating which produces energy savings at minimal cost![70] The DOE offers farmers several tools to evaluate their water heating systems in order to determine the feasibility of more energy efficient systems.[71]

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Chapter 3: Energy Efficiency and Farm Equipment

Research has concluded that on-farm energy end-uses providing farmers with the largest savings potential include: motors, lighting (with irrigation being the largest motor application), and onsite transportation (including fuel use decisions).[72] While particular efficiency measures might be more useful to some farms because of their unique characteristics, such as the needs of a farm-type or region, much of the following research is generally applicable to all farms, no matter their location or farm-type. Also remember that the farm's residence, or "home building envelope," contributes to energy expenses, and should be included in any energy efficiency evaluation. Larger farms are certain to implement these techniques, which make it critical that smaller farms also consider them in order to remain competitive and sustainable. In addition, with more consumers focused on buying locally grown products that have been farmed with "green" practices, smaller farms have the benefit of marketing their crops and products as being produced with these energy efficient techniques. Again, the sections below outline the measures that provide farms with the most potential for savings, or that give you "the most bang for your buck."

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Motors

As noted above, motors are one of the largest energy users on the farm. In fact, motor end-uses account for 18 percent of known and categorized energy uses on the farm at a national level.[73] Accordingly, they also present one of the greatest opportunities for cost savings on the farm. It is estimated that the adoption of a combination of general and application-specific measures on the farm will produce a savings of approximately 30 percent.[74] According to ACEEE researchers, the highest potential savings can come from pumps, fans, blowers and compressors.[75] Specifically, efficiency measures in the motors of pump applications are anticipated to produce a 34 percent savings.[76] Motor measures used to improve the energy efficiency of your farm will come from either a change in process on your farm, change in technology, or through motor replacement. Below you will find tips and suggestions about what to consider when implementing motor efficiency techniques on your farm. Further, financial benefits from implementing these changes will also be discussed.

Irrigation Pumps

Irrigation presents a large energy- and money-saving potential in the agriculture sector. Possible irrigation energy savings are estimated at $436 million nationally, and represent 29 percent of the total potential motor savings.[77] Motor energy use is the primary use of energy for all farm-types that use irrigation because of the energy it takes to pump water to and through the system.[78] It is important to note that the benefits of increasing energy efficiency in irrigation are not solely (or even primarily) energy related.[79] Much of the benefit stems from the water-savings that result from improving irrigation efficiency.[80]

Irrigation Energy-Saving Tips

There are several common sense guidelines a farmer can follow to improve irrigation efficiency on the farm. First, it is important to keep irrigation engines and motors serviced and well-tuned.[81] Second, make sure electric motors, switches, and control panels are clean and free of dirt, insects, or bird nests. These factors add to an inefficient motor.[82] Third, check connections to ensure they are tight, and lubricate moving parts that require it.[83] For example, to avoid sprinkler system inefficiency, inspect the system regularly, and make minor repairs such as stopping leaks, replacing worn nozzles, and trimming the impeller, as necessary.[84] Fourth, to prevent over-watering consider using an irrigation scheduling method that times irrigation watering for more efficient fuel and water use. Such methods include starting irrigation before soils are completely dry and using larger amounts of water on fewer acres per irrigation to move water through fields quicker and more efficiently.[85] Also, address watering methods to avoid patchy water distribution and inadequate pressure.[86] Either of these problems will make it impossible to maintain correct soil moisture levels, leading to crop stress, reduced yields, waste water, runoff, soil erosion, and many other problems.[87] Implementing all, or even one, of these techniques is guaranteed to combat these irrigation inefficiencies and save you money through lower energy bills!

Addressing equipment and management efficiency together is critical to creating the most energy efficient irrigation system on the farm. In addition to these common sense tips, there are more specific measures a farmer can take to address equipment inefficiencies and irrigation management inefficiencies. For instance, there are publications that describe recommended irrigation system installations, explain how utilities charge their irrigation customers for electricity and describe common causes of wasted energy, as well as common energy-saving hardware improvements. Also, there are do-it-yourself methods to estimate the efficiency of electrically powered irrigation systems.[88] In addition, see your irrigation dealer or an extension agent to find information on the following:

- What is the net water application rate for my irrigation system?
- How do I calculate the number of hours the system should be operated?
- What are different methods to measure flowing water in an open channel or pipeline?


Photograph © Msquanna. MourgeFile.

- What are possible suggestions for irrigating with limited water supplies?[89]

Finally, all farms should be encouraged to find publications explaining how to maintain irrigation pumps, motors, and engines for peak efficiency, including descriptions and diagrams of recommended installations, checklists for maintenance tasks, and a troubleshooting guide.[90]

Diary Farming

Dairy farm-types are another candidate for motor energy efficiency programs due to their large use of pumps on the farm.[91] In Vermont, Wisconsin, and other states where dairy is the primary farm-type, upgrading motors can have a significant impact on the energy efficiency of the farm and provide significant savings.[92] In fact, in states where dairy farming is dominant, programs have been established to help farmers achieve more energy efficient pumping on the farm.

For most dairy farms, the best way to improve energy efficiency is through the refrigeration system's design, operation and maintenance. However, the farmer should address refrigeration system efficiency measures in a logical, step-by-step manner.[93] If a farmer is planning a major expansion or renovation of his dairy farm refrigeration system, it may make sense to install multiple energy saving measures. These measures, in order of priority, include:[94]

1. Refrigeration Heat Recovery (RHR) units
2. Scroll compressors
3. Plate/Pre-coolers
4. Variable speed milk pumps

These measures can reduce refrigeration related energy costs substantially and maintain, or even improve, milk quality. They reduce refrigeration requirements and/or capture

Photograph © Daniele Musella, MourgeFile.

waste heat and use this excess heat energy to pre-heat water. However, before installing one or more of these measures, you might want to consult with farm refrigeration experts, because you may inadvertently increase your energy usage. For example, installing an RHR unit and a precooler may cause an increase in energy consumption if all factors are not considered when designing the new system. Experts can also help you avoid damage to equipment or equipment failures. This factor is of greatest concern for farms with 120 cows or fewer, but all farms can benefit from expert advice before proceeding.[95] Even if a major refrigeration overhaul is not expected, there are still some specific measures the farmer can take to improve the efficiency of the system that are addressed below.

Use Variable Speed Vacuum Pumps for Milking

The vacuum pump used for milking not only must operate for long hours during the day, but it tends to use a lot of energy. Standard pumps with single speed drives operate at a constant speed of seven to ten cubic feet per minute (CFM), per milking unit. On the other hand, by installing a variable speed drive on the pumping system, the pump speed can be lowered to two CFM per milking unit, yet additional power remains available if needed. The variable speed drive unit alters the vacuum power so that no more energy is needed than necessary, and the controllers on the pump are sensitive enough to prevent injury and milk back flow. The variable speed units, with corresponding controllers can lower the energy costs of a dairy vacuum system by half.[96]

Dairy Farming: Use a Water Cooled Plate Cooler

Plate coolers, also known as plate heat exchangers, use well or spring water to lower the temperature of milk as it flows from the milking system to the collection tank. Using a plate cooler can speed the cooling process so that the milk is at a lower temperature, reducing the milk temperature by an extra thirty to forty degrees. This means that the compressor does not have to expend as much energy as it would other wise.

Machinery

The use of machinery and on-site transportation dominates energy end-use on the farm. Whether tilling the fields with the tractor, moving crops with a fork-lift, or through utilization of the combine or hay baler, the average farmer spends twelve percent of their total identified energy budget fueling machines and on-farm vehicles to perform these tasks.[97] Important to note, however, is that this statistic is formulated knowing that there is an enormous amount of unavailable information with regard to national energy use in agriculture. The actual expenditures are likely to be much higher, which means the resulting savings will also increase.

Since the tractor is one of the most utilized and essential tools of farms across America, it is no surprise then that the tractor is the machine that presents the largest savings potential.[98] In addition, diesel energy use is predominant in farm machinery, including the tractor, which presents the largest opportunity for savings nationwide.[99] Commercially available technology upgrades (combustion engines only) and changes in practices on the farm result in potential savings from machinery and on-site transportation.[100] For example, certain changes in farming techniques reduce diesel fuel use as well as energy production costs to the farmer.[101] Changing farm practices to increase efficiency can vary from small adjustments in behavior such as adjustments in crop planning to larger-scale modifications such as converting to no-till farming, which can reduce diesel fuel use.[102]

Fuel

Because of the high use of machinery and on-site transportation on the farm, it is no surprise that fuel energy use is one of the most important ways to improve the energy efficiency of your farm. Researchers have found that gasoline and diesel are by far the fuels most used in the sector, making up seventy-five percent of agriculture fuel use all together.[103] Diesel use dominates because of the high use of diesel fuel in product transport.[104] Fuel expense savings is of primary importance to any farmer, especially to smaller farmers who need to do more with less. Fuel consumption varies widely due to variations in tractor efficiency, soil moisture conditions, crop yields, and other factors.[105] Here are ten ways a farmer can increase fuel efficiency of the farm:[106]

1. Reduce the number of trips associated with spring seed-bed preparation. With today's modern planter units, crop residue does not create the problems it used to with seed placement and depth control. For most field situations,

one tillage trip over the field in the spring should provide adequate leveling of the soil and seedbed preparation.

2. Change to a no-till planting system where field conditions permit. This is especially true for soybeans, as no-till soybeans are an easy and proven way to maximize yields without doing any tillage.
3. Reduce the depth of tillage associated with seedbed preparation if you are using a mulch-till or reduced-till system. In most cases, spring seedbed preparation should be performed no deeper than three to four inches. This will reduce the power and fuel requirements needed.
4. Combine trips across the field may also reduce fuel usage. Producers using 28 percent UAN solutions may be able to mix their pre-plant or pre-emergence herbicides with their fertilizer and apply with one trip over the field. Be sure to check with your ag-supplier regarding chemical compatibility of the herbicides and fertilizer products before mixing these together.
5. Custom apply either or both herbicides and fertilizer this spring. Although an application charge will be charged by the commercial company, they may be able to do it more cost and fuel-efficiently than an individual producer.
6. Use post-emergence herbicides for annual grass and broad-leaf weed control. By applying the post-emergence herbicides after the crops and the weeds emerge, producers know the crop's seedling plant population and the infestation of weed species present. In some cases, producers may only need to do "spot" treatments of either the broadleaf or grass herbicide in the field. Also, by waiting until after the crop and weeds emerge for treatment, weed control is usually improved.
7. Avoid unnecessary use of the cultivator for weed control unless weed populations cannot be controlled with herbicides.
8. Match field equipment to the appropriate sized tractor. If excess tractor horsepower is used for the job, fuel efficiency declines dramatically. Conversely, if a small horse-powered tractor is used and the tractor becomes overloaded for the job, fuel efficiency also suffers. In many situations, research studies show that a large front-wheel assist tractor or four-wheel drive tractor may actually provide the best fuel efficiency if it is appropriately sized to a large field cultivator or other tillage implement. A good rule of thumb is to usually select the smallest and lightest tractor for the job that needs to be done to enhance fuel efficiency and reduce soil compaction.
9. Perform general tractor maintenance before going into the fields this spring. Take time to properly clean air and fuel systems including replacement of filters. Also be sure to properly lubricate tractors and equipment as this will result in enhanced fuel efficiency and equipment operation when you get to the fields this spring.
10. Examine use of the pick-up truck and trips to town. According to research studies, for many farms, one of the largest users of fuel involves the pick-up truck. Without a doubt, the pick-up truck is an essential component of the entire farming operation. However, where possible, combine trips for equipment, seed, chemicals, and to arrange for other agri-business services. Also, using the telephone or the home computer may reduce a number of unnecessary trips to town.

Below is an outline of some additional practical ideas on what to do to save on fuel and increase farm efficiency:

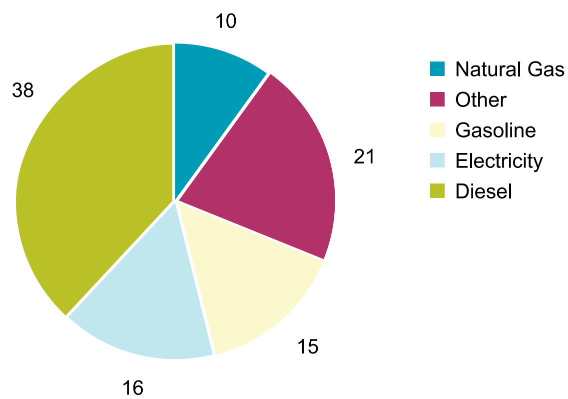

FIGURE FOUR: Total national energy use by fuel type.

Upgrading Diesel Engines or Converting from Gasoline or Electric

One smart way to improve the fuel efficiency of the vehicles or machinery on your farm is to replace any gasoline engines used on the farm with a diesel engine. Even better would be replacing old diesel engines with newer ones that contain more advanced technology. Only fifteen percent of the gasoline you put into the tank is used to move the vehicle or equipment. The rest of the energy is lost to engine and driveline inefficiencies or idling. Therefore, the potential to improve fuel efficiency with advanced technologies is enormous.[107]

Diesel engines are more powerful and fuel-efficient than similar-sized gasoline engines (about 30 to 35 percent more fuel efficient). Plus, today's diesel vehicles are much improved over diesels of the past.[108] Today's diesel engines must meet the same emissions standards as gasoline vehicles. Advances in engine technologies, ultra-low sulfur diesel fuel, and improved exhaust treatment have made this possible. Further improvements are made by combining an upgraded engine that advances in emission control technologies with "clean" diesel fuels, such as ultra-low sulfur diesel[109] and biodiesel created on your farm. Using this technology reduces hazardous air pollutants.[110] Energy efficient engine and transmission technologies are continuously improving.

The purchase price (initial cost) of an electric motor has been estimated to be only 1 to 2 percent of the total operating cost over the lifetime of the motor.[111] Because the purchase price is so insignificant, the farmer's first step in investigating energy savings by purchasing a new electric motor, or upgrading a current electric motor should be to determine how much it costs (energy) to operate current motors on their farm.

Gear up and Throttle Down

Running your tractor at the proper RPM is essential to fuel efficiency. In all cases consult the guidelines issued with the tractor. You should make sure that you don't overload the engine. However, if you are hauling hay bales or pulling a rake, consider reducing the engine RPM by "gearing up and throttling down."

Tires

Tires should always be inflated to the proper pressure. Over-inflated tires decrease traction, create ruts in soft soil and can deteriorate sidewall tread. Also, be careful to not overload your tires. Overloading can cause pre-mature tire wear, increased soil compaction and increased fuel consumption resulting from increased rolling resistance. A University of California Study demonstrated that correctly inflated tire pressure required twenty percent less fuel than those tires that were under- or over-inflated.[112] Always check your equipment owner's manual or consult your local tire distributor for the proper inflation information.

Maintenance

Make sure to perform general maintenance on your farm equipment, especially before and after harvest season. Properly lubricated tractors and equipment will result in better fuel efficiency.[113] Also, be sure to change the filters in the air and fuel systems.[114] Finally, use appropriate equipment ballast to keep wheels from slipping and using more fuel.[114] Ensuring

"Plymouth, New Hampshire: Small Farmers Benefit from Efficiency in Marketing Towards Reducing Fuel Costs"

The Plymouth Area Renewable Energy Initiative (PAREI) is a local organization in Plymouth, New Hampshire, begun to encourage energy conservation, energy efficiency practices and to promote the use of renewable energy. This group collaborated with local agricultural interests, including D-Acre Organic Farm and Educational Homestead, to organize a program to streamline the process by which local goods could get to local consumers.

The problem was that local small farmers invested all of their energy into cultivating and harvesting their crops—leaving them little time to get their crops to market, other than the weekly or bi-weekly farmers market. On the other hand, local restaurants, consumers and markets did not have the time or gas money to attend all of the local farmers' markets to find everything they needed. When PAREI learned of the marketing problems, it organized to seek out government funds from the United States Department of Agriculture—Rural Development Agency for a $3,445 Rural Business Enterprise Grant to begin Local Foods Plymouth.

Local Foods Plymouth is an on-line order and purchasing project that promotes food that is grown or produced in the Plymouth, NH area, which includes the town of Plymouth and 21 surrounding towns. The on-line purchasing system allows farmers and businesses to market their products via the net to the local community during any given week. Under the new system, buyers can purchase items online prior to crops being harvested and delivered to the Local Food Plymouth booth at the Plymouth Farmers' market.

Ultimately, farmers could benefit from the system by saving labor and money by knowing exactly how much pre-bought food to harvest. Furthermore, buyers could now know which crops were in peak season and did not have to shop around for different farmers' markets to find the produce/meat/flowers/bake goods that they wanted to purchase.[115]

“Lancaster, Pennsylvania: Tomato Farmer saves time, energy and money with no-till farming”

In Lancaster, Pennsylvania, tomato farmer Steve Groff has been able to reduce soil erosion, increase his harvest, as well as cut down on the need for herbicides and insecticides on his tomato fields.

As Groff says, “Some of my fields have not been tilled in any fashion for about 30 years. The reason I got away from plowing the soil was because I saw too much soil erosion. My soil was washing away when we had rain and, since soil is my number one asset, I want to try to manage it in such a way to keep my soil in place.”

Steve Groff uses no-till farming to save time, fuel and his soil. Steve never exposes the soil by disking or turning it up in any way. He uses a specially designed planter that places the seeds for his tomatoes and other vegetables into the ground amidst the natural stubble and detritus from last year’s harvest.

“We’ve done some testing comparing the conventional versus no-till tomatoes, and on our farm where we’ve got about a 10 percent yield increase. And we’ve been able to consistently get increased yields ever since we’ve been able to do this,” says Groff. [117]

that you follow the proper maintenance schedule will not only increase fuel efficiency, but will extend the life of the tractor.

Transportation

Minimizing the use of heavy-duty pick up trucks when driving into town can surprisingly save hundreds of dollars a year on gas. Larger trucks and pick ups are important to farm operations, but they should be saved for those tasks that require their power and hauling capacity. Also, remember to use air-conditioning selectively and considering combining trips to town so that one trip can accomplish multiple tasks.

Conservation Tillage

Conservation tillage (CT) is an agricultural strategy where crops are grown with minimal cultivation of the soil. CT can limit the amount of trips that a farmer needs to take through the field. The more traditional method of tilling to control weeds and break up the soil is replaced with other more efficient and environmentally sound practices. With CT, crops are planted directly into the stubble or plant residue of the prior year’s crop. Weeds are controlled with either herbicides or with cover crops planted in between the rows of the new year’s crop. CT has many advantages besides saving on the amount of fuel that a farmer expands caring for their field, including: an increase in soil organic matter, an elevated soil-water holding capacity and a decrease in soil erosion.[116]

72. Elizabeth Brown and R. Neal Elliott, ii On-Farm Energy Use Characterizations (2005) (note: throughout the reports, the researchers express the extreme conservative nature of the potential savings because of the relatively limited data indicating how energy on the farm is used and further lack of data on savings potentials for particular energy end-uses—where there was no data indicating savings, they assumed that there were no savings available in that end-use.) available at: http://www.aceee.org. Insightful data by farm-types that are considered to be a relatively comprehensive representation of all farms across the country (poultry, dairy, greenhouse/nursery, cattle feedlots, oilseed and grain farming, fruit and tree, and hog and pig farms) is also available at: http://www.aceee.org.
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108. Advanced Technology and Energy Efficiency http://www.fueleconomy.gov/feg/di_diesels.shtml.
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Chapter 4: Energy Efficiency: Government Programs and Technology

Energy expenses are normally a significant portion of a farm's budget, accounting for up to 10 percent of total costs.[118] As a result, energy expenditures cost the nation's farmers $10 billion in energy bills a year.[119] Accordingly, energy ranks sixth out of total production expenses.[120] In addition, profit margins on farms (especially small farms) have continued to shrink, leading to an interest in minimizing expenses.[121] Agriculture has been hit hard by recent energy price increases.[122] Of course, the smallest farms feel these effects the most.

Since operating margins for small farms are typically well under 10 percent, energy costs can have an enormous impact on the economic viability of a farm.[123] Lowering these energy costs can be achieved through the adoption of energy efficiency on the farm. According to a conservative analysis, the potential for energy and cost savings in the agriculture sector is over 34 trillion BTUs and over one billion dollars per year (a more aggressive estimate is 98 trillion BTUs).[124] Energy efficiency is the streamlining of energy use through technology and behavior in a way that minimizes energy use and cost while maximizing productivity.[125]

In the following pages we explore different state and federal programs that are available to farmers to help them take advantage of energy efficiency opportunities on their farms. We also touch on capital intensive technology that farmers could consider in the future.

Energy Efficiency Programs

Programs for energy efficiency range from and include:

- Simple tax incentives for farmers.
- An energy audit by a utility to explore opportunities for lower energy consumption on the farm.
- Educational programs that seek to promote information education and exchange between farmers.[126]

In the agriculture sector, there are four primary types of energy efficiency programs that have been most effective and provided farmers with the most benefits: audits; demonstrations; financial incentives and education; and tax related programs.[127] Ag energy efficiency programs have been diverse, reflecting the unique needs of the sector both programmatically and technologically.[128] Each region of the U.S. offers unique programs that address the differing and varying needs of the regions and farm types in order to deliver energy or economic savings while meeting the special needs of the agriculture sectors.[129]

Benefits of Energy Efficiency Programs

A major goal for education programs is to encourage information transfer of appropriate material. There is a lack of information transfer in the agriculture sector due to high sector diversity, both regionally and by farm-type.[130] Education programs raise awareness of the best practices and energy efficiency as a resource for production cost stabilization.[131] The informal ability to lower information transfer barriers contributes to making these programs a success.[132]

Conclusions

Farm houses and very small farms have energy use profiles akin to the residential sector.[133] Larger farms and their relatively intense energy needs use energy more like the industrial sector. The lighting needs reflect the commercial side of agriculture. In order to be successful, agriculture energy efficiency programs must have the best of each of the other sectors.

Most states now have an efficiency service or an energy efficiency utility that can provide many services to farmers to help them kick-start efficiency practices on their farm and in their homes. These programs help energy consumers capture the greatest energy-saving opportunities available through the installation and use of efficient construction designs, products and equipment. Businesses can receive incentives to install high efficiency equipment (such as lighting, motors and HVAC systems). Low-income farmers can receive assistance to convert from costly electric heat and hot water systems to lower cost alternatives. Electric consumers can receive instant coupons or mail-in rebates for discounts on energy efficient lighting products and appliances.

Non-Utility Energy Efficiency Program Administrators

Recently, several states have begun looking for alternative entities to administer energy efficiency programs. This change has partly been driven by restructuring activities and some of the concerns listed above regarding the role of distribution-only utilities in providing energy efficiency services.[134]

Some states (ME, IL, OH, WI and NY) have shifted the responsibility for energy efficiency administration to their respective state government.[135] Oregon has established an independent, non-profit agency, the Energy Trust of Oregon, Inc., to administer the energy efficiency programs there. Vermont established a new entity, the Vermont Energy Efficiency Utility, to act as a regulated energy efficiency utility independent of the state's electric utilities. Vermont solicited competitive bids to select the administrator of its energy efficiency utility, discussed below.

Other states (CT and MA) have explicitly decided to leave the energy efficiency responsibilities with the distribution-only utilities.[136] Massachusetts also allowed towns and cities to establish municipal aggregators to provide generation service to all customers in their boundaries, and to replace the local distribution utility as the provider of energy efficiency programs. To date only one municipal aggregator, the Cape Light Compact covering all of Cape Cod and Martha's Vineyard, has taken advantage of this option.[137]

Case Study: Efficiency Vermont

Efficiency Vermont is the nation's first statewide provider of energy efficiency services. They are operated by an independent, non-profit organization and offer technical advice, financial assistance and design guidance to help make Vermont homes, farms, schools and businesses more energy efficient. In the process they help customers save energy, reduce electric bills and protect Vermont's environment. Efficiency Vermont provides specific energy efficiency advice to dairy farmers that bring many benefits. By incorporating specific energy efficient methods and equipment into dairy farm operations farmers can lower operating costs, reduce energy bills, improve equipment reliability, improve building comfort and safety, improve milk quality, lower equipment maintenance costs and increase productivity. Efficiency Vermont provides rebates for up to 60 percent of the total installed cost of energy saving equipment and offers 0 percent financing to all Vermont farmers. In 2004, Efficiency Vermont provided $850,000 in incentives to dairy farmers that invested in energy efficiency technologies which resulted in over $385,000 in electricity cost savings to those farmers.[138]

Tax Incentive, Grant, and Loan Programs

Farmers that invest in energy efficiency will reduce their operating costs, conserving cash previously needed to pay for energy. States and the federal government are particularly eager to encourage farmers to invest in renewable and energy efficiency technologies in order to help the nation meet its energy needs and stimulate economic development in rural areas, all while helping to combat the larger issue of global climate change. For these reasons, and the myriad of additional benefits that stem from energy efficient practices, the federal government and many states have programs in place that support investment in energy efficiency. The incentives and programs offered cover a wide range of tax incentives, grants, loans, and rebates. Each state has its own set of programs, so be sure to check your state for details.[139] In addition, states are setting their own policies that reward consumers for their energy efficiency practices.[140] If you don't find information in these two areas, be sure to contact your state energy office or local utility for more information.

Farm Bill

One federal program that is available to agricultural producers and rural small businesses in eligible rural areas is the Renewable Energy Systems and Energy Efficiency Improvements Program (also known as the United States Department of Agriculture [USDA] Farm Bill Section 9006 Program).[141] This program offers farmers grants that can range from $1,500 to $250,000. The program also offers guaranteed loans for 50 percent of eligible project costs up to $10 million per project. In fiscal year 2007, there are approximately $11.4 million available in grants and $176.5 million in guaranteed loans. Projects under $200,000 total project costs qualify for a simplified application process. For more information, including information on how to apply for grants and/or loans, and who qualifies visit the USDA website.[142] Or, you can contact a Rural Energy Coordinator in your area to assist you with the process.[143]

Distributed Generation on the Farm

Because efficiency can significantly decrease your farm's energy demands, the farm's need for energy becomes easier to satisfy through distributed generation. Distributive generation (DG) refers to small, modular electricity generators sited close to customer loads.[144] Defined another way, distributed energy generation allows for the production of energy on a smaller scale, which can occur locally at the homeowner level, closer to demand, is transportable, and allows for its storage. This is in contrast to "centralized" systems where the energy is generated by a remotely located, large-scale power plant and then transmitted down power lines to the consumer."[145]

Most DG technologies generate smaller amounts of power, ranging from less than one kW to only a few hundred kWs of power.[146] This is perfect for small and medium size farms whose power requirements are significantly smaller than a larger farm. In addition, distributed power generation technologies use a variety of fuels, including natural gas, diesel, biomass-derived fuels, fuel oil, propane, hydrogen, sunlight, and wind.[147] By combining the techniques learned from Chapters 3 and 4 into a distributed energy generation technology, the potentials are limitless. DG can be a supplement to the traditional centralized system, to fulfill your farm's energy demands all together, or even as a resource to sell any surplus power generated by the DG technology back to the utility.[148]

Benefits of Distributive Generation

The benefits of utilizing distributed generation on the farm are numerous, including residual effects on the entire electricity generating infrastructure. The DOE provides a comprehensive list of these benefits, including:[149]

- By siting smaller, more fuel-flexible systems near energy consumers, distributed generation avoids transmission and distribution power losses, and provides a choice of energy systems to the utility customer.
- Many distributed power systems produce so little noise or emissions that they can be located inside, or immediately adjacent to, the buildings where the power is needed. This greatly simplifies the problems of bringing power to expanding commercial, residential, and industrial areas.
- Distributed energy systems offer reliability for U.S. businesses and consumers who need dependable, high-quality power to run sensitive digital equipment and can provide alternative, less-expensive power sources during peak price periods. The potential market for providing power during peak price periods is as high as 460 GW, according to a DOE study.
- The potential benefits include avoiding or deferring transmission and distribution (T&D) upgrades; improving power quality; lower T&D line losses; and, given the shorter lead times and the modularity of the technologies involved, reduced risk of costly generation and T&D over-capacity by more closely matching electrical supply to demand.[150]

On the "supply side" of the concept, relevant technologies include small-scale internal combustion engine generator sets, small gas and diesel-fired turbine generators, microturbines, energy storage systems, solar photovoltaics, wind generating turbines, and fuel cells.[151] Incorporating other renewable energy sources at the site provides a doubling of energy effect.

A word of caution, however, that not all DG technologies might be perfect for your farm. DG technologies should be carefully planned, selected and implemented in order to avoid the current shortcomings of the technologies. First, distributive generation technologies have capital costs that are approximately double those of the newest central generation stations.[152] Second, today's gas-fired distributive generators, such as microturbines, have an efficiency rate that is about half that of a new gas-fired central plant.[153] Third, distributive technologies are small and thus operators must purchase their natural gas as commercial or small industrial customers.[154] Fourth, while newer fuel-based distributive generation options emit conventional pollution at levels that are comparable to those reached by new central stations, their low efficiency levels result in much higher carbon emissions per unit of electricity generated.[155] One efficiency expert concluded that distributive generation technologies will have to dramatically improve their efficiency and reduce their costs if they are to become competitive with power purchased from the grid.[156]

However, with recent developments in the federal and state governments, as well as in private lending institutions, farmers across the country could soon find investing in DG the wiser choice for the long term, than the traditional short term cost of an electric bill; farmers may soon start building solar panels on the roofs of their barns to provide lighting inside the barn, or install a CHP generator fueled by biomass to run their pumps or water their crops.

Distributed Generation Measures

Distributed generation technologies (called measures here) come in many different forms. Below is a list and description of the most common types that provide the greatest promise to farmers:[157]

Fuel Cells

Fuel cells produce electricity and heat by combining fuel and oxygen in an electrochemical reaction and can operate on a variety of fuels including natural gas, propane, landfill gas, and hydrogen. Their direct conversion of chemical energy into heat and electrical energy offers quiet operation, low emissions, and high efficiencies. With present technologies, fuel cell electrical efficiencies range from 40 to 60 percent, and their combined electrical and heat efficiencies are over 80 percent, thus providing highly reliable, premium quality power. Presently, the cost of fuel cells are relatively high at about $3,000 per kW, but are expected to become considerably lower under mass production.

Microturbines

Microturbines, also known as small gas turbines, with only one moving part, range in size from 30 kW to several hundred kW, and operate on a variety of fuels including gasoline, diesel, and natural gas. Microturbines are quiet, readily dispatchable, and well suited for commercial and industrial applications. First generation microturbines yield relatively low efficiencies of about 30 percent, but also have moderate capital costs of around $600/kW. It is anticipated that microturbines that are fueled by natural gas, without cogeneration, will produce electricity for 7 to 10 cents per kWh making microturbines competitive with centrally based utility electricity generation and distributions service in the near term.

Photovoltaic

Photovoltaic (PV) devices convert direct sunlight into electricity and are modular, lightweight, contain no moving parts (unless tracking devices are used), release no emissions, need no water, and have low operation and maintenance costs. PV panels can be placed on rooftops giving this technology significant siting flexibility. PV installations require relatively large areas to produce significant amounts of power. The most common applications of PV technology to date have been to power small loads in remote, off- grid sites where utility line extension costs are prohibitive. As PV technology becomes more widely used, it is anticipated that resulting mass production will lead to significant price decreases. A number of states provide favorable tax rules for private PV investments.

Reciprocating Engine/Generator

Reciprocating engine/generator sets run on a variety of fuels, come in sizes from 5 kW to tens of MW with installed costs from $500/kW to $1,500/kW. These mass produced sets are supported by established sales and maintenance infrastructures, and are available as residential and commercial cogeneration packages. Drawbacks include relatively high emissions, noise, and maintenance requirements.

Wind Turbines

Wind turbines have been the subject of recent, ongoing technological advances having increased in efficiency and reliability while simultaneously decreasing in costs. Installation costs for wind turbines range from $1,000/kW to $3,000/kW. Adaptations to cold, icing environments has also made progress. While wind turbines have no fuel requirements and zero emissions, they typically produce power at only 30 to 40 percent of their rated capacity and can have site-dependent noise, wildlife habitat, and visual aesthetic concerns.

Storage Technologies

Storage technologies, the most common being the battery, store energy in chemical or mechanical form and like other storage devices can be used for peak shaving, spinning reserve, outage support, and voltage and transient stability. While not yet viable for storing large amounts of energy, batteries are currently used for uninterruptible power supplies, support for off-grid PV and wind systems, and emergency backup for lighting and controls. Other options include compressed air storage, pumped hydroelectric storage, and more exotic technologies such as flywheels and superconducting rings, both of which remain experimental.

Combined Heat and Power

A combined heat and power system (called cogeneration) placed on customers' farm promotes local economic development and other investments in the local community. DG resources are most often installed at the distribution level and can be on either side of the meter. They are typically small, ranging from less than one kW to only a few hundred kWs. On the supply side, gasoline and diesel fueled reciprocating engines have well-known cost and performance characteristics, while micro-turbines and fuel cells are more novel, but have potential advantages where air quality and power quality requirements are critical. Advancement in the efficiency, reliability, cost and maintainability of advanced technologies may be expected to continue and screening choices should be reviewed frequently.

The DOE provides a detailed analysis of the characteristics, benefits, drawbacks, possible fuel choices, and size of each of these distributed energy generation technologies that might be helpful when making the decision of which to choose to utilize on your farm.[158]

Financing Distributed Generation

There are a wide range of financing options for distributed energy systems. Distributed energy requires an upfront investment that is recovered through revenues or savings over time. Some of the financing mechanisms include: appropriations, debt (commercial bank loan), mortgage, home equity loan, limited partnership, vendor financing, general obligation bond, revenue bond, lease, energy savings performance contract, utility programs, chauffage (end-use purchase), and grants. Several financial strategies for businesses are also discussed including: venture capital, informal investors, bank and debt financing, and the stock market.

One example of financing, the home mortgage or home equity loan option, has several advantages to meeting the economics of small-scale of DG. Interest rates on home mortgages are tax deductible, resulting in a lower effective project cost. There are also residential energy efficiency improvement loans of up to $15,000, with interest rates that are below market interest rates.[159]

Another example is vendor financing, which is common among energy technologies. Vendor financing, where a third party such as a bank is often the actual source of financing, offers an easy, low cost solution, and is an effective way for the supplier to stimulate markets. Large companies may use this type of financing, but it is most suitable for small projects in the $25,000 to $400,000 range.[160]

Chauffage is an agreement where the customer purchases the electricity, heating, or cooling of the DG project instead of the actual prime mover itself.[161] This allows the customer not to be burdened with development and ongoing operation of the DG project and the risk of non-performance falls totally on the owner/operator of the equipment.[162]

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Chapter 5: Wood for Fuel on the Farm

The most common form of biomass is wood. For thousands of years people have burned wood for heating and cooking. In fact, wood was the main source of energy in the U.S. and the rest of the world until the mid-1800s. In the U.S., wood and waste (bark, sawdust, wood chips, and wood scrap) currently provide only about two percent of the energy we use today. Roughly 80 percent of the wood and wood waste fuel used in the U.S. is consumed by industrial and commercial businesses. The remaining 20 percent is used in homes for heating and cooking.[163]

Types of Systems: No One Size Fits all Needs

Wood biomass is burned to produce heat for space heating or energy production. There is no one-size-fits-all wood fuel specification for biomass heating. Each project will be different, and each heating system operator will have different expectations. Every state and even different areas within the same state will have different fuel type availability or potential. If you have a wood source reasonably available, a biomass system may be a good option for your farm operation.

Photograph © Mary R. Vogt. MourgeFile.

First you will need to choose a biomass heating system. Factors that should be closely examined and considered early in the planning process are the heating system's technology and capability of handling various wood fuels, the existing regional forest products industry, and the regional forest management objectives to ensure that the local wood source will be available for long-term use. Additionally, not all biomass heating systems will require the same quality of fuel, so matching the right fuel source and quality to the right system and application is extremely important.[164]

Stoves and Boilers

Stand-alone stoves provide space heating for a room. Stoves are usually fuelled by logs or pellets but only pellets are suitable for an automatic feed system. Typical output from stoves is between 6 to 12 kW, although some models can be fitted with a back boiler to provide for hot water as well.[165]

Boilers are normally connected to central heating and hot water systems. These are suitable for pellets, logs or chips, and are generally larger than 15 kW.[166] The output of each system is an important consideration because your system choice will depend on the area being heated. Higher output will be needed to heat more space.

Wood Pellets and Wood Chips

As wood is refined into other forms, its value as a fuel increases. Benefits of refining include easier handling, transportation, and storage; improved durability; higher burning efficiencies; lower variability; and higher energy density. Wood pellets provide most of these advantages, with the added bonus of being easily manufactured. They are an excellent fuel source for

Norman Dewar's Hog Farm

Norman Dewar's hog farm uses a wood chip system to heat his 100 sow farrow-to-finish operation. His 130 kW wood chip system heats the sow barn, nursery, farrowing barn, office and storage building. It also produces enough hot water to supply a four gal/min. pressure washer as well as hot water for personal use in the barn.

Dewar's wood chips are produced from waste slabs and his supply comes from a small sawmill about 9 miles away from his farm. It costs him a little over $3,000 a year for wood chips. Although this is slightly more than he was paying for oil, he is able to heat a much larger area. The extra heat is good for his hogs, especially when winter temperatures plummet well below freezing.

Eric Weeks is a dairy farmer who also heats with wood chips. His system heats both his machine shop and the farm home. It also supplies all the hot water he needs for the dairy barn.

Instead of buying wood chips, however, Weeks produces wood chips using a chipper. Producing chips is practical for Weeks as he owns 150 acres of woodland, which is actively managed under a forest management program. Small diameter limbs, tops and dead wood that cannot be sold as firewood are chipped for farm use without much additional labor or expense.[173]

automated controlled burning in pellet stoves and pellet boilers.[167] Most currently available boilers fueled by wood pellets or wood chips are highly efficient, clean burning and totally automatic, saving you time and money.[168]

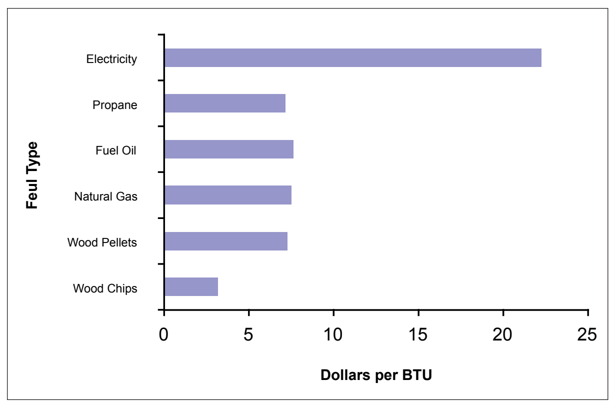
Economics

The amount of savings achievable through installation and use of a wood burning system is dependant on the wood source, the wood-burning system, the area being heated and the difference between inside and outside temperatures.

In the U.S., pellets are sold by the bag, by the ton, and by the skid (1 skid = 60 bags). The selling price currently ranges from $120 to $200 per ton ($2.40 to $4.00 per bag) and averages $150 per ton ($3.00 per bag). Similar to other heating fuels, price varies by region, availability, and season.[169]

Comparing average fuel costs, wood chips and pellets provide more energy per dollar than other energy sources such as electricity, natural gas, liquid propane and fuel oil.[170] For example, in the graph below, wood chips and pellets cost significantly less money per million BTU than all the other listed fuels.[171]

Cost Comparisons of Fuel Types in Wisconsin for Large Volumes[172]



Environmental Concerns

Biomass burning has several negative environmental impacts. Smoke from burning wood contains pollutants like carbon monoxide and particulate matter (PM). Studies have shown that people using wood-burning devices to heat their homes can be routinely exposed to unhealthy levels of fine PM in their indoor air.[174]

Boilers, however, do not have the same air quality issues that are associated with wood-burning stoves. Most boilers are installed with air pollution control devices, such as fabric filters or cyclones, which can reduce PM emissions by 70 to 99.9 percent.[175]

On the positive side, the use of wood products for fuel offers a low environmental impact, productive use for selectively harvested wood that would otherwise require open burning. This is especially applicable in the Western United States where forests have become overgrown and subject to devastating wildfires which have caused significant negative impacts on vital habitats, watersheds, and communities.[176]

Photograph © Blary54. MourgeFile.

The greatest environmental benefit of biomass systems is the potential to significantly reduce the quantity of greenhouse gas emissions. Compared to fossil fuel systems, which load carbon dioxide into the atmosphere, biomass systems do not add to atmospheric levels, when forests are sustainably managed.[177]

Regulatory Constraints

State and local regulations differ widely, with some states restricting the time of use of wood-burning systems and others requiring installation of special technology.[178] Local ordinances and regulatory agencies should be consulted prior to the installation of any wood-burning device or system to ensure compliance with local laws and regulations.

Other ways to ensure cleaner operation would be to follow guidelines set out by the Environmental Protection Agency, as it has developed a list of certified wood heaters and inserts that are designed to eliminate a substantial percentage of particulate emissions in comparison to older, non-certified wood burning technologies.[179]

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Chapter 6: Manure as Fuel on the Farm

Another source of biomass is waste that comes from plant or animal products. Using waste products as a renewable resource can improve your bottom line by reducing waste disposal costs. Additionally, you will save money because your waste products will produce energy that you would otherwise purchase from the local utility. Some dairy (as well as swine, chicken, sheep and turkey) farmers use tanks called "digesters" where they transform the manure from their barns and animal confinement buildings into valuable biogas.[180] Inside the digester, methane gas is separated from the liquid and solid waste. The methane gas can then be used to generate electricity for on-farm use or to sell to the electric power grid through net metering.[181]

Anaerobic Digestion on the Farm

Anaerobic digestion is the breakdown of organic material by bacteria in an oxygen free environment. The end products of this process are a concentrated solid waste, methane, and carbon dioxide gas. This gas is referred to as biogas, which can be used to produce both electrical power and heat. In addition to electricity and heat, anaerobic digestion can also provide a nutrient-rich organic slurry, and other marketable inorganic products.[182]

In order to achieve the benefits of anaerobic digestion, the treatment facility must be integrated into the dairy or farming operation. The operational structure of the farm provides the basis for determining the type of system and estimating the energy generated from the system.[183] The anaerobic facility must be designed to meet the individual characteristics of each dairy or farm.[184] If you are considering incorporating an anaerobic digester with your farm, there are a number of factors to consider such as cost, size, local climate, and the availability and type of organic feedstock material.[185] Also, the number of milk and dry cows, the housing, transport, manure separation, and bedding systems used by the dairy can significantly affect the quantity and quality of material that must be handled as well as the amount of energy produced.[186]

Types of Systems

You need to consider a number of important factors when evaluating whether anaerobic digestion is appropriate for your farm. These include the types and number of animals on the farm, the amount of energy required to operate the farm, and the land use available for the system (longer retention times require larger systems).

There are two basic types of digesters: batch and continuous flow. There are, however, several methods of processing manure: open lagoon, covered lagoon, plug flow digester, complete mix digester, fixed film digester, and upright cylinder digester.[187] The type of system appropriate for your farm depends on the factors listed above. You should contact someone who has experience with a variety of anaerobic digester systems to ensure that you use the correct system for your farm. Implementing the correct system will maximize the benefits that can be achieved on your individual farm.

The above table shows how much energy is likely to be produced per animal. This can help you determine whether

Animal Energy Comparison Table[188]

Livestock	Volume of Solids Production per Animal (lbs/day)	Power Potential (kWh/animal/day)
Dairy Cows	6.2	1.24
Swine	1.64	0.328
Poultry layers	0.048	0.0096
Poultry broilers	0.034	0.0068
Turkeys	0.091	0.0182
Sheep and Lambs	0.92	0.184

Photograph © Mary R. Vogt. MorgueFile.

installation of an anaerobic digester and the implementation of a biogas system is a viable option based on your energy usage and the number and types of animals on your farm.

Types of systems that you might consider include:

Covered Lagoons

A pool of liquid manure is topped by a pontoon or other floating cover. Covered lagoons are designed to use manure with two percent or less solid content. This type of digester requires high throughput in order for the bacteria to work on enough solids to produce gas. These are the least expensive systems to install and operate.[189] Covered lagoon digester operation and maintenance is simple and straightforward. The capital costs for a covered lagoon can be less than those required for other types of conventional digesters. These systems are dependent upon temperature and, as a result, biogas production varies seasonally if the lagoon is not externally heated. This means that methane production is greater in summer than in winter.[190]

Fixed Film

In a fix film operation, a tank is filled with a plastic medium that supports a thin film of bacteria called a biofilm. This design handles one to two percent solids, and uses a shorter retention time (and usually less physical space), as a result of the increased surface area provided by the medium. Retention times can be as short as two to six days.[191]

Complete mix

A complete mix system uses a silo-like tank in which the manure is heated and mixed. It is designed to handle manure with two to ten percent solids. This is the most expensive system to install and operate, but it's particularly appropriate for operations that wash out manure.[192]

Plug Flow

A plug flow system consists of a cylindrical tank in which the gas and other by-products are pushed out one end by new manure being fed into the other end. This design handles eleven to thirteen percent solids and typically employs hot-water piping through the tank to maintain the necessary temperature. A plug flow is most appropriate for livestock operations that remove manure mechanically rather than washing it out.[193]

Useful/Valuable By-Products

Anaerobic digestion provides a variety of benefits. Biogas systems can significantly reduce odor, which often plagues larger farms in areas of suburbanization. These systems also help control agricultural water runoff which is a very large contributor to non-point source water pollution in the U.S. Additionally, using an existing product to generate biogas and electricity can improve a farm's balance sheet. This is especially true if there were disposal costs originally associated with the manure.[194] The presence of pathogens in the liquid and solid products is also reduced as are greenhouse gas emissions. The anaerobic digestion process also concentrates nutrients to create a richer fertilizer for on-site use or for sale to other farms, greenhouses, or nurseries.[195]

It has been shown that "nearly all biomass materials can be digested to produce methane, and that the residual solids are odor free and serve as an excellent soil amendment/compost."[196] Unfortunately, the process of turning these waste products into valuable fertilizer is still underutilized. Anaerobic digestion may also increase the value of the manure for use as fertilizer for some farmers. "The digestion process converts organic nitrogen into a mineralized form (ammonia or nitrate nitrogen) that can be taken up more quickly by plants than organic nitrogen."[197] Another use for anaerobic digestion by-products is as bedding on dairy farms. This can be one of the most economic options for dairy farmers as the typical market price for such bedding is $10/yd^2.[198]

Economics

"A 300-cow farm can produce about 50 kW of power on a continuous basis. That amounts to about 400,000 kWh of power per year."[200] There are two ways of selling the power: selling the power directly to the utility at the wholesale rate or through net metering (this process is described in Chapter 4).[201]

A study funded by the DOE and administered by the Vermont Department of Public Service (VDPS) found that it may not be economically advantageous to implement an anaerobic digestion system on a farm with fewer than 500 cows. The study also found, though, that odor control, reduced pathogens, and other factors may be as important as economics in making decisions about the farm.[202]

Capital costs can be high with some sources estimating anaerobic digester systems to average about $400 per cow for dairy operations.[203] This could result in the farmer taking on

Colorado Swine Partners

Colorado Swine Partners is considered a small- to medium-sized operation with the hogs producing about 12,500 gallons of waste each day. A typical farm of this size would normally use $10,000 to $11,000 of electricity a month to handle its operations.

Colorado Swine Partners, however, uses its hog waste to produce a significant amount of the electricity used by the farm. Through its generation of electricity and designed-in energy efficiencies, the farm purchases only about $3,500 worth of electricity a month.

Hog manure is gravity fed to an in-ground anaerobic digester. The digester is nothing more than an enclosed pit that uses bacteria to help breakdown the manure. As the manure is digested, the methane is collected, and since it is basically the same as natural gas, it is connected directly to a modified natural gas generator and the microturbine; both of which produce electricity.

This system meets about 35 percent of the electrical needs of Colorado Swine Partners, as well as about half of the peak power (power used at any one time). Any excess electricity produced can be sent back to the grid, but to date none has been sent to the grid.

As a result of this project's electricity generation and the installed energy saving devices, such as using fluorescent lights, Colorado Swine Partners' low monthly electricity bill provides overall savings of about $48,000 per year over comparably sized hog farms with similar product output. Since the whole system cost $375,000, the payback on that investment is roughly eight to ten years.

Additionally, the airtight digester cuts down on air pollution and because the digester eliminates much of the manure volume, Colorado Swine Partners only needs a lagoon about one-sixth normal size of comparably sized hog farms, cutting down on potential water pollution and significantly reducing construction costs associated with building a larger lagoon. Moreover, less water is needed to process the hog waste. Along with the energy efficiency of the farm, the operation provides considerable environmental paybacks.[199]

the debt required to install such a system. Federal, state, and local government programs, however, may offer grants and loans to farmers to incentivize anaerobic digestion or the use of renewable fuels. In Minnesota, for example, the state offers a 1.5 cents per kWh production incentive in combination with a low or zero interest loan program to encourage farmers to install anaerobic digesters.[204]

The 2002 Farm Bill also created a program to help farmers, ranchers and rural small businesses purchase renewable energy systems. This program offers grants for up to twenty-five percent of the total project cost. Additionally, commercial loans are available for up to fifty percent of the total project cost.[205]

Environmental Concerns

Collecting and using landfill and biogas reduces the amount of methane that is released into the air. Methane is one of the greenhouse gases associated with global climate change.[206] In addition to greenhouse gas emission reduction, another environmental benefit associated with biogas production is reduction in non-point source pollution. This helps keep water sources cleaner and safer for downstream users. Also, power tax credits may be available for each kWh of power produced and greenhouse tax credits may become available for each ton of carbon recycled. Finally, the power generated is "distributed power" which minimizes strains on the electric distribution grid.[207]

Regulatory Constraints

As stated earlier, individual farms need to consider what is appropriate for their operation. Local Building Codes and Zoning requirements, if any, should be consulted and, subsequently, complied with when constructing an anaerobic digestion process with a biogas recovery system. Local and federal Fire and Safety Codes must also be observed. Each system is likely to be evaluated on an individualized basis because each set-up is different.

Conclusion

Incorporating an anaerobic digester into your farming operation can help you achieve significant economic and environmental benefits. The incorporation of an anaerobic digester can present certain disadvantages such as high capital costs and an investment of time to digester system management.[208]

Depending on your animals and the needs of your farm, these drawbacks may be outweighed by the significant advantages of anaerobic digestion. The major gain is realized through the use of waste products to generate renewable energy. This saves fuel costs while reducing dependence on non-renewable, fossil fuel sources. Other important paybacks include the production of a high-quality fertilizer, odor control, improved water quality, greenhouse gas and pathogen reduction, and the economic benefits gained from reduced disposal costs.

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Chapter 7: Biofuels: Biodiesel and Ethanol Production

Biofuels are fuels, such as ethanol and biodiesel, that are made from biomass materials instead of fossil fuels. These fuels are usually blended with petroleum fuels—gasoline and diesel—but they can be used alone. The popularity of these fuels is growing considerably due to the country's increasing concern over fuel security and greenhouse gas (GHG) emissions from the transportation sector. Large-scale production and use of ethanol has been especially predominant in the Midwest, where processing plants have been built in close proximity to existing cornfields. By keeping transportation costs for the raw materials relatively low, ethanol has become a commonly used gasoline additive in the Midwest. The use and production of biodiesel, however, is in a more developmental stage and is possibly more suitable for on-site use on independent farms than for large-scale production. One of the main limits on widespread use of pure biofuels is that the only vehicles capable of running on pure biodiesel, also referred to as B100, are those with diesel engines. For this reason, biofuel production is especially well-suited to small- or medium-sized farms, where production could fuel on-site vehicles, most of which typically have diesel engines.

Biodiesel

Biodiesel is a fuel made with vegetable oils, fats, greases or oil seed crops. The fuels from any of these products can be used in diesel engines without altering the engine. Biodiesel is the fastest growing alternative fuel in the U.S., most likely because it is safe, biodegradable, and it is a renewable fuel.[209] While more and more individuals are pursuing used restaurant grease and oil as a biodiesel source, as an agricultural endeavor, biodiesel begins with growing oil seed crops.

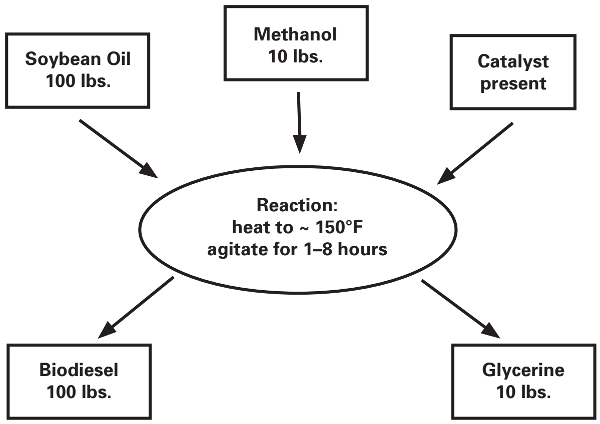
One factor that may affect the economics of biodiesel production more than any other factor is fuel yield per acre of different oil seed crops.[210] The type of crop you choose to grow will depend on a variety of factors, including your location, climate, available land, and the market in your community. But within your particular location's real-world limitations, the yield efficiency of a crop must be one of the most important factors in your crop choice decision-making. One study estimated that total operating costs range from $1.39 to $2.52 per gallon of fuel produced depending on feedstock used.[211] While costs per gallon of biodiesel produced will depend on the maintenance costs of different types of plants, such as fertilizers or irrigation, fuel yield per acre is highly determinative of the crop's value to your farm. The table below illustrates an estimate of fuel yields per acre for different crops.

Biodiesel Yield per Acre from Selected Crops[212]

Crop	Yield (gallons per acre)
Oil Palm	508
Coconut	230
Rapeseed	120
Peanut	90
Sunflower	82
Soybean	56

After the oilseed crop is grown, biodiesel production requires two processes: extracting the oil from the seed and processing that oil into biodiesel. The technology investment includes a seed cleaner (to remove husks or seed coats), an oil seed press, and the equipment necessary to convert the oil into biodiesel.

If you grow your own seeds, the cost of the equipment needed to successfully farm these seeds should be taken into account. If the farming equipment necessary to grow and harvest the seeds is readily available or you buy your seeds from another local source, the costs of getting oil out of the seeds needs to be considered. Making your own biodiesel requires an investment in a seed cleaner (to remove husks or seed coats), which can cost about $1,600 new[213] and an oil seed press, which can be purchased for about $5,000 to $10,000, depend-



ing on how large and powerful a press you need.[214] Once the oil has been pressed out of the seeds, it can be processed into biodiesel.

As the above diagram illustrates, the process of making biodiesel is relatively straightforward. The oil is heated in a processor, usually to about 150 degrees Fahrenheit. A mix of lye and methanol[216] is added to the oil and the mixture is agitated for a period of time. The length of agitation time is dependent on how much biodiesel you are making. After agitation, the biodiesel needs time to settle and separate from the glycerin, which is a by-product of the biodiesel production process. The biodiesel is then washed with water to further remove glycerin. Finally, another separation is required to remove all excess water from the biodiesel.[217]

Besides the initial cost of the processing equipment, biodiesel production costs include the cost of the chemicals used in the reaction, typically lye and methanol, gas or electricity expenses, and labor. Learning how to grow oilseed crops, use the equipment, and consistently working to get the right mix of oil, lye, and methanol to produce biodiesel can require a significant time investment.

A small-scale, on-farm production model might be a better fit to the scale of production and the economic realities of farming in smaller communities where most farms are small to medium in size.[218] There are a few commercially available biodiesel processors designed for small scale operations, such as the BioPro 190 Automated Biodiesel Processor.[219] Building your own processor is also an option. A few good online resources are:

- *Make Your Own Biodiesel.*[220]
- *Biodiesel – A Primer, Farm Energy Technical Note* by David Ryan, P.E., ATTRA Publication #IP263 (Dec. 2004).[221]
- The Appleseed Biodiesel Reactor, Collaborative Biodiesel Tutorial.[222]

One of the main problems facing small-scale biodiesel production is that regulation is unclear in most states. The legal benefits and obstacles faced by small-scale, on-farm producers of biodiesel are highly variable between different states and even between different towns. Clear policy at the federal, state, or local level would do much to advance this energy source.

In short, the economics of biodiesel production on your farm depend primarily on the seed type, the specific production process, your location, and expected use of the fuel. It is important to plan out the various aspects of biodiesel production to determine how much capital investment is needed and the value you can earn from your anticipated biodiesel output. Working with another farmer already producing biodiesel in your community or state, contacting your state extension agency, or hiring a consultant may be a good first step in evaluating whether biodiesel production would be a worthwhile investment for your farm. [223]

Useful/Valuable By-Products

Producing biodiesel yields a couple of by-products which should be considered in the decision of the feedstocks (crops) and the technology used to produce the fuel. Because of the value of biodiesel's by-products, forming a cooperative might be the best way to earn the maximum economic benefits from biodiesel production.

Glycerin, also known as glycerol, is one by-product of biodiesel production, which is used in pharmaceuticals, cosmetics, toothpaste, paints, cleansing agents, soaps, and other commercial products.[224] Although there could be a market for glycerin in your local community, traces of methanol and other products are still present in the glycerin after the biodiesel production process. Extensive washing is necessary to achieve glycerin that is marketable and the amount of time and energy required to clean the glycerin might negate any benefit achieved through its sale. Additionally, the waste water will contain traces of methanol. The costs associated with disposing of the methanol-contaminated waste water in an environmentally safe and legal manner also need to be considered.

Seed meal is another by-product of the biodiesel production process. Seed meal can function as an inexpensive livestock feed or serve a number of other purposes. For example, mustard and canola meal can be used as soil amendments, soil fumigants, pesticides, herbicides, fertilizers, and food additives for human and animal consumption.[225] If you are in a farming community, the sale of seed meal to your neighbors could be a valuable income source. Indeed, the seed meal by-product of a biodiesel operation can often be more profitable than the fuel production for farm equipment.[226]

Although virgin oils are not necessarily a by-product of the biodiesel production process, you (or other local farmers) might choose to take advantage of your seed press simply to sell high quality virgin oils. Depending on your seed type and your location, you may find markets for specialty oils or other lubricants that you could produce using the equipment you have purchased as part of your biodiesel production process. The amount of refining and marketing of additional products can add complexity and cost, but also increase potential revenue streams to the operation.[227]

Tax Implications

There are a variety of tax incentives available under state and federal programs for biodiesel production. For example, the Small Agri-Biodiesel Producer Credit provides a 10 cent per gallon credit if you produce less than 60 million gallons of biodiesel annually.[228] There is also a Federal tax credit for "Certain Fuel Mixtures" which are between $0.50 and $1.00 per gallon, depending on how your fuel is categorized.[229] However, these incentives are usually only available if the biodiesel meets certain testing requirements. The biodiesel used must typically meet ASTM D6751 and be registered with the Environmental Protection Agency (EPA) as a fuel.[230] Your EPA regional office should be able to clarify any questions you may have regarding testing requirements.

Economics

Information on the economic feasibility of small-scale biodiesel production is limited, but several studies have reviewed the market potential and the economic costs of producing biodiesel.[231] Although these studies provide a general starting point in evaluating the economics associated with biodiesel production, none of them address biodiesel in a comprehensive fashion, starting from growing the crop and ending with successful marketing and sales or use of the fuel. As one commentator noted, these studies did not consider "[s]ome cost elements including land, administration, transportation, or market development."[232] As a result, costs need to be evaluated on a site-specific basis, taking into account the type of crop you are farming, whether you need any additional equipment to successfully produce a suitable crop, and how much of a crop you need to produce your required amount of biodiesel.

The largest cost item in biodiesel production is the primary oil used for processing (80 to 85 percent), followed by energy and water.[233] Equipment costs can also be a high cost item. Most processing equipment will fall in the cost range of $5,000 to $10,000. In addition to that initial cost of the processing equipment, biodiesel production costs also include the cost of the chemicals used in the reaction, the gas or electricity expenses, and your time and labor.[234]

Environmental Trade-Offs

Biodiesel is much less polluting than petroleum diesel. It results in substantially lower emissions of almost every pollutant generally associated with the combustion of transportation fuel: carbon dioxide (CO_2), sulfur oxide (SO), particulates, carbon monoxide (CO), air toxics, and unburned hydrocarbons. Biodiesel contains almost no sulfur and through blending with petroleum based diesel, it can help reduce sulfur emissions from diesel fuel used throughout the country.[235] Biodiesel does, however, release significant nitrogen oxide (NO_x) emissions.[236] NO_x emissions are about 200 to 300 times as potent as CO_2.in terms of their greenhouse effect in the atmosphere.[237] Growing crops for biodiesel production, however, can reduce CO_2 levels in the atmosphere: for example, growing soybeans takes nearly four times as much CO_2 out of the atmosphere as the amount of CO_2 released in the exhaust from burning soybean oil biodiesel.[238]

In 2000, biodiesel became the only alternative fuel in the country to successfully complete a EPA health effects testing. The EPA testing demonstrated that biodiesel significantly reduced virtually all regulated emissions, and showed that biodiesel does not pose a threat to human health.[239]

In regard to energy security and efficiency, biodiesel helps preserve and protect natural resources by yielding more energy than is used to produce it. According to the National Biodiesel Board, "for every one unit of energy needed to produce biodiesel, 3.24 units of energy are gained. Because of this high energy balance and since it is domestically produced, biodiesel use can greatly contribute to domestic energy security."[240] When produced in a sustainable manner, biodiesel protects our natural resources because it reduces reliance on traditional fossil fuels that not only pollute the air and water, but contribute to the degradation of our nation's landscape.

Photograph © Ladyheart. MorgueFile.

The Regulatory Framework

Although biofuels are not a new fuel source, state and federal regulators have not provided any clarity as to the regulation of biofuel production. Instead, regulation is largely dictated by local permitting agencies. Thus, you should seek the assistance of the town clerk, the zoning administrator, the planning commission, or public works prior to beginning any projects or when making substantial changes to existing operations.

Types of permits, codes, or regulations that might apply to a biodiesel processing facility or production site are:

- Building codes.
- Zoning requirements.
- Fire marshal inspections.
- Department of Public Safety approval.
- Environmental permits (generally administered at the state level).

Specific Regulations for Selling or Trading On-Farm Produced Biodiesel

If you plan on selling or trading your fuel, you must register with the EPA.[241] When you register, the EPA must have access to health effects testing data on your fuel. While this may sound daunting, one advantage for biodiesel is that the National Biodiesel Board (NBB) completed this testing in 1997 and grants access to this data to all of its Biodiesel Processor and Small Producer members free of charge.[242] Because the EPA allows a group who has completed health effects testing previously, and has its data on file with the EPA, to give access for all of its members, becoming a member of the NBB could be a valuable investment if you plan to sell or trade biodiesel.

In addition to registering your fuel with the EPA prior to sale, you may also need to obtain a fuel dealer's license. These licenses are typically administered by the state and limited to those businesses that are categorized as dealers or distributors of diesel fuel which is being used in motor vehicles. The term motor vehicle is defined differently, but is usually only applicable to vehicles that are used on the public highway.[243] If the biodiesel is being sold to others for use in motor vehicles that will be used on the public highway, then a diesel fuel dealer's license may be needed and an application should be filed with the Commissioner of Motor Vehicles at the Department of Motor Vehicles.[244] Additionally, a state implemented Motor Fuel Tax may be applicable to any biodiesel that is used on the public highway.[245]

Ethanol

Ethanol is an alcohol fuel made from the sugars found in grains, such as corn, sorghum, and wheat, as well as potato skins, rice, sugar cane, sugar beets, agricultural residues and yard clippings. Over 95 percent of the ethanol used in the U.S. today is distilled from corn.[246] Ethanol has two main uses: it is used as an extender, to add volume to conventional gasoline, and as an oxygenate, "an oxygen-boosting fuel additive that is blended with gasoline to ensure more complete burning, reduce air emissions, and enable high-compression engines to run more smoothly, without 'knocking.'"[247] About ninety-nine percent of the ethanol produced in the United States is used to make E10, or "gasohol," a mixture of ten percent ethanol and ninety percent gasoline. Ethanol is also used to make E85, a mixture that is eighty-five percent ethanol and fifteen percent gasoline. Although any gasoline-powered engine can use E10, only specially made vehicles can run on E85.[248] Ethanol can also be used in the manufacturing of biodiesel, serving as a more environmentally benign alternative to methanol.[249]

On top of growing the biomass feedstock, there are three principle steps in the ethanol manufacturing process: first, converting feedstocks into simple sugars; second, fermentation; and finally, recovering ethanol and useful co-products.[250] The process for small-scale ethanol production is similar to the processes described above for biodiesel, but small-scale, on-site ethanol production is more equipment-intensive than biodiesel production. Ethanol production requires a still, which you can build[251] or purchase,[252] and you will need to learn how to ferment grains and other available feedstocks.[253] Additionally, home fuel-makers need to get a "small fuel producer" permit from the U.S. Alcohol and Tobacco Tax and Trade Bureau.[254]

In the U.S., corn ethanol is currently made by either dry milling or wet milling. It is worth noting that these processes are incredibly water intensive. A recent study from the Institute for Agriculture and Trade Policy estimates average water consumption for ethanol plants at about four gallons for every gallon of ethanol fuel produced.[255]

Wet Milling

Wet milling is the process of separating the corn kernel into starch, protein, germ and fiber. This is done by steeping the corn in water and sulfur dioxide. The main by-products of wet milling include starch, high fructose corn syrup, corn oil, and corn gluten.[256] Although wet mills produced more than 80 percent of all U.S. ethanol in 1990, dry milling has become the primary method of ethanol production, with over 90 percent of all new production coming from dry mills. Among other advantages, dry mills are considerably more energy-efficient than wet mills.[257]

Dry Milling

During conventional dry milling, the whole corn kernel is ground into a powder, mixed with water to form a mash,

State Line Farm

With help from University of Vermont scientists, John Williamson and Steve Plummer are working to produce ethanol and biodiesel. In order to distill their own ethanol, they have been growing sweet sorghum and received the necessary permit from the Bureau of Alcohol, Tobacco and Firearms. They have also learned how to make lye from wood ash.

At the other end of the shed from the ethanol still, a metal container is nearly overflowing with oil the color of melted butter. With a cost-sharing grant from the University of Vermont, Williamson and Plummer bought a $9,000 screw-auger press from Sweden that squeezes seeds, sending oil down a pipe and the pressed "seed cake" into a hopper below. Stainless steel reactor tanks sit on the concrete floor near hoppers of dry seed. Once their new facility is complete, the mixing process necessary to create biodiesel from the seed oil will take place inside these safely sealed tanks.

Their electrical power will come from a wind turbine, hot water from a solar system. The residue from the sorghum and possibly sugar beets will fuel a furnace that both heats the oil in the biodiesel reactor and fires the ethanol distillery. The by-products of each process also have value as a food source and can be used as component in animal feed stock.

"John and Steve have the goal of developing a decentralized, biodiesel production model that other farmers could adapt," Vern Grubinger, an Extension professor at the University of Vermont, says. "This model supports energy independence, reduces consumption of fossil fuels and contributes to a sustainable fuel-food cycle."[268]

and then cooked with added enzymes that turn the starch to glucose. After cooling, the mash is fermented with yeast and finally distilled to separate alcohol from the solids and water. A by-product of the dry milling process is distiller's grain, used for animal feed, and carbon dioxide. About one third of the corn kernel mass ends up in the distiller's grain.[258] A modern dry mill makes 2.6 to 2.8 gallons of ethanol and 18 pounds of distiller's grain from a bushel of corn.

Cellulosic Ethanol

Newer manufacturing processes allow ethanol to be made from cellulosic feedstocks, such as agricultural waste, forest residue and municipal solid waste. Although these enzyme-driven processes are not currently commercially available for independent farm use, they are being widely studied and researched in an effort to produce an economically viable process.[259]

While there are some fuel security and economic benefits to ethanol, the impacts and costs of feedstock production and processing can be quite significant and should be considered in any life-cycle cost-benefit analysis of ethanol.

Economics

Making alcohol from various feed-stocks like corn, barley, potatoes, or Jerusalem artichokes will cost about $1.10 to $1.20 per gallon. If you sell or use the distiller's grain as animal feed, it is possible to reduce the total net cost to about $0.95 per gallon.[260] The following table can be used to estimate how many gallons of ethanol you can produce based on the listed feedstocks.

Average Yield of 99.5 Percent Alcohol Per Acre[261]

Material	Gallons
Jerusalem Artichokes	1,200
Sugar cane	555-889
Sorghum cane	500
Sugar beet	412
Potatoes	299
Corn	214
Sweet Potatoes	190
Rice, rough	175

Tax Incentives

Federal and state incentives increase the economic viability of ethanol production. For example, at the federal level, the Volumetric Ethanol Excise Tax Credit (VEETC), provides a tax incentive of 51 cents per gallon of ethanol used in fuel.[262] At the state level, Minnesota has led the nation in supporting locally owned ethanol facilities. In the late 1980s, the state established a producer payment program of 20 cents per gallon of ethanol, limited to in-state ethanol producers that produced a maximum of 15 million gallons per year. This law encouraged the creation of many small and locally-owned ethanol plants.[263]

Environmental Trade-Offs

Since the early 1990s ethanol has been blended into gasoline to reduce harmful carbon monoxide emissions. When burned, ethanol releases carbon dioxide, a green house gas, but growing the plants that produce ethanol reduces greenhouse gases, since plants use carbon dioxide as they grow.[264] In addition to cleaner air, the use of ethanol as a fuel additive can lead to cleaner drinking water supplies because it can consistently replace methyl tertiary butyl ether (MTBE), another fuel additive that is harmful to drinking water.[265] Ethanol is also nontoxic and easily biodegradable in the environment, unlike gasoline and other petroleum products.[266] When produced on a small scale from local feedstocks, ethanol may be considered a renewable fuel source.[267]

The Regulatory Framework

As stated earlier, to produce ethanol, a federal operating permit is required by the U.S. Alcohol and Tobacco Tax and Trade Bureau. Other permitting requirements might be required similar to those involved with on-site production of biodiesel. Local and federal Building, Zoning and Fire and Safety Codes must be complied with. The local Department of Public Safety should also be contacted regarding the safe storage and use of ethanol.

Conclusion

Utilizing feedstocks already available on your farm to produce biofuels can help reduce your energy bills and your dependence on fossil fuel sources. Although there are some regulatory hurdles, producing biodiesel or ethanol could be an additional source of revenue based on the value of the fuel and by-products of the production processes.

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248. Biomass—Renewable Energy from Plants and Animals, Energy Information Administration Energy Kid's Page (last updated October 2006), available at: http://www.eia.doe.gov/kids/energyfacts/sources/renewable/biomass.html.
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253. Ethanol Fuel, available at: http://journeytoforever.org/ethanol.html.
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Chapter 8: Net-Metering and Government Programs

As some of the world's most important environmental stewards, farmers have a long tradition of protecting the land, air, and water they use to grow food for their communities. Investing in renewable energy is one way that farmers can continue this tradition. Renewable energy refers to non-fossil fuel sources of energy. Fossil fuels (coal, oil, and gas) are not renewable because they take millions of years to form and there are limited amounts of each stored in the earth. Wind and solar are both considered renewable energy sources because humans will never exhaust the supply.

Investing in renewable energy and reducing reliance on fossil fuels is also a way for farmers to join in the fight against global climate change. In fact, coupled with cost-effective energy efficiency measures and homegrown biomass, renewable energy has the potential to make many farms carbon neutral.

Finally, renewable energy is not just a benefit to farmers. It also impacts national and international energy security. With over 60 percent of U.S. energy coming from foreign sources, we are increasingly dependent on the political whims of OPEC[269] and other oil and gas producing countries.[270] The time is ripe to shift the energy balance. With the right policies and investments, farmers can begin to replace Middle Eastern oil with renewable domestic energy sources.

Photograph © Vandcooler, MourgeFile.

Net Metering: A Way Forward for Renewable Energy

Unlike a standard electric utility meter that measures only how much energy is consumed by the customer, net metering uses a bi-directional meter that records the flow of electricity both to and from the customer.[271] This simple bi-directional meter opens up a whole new opportunity for customers with their own renewable energy systems. Net metering allows users to sell extra energy back to the utility for use by other customers connected to the grid. By selling electricity back to the grid, farmers who install renewable energy systems are able to do more than simply replace dirty, expensive fossil fuel powered electricity: They are able to turn excess energy into dollars.

The mechanics of the bi-directional meter are straightforward. The meter spins forward when your farm is consuming electricity from the grid, and spins backwards when your farm has excess electricity from its renewable energy system.[272] At the end of each billing period, the utility charges you only the "net" amount of energy you consumed. If you put more electricity into the grid than you took out, you pay nothing and the balance is carried over to the next billing period. Net metering systems vary, but in some states the utility will pay you directly for excess energy delivered back into the grid.

The importance of net metering is its ability to act as a storage system for renewable energy. One of the challenges with electricity is the inability to store it in large quantities. While the wind can turn a turbine at any hour of the day or night, we typically consume most of our energy only at a few peak times during the day. Without net metering, all of the excess electricity produced by renewable energy systems at off-peak times is wasted. With net metering, that excess electricity is sold to the grid, and offsets the cost of the electricity consumed at peak times. The "net" result can be significant savings.

Unfortunately, net metering is not available in every state, and even where it is available, it may come with significant limitations. For more information on the particulars of net metering in your state, see *Freeing the Grid: How Effective State Net Metering Laws Can Revolutionize U.S. Energy Policy*.[273]

Government Initiatives: Policies that Support Renewable Energy

Net metering goes a long way toward easing the financial hurdle of the upfront costs associated with installation of a renewable energy system. There are also other ways that farmers can save money. The federal government and many states administer programs that support investment in renewable energy systems. The benefits of renewable energy production reach well beyond the farm. Regional and national benefits include improving public health due to reduced pollution, easing the burden on electric power grids, combating global climate change, and reducing dependence on foreign oil. With all of these benefits, state and federal governments are eager to promote renewable energy production on farms, as well as in homes and businesses. It is a wise investment of government money and a big help for you and your farm.

The government programs offered cover a wide range of tax incentives, grants, loans, and rebates. One federal program that is available to any U.S. farmer is the Renewable Energy Systems and Energy Efficiency Improvements Program (also known as the Section 9006 Program).[274] This program offers farmers grants for 25 percent of eligible renewable energy system investment costs up to $500,000. The program also offers guaranteed loans for 50 percent of eligible project costs up to $10 million. In fiscal year 2007, there is approximately $11.4 million available in grants and $176.5 million in guaranteed loans.[275]

Another important, and often overlooked, source of revenue for farm-powered renewable energy systems is renewable portfolio standards (RPS) and tradable renewable energy credits (RECs). Twenty-three states and the District of Columbia have implemented renewable portfolio standards,[276] which require that a certain percentage of the electricity sold by utilities in the state come from renewable energy sources. In some of these states, the requirement can be satisfied by the purchase of RECs from qualifying renewable energy producers, even if the utility doesn't directly purchase the corresponding electricity. This means that farmers who install renewable energy systems may produce valuable RECs that can be sold to electric utilities. Each state's system is different, with some requiring that the renewable energy be produced in-state and others allowing purchases from out-of-state sources. Regardless of the specifics, every RPS program creates strong incentives for renewable energy production that can be turned into real money for farmers.

The REC market is not limited to electric utilities. Many businesses and non-profit organizations purchase RECs from renewable energy producers to offset emissions of the greenhouse gases that cause climate change.[277] Right now these offsets are done on a voluntary basis, but with growing concern over global climate change, a national cap-and-trade system for greenhouse gases could be implemented in the near future.[278] When such legislation is passed, utilities will be looking for the cheapest way to offset greenhouse gas emissions and the market for RECs will explode. Farm-powered renewable energy will become even more valuable. With RECs adding a second source of revenue in addition to the energy itself, renewable power systems can be a great investment for forward thinking farms.

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269. OPEC is the Organization of the Petroleum Exporting Countries, consisting of Algeria, Angola, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates (UAE), and Venezuela. See, http://www.opec.org/aboutus/.

270. Strengthening National Energy Security, available at: http://www.fueleconomy.gov/feg/oildep.shtml.

271. Network for New Energy Choices, *Freeing the Grid: How Effective State Net Metering Laws Can Revolutionize U.S. Energy Policy*, Report No. 01-06, Nov. 2006, available at: http://www.newenergychoices.org/uploads/netMetering.pdf.

272. Id.

273. Id.

274. The Secretary of Agriculture's final rule implementing the Section 9006 program is published at 7 C.F.R. § 4280 (2006).

275. See, Renewable Energy and Energy Efficiency, available at: http://www.rurdev.usda.gov/rbs/farmbill/index.html.

276. For more information, see, http://www.pewclimate.org/what_s_being_done/in_the_states/rps.cfm.

277. For example, companies like TerraPass Inc. sell emission offsets for vehicles and air travel, investing the proceeds into renewable energy projects through the purchase of RECs. See, http://www.terrapass.com.

278. For a list of recent Senate bills proposing carbon cap-and-trade systems, see, http://www.pewclimate.org/docUploads/Cap-and-trade%20bills%20110th_Feb5.pdf.

Chapter 9: Renewable Energy: Wind

Anyone who has been outside in a strong storm is familiar with the power of the wind. For centuries, farmers harnessed this power using windmills to grind grain and pump water.[279] In a similar fashion, wind turbines turn wind into valuable electricity that powers pumps, motors, and equipment, as well as provides light and heat for barns and homes. When combined with net metering, a wind turbine may reduce expensive electricity bills, or, if the turbine is installed on a site for optimum efficiency, it may actually turn a profit. Along with other means for achieving energy efficiency such as, biomass, solar and methane, etc., wind may help small and medium farms become completely energy independent.

Turbine Type	Power Rating (kW)	Blade Diameter (ft)	Tower Height (ft)
SWWP AIR-X	0.4	3.8′	60′
Bergey XL 1	1.0	8′	80′
SWWP Storm	1.8	12′	40′
SWWP Wh. 500	3	15′	80′
Bergey Excel	7.5	22′	80′
FL 30	30	43′	120′
NW100/19	100	63′	115′
V27 (225 kW)	225	89′	110′
V47 (e.g. Hull, Mass)	660	154′	164′
GE 1.5SL	1,500	253′	197′

Common Types of Turbines with Corresponding Power Ratings and Sizes

In addition to proper siting of the turbine itself, one of the main factors for efficient wind power generation is the turbine's blade size. Typically, the larger the turbine's blade diameter, the more electricity it may generate (qualified by the nature of the winds in your area—the largest turbines are best suited for high wind areas, for example). The maximum amount of power produced by a turbine is called the turbine's "rating."[280] The higher the power rating, measured in kW, the more electricity a wind turbine potentially produces. If you are looking to offset the energy needed to power your home or building, a small, "micro-wind" unit may be sufficient. However, if you are looking to produce enough electricity for the whole farm a larger commercial size turbine may be necessary.

"Micro-wind" turbines attach to roof tops or 30 to 60 foot towers.[281] However, turbines placed on roofs are often less efficient and may produce excess noise and vibration. Commercial size turbines may require you to work with a developer to install the 200 to 250 foot towers.[282] These can produce up to several megawatts of electricity, but keep in mind that with increasing size and power outputs, comes increasing start-up costs. Also, all turbines require repair over their lifespans, so it is important to factor in maintenance and service costs into your calculations. We strongly recommend that you consult a wind expert, financial advisor, and your lawyer before installing larger scale wind turbines.

For those with a technical, "do-it-yourself" inclination, Scoraig Wind Electric, run by Hugh Piggot, offers publications, courses, and general information about building your own wind turbines.[283] Home built and installed turbines are generally less expensive than purchasing manufactured turbines. Keep in mind, however, you will still need to hire a certified electrician to connect your system to a power inverter and then to the grid according to local utility interconnection standards.[284]

Regulatory Issues

There are several regulatory issues that need to be addressed if you are considering installing a wind turbine. First, many towns require a siting permit, and some have height or location restrictions.[285] Be sure to check with your local town council or

Burmeister Farm, Central Kansas: An AWEA Success Story

Since 1984, Paul Burmeister has been enjoying the benefits of his 10 kW Bergey EXCEL-S wind turbine, which supplies 183,000 kWh of reliable, clean energy to his farm near Clafin, Kansas. With his net-metered system, Paul's monthly electric bills fell from $50–60 to about $5. Plus, at the end of each year, his electric utility pays him a few hundred dollars for the excess power he sold back to the grid.

Paul first installed his wind turbine because of a concern with our reliance on fossil fuels and their negative environmental impacts—greenhouse gases, acid rain and smog forming pollutants, and harmful mercury emissions. But once the electricity bills started falling, Paul realized that wind power isn't just good for the environment, it's good for his bottom line.

For more examples of successful wind installations on farms see the American Wind Energy Association's website at http://www.awea.org/smallwind/success_stories.htm.

select board to understand the requirements. It is also a good policy to talk to your neighbors about your plan before you start construction. If the wind turbine will be visible from their property, it is common courtesy to raise the issue and find out if a wind farm will cause any debate. Plus, it is a great opportunity to spread the word on the big benefits of renewable energy on farms.

For larger commercial scale wind turbines or for those individuals interested in net-metering, you may need special certification.[286] Each state has different standards and requirements for connecting to the electricity grid.

Who Should Install Wind Systems On Your Farm?

The first element required for the installation of a wind turbine is a windy location. To get a rough idea of whether or not your property contains the proper wind speeds you can refer to the National Renewable Energy Lab's wind atlas maps.[287] If the maps suggest good wind resources, you may want to collect data on your farm for up to a full year. Many wind development firms will do this for you, or you can participate in an anemometer (a wind speed measurement device) loan program. Check with your local colleges, public utility companies, and Natural Resources Conservation Service (NRCS) or USDA office for programs near you.

If you have good wind on your farm, the next step is to find a suitable location for your turbine(s). A general rule of thumb for siting turbines is that the distance from an obstruction, like a house or barn, must be 20 times the height of that obstruction. For instance, if you have a barn that is 50 feet high, the wind turbine should be 1,000 feet from the barn for the best results. In addition, the turbine should be twice as tall as the structure. So for the same 50 feet tall barn, the wind turbine should be 100 feet tall.

Small scale wind turbines may need to be secured with guy wires, which will require additional space. If you are considering multiple turbines, they should be placed five rotor diameters apart to ensure enough room for maintenance, wildlife movement, and to reduce interference between the turbines.[288] All turbines should be located in areas with minimal obstructions, such as buildings, trees, and hills. The most desirable site for turbines is on a hilltop or ridgeline with a flat surface. Also, potentially environmentally sensitive locations should be taken into account. For instance, bird and bat migratory pathways are not good locations for turbines.[289]

Finally, it is important to keep in mind the cost of installing a wind turbine. According to the American Wind Energy Association, the installation of a micro-turbine producing about 10 kW of electricity costs approximately $32,000. Generally costs can range from $20,000 to $60,000.[290] The cost is related to many things such as size, tower type, permitting fees, service agreements, installation, equipment, and maintenance. Fortunately, the federal government and many states offer strong incentives for wind turbine installation, including grants, low or no interest loans, and tax benefits.

Commercial Wind Farms: Leasing Your Property

Some farmers with appropriate wind resources and space may want to consider leasing their land to a large wind developer. This can be a very lucrative arrangement in which a developer leases a plot of your land (typically with right of way access), and builds, owns, and operates one or more large commercial size turbines on your property.[291] Your farm may not receive any electricity from this turbine, but instead you will receive considerable lease income. Plus, by leasing your land, you support wind energy on a larger scale benefiting many other citizens. Most lease agreements pay the farmer a fixed percentage of the revenues produced by the wind turbine, but other arrangements may be possible.[292] If a developer approaches you, make sure to speak with your lawyer before signing any contracts.

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279. Robert Righter, Wind Energy In America: A History 15 (1996).

280. J.F. Manwell et al, Wind Energy Explained 60 John Wiley & Sons Ltd (2004).

281. United States Department of Energy Office of Energy Efficiency and Renewable Energy, *How Wind Turbines Work*, available at: http://www1.eere.energy.gov/windandhydro/wind_how.html.

282. Id.

283. See Scoraig Wind Electric, available at http://www.scoraigwind.com/ (noting this website is a good source of information for building your own turbine).

284. Vermont Agency of Agricultural, Farm Energy Handbook: A Guide to Renewable Energy Opportunities at 29 (2007), available at: http://www.vermontagriculture.com/news/energyHandbookJan23.html.

285. Vermont Agency of Agricultural, Farm Energy Handbook: A Guide to Renewable Energy Opportunities at 30 (2007), available at: http://www.vermontagriculture.com/news/energyHandbookJan23.html.

286. Kathy Belyue, *Frequently Asked Questions About Net-Metering*, American Wind Energy Association, available at: http://www.awea.org/pubs/factsheets/netmetfin_fs.PDF (last visited Nov. 5, 2007).

287. National Renewable Energy Lab *Wind Energy Resource Atlas of the United States*, available at: http://rredc.nrel.gov/wind/pubs/atlas/maps.html; United States Department of Energy State wind resource maps available at: http://www.eere.energy.gov/windandhydro/windpoweringamerica/wind_maps.asp.

288. United States Department of Energy, *Wind Powering America: Clean Energy for the 21st Century*, 3 (2001), available at: http://www.eere.energy.gov/windandhydro/windpoweringamerica/.

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290. Vermont Agency of Agricultural, Farm Energy Handbook: A Guide to Renewable Energy Opportunities, 29 (2007), available at: http://www.vermontagriculture.com/news/energyHandbookJan23.html.

291. United States Department of Energy, *Wind Energy for Rural Economic Development*, 4 (2004), available at: http://www.nrel.gov/docs/fy04osti/33590.pdf.

292. Id.

Chapter 10: Renewable Energy: Solar

Every farmer knows the power and importance of the sun. It keeps our planet warm and it is a key ingredient in growing crops and feed. Most people are familiar with using the sun's energy for heat—greenhouses trap the sun's energy to warm plants in cold times, allowing production year-round even in northern climates. But the sun's energy does more than provide heat. Solar panels, also known as PV cells, convert sunlight into valuable electricity. The most efficient solar cells convert about fifteen percent of direct sunlight into energy.[293] Historically, this electricity heated and provided light to buildings and produced hot water. Presently, farms utilize solar panels to power electric fences, water pumps, irrigation systems, and much more. The most commonly installed solar panels mount on roof tops or are free standing, angled cells placed on small towers.[294]

There are two main ways to configure a solar energy system: stand-alone or grid connected. Stand-alone systems simply provide electricity when the sun is shining. The more sun, the more electricity the system will produce. Since the sun doesn't shine 24 hours a day, however, stand-alone systems are more flexible when coupled with batteries to store energy. Systems with batteries are often more expensive but they supply a reliable source of power, regardless of weather conditions or time of day.[295] Grid-connected systems, on the other hand, use net-metering to sell power to the public utilities when the solar cells produce more than the farm needs. Farmers may use those sales to offset the electricity the farm consumes at night or on very cloudy days.

Unlike the installation of other forms of renewable energy generators, such as wind turbines, there are very few local regulations that must be considered. However, there may be local ordinances regarding rooftop structures or reflected light, so make sure to contact your local zoning commission before installing solar panels. You may also want to check on the property tax implications of adding a solar energy system. Many states exempt renewable energy systems from property taxes, but that is not something you want to leave up to chance.

Who Should Install Photovoltaic Cells On Your Farm?

Those farms located in regions with moderate to full sunlight are best suited for solar panel installation. To get a rough idea of whether or not your property contains the proper amount of sunlight, please refer to the National Renewable Energy Lab's solar days maps.[296] Another way to verify the amount of sunlight your farm receives, is to examine local weather reports or the Farmer's Almanac to determine the average annual days of sun in your area. You will also want to find the best location on your farm for the solar panels. South facing sunny exposures are usually the best bet.

Given the expensive up front costs associated with solar power systems, an incremental installation is often easiest to manage. Fortunately, there are several state and federal incentive programs to alleviate the costs and encourage solar resource development. These include the USDA Farm Bill Grant Program, Residential Federal tax credit and Business Federal tax credit.[297]

How Do I Go About Installing Solar?

The first step is to decide what you will power with your solar system. If you can afford it, a larger system could power your whole farm or provide the electricity for your home and some farm buildings. Smaller systems could be used to power many remote applications such as electric fences and automated water/feed distribution systems. The more power kW of electricity required, the more PV cells you will need.[298] The particular plan used for your system will dictate the number, placement, and configuration of your PV cells.

With an increased size and number of cells there is obviously an increased cost. Small remote systems, which provide a simple light source, may cost around $500. However, a grid-connected system that powers an entire building or home

Farm & Granary, Wawarsing, NY: An NYSERDA Success Story

With a sizable grant from New York's Energy $mart program, Michael Siegel and Barbara Caldwell were able to install a solar energy system on their 14-acre farm to cut electricity costs and reduce their environmental impact. Their system is comprised of 30 PV cells each rated at 140 Watts, for a combined power rating of 3.5 kW. The system, installed on the roof of their barn, reduces their electric bills by 85 percent, while also reducing their contribution of greenhouse gases that cause global warming.

The system had a total installed cost of $34,200, but the state incentive chipped in $16,800 (almost 50 percent!), making it a good long-term investment for the farm and the environment. The New York State Energy Research and Development Authority (NYSERDA) also helped arrange for qualified technicians to install the system.

may cost close to $25,000.[299] The higher cost is offset by major energy savings, reducing electricity consumption by fifty percent or more.

Once you have settled on a system size, you should contact your local zoning commission to find out if any permits are required or if any ordinances restrict installation. Next, you should contact your local public utility to further explore net metering options. Public utilities may also be able to suggest retailers and licensed electricians to install the solar panels. Finally, you should consult with the installation company to determine what size, placement, and type of solar panels are right for your farm. [300]

Example of Estimated Costs from a Vermont Solar Dealer*

Solar Electric Systems	1800 Watt Output	2520 Watt Output	3600 Watt Output
Number of Panels	10	14	20
Area – Sq. Feet	161	225	322
Avg. Monthly Output (kWh)	174	244	348
Price Before Rebates	$17,979	$22,925	$32,411
VT State Rebate ($1.75/ watt)	($3,150)	($4,410)	($6,300)
Cost After State Rebate	$14,829	$18,515	$26,111
Federal Tax Credit	($2,000)	($2,000)	($2,000)
Total Cost after Federal Tax Credit	$12, 829	$16,515	$24,111

* Prices will vary depending on region and dealer.

Combining Wind and Solar

You may have heard nay-sayers complain that renewable energy like wind and solar are unreliable because they only work when the sun shines or the wind blows. It is true that wind and solar power systems do not produce the same amount of electricity at all times. However, it is important to note that wind and solar systems can be used in combination. In fact, they are complementary systems.[301] Usually, wind speeds are the highest in the winter months, producing more electricity.[302] This means that in the calmer summer months, you may have less of your farm's energy needs met by wind turbines. Photovoltaic cells, on the other hand, produce more energy in the sunniest months, which are usually in the summer. Adding solar to wind can compensate for the lack of energy produced by the wind turbines on lazy summer days. Farms with both systems often have consistent amounts of energy to use and can put more energy back into the grid.

293. *US Department of Energy, Solar Technologies Program Photovoltaics*, available at: http://www1.eere.energy.gov/solar/photovoltaics.html.
294. Id.
295. Vermont Agency of Agricultural, Farm Energy Handbook: A Guide to Renewable Energy Opportunities, 37 (2007), available at: http://www.vermontagriculture.com/news/energyHandbookJan23.html.
296. National Renewable Energy Lab, Dynamic Maps, GIS Data, and Analysis Tools, available at: http://www.nrel.gov/gis/solar.html.
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299. Id.
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301. Virinder Singh, Center for Renewable Energy and Sustainable Thechnology Renewable Energy Policy Project, Blending Wind and Solar into Diesel Generator Market 8 (2001).
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