CONTENTS

Clean Energy Farming: Cutting Costs, Improving Efficiencies, Harnessing Renewables

Photos (clockwise) **Pasturing cows, harvesting wind: two big energy savers.** *–Troy Bishopp* **Maine canola grown for biofuel.** *– Peter Sexton* **Fuel from the farm ready at the pump.** *– DOE-NREL*

MISSOURI FARMER DAN WEST FOUND A SOLUTION FOR THE waste fruit that remained after harvest: He distills it into clean-burning, high-octane fuel to power his farm equipment. New Mexico farmer Don Bustos uses recycled solar panels to heat a new greenhouse, extending his season and nearly eliminating sky-high fossil fuel bills that were threatening his family's 400-year-old farm. With high-efficiency irrigation, rancher Rick Kellison avoids expensive and energy-intensive pumping from Texas' ever-lowering Ogallala Aquifer.

Across the country, as energy prices climb, farmers and ranchers are turning more and more to clean energy practices. From energy-saving light bulbs to solar panels to fuel grown and processed on the farm, farmers are making their operations more profitable, efficient and cleaner. In the process, they are helping the nation. Generating renewable energy and using fossil fuels more efficiently reduces dependence on foreign oil, providing greater local and national energy security. It also curbs global warming pollution and offers new economic opportunities for communities. In short, clean energy practices are quickly becoming core to the operations of farmers and ranchers across America.

Clean Energy Farming explores this emerging trend in agriculture and explains how farmers can:

- improve energy efficiency while saving money;
- implement farming practices that both save energy and protect natural resources; and
- produce and use renewable energy.

For example, Bustos' solar-heated greenhouse can eliminate most fossil fuel costs. Energy audits, such as those recently performed on 25 farms on Maryland's Eastern Shore, revealed potential total savings of almost $115,000 annually for the participating farmers.

While energy efficiency measures are generally the fastest and cheapest way to reduce energy-related costs, many farmers are now turning to their land and operations to generate renewable energy.

Recently, much national attention has focused on corn ethanol. Yet other renewable types of energy, such as solar, wind and fuels from animal waste or other energy crops, also offer many opportunities to

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Lavinia McKinney of Elixir Farm in Brixey, Mo., installed solar panels to provide power for the main garden house. She fills her tractor's modified fuel tank with filtered vegetable oil, an alternative to petro-diesel.

– Photo by Daniel Roth

FIRST STEPS ON THE CLEAN ENERGY PATH

Farmers and ranchers have a key role to play in creating an energy future for the nation that is profitable, a force for excellent land and water stewardship, and provides communities with new economic opportunities. But where to begin?

- Start simply and carefully: Conduct an energy audit and consider implementing efficiency measures such as energy-efficient light bulbs, machinery upgrades and green building design.
- Determine your fuel use and demands, and look for ways to cut back.
- Consider farming practices that conserve and build soil, save water and curb the release of greenhouse gases.
- Assess your natural energy resources: Do you have wind? Sun? Suitable land for biomass? Adequate manure reserves for biogas production?
- Take stock of your financial resources: Can you comfortably experiment?
- Talk to others about their clean energy practices.
- See "Getting Started" (p. 20) for more information.

reduce fuel costs and increase energy self-sufficiency on the farm. As an added bonus, these energy sources can generate extra income through sales of surplus and offer a more sustainable alternative to energy-intensive corn.

As with all agricultural practices, renewable energy production will vary widely by region. For example, a wide variety of oilseed crops for biodiesel show excellent promise in the Pacific Northwest and Northeastern states, while switchgrass, a high-yielding and relatively easy-to-grow crop, and potential fuel feedstock, appears very well suited to the South and Midwest. As the clean energy industry grows, farmers will be able to tap into their local resources – soil, wind and water – to find the best energy sources for their area. It's safe to say that it is no longer a question of if or when, but how this country will transition to cleaner energy sources. *Clean Energy Farming* highlights research and examples of farmers and ranchers who are successfully transitioning toward energy systems that are profitable, demonstrate good stewardship of America's land and water, and benefit their operations and communities.

For resources on clean energy farming, see Getting Started (p. 20). For definitions, see Glossary (p. 19).

PART 1

Cut Costs and Energy Use Through Efficiency

opposite page

Leo Busciglio uses a wind turbine and an energy efficient greenhouse to save energy on his New York farm.

– Photo by Jennifer May

FIFTEEN PERCENT OF AGRICULTURAL PRODUCTION COSTS ARE energy related, according to the U.S. Department of Agriculture (USDA) – and as energy prices rise, these costs claim an ever-bigger portion of farm budgets. The quickest, cheapest and cleanest way to lower these costs, as well as cut non-renewable energy consumption, is by improving energy efficiency.

Upgrade Machinery and Equipment

SIMPLE PROCEDURES, SUCH AS KEEPING TRACTOR TIRES properly inflated and engines tuned, can go a long way toward saving fuel. Clogged air and fuel filters and injectors burn more fuel, as do motors or engines with rusty or corroded parts, worn bearings, loose belt drives and clogged condenser coils. Dirty fans can be up to 40 percent less efficient.

Replacing incandescent bulbs with fluorescents not only reduces energy use, but saves farmers money far beyond the original investment. An energy audit on a Maryland poultry farm, for example, found that switching the farm's 40- and 60-watt incandescent light bulbs to five-watt cold cathode fluorescent bulbs required an initial outlay of $2,168, but would save the farmer $2,658 per year in energy costs. Given the bulbs' 5–8 year life span, this farmer can expect total savings of $11,000-$18,000.

Modifying irrigation systems can also reduce energy and costs. According to the Natural Resources Conservation Service (NRCS), in certain areas of the United States, switching from high- to low-pressure sprinkler systems can save about $55 and 770 kWh per acre annually. In areas where ground and surface water is diminishing, efficient irrigation tools such as drip, trickle and lower-flow sprinkler systems save energy, water and money.

Dairy farms' heavy reliance on electricity – mostly for collecting and cooling milk, heating water and lighting – provides many energy conservation opportunities. The Massachusetts-based Center for Ecological Technology (CET), which received a SARE grant to implement energy conservation measures, conducted an audit for dairy farmer Randy Jordan, showing him how much he could save with a variable speed drive. Variable speed drives use sensors to adjust pump capacity to demand, thus doubling efficiency and lowering expenses 50–80 percent. They cost from $1,800 for a five-horsepower (3.7 kW) unit to $7,400 for a 30-horsepower (22.4 kW) unit. But the significant energy savings for Jordan – as much as $4,750 per year – allow for a quick payback, from six months to four years.

Plate coolers – simple heat exchangers that take the heat from warm milk and transfer it to cold well- or pipe-water – are also excellent energy savers. According to Florida Cooperative Extension, plate coolers can save a 500-cow dairy farm as much as $2,000 per year in electricity costs or $750 in propane costs.

DESIGN EFFICIENT BUILDINGS

EFFICIENT BUILDINGS SAVE MONEY AND IMPROVE COMFORT while reducing energy consumption. Properly sited windows light the inside of a building while operable windows and skylights can enhance ventilation and cooling, especially in regions with large nighttime temperature differentials.

Proper insulation also reduces heating and cooling expenses by protecting buildings against extreme temperatures. In an old dairy barn converted to a winter farrowing house, SARE grant recipient Gary Laydon of Plainfield, Iowa, insulated the small room where he keeps 35 pigs. Indoor winter temperatures rose by 20 degrees.

Greenhouses do their job most successfully using efficient designs and siting. In the Missouri Ozarks, SARE grant recipient Nicola MacPherson wanted to take advantage of the busy fall market for her shitake mushrooms without using more fossil fuel than necessary. So she built a 96-by-36-foot greenhouse "in-ground" to a depth of 3–4 feet in order to use the earth's natural moderating properties against temperature extremes. She didn't stop there. MacPherson heats the greenhouse by burning spent shitake logs in a clean-burning wood furnace that pumps fluid into tubes beneath a slab radiant-heated floor. A trench down the floor's middle drains misting and irrigation water for the moisture-sensitive fungi and allows better side-to-side control of the heat. The wood furnace is so efficient that MacPherson has only needed the back-up propane water heater a handful of times.

Steven Schwen of Minnesota elevated efficient greenhouse design to an art form. He sited glazed windows to the south, and insulated the north side by building it against a small hill. He then harnessed the sun with a "thermal-banking" floor, which stores heat generated by the sun during the day to be released during the cold nights. He also installed a solar-powered variable speed fan, which helps blow hot air under the soil, heating it to germination-friendly temperatures. Schwen has been able to maintain steady temperatures to grow frost-tolerant crops, such as salad mix, braising greens and herbs. (See SARE's video series on Steven Schwen at www.sare.org/schwen).

"In February, even if it's below zero, the greenhouse is in the mid-20s and the ground inside doesn't freeze," said Schwen. "Later in the month, when it's ten degrees outside, we can take advantage of the sunny days and

Various studies estimate that 7–10 units of fossil fuel energy are needed to produce one unit of food energy. Approximately one-third of energy used in U.S. agriculture goes to produce commercial fertilizer and pesticides, the most energy-intensive of all farm inputs.

maintain a temperature differential of 40 degrees between the inside and outside."

Although Schwen only grows frost-tolerant crops in the winter, he occasionally uses a wood stove for backup heat. He also plans to install a wood-fired boiler to pipe hot water through radiant floor heating so he can grow less hardy winter crops. Although the greenhouse is entirely off the grid, Schwen plans to eventually install more solar panels and a wind turbine to avoid purchasing fuel or electricity for the rest of the farm.

Like Schwen, Leonardo Busciglio of Bearsville, N.Y., wanted the energy captured by the sun to do double duty. He took a tanker trailer and sliced it longitudinally in half to form a huge 4,000-gallon trough (Note: Many types of tanker trailers, such as fuel and chemical, are not suitable for reuse). The tank, which must be big enough to keep the water from freezing, absorbs heat during the day and releases it back into the greenhouse at night. He also uses the tank to raise trout and tilapia. Busciglio discovered yet another benefit from the water tank: The ever-present humidity means his salad greens and watercress no longer need misting.

Busciglio, who used a SARE grant to add both solar and wind to his operation, operates a wood furnace about an hour per day during the coldest days to keep the water temperature optimal for the fish and, when necessary, to maintain temperatures in the greenhouse. He runs the fish waste through a bio-filter, which kills the algae, and then recycles the filtered water as plant fertilizer. "In the winter before I installed the water tank, I couldn't grow enough to afford the propane to heat the greenhouse, but now it's profitable," said Busciglio.

Reduce "Food Miles"

ACCORDING TO A STUDY DONE BY IOWA'S LEOPOLD CENTER FOR Sustainable Agriculture, food travels, on average, 1,500 miles before reaching the plates of Midwesterners. In the same study, researchers found that food trucked into Iowa used an average of four times more fuel and five times more CO_2 than a locally supplied and marketed system. Community supported agriculture (CSA), direct marketing, farmers markets and on-farm sales are just some of the many time-tested methods that can cut energy-intensive "food miles" drastically, while also providing marketing advantages for growers and benefits to the community.

- *Community supported agriculture (CSA):* In a CSA, members of a community invest in a local farm operation by paying up front for a share of the harvest. CSAs have been growing steadily since the 1980s, providing members with an increasing variety of products.
- *Direct marketing to local restaurants and institutions:* More and more farmers are tapping into burgeoning consumer interest in locally grown food by marketing directly to restaurants. In Arkansas, a SARE grant helped establish a network of farmers and chefs,

ENERGY AUDITS: A VALUABLE TOOL

Energy audits are a vastly underused tool that can help farmers save energy and money. Such an audit typically analyzes equipment and processes such as lighting, ventilation, power units, drives, compressors, insulation and heat exchange, and then provides recommendations for saving energy. The Center for Ecological Technology (CET) in Massachusetts used SARE funds to conduct energy audits on 22 farms across the state, helping each grower save from $350–$900 per year in lighting costs alone. Fifteen of the audited farms installed energy improvements that had a 1- to 2-year payback.

A number of Maryland state and local agencies launched the Maryland Farm Energy Audit Program to audit 25 poultry, dairy, beef and mixed-crop farms on the state's Eastern Shore. Working with the Vermont-based energy audit company EnSave, the audits uncovered potential aggregate savings of more than 470,000 kWh of electricity and 46,000 gallons of propane, which could save a total of $115,000 per year for the growers.

The audit's recommendations for the poultry farms also revealed that energy-saving methods — such as insulation to seal air leaks or radiant tube heaters to provide more efficient heating — can provide potential annual production benefits worth $319,800. These methods decrease costly animal mortality by increasing comfort.

– Photo by Don Bustos

WESTERN REGION PROFILE

DON BUSTOS: SAVED BY THE SUN

New Mexico grower Don Bustos uses a solar-heated greenhouse, allowing him to farm year round.

– Photo by Victor Espinoza, New Mexico State University

Perched at the edge of the Sonoran desert, Don Bustos' family farm has always been endowed with ample sunshine and daylight. However, the New Mexico grower had long been bedeviled by cool temperatures that limit the growing season to 4–5 months. With rising costs hampering his ability to support his family in the off-season, Bustos decided to tap nature's own unlimited and free energy source: the sun.

Heating a greenhouse with solar power was a logical choice for Bustos, who incorporates principles of sustainability throughout his three and a half acres of certified organic land in the small town of Santa Cruz. "I wanted to be more light on the earth and use energy more consciously," said Bustos, who farms more than 72 varieties of horticultural crops, including blackberries, raspberries, strawberries, tomatoes, squash, peppers and braising greens.

Bustos also had a powerful economic incentive: One winter, he received a $700 gas bill for one month's heat for the greenhouse. After researching solar options, Bustos eventually decided to install a root-zone thermal heating system, partially funded by a SARE grant.

To minimize costs, Bustos picked up recycled solar collectors from a building demolition site. The panels sit 12 feet from the greenhouse, facing due south, and at a 45-degree angle to maximize exposure to the winter sun. The panels are able to generate enough heat to raise a glycol/water mix to approximately 200 degrees. This heating fluid runs through a closed-loop system of copper tubing to an underground tank just a few feet away from the panels. The tubing is buried to a depth of seven feet to take advantage of the earth's natural insulating properties. A heat exchanger raises the tank's water temperature to 180 degrees. The water then flows through the plastic tubes under the greenhouse's beds, raising root-zone soil temperatures to a comfortable 48–52 degrees.

The first season was extremely successful, cutting annual heating costs from $2,000 to zero, and increasing yields 30–40 percent above that from the standard cold frame. The only ongoing cost related to the solar heating system is a $5 monthly electricity charge for the two pumps that circulate the heated water from the underground tank through the greenhouse.

Thanks to the solar-heated system, Bustos now can produce a steady supply of salad greens, arugula, Swiss chard, kale, carrots and radishes from October to March, even when outside temperatures drop below freezing. During the most frigid nights, Bustos blankets the beds with sheets of polyester, creating heat-retaining igloos. The system even works in reverse: When the soil is too hot during summer, Bustos runs the pumps to circulate water, now cooled by the geothermal properties of underground storage.

Bustos has a solid, local market for his winter crop thanks to a strong collaboration among the New Mexico Department of Agriculture, private citizens and farmers that permits the Santa Fe school district to buy directly from growers. In keeping with his energy-conscious philosophy, Bustos markets his food year round within 28 miles of his farm. Bustos is also investigating how to get entirely off the grid by increasing energy efficiency, expanding the solar panels to the house and filling his tractors with biodiesel.

For Bustos, the solar greenhouse and the added economic benefit it provides fit perfectly with his philosophy of keeping the land in the family. "We wanted the ability to retain our land for future generations and not have to develop it into houses," said Bustos, whose family has farmed the same ground for 400 years. "We wanted to stay close to what we've done. Preserving our land ties into the spirituality of how we grew up."

resulting in a weekly listing of available products for chefs and restaurants. Selling to local institutions is another increasingly popular option. St. Andrews High School in Delaware tries to purchase all of the school's pork products, honey and many of its fruits and vegetables from within a 100-mile radius.

- *Farmers markets:* Since 1994, the number of U.S. farmers markets has more than quadrupled to about 7,800, reflecting an enormous demand for farm-fresh produce. Most farmers markets offer a reliable, flexible outlet where vendors can sell a wide range of fresh produce, plants, honey, value-added products like jams or breads, and even (depending on local health regulations) meats, eggs and cheeses.
- *On-farm sales:* "U-pick" farms, or on-farm stalls and shops, bring local customers to the farm. This has an added advantage: Farmers can raise consumers' awareness of how the food is produced and promote its quality.

PART 2

Farm to Save Energy, Curb Pollution

A SIGNIFICANT PORTION OF THE ENERGY USED IN AGRICULTURE comes from sources such as fertilizers, pesticides and other inputs that require significant energy to produce. Reducing the use of these materials, especially nitrogen fertilizer, is an effective way to cut back energy use on the farm. For example, substituting manure for a ton of nitrogen fertilizer saves 40,000 cubic feet of natural gas and can reduce fertilizer costs by $85 per acre.

Farming practices such as grazing livestock, decreasing tillage, cycling nutrients through manure and cover crops, and using rotations to control pests also reduce energy use while improving soil organic matter and decreasing soil erosion. Nutrient management plans, soil testing, banding fertilizers and pesticides, and precision agriculture similarly help reduce energy use.

Diversify Cropping Systems

IN 1981, THE RODALE INSTITUTE IN KUTZTOWN, PA., LAUNCHED what is now the longest running field trial in the United States comparing organic and conventional cropping systems. The conventional system received fertilizers and pesticides following Penn State recommendations. The other two systems were managed according to organic standards using crop rotations, biological control and cover crops.

While all three systems produced similar yields of corn and soybeans averaged over 20 years, the additional organic matter from manure and cover crops enabled the two organic systems to do a far better job of improving soil health, increasing water infiltration and storing carbon. In the corn portion of the rotation, the organic systems used only 63 percent as much energy as the conventional system.

In northern Texas, drought and inefficient water use have forced traditional cotton operations to pump water from the Ogallala Aquifer at increasingly higher energy costs from ever-lowering water levels. As of 2007, pumping water from 150 feet consumed $2.67 worth of electricity per acre-inch of water. Pumping from 300 feet, by comparison, costs $4.84 per acre-inch.

SARE-funded research at Texas Tech University led by scientist Vivien Allen showed that farmers could successfully integrate pastures into existing cotton monocultures to reduce demand for water and energy. Instead of growing thirsty cotton continuously, farmers have started putting some cotton land into pastures for

Texas farmers integrate old-world bluestem into cotton systems to save water and energy.

– Photo by Vivien Allen

SOUTHERN REGION PROFILE

RICK KELLISON: SAVING ENERGY BY SAVING WATER

Rick Kellison's cow/calf herd enjoys a daily diet of drought-tolerant forages.

– Photo by Kathy Kellison

On the Texas High Plains, livestock and crops are largely dependent on water from the Ogallala Aquifer. However, declining groundwater means more energy is required to pump water from ever-deeper levels. (See SARE's video on the Ogallala Aquifer at www.sare.org/ogallala).

When rancher Rick Kellison began farming his own 300 acres in the early 1990s, he set out not only to stay away from thirsty cotton, but to plant drought-tolerant grasses and forages and implement water-saving measures, all of which help him save energy.

"I've always been very concerned about what we're doing with our water," said Kellison, who runs his registered cow-calf operation in Lockney, about an hour north of Lubbock. Producers value water by what it costs to deliver it to the crop, he added, but water can be a finite resource, like oil and natural gas, and needs to be used carefully. Not long after Kellison purchased his land in 1995, he converted 210 of his acres from furrow irrigation to pivot and drip, and now saves more than 2,200 acre-inches of water, 89,966 kWh and $13,000 per year.

His permanent pastures also confer environmental and energy-saving benefits. One sowing per crop means no yearly planting or tilling, cutting fuel costs. Permanent pastures hold the soil in place, reducing erosion and building soil organic matter. Kellison fertilizes every year with approximately 75 pounds of nitrogen, 20 pounds of phosphorus and 15 pounds of sulfur for high-potash soils. But he is now experimenting with substituting alfalfa for energy-intensive nitrogen fertilizer. In his first year, he interseeded a 25/75 percent alfalfa/grass mix on 25 acres and was sufficiently pleased with the results that he plans to substitute alfalfa for nitrogen fertilizer on another 30 acres of pasture.

Kellison's pastures, primarily drought-tolerant old-world bluestem with a little bit of Bermuda grass, are now less an anomaly in the Texas Panhandle than when he first began. The growing acceptance results partly from the research of SARE grant recipient Vivien Allen at Texas Tech. Together with Kellison and others, Allen has demonstrated how growers can reduce water and energy use, but maintain profitability by integrating drought-tolerant forages, grasses and livestock into traditional cotton and row crop systems (See p. 6).

Kellison is very positive about the influence of Allen's work. "She's had a tremendous impact on the number of acres. Many people who took some aspect of her research and incorporated it in their operations might not have if they hadn't seen it work at Texas Tech," said Kellison. "In this area, we're starting to see people putting the land into improved perennial pastures."

Kellison is project director of the Texas Alliance for Water Conservation (TAWC), a group of farmers, researchers and state and local agencies collaborating with Allen to develop strategies for reducing water use. "I feel like it's my charge to leave the land in better shape than I found it. If I can accomplish that and be a good steward, then that's a step in the right direction."

grazing livestock. Compared to continuous cotton, the integrated crop/livestock system requires 23 percent less irrigation, 40 percent less purchased nitrogen fertilizer and fewer pesticides.

In 2004, Allen was awarded a $6.2 million grant from the state of Texas to continue the SARE-initiated work across 26 farmers' fields. Early results confirm that the specific crop or variety chosen can make large differences. Substituting a forage sorghum for corn to make high-quality silage, for example, uses about one-half to one-third the irrigation water while netting similar yields and higher returns.

DIVERSIFY ANIMAL OPERATIONS

ACCORDING TO THE CENTER FOR SUSTAINABLE SYSTEMS AT the University of Michigan, grain-fed beef requires 35 calories of fossil fuel energy for every calorie of beef protein produced. Raising livestock on pasture helps reduce dependence on energy-intensive annual feed crops and transportation, as well as temperature-controlled livestock housing. Grazing systems improve animal well-being, water quality, and plant and soil health, while also providing habitat for wildlife.

Grazing systems can be good for the pocketbook too: According to NRCS, producers can save about $11 per cow per month for each month the cow stays on pasture, thanks to reduced fertilizer and fuel costs.

Iowa State University professor Mark Honeyman advocates "deep straw" systems for hogs as a cost- and energy-saving measure. This system involves huts on pasture or deep bedding in hoop barns, or both. According to Honeyman, these systems are much less capital-intensive than confinement, and have several added efficiency benefits: Bedding compost inside the hoop structures provides natural heat; manure packs can be used as compost; and costly power fans for ventilating confinement buildings aren't needed with these smaller structures because window and door openings provide enough natural air flow.

CUT BACK ON TILLAGE

ACCORDING TO USDA, SWITCHING FROM CONVENTIONAL TILLAGE to no-till can save about 3.5 gallons of fuel per acre. No-till also means farmers can use smaller, more fuel-efficient tractors. Assuming diesel costs of $2 per gallon, a 70-horsepower tractor can run for about $6 per hour while a 150-horsepower tractor consumes slightly more than double that.

In western Colorado, as in other arid regions, most farmers irrigate in furrows between crop rows plowed clean to facilitate water flow. Aided by a SARE grant, Randy Hines, in Delta, Colo., developed a tool to leave vegetative residue on the soil while creating irrigation furrows every other 30-inch row. Not only did Hines reduce erosion, he also cut by half his number of tractor passes (and fuel use) before planting corn. This saved $35–$50 per acre from reduced wear and tear on the machinery, labor costs, and fertilizer and herbicide applications.

In Arizona's arid cotton fields, a state mandate requires producers to plow down cotton stalks to help control pink bollworm. These tillage operations generally coincide with the driest time of year, creating large amounts of fugitive dust, specifically small EPA-regulated particulates known as PM10, which cause respiratory problems.

To help growers reduce dust and meet plowing requirements, University of Arizona professor Robert Roth used a SARE grant to study three types of tillage systems. Each of the systems used half the amount of fuel and significantly cut down on dust. For example, the Sundance system, which uses a root puller attached to the front of the tractor, and a ripper/disk lister to the back, saved growers $8–$16 per acre. Today, growers are using different combinations of these three systems to reduce their costs and dust while still meeting the plow-down requirement.

"High energy costs are [encouraging] people to reduce the number of passes and costs so they can remain sustainable," said Roth.

CURBING CLIMATE CHANGE

Specific agricultural and forestry practices can capture and store, or "sequester," carbon, which can be released into the atmosphere as carbon dioxide (CO_2), a primary greenhouse gas. According to the Intergovernmental Panel on Climate Change (IPCC), roughly 100 billion metric tons of carbon could be sequestered in the world's soils during the next 50 years, offsetting 10–20 percent of carbon emissions from fossil fuels.

Carbon storage is also good for soils. It increases organic matter, improving soil structure and water infiltration, which can improve yields and profits for growers. At Pennsylvania's Rodale Institute, the long-running Farming Systems Trial showed that after 23 years, organic systems each stored about 1,000 pounds of carbon per acre per year due to cover crops and crop rotations. The conventionally fertilized system did not accumulate significant amounts of carbon.

To effectively store carbon in soils:

- Add organic materials, such as manure and cover crops.
- Reduce or eliminate tillage.
- Return the maximum possible crop residue to the soil.
- Plant a permanent cover.

Finding the best approach to tilling to mitigate greenhouse gases is a bit tricky, however. To store carbon, no-till is certainly best. The more undisturbed the soil the better, as mixing and aerating feeds otherwise dormant microorganisms that will hungrily metabolize carbon and then release it as CO_2. However, no-till systems can also increase emissions of nitrous oxide (N_2O) — a far more potent greenhouse gas than CO_2. Scientists are not completely sure of the processes and conditions that increase N_2O emissions but believe it is due to the higher soil moisture levels and increased fertilizer use that can occur under no-till.

To minimize release of N_2O, no-till producers should use nutrient management plans, nutrient testing and the "pre-sidedress nitrate test" (PSNT) to help synchronize nitrogen application and availability with crop demand.

Storing carbon may also offer financial benefits. In the early 2000s, the Chicago Climate Exchange began offering farmers the opportunity to earn money for practices that reduce emissions of major greenhouse gases by buying and selling carbon credits. Credits sold in 100-ton units, too large for individual farmers, so both the Farmers Union and Farm Bureau organized large blocks of farmers — representing about one million acres from each organization — to sell credits.

When the Climate Exchange program began, carbon traded at 50 cents per acre for land in no-till. By 2007, the going rate on the same land was about $2 per acre. Alfalfa and some grasses in 2007 traded for about $3 per acre; forest land got $4–$20 per acre, depending on the type, age and location of the trees; and dairy farmers capturing methane earned about $20–$30 per cow per year.

However, carbon prices were dependent on market forces and an expectation that mandatory limits would be set. When this failed to happen, rates plummeted, and in 2010 the Farmers Union suspended the program. Until mandatory caps are placed on carbon emissions, the value of carbon will remain dependent on goverment legislation and programs that set national, state or local limits on the amount of carbon that can be released into the atmosphere.

PART 3

Generate Energy on the Farm

BIOMASS CROPS, CONVERTED VEGETABLE OIL OR ANIMAL manure, windmills and solar panels – across America, farmers are increasingly exploring a range of energy technologies to "grow" energy on the farm. Some produce primarily for their own use, while others generate enough energy to sell back to the grid or in biofuels markets.

Many farmers combine different renewable energy sources to develop highly self-sufficient systems.

- In Minnesota, Steven Schwen uses both solar and biomass to heat his greenhouse.
- In Vermont, John Williamson constructed a passive solar facility where he will produce biodiesel from locally grown canola, mustard and flax.
- In Missouri, Dan West is developing a prototype solar concentrator to help power his waste-fruit ethanol still.

TAP INTO THE WIND

IN RECENT YEARS, GOVERNMENT INCENTIVES AND TAX CREDITS and consumer demand for green energy have spurred huge growth in wind energy generation. Modern turbines are now powering individual farms. And across the "wind states" – those located in the Great Plains, Midwest and West – the tall, white towers of mass-scale wind farms have become common sights.

Jess Alger, a fourth-generation Montana rancher, used do-it-yourself installation and federal and state incentives to make wind power economical. In 2003, Alger installed a 100-foot tower that now provides electricity for his home and 1,200-acre ranch. In total, the system cost $36,850 less than normal because he did not pay a dealer and prepared the site himself. He also obtained funding from USDA and the National Center for Appropriate Technology (NCAT). Today, Alger produces electricity in excess of his needs.

Wind is not limited to just the West or Midwest. Leonardo Busciglio bought and installed a decommissioned wind tower from California for his New York farm. The SARE grant recipient knew he had a wind tunnel in the valley near his house, and although he paid more to ship the 10 kW turbine than buy it, he estimates a payback of only five years, thanks to his reduced electric bill.

Choosing an appropriate small-scale system depends on a farmer's needs and site. Smaller turbines requiring less wind can run a water pump; bigger turbines can provide the farm's entire electrical needs. While the amount of wind needed varies, a rule of thumb is that a location should have a minimum of Class 2 winds. If wind speeds are too low, due either to climate or not enough tower height, the system will not produce enough energy to be economically viable.

Other factors to consider are zoning restrictions, land area, and availability of state tax credits or incentives. Each site's conditions must be evaluated individually. And the financial outlay can be high. For a 10 kW turbine, the system can cost $40,000–$60,000 installed; smaller, appliance-specific windmills run about $15,000. However, many states, especially those generously endowed with wind, offer tax credits, grants and other incentives that can make wind power worth a farmer's while.

Because operating a wind farm requires a substantial outlay of funds and research time, some farmers are forming cooperatives. Large-scale wind farmers have the added consideration of having to deal with utilities, which can be daunting. The ease of hooking up to the grid varies from state to state, and is dependent on such variables as the type of utility, local regulations and net metering laws (For more information, see "Working with Rural Utilities: What's the Buzz?" p. 11).

Stateline Farm in Shaftsbury, Vt., is gearing up to produce 100,000 gallons per year of biodiesel at its on-farm facility.

– Photo by Vern Grubinger

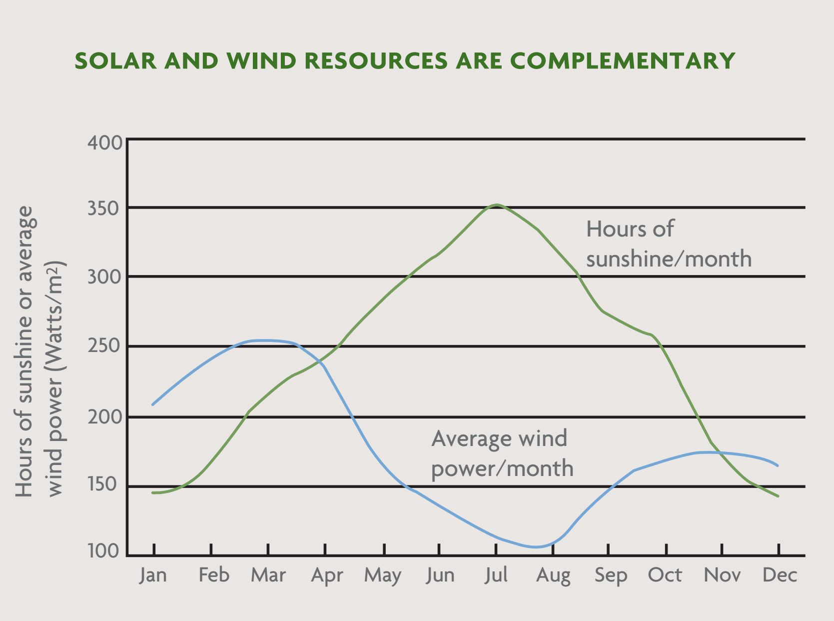
Tap into the Sun

WHEN BROOKFIELD FARM BEGAN BUILDING A NEW BARN IN 2003, community members thought its sun-exposed roof would be a good place to generate solar power. Two years later, Brookfield, located in Amherst, Mass., installed a 3.8 kW solar electric system that today generates enough electricity to power walk-in coolers, greenhouse fans, the office computers and lights for its 520-member community-supported farm operation. The panels supply anywhere from 20–50 percent of the farm's electricity.

To get the project off the ground, the farm had to harness financing and technical support, as well as the sun's rays. It approached CET, which, with help from a SARE grant, connected the farm with engineering, electrical and solar energy consultants. To pay for the entire system, Brookfield landed a state energy grant and also received $15,000 in donations from its members.

"It's great to see the meter spinning fast on sunny days," said Jeff Tober, Brookfield assistant farm manager, who often shows the system to other farmers and business owners. "We want to use as little as possible from the grid."

Brookfield Farm is just one example of how the sun can power everything from water pumps to lighting systems, from electric fencing to greenhouse heating. With the high cost of running transmission lines to locations more than a half mile from a traditional power source, solar can make economic sense. Grants and tax incentives offered by some states can also make a big difference. And the technology is improving: Today's photovoltaic (PV) panels are easy to install and maintain, long-lived (up to about 25 years) and come with extended warranties. That said, the price of solar panels can fluctuate widely, depending on availability and other market forces.



In the hot summer months when the sun shines, the wind often doesn't blow. During the cool and cloudy fall and winter seasons, wind speeds are often at their highest. If your site is accommodating, combining wind and solar can be an effective renewable energy system. *— Roya Stanley and DOE-NREL*

Sunny rooftops or other locations with clear access to the sun and a south-facing roof are the best place to site a solar energy system, although east- or west-facing roofs might work. If a rooftop can't be used, solar panels can be placed on the ground, either on a fixed or tracking mount that follows the sun during the day.

Passive solar construction – intentionally siting and designing a building to optimize heating and cooling – can reap maximum energy gain with minimal investment. For warming, a passive solar building can include south-facing windows, heat-absorbing tile, concrete flooring and other "thermal mass" material. For keeping buildings cool, well-sited trees, window coverings and awnings can effectively block the sun.

Solar has been especially useful to ranchers and dairy farmers for powering water pumps in remote pastures. With help from a SARE-funded managed grazing program, Richard Bossard, a dairy farmer in Steuben County, N.Y., installed such a system. Today, his cows no longer hover around one well, but drink from five water stations across 100 acres of pasture.

Capture Fuel from Animal Manure and Plant Waste

CONVERTING ANIMAL AND PLANT WASTE INTO ENERGY CAN BE a triple-hitter: It not only helps reduce waste going to landfills or from being released as gas into the atmosphere, but saves energy and money. Waste materials – ranging from animal manure for methane to wood chips for direct heat to waste vegetable oil for straight use or conversion to biodiesel – also have a positive energy and carbon balance. That is, more energy is derived from the fuel than is spent converting it. Therefore, no net CO_2 is generated.

Animal Manure

Nature has always used anaerobic digestion – bacteria breaking down organic material in the absence of oxygen – to recycle waste. Modern anaerobic digester systems on livestock farms work on the same principle: The solids in

WORKING WITH RURAL UTILITIES: WHAT'S THE BUZZ?

The Century Wind Farm in the Northeast powers an average of 51,000 homes with 135 wind turbines. The land is leased from area farmers, providing them with extra income.

– Photo by Melissa Hemken

If you are considering installing a renewable energy system with an eye toward selling power to your utility, do your homework carefully. Rules, regulations and policies vary widely across states, municipalities and utilities. In some areas, utilities are more cooperative due to regulatory mandates to buy a certain amount of renewable energy. In other areas, utilities are less helpful, fearing potential hassles and lost revenue.

"Utilities are a mixed bag," said Mike Morris, Farm Energy Team Leader for the National Center for Appropriate Technology (NCAT). "There are many excellent investor-owned utilities and rural electric cooperatives committed to helping people hook up to the grid, but in many areas, that is not the case."

Some tips to consider when working with your local utility:

Research Your Utility: Is it willing to work with small or "distributed" power generators? Some utilities are open to the idea; others more resistant. Their reluctance may be as simple as not having the proper infrastructure in place. For example, in many rural areas electric power distribution was designed to be a one-way street; sending electric power backward may require installation of different controls. Talk to the distribution utility early in the process to determine its requirements. The costs to upgrade the distribution system may dramatically change the economics of a generation project.

Talk to the Pioneers: Look into regulations and potential red tape by talking with people in your community who have hooked up to the grid. Local renewable energy dealers and installers are also good sources of information.

Know State Net Metering Laws: Forty-two states and the District of Columbia require utilities to "net meter" — that is, allow customers to hook up to the grid. But each state has different requirements. In Montana, for example, investor–owned utilities are required to net meter while rural electric cooperatives are not. Each state also has a different maximum allowable system size for net metering. In Maryland, consumers can install and link systems up to 2,000 kW, while in California the limit is 1,000 kW.

Understand Technology Differences: Solar, wind and biogas all have different requirements for hooking up to the grid. Be sure you understand the technical specifications.

Investigate the Financial Benefits: When net metering, you will probably only receive credits to your electric bill. For some customers, the savings can be significant. To sell back to a utility, you must become a qualifying facility (QF) as outlined by the Public Utility Regulatory Policies Act of 1978 (PURPA). However, even if you qualify, in many states you will be selling back to the utility at low rates. Don't expect to get rich. The main benefit will accrue from what you save by generating your own electricity.

Ask for a Policy: If you are working with a rural electric cooperative in a state or area that doesn't require net metering, suggest that the cooperative develop a policy. Often, cooperatives want to be responsive to members' needs.

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manure are converted by bacteria into biogas, primarily methane, which can then be used to generate electricity.

Anaerobic digesters have traditionally been geared toward large livestock confinement operations, which produce a lot of manure. The digester's broader-use potential, however, has spurred manufacturers to explore scaling down the technology for small- and mid-sized farms. China and India have long promoted smaller digesters. And nearly 2,000 farm-based digesters operate in Europe, where researchers are trying to improve efficiency and cost-effectiveness for smaller operators by combining food and animal waste.

Digesters resolve multiple problems simultaneously:

- When the liquids and solids are separated and treated, odor is reduced. The liquid portion is much easier to apply as fertilizer and is often mixed directly with irrigation water.
- The odor- and pathogen-free solids can be sold as compost or reused as bedding, either generating new revenue streams or saving producers money on purchased bedding.
- Fly populations in and around the manure storage systems are reduced, as are weed seed populations in the compost.
- Biogas is captured and burned to power the farm and/or generate electricity to be sold back to the power supplier. Capturing and using the methane prevents its discharge to the atmosphere, where it has 21 times more global warming potential than CO_2.

In 1998, AgSTAR, a collaborative effort of various federal agencies, selected the 1,000-acre, four-generation Haubenschild family farm near Princeton, Minn., to demonstrate the effectiveness of an on-farm digester

top left to right

The Blue Spruce dairy, a member of Vermont's Cow Power program, uses an anaerobic digester (pictured) to turn manure into methane, which is used to generate electricity.

– Photo by Vern Grubinger

Mike Collins grows tomatoes in a greenhouse heated by used vegetable oil.

– Photo by Vern Grubinger

operation. The Haubenschild's digester receives, on average, 20,000 gallons of manure per day, producing 72,500 cubic feet of biogas, most of which is used to power a 135 kW generator. Waste heat recovered from the generator's cooling jacket is used to heat the barn. As an added benefit, the Haubenschilds are able to supply enough electricity for an additional 70 households, and by December 2005, the farm had generated a total of 5.8 million kWh.

The energy produced by the digester prevents the equivalent of burning 50 tons of coal per month. Because it reduces methane release, the Haubenschild Farm can sell 90–100 tons of carbon credits per week through the Environmental Credit Corporation. The farm has also saved an estimated $40,000 in fertilizer costs because they use resulting "digestate" as a soil amendment.

The Haubenschilds are committed to conserving resources and saving money in other ways as well. For example, they reuse milk cooling water for cow drinking water and to wash the floor, then reuse this water for the digester. They also use four tons of recycled newspaper per week as bedding because it promotes excellent anaerobic breakdown of manure.

While promising, digester technology is still evolving, and installation and operating costs are high. Digesters are very sensitive to temperature, alkalinity, loading rate of waste and hydraulic retention time. They require consistent oversight by at least one person. Other challenges include high capital costs, low wholesale electricity prices, still-emerging industry support and hooking up to the grid. (For more information, see *Working with Rural Utilities: What's the Buzz?* p. 11).

A unique partnership between an investor-owned utility and several Vermont farms is making "cow power" more feasible for a number of growers by allowing customers to choose sustainable energy. Thousands of Central Vermont Public Service (CVPS) customers have signed up to get a portion of their energy through the CVPS Cow Power program. They pay an additional 4 cents per kWh knowing that 100 percent of the premium supports Vermont dairy farmers who use digesters.

It currently takes about 500 milking cows to produce enough energy for Cow Power to be economically viable, so a number of small-scale farms are considering combining their manure to become eligible.

Plant Waste

Fuel made from plant waste is made primarily from either waste vegetable oil (WVO) or WVO converted into biodiesel, a diesel fuel made either partially or wholly from biological materials. With a few exceptions, WVO requires modifying existing equipment, while WVO converted into biodiesel can be used in most diesel-burning engines.

Fuel from waste or converted vegetable oil has pros and cons, but both confer many environmental and economic benefits. Used oil contains nearly twice the energy value of coal and more energy than No. 2 fuel oil. Compared to petroleum diesel, biodiesel produces fewer volatile organic compounds (VOCs) and particulates and less CO_2, sulfur dioxide, carbon monoxide and mercury. Some studies suggest that biodiesel produces slightly higher levels of nitrogen oxide (NOx) pollution, but researchers are investigating new additives and diesel technology that could significantly lower these emissions.

Mike Collins and Rebecca Nixon of Old Athens Farm in southeastern Vermont decided to switch to straight waste-vegetable oil to heat their three greenhouses after using as much as 3,000 gallons of No. 2 oil in one winter. Each greenhouse now has a waste oil burner, generating 350,000 BTU for 3,200 square feet.

Collins and Nixon, who grow organic vegetables and berries for direct markets on two acres, and produce greenhouse tomatoes, cucumbers and eggplants, collect waste oil from nearby restaurants. The restaurants are within normal vegetable delivery routes, saving transport-related time and energy. Collins and Nixon avoid oil with hydrogenated fats as it does not perform well in waste oil burners.

The oil, generally kept in containers ranging from five to 50 gallons, is brought to the farm, filtered through a screen and then stored in large plastic tanks in the greenhouse. Because it solidifies in cold weather, any oil kept outside in the winter must be pre-warmed before use.

Like all new energy systems, a vegetable oil system requires initial start-up costs. For Collins and Nixon, each burner cost about $5,000 and another $500 to set up. About four hours per week are required to collect the oil, and to maintain the heaters. Assuming labor costs of $10 per hour, their waste vegetable oil system costs them an additional $2,000 annually in labor.

But the payback is quick. Eliminating expensive fuel purchases meant that during the 2005–2006 growing season, the farm saved almost $7,000 in fuel costs. With heating oil prices just above $2.25 per gallon, payback on this system could be as fast as three and a half years.

Like straight vegetable oil, converting WVO to biodiesel can be cost effective: less than $1 per gallon in materials, plus labor. Matt Steiman, biodiesel project supervisor at Dickinson College in Carlisle, Pa., has long-promoted its benefits. In 2005, on behalf of Wilson College, he received a SARE grant to teach farmers to convert vegetable oil into biodiesel, holding six hands-on workshops and attracting more than 100 growers from Maryland, Virginia, West Virginia and Pennsylvania. Several participants are now receiving seed money to produce biodiesel on their own farms.

– Photo by Sally Colby

BIODIESEL 101

Know the Blends: Biodiesel can be used in any standard unmodified diesel engine and in any percentage — from B2, a 2-percent biodiesel mixed with 98 percent petroleum, to pure biodiesel, known as B100.

Prepare for Cold Weather: Cold weather can be a problem for high-percentage blends of biodiesel. B100, for example, will cloud at temperatures slightly above freezing and can clog fuel filters if the temperature drops below 28 degrees. Cloud and gel points depend on what oil was used to make the biodiesel. One solution is two fuel tanks — one with regular diesel that can start in cold temperatures and warm up the other tank, which contains the biodiesel. Other cold-weather strategies include using additives or lower blends, such as B50 or B20.

Use It or Lose It: Biodiesel has a shelf life of about six months; sealed opaque containers with minimal head space (to prevent water condensation) are best for storage.

Know On- and Off-Farm Restrictions: Different tax laws apply for on- and off-farm use. On-farm use is exempt from federal excise tax and most federal regulations, except for storage. For off-farm use or sales, follow state and federal laws.

Check Warranties: Some engine warranties are valid for blends up to B20, but only if used with biodiesel that meets strict industry standards (ASTM D6751). Check your owner's manual carefully.

Beware of Corrosion: Because biodiesel is a solvent, it may loosen debris in pipes and tanks, clogging filters initially. Changing filters soon after first use, however, remedies the problem. Sometimes rubber hoses and gaskets on older vehicles don't hold up well with B100. When using high blends, you may need to tweak injection rates and vehicle timing for optimal performance.

Investigate Storage Regulations Carefully: States set regulations for blends up to B20. For higher blends, EPA regulations apply. As more people produce and store biodiesel, these rules are likely to change.

Exercise Caution: Biodiesel production requires careful attention to safety. Methanol, an alcohol used in the conversion process, is flammable and can be toxic to skin and the lungs. Lye, the catalyst, can cause skin and lung irritations and, in a worst case scenario, blindness. Consult your state environmental agency and local fire officials to ensure compliance with regulations.

PART 4

Biofuels: Look Toward Future Feedstocks

"BIOENERGY WILL BE THE BIGGEST CHANGE IN AGRICULTURE IN our history," said Gale Buchanan, USDA's Undersecretary of Agriculture for Research, Education and Economics in 2007. In fact, change is already widespread across the Midwest, where corn is fetching record prices and the rapidly expanding ethanol industry has been a boon to many rural communities.

As far as biofuels are concerned, however, a clean energy future will not be limited to corn-based ethanol, but will include a wide variety of alternative energy crops, or feedstocks. Such feedstocks can be used for both ethanol and biodiesel, grown in varied climates and farming systems, and lead to more diversity on the farm. Also on the horizon are improvements in the conversion efficiency of existing feedstocks, such as wood and grass pellets.

CONSIDER ALTERNATIVE FEEDSTOCKS FOR ETHANOL

CORN IS CURRENTLY THE PRIMARY FEEDSTOCK FOR ETHANOL because it is easy to grow, the conversion technology is well-developed, and a combination of government incentives and fuel prices ensure profitability. However, many other plant materials provide a much higher net energy gain for ethanol than corn. Research to develop these alternative feedstocks has been ongoing for many years and produced many suitable crops, yet challenges still remain to develop profitable conversion technologies.

Cellulosic biomass – the fibrous, woody and generally inedible portions of plant matter – is an emerging alternative feedstock. It comes from a wide variety of crops and offers positive environmental benefits. With the exception of crop residues, such as corn stover or wheat straw, most cellulosic material comes from perennial crops, which generally require less intensive planting methods, integrate well into existing rotations and provide better soil cover than annual row crops. Cellulosic crops, such as perennial grasses, poplar trees and alfalfa, allow for more diversity across the landscape and can be grown successfully in many areas, providing opportunities for growers across the United States.

Switchgrass for Ethanol

Already on the radar of many researchers, switchgrass was thrust into the spotlight when former President George W. Bush first mentioned it in his 2006 State of the Union address. Although currently almost no market exists for switchgrass as an energy crop, it is emerging as a leading contender for cellulosic ethanol production.

A long-lived perennial, switchgrass has positive attributes as a sustainable energy crop, because it can:

- extract soil nutrients efficiently, reducing the need for external inputs, and, with its extensive root system, store large amounts of below-ground carbon;
- thrive on less productive soils, reducing competition for more fertile ground that can be used to produce food;
- supply sufficient cover to curb soil erosion and provide good nesting habitat for birds and other wildlife;

EMERGING FEEDSTOCKS FOR ETHANOL

In addition to switchgrass, researchers are currently exploring more than 81 fuel sources for ethanol, including:

Hulless Barley: Barley can do double duty as a cover crop and energy crop.

Hybrid Poplars: These poplars can be planted on marginal land, and converted into ethanol or used directly for heat. Poplars have excellent energy crop potential because they require few pesticides and fertilizers and grow well on land unsuitable for food crops, such as old mining or wastewater treatment sites.

Algae: Already known to be highly efficient at capturing nutrients, algae are currently in use at the USDA-Agricultural Research Service (ARS) site in Maryland to filter dairy wastewater. Researchers believe it could generate methane, or be converted directly into biodiesel or ethanol.

Alfalfa: New varieties don't lodge and require less frequent harvesting than a typical forage crop. Researchers at the USDA-ARS in St. Paul, Minn., have shown initial yield increases of 42 percent. Decreased cuttings protect nesting birds in the spring. Alfalfa also has low energy input requirements, fixing its own nitrogen. One more added benefit: Growers already know how to produce alfalfa and it slots well into existing rotations.

Mixtures of Native Species: Work by ecologist David Tilman of the University of Minnesota suggests that growing mixtures of native species may produce more biomass and fewer fluctuations in productivity than one or a few species of grasses. Like switchgrass, mixed species produce far more net energy than corn and soybeans and require minimal fertilizer and pesticide inputs. Native species can also be grown on marginal lands and are more resilient to drought and pests. As an added benefit, they store more carbon than they release.

NORTH CENTRAL REGION PROFILE

DAN WEST: FROM FRUIT TO FUEL

Dan West harnesses the sun's rays to help produce ethanol from his orchard's excess fruit.

– Photo by Mary West

As tree fruit growers know well, annual harvests do not remove all the fruit from the orchard. A great deal is left behind littering the orchard floor. While pondering his fruit waste problem, Dan West of Macon, Mo., who grows apples, peaches, apricots, nectarines, plums and pears, hit upon a novel approach: Why not turn the waste into energy?

West already had been distilling the waste fruit into natural wine using a still he designed out of a beer keg. (West received a distilling permit from the Bureau of Alcohol, Tobacco, Firearms and Explosives.) Then, driven by an over-supply of waste fruit, coupled with his growing concern about the supply and cost of fossil fuel, West decided to produce ethanol from his fruit wine by heating it and removing the alcohol, at a rate of about 1.5 gallons per hour.

"Using waste was the main thing," recalled West, who has been running an orchard on 10 acres since 1995, and received a SARE grant in 2003 to experiment with ethanol production. "I also thought it would be nice to be self-sufficient, using our ethanol to power our mower and tractor."

West built a second still from a 500-gallon propane tank, in which he heats his fruit wine to just below boiling, gathers steam in a fractionating column, and distills the alcohol portion of that steam to 190 proof. This still should easily produce 4–5 gallons per hour, although he expects to speed up the distillation as he improves the second still.

"Even at $2-a-gallon fuel prices, my ethanol distillation process is well worth doing," West said. Discounting the labor to gather and crush fruit — now his most time-consuming task — distillation costs only 65 cents per gallon in electricity costs. Those gallons of ethanol, however, now power his farm engines at a higher octane than gasoline and provide a cleaner burn.

"It's exciting," he said, reflecting on the first time he powered up his lawn tractor with homemade ethanol.

Others have been similarly fired up. At least 1,000 people per year visit West's orchard, about 120 miles from Kansas City, in part to see his energy-saving invention.

West never stops thinking up innovative ways to get the most from his farm. Since gathering waste fruit is time consuming, he has focused his keen inventor's mind on finding a better way. With a second SARE grant, West is designing a machine that gathers up waste fruit, then crushes it into pulp, some of which is spread back on the orchard floor as fertilizer, and some of which is squeezed into juice and then fermented into wine.

West also received another SARE grant to design a closed-loop energy production system using a solar concentrating method that reduces electricity needed to heat the still. The prototype has produced 170-proof ethanol. "When it worked after three or four tweaks, I was jumping up and down," he recalled. "Winning the initial grant opened up many doors for me."

- be harvested for forage in the spring and biomass in the fall, providing growers a double-income stream;
- adapt easily to the southern and central parts of the country;
- be established by no-till direct seeding into crop stubble or grass sod, further minimizing erosion and reducing soil carbon loss from tillage; and
- be grown easily by many farmers who already have the necessary planting and haying equipment.

Most current switchgrass research has focused on the grass' use as forage and a buffer crop. Further work is needed to develop best management practices, integrate switchgrass into existing systems, and determine its economic feasibility as an energy crop. Switchgrass also has potential drawbacks, some of which researchers are currently addressing:

- Yields vary greatly, ranging from one to 16 tons per acre, creating uncertainty for growers.
- In certain regions of the country, switchgrass may act as an invasive species.
- Switchgrass establishment can be difficult in certain climates and farming systems.
- Tough switchgrass stems can puncture tractor tires.

While a perennial, such as switchgrass, is gentler on the environment than input-intensive row crops, monocultures of any crop reduce landscape diversity essential for wildlife habitat and healthy soil flora and fauna. They can also create higher risks for the producer, as they are susceptible to pathogen and insect infestations as well as market fluctuations. As the bio-economy continues to grow, farmers, researchers, agricultural educators and policy makers must all pay close attention to the balance between efficiency of scale and the benefits of environmental diversity, even with crops such as switchgrass.

Solid Fuels: Wood and Grass Pellets

For decades, Europeans have been burning grass for energy. But in the United States, the use of solid fuels, such as wood pellets and corn, has only recently seen a resurgence for home heating. Along the shores of Vermont's Lake Champlain, Marshall Webb of Shelburne Farms is quite excited about the prospect of using a locally grown and readily available product – grass – to heat the farm.

"Our goal is to produce energy on the farm and become carbon neutral by 2020," said Webb. The farm, a nonprofit educational center and a grass-based dairy of 125 pure-bred, registered Brown Swiss cows, has 150 acres of tough-to-harvest grass in wet and hilly areas. "We let these acres grow until mid-August, which allows the field nesting birds to fledge, and then harvest 100 acres for bedding, while the remaining 50 get mowed." Those 50 acres and other potential neighboring land could produce enough heating energy from grass to satisfy winter demand, added Webb.

When the grass is mowed at the end of the summer, the nutrients are stored in the root mass and the sun has done all the necessary drying. "It's the perfect timing," said Webb. "We've looked at habitat restoration, and the birds are finished nesting in the grass. The equipment is all idle at that time, and we could conceivably save thousands of gallons of oil by burning the grass." Even with the energy required to cut and pelletize the grass,

PROFITABLE, COMMUNITY-SCALE BIOFUEL PRODUCTION

While much national attention has been focused on the mega-million-gallon ethanol and biodiesel plants sprouting across the country, on-farm biofuel production facilities run by farmers for farmers, and by small businesses, are also taking root.

"In the Northeast, we are trying to develop community-scale fuel systems that minimize infrastructure costs and transportation requirements, while using raw products that can be sustainably grown by local farmers, providing them a fair and stable return," said Vern Grubinger, Extension specialist for the University of Vermont and Northeast SARE coordinator.

– Photo courtesy of Piedmont Biofuels

At State Line Farm in Shaftsbury, Vt., SARE grant recipient John Williamson is attempting to create such a model. Williamson began by making biodiesel from waste vegetable oil. He has since constructed a passive solar facility on his 110-acre farm to process locally grown oilseed crops, such as sunflower, canola and mustard, into biodiesel. He also grows sweet sorghum to distill into ethanol with the eventual goal of producing all of the alcohol needed for biodiesel production. Williamson strives for a closed-loop system that when fully operational, could have an annual production capacity of 100,000 gallons of biodiesel, and will produce a valuable by-product: tons of seed meal for sale as animal feed.

"These systems have great potential," added Grubinger. "But the devil is in the details. We're still learning how to grow, harvest and process crops that have not been traditionally grown here, and we're also figuring out the regulatory and market issues. Pioneers such as State Line Farm are laying the groundwork for survival of small-scale farms when the time comes that fuel costs a whole lot more."

In North Carolina, a small group of backyard biofuel brewers are pioneering an attempt to scale up community-based and financially viable sustainable fuel operations. For many years, the cooperative resisted expanding their highly successful operation. When an old chemical factory became available outside Pittsboro, however, members of the Piedmont Biofuels Cooperative took it over to launch Piedmont Biofuels Industrial, a private company. They raised $1 million and hired contractors to convert the factory. Only six months after opening, the plant reached its production target of 80,000 to 100,000 gallons per month, which still isn't enough to meet growing demand.

Piedmont Biofuels Industrial hopes to demonstrate that "distributed" biofuel centers — ones that gather, process and sell feedstocks locally — are economically viable. The plant only uses local soybeans and chicken fat as its main feedstocks, although it can use any oil. Its goal is to obtain all feedstocks from within a 100-mile radius, because biomass is heavy and expensive to transport. Piedmont's principal buyers are school districts that use the fuel for transportation, county governments, municipalities and petroleum distributors who blend the fuel with petro-diesel. The plant has its own delivery trucks and is also equipped with a full terminal to allow 18 wheelers to pick up the fuel on site.

The facility itself is a model of energy sustainability: Solar panels across the rooftop pre-heat water needed for washing the biodiesel. After the fuel has been processed, it's stored in a solar-heated tank until shipped.

the pellets' output-input energy ratio is 12:1. The farm is awaiting final construction of a mobile grass pelletizer, which Webb envisions sharing with others in the community.

Like many feedstocks, grass pellets are still in a developmental phase as their higher ash content makes them more difficult to burn in standard wood-pellet or corn-burning stoves and furnaces. However, a number of corn, wood and biomass stove and manufacturing companies have modified equipment for grass pellets. According to researchers at Cornell University, grass pellets have excellent potential as a low-tech, small-scale, environmentally-friendly, renewable energy source that can be locally produced, processed and consumed.

Oilseed Crops for Biodiesel

Soybeans, because they produce high-priced meal and quality oil, have long held center stage as the predominant feedstock for biodiesel. But biodiesel can be produced from a wide variety of crops. From the Northeast to the Pacific Northwest, researchers are exploring a variety of oilseed crops, focusing on those that fit well into existing rotations and provide a higher net oil yield.

In Washington state, for example, Washington State University and USDA-ARS researchers have been studying safflower, mustard and canola, all of which fit well into existing dryland and irrigated rotations.

Canola uses planting and harvesting equipment similar to what is used for small-grain production, and the meal commands high prices in the feed market. Canola is an excellent rotation crop, doubling as both cover and energy crop because it:

- has deep, tough root systems that scavenge well for water and nutrients, and can break up hard pans;
- can be planted either in the fall or spring, although fall-planted crops tend to yield double, at least in the Pacific Northwest;
- is resistant to numerous pests such as the Russian wheat aphid, the Hessian fly and certain wheat diseases; and
- gels at lower temperatures than other feedstocks when converted to biodiesel, making it a more suitable fuel for colder regions.

– Photo by Vern Grubinger

PRODUCING BIOMASS FOR ENERGY: WHAT YOU NEED TO KNOW

- What crops can you plant with the equipment, soil type and knowledge base you already have?
- What is the season of crop you are considering relative to season of energy demand?
- What kind of storage capacity do you have for the biomass?
- How much land can you safely dedicate to new and experimental crops?
- Can you use perennial and diverse cropping systems for bioenergy feedstocks?
- Do you have underused or marginal land that could be used for woody biomass or grass mixtures?
- Have you calculated the inputs needed for biomass crops? Energy crops should produce more energy than they require to grow and process.
- How can you integrate sustainable energy into a whole-farm plan?

(Adapted from a www.climateandfarming.org fact sheet.)

Mustard has also been shown to be an excellent cover crop with high potential as a biodiesel feedstock. Although it produces less oil than canola, it is drought tolerant, grows well on marginal soils and contains compounds that act as a natural fumigant against soil pathogens. Mustard also suppresses nematodes and weeds, and, acting as a catch crop, provides fertility for subsequent crops. In recent years, its use as a soil fumigant has expanded significantly in the Pacific Northwest, in part due to research by Andy McGuire of Washington State University Extension, also a SARE state coordinator, who showed that incorporating mustard cover crops could save growers $100 per acre. Researchers in Vermont and Maine are also

> ***Monocultures of any crop reduce landscape diversity essential for wildlife habitat and healthy soil flora and fauna. They can also create higher risks for the producer, as they are more susceptible than mixtures to infestations and market fluctuations.***

experimenting with growing canola and processing it into fuel. In SARE-funded trials, Extension specialists Peter Sexton, University of Maine, and Heather Darby, University of Vermont, were largely pleased with their initial yields, averaging from 1,100 pounds per acre for low-input systems to 1,700 pounds per acre for conventionally managed fields. Sexton cited the growing environment in Maine – no irrigation and untimely rainfall that can cause white mold – as a problem for yields, but added these could be readily addressed.

"We could do a little better," said Sexton, referring to the first trials. "But it looks promising enough that we are pursuing it further."

Close-up of canola in full bloom.

NORTHEAST REGION PROFILE

ROGER RAINVILLE: GROWING CANOLA FOR BIODIESEL

Roger Rainville hopes to achieve energy independence on his farm. One of his fuel feedstocks is home-grown canola.

– Photo by Bill DeLillo

Just steps from the Canadian border, Vermont dairy farmer Roger Rainville is one of many farmers looking to determine his own energy future. At his aptly named Borderview Farm, a 300-acre mix of row crops, pasture and dairy replacement heifers, Rainville is gearing up to become self-sufficient in energy, using biodiesel converted from his own canola crop. (See SARE's video series on Roger Rainville at www.sare.org/rainville).

Rainville, who has farmed outside of the small town of Alburgh since 1982, has long been interested in alternative energy. When Vermont Extension Specialist Heather Darby invited him to participate in a SARE-funded farmer research project evaluating canola varieties for biodiesel production, he was thrilled at the prospect.

"We had been dabbling for a while so we were pleased to jump in," Rainville said. "It's been frustrating to see big companies get millions and tell us we couldn't [produce our own energy], when, in fact, farmers can do this themselves."

Rainville was particularly excited about the multiple prospects from canola. "We could see growing our own canola oilseed, producing our own fuel and still having the byproduct for cattle feed," he said. Given that there are approximately 10,000 cows within a 20-mile radius of his operation, and that canola meal can fetch up to $200 per ton, Rainville quickly grasped how the economics would work in his favor.

In 2005, the first year of the trial, Darby and Rainville planted more than 21 varieties of canola, selecting the top three for the following year. "We wanted varieties that were high yielders, high oil [producers], and [would be] available in years to come," said Darby. The farmers also selected varieties that enabled them to save seed.

Rainville found it easy to grow the canola and fit it into his existing corn-alfalfa rotation, but harvesting the seed proved more of a challenge. In the gusty, cool plains of the Midwest, where canola is traditionally grown, the crop is mowed to shelter it from blustery winds. In Vermont, however, correct timing of the swathing proved difficult. Rainville found that waiting too late caused a high proportion of seed pods to shatter. The following year, an unusually wet August caused many of the seeds to rot. By the third year of the trials, however, Rainville realized that in Vermont, unlike the windy Dakotas, the canola could ripen and dry without swathing. In 2007, Rainville harvested the canola directly out of the field, achieving yields of 1.5 tons per acre, leaving him very optimistic about future production.

Because he anticipates excellent returns from the meal by-product, Rainville is not worried about time and labor costs for biodiesel processing. He recently purchased a press to begin converting the canola seed to oil. Next, he plans to set up a cooperative on his farm with other area oilseed farmers, who will use his facility to convert their own canola to biodiesel. Rainville predicts he can grow and process enough canola to produce 2,000 gallons per year of biodiesel, enough to free his farm from fossil fuels.

"Years ago, farmers used 10 percent of their land to fuel the farm — the feed went to the horses," said Rainville. "This is the same idea," he added, referring to the canola crop being used to "feed" the tractors.

"The whole concept of being [energy] self-sufficient on the farm is really pretty exciting," Rainville said.

Glossary

Anaerobic digesters: systems that convert biomass, particularly food waste and animal manure, into energy.

Biodiesel: a fuel made from renewable, biodegradable sources, usually vegetable oil or animal fat.

Bioenergy: energy derived from recent living organisms.

Biofuel: solid, liquid or gas fuel consisting of, or derived from, biological materials.

Biogas: a gas mixture of primarily methane and carbon dioxide, produced by anaerobic digestion or fermentation of organic matter, including manure, sewage sludge, municipal solid waste, or any other biodegradable feedstock.

Cellulose: a complex carbohydrate found in the cell walls of plants.

Carbon neutral: any activity that results in no net carbon emissions to the atmosphere.

Energy audit: a survey and analysis of the energy flows in a building or system including specific recommendations for improving efficiency and conservation.

Ethanol: an alcohol-based fuel produced by fermenting and distilling sugars from plant materials.

Feedstock: a raw biomass material that is converted to another form or product.

Net energy gain: when the energy obtained from an energy source is greater than the energy required to produce it.

Net metering: a state-level electricity policy that allows consumers producing energy to hook up to the grid. When customers are net metered, the utilities can only charge for energy consumption minus production.

Photovoltaic (PV) cells: solar cells or solar photovoltaic arrays that convert sunlight into electricity.

Renewable energy: an energy resource that is replaced rapidly by natural processes.

Switchgrass (Panicum virgatum): a warm-season grass that is a dominant species of the central North American tallgrass prairie.

Volatile organic compounds (VOCs): organic chemical compounds that under normal conditions can vaporize and enter the atmosphere.

Switchgrass has great potential as a bioenergy feedstock and can be grown in many parts of the United States.

– Photo by Martin van der Grinten

General Information for Clean Energy Farming

Sustainable Agriculture Research and Education (SARE) program. National grantmaking program to advance farming systems that are profitable, environmentally sound and good for communities. Currently funding sustainable energy projects. www.sare.org or (301) 374-9696 for print copies of publications.

Department of Energy National Renewable Energy Laboratory (DOE-NREL). Renewable energy and energy efficiency information for farmers and ranchers. www.nrel.gov/learning/farmers_ranchers.html.

Natural Resources Conservation Service (NRCS). Conservation planning and technical assistance to landowners to conserve natural resources, with increasing focus on energy conservation and efficiency. www.nrcs.usda.gov/technical/energy.

National Sustainable Agriculture Information Service (ATTRA). Publications on all aspects of on-farm energy use and production. www.attra.ncat.org/energy.php or (800) 346-9140 (English) and (800) 411-3222 (Spanish) for print copies of publications. See also Farm Energy Search Tool, a website for energy-related equipment, funding and technical assistance. www.attra.ncat.org/attra-pub/farm_energy/search.php.

Environmental Law and Policy Center. Energy efficiency and renewable energy opportunities for farmers, ranchers and rural communities. www.farmenergy.org.

Department of Energy Office of Energy Efficiency and Renewable Energy (DOE-EERE). Access to hundreds of renewable energy and efficiency websites and documents. www.eere.energy.gov.

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USDA SARE Sustainable Agriculture Research & Education

Getting Started with Clean Energy Farming

MACHINERY AND EQUIPMENT

Calculate air conditioning, heating and utility costs and potential savings. Western Area Power Administration Energy Services Team. www.wapa.gov/es.

Plate coolers, variable frequency drives and other on-farm, energy-saving measures. Center for Ecological Technology. www.cetonline.org/FarmBusiness/for_your_farm_or_business.php.

BUILDING EFFICIENCY

Improve Energy Efficiency in Agricultural Buildings. ATTRA. www.attra.ncat.org/attra-pub/agbuildings.html.

Energy Estimator for Animal Housing. Online tool to estimate energy costs and savings for lighting, ventilation, heating, air circulation, milk cooling and water heating. NRCS. http://ahat.sc.egov.usda.gov.

ENERGY AUDITS

Sample energy audits of Maryland dairy and poultry farms. EnSave. www.ensave.com/services/farm-energy-audits/sample-audits/.

Professional or do-it-yourself home energy audits. EERE. www.energysavers.gov/your_home/energy_audits/index.cfm/mytopic=11160.

Do-it-yourself online energy efficiency calculator. Alliant Energy. www.alliantenergy.com, then enter *calculator* in the search box.

FOOD MILES

Marketing Strategies for Farmers and Ranchers. A bulletin on marketing strategies that save transportation-related energy costs. SARE. www.sare.org/marketing.

Links and publications on reducing food miles through community supported agriculture, farmers markets, direct marketing, etc. ATTRA. www.attra.ncat.org/attra-pub/farm_energy/food_miles.html.

DIVERSIFIED CROPPING SYSTEMS

Diversifying Cropping Systems. A bulletin on agronomic crop alternatives. SARE. www.sare.org/diversify.

Energy Estimator for Nitrogen. Online tool to calculate nitrogen savings based on fertilizer type, costs, timing and placement. NRCS. http://nfat.sc.egov.usda.gov.

WATER SAVINGS

Energy Estimator for Water. Online tool to estimate energy savings using different irrigation methods. NRCS. http://ipat.sc.egov.usda.gov.

Energy Saving Tips for Irrigation. ATTRA. www.attra.ncat.org/attra-pub/summaries/summary.php?pub=119.

Smart Water Use on Your Farm or Ranch. A bulletin on sustainable water use. SARE. www.sare.org/water.

DIVERSIFIED ANIMAL OPERATIONS

Grazing Systems Planning Guide. A comprehensive guide to grazing. University of Minnesota Extension. www.extension.umn.edu/distribution/livestocksystems/DI7606.html.

Rangeland Management Strategies. A bulletin on creating and sustaining a healthy range. SARE. www.sare.org/rangeland.

REDUCED TILLAGE

Interactive no-till web page for farmers. New Farm/Rodale Institute. www.rodaleinstitute.org/no-till_revolution.

Energy Estimator for Tillage. Online tool to estimate diesel fuel use and costs for key crops. Compares energy savings between conventional and alternative tillage systems. NRCS. http://ecat.sc.egov.usda.gov.

CLIMATE CHANGE AND CARBON SEQUESTRATION

Information on carbon and greenhouse-gas trading. Chicago Climate Exchange. www.chicagoclimatex.com.

Resources for farmers to make practical and profitable decisions regarding climate change. www.climateandfarming.org.

Climate Friendly Farming project. Washington State University. http://csanr.wsu.edu/CFF/.

WIND

Calculate local wind speeds. The Iowa Energy Center: www.iowaenergycenter.org/ and The Wind Energy Resource Atlas: www.nrel.gov/rredc/, then click on *wind resource information*. For western regions only: www.windpowermaps.org and www.energyatlas.org.

Government incentives and other information on small wind systems. The American Wind Energy Association. www.awea.org.

Wind maps and resources, online calculator to evaluate wind projects and determine feasibility of small wind systems. www.eere.energy.gov, then click on *wind* and *hydropower*.

SOLAR

Basic information on small photovoltaic systems for homes and farms, and tools to estimate local solar resources. www.nrel.gov/learning/fr_photovoltaics.html.

Information on solar-powered livestock watering systems, greenhouses and renewable energy on the farm. ATTRA. www.attra.ncat.org/attra-pub/farm_energy/solar.html.

ANIMAL DIGESTERS

Anaerobic Digestion of Animal Wastes: Factors to Consider. Introductory publication on digesters. ATTRA. www.attra.ncat.org/attra-pub/farm_energy/.

Farm-based Anaerobic Digesters: Potential Benefits and Types. Michigan State University Extension. www.animalagteam.msu.edu/uploads/files/20/anaerobic.pdf.

Information on biogas recovery to reduce methane emissions from livestock operations. AgSTAR. www.epa.gov/agstar.

BIODIESEL

Biodiesel: A Primer; Biodiesel: The Sustainability Dimensions; Biodiesel Production for On-Farm Use: A Curriculum for Agricultural Producers. ATTRA. www.attra.ncat.org/attra-pub/farm_energy/biodiesel.html.

Comprehensive information on biodiesel. The National Biodiesel Board. www.biodiesel.org.

Biofuels curriculum and general information on biodiesel. Piedmont Biofuels Cooperative. www.biofuels.coop.

ETHANOL

Alcohol Can Be A Gas. Comprehensive book on sustainable ethanol production. International Institute for Ecological Agriculture. www.permaculture.com.

Ethanol Opportunities and Questions. Uses and benefits of ethanol. Includes suggestions for further reading on corn and cellulosic ethanol. ATTRA. www.attra.ncat.org/attra-pub/farm_energy/ethanol.html.

Information on economics and energy balance of biofuels. USDA. www.usda.gov/oce/energy.

GRASS PELLETS

Research and equipment from REAP Canada: www.reap-canada.com, then click on *bioenergy* and *climate change*.

Grass pellet information from Cornell University: www.grassbioenergy.org/.

SUSTAINABLE BIOFUEL PRODUCTION

Biofuel library and information on making your own biodiesel. Journey to Forever. http://journeytoforever.org.

Articles on sustainable approaches to ethanol and biofuel production. The Institute for Self-Reliance. www.ilsr.org/initiatives/energy/.

Bioenergy, Climate Protection, Oil Reduction. Newsletter of current information on biofuels, bioenergy and biobased products. The Environmental and Energy Study Institute. www.eesi.org.

Alliance to build sustainable biodiesel practices, including harvesting, production and distribution. The Sustainable Biodiesel Alliance. www.sustainablebiodieselalliance.com.

FUTURE FEEDSTOCKS

Switchgrass as a Bioenergy Crop. Switchgrass as a cellulose-to-ethanol and direct-combustion feedstock. ATTRA. www.attra.ncat.org/attra-pub/summaries/summary.php?pub=311.

Up-to-date research findings on biomass feedstocks and conversion technologies. EERE: www1.eere.energy.gov/biomass/.

The Bioenergy Feedstock Information Network (BFIN): http://bioenergy.ornl.gov.

Research-based site on biomass resources for bioenergy and bioproducts. The Sun Grant Initiative. http://bioweb.sungrant.org.

FINANCIAL RESOURCES

Energy-related equipment, funding and technical assistance by state. www.attra.ncat.org/attra-pub/farm_energy/search.php.

State-by-state listing of state, local, utility and federal incentives, tax credits, local audits, net metering regulations and available rebates. North Carolina Solar Center. www.dsireusa.org.

Grants and loan guarantees to assist agricultural producers with purchasing renewable energy systems and energy efficiency improvements. USDA-Rural Development. www.rurdev.usda.gov/energy.html.

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