Chapter IV B

BIOFUELS AND ENERGY PRODUCTION OPTIONS FOR THE FARM

Biofuels and Other Energy Production Options for the Farm
An Overview

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Introduction

Climate change is full of risks and opportunities for farmers, not the least of which has to do with production and use of energy on the farm. As the price and reliability of fossil fuels continues to grow more volatile, and the environmental cost of their use ever higher, many farmers are seeking ways to reduce fossil fuel use while supporting increased economic vitality for their farms.

American farmers have already reduced consumption of energy on the farm by more than 30 percent over the last few decades.[1] While there are certainly ways to become more efficient, much of the opportunity these days comes from the ability to "harvest" a variety of new energy sources.

Most people are aware of many of the more dramatic advances in alternative energy, including new wind and solar generation systems that make these sources competitive in the marketplace. And farmers are generally aware that the solar energy stored in plant crops in the form of oils or sugars is also a potential source, as biogas (aka methane) is for livestock farmers. Less well known are options like geothermal energy and cellulosic feedstocks.

We present here a survey of the major on-farm energy sources that are considered economically viable. It will be helpful to understand the concept of "bioenergy" and the distinction between biofuel, biodiesel, ethanol, and cellulosic biomass. To aid the reader, a partial glossary has been included below.

This fact sheet is not intended to be exhaustive, because 1) technology is changing rapidly, and 2) the suitability of any given fuel crop or technology is specific to the size, type, geographic location, and land types of each particular farm. Each energy source discussion includes questions that need to be answered by farmers on an individual basis. Some

[1] Miranowksi, J. A. "Energy Consumption in US Agriculture," chapter 3, *Agricultural and Environmental Resource Economics*, with Gerald A. Carlson, David Zilberman, Oxford University Press, 1993.

discussions also include information on the potential for that source to be useful in producing revenue as well as power or heat and cooling.

It is also important to understand the complexity behind calculating both best energy value from a given crop and the actual reductions in greenhouse gas (GHG) emissions from the use of fuels created from plants. Issues related to the true energy values of various crops are reviewed in "Energy and Greenhouse Gas Budgets for Biomass Fuels" elsewhere in this section as well as "Considerations for Diversifying the Farm Portfolio to Include Biofuels," in the Resources section.

Another piece of the landscape that is rapidly changing is the area of subsidies available through local governments, states, and the federal government. Our best advice is to contact your Congressional representative, local Cooperative Extension, utility, state department of agriculture or the USDA for information on what is available in your area or for the particular energy source you are considering.

Glossary

Biodiesel: A biodegradable transportation fuel for use in diesel engines that is produced through the transesterfication of organically- derived oils or fats. It may be used either as a replacement for or as a component of diesel fuel. **B20:** A mixture of 20% biodiesel and 80% petroleum diesel based on volume.

Bioenergy – 1. Useful, renewable energy produced from organic matter. 2. The conversion of the complex carbohydrates in organic matter to energy. 3. Organic matter used directly as a fuel or processed into liquids and gases. 4. Biomass used in the production of energy (electricity; liquid, solid, and gaseous fuels; and heat). Also: ***Biomass, biomass fuel***

Biofuels: Biomass converted to liquid or gaseous fuels such as ethanol, methanol, methane, and hydrogen.

Biogas: A combustible gas derived from decomposing biological waste under anaerobic conditions. Biogas normally consists of 50 to 60 percent methane. See also ***Landfill gas***.

Biomass: 1. Any plant-derived organic matter. Biomass available for energy on a sustainable basis includes herbaceous and woody energy crops, agricultural food and feed crops, agricultural crop wastes and residues, wood wastes and residues, aquatic plants, and other waste materials including some municipal wastes. Biomass is a very heterogeneous and chemically complex renewable resource. 2. An energy resource derived from organic matter. These include wood, agricultural waste and other living-cell material that can be burned to produce heat energy. They also include algae, sewage and other organic substances that may be used to make energy through chemical processes. Also: ***Biomass fuel*** – Liquid, solid, or gaseous fuel produced by conversion of biomass. Examples include bioethanol from sugar cane or corn, charcoal or woodchips, and biogas from anaerobic decomposition of wastes.

Carbon neutral: Referring to an energy source that does not produce any new carbon emissions, usually because the carbon emitted will be reabsorbed by new plant growth, some times because the fuel used to produce the energy is not carbon-based, e.g., wind.

Cellulose: the main constituent of the cell walls of plants and algae. Its derivatives are used for making plastics, lacquers, explosives, and synthetic fibers. Adj.: ***cellulosic***

Energy crops: Crops grown specifically for their fuel value. These include food crops such as corn and sugarcane, and nonfood crops such as poplar trees and switchgrass. Currently, two energy crops are

under development: short-rotation woody crops, which are fast-growing hardwood trees harvested in 5 to 8 years, and herbaceous energy crops, such as perennial grasses, which are harvested annually after taking 2 to 3 years to reach full productivity.

Ethanol: (CH3CH2OH) A colorless, flammable liquid produced by fermentation of sugars. Ethanol is used as a fuel oxygenate. Ethanol is the alcohol found in alcoholic beverages. **E-10:** A mixture of 10% ethanol and 90% gasoline based on volume. **E-85:** A mixture of 85% ethanol and 15% gasoline based on volume.

Herbaceous Energy Crops — Perennial non-woody crops that are harvested annually, though they may take 2 to 3 years to reach full productivity. Examples include: Switchgrass (*Panicum virgatum*), Reed canarygrass (*Phalaris arundinacea*), Miscanthus (*Miscanthus x giganteus*), and Giant reed (*Arundo donax*).

Geothermal: 1. Heat or energy from the Earth, usually passive subsurface temperature; 2. relating to or produced by the heat in the interior of the Earth

Kilowatt: (kW) A measure of electrical power equal to 1,000 watts. 1 kW = 3,413 Btu/hr = 1.341 horsepower. See also watt.

Kilowatt hour: (kWh) A measure of energy equivalent to the expenditure of one kilowatt for one hour. For example, 1 kWh will light a 100-watt light bulb for 10 hours. 1 kWh = 3,413 Btu

Landfill gas: A type of biogas that is generated by decomposition of organic material at landfill disposal sites. Landfill gas is approximately 50 percent methane. See also ***biogas***.

Photovoltaic: able to generate a current or voltage when exposed to visible light or other electromagnetic radiation

Renewable: able to be sustained or renewed indefinitely, either by inexhaustible supplies or by of new growth

Residues, Agricultural: Agricultural crop residues are the plant parts, primarily stalks and leaves, not removed from the fields with the primary food or fiber product. Examples include corn stover (stalks, leaves, husks, and cobs); wheat straw; and rice straw. With approximately 80 million acres of corn planted annually, corn stover is expected to become a major biomass resource for bioenergy applications.

Residues, Biomass: Byproducts from processing all forms of biomass that have significant energy potential. For example, making solid wood products and pulp from logs produces bark, shavings and sawdust, and spent pulping liquors. Because these residues are already collected at the point of processing, they can be convenient and relatively inexpensive sources of biomass for energy.

Biodiesel

The increased use of diesel-powered equipment on farms has accounted for much of the energy-use reduction since the 1970s. Because Diesel engines produce more power with less fuel than conventional gasoline engines, farmers have achieved more work at a lower cost.

Ironically, few people realize that the Diesel engine was created in 1892, by inventor Rudolf Diesel to run on peanut oil, its inventor believing that "petroleum is much too valuable to burn." Over the past few decades, the fact that these powerful, relatively efficient engines will run on vegetable oil, even if it has been used already for cooking, has brought about a wave of new interest in, and subsequent technology dedicated to, the production of "biodiesel" as the plant-based fuel has come to be called.

While biodiesel in its pure "neat" form is a completely renewable fuel, it is not simply raw vegetable oil.[2] Chemically speaking, it is comprises methyl esters of long-chain fatty acids, and is derived from vegetable oil or animal fat by removing the glycerin in a reactive refinery process.[3].

Today, it is commonly understood that, with little or no modification, Diesel engines (including those used for electric generation) will run on a blend of petroleum diesel and biodiesel. They even will run on B100, or 100% biodiesel, depending on temperatures and minor modifications to accommodate the detergent qualities of biodiesel.[4] While concerns about warranty violations persist, most farm equipment, including tractors and combines, can run on biodiesel. It also appears, from recent research and experience, that B100 can be used for most of the growing season, at temperatures above 50 degrees. Additionally, biodiesel can replace No. 2 fuel oil, and so will burn in furnaces, whether they are heating homes, hothouses, or barns, with slight modifications to hoses, connectors, and nozzles, because of the detergent qualities of biodiesel.

Benefits of using biodiesel include better air quality because of a reduction in particulates, volatile organic compounds, and sulfur dioxide, carbon monoxide, and mercury. In addition, with an increase in the blend from B2 to B100 comes a reduction of harm from potential spills and leakage because of it is biodegradability and nontoxic properties. Finally, experience among biodiesel users has shown that the increased lubricity of the fuel actually reduces engine wear, while the reduction in pollutants improves the health of operators and mechanics.

The availability of biodiesel has also increased dramatically, with supplies available at competitive or better-than-diesel prices in most markets in the Northeast.

Some farmers have begun to grow "fuel crops" to be used as feedstock for commercial scale biodiesel production. Rapeseed, one leading example, produces approximately 2,000 pounds of seed per acre from which is extracted about 100 gallons of vegetable oil for fuel and can

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[2]National Biodiesel Board, *Biodiesel Definitions*. National Biodiesel Board, Jefferson City, MO. Available from http://www.nbb.org/resources/definitions/default.shtm

[3] ibid

[4] National Biodiesel Board. *FAQs*, National Biodiesel Board, Jefferson City, MO. Available from http://www.nbb.org/resources/faqs/default.shtm

have a positive energy ratio as high as 1:3.78 – meaning that producers of biodiesel from rapeseed may produce 3 and ¾ units of energy for each unit of energy put into producing it. Additionally, 1,200 pounds of meal will be produced that can be used for energy (See cellulosic biomass, below), livestock feed as protein meal, or other industrial purposes.[5]

Considerations

- Using biodiesel on the farm can be as simple as purchasing the fuel from a local distributor and having it delivered to a designated tank on the farm. A list of registered fuel marketers is maintained by the National Biodiesel Board and is available at http://www.biodiesel.org or by calling the NBB at (800) 841-5849. Anyone using biodiesel is cautioned, however, to be sure the product they use is guaranteed to meet standards set by ASTM International. Also be aware that biodiesel produces slightly more than 90 percent of the BTUs in combustion as the same volume of petroleum Diesel, some of which is made up for by engine efficiency because of the increased lubricity of biodiesel.
- Keeping the B100 fuel warm enough so that it flows well is an issue below 50 degrees F. If using biodiesel for space heating, consider locating the storage tank in the area you are heating, and use the exhaust heat from the furnace to heat that space. If using biodiesel in an engine running a generator, use the exhaust heat from the gen-set the same way.
- Producing biodiesel on the farm by growing the plant source and then converting it requires time and expensive equipment. This "grow your own fuel" decision can only be made after pricing the equipment, calculating the time, and doing a thorough cost-benefit analysis and estimate of time for return on investment. For more information, see https://store.biodiesel.org/comersus/store/comersus_viewItem.asp?idProduct=3097
- Production of revenue-producing fuel crops for biodiesel depends on a number of factors, including available acreage, cost analysis versus other crops, and availability of market services in your area, such as transportation or refining.
- While using biodiesel reduces most pollutants in comparison to petroleum Diesel, it does not reduce emissions of smog causing nitrogen oxides. When used in vehicles there is an increase by about 4 percent for B20 and by about 10 percent for B100. However, this does not apply when used in stationary applications like space heating or electric generation. See also "Considerations for Diversifying the Farm Portfolio to Include Biofuels," in the Resources section.
- It is worth checking on federal, state or local incentive programs. Federally, in 2004, President Bush extended the ethanol tax incentive program to include biodiesel. The biodiesel tax incentive, which is structured as a federal excise tax credit, amounts to a penny per percentage point of biodiesel blended with petroleum diesel for first-use oils, like soybean oil, and a half-penny per percentage for biodiesel made from other sources, like recycled cooking oil. It will lower the cost of biodiesel to consumers in taxable and tax exempt markets.[6]

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[5] University of Idaho, Department of Agricultural Engineering, Moscow, ID. *On Road Testing of Biodiesel – A report of past research activities*. Available from http://www.uidaho.edu/bae/biodiesel/research/past_research.html.

[6] National Biodiesel Board, *President Signs Bill Containing Biodiesel Tax Incentive, October 22, 2004*. National Biodiesel Board, Jefferson City, MO. Available from http://www.biodiesel.org/resources/pressreleases/_gen/20041022_tax_Incentive_Passage.pdf

Obstacles

- Cost and availability. Biodiesel has traditionally been pennies on the dollar more expensive than petroleum diesel, and far harder to get. Both of these problems are going away due to demand for biodiesel as the price of Diesel goes up and stays up.
- Road fuels taxes. It is difficult for an individual or coop to make arrangements to pay the fuel taxes when producing biodiesel for on-road use. This is not a problem when using in off-road vehicles.
- Gelling. At low temperatures, biodiesel will not pour, which can limit the use of biodiesel produced on the farm or in coops for space heating, unless there is a way to keep the fuel relatively warm, or if the farm or coop has a means of blending the fuel and treating it.

Biomass

Included in this category of fuels are those plant-based feed stocks that are either burned directly (such as wood and woody crops, corn, and various residue that is chipped or pelletized) or "refined" so that fuel, in the form of sugars or starches, are separated from cellulose.

Cellulose, the primary component of "biomass" fuels, is found in all plant materials. Properly processed, cellulosic or lignocellulosic biomass is an economical source of energy for heating, transportation, and electric generation. There are a number of different processes in development (such as enzymatic conversion of sugars for liquid fuels or a pyrolysis for hydrogen or liquid fuels) for conversion of all types of biomass products, including wood and "short rotation" woody crops, waste wood, wood residue, grains, grasses, and agricultural residue, such as corn stover.

The biorefinery concept (Figure 1.) is the hottest area of current research. A biorefinery of the not-too-distant future would extract from plants chemicals and then fuels through depolymerization of cellulose and hemicellulose and the conversion of lignin for process fuel and synfuels. While the technology to do this is not ready, many researchers[7] feel the pressure of energy needs, greenhouse gas reductions, and opportunities for a new farm economy will lead to rapid development in this area.

There are basically two streams from biomass, one for sugar feedstocks and the other for syngas feedstocks. Both contribute residues for direct firing, resulting in potential for combined heat and power, and result in a number of petroleum-replacement fuels and products. Advances in technologies like pyrolysis and gasification may allow economical production of hydrogen and syn fuels from wood and woody crops and perhaps crop residues. These technologies are being tested in series, designed to operate much like a petroleum refinery, where different products are taken out of the process at different times. A major emphasis in this area is pyrolytic conversion of "bio-oil" from wood for use as a replacement for space-heating fuel; by products could be used for a variety of purposes, including replacement of propane and hydrogen production.

[7] Ragauskas, A. J., et. al., *The Path Forward for Biofuels and Biomaterials*, Science, vol. 311, 27 Jan. 06.

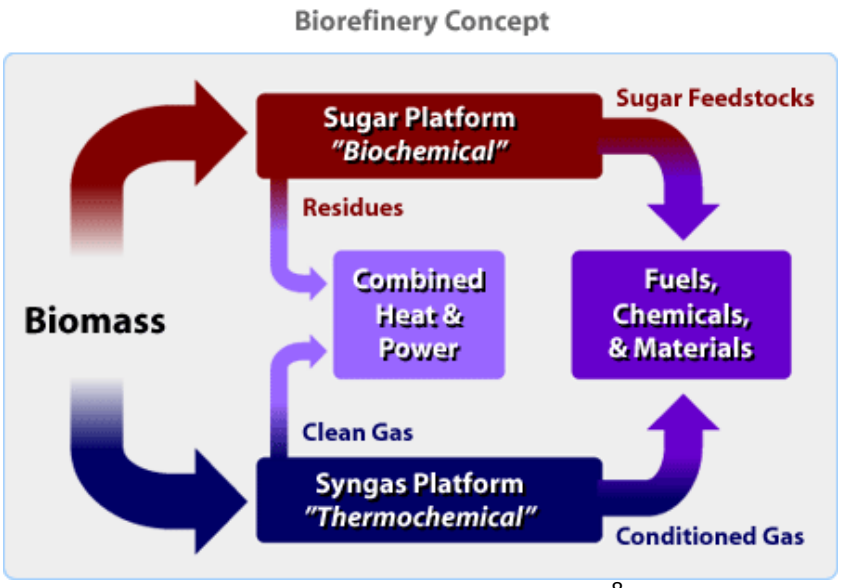

Figure 1. Two streams for biomass refining. [8]

It is unclear which of these processes is likely to be most feasible from an economic and farm-production point of view. It is clear, however, that energy production from biomass is very likely to be the most advantageous route for farmers in the Northeast because all of these biomass fuels are either produced from plants native to or suitable for production on marginal or nonproductive land – or they are already produced as waste from current production.

Since the energy crisis of the mid-1970s, an industry has developed turning scrap wood into pellets for fuel. Today that industry has achieved major commercial status, with the ability to provide an efficient source of heat for commercial establishments.[9] Pelletized sawdust, grasses, corn residue, wood chips and other "waste" cellulose – along with corn grain – are primarily used in direct firing for space heating, but also for some larger, commercial applications, as stove and furnace technologies improve.

Wood pellet use in the Northeast has increased rapidly in the last decade, enjoying the benefit of no-cost or low-cost waste sawdust as feedstock that is easy to pellet. Though hay or grass for pelletized fuel is generally from excess crop, as sawdust and scrap-wood chips are depleted by increased demand, new sources, among them hay and grasses, will become economically attractive.

This opportunity for farmers is particularly good because grass production is an activity that most farmers are already equipped to do, is very suitable for low-quality lands and requires less time when feed quality is not a factor. [10] In addition, the energy ratio for grass pellets is very good, currently estimated as high as 1:15.[11] As perennial crops for pelletized fuel reduce the

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[8] National Renewable Energy Laboratory, available at: http://www.nrel.gov/biomass/biorefinery.html.
[9] National Pellet Fuels Institute, Arlington, VA *Industry specifics.* Available from : http://www.pelletheat.org/3/industry/index.html
[10] ibid
[11] Cornell University, College of Life Sciences and Agriculture, Ithaca, NY. GrassBioenergy.org, *Introduction.* Available from: http://www.grassbioenergy.org/intro/intro.asp

need for tillage and the application of chemicals, thus reducing costs and environmental impacts; they may also be planted on land considered unuseable for food or feed crops.

Company	Location	Phone	Contact
Allegheny Pellet Corp.	Youngsville, PA	814/563-4358	Ron Leofsky
Associated Harvest Co.	Lafargeville, NY	315/658-2926	Glenn Walldroff
Dry Creek Products, Inc.	Arcade, NY	585/492-2990	Greg Palmer
Energex Pelet Fuel, Inc.	Mifflintown, PA	800/373-5538	Darryl Rose
Hamer Pellet Fuel Co.	Kenova, WV	304/453-6381	Lori Hamer
Ironstone Mills, Inc.	Leola, PA	717/656-4539	Frank Diem
Lignetics of West Virginia	Glenville, WV	304/462-4848	John Cordeau
New England Wood Pellet, Inc.	Jaffrey, NH	603/532-9400	Steve Walker
Penn Wood Products, Inc.	East Berlin, PA	717/259-9551	Brian Markle
Wood Pellets Co.	Summerhill, PA	814/495-9335	Terry Smith

Figure 2. Pellet Mills in the Eastern US

Advances in genomics and industrial biotechnology are making it possible to convert cellulose to fermentable sugars that can be used as feedstocks for a new type of "carbohydrate crude oil."[12] USDA and DOE have a joint program to spur development in this area to produce a billion dry tons, at a market price of $35 per ton, of cellulosic biomass annually for refining by 2050.[13] With further development of cellulosic biofuels, the U.S. could, according to one report, replace 50 percent of U. S. transportation oil use, or nearly 8 million barrels a day.[14]

It is estimated that, without disruption of food, feed and exports demands, agricultural lands can provide nearly 150 million dry tons of sustainably collectable biomass annually by 2010[15], primarily from crop residues (such as corn stover) and perennial crops, as well as grains used for biofuels, and animal manures and other various residues from farming and food production. The perennial crops are crops dedicated primarily for bioenergy and biobased products and will likely include a combination of grasses and woody crops.

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[12] Energy Futures Coalition. *Challenge and Opportunity, Charting a New Energy Future*: *Report by the Bioenergy and Agriculture Working Group*. Energy Futures Coalition, Washington, DC. 2005. Available from http://www.energyfuturecoalition.org/

[13] Perlack, R.D., et al. *Biomass as Feedstocks for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply.* April, 2005. *A* Joint Study by the U.S. Department of Agriculture and U.S. Department of Energy. Available from http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf

[13]Greene, N.,*Growing Energy: How Biofuels Can Help End America's Oil Dependence*, p. v-viii., Natural Resources Defense Council, Washington, DC. 2004. Available from http://www.nrdc.org/air/energy/biofuels/contents.asp

[14] Perlack, R.D., et al. *Biomass as Feedstocks for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply.* April, 2005. *A* Joint Study by the U.S. Department of Agriculture and U.S. Department of Energy. Available from http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf

Considerations

- Utilizing crop residues and growing perennial crops on a large scale would require significant changes in current crop yields, tillage practices, harvest and collection technologies, and transportation.
- There are long-term economic and environmental concerns associated with the removal of large quantities of residues from cropland. Removing any residue on some soils could reduce soil quality, promote erosion, and lead to a loss of soil carbon which in turn lowers crop productivity and profitability. Establishment and communication of research-based guidelines is necessary to ensure that removal of residue biomass is done in a sustainable manner.[16]
- If residue removal results in larger fertilizer applications, then the environmental and economic costs associated with producing and acquiring those fertilizers (nitrogen, phosphorous and potassium as well as micro-nutrients) must be considered.
- One of the proposed solutions to the nutrient runoff problem has been to increase the acres of perennial crops relative to annual crops. Perennial crops require fewer applications of pesticides and fertilizers. When strategically placed, they can absorb the runoff from annual crop plantings. Other benefits of perennial crops include less erosion and less soil compaction due to less soil disturbance. Perennial crops also provide better habitat for birds, such as migratory song birds and for several types of mammals.[17]
- Redirecting large quantities of animal manure to bioenergy uses can lessen nutrient runoff and reduce contamination of surface water and groundwater resources.
- With increased production of ethanol from corn and small grains, the amount of dry distiller grains, gluten feed and gluten meal will increase. Also, soybean meal will increase as more soybeans are crushed for biodiesel. The co-products of biofuels production can be used as a protein supplement for livestock in place of corn grain. It is also assumed in this evaluation that perennial grasses are processed to remove proteins prior to their utilization as a low-cost ethanol feedstock. With all of these protein sources, there is sufficient feed material for livestock under all scenarios.
- Further research, demonstration, and development needs to occur for farmers to begin cropping cellulosic feedstocks such as switchgrass. Though switchgrass can provide some commercial value in the first year, it makes financial sense only when cultivated for six to ten years.[18]

Obstacles

- The market for cellulosic biomass, including economically competitive means of refining cellulose and the necessary infrastructure for transporting feedstock and refined fuel, is still in development.
- While individual farms or farmer-owned and -operated coops often refine biodiesel themselves, where fuel is used in equipment, heating, and possibly electric generation, biorefining of cellulosic feedstocks is a much more costly and complicated technology. It is unlikely that refineries of this type will be maintained by farmer-owned coops in the future.

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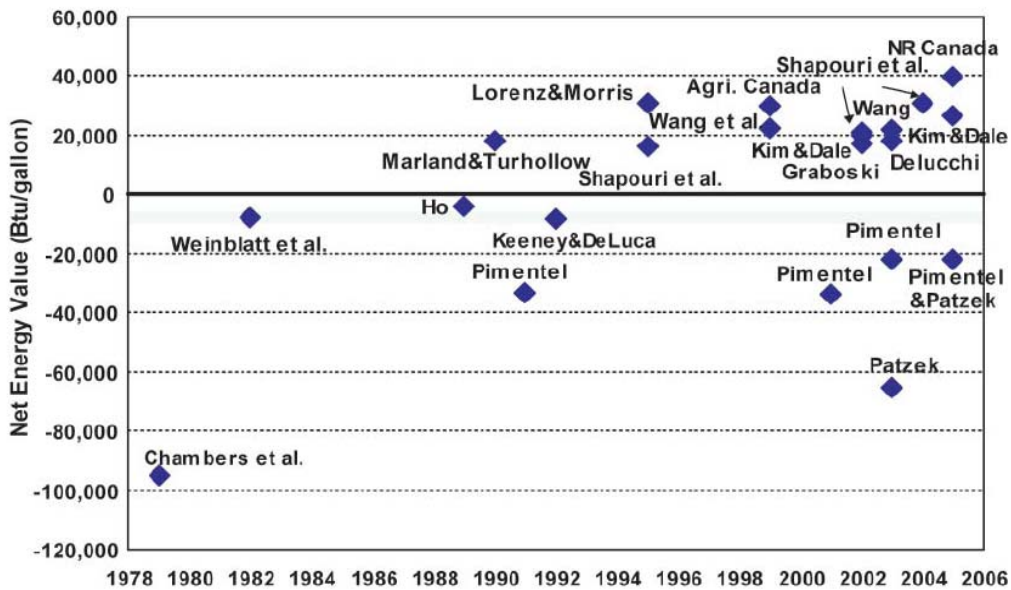
[16] Ibid.
[17] Ibid.
[18] Greene, N. *Growing Energy: How Biofuels Can Help End America's Oil Dependence*, p. 14, Available from http://www.nrdc.org/air/energy/biofuels/contents.asp Natural Resources Defense Council, 2004.

Ethanol (biomass)

Probably the best known farm-to-fuel story is that of ethanol, and it has also been a controversial one of late. Ethanol, like biodiesel, is a biofuel that can serve as an alternative to petroleum fuels, though it can only be substituted for or added to gasoline and not diesel.

Because ethanol is currently produced from the oil of the seed, which has competing values in food production, and since most ethanol is being produced from corn that is relatively energy-intensive, researchers have put considerable time and attention into the question of the energy-ratio and economic viability of commercial-scale ethanol production.[19] It currently appears that ethanol can be produced at a positive energy balance (See Figure 3), with a ratio of better than 1:2, and possibly as high as 1:4 or 1:5 when all of the uses of the crop are considered (e.g., distiller grains, protein meal, etc., for corn). See also "Energy and Greenhouse Gas Budgets for Biomass Fuels" elsewhere in this section.



Energy balance here is defined as BTU content a gallon of ethanol minus fossil energy used to produce a gallon of ethanol

With the increasing efficiency of ethanol production since the modern ethanol industry was born in the 1970s, most studies show that corn-based ethanol generates more energy than it uses in production. The exceptions are based on pessimistic efficiency statistics and failure to count the energy value of coproducts.
Credit: Michael Wang, Argonne National Laboratory

Figure 3.[20] By considering all the possible uses for a crop, as well as new technologies for fuel production and planting and harvesting, researchers have found a positive energy balance for ethanol production.

Though most of today's ethanol is produced from starch-based feedstock (i.e. corn or sugarcane), it can also be produced from cellulosic feedstock such as fast growing grasses like

[19] Glasgow, N. and Hansen, L., Rocky Mountain Institute. *Setting the Record Straight on Ethanol: Focusing on the Nexus of Agriculture and Energy Value Chains*. October 31, 2005.
[20] Mazza, P., and Heitz, E., *The New Harvest:Biofuels and Windpower for Rural Revitalization and National Energy Security*, The Energy Foundation, 2005.

the perennial switchgrass or short rotation woody crops like poplar.[21] Though these crops are not cost-competitive yet, the technology is advancing with development and testing of advanced conversion process such as thermal gasification and enzymatic reduction hydrolysis.[22] Additionally, it is important to recognize the importance of the corn-ethanol industry in setting the stage for technology advancement to convert cellulosic feedstocks. The corn industry will provide much of the feedstock such as corn stover and corn fiber, and the corn-ethanol mills will be testing grounds for the next-generation technologies.[23]

Perhaps the single biggest advantage to farmers in cropping for ethanol is that market and market infrastructure are established and growing, especially with the gradual adoption of ethanol to replace MTBE as an oxygenator for unleaded gasoline. This makes it relatively easy for farmers to get into production.

Considerations

- Before a farmer makes a decision to dedicate a portion of any crop to ethanol production, he or she will need to consider whether (1) the crop is more valuable as feed, food, or as fuel, (2) another fuel crop, like grasses can be grown on less productive land and be equally profitable leaving prime land for production of corn or other ethanol crops for food or animal feed, and (3) the farm has a means of getting its fuel crop to a refinery that is as economical as it would be to get the feed crop to the market.
- It is estimated that corn oil production for ethanol cannot exceed 20 percent of total U. S. crop production without adversely affecting corn and livestock feed prices.
- As the next-generation technology and the market develops for enzymatic refining of cellulosic ethanol, it may be less economically feasible to produce ethanol from plant oils. Farmers may find that growing cellulosic feedstocks such as switchgrass are profitable and bring the extra benefit of a native perennial plant that yields more per acre, provides erosion control, and needs reduced inputs of water, pesticides, and fertilizer.
- Federal, state or local incentive programs. The small ethanol producer credit provision will make farmer-owned cooperatives eligible for this tax credit, which will provide millions of dollars per year in tax relief to the farmer owners.[24] Many states provide some sort of incentive for ethanol production or use, and many have both.

Obstacles

- There are relatively few obstacles to the production of ethanol using starch-based crops like corn or sugarcane, because the market is well established. Only the issue of the tradeoff in the economics of land use stands as a potentially significant obstacle.

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[21] Ibid.
[22] Ibid.
[23] Greene, N. *Growing Energy: How Biofuels Can Help End America's Oil Dependence*, p. 19, Available from http://www.nrdc.org/air/energy/biofuels/contents.asp Natural Resources Defense Council, 2004
[24] National Corn Growers Association. *NCGA Applauds Congressional Passage of American Jobs Creation Act*, October 11, 2004. National Corn Growers Association, Washington, DC. Available from http://www.ncga.com/news/releases/2004/october/news101104a.htm

Geothermal

Because most parts of the Northeast have cold winters, hot summers, and underground temperatures that tend to be about a temperate 50 degrees F, as well as relatively high energy prices, simple ground-source heat pumps (GSHP) can be an excellent source of heating and cooling in the Northeast. Some recent technological advances have considerably lowered the cost of installing geothermal systems. A system that would heat and cool a typical residential structure will cost about $7500.[25] At savings up to 60 percent on heating and 50 percent on cooling, however, return-on-investment times are relatively short.[26] These costs may be reduced by state, local, or utility energy-efficiency incentive programs or federal renewable energy programs.

There are three main types of closed-loop underground geothermal systems of varying cost and efficiency. They use air, water, or a special thermal fluid that is pumped through underground pipes, exchanging the above ground temperature for the temperature below ground. Costs for the systems vary depending on the size of the system, the type, and the soil types into which the pipes need to be installed. Some systems can also be installed underwater if the body of water used is clean enough and large enough to remain at a reasonable temperature throughout the year.

Typically, pipes for the system are buried 12 to 20 feet underground, some in bore holes when vertical installation is needed, and some in trenches when disturbing the landscape is not an issue. Electric pumps push air or fluid through the buried pipes or tubes so that it gradually cools or heats up, depending on the temperature above ground. The closed loop then brings the heated or cooled air or fluid back into the building, where it is distributed through one of a variety of mechanisms.
Applications for these systems are primarily related to space heating and cooling, though water heating is also possible.

Considerations[27]:

- Simultaneously heat and cool different rooms of the same building with the ability to create multiple zones, with each zone having an individual control
- Greater freedom in building design because equipment is underground or inside thus giving more mechanical room space and no outside equipment to hide
- Equipment and pipes have a 40-plus-year life expectancy and are maintenance free
- Savings of 25-50% on energy consumption.
- Federal and state incentive programs may exist and some local electricity utilities offer rebates or incentives to their customers who purchase GSHPs. A listing of state incentives can be found at the Geothermal Heat Pump Consortium website.[28]

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[25] California Energy Commission. *Geothermal Heat Pumps*. California Energy Commission, Consumer Energy Center, Sacramento, CA. Available from http://www.consumerenergycenter.org/homeandwork/homes/inside/heatandcool/heatpumps.html

[26] International Ground Source Heat Pump Consortium. *Frequently Asked Questions*. International Ground Source Heat Pump Consortium, Stillwater, OK. Available from http://www.igshpa.okstate.edu/geothermal/faq.htm

[27] Ibid.

[28] Geothermal Heat Pump Consortium, Washington, D.C. Available from: http://www.geoexchange.org/incentives/incentives.htm

Obstacles

- Depth and type of subsurface soils can be an issue.
- The installation of a GSHP system is somewhat expensive initially and can be disruptive of other operations on a farm.
- Economical operation of a GSHP system is relative to fuel costs and air-temperature differentials.
- Economy of operation is often based on the number of square feet available for heating and cooling by a single system.

Biogas (Methane)

Bio-gas, which can be produced and captured in an anaerobic digester, contains methane (60-70%), carbon dioxide (30-40%), and various toxic gases, including hydrogen sulfide, ammonia, and mercaptans. Bio-gas also typically contains 1-2% water vapor.[29]

Methane, the principal gas emitted in the process, is a potent global warming gas, having at least 20 times the warming potential of CO_2. (The concept of a Global Warming Potential [GWP] has been developed to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to another gas. Carbon dioxide [CO_2] was chosen as the reference.)[30] The average, well-fed dairy cow in the US produces about 120 pounds of manure and between 100 and 200 liters of methane a day, representing a major challenge for farmers, in terms of safe storage and disposal of manure, and reduction of this greenhouse gas.

The U. S. EPA estimates emissions of methane from livestock manure at 17 million tons carbon equivalent, or 10 percent of total 1997 methane emissions, mostly from large swine (hog) and dairy farms that manage manure as a liquid. These emissions are expected to grow by more than 25 percent by 2020.

Cost-effective technologies are available to turn this liability into an asset by capturing methane, which has a fuel BTU content of 60 percent that of natural gas when used as an energy source. These anaerobic digesters include covered lagoons, “complete mix” silo systems, and “plug flow” systems. Each design allows manure to decompose in a controlled environment and methane to be recovered, leaving solids for use in soil amendment. The recovered methane can fuel power generators to produce electricity, heat, and hot water. Digesters also reduce foul odor and can reduce the risk of ground- and surface-water pollution.

In the past several years, research into the use of anaerobic manure digesters to capture methane for use as a fuel has shown that this approach is economically viable for livestock farms of more than 250 cows or the equivalent in other animals. A particularly successful design is the covered-lagoon system, which captures 90 percent of the methane, uses waste heat from the electric generator to produce hot water, and creates fertilizer from the remaining lagoon water and solids.

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[29]Balsam. John, *Anaerobic Digestion of Animal Wastes: Factors to Consider*, ATTRA - National Sustainable Agriculture Information Service, 2002.

[30] Evironmental Science Published for Everybody Round the Earth. Available from: http://www.atmosphere.mpg.de/enid/7c45cd4178024d25f4cd9a1d9a1bcb7a,0/2__Radiation___greenhouse_gases/-_CO2__CH4_253.html

	Swine	Dairy	Beef	Poultry (layers)
Electricity Equivalent	----- per head per year -----			
kWh (20% combined generating efficiency)	32	385	230	2.5
Value (@ $.04/kWh)	$1.30	$15.45	$9.20	$0.10
Natural Gas Equivalent				
Mcf	0.55	6.60	3.90	0.04
Value (@ $3.60/Mcf)	$2.00	$23.75	$14.15	$0.15
Propane (LP Gas) Equivalent				
Gallons	6	72	43	0.45
Value (@ $.58/gallon)	$3.49	$41.60	$24.80	$0.26
No. 2 Fuel Oil Equivalent				
Gallons	4	48	28	0.3
Value (@ $.88/gallon)	$3.53	$42.10	$25.05	$0.26

Figure 4. Bio-gas Net Returns from Various Animals.[31]

	Swine (per head)	Dairy (per head)	Beef (per head)	Poultry (layers) (per bird)
Animal weight (lbs.)	135	1,400	800	4
Expected Energy Content				
Gross energy content (Btu/head/day)	2,300	27,800	16,600	180
Net energy content (Btu/head/day) (uses 35% of gross to operate digester)	1,500	18,000	10,700	110

Figure 5. Energy Content of Bio-gas from Various Animals[32]

[31]Balsam. John, *Anaerobic Digestion of Animal Wastes: Factors to Consider*, ATTRA - National Sustainable Agriculture Information Service, 2002.
[32] Ibid

Considerations

- EPA recommends that a farmer consider three issues when deciding whether a digester is appropriate, 1) how is manure handled, as a liquid, slurry, or semi-solid, the manure characteristics play a role in type of system to use, 2) what is the frequency of manure collection, farms with year-round stable production are best suited, and 3) which gas use option will work the best, to produce electricity, heat, or simply flare.[33]
- Biogas is explosive, and safety is a significant concern.
- The farther north you are, the more difficult it is to maintain optimum temperatures for digestion.
- Digesters must be "seeded" with waste from a local treatment plant, and will not begin producing gas for a few to several months.
- Pure manures work well, but bedding mixed in is problematic.
- Digesters require regular monitoring to perform well.
- Biogas cannot be liquefied economically.

Obstacles

- Cost of the system.
- Mismatch with energy needs.
- Size of the farm

Solar

Options for using solar energy on the farm are usually categorized in two ways: projects that passively harness the sun's energy or those that actively convert it. Examples of passive solar include simple daylighting techniques such as installing skylights to replace electric lights, or using the heat from the sun's rays to warm a building. Active solar applications have a wider range, from solar water heating to the use of solar cells to convert photons into electricity to power fans, irrigation pumps, and other electrical equipment.

Some solar applications are as simple as a black-roofed haybarn with fans that draw air through the space, thus saving money on energy used to dry hay. Solar heaters are often used to supplement traditional heaters that run on fuels like propane.

Photovoltaic installations are economical for a variety of uses in remote locations, like electric fencing, water pumps, and even small irrigation systems. As the cost of solar panels continues to drop and their efficiency continues to rise, larger and larger applications will become feasible.

Solar energy continues to be relatively expensive for large installations, running an average of $10,000 for a 1 kW installation. For remote applications, however, where the cost of bringing in power lines is prohibitive or wastes arable land, the real costs drop. Because of these limitations, installation of small solar systems of less than 1kW for remote locations is often very cost competitive.

[33] U.S. EPA, "Managing Manure with Biogas Recovery Systems: Improved Performance at Competitive Costs", The AgSTAR Program, Winter 2002. Available from http://www.epa.gov/agstar/overview.html

Considerations

- A cost/benefit analysis, including the solar potential for the individual farm, is essential because of the continuing relatively high cost of solar installations.
- Availability of distinct, remote applications on the farm.
- Federal, state, local or utility incentive programs such as tax credits or rebates.

Obstacles

- Lack of sufficient sun.
- Cost for a system.
- Lack of net metering legislation requiring utilities to purchase excess power from solar generators.

Wind

Wind is the big winner in the renewable energy revolution going on in the United States; though representing only a fraction of the nation's energy, growth has been steady. During the years 1999-2003, wind generating capacity expanded at an annual average rate of 28%. [34] Technological advancements in wind turbine design have made wind cost effective, and electricity from wind is now very competitive in price, making returns on investment for wind farms short-term, and the farms profitable. This makes wind more feasible both for an individual farm, and for wind developers looking for farms on which to locate turbines.

Farmers have two choices when it comes to utilizing wind energy. The more complicated option is when farmers lease their land to a wind plant developer. Wind developers typically arrange a 30-year lease from landowners for an annual fee of $1,500-2,000 for each large-scale wind turbine sited on their land.[35] Each turbine takes around one-half acre to two acres away from crop production, primarily for access roads. A large-scale wind turbine produces around 750 kiloWatts (kW); for illustrative purposes, production of 1,000 kW can power the equivalent of 300 American households.[36]

The second option is for the farmer to install a small-scale wind turbine to supply electricity to the farm itself. These small turbines produce 75 kW or less and make sense for all types of farm operations dependant upon electricity for operation. Generally these are livestock, particularly dairy or poultry, operations, as well as some hothouse crop farms or farms with significant irrigation needs, where electricity can be put to good use as a power source. Small installations average an upfront cost of about $3000 per kilowatt.[37]

A typical single-turbine, 10 kW system costs about $50,000. The cost includes all the necessary hardware and electrical apparatus, including connection to the electricity grid, allowing unused power to enter the grid from the farm, and allowing the farm to continue to draw from the grid when wind cannot meet the farm's electricity needs. This important

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[34] American Wind Energy Association, *Wind Power Outlook 2004, Stiff Challenges, Big Opportunities*.
[35] Patrick Maza, *Harvesting Clean Energy for Rural Development, Part One, Wind*
[36] American Wind Energy Association, *Wind Power Outlook 2004, Stiff Challenges, Big Opportunities*.
[37] Harvesting Clean Energy Program, Climate Solutions, Olympia, WA. Available from: http://www.harvestcleanenergy.org/wind/sub_wind_onfarm.htm

supply/demand feature is known in the electricity industry as "net metering" and is crucial to the viability of renewable energy. Under net metering, excess electricity produced by the wind turbine will spin the existing meter backwards, in effect banking the electricity until it is needed by the customer, thus providing the customer with full retail value of the electricity produced.[38] Without net metering the excess production is lost or, at best, sold to the utility at a much lower price.

The process for deciding whether wind is right for a given farm begins with the determination of wind availability in that location. Mapping has already been done by a number of organizations and these maps indicate the potential for wind in a given location.

Wind charts available from a number of sources indicate fair-to-good wind availability in mountainous or hill country in the Northeast. Since this terrain is characteristically home to some of the farm types previously mentioned, it is conceivable that wind may be able to play a role in powering farms in the Northeast.

Developers will often pay a landowner a few thousand dollars to conduct testing. Usually, turbines require a minimum wind speed between 12 and 15 miles per hour to begin generating electricity.

Considerations

- Federal, state or local incentive programs, such as tax credits and rebates.
- A cost/benefit analysis and determination of Return on Investment (ROI)
- Lease to wind developer or use on the farm, or a contractual combination
- Turbines are hundreds of feet high
- Turbines produce noise similar to traffic

Obstacles

- Lack of wind
- Local ordinances that restrict the height of structures in your area whether zoned residential or agricultural or that specify the use and restrictions on wind turbines. The local building inspector, planning board, or board of supervisors should provide you with necessary information regarding restrictions and permitting and of course, you may be able to apply for a variance.[39]
- Lack of net metering / net billing laws as enacted by state legislatures that require electric utilities to offer retail rates to small wind systems. Without net metering, the utility is purchasing the extra electricity at a lower price, the wholesale price rather than retail. Currently, approximately 35 states require at least some utilities to purchase from wind systems under net metering rules.[40] To determine what state net metering rules and specifications exist for your state, visit the U.S. Department of Energy website at http://www.eere.energy.gov/greenpower/markets/netmetering.shtml

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[38] American Wind Energy Association. *Wind Energy Fact Sheet: Frequently Asked Questions About Net Metering*.
[39] *Small Wind Electric Systems, A U.S.Consumers Guide*. U.S. Department of Energy, Energy Efficiency and Renewable Energy.

[40] U.S. Department of Energy, Energy Efficiency and Renewable Energy. Available at: http://www.eere.energy.gov/greenpower/markets/netmetering.shtml.