Chapter 5: Wood for Fuel on the Farm

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

Types of Systems: No One Size Fits all Needs

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

Photograph © Mary R. Vogt, MourgeFile.

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

Stoves and Boilers

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

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

Wood Pellets and Wood Chips

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

Norman Dewar's Hog Farm

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

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

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

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

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

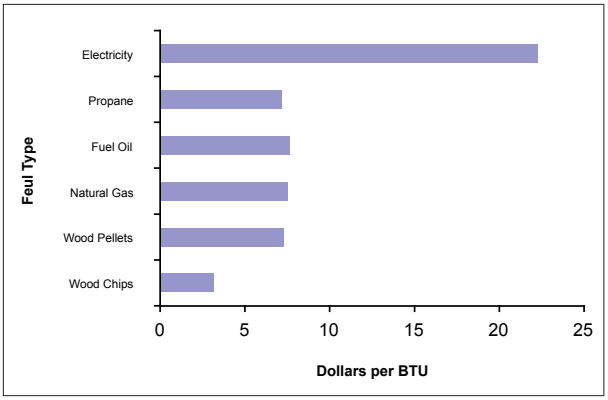
Economics

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

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

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

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



Environmental Concerns

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

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

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

Photograph © Blary54. MourgeFile.

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

Regulatory Constraints

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

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

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Chapter 6: Manure as Fuel on the Farm

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

Anaerobic Digestion on the Farm

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

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

Types of Systems

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

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

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

Animal Energy Comparison Table[188]

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

Photograph © Mary R. Vogt. MourgeFile.

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

Types of systems that you might consider include:

Covered Lagoons

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

Fixed Film

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

Complete mix

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

Plug Flow

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

Useful/Valuable By-Products

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

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

Economics

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

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

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

Colorado Swine Partners

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

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

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

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

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

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

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

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

Environmental Concerns

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

Regulatory Constraints

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

Conclusion

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

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

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Chapter 7: Biofuels: Biodiesel and Ethanol Production

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

Biodiesel

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

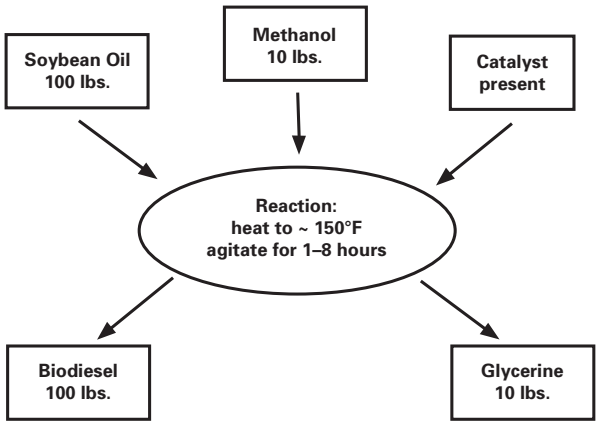
One factor that may affect the economics of biodiesel production more than any other factor is fuel yield per acre of different oil seed crops.[210] The type of crop you choose to grow will depend on a variety of factors, including your location, climate, available land, and the market in your community.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

Biodiesel Yield per Acre from Selected Crops[212]

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

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

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



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

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

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

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

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

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

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

Useful/Valuable By-Products

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

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

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

Although virgin oils are not necessarily a by-product of the biodiesel production process, you (or other local farmers)

might choose to take advantage of your seed press simply to sell high quality virgin oils. Depending on your seed type and your location, you may find markets for specialty oils or other lubricants that you could produce using the equipment you have purchased as part of your biodiesel production process. The amount of refining and marketing of additional products can add complexity and cost, but also increase potential revenue streams to the operation.[227]

Tax Implications

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

Economics

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

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

Environmental Trade-Offs

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

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

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

Photograph © Ladyheart. MourgeFile.

The Regulatory Framework

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

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

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

Specific Regulations for Selling or Trading On-Farm Produced Biodiesel

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

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

Ethanol

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

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

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

Wet Milling

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

Dry Milling

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

State Line Farm

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

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

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

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

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

Cellulosic Ethanol

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

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

Economics

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

Average Yield of 99.5 Percent Alcohol Per Acre[261]

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

Tax Incentives

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

Environmental Trade-Offs

Since the early 1990s ethanol has been blended into gasoline to reduce harmful carbon monoxide emissions. When burned,

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

The Regulatory Framework

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

Conclusion

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

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