ENERGY CONSERVATION SERIES:

Biomass for On-Farm Energy

New Jersey

INTRODUCTION

Biomass energy, or "bioenergy", is energy produced from recently living organisms. There are three forms of bioenergy available with today's technology: heat, fuels, and electrical power. Farmers are potentially in a good position to utilize bioenergy because they are already knowledgeable and well-equipped for the production of biomass, including that which can produce energy. As consumers of energy, farmers can produce and utilize bioenergy at the same location.

Bioenergy, primarily in the form of heat, has been produced for thousands of years, providing a good precedent to build upon in planning for its use in agriculture. This burning of the biomass or products from it is known as direct combustion. Direct combustion is a comparatively efficient means of using bioenergy, due to its minimal processing needs, the diversity of feedstock that can be used, relatively simple equipment needs, and a relatively high rate of energy recovery. For most operations, direct combustion is the only practical means of harnessing bioenergy. For some select types of farming operations, anaerobic digestion and gasification of biomass are also practical bioenergy technologies for on-farm use. On-farm production of biodiesel from oil crops is also possible. This fact sheet will therefore focus primarily on direct combustion and secondarily on anaerobic digestion, gasification, and biodiesel production.

ENERGY CHARACTERISTICS AND SOURCES

Firewood for direct combustion is the most traditional form of bioenergy. When harvested sustainably, trees are good sources of bioenergy on farms with large woodlots. Wood felled by storms can also be a significant and acceptable source of material for direct combustion. Combustion of hardwoods works well at any scale, and is one of the few practical options for heating with bioenergy because there are many small and inexpensive appliances available for burning it efficiently in small quantities.

The wood of coniferous trees, known as softwood, is less desirable for direct combustion, because potentially low temperatures in small-scale direct combustion units can produce tars and condensation on the inner lining of the chimney. This causes inefficient operation of equipment, as well as a serious safety hazard. Nonetheless, softwood biomass may be burned safely and efficiently in larger equipment such as boilers, and most commercially-prepared biomass contains a percentage of softwood as a binder additive.

Two models exist for the use of wood as bioenergy. The first, traditional, model involves the burning of relatively large pieces of wood, sometimes split (known as cordwood), in low-temperature equipment such as wood stoves. This model is often used for heating living and working spaces with wood produced on or near the farm. Its main disadvantages are the inefficiency of handling and transporting such large pieces of wood; and the absence of an efficient way to mechanically feed it into combustion equipment, thereby requiring periodic stoking by hand.

The second model has emerged in the past few decades, and involves the conversion of wood into pellets, chips, or briquettes, at centralized facilities or with large on-farm equipment. This processed biomass can be transported easily and sold in bulk, and can be mechanically fed into burners. This model is widely used for combustion of wood at off-farm locations, and also for large on-farm equipment where automated, mechanical stoking is used. Pelletized wood can also be made from a wide variety of feedstocks, such as forestry wastes, old pallets, and fallen limbs.

While the wood of trees is an efficient and cheap source of bioenergy, the energy needs of most New Jersey operations are larger than can be supplied entirely by uncultivated wood on-site. Other options include cultivating wood or cultivating herbaceous plants. Many farms that are located near urban areas may also be able to source cordwood and wood chips from tree service companies and power line right-of-way maintenance companies.

Wood cultivation involves significant long-term risks because it ties up large tracts of land for over 10 years. Conversely, cultivation of herbaceous annuals may work well for many farmers because harvesting can often begin one season after planting, lending flexibility to the operation and allowing crop rotation. Additionally, many herbaceous annual crops planted for grain, such as corn, produce residues that can be used as a biomass feedstock after harvesting of the primary product. Both Poplar (*Populus spp.*) and Willow (*Salix spp.*) are perennial wood species available in hybrid forms that are optimized for biomass production. See the Cornell Willowpedia (13) and State University of New York-Environmental Science and ForestryWillow Portal (14) for more information. Common herbaceous annual bioenergy crops include corn (*Zea mays*), switchgrass (*Panicum virgatum*), rye (*Secale cereale*), and miscanthus (*Miscanthus spp.*).

Switchgrass Ready for Harvesting
PHOTO: USDA

The by-products of farming or processing operations can be used as a source of energy, either by combustion or by conversion to methane through anaerobic digestion. Manure, vegetable processing wastes, corncobs, tree trimmings, and cover crops can all be used as sources of energy. The Rutgers Cooperative Extension publication "Crop Residues as a Potential Bioenergy Resource" (8) provides detailed information about using cover crops and field residues for bioenergy while maintaining soil health. Refer to the fact sheet in this series "Conserving Energy in Livestock Operations" (9) for more information about anaerobic digestion of manure.

Another valuable source of information for the types and quantities of biomass available in NJ, as well as the possible conversion technologies, is the New Jersey Assessment of Biomass Energy Potential (18).

All of the aforementioned sources of bioenergy burn most efficiently when dry; therefore, drying procedures must be taken into account when choosing a feedstock. In general, the densest sources, such as wood, tend to be hardest to dry. Wood may take up to four months to properly dry, and cannot be field-dried. Switchgrass and other herbaceous crops can be dried in less than a week given the right conditions, often in the field.

Another important consideration pertaining to fuels is ash content. Ash of all common bioenergy fuels is composed mainly of phosphorus (P), potassium (K), and silica, all of which are noncombustible and leave deposits. Ash from low-temperature combustion may also include significant carbon (C) content. These deposits can clog the grates, vents, ducts, and flues of equipment, reducing its efficiency and safety while making frequent cleaning a necessity. Disposal of ash can be a problem for biomass consumers who don't have land to spread it over. Biomass producers should follow relevant production guidelines to minimize the amount of ash contained in biomass. Ash content can be reduced by selecting low-ash biomass crops, minimizing contamination of harvested biomass by soil, and proper timing of harvest. Wood generally contains 1% or less of ash, while winter-harvested switchgrass usually contains about 2%.

Harvesting Willow Trees
PHOTO: L. SMART, CORNELL UNIVERSITY

Any biomass-energy plan will most likely make use of a combination of several sources of biomass energy, which helps to both stabilize feedstock costs and improve surety of supply. Table 1 provides a comparison among the dried energy densities of several common on-farm energy sources. Values given are "high" heating values, the maximum that can be achieved when all heat can be collected and utilized.

Table 1- Energy Density of Common Biofuels (BTU/lb.)

Source: Miller (2), US Dept. of Energy (1)

Beef Manure	3000
Wood Chips, Shavings	5000
Corn, Soy Stover	7750
Switchgrass, Miscanthus	8000
Willow	8000
Hybrid Poplar	8250
Black Locust	8500
No. 2 Fuel Oil*	19500

All figures given as calorimeter values for dried material.
*Not a biofuel. Listed for comparison purposes only.

HARVEST AND STORAGE

Bioenergy crops are generally harvested when they are either dead or dormant. Unlike hay, crops for bioenergy may be allowed to collect moisture at times, as long as they are dry at harvest (7) and are allowed to re-dry before use. For tall herbaceous bioenergy crops harvested while living, such as switchgrass, miscanthus, or canarygrass, harvesting should be done after at least one hard frost has made the stems dormant. This will reduce moisture content and allow some P and K to return to roots, rhizomes, and the soil from translocation and weathering of the plant. Harvest can also be conducted in the winter, further reducing moisture and ash content of harvested material. However, yields may suffer from a reduction in plant mass due to weathering.

Tall grasses for bioenergy are either baled for combustion as-is, chopped, or converted to pellets for storage and transportation. Baling can be accomplished using a typical hay baler. After harvest, bales can be stored covered at the field edge. They should be kept dry and away from sources of ignition, much like feed hay. Storage requires a tarpaulin, and can benefit from racks which keep wood off the soil surface.

Tall woody plants for bioenergy should be harvested during the coldest months of the year, because the moisture content is lower and any leaves have fallen off. Such material should be covered for no less than six months, to allow for drying, or combustion efficiency is reduced nearly to the point of being impractical. For this reason, a practice that works well for cordwood is to use wood the winter after it is harvested. Equipment needed includes chainsaws, a truck with high sides and dumping body, either axes and mauls, a hydraulic splitter, or sometimes a skidding frame for a small tractor. Newly available harvesting equipment, like the machine in the photo to the left, can harvest and process trees into chips with one pass.

CONVERSION TECHNOLOGIES

The best commercially available technologies for conversion of biomass into renewable forms of energy at the farm scale fall into three main classes: Direct combustion, anaerobic digestion, and small-scale gasification.

Direct combustion can be used for heating of water or air. Traditional uses for direct combustion include the use of fireplaces or woodstoves to heat ambient air in shops, living, and working spaces. This remains a good use of bioenergy for small and large spaces when wood is readily available.

Systems are available for burning either cordwood or pelletized and densified materials. Those systems designed for pelletized materials are usually able to burn pelletized wood as well as corn seed and pelletized grass biomass, and are automatically stoked. A common application for biomass water-heating systems is the combined, building, and potable hot water heating systems. .

Capital and operating costs for biomass pelletizing equipment can range from $35 to $85 per ton, depending on feedstock consistency, size of equipment, and other factors. The cost and life expectancy of such equipment must be compared to transportation costs, savings, and profits resulting from centralized pelletizing done at a remote location or by a third party.

A process known as anaerobic digestion, which is bacterial decomposition in low-oxygen conditions, can be used to produce methane gas from biomass sources which contain 75% or more moisture. Such biomass may include manures and processing wastes, such as from fruits and vegetables. The National Non-Foods Crops Centre of the UK describes anaerobic digestion as “the process where plant and animal material (biomass) is converted into useful products by micro-organisms in the absence of air” (16). The process results in the production of biogas, a mixture of methane and carbon dioxide (usually around 60% and 40%, respectively) along with water vapor and small amounts of other compounds, depending on the nature of the biomass. The process also produces a slurry (digestate) of solids and water that retains some of the nutrient properties of the original biomass that can be land applied or further processed. The biogas can be burned in conventional boilers and furnaces modified for the lower energy content of the fuel, or for electrical generation. The electrical generation equipment can also be a source of heat for on-site operations. Biogas contaminants (in particular sulfur compounds) can create problems in combustion equipment and may need to be stripped from the gas before it can be burned. Most equipment designed to use natural gas as fuel can be converted to use digester gas.

Anaerobic Digester
PHOTO: NRCS NEW YORK

Anaerobic digestion generally uses one of two digester designs. The type used for high-solids mixtures is the plug-flow design, in which wastes are slowly moved, in a laminar flow, along a long trench-shaped vessel. Alternatively, the biomass may be placed in an airtight building. Most digestion and biogas production occurs over the course of a 20-day period. Mixtures containing fewer solids can be digested in a complete-mix digester, which is a large cylindrical tank in which digestion takes place.

Miscanthus (foreground), Switchgrass (background)
PHOTO: NJ AGRICULTURAL EXPERIMENT STATION

Anaerobic digestion does require some energy inputs. Waste materials must be chopped and mixed with water to make them fluid and more easily digestable. All systems must be agitated, and in the colder months, heated. The design and pattern of the digester must take into account seasonal waste production patterns of an operation. Once digesters are running, it is best that they not be shut down except for routine maintenance. For further information on anaerobic digestion systems, see the publications “Turning Manure into Gold” (11) and NRCS Conservation Practice Standard 366 (12).

A combustible gas known as synthesis gas, or “syngas”, can be produced from plant biomass through the use of a technology known as gasification. The process involves heating of plant material in an oxygen-limited environment, while gases are drawn off. The process is very similar to the production of coal gas by coke ovens. Small-scale gasification can be used to power either internal combustion engines, microturbines, or conventional equipment designed to burn LP or natural gas. Syngas will need to be cleaned before use in equipment designed for LP or natural gas. For more information on gasification technology, see “Market Assessment of Biomass Gasification and Combustion Technology for Small- and Medium-Scale Application” (12).

Producing oil crops for on-farm biodiesel production may be an opportunity to replace some portion of the petroleum diesel used by a farm. Oil crops include soybeans, sunflowers, canola, and others. On-farm processing units typically use a mechanical expeller or screw press to extract the oil from the seed, followed by conversion to biodiesel that includes reaction with methanol and sodium hydroxide, a catalyst, to produce glycerol and biodiesel. . While the process of oil extraction and refinement is fairly basic and has long been known, there are many details of each process step that must be adhered to strictly in producing fuels usable in late-model diesel engines. Methanol is highly flammable and burns invisibly, while sodium hydroxide is caustic, so safety precautions must be the farmer's first consideration when planning for biodiesel production. Additionally, while biodiesel for older, mechanically-injected engines may be of varying quality and consistency, today's electronically-injected engines designed for Ultra Low Sulfur Diesel (ULSD) fuel cannot tolerate any detectable impurities whatsoever. For this reason, biodiesel production may be prohibitively expensive unless the fuel is to be used in mechanically-injected engines. In biodiesel production, the final product must be tested often to ensure conformance with ASTM Standard D6751, "Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels" (16), if it is sold off-farm or used in newer equipment. Economics play an important role. The investment that would be necessary to ensure adequate quality must be balanced with the cost of possible increased wear and downtime for diesel engines. Additionally, finding a use for the byproducts, such as meal and glycerol, will improve viability of the process. See the National Biodiesel Board's website (17) for more information.

INTEGRATION INTO EXISTING OPERATIONS

As a sustainable practice, bioenergy technology is designed to be adventitiously integrated with other production in the farming operation. Many crops that are bred for optimal bioenergy potential, such as switchgrass, are designed to be grown under the same conditions which farmers are utilizing for their other crops.

Additionally, residues from many types of crops and livestock in New Jersey can be used as a source of bioenergy with current equipment. Up to 70% of the stover remaining in corn fields after harvest can be used for bioenergy without disrupting soil conservation practices. Non-cash cover crops, such a rye, can be used in a similar way as a source of bioenergy. Equipment needs for harvesting of bioenergy crops can be the same or similar to those of the operation's other crops. For example, switchgrass can be a good choice for hay-producing operations because it can be harvested, stored , and shipped using conventional hay balers, wagons, storage facilities, and trucks.

Typically, switchgrass has nutrition needs lower than most common cash crops, and can be grown in marginal soils. Because switchgrass grows slowly at first, especially during the establishment of seedlings, nitrogen levels in the field should be kept low to minimize competition from weeds. The publications "Planting and Managing Switchgrass as a Biomass Energy Crop" (7) and "Switchgrass Production and Use in New Jersey" (10) provide technical details needed to plan for growing biomass.

Because land devoted to the production of fresh food and ornamental crops is especially scarce and valuable in New Jersey, conversion of existing agricultural lands from its current use to biomass production is impractical for most commercial farms in the state. However, many bioenergy crops, such as switchgrass, will grow on marginal soils unsuitable for other crops, making soil stabilization and land conservation possible while producing an economic source of energy. For this reason, many large tracts of government land could be used for for bioenergy production. Parks, conservation areas, brownfields, and freeway medians are other potential areas that may be well-suited for use in biomass production.

BARRIERS TO IMPLEMENTATION

Regulatory barriers are mainly those created by either environmental or land-use regulation structures. In New Jersey, local regulations often affect the use of bioenergy equipment on farms, particularly if the energy produced is intended to be sold for off-farm use. The Federal Clean Air Act prohibits or requires permits for many bioenergy-related activities, and sets limits for visible smoke, particulate matter, and other substances deemed pollutants; as well as requiring testing, reporting, and inspections for certain activities. In New Jersey, the Clean Air Act is administered by NJDEP, which sets rules and procedures for permitting. NJDEP currently does not require operating permits for smaller boilers. Stricter requirements exist for large boilers designed for energy inputs over 1 million BTU per hour.

Pellet-Burning Boiler
PHOTO: NRCS NEW HAMPSHIRE

Dust and safety hazards are two other important considerations. Dust may be created during biomass production, which can decrease air quality, causing health hazards to the farmer and his community. Dust hazards may also increase both the safety risk to the farmer and the risk of legal barriers to bioenergy use. Safety hazards resulting from dust can be reduced through the use of adequate ventilation of storage facilities, processing of biomass outdoors whenever possible, and proper selection of equipment. However, the ventilation or outdoor processing of biomass may irritate neighbors. Operations located adjacent to highways or non-agricultural land uses must plan to either sequester dust or ensure that it is not carried by wind into neighboring properties. . Safety hazards include fire and explosion, both of which can generally be adequately minimized by compliance with local fire and boiler-construction regulations.

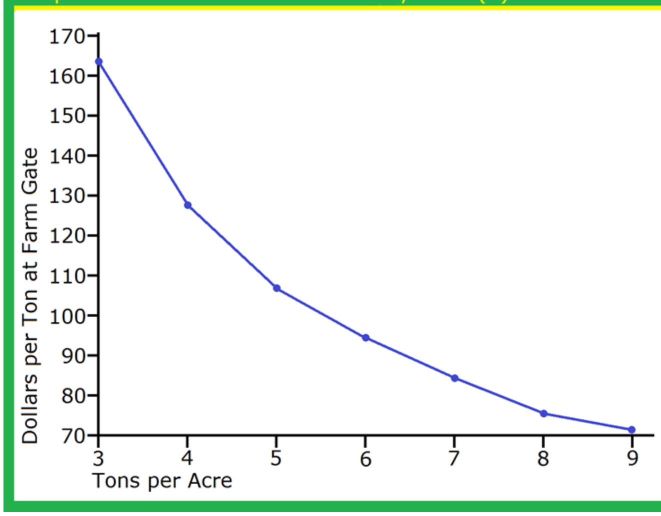
ECONOMICS

Chief factors to consider are the explicit and opportunity costs of using land for bioenergy production, equipment for conversion to power or heat, and inputs for cultivation of energy crops. The cost of land use is dependent on the nature of the operation in question, and therefore varies between each individual farmer. Other costs, such as for seed and field cultivation, are more easily calculated and can be estimated on an acreage basis. While most bioenergy producers are able to grow and use bioenergy very efficiently, most common unforeseen challenges are related to processing and transportation.

Miscanthus usually cannot be harvested until the third, and switchgrass the second, growing season after planting, but may be harvested for 10 years or more afterward. Fields must periodically be replanted with new plants and soil amendments to replace P and K lost to harvested material (7). An economic evaluation conducted by the New Jersey Agricultural Experiment Station in 2011 has indicated a cost of approximately $550, not including land costs, for production of an acre of switchgrass for one season in (6). The NRCS fact sheet "Planting and Managing Switchgrass as a Biomass Energy Crop" (7) also provides a framework for estimating production costs and expected yield for a particular operation. Factors such as these can be considered alongside Figure 1, in making business decisions about bioenergy.

Figure 1- Break-Even Points for Switchgrass Production

Adapted From: Brumfield and Helsel, 2011 (6)



With current prices of nonrenewable energy sources, biomass energy production may not be economically feasible without some amount of subsidy. However, the costs associated with on-farm bioenergy production are fairly stable when combined with the many available government incentives. Therefore, bioenergy may be a good option for farmers. The USDA Energy Portal (3) and Department of Energy's Programs website (4) can provide information about federal financial incentives for bioenergy use and production.

Farmers planning to use biomass as a source of on-farm energy should be aware of potential operational challenges that may accompany new technologies and their integration into the farm operation. Some bioenergy technologies are not "mature". For many of these technologies, difficulties in operation may result in very high downtime percentages as compared to other, mature technologies. This and other operational challenges often lead to costs higher than those that were anticipated. A large driver of these costs is "balance-of-plant", the accessories and infrastructure needed to operate biomass energy technologies. These factors include storage, delivery, and quality control, many of which themselves are not mature technologies. These costs tend to be highest when a biomass energy operation commences, and decrease with time. Costs will be lower when handling, storage, harvest, and by-product handling are carefully integrated with the farm operation.

However, there can be operational benefits as well. Many are difficult to quantify financially, but provide such long-term benefits as energy security or increased community goodwill. For example, fields which for whatever reason can be used for neither cover nor cash crops, if devoted to bioenergy, can provide some means of financial stabilization to the operation. Additionally, many farm wastes may be cheaper to burn, notwithstanding energy production, than to dispose of otherwise, leaving bioenergy production as the natural end of disposing of such materials.

New Jersey operations can participate in the USDA Farm Service Agency's Biomass Crop Assistance Program (BCAP), which provides financial assistance to farmers who produce biomass for use by other enterprises. The program is designed to foster the development of biomass infrastructure, as well as improve relations between farmers, the environmentalist community, and the consumers of bioenergy. For more information on the BCAP program, visit the FSA's BCAP Fact Sheet site (5).

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Biomass Pellet Storage
PHOTO: USDA

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