




EPA RE-Powering America's Lands: Kansas City Municipal Farm Site—Biomass Power Analysis

R. Hunsberger and G. Mosey

National Renewable Energy Laboratory

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

Technical Report
NREL/TP-5D00-62097
January 2015

Contract No. DE-AC36-08GO28308

EPA RE-Powering America's Lands: Kansas City Municipal Farm Site—Biomass Power Analysis

R. Hunsberger and G. Mosey
National Renewable Energy Laboratory

Prepared under Task No. WFD3.1001

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

Technical Report
NREL/TP-5D00-62097
January 2015

Contract No. DE-AC36-08GO28308

NOTICE

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

Available electronically at http://www.osti.gov/scitech

Available for a processing fee to U.S. Department of Energy and its contractors, in paper, from:

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
phone: 865.576.8401
fax: 865.576.5728
email: mailto:reports@adonis.osti.gov

Available for sale to the public, in paper, from:

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone: 800.553.6847
fax: 703.605.6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/help/ordermethods.aspx

Cover Photos: (left to right) photo by Pat Corkery, NREL 16416, photo from SunEdison, NREL 17423, photo by Pat Corkery, NREL 16560, photo by Dennis Schroeder, NREL 17613, photo by Dean Armstrong, NREL 17436, photo by Pat Corkery, NREL 17721.

Printed on paper containing at least 50% wastepaper, including 10% post consumer waste.

Acknowledgments

The National Renewable Energy Laboratory (NREL) thanks the U.S. Environmental Protection Agency (EPA) for its interest in securing NREL's technical expertise.

Special thanks go to Andrew Bracker, Michael Shaw, and Marleen Leonce of the City of Kansas City; Roland Maliwat of Kansas City Power and Light Company; Shelley Brodie from EPA; and Katie Brown, AAAS Science & Technology Policy Fellow hosted by EPA. We also thank the people from Kansas City and the vicinity who attended various meetings held during NREL's site visit October 22–23, 2012.

Gregg Tomberlin of NREL also provided material help in this analysis.

List of Acronyms

BAM	biomass availability multiple
Btu/h	Btu per hour
CHP	combined heat and power
CLUP	conceptual land use plan
CO	carbon monoxide
CO_2	carbon dioxide
DOE	U.S. Department of Energy
EAB	emerald ash borer
EIA	U.S. Energy Information Administration
EPA	U.S. Environmental Protection Agency
GT	green tons
KCP&L	Kansas City Power and Light Company
MC	moisture content
NO_X	nitrous oxide
NPV	net present value
NREL	National Renewable Energy Laboratory

Executive Summary

The U.S. Environmental Protection Agency (EPA) Office of Solid Waste and Emergency Response Center for Program Analysis developed the RE-Powering America's Land Initiative to reuse contaminated sites for renewable energy generation when aligned with a community's vision for a particular site.

The Kansas City, Missouri, Municipal Farm site, a group of city-owned properties, was selected for a feasibility study under this initiative. The city was originally interested in both biomass and solar; however, after additional discussions with the program and experts at the National Renewable Energy Laboratory (NREL), the city ultimately chose to analyze the potential feasibility of the site for biopower through the RE-Powering Initiative. The city is separately funding a solar feasibility study, the results of which will be released at a later date.

Results

Due to the low site loads and long distances between existing buildings, none of the technologies reviewed—which include biomass heat, power, and combined heat and power (CHP)—are economically viable options for the Municipal Farm site as it is currently developed. However, if additional buildings on the site were to be developed around a future central biomass heating or CHP facility, biomass could be a good option for the site.

Using data provided by the city, NREL has estimated that there is a steady supply of available low-grade biomass suitable for a biomass facility producing CHP in the range of approximately 12,000 green tons (GT) per year. Another 90,000 GT per year could be available as a result of tree mortalities caused by the emerald ash borer, an invasive species of beetle. We estimate that the combined 102,000 GT per year could support a 6-MW biomass electric power facility; thus, it would appear that local biomass resources are adequate for the described facility. However, because the existing electrical loads total only approximately 100 kW—and because the city cannot sell power to the grid—we do not recommend producing electric power from biomass at this site.

For the same reasons, NREL does not recommend a biomass CHP installation at the site, because the electrical load is too low and the available revenue from energy sales would not be sufficient to cover the high capital and operating costs.

Finally, we evaluated the feasibility of biomass heating for three building configurations, but none of these proved to be economically attractive.

Recommendations and Next Steps

Based on preliminary numbers, none of the reviewed biomass-fired options—electric generation, CHP, and heat only—are economically feasible for the Municipal Farm site at this time. If desired, further analysis could be undertaken to confirm assumptions used in this report, particularly biomass availability, and biomass fuel cost, equipment sizing and cost, and operations and maintenance costs.

Table of Contents

List of Figures

List of Tables

1 Background and Scope of Work

The U.S. Environmental Protection Agency (EPA) Office of Solid Waste and Emergency Response Center for Program Analysis developed the RE-Powering America's Land Initiative to encourage renewable energy development on current and formerly contaminated lands, landfills, and mine sites when it is aligned with the community's vision for the site. The EPA engaged the U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) to conduct feasibility studies to assess the viability of developing renewable energy generation facilities on contaminated sites. The Municipal Farm site in Kansas City, Missouri, was selected for a feasibility study under the RE-Powering Initiative.

Kansas City developed a document titled *The Municipal Farm Sustainable Reuse Plan,* which was funded under the EPA's Brownfields Area-Wide Planning Pilot Program (2012). This document is part of an area-wide planning approach to managing brownfield sites.

The area surrounding the Municipal Farm site has limited woody biomass to support a bioenergy project. We analyzed the potential to sell electricity to Kansas City Power and Light Company (KCP&L)[1] and to sell heat on-site to an Army National Guard installation and a commercial greenhouse.

Chapter 2 discusses the development of biomass energy on Superfund Sites. Chapter 3 contains an introduction to biomass heat and power technologies and equipment. Biomass properties, costs, and availability are covered in Chapter 4. The site and property are described in Chapter 5.

State and regional energy use are described in Chapter 6. Potential off-takers and associated loads are analyzed in Chapter 7.

1.1 Study Level and Uncertainty

This high-level analysis is intended to serve as a first step toward deciding whether conditions seem favorable for a biomass project at the Municipal Farm site. As such, there is a high level of uncertainty in most of the study components, including biomass availability and cost, equipment costs, operations and maintenance costs, annual energy use, and other figures.

Recommendations are provided in each relevant chapter for steps that will further reduce these uncertainties in the next level of analysis.

[1] KCP&L provided a tentative letter of support, which is included in Appendix A.

2 Development of Biomass Energy on Superfund Sites

One very promising and innovative use of contaminated sites is to repurpose them for biomass power (biopower) systems. Biopower systems work well on Superfund sites where an adequate biomass fuel supply and favorable power sales rates exist.

The cleanup and reuse of potentially contaminated properties provides many benefits, including:

- Preserving greenfields
- Reducing blight
- Raising property values and creating jobs
- Allowing for access to existing infrastructure, including electric transmission lines and roads
- Enabling a potentially contaminated property to return to a productive and sustainable use.

By taking advantage of these potential benefits, biopower can provide viable, beneficial reuses—in many cases generating revenue on a site that would otherwise go unused.

The Municipal Farm site in Kansas City, Missouri, is owned by the City of Kansas City. As with many contaminated or formerly contaminated sites, the local community has significant interest in the redevelopment of the site, and community engagement is critical to match future reuse options to the community's vision for the site. The subject site has the potential to be used for functions beyond the proposed biopower project. Any potential use should align with the community vision for the site and should work to enhance the overall utility of the property.

Most states rely heavily on fossil fuels to operate their power plants. There are many compelling reasons to consider moving toward renewable energy sources and away from fossil fuels for power generation, including:

- Using fossil fuels to produce power is not sustainable.
- Burning fossil fuels can have negative effects on human health and the environment.
- Extracting and transporting fossil fuels can lead to accidental spills, which can be damaging to the environment and communities.
- Fluctuating electric costs are associated with fossil fuel–based power plants.
- Burning fossil fuels emits greenhouse gases, contributing to climate change.

3 Bioenergy Technology

Biopower is the use of biomass to generate electricity. Biopower system technologies include direct firing, co-firing, gasification, pyrolysis, and anaerobic digestion. Most biopower plants are direct-fired systems, thus this section is focused on this type of system.

Co-firing refers to mixing biomass with fossil fuels in conventional power plants. Coal-fired power plants can use co-firing systems to significantly reduce emissions, especially sulfur dioxide.

Gasification systems use elevated temperatures and a reduced-oxygen environment to convert biomass into synthesis gas, or syngas, which is a mixture of hydrogen and carbon monoxide (CO). The syngas can then be chemically converted into other fuels or products, burned in a conventional boiler, or used instead of natural gas in a gas turbine. Gas turbines are very much like jet engines, but they are used to turn electric generators instead of to propel a jet. Gas turbines are very efficient, but their overall system efficiency can be further improved by operating them in a combined cycle arrangement. During combined-cycle operation, the exhaust gases are used to boil water for steam to provide additional power generation or heat.

Pyrolysis is a thermal process that occurs without oxygen and produces syngas, liquids, and charcoal. These intermediate products can be used to produce heat and power or be reformed into liquid fuels and chemical products.

Anaerobic digestion is a process for producing biogas through biological degradation of organic matter without oxygen. The biogas can be used to produce heat or electricity.

3.1 Bioenergy Production

The amount of energy that can be economically produced by a biopower system depends on several factors, including the type of biomass, the technology employed, and numerous financial factors. Biopower systems can be sized to supply internal energy needs only or sized larger to sell energy to the grid.[2]

[2] NREL has investigated small-scale biomass CHP systems—as small as 15 kW. Systems of this scale have been under development for several years, but they have not proven to be efficient and tend to be very sensitive to feedstock properties and particle size. Because of their lack of demonstrated feasibility, they are not considered commercial as of January 2014.

Figure 1. Direct-fired biopower system. ***Photo by Wheelabrator Shasta Energy Co., NREL 07163***

Figure 1 shows a typical biopower direct-fired system. These plants burn biomass feedstocks directly to produce steam. The steam is used to drive a turbine, which turns a generator to produce electricity.

In some biomass plants, turbine extraction steam from the power plant is also used for manufacturing processes or to heat buildings. Such CHP systems increase overall energy efficiency. This often makes economic sense when a large heat user (thermal host or steam host) is located nearby. These systems normally operate 24 hours per day and 7 days per week, with several weeks of downtime per year for maintenance and repairs.

Plants of this type are not normally cycled with many starts and stops. Frequent cooling and reheating of equipment components leads to fatigue and failure, making it more cost-effective to operate around the clock, even though power rates may be lower during off-peak hours.

3.2 Types of Bioenergy Systems

A biopower system should be sized based on both the availability of cost-effective biomass feedstock and the energy requirements of the end user. The most common installation types are described below. In general, these systems can be divided into thermal energy only, power generation only, and CHP categories. The system choice is mostly dependent upon economics. The cost of fuel, the rate that power can be sold, and the rate available for the sale of thermal energy are a few of the key economic parameters.

3.2.1 Thermal Energy Only

Figure 2 illustrates a “thermal energy only” system. Biomass energy is converted to steam, which can be used for heating, cooling, manufacturing, or a number of other industrial uses (shown as “boiler steam to load”). The steam is condensed as the energy is extracted, and the warm condensate is pumped back to the biomass facility, where it is reintroduced to the boiler and converted again to steam. This type of system can be economical because the inefficiencies associated with generating electric power on a small scale are avoided and the capital costs for a steam turbine, condenser, cooling tower, circulating water pumps, and other items are not incurred. High-pressure, superheated steam is not required, making the boiler less expensive and easier to operate. This system is common and has been in use for many decades.

Finding a business that is located close enough to accept steam without lengthy piping systems is often challenging. In many cases when a steam host is present, it makes sense to generate both steam and electricity.

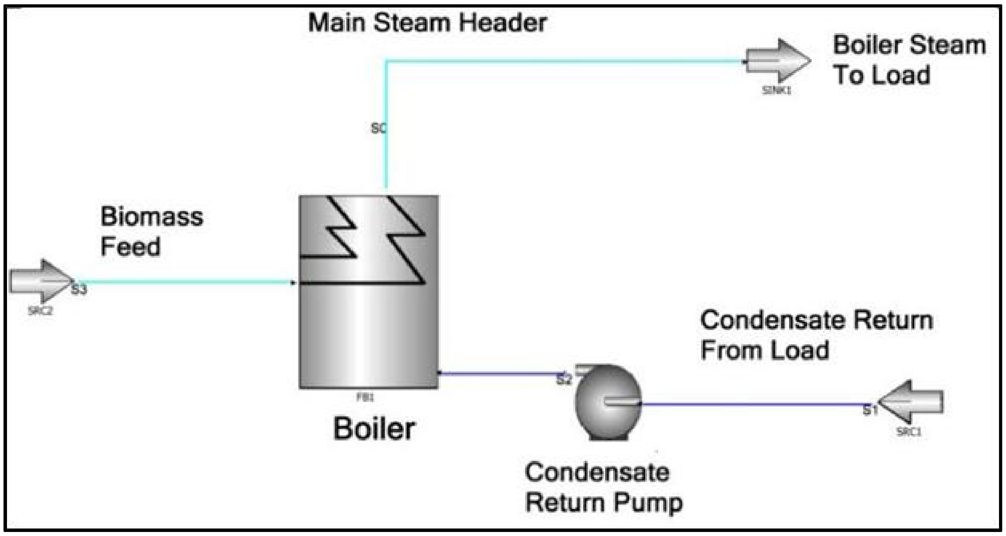


Figure 2. Thermal-only biomass energy system

3.2.2 Power Generation Only

Figure 3 illustrates a "power generation only" system. Biomass energy is converted into high-pressure, superheated steam for introduction into a steam turbine. The turbine generates electricity at the most efficient rate practical; the amount of money spent on improving efficiency is typically dependent on the size of the system and other factors, with more effort directed toward efficiency with larger systems. This is usually an economic decision.

The steam is condensed at very low pressures to maximize efficiency. This is accomplished in a condenser, which uses cooling water that typically comes from an evaporative cooling tower. It is also possible to use a dry type of air-cooled condenser.

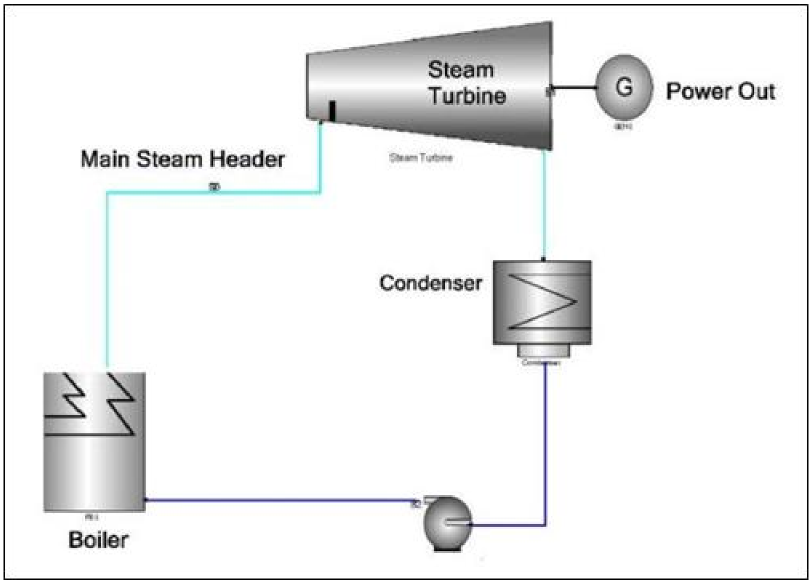


Figure 3. Power generation–only biomass energy system (Note that the cooling tower is not shown.)

3.2.3 CHP

CHP, also called cogeneration, is the concurrent generation of multiple forms of energy in a single system. CHP system prime movers can include reciprocating engines, combustion or gas turbines, steam turbines, microturbines, and fuel cells. These systems are capable of using a variety of fuels, including natural gas, coal, oil, and alternative fuels. The thermal energy produced by the system can be used in direct applications or indirectly to produce steam, hot water, or chilled water. More than 60% of biomass power systems are configured as CHP systems.

For biomass direct-fired systems, the most common CHP configuration consists of steam from a biomass-fired boiler directed to a steam turbine. At some point in the process—determined by required pressure—steam is extracted to provide heat to meet internal requirements of the facility or to sell to a local steam host. The steam can be taken from the power process via three primary methods:

1. Main steam extraction
2. Extraction turbine
3. Backpressure turbine

In a main steam extraction system, some of the boiler outlet steam is extracted from the main steam header, whereas the remainder is directed into the steam turbine. The extraction steam is at a high pressure and temperature, which would typically have to be reduced prior to the steam being delivered to the end user. The remaining steam runs through the entire length of the turbine and then discharges into a condenser at very low pressure (often below atmospheric pressure) to maximize the electric power generated.

The condenser circulates large quantities of cooling water, which is typically cooled by evaporation in a cooling tower or by an air-cooled condenser (Figure 4). By far the most common cooling method is to use a cooling tower, because it is less expensive and requires less power to operate, although a large quantity of water is evaporated. An air-cooled condenser is more expensive, but it is advantageous when large volumes of water are not available or where water is expensive. Warm condensate is pumped back to the biomass facility, where it is reintroduced to the boiler and converted again to steam.

This is not the most efficient method of producing electric energy, but it avoids the cost of a more expensive extraction turbine (described below).

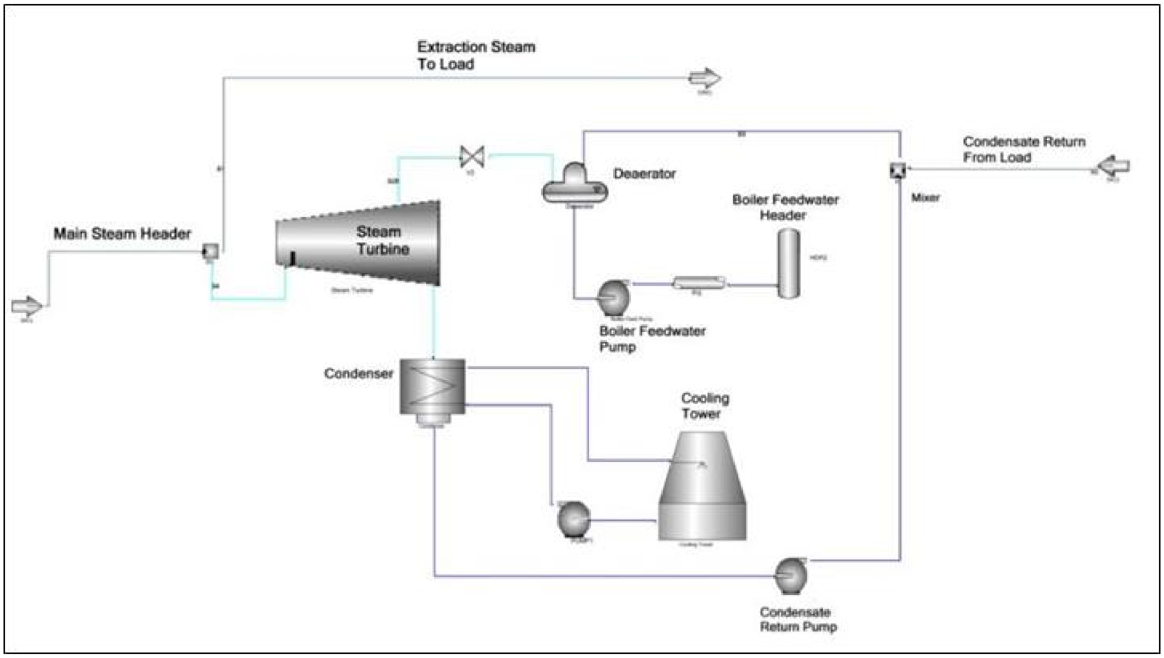


Figure 4. CHP main steam extraction

An extraction turbine accepts all boiler steam at its inlet and outputs the required process steam at some intermediate point along the turbine steam path. This allows the process steam to produce electric power prior to its extraction, increasing the efficiency of the overall process. The remaining steam continues through the lower pressure stages of the turbine and then discharges into a condenser (Figure 5).

The cost for an extraction turbine is typically higher and thus not normally utilized in smaller systems (less than approximately 10 MW).

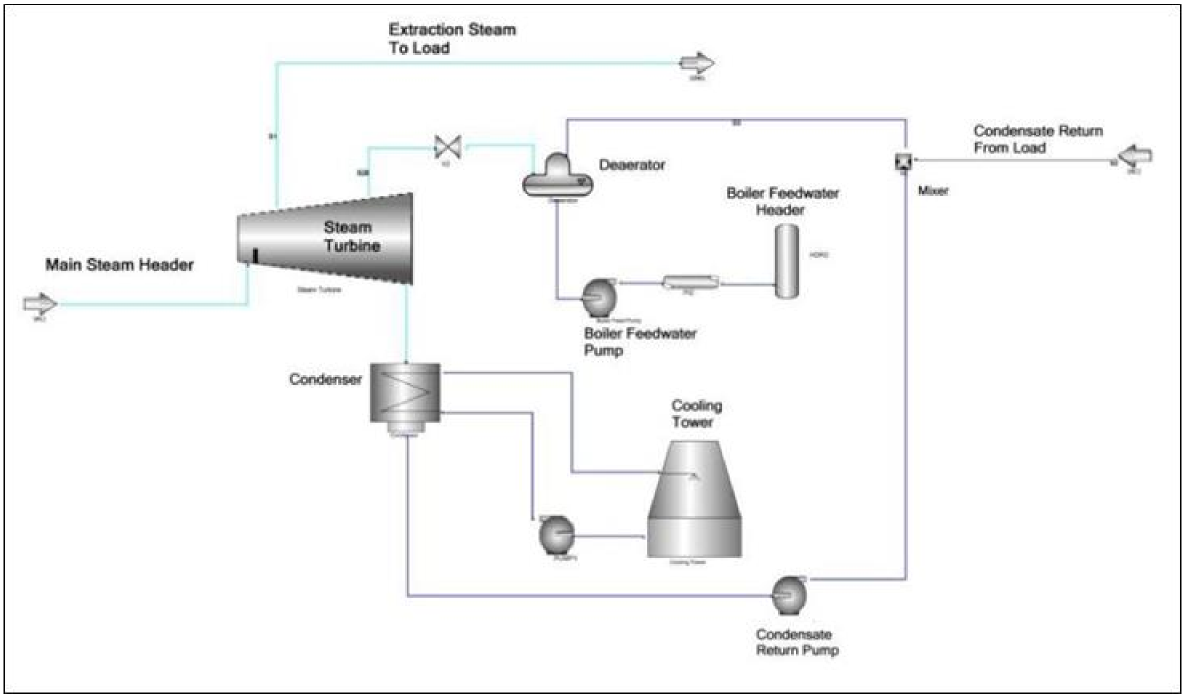


Figure 5. CHP extraction turbine

A backpressure turbine accepts all boiler steam at the steam turbine inlet and discharges all of the steam at the pressure required by the end steam user (Figure 6). Compared to the two previously discussed methods, this approach offers considerable cost savings. The steam turbine is much less expensive because the lower-pressure sections of a turbine are the largest and costliest. There is no need for a condenser, a cooling tower, or large circulating water pumps to push the cooling water through the condenser. The steam is typically condensed by the load and then returns to the plant as warm condensate to be reheated and reintroduced to the system.

There are two disadvantages to this arrangement. First, the amount of electric power produced is greatly reduced as a result of the shortening of the turbine and the relatively high discharge pressure. Second, if the steam host reduces its steam requirements to a quantity less than the full steam turbine capacity, the steam turbine must be turned down or the excess steam must be condensed by way of an external steam condenser, which would require a cooling water source.

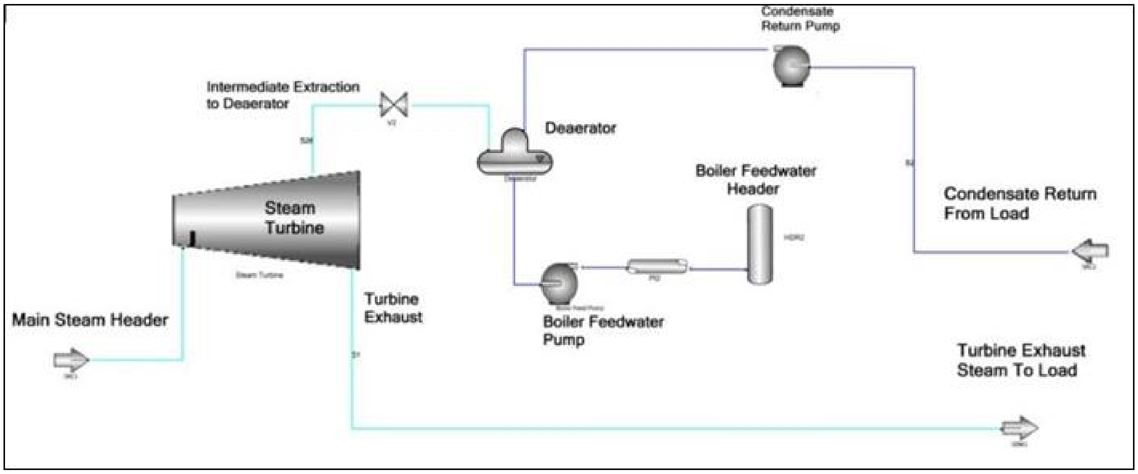


Figure 6. CHP backpressure turbine

3.3 District Heating

District heating is defined as a central unit providing heat to nearby buildings and homes through a series of pipes carrying hot water or steam. Hot water is delivered through piping to a building's conventional heating system where heat is released through a heat exchanger. After the heat is extracted, the water is piped back to the central heating plant. Pipes are typically double walled and generally buried underground. District heating systems are common in Scandinavia. In Denmark, district heating provides 60% of thermal energy, with 17% derived from biomass (DEFRA/BEER 2007). Lower temperature district heating systems are under development, using hot water as low as 122°F (Thorson, Christiansen, and Marek 2011).

Capital costs are high for district heating systems as a result of the network of piping and heat exchangers and other equipment that must be installed for each customer. Economics are usually best for district heating when waste heat can be obtained from a nearby power plant at minimal cost, when replacing electric heating systems, and in densely populated areas with high-rise apartments. Several cities and universities have district heating systems powered by traditional energy sources. Most were built many decades ago.

District heating systems exist in the United States, but only two of them use biomass as an energy source.

- District Energy in St. Paul, Minnesota, operates a biomass district heating system ("District Energy St. Paul" 2013). It is the largest hot water district heating system in the United States. It is part of a CHP system that uses waste wood as a fuel source. It also includes a recently installed solar thermal system.
- The University of New Hampshire meets all heat and electricity requirements from a district system using methane from a nearby landfill (UNH Media Relations 2007). Many other universities have district heating systems powered by traditional energy sources.
- Montpelier, Vermont, is in the process of building a biomass-fired district heating system for the state government, city government, schools, and portions of the downtown area. This will be an upgrade to an existing wood-fired system ("District Heat Montpelier" 2013).

3.4 Biopower System Components

The following components comprise a typical direct-fired biopower system.

3.4.1.1 Major Components

- Fuel receiving, storage, and handling
- Combustion system and steam generator
- Steam turbine plus electrical generator
- Air pollution control
- Condenser and cooling tower

3.4.1.2 Other Equipment and Auxiliaries

- Stack and monitoring equipment
- Instrumentation and controls
- Ash handling
- Fans and blowers
- Water treatment
- Electrical equipment
- Pumps and piping
- Buildings

3.4.2 Fuel Receiving, Storage, and Handling

Biomass can be received at a site by truck or rail. It can be delivered as chips or pellets, or as logs and brush that can be processed on-site into chips. Wood chips are typically stored in a fuel yard (exposed or covered) or in storage silos (Figure 7). Wood pellets are stored in silos and are easily handled and fed using standard equipment. Fuel handling may be fully automated or semi-automated, requiring some additional labor. A fully automated system is typically installed below grade. Wood chips are delivered by truck to the storage bin, and conveyor belts automatically feed the boiler. Automated systems are generally used to serve large facilities. Semi-automated systems have lower capital costs but require more labor. They typically include above-ground chip storage and a hopper with capacity sufficient to supply the boiler for a few days. An operator moves woody biomass from the storage area to the hopper as needed. Operator workload is estimated at 60 to 90 minutes per day (BERC 2011).

Small biomass power or CHP facilities require a minimum of 2 to 10 acres, depending on fuel storage methods and quantities required to be held on-site.

Fuel yard

Fuel silo

Figure 7. Biomass storage options. ***Photos by (left) Warren Gretz, NREL 04736, and (right) Gerry Harrow, NREL 15041***

3.4.3 Combustion System and Steam Generator

A direct-fired combustion system is the most common system for converting solid biomass fuel into energy. Fuel is typically burned on a grate or in a fluidized bed to create hot combustion gases that pass over a series of boiler tubes, transferring heat into water inside the tubes and creating steam. The combination of the burning apparatus and the heat transfer surface areas are typically referred to as the boiler.

Boilers are differentiated by their configuration, size, and the quality of the steam or hot water produced. Boiler size is most often measured by the fuel input in Btu per hour (Btu/h), but it may also be measured by output in Btu/h or in pounds per hour of steam produced. Stoker boilers and fluidized bed boilers are the two most commonly used types of boilers for biomass firing. These combustion systems can be fueled entirely by biomass fuel or co-fired with a combination of biomass and coal or other solid fuel (EPA CHP 2007).

The traveling grate stoker boiler introduces fuel at one end of the furnace. The grate slowly moves the fuel through the hot zone until combustion is complete and the ash falls off at the opposite end. The fuel is either dropped onto the grate and travels away from the feeder or it is thrown to the opposite end and comes back toward the feeder. The latter is called a spreader stoker. A fluidized bed boiler introduces feedstock into the bed with a heat transfer medium (typically sand) (Crawford, M.). The bed material is fluidized using high-pressure air from underneath the grate, creating a good mixing zone.

3.4.4 Steam Turbine

The steam turbine is a key component and major cost element for a biopower facility. In many cases, increased turbine efficiency can be achieved, but at a cost that must be assessed with regard to overall plant economics. The higher the steam inlet pressure and the lower the steam exhaust pressure, the more energy that can be extracted from the steam. These both come at a cost that would have to be accounted for in determining the economics of the system. Typically, smaller systems use lower pressure steam; larger systems can afford to operate at higher pressures, yielding more power production to compensate for the increased capital costs.

3.4.5 Air Pollution Control

Biomass is a relatively clean fuel and contains lower quantities of the pollutants commonly found in coal and other solid fuels. The primary pollutants of concern in biomass combustion are CO, nitrogen oxides (NO_X), and particulate matter.

CO emissions can be minimized through good combustion. Good air mixing will oxidize most CO molecules into carbon dioxide (CO_2), which is not a regulated pollutant. Oxides of nitrogen can be controlled by either selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR). SNCR is accomplished by the introduction of nitrogenous reagents (urea or ammonia) at specific temperatures, creating a reducing reaction. SCR is a similar process but also uses a catalyst to achieve higher removal efficiencies.

Small ash particles, typically referred to as particulates or particulate matter, are captured in the fabric of large bags. The bags are pulsed occasionally to dislodge the dust into an ash hopper for removal. These systems are known as fabric filters or baghouses. Electrostatic precipitators are also commonly used for particulate removal.

EPA's "Final Air Toxics Standards for Industrial, Commercial, and Institutional Boilers at Area Source Facilities" was released on February 1, 2013, and applies to biomass boilers. The following provisions apply to new biomass boilers ("Industrial/Commercial/Institutional Boilers and Process Heaters" 2013):

- New boilers with heat input capacity greater than 10 MMBtu/h that are biomass-fired or oil-fired must meet GACT-based numerical emission limits for PM.
- New biomass-fired boilers with heat input capacity of 30 MMBtu/h or greater must have filterable PM of less than 3.0E–02 lb per MMBtu of heat input.
- New biomass-fired boilers with heat input capacity of between 10 and 30 MMBtu/h must have filterable PM of less than 7.0E–02 lb per MMBtu of heat input.
- New biomass-fired boilers with heat input capacity less than 10 MMBtu/h must:
    - Minimize the boiler's start-up and shutdown periods and conduct start-ups and shutdowns according to the manufacturer's recommended procedures. If manufacturer's recommended procedures are not available, you must follow a similar design for which manufacturer's recommended procedures are available (Federal Register 2013).

3.4.6 Condensers and Cooling Towers

As steam exits a turbine, it is condensed for reuse in the cycle. The most common condensing method uses a steam surface condenser and a cooling tower. The surface condenser is a large vessel filled with tubes in which cool water from the cooling tower is circulated. The steam flows over the tubes, which cools it and condenses it into a hot well at the bottom of the condenser. The cooling water that leaves the condenser is pumped back to the cooling tower, which typically uses evaporative cooling to cool the water for reintroduction into the condenser.

A large amount of water is lost to evaporation from the cooling tower, and that water needs to be continuously replaced. In areas where water is scarce and expensive, this introduces a large operating cost. In these cases, the water is commonly cooled by an air-cooled system. Compared to a wet cooling tower, the capital costs for this equipment are higher, and the electric power to operate the fans is higher, but water consumption is significantly reduced.

4 Biomass Feedstock—Properties, Cost, and Availability

In this section, we study the properties, cost, and availability of woody feedstock for a biomass facility in Kansas City.

4.1 Biomass Properties

The operating success of a biomass facility is determined by several important properties of the biomass feedstock, including its energy content, moisture content (MC), ash content, cleanliness, and particle size distribution.

In Missouri, biomass MC[3] typically ranges from 40% in summer and fall to 50% in winter. Moisture content affects the efficiency of a biomass combustion process in a nonlinear manner. For example, a biomass system operating under a specific set of conditions might have a recoverable energy of 4,000 Btu per pound of 40% MC biomass, but the same system operating with 50% MC fuel might produce only 3,133 Btu per pound—a decrease of more than 21%.

If feedstock prices are not adjusted for changing moisture content, the cost per Btu greatly increases with increasing moisture content.

The Southeast Clean Energy Application Center's Wood Energy Calculator[4] can be used to explore the effect of moisture content on energy production. Figure 8 shows an example of the program's inputs and outputs.

[3] In this report, MC is specified on a wet basis—i.e., MC, wb = weight of water divided by (weight of water plus weight of dry wood). In some industries, MC is reported on a dry basis—i.e. MC, db = weight of water divided by weight of dry wood. Note that 50% MC, wb = 100% MC, db.

[4] Accessed June 9, 2014: http://www.southeastchptap.org/resources/calculators.aspx

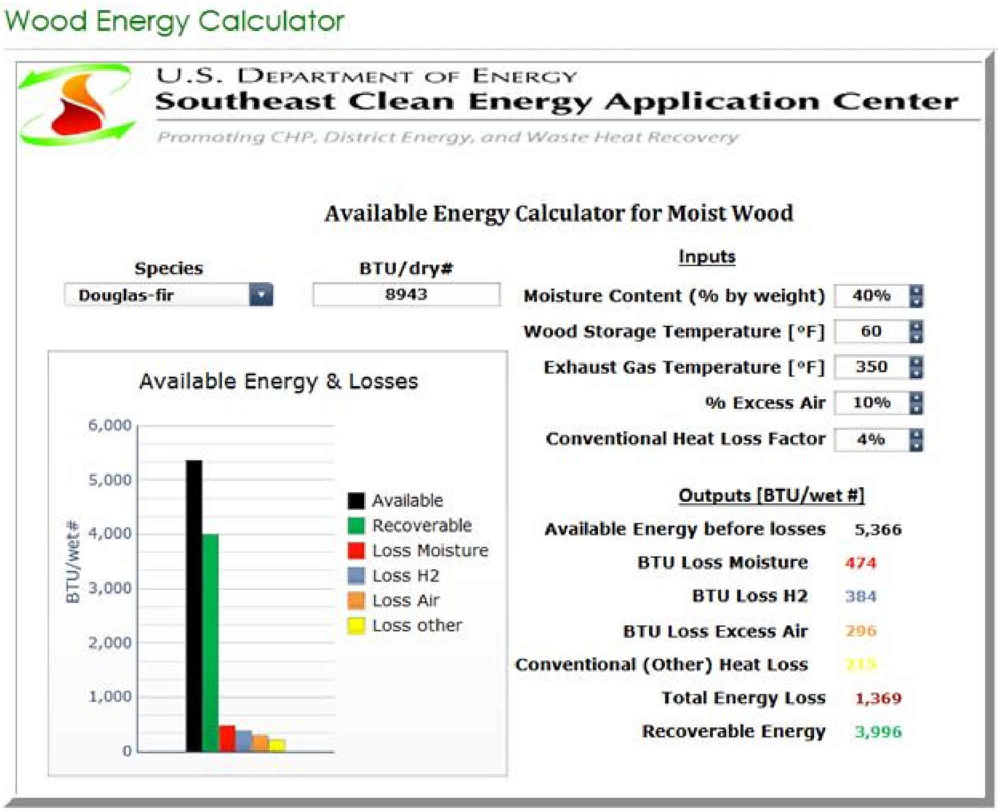


Figure 8. DOE Southeast Clean Energy Application Center's Wood Energy Calculator

4.2 Biomass Cost—Potential Tipping Fees

An important factor in assessing the feasibility of a biomass project is the cost of the resource. Biomass collection facilities are located near the Municipal Farm site. These facilities receive a tipping fee for accepting woody biomass. We estimate that this fee is approximately $22.50 per ton of this material. However, this money is already being collected, so it would not be an additional source of revenue. Also, residents may deposit material for free on certain days, and the city collects curbside wood waste on a biannual basis at no cost to residents. Therefore, actual fees collected from fee payers may be significantly less than stated. This study assumes that the material is available at no cost, but tipping fees for collecting wood waste is not considered a source of income for a biomass project on the site.

4.3 Biomass Availability—Resources and Resource Consumption

Even though many materials are included in the category of biomass—crop residues, animal manures, food waste, and municipal solid waste—in this study, we focus on woody biomass as a feedstock for a biopower project.[5]

Feedstock for a biomass energy plant is generally composed of low-valued woody components, often resulting from the harvest of more valuable material such as saw logs for dimensional lumber. This type of wood can also result from land maintenance and clearing operations, thinning for fire mitigation, urban tree trimming, storm cleanup, power line right-of-way

[5] For details regarding the availability by county of other biomass in Missouri, see Fink and Fink 2006.

maintenance, disposal of diseased trees (e.g., beetle kill), etc. Note that the material resulting from these processes is generally considered a waste product or results from procedures that improve forest health or reduce risks of catastrophic wildfires.

Additional materials will be available from the eradication of exotic species (honeysuckle, tree of heaven), which will be pursued at Municipal Farm in partnership with the Missouri Department of Conservation, U.S. Army Corps of Engineers, and City of Kansas City Parks and Recreation Department (Shaw 2012).

4.3.1 Biomass Assessment Tools

Biomass Site Assessment Tools (BioSAT 2007–2014) are a set of web-based tools that provide data to help with biomass collection and processing for sites in 33 states in the eastern United States. Data coverage on the BioSAT website includes Missouri and other Midwest and eastern states (plus Texas and Oklahoma), but it does not include Kansas.[6]

Figure 9 shows logging residues for Missouri, and Figure 10 shows the cost of those residues. Both of these figures were produced on the BioSAT site.[7] Note that this data indicates that biomass availability in the area around the Municipal Farm site is fairly low.

[6] Given the site's proximity to Kansas, any biomass system at the site presumably would have also access to available biomass in that state as well. However, given the site's other limitations (e.g., lack of onsite and nearby load), having the biomass data for Kansas would not impact the overall conclusions reached in this study.
[7] Images from James H. Perdue

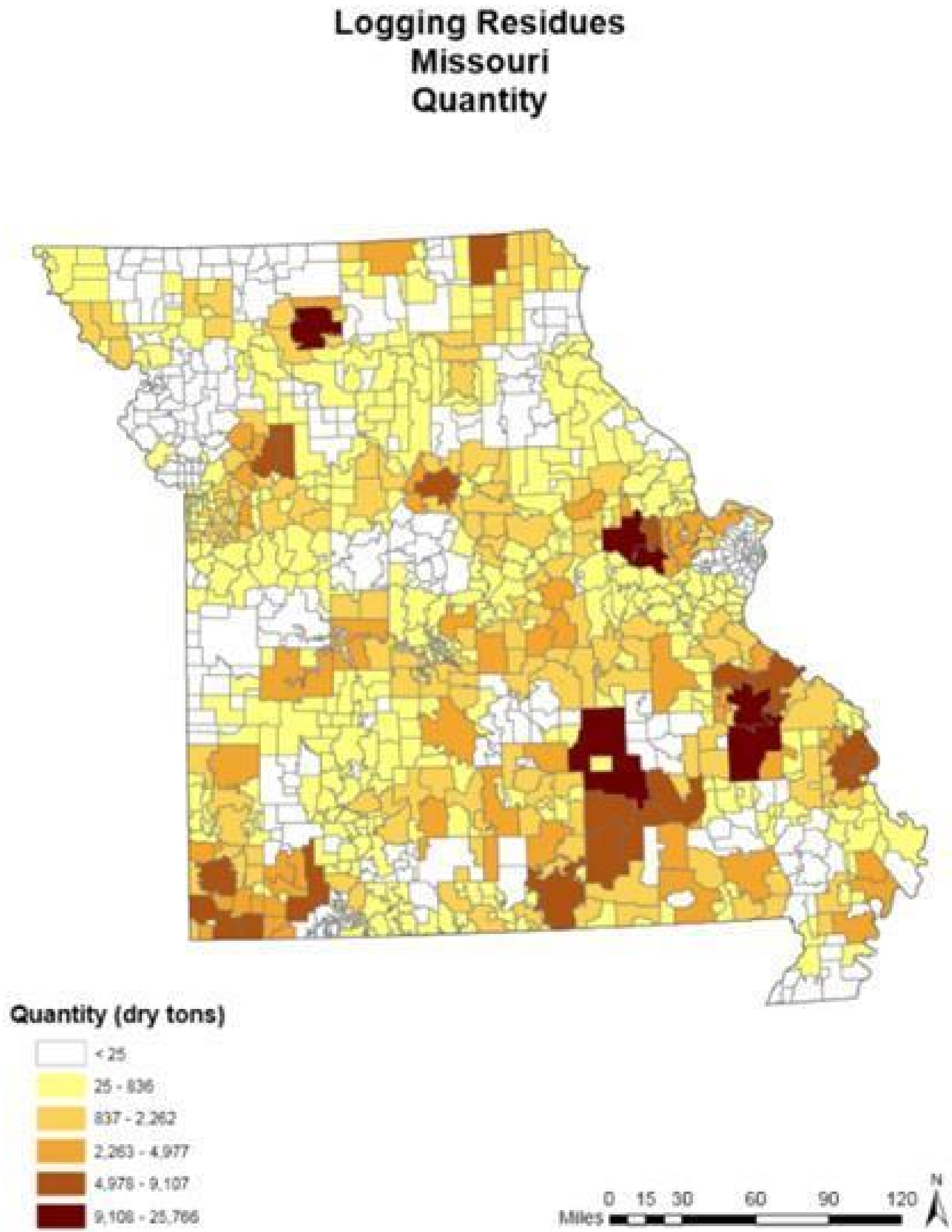


Figure 9. Missouri logging residues. ***Illustration from "BioSAT"***

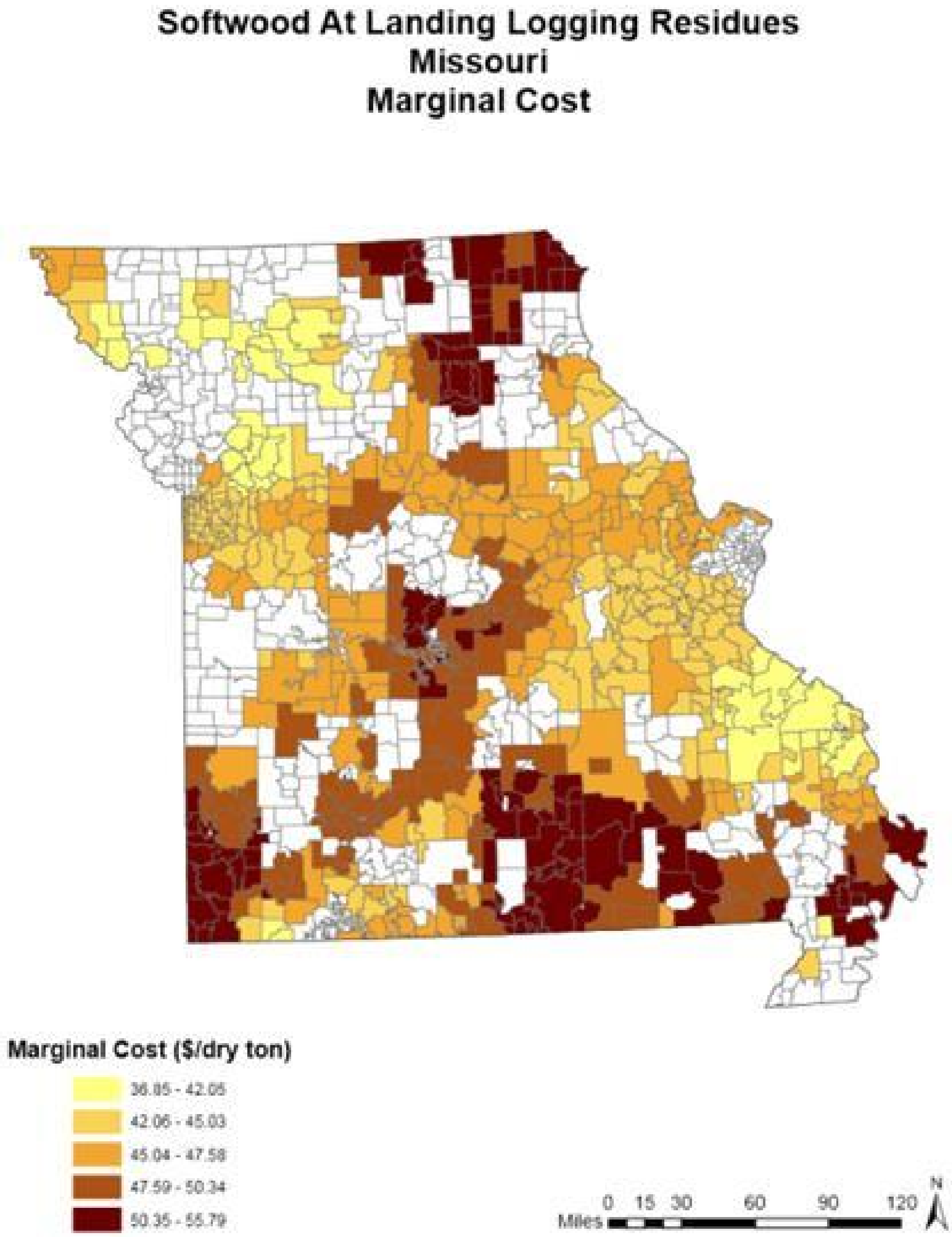


Figure 10. Missouri marginal cost of logging residues. ***Illustration from "BioSAT"***

4.3.2 Biomass Available from Collection Near the Site

The City of Kansas City contracts with Missouri Organic—a local compost and mulch business—to operate two leaf and brush drop-off sites, one at I-470 and Raytown Road and the other at 1815 N. Chouteau Trafficway. The leaf and brush collections could be delivered to the Municipal Farm location, and it would be possible to create an on-site leaf and brush drop-off center to accept material at the Municipal Farm site for a biopower project (City of Kansas City 2007). The total collection is 60,000 to 70,000 cubic yards per year (Shaw 2012). At five cubic yards per ton, that is 12,000 to 14,000 green tons (GT) of biomass per year, or 33 to 38 GT per day.

The collection fee is $4.50 per cubic yard, which—using the same conversion factor of five cubic yards per ton—is approximately $22.50 per GT.

In addition, railroad ties may be available in the future if the Rock Island Rail Corridor—which would turn the unused railroad track into a hiking and biking path—is developed. Part of this rails-to-trails project would be adjacent to the Municipal Farm project area (Shaw 2012). These railroad ties might be useable in a biopower plant, but they would first need to be tested to ensure that they would not produce harmful emissions when combusted.

4.3.3 Potential Biomass from Emerald Ash Borer

The emerald ash borer (EAB) is an invasive species of beetle that is thought to have entered the United States near Detroit, Michigan, in 2002. Since the original infestation, EAB have been spreading radially across the United States and southern Canada. It has reached as far west as Kansas. According to the Emerald Ash Borer informational website, on July 23, 2008, EAB was confirmed in Missouri near Lake Wappapello ("Missouri Information" 2013).

The Emerald Ash Borer website has links to several web pages focusing on EAB in Missouri, including the following:

- The University of Missouri Extension EAB Program: http://extension.missouri.edu/emeraldashborer/;
- Missouri Department of Conservation EAB Management site: http://mdc.mo.gov/your-property/your-trees-and-woods/tree-diseases-and-pests/emerald-ash-borer-management;
- Missouri Department of Agriculture EAB site: http://mda.mo.gov/plants/pests/emeraldash.php; and the
- Missouri Department of Natural Resources Missouri State Parks EAB site: http://mostateparks.com/page/54116/emerald-ash-borer.

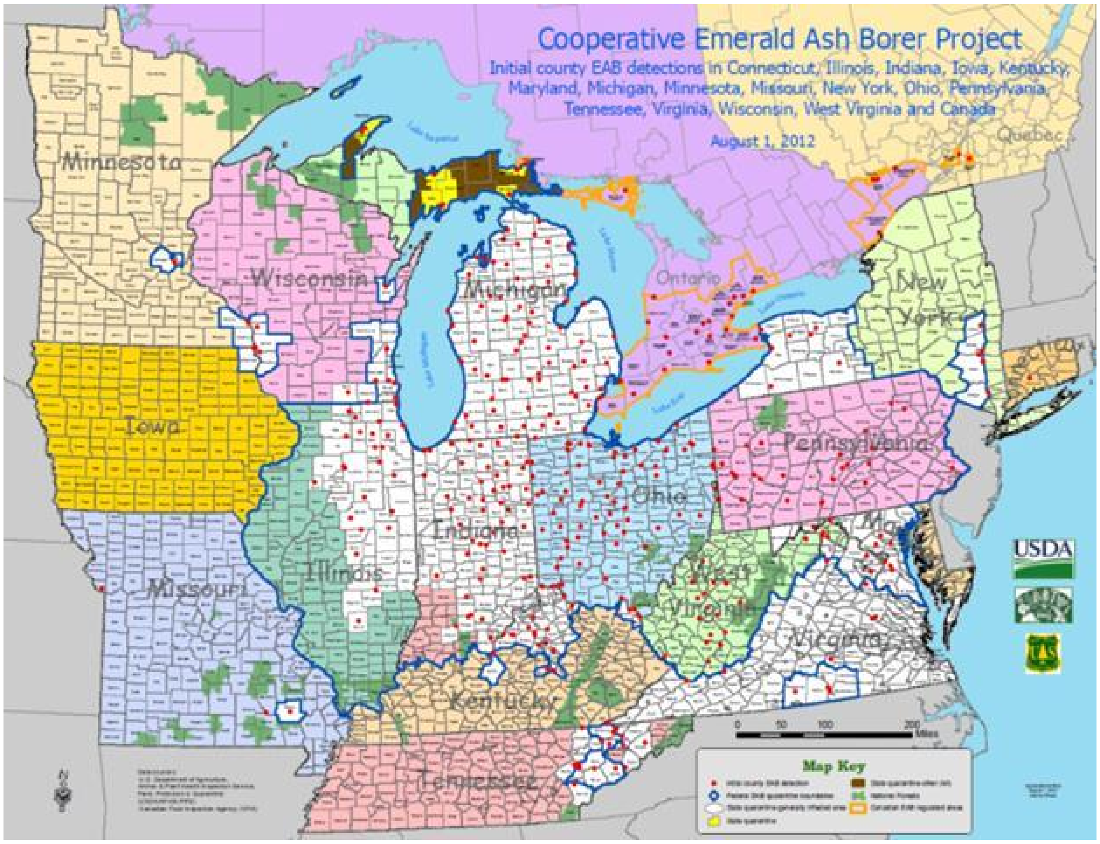


Figure 11. EAB map as of August 1, 2012. ***Illustration from "Maps and State EAB Information"***

On July 25, 2012, EAB was confirmed in Kansas City, Missouri ("Where EAB Has Been Found" 2014). On December 6, 2012, the city released a report titled *Emerald Ash Borer and Its Impact to the Urban Forest of Kansas City, Missouri* (Kansas City Parks and Recreation 2012). This study reports (pp. 2–3):

> In Kansas City, there are roughly 20,000 Ash trees currently on public property under the jurisdiction of Forestry Operations. Approximately 3,000 of these are on Boulevards and Parkways. The number of private residential property Ash trees is estimated at 120,000. There are also a large number of Ash trees in Kansas City's forested areas, many of which are public property. A 2010 MARC [Mid-America Regional Council] survey estimates that we have as many as 400,000 Ash trees on public, private and forested lands within Kansas City.
>
> Estimates are that it will take approximately ten years to spread throughout the entire geographic area of Kansas City. The number of Ash tree deaths will be small at first, but will compound rapidly each year until nearly 100% of the Ash trees in Kansas City are affected.

The height of a fully grown white ash tree is between 65 and 100 feet with a diameter between two and five feet. Based on data derived for oak and hickory trees (Myers, Polak, and Stortz 1975), we estimate that a 65-foot-tall tree with a diameter-at-breast height (dbh, a common forestry term) of 30 inches would weigh six to eight tons, and a 100-foot tree with a dbh of 60 inches would weigh 30 to 45 tons.

Using these very rough mass estimates, assuming smaller trees outnumber larger trees, and without specific size distributions for Kansas City, for the purposes of this analysis we use an average weight of 11 GT per tree.

If the entire tree inventory were to die from EAB, and assuming that the mortality occurred evenly during a 10-year period (which we acknowledge is highly unlikely, but useful for a first approximation), the average biomass available from ash trees killed by EAB would be approximately 440,000 GT per year.

To be conservative, we assumed that 20% of this material would be collected and available for a biopower facility at Municipal Farm. This equals 88,000 GT per year, or approximately 240 GT per day.

4.3.4 Biomass Consumption in Missouri

In addition to knowing the quantities of biomass produced, it is important to understand the existing biomass consumption in an area. Figure 12 shows institutional facilities in Missouri that use biomass ("Wood2Energy" 2013). Note that there are several institutional biomass consumers in Missouri, but none near the Municipal Farm site.

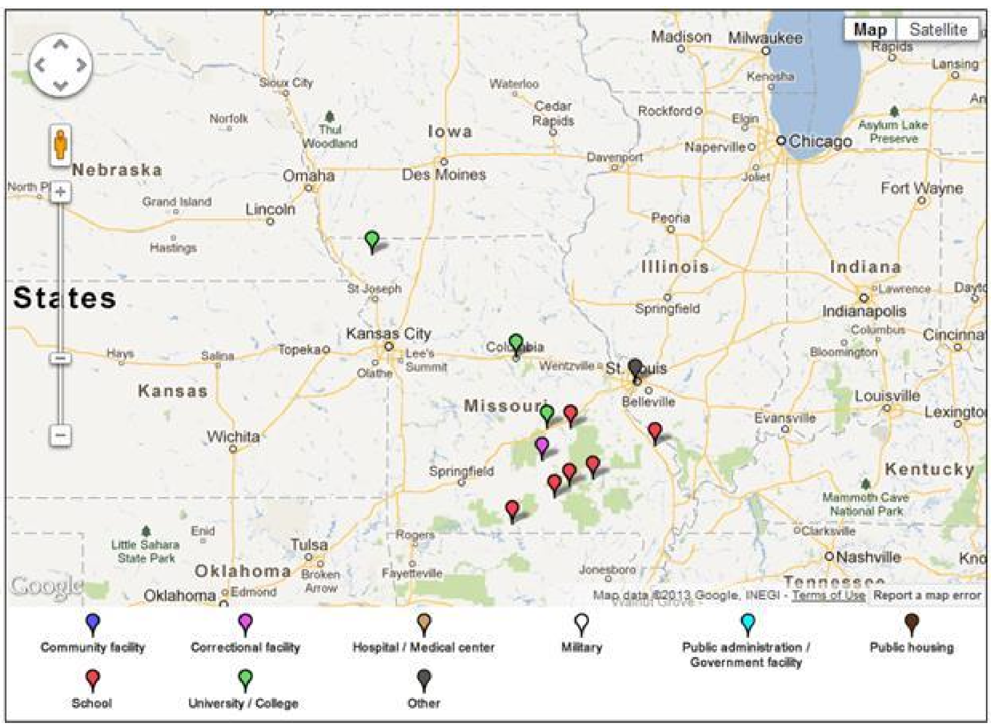


Figure 12. Institutional wood energy users in Missouri. ***Illustration from "Wood2Energy"***

Table 1 provides some details about the facilities shown in Figure 12. For the electronic version of this report, the facility name in each line of the table includes an embedded URL to a wood2energy.org web page, with additional information about each facility.

Table 1. Institutional Wood Energy Users in Missouri. ***Information from "Wood2Energy"***

Facility Name	City	County	Facility Type
Anheuser-Busch	St. Louis	St. Louis	Other
Ellington Schools	Ellington	Reynolds	School
Eminence Ri Elementary School	Eminence	Shannon	School
Gainesville High School	Gainesville	Ozark	School
Liberty High School	Mountain View	Howell	School
Northwest Missouri State University	Maryville	Nodaway	University/College
Office of Administration FMDC	Licking	Texas	Correctional facility
Perry County School Main Campus	Perryville	Perry	School
Steelville Elementary and Middle School	Steelville	Crawford	School
University of Missouri at Rolla	Rolla	Phelps	University/College
University of Missouri at Columbia	Columbia	Boone	University/College

The only biomass power producers in Missouri are located in Columbia, at the University of Missouri. Table 2 provides information about them. The University of Missouri plant is a combined-cycle heat and power plant that integrates a gas turbine with a biomass-fired fluidized bed boiler to produce heat, cooling, and electricity. It was completed in December 2012 and is expected to burn more than 100,000 tons of biomass per year. The University of Missouri has a second boiler in which biomass is co-fired with coal.

Table 2. Biomass Electric Power Producers in Missouri. ***Information from "Wood2Energy"***

Facility Name	City	County	Facility Type
Columbia Municipal Power Plant	Columbia	Boone	Electric utility (co-firing)
University of Missouri at Columbia	Columbia	Boone	100% biomass

4.3.5 Biomass Summary

Regarding potential biomass availability, we estimate that approximately 12,000 to 14,000 GT of biomass per year could be collected at the leaf and brush site and that there is the potential for an additional 88,000 GT per year as a result of mortalities caused by emerald ash borer. However, the availability of material from EAB is projected to be limited to a 10-year supply.[8]

Biomass material available from leaf and brush collection, including the potential materials from EAB mortalities, should earn a tipping fee of $20 to $23 per GT. Feedstock demand in excess of that amount would incur costs of $35 to $55 per dry ton in disposal costs.

Tools for assessing biomass availability in Missouri include:

- BioSAT: http://www.biosat.net/
- "Wood2Energy": http://www.wood2energy.org

[8] This ten-year limit may be conservative. Although it is projected to take 10 years for EAB to spread throughout the region, after a tree has become affected it may take considerably longer for the tree to die, and longer still for the City of Kansas City or private entities to contract for removal services. According to the State of Michigan, "most of the canopy will be dead within 2 years of when symptoms are first observed" (http://www.emeraldashborer.info/faq.cfm#sthash.aqZ5DBpM.dpuf). Tree death occurs within 2 to 4 years of initial infestation. (http://www.emeraldashborer.info/cdfiles/informationeducation/what_is_eabfactsheetOH.pdf). Therefore, material from EAB may continue to flow into collection facilities for up to 14 years, but at lower volumes.

- “Missouri Woody BioMass Assessment Tool”: http://projects.cares.missouri.edu/MoBAT.[9]

4.4 Recommended Activities for the Next Level of Analysis

The wide range of predicted available biomass for this region highlights the importance of performing a site-specific biomass resource assessment for a bioenergy facility.

As a next step, we recommend contacting foresters, wood utilization specialists, lumber mills, and others to obtain a firmer analysis of available biomass, biomass properties, and biomass cost.

In addition, Kansas City, long a major goods warehousing and distribution hub for trucks and rail, has a large pallet industry that should be consulted for material. Also, deconstruction is growing in Kansas City as a method of removing structures, aided by local nonprofits such as Heartland Habitat for Humanity ReStore. Wood material recovered from these and conventional demolition operations should be considered. In addition, in 2012 an NREL biomass study project based on crop residue from the surrounding vicinity was completed for Lawrence, Kansas, which is less than 50 miles from the Municipal Farm site. Crop residue might be considered as a supplement feedstock.[10]

[9] As of February 10, 2014, the site is down. It is in the process of being migrated to a different server (Stelzer 2014).

[10] It is not always possible to use crop residues in a biomass plant because of differences in handling and feed characteristics with wood chips. In addition, crop residues sometimes contain chemical components, such as silica, that can increase wear and maintenance requirements of equipment. Finally, crop residues tend to be seasonal, requiring either long-term storage or fuel flexibility, which increases capital and operating costs.

5 Site Description

The property for this analysis is located in Kansas City, Missouri, and is owned by the City of Kansas City. It is divided into several lots, with a total area of 441 acres[11] "located on both sides of I-435 (east and west) and south of Raytown Road and the Blue River" (Bracker 2011).[12] The east portion includes 187 acres, and the west portion includes 254 acres.[13] The eastern parcel includes a closed landfill, which site managers consider could be a good location for a solar facility.[14]

Figure 13. A portion of the Municipal Farm RE-Powering America's Land Initiative study site

In 2012, the City of Kansas City published *The Municipal Farm Sustainable Reuse Plan*, which is a comprehensive, long-term plan to develop the most beneficial, integrated, and sustainable

[11] This is an updated figure based on the completed *Municipal Farm Sustainable Reuse Plan* (2012).
[12] The site is within the Eastwood Hills neighborhood and includes diverse ecosystems (e.g., the Blue River, a floodplain, and heavy woods), transportation networks (I-435, railroads, and local roads), and land uses (industrial, residential, commercial, and the Truman Sports Complex).
[13] This is an updated figure based on the completed *Municipal Farm Sustainable Reuse Plan* (2012).
[14] A separate study, funded by the City of Kansas City, investigating the feasibility of photovoltaics at Municipal Farm is under way.

uses for the Municipal Farm site.[15] The plan conceptualizes the site as divided into 21 numbered areas; describes the brownfield status, land uses, natural resources, and infrastructure of each area; and makes recommendations for the use of each section and the site as a whole.[16] Figure 14, which is extracted from the conceptual land use plan (CLUP) for the site, is a map of the site divided into numbered areas.

Figure 14. CLUP map showing the numbered areas of the Municipal Farm site. ***Illustration from City of Kansas City 2012***

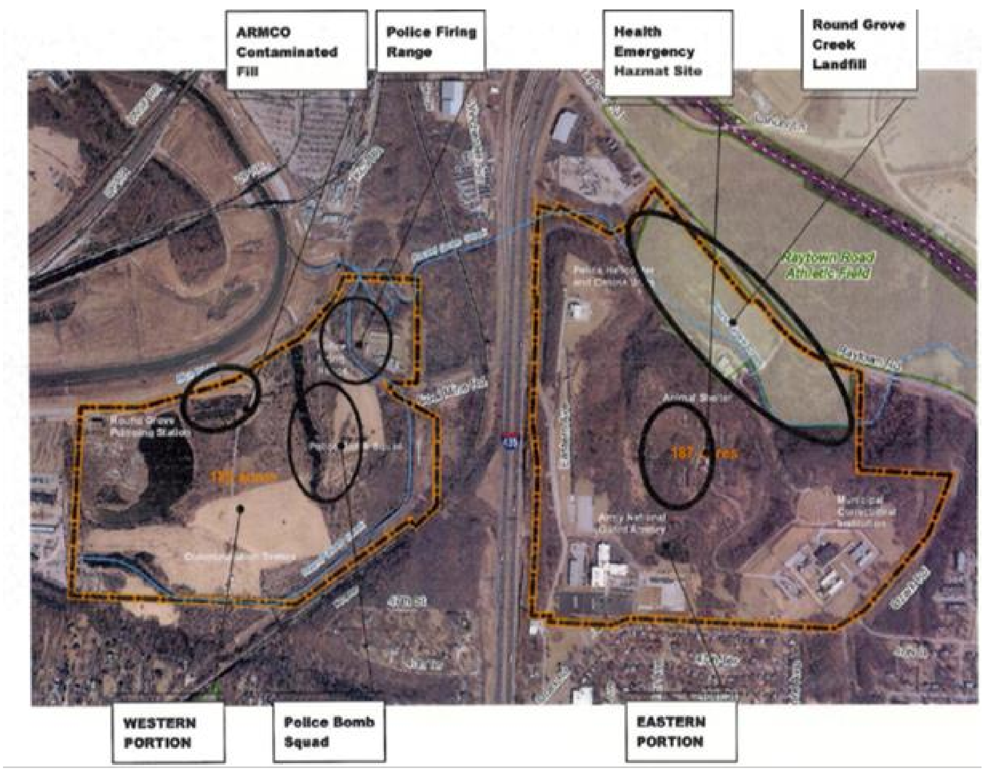
There are several active operations on the site, including a National Guard Armory, athletic fields, the Kansas City animal shelter, a police firing range, and a police bomb detonation area. Some of these facilities have an electrical load that could be served by a biomass power facility.

[15] The plan was funded by a Brownfields Area-Wide Planning Pilot Program grant from the EPA. Municipal Farm was one of the initial 26 projects to be awarded this grant.
[16] Details regarding each numbered parcel can be found on p. 51 of CLUP.

There is rail service to the western portion of the site, as well as water and sanitary sewer, but no storm sewer. The site is mostly flat with portions in the floodplain; Areas 2 through 4 and Areas 9 through 18 are mostly out of the floodplain.[17] Floodplain boundaries are subject to incremental change as new maps reflecting the re-channelization of the Blue River are officially adopted (Shaw 2012). Areas where a project cannot be sited include surface water and wetlands, occupied structures, the firing range, and land occupied by radio towers. The site has been described as having good truck access on Coal Mine Road from Blue Parkway (Shaw 2012).

There is currently a planned expansion of the National Guard Armory and a proposed commercial greenhouse development at the site. In general, sustainable commercial, industrial, institutional, and/or recreational development is anticipated in the future (Shaw 2012). This report considers other uses for this property.

Multiple brownfield concerns throughout the site have been identified, and some have been assessed. Historical uses of the site included a former concrete batch plant, a mine, a police firing range, a former municipal landfill, a separate landfill for contaminated river sediment, and a hazardous waste storage facility (the Health Emergency Hazmat site). The site also hosted a working farm and dairy, orchards, cemeteries, a hospital, and a prison. Figure 15 shows the site layout and areas of current activity.



[17] See Figure 14 for a map showing the numbered areas.

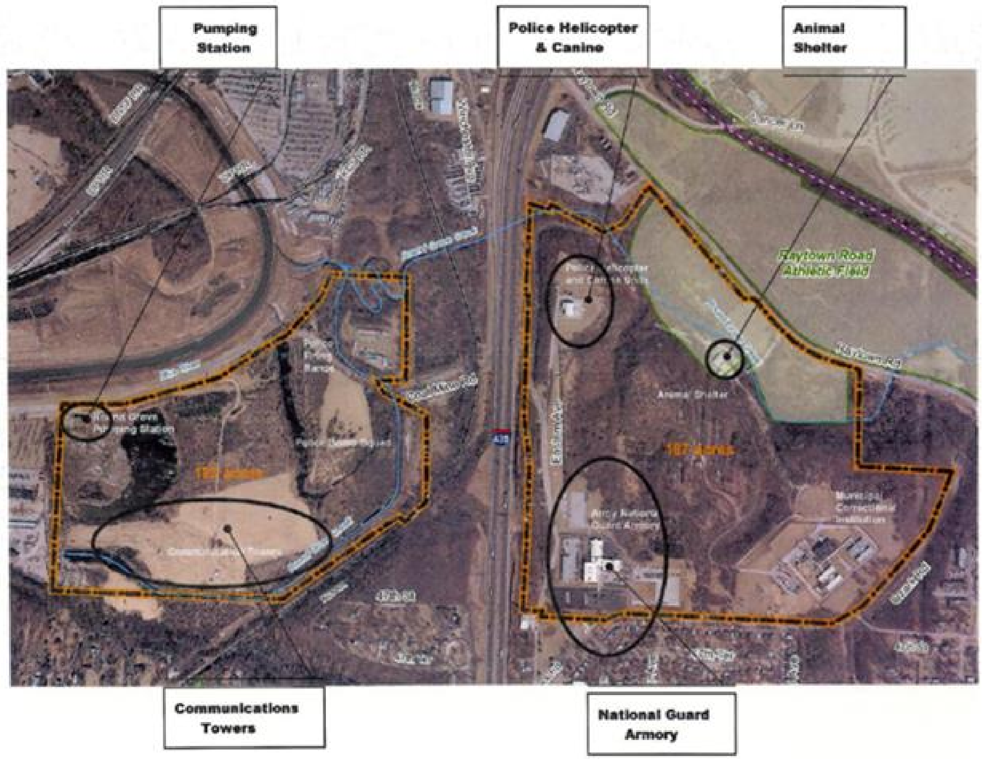


Figure 15. Municipal Farm site overlaid on an aerial photograph. ***Photo from Bracker 2011***

To address the brownfield concerns, the *Municipal Farm Sustainable Reuse Plan* included an in-depth investigation of known and suspected environmental data and concerns for each area, titled the Municipal Farm Brownfields Area-Wide Plan. Reports, records, and existing data—similar to that evaluated by a Phase I environmental site assessment—were collected for each area, evaluated by environmental professionals, and used to develop a ranking of relative environmental concerns, data uncertainties, and recommendations for future assessments. Based on the work of the Brownfields Area-Wide Plan, and at the request of the city to investigate priority development areas of the site, the EPA conducted Phase I and limited Phase II environmental site assessments in 2013 for Areas 2 through 4, Area 13, and Area 19. Area 13 is the location of the proposed commercial greenhouse and proposed biomass facility; the National Guard Armory is nearby, in Area 11. No significant environmental impacts were identified—and no further environmental assessments were recommended—for these assessed areas.

5.1 Site and Area Photos

The photograph in Figure 16 was taken by NREL during the site visit in October 2012.

Figure 16. Former concrete plant at the Municipal Farm site. ***Photo by Gregg Tomberlin***

The following photographs show Area 13, the former site of the Municipal Correctional Institution (MCI). The images were provided by Andrew Bracker, Brownfields Coordinator for the City of Kansas City, Missouri.

Figure 17. CLUP Area 13—east view of middle portion

Figure 18. CLUP Area 13—site of the groundbreaking for the Eastwood Hills community garden

Figure 19. CLUP Area 13—east-northeast view

5.2 Site Location and Nearby Loads

A biomass facility could be located on the site in a region that includes parts of Areas 12, 14, and 15, as shown in Figure 20. The facility may include a city leaf and brush drop-off center where wood waste could be accepted, ground, and managed to supply feedstock. This location is near an existing National Guard Armory, an 83,000-square-foot facility in Area 11, and a future 100,000-square-foot commercial greenhouse and corporate office in Area 13. It is also close to an existing animal control facility in Area 19, an existing police helicopter unit in Area 18, and a radio tower on the east end of Area 13. Details of these site loads are covered in Chapter 7.

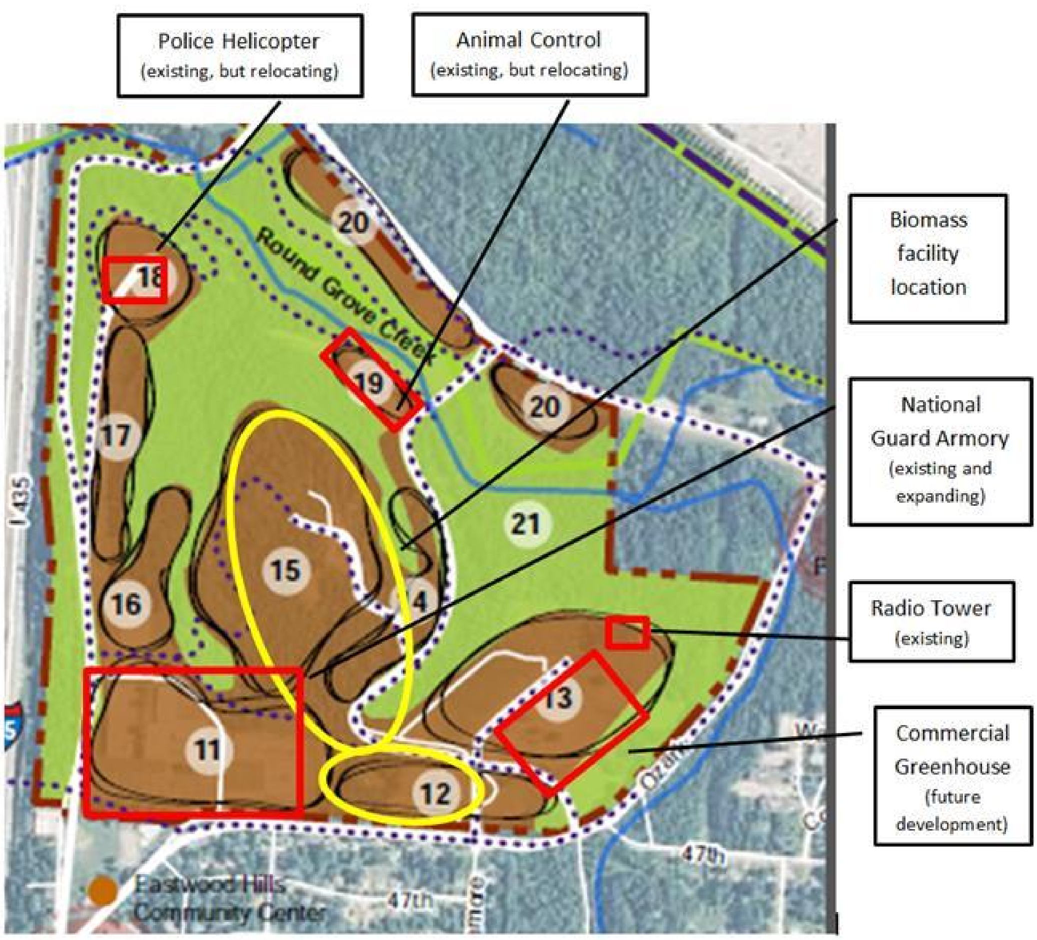


Figure 20. The portion of the Municipal Farm site considered for biomass facility location

The proposed biomass facility site includes the former central buildings and facilities of the farm operations at Municipal Farm. As shown in Figure 21, the location topography is uneven—it includes a gently sloped portion in Area 12 and rises to a generally level area in the north part of Area 15. An existing access road reaches all portions of the proposed site, and the city is planning improvements to portions of the road to accommodate heavy vehicles.

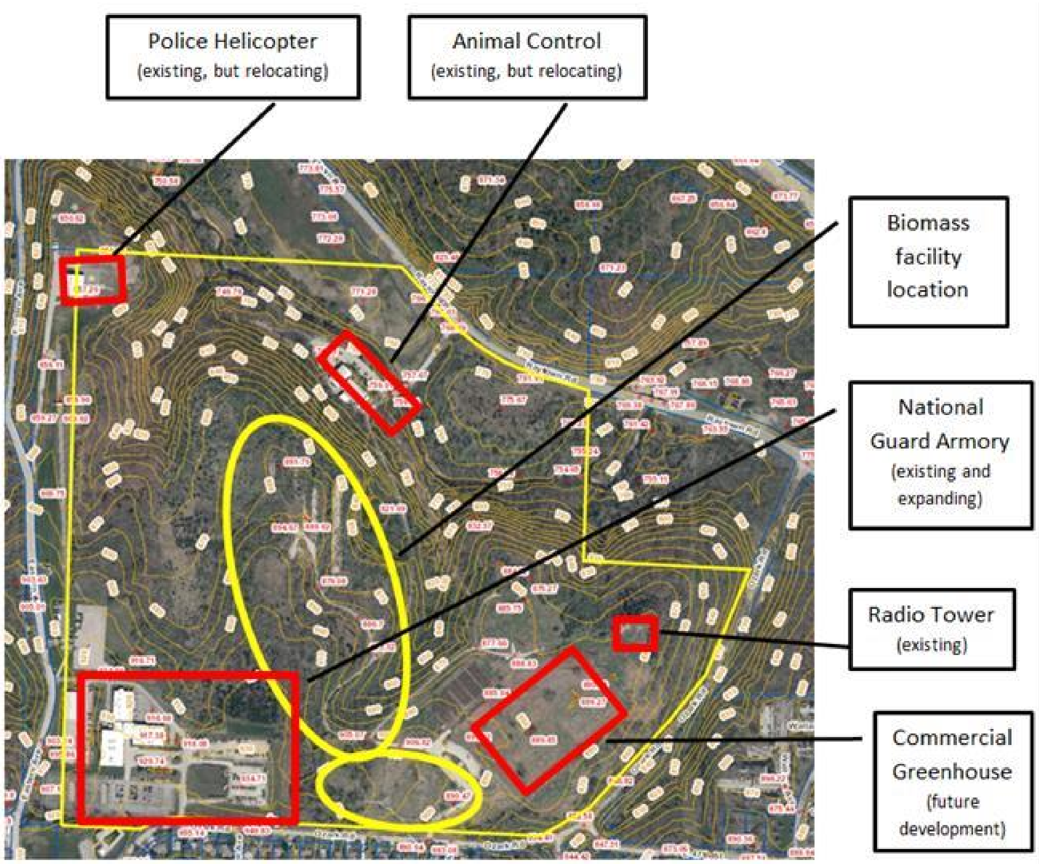


Figure 21. Site topography

5.3 Utility Provider

KCP&L is the electric utility serving the Municipal Farm site. They have provided a tentative letter of support, a copy of which is included in Appendix A. KCP&L operates a solar renewable rebate program and has the capacity for and experience in renewable energy projects. Utility staff reviewed a preliminary draft of this report and agreed to discuss details of this biomass study and provide input.

5.4 Recommended Activities for the Next Level of Analysis

Existing bioenergy facilities range in size from a few acres up to hundreds of acres. Some of this space is required for equipment, and some is required for feedstock storage. As part of the next level of analysis, it is important to determine the space required by a biomass combined heat and power (CHP) facility, including fuel storage, and if space is available that is compatible with other potential uses on the site.

6 State and Local Energy and Utility Details

In this section, we provide some background information about energy production and consumption in Missouri as well as information about the electric utility serving the site.

6.1 U.S. Energy Information Administration

The U.S. Energy Information Administration (EIA) ("Profile Overview" 2013) provides utility data by state and sector ("Data Tables" 2013) Tables of data by sector for Missouri are included below.

Table 3. EIA Residential Data 2011. ***Information from "Missouri State Energy Profile" 2014***

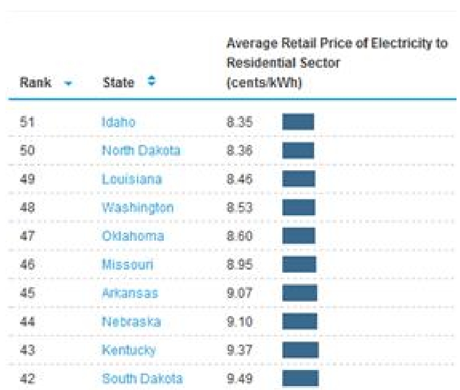
Missouri Quick Facts
• The Rockies Express (REX) is a 42-inch, 1,679-mile natural gas pipeline stretching from Colorado to Ohio. The REX West portion of the System passes near Kansas City before terminating in northeast Missouri where it meets the REX East pipeline. • Missouri was the first State west of the Mississippi River to produce coal commercially. • Coal supplied 83% of Missouri's net electricity generation in 2013. • Missouri has one nuclear power plant, Callaway Nuclear Generating Station, which in 2013 contributed 9% of the state's net electricity generation. • Renewable energy resources accounted for nearly 3% of Missouri's net electricity generation in 2013; most of that generation came from conventional hydroelectric power and wind. Last updated in March 27, 2014.

According to the EIA, Missouri ranks 25th highest among all states in energy consumption per person.

Rank	State	Total Energy Consumed per Capita (million Btu)
1	Wyoming	948
2	Alaska	899
3	Louisiana	894
4	North Dakota	713
5	Iowa	489
6	Texas	466
7	South Dakota	465
8	Nebraska	461
9	Kentucky	455
10	Indiana	442
11	Oklahoma	413
12	Alabama	410
13	Kansas	408
14	Montana	405
15	Mississippi	400
16	West Virginia	398
17	Arkansas	385
18	South Carolina	358
19	Tennessee	354
20	Minnesota	352
21	Idaho	340
22	Ohio	332
23	New Mexico	329
24	Georgia	325
25	Missouri	322
26	Wisconsin	316

Figure 22. State rankings for energy consumption—the first 26 states. ***Illustration from EIA 2014***

Missouri pays the 20th highest amount for natural gas, at an average of $9.95 per million Btu, and is at the low end for the cost of electricity, at an average of 8.95 cents per kWh (residential sector).



Rank	State	Average Retail Price of Electricity to Residential Sector (cents/kWh)
51	Idaho	8.35
50	North Dakota	8.36
49	Louisiana	8.46
48	Washington	8.53
47	Oklahoma	8.60
46	Missouri	8.95
45	Arkansas	9.07
44	Nebraska	9.10
43	Kentucky	9.37
42	South Dakota	9.49

Figure 23. State rankings for residential price of electricity—the lowest 10 states. ***Illustration from EIA 2014***

As shown in Figure 24, by far the largest fuel for electricity production in Missouri is coal, with production of nearly 7,000 GWh per year. Second is nuclear, at slightly less than 1,000 GWh/yr ("Profile Overview" 2013). Approximately 3% of Missouri's annual electricity generation is from hydropower and other renewable energy sources.

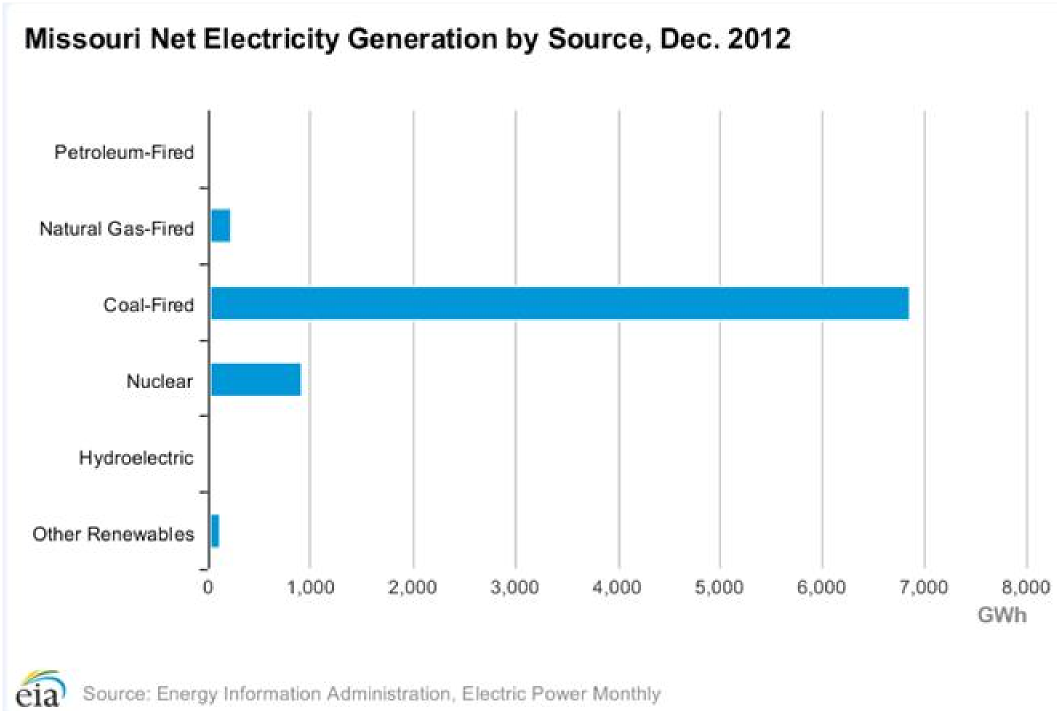


Figure 24. Missouri electricity production by source. *Illustration from EIA 2014*

Figure 25 shows power generation by type in Missouri and the surrounding states. According to the EIA, there are only two biomass power plants in Missouri,[18] both of which are landfill-gas-to-energy plants: a 2.7-MW Ameresco plant in Jefferson City and a 3-MW plant in Springfield. There are other landfill-gas-to-energy plants in neighboring states.

[18] The University of Missouri does burn 10% biomass in their solid-fuel boilers, and it has begun the phased start-up of a 100% biomass fueled boiler in December 2012. See http://mizzoumag.missouri.edu/2012/12/mu-fires-up-biomass-boiler (accessed June 2013).

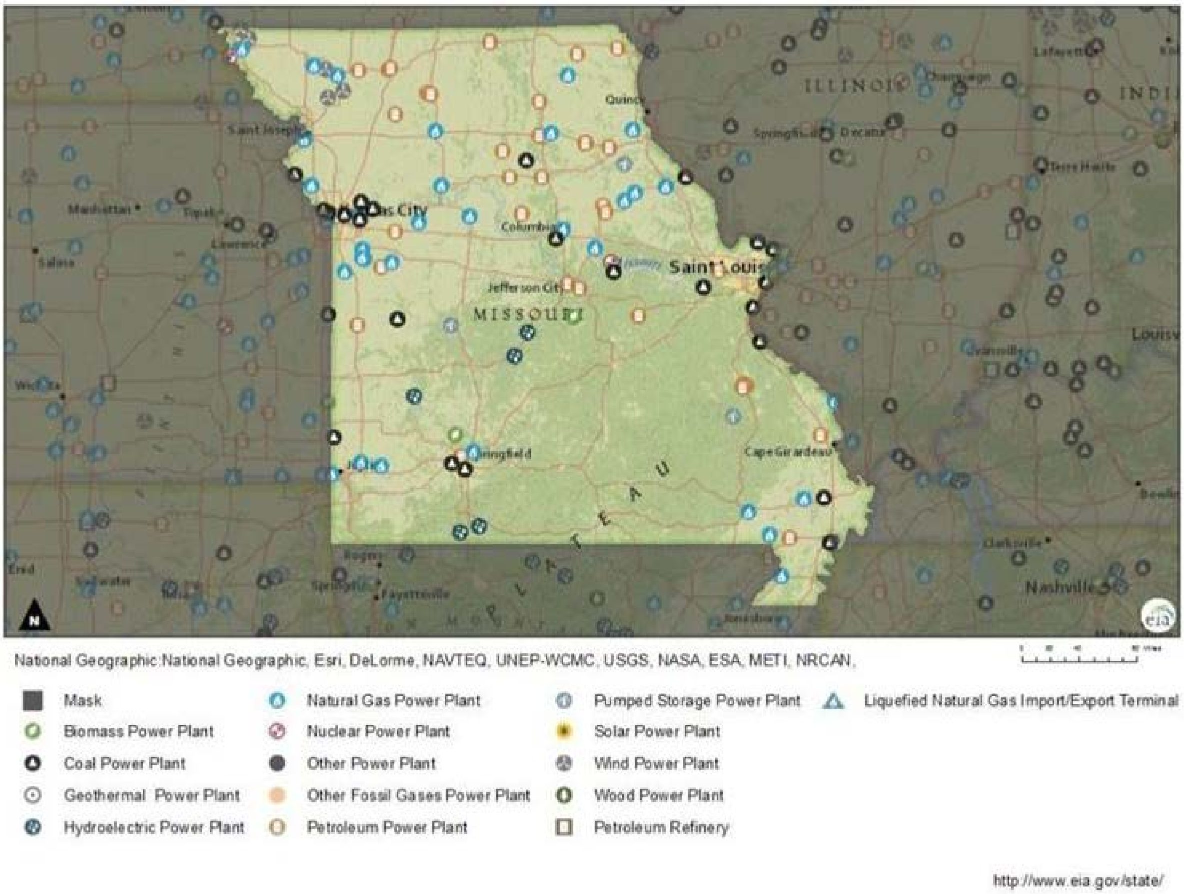


Figure 25. Electric power generation in and around Missouri. ***Illustration from EIA 2014***

Table 4 shows the ten largest electric generating plants in Missouri as of 2010.

Table 4. Missouri's Ten Largest Plants by Generation Capacity as of 2010. ***Information from "EIA 860 Detailed Data" 2013***

Rank	Plant	Primary Energy Source	Operating Company	Net Capacity (MW)
1	Labadie	Coal	Union Electric Company	2,407
2	Iatan	Coal	KCP&L	1,555
3	Rush Island	Coal	Union Electric Company	1,204
4	Callaway	Nuclear	Union Electric Company	1,190
5	New Madrid	Coal	Associated Electric Coop, Inc.	1,160
6	Thomas Hill	Coal	Associated Electric Coop, Inc.	1,125
7	Sioux	Coal	Union Electric Company	986
8	Hawthorn	Coal	KCP&L	979
9	Meramec	Coal	Union Electric Company	951
10	Aries Power Project	Gas	Dogwood Energy, LLC	614

MW = Megawatt

7 Potential Heat and Power Loads

We investigated the possibility of using biomass to serve heat and electrical loads near the most-probable location of a biomass plant at the Municipal Farm site. In this section, we discuss the loads, and in Chapter 8, we present the results of the analysis of heating, power, and CHP systems to meet these loads.

Typically, a biomass plant should be sized based on electricity and/or heat demand from nearby loads. Figure 26, which is a duplicate of Figure 20, shows potential energy users near the proposed biomass facility. Thermal and electrical loads have been provided for the police helicopter unit, the Kansas City Armory, and the radio tower.[19] In addition, projected loads for a future greenhouse were also provided.

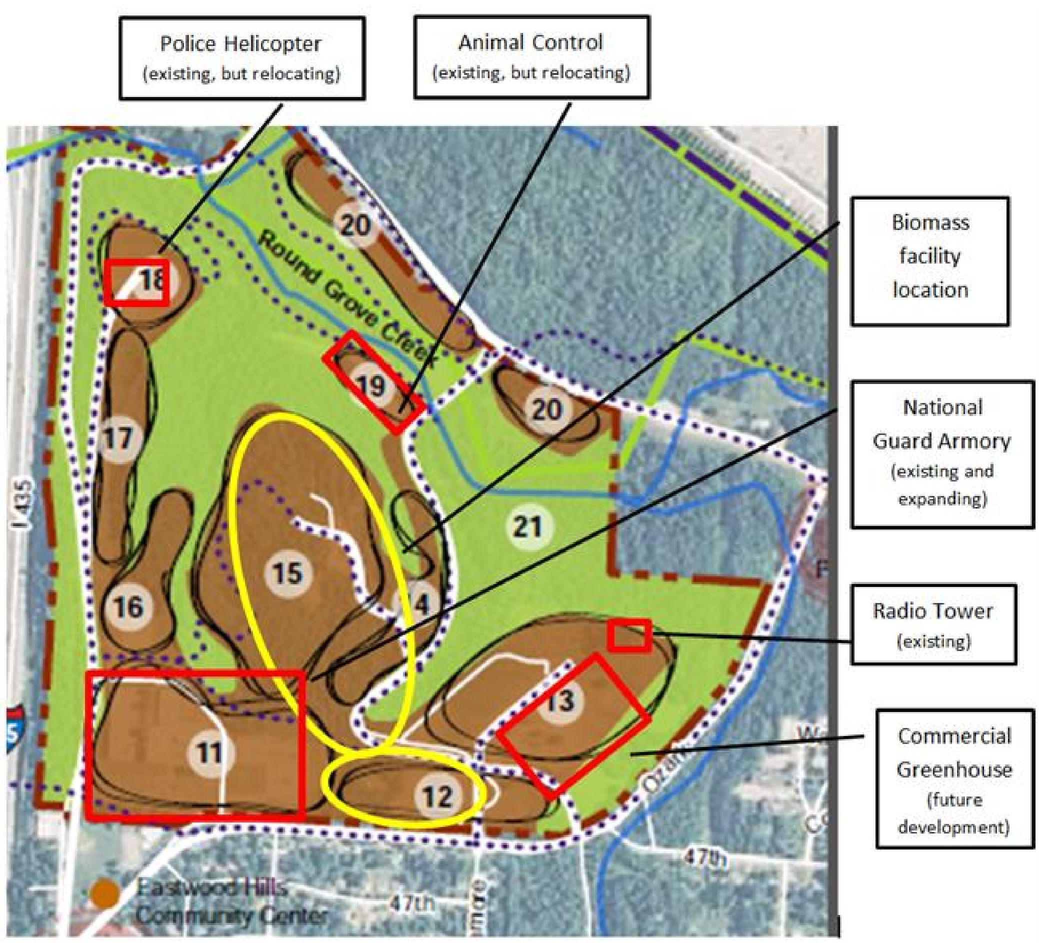


Figure 26. Potential loads near the proposed biomass CHP facility

For these facilities, the electrical load from October 2011 to September 2012 averaged approximately 77,000 kWh per month, for an hourly average of approximately 92 kW. The

[19] The radio tower has only an electrical load, no thermal load.

thermal load for the same period was approximately 2,700 therms[20] per month, with the peak months (December and January) reaching approximately 8,200 therms.

Individual facilities are described below.

7.1 Army National Guard Armory

An existing Army National Guard Armory facility is located in Area 11 of the Municipal Farm site. The size of the facility is approximately 83,000 square feet.

Of the facilities analyzed, the National Guard Armory is by far the largest electrical and thermal load. According to utility records supplied by the National Guard Armory, during a 12-month period the facility consumed an average of 750,000 kWh per year and 26,000 therms of natural gas per year. The City of Kansas City contacted the Missouri National Guard energy manager, who has indicated a willingness to discuss the possible use of renewable energy outputs to help reduce utility costs and meet agency goals for the utilization of renewable energy.

Funding was recently approved to expand the facility by adding 8,500 square feet (Bracker 2013). If the loads scale with the building size, this would increase the electrical load to approximately 825,000 kWh per year and the thermal load to approximately 29,000 therms per year.

The distance from the proposed biomass plant site to the National Guard Armory is approximately 1,000 feet.

7.2 Greenhouse

A proposal has been received from Missing Ingredient, LLC, to build a commercial greenhouse and headquarters/office building at the Municipal Farm site. The office building would be approximately 10,000 square feet, and the greenhouse would be approximately 100,000 square feet, with the option of adding a second building reserved for the future. It is likely that the greenhouse would be located in Area 13, next to the existing community garden (Bracker 2013). All of these facilities are shown in Figure 27.

Missing Ingredient has indicated in their development plan that they would like to include 100 kW of photovoltaic panels in addition to the greenhouse.

In addition to helping to meet thermal and electrical loads at the greenhouse, a biopower plant could supply CO_2 to the greenhouse to increase plant growth. For most greenhouse crops, the rate of photosynthesis increases with increasing CO_2 levels, up to a CO_2 level of approximately 1,300 parts per million (Ontario Ministry of Agriculture, Food, and Rural Affairs 2013). Other greenhouses have used biomass boilers to provide CO_2 to increase plant growth rate.

The commercial greenhouse is designed to include solar panels to supplement conventional power. The city has discussed the potential development of a biomass facility, and the greenhouse developers have indicated an interest in discussing the use of heat and possibly power.

[20] One therm is equal to 100,000 Btu. One hundred cubic feet of natural gas (1 CCF) is approximately 1 therm.

The distance from the proposed biomass plant site to the greenhouse site is approximately 1,100 feet. (If the plant is shifted south, that would reduce the distance to the largest loads—the armory and the greenhouse—which would reduce costs for construction and for operations and maintenance. This would probably make sense if no other large loads are to be located at the north end of the property. It might be even better to co-locate the biomass plant with the greenhouse and supply electricity, heat, and CO_2 directly to the greenhouse.)

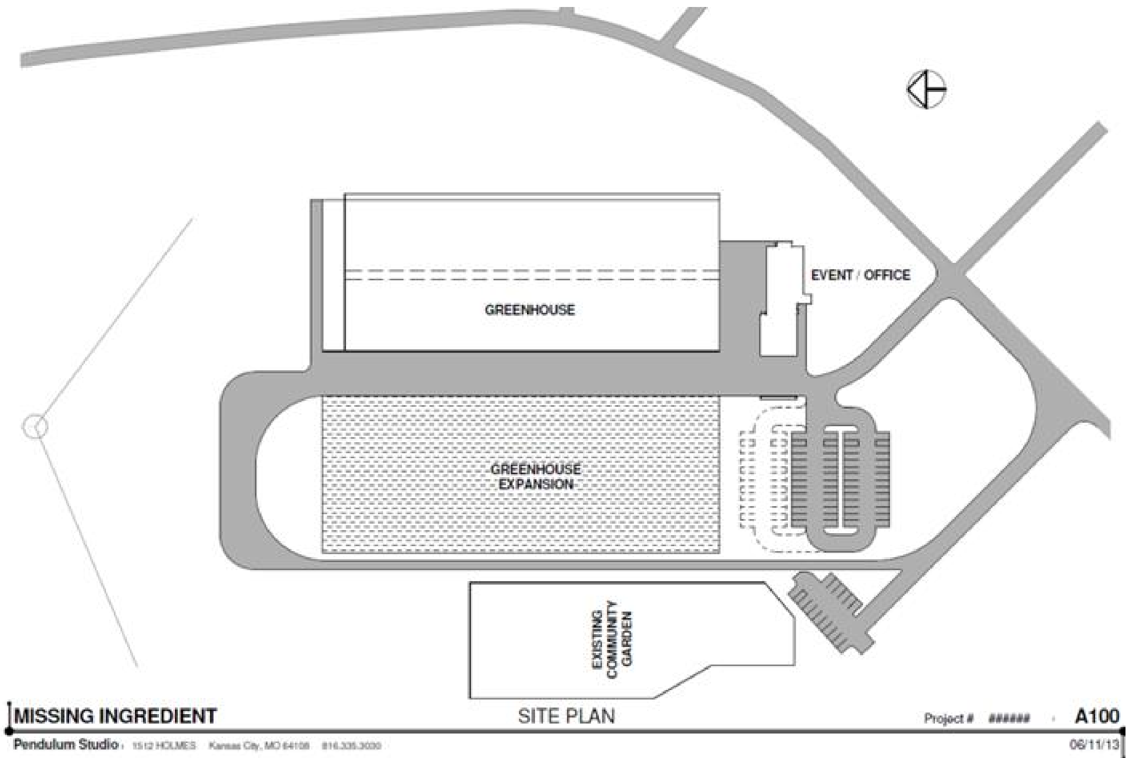


Figure 27. Greenhouse site plan

7.3 Other Loads

The existing animal shelter is expected to be relocated, so it was not included in this analysis. However, the Sustainable Reuse Plan recommends commercial or institutional redevelopment for Area 19, so a future utility load for the site is expected. The existing police helicopter facility in Area 18 utilizes an average of 163,000 kWh per year. Long-term plans include relocation of the police helicopter unit. The *Municipal Farm Sustainable Reuse Plan* recommends commercial or institutional redevelopment for Area 18 also, so a future utility load for this site is expected.

The distance from the biomass plant site to the animal shelter location is approximately 1,000 feet, and the distance to the police helicopter unit is approximately 1,700 feet.

7.4 Summary

The total current electrical loads for the site are shown in Table 5,[21] and thermal loads are shown in Table 6. Some utility data were unavailable at the time of this study, so an approximate analysis was performed. For the electrical analysis, we used data from October 2011 to September 2012 (except for the radio tower data, which was from 2013) to determine an annual energy load of 927 MWh per year and a peak monthly average power demand of 141 kW.

The thermal data is sparser than the electrical data. The highest loads occur in December and January, with use for both months at approximately 8,200 therms.

Table 5. Electrical Loads Near a Potential Biomass CHP Plant (Note that 2013 data were used for the radio tower for both years.)

Electrical	J	F	M	A	M	J	J	A	S	O	N	D	Monthly
Site	2011 kWh/month												average
Helicopter Unit (28) a	2,528	3,004	2,139	1,237	626	1,138	1,593	2,096	1,901	995	716	822	1,566
Helicopter Unit (28) b	13,600	14,000	12,000	10,560	10,400	12,000	12,080	14,320	13,040	10,000	10,000	12,400	12,033
Kansas City Armory	0	0	0	0	0	0	0	0	0	57,146	56,987	58,747	57,627
Animal Control?	0	0	0	0	0	0	0	0	0	0	0	0	0
Radio Tower (usage in 2013)	1,795	954	976	1,248	1,337	1,284	1,310	1,346	1,230	1,184	1,266	1,266	1,266
Greenhouse (estimated)	0												0
2011 Total	**17,923**	**17,958**	**15,115**	**13,045**	**12,363**	**14,422**	**14,983**	**17,762**	**16,171**	**69,325**	**68,969**	**73,235**	**29,273**
	2012 kWh/month												
Helicopter Unit (28) a	1,920	1,930	1,406	1,028	909	1,605	2,306	2,470	1,506	941	372		1,490
Helicopter Unit (28) b	12,640	11,840	11,280	10,240	11,520	11,600	13,680	15,120	13,040	10,880	10,480		12,029
Kansas City Armory	56,243	53,658	56,770	54,882	61,581	72,104	87,607	74,935	60,380				64,240
Animal Control?	0	0	0	0	0	0	0	0	0	0	0		0
Radio Tower (usage in 2013)	1,795	954	976	1,248	1,337	1,284	1,310	1,346	1,230	1,184	1,266	1,266	1,266
Greenhouse (estimated)	0												0
2012 Total	**72,598**	**68,382**	**70,432**	**67,398**	**75,347**	**86,593**	**104,903**	**93,871**	**76,156**	**13,005**	**12,118**		**67,346**
#days	31	28	31	30	31	30	31	31	30	31	30	31	365
kW avg	98	102	95	94	101	120	141	126	106	17	17		92

[21] An inventory of power loads and some heat loads at Municipal Farm has been created. Expected loads for the greenhouse have been provided, although installation of a photovoltaic system is being planned, to supplement power needs. However, some existing uses (such as the animal shelter and the small radio tower) have not been factored.

Table 6. Thermal Loads Near a Potential Biomass CHP Plant

Gas (therms/mo)	J	F	M	A	M	J	J	A	S	O	N	D	Monthly average
Site	**2011 (therms/mo)**												
Helicopter Unit (28) a	1,040	1,434	829	0	0	0	0	0	0	0	1,324	1,265	491
Helicopter Unit (28) b	1,137	1,567	906	0	0	0	0	0	0	0	1,447	1,382	537
Kansas City Armory	0	0	0	0	0	0	0	0	0	1,690	3,902	5,533	3,708
Animal Control?	0	0	0	0	0	0	0	0	0	0	0	0	0
Radio Tower (usage in 2013)	0	0	0	0	0	0	0	0	0	0	0	0	0
Greenhouse (estimated)	0												0
2011 Total	**2,176**	**3,001**	**1,735**	**0**	**0**	**0**	**0**	**0**	**0**	**1,690**	**6,672**	**8,180**	**1,955**
	2012 (therms/mo)												
Helicopter Unit (28) a	1,144	1,602	1,215	600	0	0	0	0	0				507
Helicopter Unit (28) b	1,250	1,751	1,328	656	0	0	0	0	0				554
Kansas City Armory	5,797	4,214	2,062	942	587	199	92	195	815				1,656
Animal Control?	0	0	0	0	0	0	0	0	0				0
Radio Tower (usage in 2013)	0	0	0	0	0	0	0	0	0				0
Greenhouse (estimated)	0												0
2012 Total	**8,192**	**7,567**	**4,605**	**2,198**	**587**	**199**	**92**	**195**	**815**	**0**	**0**	**0**	**2,717**
#days	31	28	31	30	31	30	31	31	30	31	30	31	
therms/hr avg	1.1	1.1	0.6	0.3	0.1	0.0	0.0	0.0	0.1	0.0	0.0		

7.5 Recommended Activities for the Next Level of Analysis

We recommend the following activities:

- Follow-up with the Army National Guard to assess their interest in purchasing heat and/or electricity from a biomass facility and to help estimate the increased future loads (Slade-Sevener 2013).
- Contact Missing Ingredient, LLC, to determine their expected loads and to assess their interest in purchasing heat, electricity, and CO_2 from a biomass facility.
- Estimate other potential thermal and electrical loads resulting from future development.

8 Potential Energy Generation

We performed preliminary evaluations for the use of three biomass technologies on the Municipal Farm site: heat only, electricity only, and CHP.

Biomass heating would be the simplest option for the site; there are several types of commercially available heat-only systems.

The biomass electric-only option would add considerable cost and complexity compared to the heat-only option; biomass CHP would be the most complex and have the highest costs.

Brief discussions of these options are provided below, starting with a system to provide only heat to the facilities. We then discuss electric-only systems and finish with CHP.

8.1 Heat Only

Several types of biomass heating systems are available, including simple woodstoves, pellet stoves, pellet furnaces, and outdoor wood boilers. For larger loads, a chip system is often best.

8.1.1 Analysis Results

RETScreen analyses were performed for three different configurations of buildings. The results and details are presented below. A more detailed analysis is presented in Appendix B: RETScreen Analysis of Biomass Heating.

8.1.1.1 Configuration 1

We first analyzed a biomass heating system serving three buildings—the armory (with expansion), the future greenhouse, and the helicopter unit—but the results of the economic analysis were negative for all system sizes.

For example, a 1.2-MMBtu/h wood boiler, supplemented by natural gas heat at each facility, resulted in a negative $600,000 net present value (NPV) over 25 years; and a 3.7-MMBtu/h biomass system serving the same facilities produced a negative $835,000 NPV. The poor economic results are largely because of high installation costs, which are increased by the long distance between the proposed boiler site and the helicopter units.

8.1.1.2 Configuration 2

We next eliminated the helicopter units and evaluated a system that would supply only the greenhouse and armory. If the biomass system location is chosen to minimize piping runs, these facilities would still be 700 to 900 feet from the biomass site.

The results of this analysis were a little better than those for Configuration 1, but still negative. Using a 1.6-MMBtu/h wood boiler, we estimated a 25-year NPV of -$430,000. The cost savings from using free fuel ($30,000 per year) would be partially offset by increased operations and maintenance costs, and the net savings would not be sufficient to offset the high capital and installation costs over a 25-year period.

A sensitivity analysis indicates that capital costs would have to decrease by more than 40% *and* natural gas costs would have to increase by more than 40% before a positive NPV could be achieved for this configuration.

8.1.1.3 Configuration 3

Our final analysis was for a single building. Because it had the largest heating load and the best chance for success, this analysis focused on the armory.

Heating a single building—and assuming that the heating system can be located directly in that building—eliminates the capital and maintenance costs for the distribution system, and it eliminates the energy losses associated with pumping the hot water over long distances.

Even with these advantages, the NPV for this configuration was still negative. We also performed a sensitivity analysis for this configuration and found that NPV is negative even when the initial costs are reduced by more than 50%.

8.2 Electric Only

A biomass power plant can be built to provide electricity either to an on-site load or for sale. Electricity can be sold to a local or distant load, but this will almost always involve one or more electric utility companies.

For the Municipal Farm site, we considered potential electricity generation from the available biomass.

As discussed previously, the current site load is approximately 100 kW. A system of this size would require between four and five tons of biomass per day—approximately 1,800 tons per year. This is generally too small for a steam system. Gasification systems in this size are under development—and have been for several years—but nothing in this size is commercially viable or economically feasible.

In Chapter 4, we presented data estimating that the leaf and brush collection is currently approximately 12,000 to 14,000 GT per year. By itself, this is sufficient to produce approximately 600 to 700 kW of electricity. With the projected additional 88,000 GT per year resulting from the collection of ash trees, the total production could be as high as 6 MW.[22] Unfortunately, the Missouri Public Utilities Commission does not allow a facility to generate more electricity than can be used at the site, either for sale to the utility or to a third-party customer (also known as distribution wheeling). It is our understanding that the City of Kansas City cannot be an energy reseller in the state, unless the buyer is also owned by the city.

[22] It is common practice to assume that not all of the existing biomass will be available for a specific installation. A biomass availability multiple (BAM)—the ratio of available fiber in a woodshed to the quantity of fiber required by a project—is typically used to estimate how much material can reliably be acquired for a project. Some of the identified resources may not be solvent long term, thus lenders and investors desire some insurance that enough fuel will be available on a long-term basis. If the amount of identifiable fuel is double or triple the requirement, lenders feel that the fuel risk is lower. Generally, a BAM of 3x or more supports a projection of long-term availability of sufficient woody biomass for the project at stable prices. A BAM of 3x means that significant impacts on feedstock cost over the long term are likely to be limited to changes in diesel fuel prices. If we assume a BAM of 3, we can expect a reliable feedstock to serve a 2-MW electric project based on available biomass data.

For these reasons and under the current conditions, biomass power is not recommended for the Municipal Farm site.

8.3 Biomass CHP

As discussed previously, a biomass CHP system could use either a backpressure turbine or an extraction turbine. The backpressure option would produce electricity proportional to the thermal energy demand. Because the demand is currently high only in the winter, this option would not make sense for serving the current loads.

An extraction turbine would need to be designed to serve the Municipal Farm site electrical and thermal loads, but, again, the electrical loads are too small to justify the cost of an extraction turbine.

9 Conclusions and Recommendations

Preliminary estimates of available low-grade biomass range from 12,000 to 102,000 GT per year. This is technically enough biomass to produce 600 kW to 6 MW of electricity. Unfortunately, the site load is only approximately 100 kW, and the City of Kansas City cannot be an energy reseller based on current regulations. Thus, neither biomass power nor CHP would be economically viable at the Municipal Farm site with the current loads.

Three building combinations were analyzed for biomass heating. Because of low loads, none of these analyses resulted in positive economic performance.

Based on current loads, our conclusion is that none of the biomass applications reviewed for the Municipal Farm site will produce positive economic returns, even with free biomass fuel.

This is not to imply that biomass will not work at the site. What is lacking is sufficient load. If the site is eventually built out to include facilities with high thermal demand in close proximity to a future biomass central plant, biomass could be a viable resource, particularly because it is already being collected by the city.

9.1 Summary of Key Recommended Activities

As stated previously, the loads and energy costs at the site—under current conditions—are not conducive to an economically viable biomass installation. If conditions change, the following steps should be taken. They are drawn from earlier sections of this report.

9.1.1 Biomass Feedstock

Contact foresters, wood utilization specialists, lumber mills, and others to obtain a firmer analysis of available biomass, biomass properties, and biomass cost.

Other potential sources of waste biomass include the pallet industry and the construction and demolition industry, and local nonprofits such as Heartland Habitat for Humanity ReStore should be consulted for waste materials that could be used in a larger biomass plant. In addition, crop residue might be considered as a supplement feedstock.

9.1.2 Loads

- Follow-up with the Army National Guard to assess their interest in purchasing heat and/or electricity from a biomass facility and to help estimate the increased future loads.
- Contact Missing Ingredient, LLC, to determine their expected loads and to assess their interest in purchasing heat, electricity, and CO_2 from a biomass facility.
- Estimate other potential thermal and electrical loads resulting from future development.

10 References

Biomass Energy Resource Center (BERC). (2011). "Woodchip Fuel Specifications in the Northeastern United States." Montpelier, VT. Accessed September 11, 2013: http://www.biomasscenter.org/images/stories/Woodchip_Heating_Fuel_Specs_electronic.pdf.

"BioSAT." (2007–2014). Perdue, J.H.; Young, Timothy, M. USDA Forest Service, Southern Research Station, and the University of Tennessee, Knoxville, TN. Accessed September 11, 2013: http://www.biosat.net/.

Bracker, A. (2011). "Kansas City Municipal Farm RE-Powering Application." Kansas City, MO.

Bracker, A. (Sept. 12, 2013). Personal communication with Bracker, A., Brownfields Coordinator, City of Kansas City, Missouri, Department of City Planning and Development, Urban Redevelopment Division.

Ontario Ministry of Agriculture, Food, and Rural Affairs. (2013). "Carbon Dioxide in Greenhouses." Fact Sheet. Accessed September 9, 2013: http://www.omafra.gov.on.ca/english/crops/facts/00-077.htm#f1.

City of Kansas City. (2007). "Missouri Organics Recycling Contract 2007–2010 (EVO356)." Kansas City, MO.

City of Kansas City. (2012). *Municipal Farm Sustainable Reuse Plan.* Kansas City, MO. Accessed May 2014: http://www.kcmo.org/idc/groups/cco/documents/citycommunicationsoffice/sustainablereuseplan.pdf.

Crawford, M. "Fluidized Bed Combustors for Biomass Boilers." American Society of Mechanical Engineers. Accessed September 11, 2013: https://www.asme.org/kb/news---articles/articles/boilers/fluidized-bed-combustors-for-biomass-boilers.

"Data Tables." (2013). Electricity: Electric Sales, Revenue, and Average Prices, EIA. Accessed September 11, 2013: http://www.eia.gov/electricity/sales_revenue_price/index.cfm.

DEFRA/BERR. (2007). *Renewable Heat Initial Business Case.* London: United Kingdom. Accessed September 9, 2013: http://webarchive.nationalarchives.gov.uk/+/http://www.berr.gov.uk/files/file41432.pdf.

"District Heat Montpelier." (2013). Montpelier, Vermont: The Official City Website. Accessed September 11, 2013: http://www.montpelier-vt.org/group/99.html.

"District Energy St. Paul." (2013). Accessed September 11, 2013: http://www.districtenergy.com/technologies/district-heating/.

"EIA 860 Detailed Data." (2013). Electricity, EIA. http://www.eia.gov/electricity/data/eia860/.

EPA. (2011). "Final Air Toxics Standards for Industrial, Commercial, and Institutional Boilers at Area Source Facilities." Fact Sheet. Accessed September 11, 2013: http://www.epa.gov/airquality/combustion/docs/20110221aboilersfs.pdf.

EPA CHP Partnership. (2007). *Biomass Combined Heat and Power Catalog of Technologies.* Accessed September 11, 2013: http://www.epa.gov/chp/documents/biomass_chp_catalog.pdf.

Federal Register. (2013). *Rules and Regulations.* Vol 78, no. 22, p. 7,518. Friday, February 1.

Fink, R.J.; Fink. R.L. (2006). *An Assessment of Biomass Feedstock Availability in Missouri.* Prepared for the University of Missouri Office of Special Programs, Missouri Department of Natural Resources, and the DOE/SSEB Southeast Biomass State and Regional Partnership. Accessed May 29, 2014: http://ded.mo.gov/energy/docs/biomass-inventory2005-07.pdf.

"Industrial/Commercial/Institutional Boilers and Process Heaters." (2013). Technology Transfer Network—Air Toxins Website, National Emission Standards, EPA. http://www.epa.gov/airtoxics/boiler/boilerpg.html

Kansas City Parks and Recreation. (2012). *Emerald Ash Borer and Its Impact to the Urban Forest of Kansas City, Missouri.* Kansas City, MO.

"Maps and State EAB Information." (2014). Emerald Ash Borer. USDA Forest Service, Michigan State University, Purdue University, and Ohio State University. http://www.emeraldashborer.info/map.cfm#sthash.zz8Q9xTX.hhvavNBf.dpbs.

"Missouri Information." (2013). Emerald Ash Borer. USDA Forest Service, Michigan State University, Purdue University, and Ohio State University. Accessed September 9, 2013: http://www.emeraldashborer.info/missouriinfo.cfm#sthash.cUHNCE0t.dpbs.

"Missouri State Energy Profile." (2014). EIA. http://www.eia.gov/state/print.cfm?sid=MO.

Myers, C.; Polak, D.; Stortz, L. (1975). *Full Tree Weight Equations and Tables for Selected Central Hardwoods.* Carbondale, IL: Southern Illinois University, pp. 7.

"Profile Overview." (2013). Missouri: State Profile and Energy Estimates, EIA. Accessed September 11, 2013: http://www.eia.gov/state/?sid=MO.

Shaw, M. (2012). "EPA RE-Powering Biomass Questionnaire—KCMO." June 6.

Slade-Sevener, M. (Sept. 16, 2013). Personal communication with Monica Slade-Sevener, Energy Program Analyst, Installations Division, ARNG-ILI-F.

Steltzer, H. (Feb. 10, 2014). Personal communication with Hank Stelzer, University of Missouri.

Thorson, J.; Christiansen, C.; Marek, B. (2011). "Experience on Low-Temperature District Heating in Lystrup, Denmark." Portoroz, Slovenia: International Conference of District Energy.

University of New Hampshire (UNH) Media Relations. (2007). "First University in Nation to Use Landfill Gas as Primary Energy Source." August 14. Accessed September 11, 2013: http://www.unh.edu/news/cj_nr/2007/aug/kb14landfill.cfm.

"Where EAB Has Been Found." (2014). Tree Pests: An Informative Service from the Missouri Invasive Forest Pest Council, University of Missouri Extension. Accessed May 29, 2014: http://extension.missouri.edu/emeraldashborer/kansascity.aspx.

"Wood2Energy." (2013). Accessed September 11, 2013: www.wood2energy.org.

11 Appendices

11.1 Appendix A: KCP&L Letter of Support

The utility serving the site, KCP&L, provided the following letter of support for this project.

KCP&L
energizing life

May 18, 2011

Mayor Sylvester James
City of Kansas City, Missouri
City Hall, 29th Floor
414 E. 12th Street
Kansas City, Missouri 64106

Re: Kansas City Municipal Farm Renewable Energies Feasibility Study

Dear Mayor James:

Kansas City Power & Light Company (KCP&L) is familiar with your plans for applying to the Environmental Protection Agency (EPA) for the Municipal Farm Renewable Energies Feasibility Study. It is KCP&L's intent to monitor the progress of the proposed project and associated studies. Further, KCP&L will continue to dialogue with the City of Kansas City, Missouri in an effort to find ways to collaborate on renewable project opportunities at this site.

KCP&L is supportive of initiatives that enable the development of sustainable energy resources and will continue to work with the City in furthering renewable energy production initiatives in Missouri.

Sincerely,

C A Caisley

Chuck Caisley
Vice President
Marketing & Public Affairs

11.2 Appendix B: RETScreen Analysis of Biomass Heating

We used the RETScreen[23] program to analyze three biomass heating cases: (1) the Army National Guard Armory, a greenhouse, and helicopter units; (2) the National Guard Armory and a greenhouse; and (3) the National Guard Armory only. Results of the second analysis—a heating system to serve the National Guard Armory (with expansion) and the (future) greenhouse—are shown below.

11.2.1 Building Heating Loads

Table 7 shows the building details used for the base case, in which natural gas is used to heat both facilities. (Building 1 is the greenhouse, and Building 2 is the armory). The biomass case is compared to this base case.

Table 7. Building Details and Thermal Loads—Base Case

Base case heating system	Multiple buildings - space heating		Building clusters	
			1	2
Heated floor area per	ft²	191,500	100,000	91,500
Number of buildings ir	building	2	1	1
Fuel type			Natural gas - therm	Natural gas - therm
Seasonal efficiency	%	-	80%	80%
Heating load calculation				
Heating load for buildi	(Btu/h)/ft²	-	5	23.3
Domestic hot water h	%	15%		
Total heating	million Btu	2,837	539	2,298
Total peak heating loa	million Btu/h	3	0.5	2.1
Fuel consumption - unit		-	therm	therm
Fuel consumption - annual		-	6,736	28,721
Fuel rate - unit		-	$/therm	$/therm
Fuel rate		-	0.855	0.855
Fuel cost		$ 30,316	$ 5,759	$ 24,557

For this system, we estimated that a 1.6-MMBtu/h boiler would provide 95% of the annual load. Individual natural gas heaters in each building would serve as backup units and would provide the remaining 5% of the heating load.

11.2.2 Cost Estimates

Including distribution piping, a biomass heating system, fuel storage, feasibility studies, and engineering, we estimated a total initial cost of slightly less than $700,000. We estimated

[23] RETScreen is a software program developed by Natural Resources Canada in collaboration with international partners including NASA, REEEP, UNEP, and others. It is available at http://www.retscreen.net/.

operations and maintenance costs of approximately $6,000 per year[24] and natural gas fuel costs of $1,700 per year.

11.2.3 Financial Analysis

Table 8 shows the financial parameters used in the analysis. We also assumed that the debt would be zero, meaning that no money would be borrowed to pay for the project.

Table 8. Financial Parameters Used in the Analysis

Financial parameters		
General		
Fuel cost escalation rate	%	2.0%
Inflation rate	%	2.0%
Discount rate	%	9.0%
Project life	yr	25

Table 9 shows the results of the financial analysis. Note that the NPV is negative, as are the annual life-cycle savings.

Table 9. Results of the Financial Analysis

Financial viability		
Pre-tax IRR - equity	%	0.2%
Pre-tax IRR - assets	%	0.2%
After-tax IRR - equity	%	0.2%
After-tax IRR - assets	%	0.2%
Simple payback	yr	30.3
Equity payback	yr	24.3
Net Present Value (NPV)	$	-428,794
Annual life cycle savings	$/yr	-43,654
Benefit-Cost (B-C) ratio		0.37
Debt service coverage		No debt

Table 10 shows the yearly cash flows, starting in year 0, for the 25-year life of the project. Annual cash flows just start to become positive in year 25.

[24] This does not account for any other costs for operating the biomass system, such as personnel time to deliver fuel to the site, or to load wood chips to the fuel bunker, or to do a daily walk-through of the facility. If costs need to be assigned to these activities, that will further degrade the economic results.

Table 10. Yearly Cash Flows

Yearly cash flows			
Year	Pre-tax	After-tax	Cumulative
#	$	$	$
0	-685,565	-685,565	-685,565
1	23,086	23,086	-662,479
2	23,548	23,548	-638,930
3	24,019	24,019	-614,911
4	24,499	24,499	-590,412
5	19,469	19,469	-570,943
6	25,489	25,489	-545,454
7	25,999	25,999	-519,455
8	26,519	26,519	-492,936
9	27,049	27,049	-465,886
10	21,495	21,495	-444,391
11	28,142	28,142	-416,249
12	28,705	28,705	-387,544
13	29,279	29,279	-358,265
14	29,865	29,865	-328,400
15	23,733	23,733	-304,667
16	31,071	31,071	-273,596
17	31,693	31,693	-241,903
18	32,327	32,327	-209,577
19	32,973	32,973	-176,604
20	26,203	26,203	-150,401
21	34,305	34,305	-116,096
22	34,991	34,991	-81,105
23	35,691	35,691	-45,413
24	36,405	36,405	-9,009
25	28,930	28,930	19,921

11.2.4 Sensitivity Analysis

All of the estimates provided for capital and operations costs have a high margin of error. We performed a sensitivity analysis to see how the net present value would change over a range of capital costs and of natural gas costs. The sensitivity analysis results are presented in Table 11.

Table 11. Sensitivity Analysis for NPV

Perform analysis	Net Present Value (NPV)					
Sensitivity range	30%					
			Initial costs			$
Fuel cost - base case		479,895	582,730	685,565	788,400	891,234
$		-30%	-15%	0%	15%	30%
21,221	-30%	-330,435	-433,270	-536,105	-638,940	-741,774
25,769	-15%	-276,780	-379,615	-482,450	-585,284	-688,119
30,316	0%	-223,125	-325,960	**-428,794**	-531,629	-634,464
34,863	15%	-169,470	-272,304	-375,139	-477,974	-580,809
39,411	30%	-115,814	-218,649	-321,484	-424,319	-527,153

Throughout the range of costs examined, the NPV for this project is negative, even if fuel costs increase by 30% and initial costs drop by 30%. In fact, both amounts would have to change by more than 40% before the NPV becomes positive.