COLUMBIA UNIVERSITY
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FEASIBILITY REPORT FOR BIOMASS ENERGY PLANT IN BERLIN, NEW YORK

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The capstone workshop is a client-based consulting project that students undertake to address critical sustainability management issues. The workshop is specially designed to integrate the program's distinct curriculum areas, including: integrative sustainability management, economics and quantitative analysis, environmental sciences, engineering, and planning, general and financial management, and public policy.

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EXECUTIVE SUMMARY

The small town of Berlin in central New York State, like many other towns around the United States, faces a dwindling economy owing to closure of industries, diminishing employment opportunities and an aging population. Berlin hopes to promote job creation, support growing industry and promote sustainable forestry practices by building a biomass energy plant that utilizes the region's abundant forests. A biomass energy plant can use woody biomass, trees and woody plants that are the by-products of sustainable forest management, as input to produce electricity, heat or fuel. This study researches the feasibility of building such a biomass energy plant in the town of Berlin, New York.

DETERMINING THE ENERGY LOAD AND PLANT SIZE

Preliminary research of biomass energy plants indicated that a wide variety of technologies was available for conversion of woody biomass to energy and that biomass energy plants existed in varying sizes, in terms of energy generation capacity. A necessary first step, therefore, was to determine the size of a potential plant in Berlin by using the town's current and future energy loads. Using New York State aggregate data, the current heat and electricity loads for the town were estimated; electricity load was found to be 50.39 MWh / day (Megawatt hours per day) and heat load was found to be 78.24 MWh /day. In terms of plant capacity, this translated to a 2.5 MW capacity power plant that will be able to meet the town's existing load. The possibility of additional electricity and heat load for the future was also considered, either in the form of energy demand from an aquaponics farm currently under construction in Berlin or through potential future industry. This additional future load was found to be 240 MWh/day of electricity & heat load, which translated to an additional 10MW of generation capacity. In sum, it was determined that a 2.5 MW plant could cater to Berlin's existing energy loads, while a 12.5 MW plant will be able to meet both existing and future anticipated loads.

AVAILABILITY OF WOODY BIOMASS RESOURCES AND HARVESTING IMPACTS

Understanding the potential plant size for Berlin led to the next step of the feasibility analysis, the availability of sufficient wood resources to serve as input for a biomass energy plant. Research of Berlin's surrounding forest resources and the types of suitable wood and quantities of wood required for a biomass energy plant was undertaken. It was found that within a 50 and 100 mile radius of Berlin, there is a positive average annual net change in volume, which indicates that the growth rate of trees exceeds the removal rate. Hence, sufficient quantities of woody biomass resources were found to be available to support a biomass energy plant in Berlin.

However, harvesting of wood resources from nearby forests could have potential positive and negative impacts on the ecological health of the forests and could impact the continued availability of woody biomass resources for the energy plant. Various sustainability considerations of biomass harvesting must be examined, in particular the issue of carbon neutrality and its impact on climate change. Concerns over climate change are increasingly shaping global policy and initiatives and carbon emissions from energy generation assume center stage in such discussions. In the context of biomass energy, carbon neutrality refers to the idea that the amount of carbon released from the burning of biomass is balanced by the capture of carbon by trees that utilize carbon dioxide for photosynthesis. While the carbon neutrality of biomass energy production is highly debated, further analysis found that biomass, a form of renewable energy, is not carbon neutral, though existing policy might indicate otherwise. Considering the sustainability implications of biomass harvesting, it is highly recommended that a sustainable forest management plan be implemented to ensure the continued regeneration of woody biomass resources and to reduce biomass' impacts on climate change.

TECHNOLOGY OPTIONS FOR BIOMASS ENERGY CONVERSION

Converting woody biomass resources into energy can be done through the use of many different types of technologies; the woody biomass resources used as input in an energy plant are referred to as feedstock. This study considered five major available technologies: combustion, gasification, combined heat and power (CHP), co-firing and liquid biofuels (ENSYN). The technologies considered produced energy in the form of electricity, heat or fuel or a combination of these. However, it was determined early on that a co-firing energy plant requires an existing power plant operating on coal; in the absence of such a plant in Berlin, this technology option was eliminated from further analysis. The remaining four technologies had their respective operational parameters along with positive and negative impacts based on multiple factors. This led to a deeper investigation of such factors to determine the best technology option for Berlin.

DETERMINING THE BEST TECHNOLOGY OPTION

Crucial qualitative factors were found to be pertinent to the operations and sustainability of a biomass plant. Qualitative factors, classified into five broad categories were studied: environmental factors (emissions, waste generation, air pollution and pollution control technologies required), policy incentives (available incentives for technology options), social factors (health and safety impacts and jobs created, aesthetic impacts), siting and infrastructure factors (infrastructure requirements and water requirements) and operational factors (feedstock requirements, plant efficiency and feedstock variability). Analyzing the qualitative factors in the context of technology options as well as Berlin's requirements and constraints, resulted in a ranking system to determine the best option for Berlin based on qualitative scoring. This ranking system favored a 12.5 MW CHP biomass energy plant. Figure 0-1 shows the ranking of technology options based on qualitative scoring.

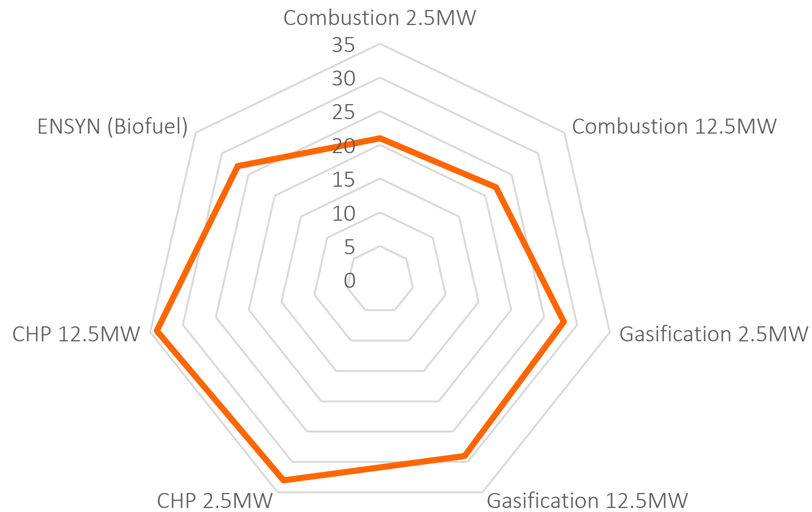

Figure 0-1: Qualitative scoring of technologies

ECONOMIC IMPACTS AND FINANCIAL FEASIBILITY

To further determine the feasibility of this potential CHP 12.5 MW plant in Berlin, a quantitative analysis was performed to examine its economic impacts analysis and financial feasibility. Using the Jobs and Economic Development (JEDI) model, it was found that the ongoing operations of the biomass plant would support 15 direct employees. It would also support 18 indirect jobs outside the plant, which includes two major types: those within the biomass plant's supply chain, such as at logging companies, and those at companies that benefit from the spending of biomass plant employees such as at local restaurants, hotels, and healthcare. Overall, the biomass plant could yield an annual increase in employment in the form of 33 jobs and an economic output of almost $4.5 million annually. The construction cost for the plant would be an estimated $70.9 million, based on National Renewable Energy Lab (NREL) data. The construction period would provide 83 jobs. Under a base case set of assumptions, the results of the financial analysis indicated that the biomass plant would have a positive project Net Present Value when supplying electricity above $0.125/kWh. That breakeven NPV can be lowered to $0.10/kWh if reasonable amounts of subsidies are included. However, the current retail price of electricity available in the town of Berlin is $0.065, a level that could not be feasibly matched by the plant under any currently defensible assumptions.

CONCLUSION

Based on the quantitative analysis, the potential biomass energy plant was not found to be feasible under the present circumstances. A variety of factors could affect the future feasibility of a Biomass Energy Plant in Berlin, NY. Perhaps the most prominent is the potential change in electricity prices. If market conditions shifted and electricity prices within the town of Berlin moved from their current price at $0.065/kWh to $0.10/kWh, while all other factors (feedstock price, incentives) remained the same, the proposed biomass energy plant would approach feasibility. A shifting policy landscape that favored biomass energy production could also move this project toward feasibility.

RECOMMENDATIONS AND NEXT STEPS

- Remain in close contact with federal (USDA) and state (NYSERDA) agencies to keep abreast with changing policy and incentive landscape that could offset both production and operational costs of the plant
- Monitor forecasts for electricity prices, understanding that $0.10/kWh is the feasibility threshold for this particular plant and size
- Seek out private investment capital to offset construction capital costs
- Develop a Forest Management Plan (FMP) that contains best management practices (BMPs) to ensure genuine regenerative forest growth and have the ability to sequester maximum possible amount of carbon released as a result of the biomass energy plant
- Build in additional costs of emissions mitigation technology for the proposed plant to reduce emissions
- Consider siting criteria and suggested recommendations for the proposed plant

- Explore the possibility of developing a pellet plant, as opposed to a biomass energy plant. This facility would utilize the abundant local forest resources to provide a local source of pellets for town residents to use in their home heaters

Although it is not recommended that Berlin pursue building a biomass energy plant in current conditions, it could be possible in the future as several market and policy factors change. It is therefore important for the town to understand the options available for this type of project and to revisit this topic again in the future.

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ABBREVIATIONS

BACT	Best Available Control Technology
CAA	Clean Air Act
CHP	Combined Heat and Power
ESP	Electrostatic Precipitator
IRENA	The International Renewable Energy Agency
IRR	Internal Rate of Return
MACRS	Modified Accelerated Cost-Recovery System Depreciation
NREL	National Renewable Energy Laboratory
NPV	Net Present Value
NYS DEC	New York State Department of Environmental Conservation
NYSEG	New York State Electric & Gas Corporation
NYSERDA	New York State Energy Research & Development Authority
NYSWET	New York Statewide Wood Energy Team
PM	Particulate Matter
PPA	Power Purchase Agreement
PSD	Prevention of Significant Deterioration
RBEG	Rural Business Enterprise Grants
REAP	Rural Energy for America Program
REC	Renewable Energy Certificates
REDLG	Rural Economic Development Loan and Grant
RGGI	Regional Greenhouse Gas Initiative
US DOE	United States Department of Energy
US EPA	United States Environmental Protection Agency
USDA	United States Department of Agriculture
USFC	United States Forest Service
VOC	Volatile Organic Compounds

GLOSSARY OF TERMS

Biomass	Biomass most often refers to plants or plant-based materials and can be used as a source of energy.
Biomass feedstock	Refers to any renewable, biological material that can be used directly as a fuel, or converted to another form of fuel or energy product. In the context of this study, biomass feedstock typically refers to woody biomass as a raw material, unless specified otherwise.
Feedstock	A feedstock typically means raw material to supply or fuel a machine or industrial process.
IRR	IRR is a metric measuring the profitability of potential investments. Internal rate of return is a discount rate that makes the NPV of all cash flows from a particular project equal to zero. Generally speaking, the higher a project's internal rate of return, the more desirable it is to undertake the project. [1]
NPV	NPV is the difference between the present value of cash inflows and the present value of cash outflows. NPV is used in capital budgeting to analyze the profitability of a projected investment or project. Generally, an investment with a positive NPV will be a profitable one and one with a negative NPV will result in a net loss. [2]
PPA	PPA is a contract between two parties, one which generates electricity (the seller) and one which is looking to purchase electricity (the buyer). Generally, PPAs may be appropriate in cases where the projected revenues of the project are uncertain and so some guarantees as to quantities purchased or price paid are required to make the project viable or in cases where the purchaser wishes to secure security of supply. In the U.S., PPAs are typically subject to regulation by the FERC.[3]
REC	RECs also known as “green tags,” “green certificates,” and “renewable energy credits,” are tradable instruments which can be used to meet voluntary renewable energy targets as well as to meet compliance requirements for renewable energy policies. [4]
Sustainability	Meeting the needs of current generations without compromising the ability of future generations to meet their own needs.[5]
Woody biomass	The trees and woody plants, including limbs, tops, needles, leaves, and other woody parts, grown in a forest, woodland, or rangeland environment, that are the by-products of forest management. [6]

1 “Internal Rate of Return”, Investopedia, Accessed April 29, 2016 < http://www.investopedia.com/terms/i/irr.asp>
2 “Net Present Value”, Investopedia, Accessed April 29, 2016 < http://www.investopedia.com/terms/n/npv.asp>
3 “Power Purchase Agreements”, Wikipedia, Accessed April 29, 2016 < https://en.wikipedia.org/wiki/Power_purchase_agreement>
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5 Brundtland Commission, Sustainable development, 1987
6 USFS. 2008. Woody Biomass Utilization. Accessed August 10, 2011. <http://www.fs.fed.us/woodybiomass/whatis.shtml>

1. INTRODUCTION

1.1 BERLIN – A BRIEF HISTORY AND OVERVIEW OF PRESENT NEEDS

Berlin is a small town located in central New York in the eastern most portion of Rensselaer County, at the border with Massachusetts. Figure 1-1 shows Berlin's geographic location in relation to surrounding towns and states. A community rich in history, traditions and natural resources, Berlin was first settled in 1765. [1]

Figure 1-1: Location of Berlin, Source: Google Earth

The Little Hoosick River that runs through Berlin gave the valley fertile soils, which along with Berlin's ample forests and abundant water resources allowed Berlin to quickly develop settlements and industries. By the middle of the nineteenth century, the town had three village areas that housed many stores and small factories to supply its residents and those from the surrounding Rensselaer County. The Rutland Railroad line traditionally supported the town's thriving commerce.

However, throughout the last half of the twentieth century, Berlin has experienced an economic downturn that mirrors that of many small, rural American towns. The loss of the railroad and the slow decline of businesses has resulted in limited job opportunity and population stagnation. The population has hovered between 1,400 and 1,900 over the past few decades, with a current population of approximately 1,880 (2010 Census). Table 1-1 shows Berlin's population and the comparative age make up of its residents. The median age in Berlin has been increasing over the past 4 decades and currently stands at 44.6 years, indicating an aging population and an outflow of young people from the town to other parts of the state and country.[2]

Table 1-1: Population and comparative age makeup of Berlin [3]

Year	Population	Change in Population	Residents ages 0-19	Residents ages 20-44	Residents ages 45-64	Residents ages 65 and over	Median Age of Population
1980	1,696	--	581	565	339	211	30.8
1990	1,929	13.70%	638	678	373	240	31.4
2000	1,901	-1.50%	585	618	440	258	37.5
2010	1,880	-1.10%	457	496	589	338	44.6

Industry has also slowed in the town, resulting in a decline of commerce and employment. Berlin's identity has been reinvented several times, from agrarian to industrial to floral capital; the town is presently in a state of flux and is looking for ways to improve the local economy.[4] Currently, the largest employer in the town is the central school district, with more than 200 employees. Other employers, including small businesses employ less than 20 people. A landscaping and mulch based industrial facility called Green Renewable, Inc. is currently operating in Berlin. It uses naturally available wood resources available in the area to produce a wide range of wood-based products. A large scale hydroponic and aquaponic farm, Sustainable Aqua Farms, is presently under construction in Berlin.

BERLIN'S PRESENT NEEDS

In light of the challenges that the town has experienced, the town of Berlin hopes to leverage its abundant natural resources and sound infrastructure to attract new industry, create jobs, and retain its younger generations.

BERLIN'S AVAILABLE NATURAL RESOURCES AND INFRASTRUCTURE

The town of Berlin is well endowed with abundant natural resources, benefitting from its location between the Taconic Mountain Range and Rensselaer Plateau. Rain and snow melt feed underground aquifers, the Hoosick River, and many ponds and lakes in the region, making water readily available.[5] Additionally, there are abundant forest resources in the region, with estimates showing 64% timberland[6] coverage within a 50-mile radius of Berlin,[7] making it an ideal location for forest-related industries.

Berlin also benefits from existing infrastructure that could support future industry, including roads, water and power lines. Some infrastructure, however, may need to be modified, upgraded or even added to, to support the needs of future industry.[8] The electric system in Berlin is owned by New York State Electric and Gas (NYSEG). It is above ground, making it susceptible to weather outages and overgrown trees.[9] The town's heating needs are met by the use of propane, wood, and electricity; no natural gas service is currently provided in Berlin.[10] While abundant water resources exist in Berlin, the town's water infrastructure is in need of repair, and could additionally benefit from a more efficient and up-to-date metered billing system.[11] The sewer system is a combination of individual septic tanks, pump out tanks or a sand filter system; there is no town public sewer system. Technology-related infrastructure like cellular and internet service is increasing in the town, but not ubiquitous.[12]

1.2 BIOMASS ENERGY PLANT

The Town of Berlin is looking to revitalize its economy and community by creating jobs in the town and attracting new industry and businesses. To do so, the town intends to explore the development of a biomass energy plant as a potential solution. A biomass energy plant would make use of the abundantly available forest resources surrounding Berlin, converting woody biomass to energy to support future industry. Such a plant would add employment across its supply chain and provide other ancillary benefits in the form of increased commerce and attraction of other industries and businesses. Additionally, it would provide a source of renewable energy in the form of electricity and/or heat for its residents. It is the intent of this report to explore the economic, social, and environmental feasibility of this energy plant.

1.3 AN OVERVIEW OF BIOMASS

Biomass, the solid matter in biological organisms, is the oldest source of renewable energy in the world.[13] It is often considered a renewable energy source because the energy contained within biomass comes from the sun and because biomass can regrow over a relatively short period of time (a few years) compared with the millions of years it takes to form fossil fuels.[14]

Woody biomass refers to trees and woody plants, including limbs, tops, needles, leaves, and other woody parts, grown in a forest, woodland or rangeland environment, that are by-products of forest management[15]. Woody biomass supplies nearly 2 billion people with heat and cooking fuel across the world[16]. In the U.S., wood is used to supply 1% of the electricity supply and 2% of primary energy, mainly to industrial users.[17]

As the world population increases, global energy use continues to rise. Major concerns exist regarding the burning of fossil fuels and the resulting carbon dioxide emissions. The use of woody biomass is becoming more prevalent as a replacement fuel,[18] since it is considered a renewable energy source that can provide a combination of heat and electricity to local communities with relatively more accessible feedstock. As an alternative to fossil fuel, the use of biomass faces several challenges. Biomass is considered an important option for energy because of its potential for increased energy security, job creation and initiatives for rural development.[19] However, increasing the demand for woody biomass energy production may severely affect wildlife, cleanliness of water, purity of air and other recreational values offered by this natural resource.

Historically, overuse of forest resources has caused communities to be cautious when considering use of wood biomass for energy.[20] If not managed and monitored correctly, biomass can be harvested at unsustainable rates, damaging ecosystems, producing harmful air pollution, consuming large amounts of water, and producing emissions that contribute to climate change.[21]

While the debate around sustainable and acceptable levels of forest biomass harvesting continues, the biomass industry, and more specifically woody biomass energy, has benefited from a variety of federal, regional, and local policy initiatives and incentive programs designed to look further at the potential of woody biomass to produce a larger percentage of U.S. energy. New technologies designed to more efficiently and cleanly extract energy have been developed. However, the financial viability of biomass energy projects is very highly interlinked to the prevailing oil and gas prices in the market.[22] Given the current oil prices well below $40 per barrel, many biomass-based power plants are shutting down as they become economically uncompetitive.[23]

1.4 STUDY METHODOLOGY

The feasibility of a biomass energy plant depends on a wide range of variables, and can be approached in a number of different ways. For the purposes of this report and based on the needs put forth by the town, the following approach was implemented.

Preliminary research was conducted by the team to gain a broad understanding of the biomass industry. Such research indicated that biomass energy plants exist in varying sizes (in terms of megawatts of energy output) and use a variety of different technologies for energy conversion.

To better understand the energy demand in Berlin and, consequently, the expected size for a biomass energy plant in Berlin, an approximate energy demand was calculated. Details of the calculation are presented in Section 2. Subsequently, research was performed to determine the availability of forest resources that would service the plant. Discussion and analysis of the availability of wood resources is presented in Section 3. Procuring wood resources for the proposed biomass plant creates positive and negative impacts on the forests and such issues were examined and have been included in Section 3.2 and Appendix 1.

The type and quantity of wood resources used and the energy produced were found to depend on the technology employed. To gain deeper insight into different technology options, forty-eight biomass energy plant case studies from New York State, the U.S. and around the world were examined. A list of examined case studies is presented in Appendix 8. A diverse array of plants operating with different technologies was examined to gain an understanding of the range of issues that could potentially impact the feasibility of the Berlin plant.

Five major technologies emerged from examination of the case studies: combustion, gasification, co-firing, combined heat and power (CHP) and biofuels. An overview of each technology is presented in Section 4. One technology option, co-firing, could be easily eliminated from further consideration. However, all other technology options warranted a deeper investigation of their potential feasibility for the town of Berlin.

Crucial factors impacting the feasibility and sustained operation of the potential biomass energy plant were examined. The most important qualitative factors were determined through research and conversations with the town. Subsequently, each technology was given a score and ranked from worst to best based on these factors. A discussion of the qualitative factors and ranking of technologies is presented in Section 5.

Upon identifying the most appropriate technology option for Berlin, a robust quantitative analysis was undertaken to determine the financial feasibility of the proposed biomass energy plant. Detailed discussions of the economic factors that may impact the plant and the quantitative model used to determine its financial feasibility have been presented in Section 6. Ultimately, a final recommendation was arrived at, discussing the feasibility of building a biomass energy plant in Berlin. The team's conclusion and recommendations are presented in Section 7.

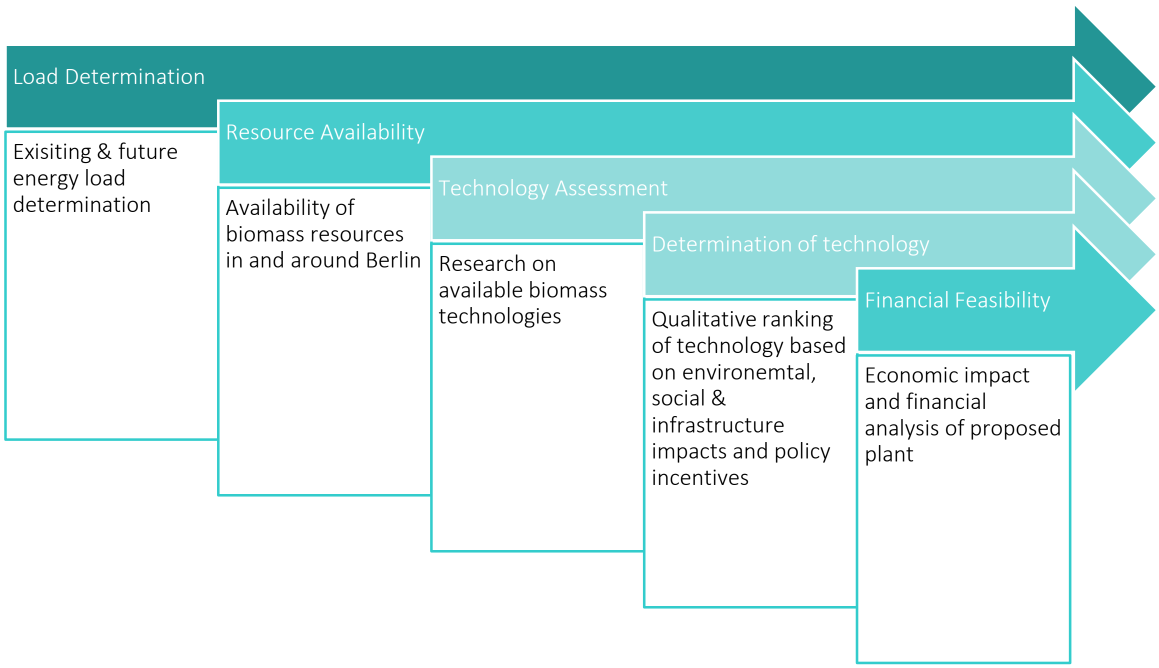

Figure 1-2: An overview of the steps employed to determine feasibility study

1 Robert C. Jaeger, et al., Comprehensive Plan: Town of Berlin, Final Draft, 2011 (Berlin, New York)
2 ibid
3 ibid
4 ibid
5 Robert C. Jaeger, et al., Comprehensive Plan: Town of Berlin, Final Draft, 2011 (Berlin, New York)
6 Timberland is a subset of Forest Land that does not include forested land off-limits to harvesting due to regulations or management directives
7 Forest Research Group, Fiber Study, June 2015
8 Robert C. Jaeger, et al., Comprehensive Plan: Town of Berlin, Final Draft, 2011 (Berlin, New York)
9 ibid
10 ibid
11 ibid
12 ibid

13 “How Biopower works”, Union of Concerned Scientists, Updated November 12, 2015, Accessed on May 01, 2016 <http://www.ucsusa.org/clean_energy/our-energy-choices/renewable-energy/how-biomass-energy-works.html#.VyZjr_krLrc>
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15“What is Woody Biomass Utilization?”, US Forest Service, accessed April 14,2016, < http://www.fs.fed.us/woodybiomass/whatis.shtml>
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19 Linking Renewable Energy to Rural Development, Organisation for Economic Co-operation and Development, 2012, Accessed May 1st, 2016
20 Massachusetts Environmental Energy Alliance, The Harmful Impacts of Biomass Energy Generation: Undermining the Fight Against Global Warming, www.massenvironmentalenergy.org/docs/biomassfactsheet, accessed Match 17, 2016
21 Stewart, William, Powers, Robert F., McGown, Kathyrn, Chiono, Lindsay, Chuang, Teresa, Potential Positive and Negative Environmental Impacts of Increased Woody Biomass Use for California, State of California Energy Commission, July 2011, Accessed February 5th, 2016
22 Ron Kotrba, “The Untold Upside of Low Oil Prices”, Biomass Magazine, December 27, 2015, Accessed on May 01,2016 < http://biomassmagazine.com/articles/12691/the-untold-upside-of-low-oil-prices>
23 Staff Reports, “Two Maine biomass plants to go offline…”, Portland Press Herald, January 7, 2016, Accessed April 20, 2016 <http://www.pressherald.com/2016/01/07/two-maine-biomass-plants-to-go-offline/>

2. DETERMINING PLANT SIZE

An important initial step in determining the feasibility of a biomass energy plant is determining the size (i.e. generation capacity in Mega Watts) of such a plant. This process begins with a determination of the current and expected electricity and heat loads in the area to be served by the plant. This section details the load calculation for the town of Berlin.

Heat and electricity loads for Berlin have been calculated based on the town's current population of 1880[1] people and the existing loads from residential, commercial, school and anticipated new industrial consumption. The average consumption was based on New York State data from the U.S. Energy Information Authority. The information in the following tables was used to calculate both residential and commercial loads for the town.[2]

Table 2-1: Estimated Berlin electricity & heat Consumption

	Berlin Statistics (2010)[3]	New York State Energy Consumption Statistics		Estimated Berlin Energy Consumption	
		Heat	Electricity	Heat (MWh/day)	Electricity (MWh/day)
Residential Households	789	15,120 kWh/day[4]	14,051 kWh/day[5]	54.24	16.86
Schools in the District	2			8	1.50
Commercial Establishments	10	6,101 kWh/month[6]		8	2.03
Current Industrial Establishments	2			8	30.00
Proposed Industrial Establishment	1	10 MW[7]	10 MW[8]	240	240
Current Overall Consumption in kWh/day (Potential Overall Consumption kWh/day)				78.24 (318.24)	50.39 (290.39)
Current Capacity in MW) (Potential Capacity in MW)				3.26 ~ **3.5** (13.26 ~ **13.5**)	2.1 ~ **2.5** (12.1 ~ **12.5**)

Based on these calculations, the existing heat load for the town was estimated at 3.5 MW (predominantly in the winter months) and the existing electricity load was estimated to be 2.5 MW. Considering heat and electricity loads of anticipated future industry, the potential heat load would be 13.5 MW and electricity load would be 12.5 MW. Generally, the heat load is often a by-product of electricity generation and the amount of heat generated varies based on the amount of electricity output required. Therefore, for Berlin a 12.5 MW electricity generation plant is considered the optimal size to meet its current and future needs for both electricity and heat.

1 Robert C. Jaeger, et al., Comprehensive Plan: Town of Berlin, Final Draft, 2011 (Berlin, New York)
2 Energy Information Administration. Household Energy Use in New York. Energy Information Administration, 2009.
3 Robert C. Jaeger, et al., Comprehensive Plan: Town of Berlin, Final Draft, 2011 (Berlin, New York)
4 Energy Information Administration. Household Energy Use in New York. Energy Information Administration, 2009.
5 ibid
6 ibid
7 Pasternak, Michael L. Chief Executive Officer, Sustainable Aqua Farms, interview by Mary Elizabeth Foster, Ajay Ranjith Vempati. (February 14, 2016).
8 ibid

3. BERLIN'S BIOMASS RESOURCES

Since the generation of energy from a biomass energy plant depends on securing a consistent and reliable fuel source, it is important that the town of Berlin is surrounded by a wealth of forestland. While some biomass energy plants use agricultural crop residue or municipal waste as fuel, wood-based plant materials (hereinafter referred to as "woody biomass") are most common. Berlin, therefore, seems well situated, from a fuel source perspective, to consider a woody biomass energy plant. However, not all available wood can be used as woody biomass for an energy plant, and specific wood varieties, their moisture content, and size are critical factors in determining a plant's efficiency. Further, the harvesting of woody biomass has a range of environmental impacts that need to be considered.

3.1 RESOURCE AVAILABILITY

The use of woody biomass as an energy fuel source proposes unique availability challenges to plant operators. Woody biomass has a lesser calorific value than coal or similar fuels; therefore, relatively large quantity of biomass needed to create a single unit of energy compared to other fuels, transportation and sourcing distances are critical factors in plant feasibility.[1] Generally, plant operators do not source biomass feedstock from more than a 100-mile radius surrounding the plant.[2] Beyond 100 miles, transportation costs become too high compared to the amount of energy produced. For many operators, this minimum radius is reduced to 75, 50 or only 25 miles. For the purposes of this study, research was performed for feedstock availability within no greater than a 100-mile radius surrounding the town of Berlin.

Many additional factors limit the ability to harvest woody biomass from within a 100-mile radius of the proposed plant. The U.S. Forest Service limits biomass harvesting exclusively to what it designates as timberland, or an accessible and operable land producing or capable of producing at least 20 cubic feet per acre per year of industrial wood.[3] Large areas of land situated within the 100-mile radius around Berlin, such as Green

Mountain National Forest in Vermont and the Adirondack Park in New York, are designated as forest land and are therefore restricted and/or prohibited for woody biomass harvesting. Today, timberland makes up to 64% and 60% of the land within a 50- and 100-mile radius, respectively.[4] These areas include parts of New York, Vermont, and Massachusetts, and small portions of Connecticut and New Hampshire.

Of the existing harvestable timberland, The Forestland Group is the primary landowner.[5] Their ownership includes 22,735 acres in New York, Vermont, and Massachusetts. Their property ownership in the Berlin area has been divided into four compartments based on four geographic clusters: the Rensselaer Plateau, 9,141 acres; the southern Taconic cluster, 6,449 acres; the northern Taconic cluster, 7,088 acres; and the Berlin mill complex, 57 acres.[6] Across their ownership, the forest condition can generally be considered 'very good' to 'excellent'.

3.1.1 TYPES OF SUITABLE WOOD

Three main factors contribute to the performance of woody biomass feedstock in terms of its ability to produce energy production: moisture content, density, and size. Generally, low moisture, high density, and consistent sizing are favorable attributes.[7] Virgin wood, which is considered untreated and clean wood without any chemical treatment or finishes, is the most suitable biomass feedstock.[8] Freshly harvested green wood may have a moisture content of 60% or higher, whereas dry wood has a moisture content between 12% and 20%.[9] The preference is for denser or heavier wood, sourced from hardwood trees, since it contains more heat per volume. According to the study "Fiber Supply for Berlin, NY," close to 90% of the net growing stock available in the surrounding forests of Berlin are hardwoods.[10]

Other grades of trees, as defined by the U.S. Forest Service Forest Inventory and Analysis Program[11] database, are potentially available for consumption by a biomass plant. The aforementioned grades are included in Table 3-1 below:

Table 3-1: Grades of trees with requirements for use in biomass plant

Grade	Quality
Less than grade 3	Poor to very poor saw timber that does not meet minimal saw log grade specifications
Grade 3	Very rough - up to 50% cull deduction
Branches	Volumes may vary by season and/or weather conditions
	Used by some loggers to cover trails for heavy machinery
	High content of bark that does not make them suitable for biomass plant
Foliage	Needs to be chipped
	Unavailable during winter months
	Not suitable for biomass plant
Stump and Roots	Not extracted during harvesting
	Not suitable for biomass plant
Saplings	Do not meet sustainable forest management practices

3.1.2 WOOD AVAILABILITY SURROUNDING BERLIN

To understand if a biomass energy plant is feasible in Berlin, it is vital to understand the quantity and the type of wood that is available within the designated 100-mile radius around the town. Tables 3-2 and 3-3 provide useful insight into the overall size as well as species and quality of wood that is available within the 50- and 100-mile radius around Berlin.[12]

Table 3-2: Feedstock available within 50-mile radius of Berlin[13]

	Total	Pines	Other Softwoods	Soft Hardwoods	Hard Woods	Total
	Total Volume (,000 Green Tons)					Tons/Acre
Available Pellet Stock & Biomass fuel						
Gross growing stock (Merchantable)	312,470	31,620	39,524	65,050	176,294	95.7
Less saw timber portion of growing stock	171,909	27,184	29,431	36,582	78,712	52.7
Net growing stock (Merchantable)	140,562	4,41	10,093	28,468	97,582	43.1
Cull	40,479	3,219	5,724	9,335	22,200	12.4
Salvageable dead trees	7,694	778	973	1,602	4,341	2.4
Available pellet stock & biomass fuel	188,735	8,416	16,791	39,405	124,124	57.8
Composition		4.5%	8.9%	20.9%	65.8%	
Other Pellet & Biomass Fuel						
Very poor saw timber trees (< Grade 3)	37,847	11,397	1,921	8,504	16,025	11.6
Grade 3 trees	51,182	9,270	0	17,642	24,270	15.7
Other pellet stock & biomass fuel	89,029	20,667	1,921	26,146	40,295	27.3
Other Biomass Fuel						
Branches	34,052	2,142	3,485	7,953	20,471	10.4
Foliage	17,069	1,074	1,747	3,987	10,261	5.2
Stump & roots	73,144	4,601	7,487	17,084	43,972	22.4
Saplings	121,773	12,316	15,403	25,351	68,703	37.3
Other fiber sources	246,037	20,132	28,122	54,375	143,408	75.4
Total pellet stock & biomass fuel	523,801	49,215	46,834	119,925	307,827	160.5

Table 3-3: Feedstock available within 100-mile radius of Berlin[14]

	Total	Pines	Other Softwoods	Soft Hardwoods	Hard Woods	Total
	Total Volume (,000 Green Tons)					Tons/Acre
Available Pellet Stock & Biomass fuel						
Gross growing stock (Merchantable)	1,090,835	128,161	107,575	239,151	615,948	90.1
Less saw timber portion of growing stock	586,558	109,519	78,169	129,065	269,804	48.5
Net growing stock (Merchantable)	504,278	18,642	29,406	110,086	346,144	41.7
Cull	141,003	10,018	18,174	38,936	73,874	11.6
Salvageable dead trees	26,860	3,156	2,649	5,889	15,167	2.2
Available pellet stock & biomass fuel	672,141	31,815	50,229	154,911	435,186	55.5
Composition		4.7%	7.5%	23.0%	64.7%	
Other Pellet & Biomass Fuel						
Very poor saw timber trees (< Grade 3)	143,043	43,395	5,181	37,041	57,426	11.8
Grade 3 trees	184,799	39,080	0	55,706	90,013	15.3
Other pellet stock & biomass fuel	327,842	82,475	5,181	92,747	147,439	27.1
Other Biomass Fuel						
Branches	121,192	8,712	10,134	31,439	70,907	10
Foliage	60,749	4,367	5,080	15,759	35,543	5.0
Stump & roots	260,327	18,714	21,769	67,533	152,311	21.5
Saplings	425,108	49,945	41,923	93,199	240,040	35.1
Other fiber sources	867,377	81,738	78,906	207,931	498,802	71.7
Total pellet stock & biomass fuel	1,867,360	196,028	134,317	455,589	1,081,426	154.3

To understand the quantities and future sustainability of feedstock available for use in Berlin's plant, it is necessary to calculate the 'Average annual net change in volume'. This calculation uses data sets for growth and expected removal to determine the long term sustainability of feedstock harvesting.[15] Table 3-4 shows the average annual net change in volume in the 50- and 100-mile radius around Berlin.

Table 3-4: Growth and removal rates

	50-mile radius	100-mile radius
Gross Growing Stock Inventory (1,000 tons)	312,470	1,090,835
Average Annual Net Growth of Growing Stock (1,000 tons/year)	6,147	18,508
Growth Rate (Growth/Inventory)	2.0%	1.7%
Per Acre Growth (tons/acre/year)	1.9	1.5
Average Annual Net Removals of Growing Stock (1,000 tons/year)	2,482	8,696
Removal Rate (Removals/Inventory)	0.8%	0.8%
Annual Average Net Change in Volume	1.2%	0.9%

As Table 3-4 notes, within both the 50- and 100-mile radius, Average Annual Net change in volume is positive, implying that growth rate exceeds the removal rate and therefore sustainable harvesting of wood from a 50-mile or a 100-mile radius is feasible in the case of Berlin. This translates to nearly 2 million tons per year of wood, half of which is hardwood, available for utilization within the 50-mile radius. In addition, nearly 6 million tons per year of wood is available for utilization within the 100-mile radius; hardwood accounts for 3 million tons, while softwood accounts for approximately 1.5 million tons.[16]

Therefore, the area under consideration has sufficient resources to satisfy the requirement for the sustainable operation of a wood-based biomass plant.

3.1.3 PROCUREMENT OF FEEDSTOCK

While the type of wood and the availability of such biomass feedstock have been detailed above, the procurement of the feedstock has many impacts and implications for Berlin. Feedstock procurement sets in motion a chain of operations, from logging to transport, stocking, delivery and more, each with their own set of impacts to be considered.

STAKEHOLDERS

There are three main stakeholders that need to be considered when developing a biomass procurement plan: land owners, land managers/forestry consulting firms, and logging companies. Further details including names of certain logging and management companies operating in the Berlin area are provided in Appendix 1.

COSTS

The price of 1 ton of woody biomass delivered to a biomass energy hub can be broken down into two main cost components: stumpage costs (including harvesting costs) and transportation costs. Stumpage costs include cutting, skidding, hauling, fuel adjustments, and management fees. Below are estimates of stumpage prices provided by the Forestland Group:

Softwood pulpwood/Biomass stumpage price range: $5-$14/cord (average $13/cord)

Hardwood pulpwood/biomass stumpage price range: $3-$16/cord (average $15/cord)

Biomass only stumpage range: $2.50-$5.00/cord

Transportation costs consider the costs of transporting biomass from the forest to the end user but usually do not include costs of hauling the biomass to the roadside after harvesting. This is loosely estimated at $0.12-$0.15/ton/mile. 100 miles is generally considered the maximum haul length for woody biomass. The summation of the stumpage price and the transportation cost make up the “round wood delivery price”.

For this study, “pulpwood” prices were considered because the proposed biomass plant would most likely need to use high quality chips, which require a minimal amount of bark in the mix. Debarked pulpwood logs would be the best source of this material.

Green Renewable, Inc. is a local company providing landscaping related products and services, and is a major woody biomass recipient in the area. Sean Gallivan of Green Renewable indicated that the prevailing cost of green wet feedstock for his company’s existing 1.4MW plant ranges between $22 to $45/ton, while published prices suggest softwood pulpwood prices could be a little lower.[17] Given the weak markets for pulpwood material in the southern New York price regions, as indicated by the sporadic price reporting, wood drawn from this area could be less expensive.

3.2 SUSTAINABILITY CONSIDERATIONS

IMPACTS OF BIOMASS HARVESTING

Management of the forests from where the woody biomass is harvested is extremely important to maintain the ecological health of the region and to ensure continued availability of feedstock for the biomass plant. The Food and Agricultural Organization (FAO) defines Sustainable Forest Management as the stewardship and the use of forests and forestlands in a way, and at a rate, that maintains their biodiversity, activity, regeneration capacity, and vitality. It also includes their potential to fulfill now and in the future, relevant ecological, economic and social functions, at local, national and global levels that does not cause damage to other ecosystems.[18]

Woody biomass harvesting, which generally uses the smaller diameter materials and tops, branches, and logging debris that are typically left on site during traditional timber harvest, can affect Sustainable Forest Management in a variety of ways.[19] First, it can increase demand for small diameter, poor quality, or previously non-commercial biomass leading to implementation of management activities in stands that have been unmanaged. Second, it can increase harvesting in managed forests through increased residue removal. And finally, it has the potential to expand the amount of energy crops that are grown for biomass sources.[20]

Although woody biomass is quickly becoming a highly viable renewable energy fuel source, it is important for forest managers to look past just the potential economic boost, and consider some of the wider environmental impacts. Detailed information on the beneficial and negative impacts of woody biomass harvesting is provided in Appendix 1.

CLIMATE CHANGE IMPACTS AND CARBON NEUTRALITY

The recent surge to switch from fossil fuel to woody biomass energy sources is based on a number of social, economic, and environmental benefits. These include a reduced reliance on foreign petroleum, improved forest management practices, conservation of working forests and local resource utilization.[21]

Another more disputed factor is the belief that use of woody biomass for energy production is considered carbon neutral.[22] This is based on the argument that the combustion or decay of woody biomass is a natural component of the global carbon cycle, and that sequestration of CO_2 emissions are offset by future forest growth.[23] Therefore, as the argument goes, biomass energy production does not increase the amount of carbon released into the atmosphere.[24] The Environmental Protection Agency (EPA) supports this argument in its determination that the use of woody biomass is a Best Available Control Technology (BACT) for emissions control.[25]

This claim, however, has been the subject of heated debates over the past few years. Carbon neutrality of biomass-based energy depends on various factors across the life cycle including the age of harvested wood and the technology used to convert it to energy.[26] Woody biomass emits more greenhouse gases than fossil fuels per unit of energy produced due to the lower energy to carbon ratio of biomass (See section 5.1.1 for more details).[27] These excess emissions contribute to the carbon "debt" when considering the overall global carbon released into the atmosphere. Re-growth of the harvested forest over time removes this carbon. The benefits for utilizing woody biomass are considered at the timescale at which the carbon debt is paid off and atmospheric greenhouse gas levels are lower than would have occurred from the use of fossil fuels to produce the same amount of energy.[28]

The concept that utilizing biogenic fuel sources is carbon neutral discounts the boundaries used in net emissions calculations and the effects of land use change resulting from the increased harvesting of the necessary feedstock.[29] One way to consider the impact of biomass energy production on the carbon cycle is to evaluate the point at which the carbon debt is paid off through sequestration by forest recapture of carbon in the atmosphere relative to continued use of burning fossil fuels. Most sequestration of biogenic carbon will occur beyond the critical timeframe for addressing global climate change.[30]

Recent studies suggest that burning woody biomass for energy production over the next 35 years would release the same GHG emissions as would occur from energy production using coal over the same period. The balance for natural gas would extend that time frame to over 90 years.[31]

Another debate regarding the use of biomass for energy production is the concept that the net impact in the carbon cycle is neutral as long as forests are sequestering carbon elsewhere from the areas being harvested.[32] This argument suggests that biogenic carbon in the atmosphere is different than carbon released from geologic carbon stock in terms of net atmospheric impact. Although fossil fuels release new carbon into the atmosphere from the geologic pool, biogenic release of carbon when the sequestration rate is low or delayed, as in the growth of new mature forests (greater than 50 years), will not contribute to the net reduction of carbon in the atmosphere within the timeframe where it will have a positive effect in mitigating irreversible climate change.[33] Moreover, assuming successful sequestration of carbon through proper forest management and accelerated regrowth still doesn’t take into account the impacts on loss of biodiversity of forest land or the impact of increased forest harvesting.[34]

In summary, five parameters need to be considered to fully understand if biomass is able to reduce CO_2 emissions compared to other fossil fuels: feedstock type, feedstock management and harvesting, transportation, energy generation technology and time required to replenish the feedstock. Therefore, each situation is different and the CO_2 assessment can vary greatly as a function of the five aforementioned parameters. For example, one biomass plant could be carbon neutral because the wood is harvested following strict sustainable practices and in the vicinity of the plant, while another plant may not be CO_2 neutral because the type of wood harvested will take longer to regrow and the technology used has a lower efficiency.

Carbon neutrality can be an inaccurate statement when used to describe biomass use for energy production under all conditions. It may be more accurate to consider the use of biomass in energy production as a renewable energy source rather than suggest it is carbon neutral. By comparison, fossil fuels are neither.[35] For all the above mentioned reasons, it is strongly recommended that the potential biomass plant in Berlin exclusively use wood procured from nearby, sustainably managed forests that follow stringent sustainable forestry practices and that the plant employ efficient technology.

3.3 HARVESTING RECOMMENDATIONS

Given the wide range of both beneficial and negative impacts of woody biomass harvesting, it is our recommendation that the town of Berlin work closely with sustainably-minded landowners, forest management firms, and loggers to develop robust sustainable harvesting best management practices. These practices will ensure greater levels of biodiversity, increased habitat, increased water yields, and reduced forest fire risk without effecting soil erosion, biodiversity loss, or decreased water yields.

Additionally, and perhaps most importantly, a sustainable forest management plan that follows these guidelines will ensure the continued regeneration of woody biomass resources for use in a biomass energy plant.

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4. BIOMASS CONVERSION TECHNOLOGIES

Five major technologies were considered for implementation in Berlin: combustion, gasification, cogeneration / combined heat and power (CHP), co-firing and biofuels. Each has its own benefits and drawbacks in terms of the input required and the resulting output, therefore it is important to discuss the overall characteristics of each type for later comparison later in the report.

4.1 TECHNOLOGY: COMBUSTION

OVERVIEW

Combustion is the simplest method for converting biomass to energy; it has been used for millennia to provide heat. The heat can be used in a number of ways: for space heating, for water (or other fluid) heating for central or district heating, and for generating steam which is in turn used for electricity generation.[1] Most electricity generated from biomass is produced by direct combustion using conventional boilers. These boilers typically burn waste wood products from agriculture and wood-processing industries.

Wood, typically in a variety of forms particularly green chips[2], is shipped and maintained at a holding site by the energy plant. Augers or belt conveyors transport the wood chips to the combustor, where they are burned, and the heat of combustion is transferred to a steam or hot water boiler. Steam is converted to electrical power by steam turbines.

While wood is the most commonly used feedstock, a wide range of materials can be burned effectively, including byproducts from sawmills and “energy crops” grown specifically to create feedstock. Pelletized agricultural and wood residues are also an increasingly popular option because they are very easy to handle.[3] For Berlin, however, the most abundant and available feedstock will be wood from nearby forests. More homogenous feedstock helps the plant run more efficiently, which means that loggers should try to provide wood with the same moisture content that is cut into consistently sized woodchips.

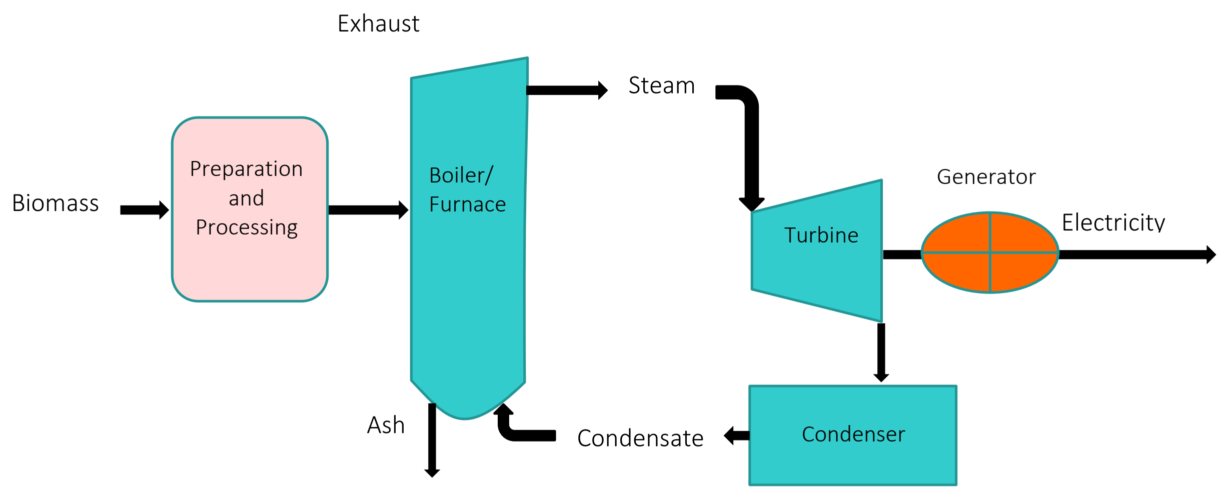

Figure 4-1: Process flow diagram of combustion technology

REQUIREMENTS AND COSTS

Combustion boilers are generally considered one of the least expensive among biomass conversion technologies, requiring an investment of $1,800 - $4,200/kW.[4]

Input Requirements	Woodchips, <20% moisture[5]
Outputs	Steam, electricity[6]
Waste	Bio-char, particulate matter, CO_2, tar at certain temperatures[7]
Efficiency	20-25%[8]

Renewable energy incentives and biomass-based incentives (at the federal and state level) may be applicable for combustion-based plants, a few specific incentives are also available. The most notable incentive program which Berlin may be eligible for is NYSERDA's Renewable Heat NY Program[9], which offers funding of up to $270,000 for large commercial pellet boilers. This program has very specific eligibility criteria and only applies to boilers producing heat.

4.2 TECHNOLOGY: GASIFICATION

OVERVIEW

Gasification is a slightly newer technology, adding to the complexity of a traditional combustion system. This technology heats the wood feedstock in an environment with little to no oxygen in order to cause volatile pyrolysis gases, such as carbon monoxide and hydrogen, to be released into the gasification chamber.[10] The resulting gas, called syngas, can be treated in two ways. One option is to mix the syngas with air or pure oxygen gas to produce heat through combustion; this heat can be distributed externally or sent to a boiler to produce energy for distribution. The second option is to cool the syngas in order to filter and purify it, removing as much tar and particulates as possible, so it can ultimately be used as fuel for gas turbines and combustion engines.[11]

The four main types of gasifier reactors are entrained flow, fixed bed, fluidized bed, and rotary kiln.[12] Each type has a different set of requirements in terms of the temperature, pressure, and gasifying agents. The general process of forming the syngas remains the same, however: after the fuel is fed into the gasification chamber, a gasifying agent is introduced into the system. As the fuel and gasifying agent interact, the fuel releases syngas, which leaves the gasification chamber. Different reactor types will vary in terms of how the gasification agent is introduced to the fuel, but the output is generally the same.[13]

Gasification plants can vary in size; the boilers are often approximately 20-50MW, although they can be as small as 30kW.[14] In order to produce power, it is most efficient to use engines for plants that produce 5-10MW, while turbines are better for 10-30MW plants.[15]

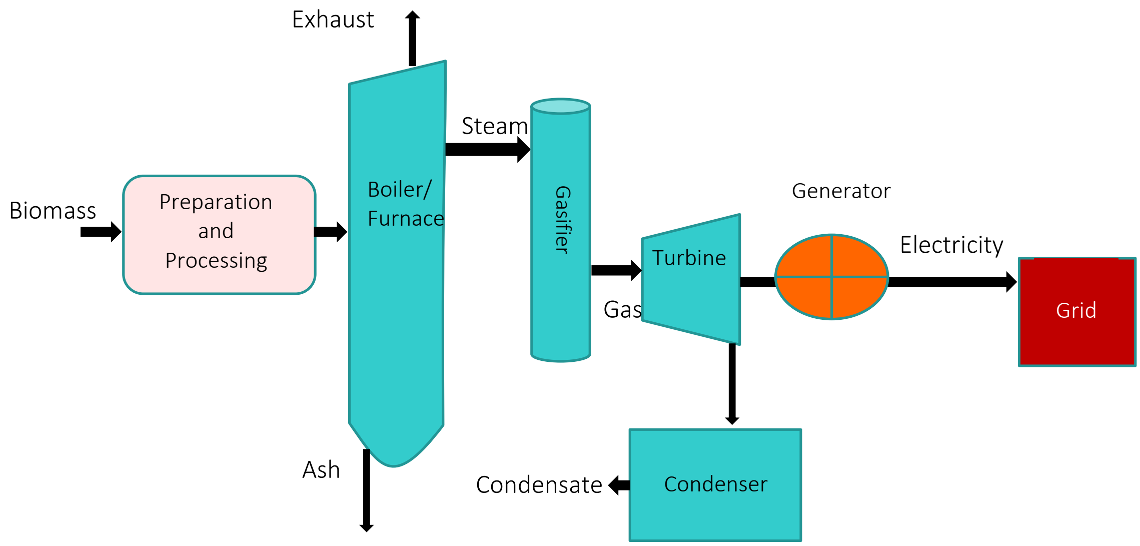

Figure 4-2: Process flow diagram of gasification technology

REQUIREMENTS AND COSTS

Gasifiers are generally more expensive than combustion boilers; fixed and fluidized bed gasifiers require investment costs of $2,140-$5,700/kW, which can be anywhere from $1,200 to $3,800/kW more than combustion boilers.[16]

Input Requirements	Woodchips, log wood, oven dry wood, or wood pellets; <30% moisture with best results at lowest moisture[17]
Outputs	Gas[18]
Waste	Biochar, tar, particulate matter, CO_2, ammonia, sulphuric/hydro chloric acid, water/condensate[19]
Efficiency	15-45%[20]

There are a few major federal incentives in place for gasification plants. Section 48B of the Internal Revenue Code states that gasification projects qualified according to the DOE are able to receive a property investment tax credit of up to 20%, not to exceed an award of over $350 million.[21] As part of the Renewable Energy Production Tax Credit, qualifying gasification plants with closed-loop systems can receive $0.023/kWh.[22]

4.3 TECHNOLOGY: COGENERATION / COMBINED HEAT AND POWER (CHP)

OVERVIEW

Typically, nearly two-thirds of the energy used to generate electricity is wasted in the form of heat discharged to the atmosphere.[23] Additional energy is wasted during the distribution of electricity to end users. Combined Heat and Power (CHP) is on-site electricity generation that captures the heat that would otherwise be wasted to provide useful thermal energy such as steam or hot water, that can be used for space heating, cooling, domestic hot water and industrial processes. In this way, and by avoiding distribution losses, CHP can achieve efficiencies of over 80%.[24] Although CHP and cogeneration are sometimes used interchangeably, technically cogeneration incorporates using heat energy from electricity production that is used for cooling and other non-heating purposes, while CHP refers only to using the energy for heat.[25]

There are two main types of CHP: "topping cycle" and "bottoming cycle." The most common type of CHP is the "topping cycle," where fuel is first used to generate electricity or mechanical energy at the facility and a portion of the waste heat from power generation is then used to provide useful thermal energy. The less common "bottoming cycle" type of CHP systems first produce useful heat for a manufacturing process and recover some portion of the exhaust heat to generate electricity.[26]

CHP systems are categorized according to their prime movers (the heat engines), though the systems also include generators, heat recovery, and electrical interconnection components. There are currently five primary commercially available prime movers: steam turbines, gas turbines, reciprocating engines, micro turbines, and fuel cells.[27]

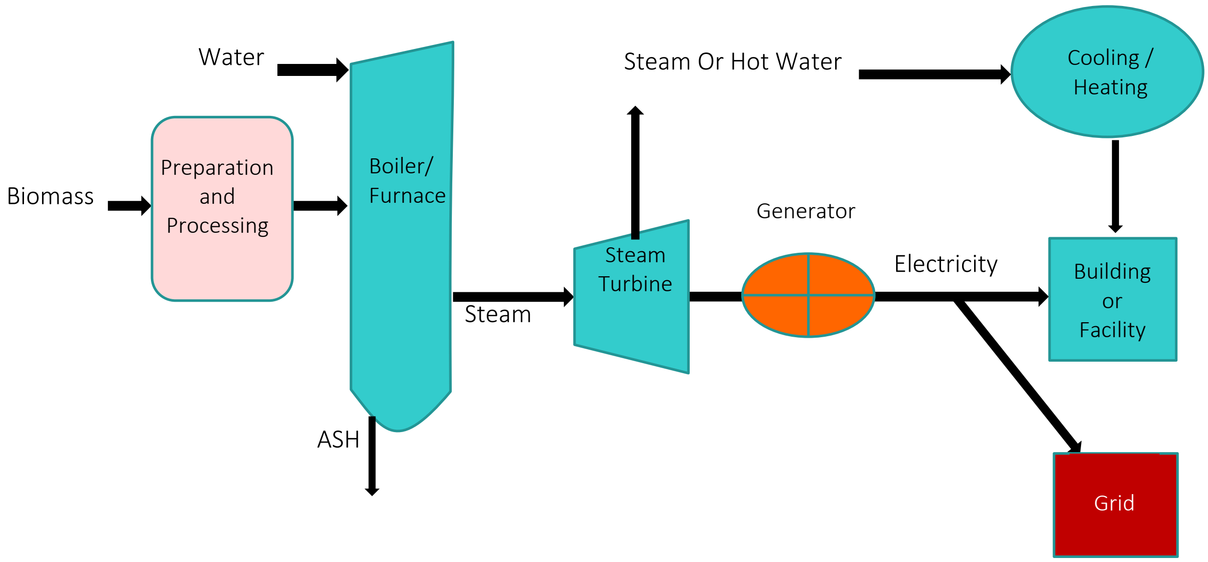

Figure 4-3: Process flow diagram of CHP

REQUIREMENTS AND COSTS

The cost of a CHP system depends on the level of complexity of features beyond the basic prime mover, such as the heat recovery or emissions monitoring systems, as well as location, labor, and the financial carrying costs during construction.[28]

Input Requirements	Wood chips, agricultural waste;
Outputs	Steam, electricity
Waste	Bio-char, tar, particulate matter, CO_2
Efficiency	75-80%[29]

Investment costs are typically in the range of $3,500 - $6,800/kW.[30] The economic viability of CHP systems depends on their ability to safely, reliably, and economically interconnect with the existing grid, which is currently not a uniform process.[31]

CHP plants benefit from incentives and grants under many state and federal programs. Some examples include NYSERDA's CHP Performance Program PON 2701 or CHP Acceleration Program (depending on the plant's size), the New York Renewable Portfolio Standards, the US Internal Revenue Code's Business Energy Investment Tax Credit, and the ability to work with the EPA CHP Partnership.[32] See Appendix 3 for more information on these policy options.

4.4 TECHNOLOGY: CO-FIRING

OVERVIEW

Co-firing involves replacing a portion of the fuel in coal-fired boilers with biomass. Co-firing has been successfully demonstrated in most boiler technologies, including pulverized coal, cyclone, fluidized bed, and spreader stoker units.[33]

Co-firing is a near term, low-cost option for efficiently and cleanly converting biomass to electricity by adding biomass as a partial substitute fuel to coal boilers. There is little or no loss in total boiler efficiency after adjusting combustion output for the new fuel mixture. Extensive demonstrations and tests also confirmed that biomass energy can provide as much as 15% of the total energy input with only feed intake system and burner modifications.[34]

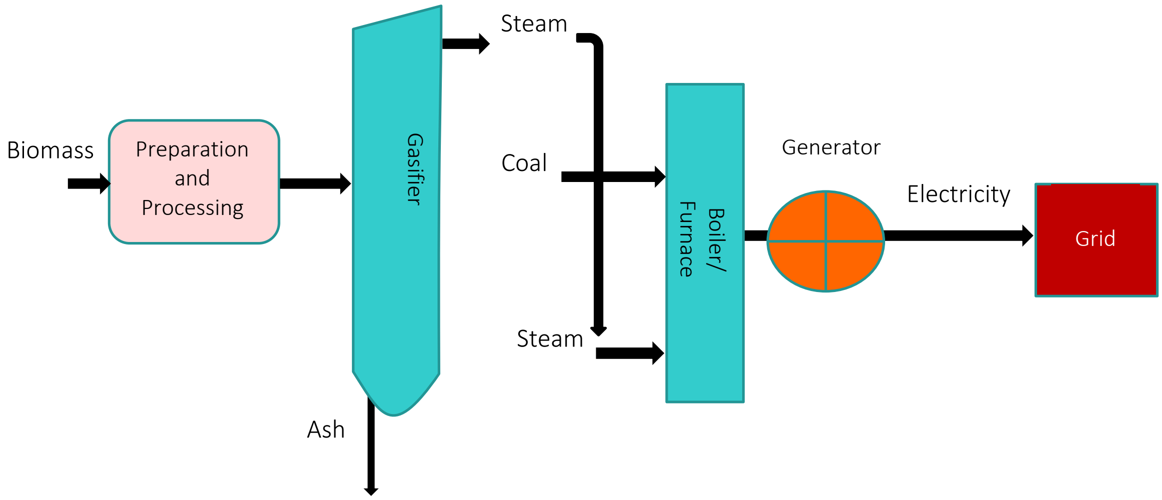

Figure 4-4: Process flow diagram of Co-firing

REQUIREMENTS AND COSTS

Co-firing economics depends on location, power plant type, and the availability of low-cost biomass fuels. A typical co-firing installation includes modifications to the fuel-handling and storage systems, and possibly the burner to accommodate biomass. Costs can increase significantly if wood needs to be dried, size needs to be reduced, or the boiler requires a separate feeder. Retrofit costs range from $150 to $300 per kilowatt (kW) of biomass generation in pulverized coal boilers.[35] Cyclone boilers offer the lowest cost opportunities, as low as $50 per kW.[36] Fuel supply is the most important cost factor. Costs for biomass fuels depend on many factors such as climate, closeness to population centers, and the presence of industries that handle and dispose of wood. Low price, low shipping cost, and dependable supply are paramount. Usually the cost of biomass fuels must be equal to or less than the cost of coal per unit of heat for co-firing to be economically successful.[37]

Input Requirements	Green wood or dry sawdust (<2" diameter)[38]
Outputs	Electricity
Waste	CO_2, sulphur dioxide, nitrogen oxides, particulate matter[39]
Efficiency	33-37%[40]

4.5 TECHNOLOGY: BIOFUELS

OVERVIEW

In bio-fuel production from wood, gases from pyrolysis of wood are condensed, forming a brown liquid 'oil' that is similar to crude oil. Bio-oil is a complex mixture of chemicals and technologies have been developed to break them down into fractions similar to those from crude oil to manufacture vehicular fuels and chemicals.[41]

This is a relatively new and proprietary technology that gained traction due to high oil prices in the past few years. In this technology, the wood is pyrolized under high temperatures in either static or fluidized beds in the presence or absence of catalyst.[42] The gases are then condensed to generate bio-oil, which can be further cracked in bio-refineries to produce value added fuels and chemicals or fed directly to boilers or special diesel generators to generate electricity.[43] While many versions of bio-fuel production technology are available, as part of this feasibility study, the technology explored is that of ENSYN Corporation, one of the most advanced versions available in the market today. This technology uses heat to thermally crack carbon-based feedstock such as wood biomass (cellulose, lignin) into high yields of a higher-value liquid product.[44] Dried wood is typically converted to approximately 75% (by weight) liquid with the balance converted to combustible gases and char. Relative yields can be varied in response to customer product requirements.[45] This is the only known commercial technology, worldwide, that can convert wood and other woody biomass to such high yields of liquids. With this technology, conversion typically takes place in less than two seconds. This allows for the production of new, higher value products, at high yields and with relatively low capital costs. The biomass to power conversion efficiency for this technology is as high as 36%.[46]

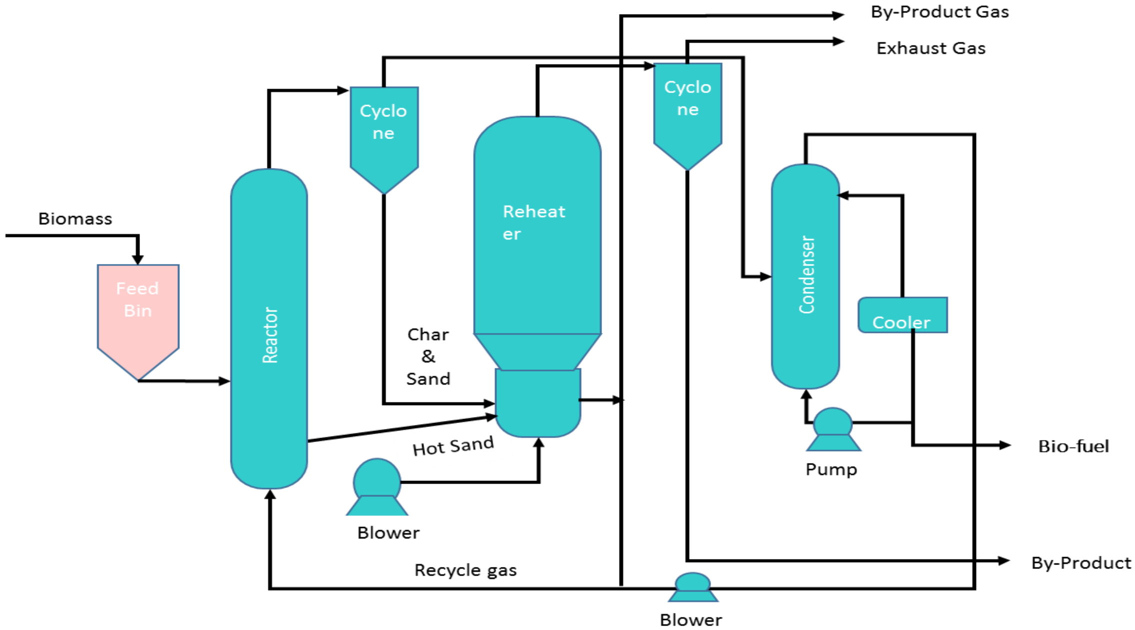

Figure 4-5: Process flow diagram of biofuel production using ENSYN technology

The installation cost for this technology with plant capacity of 150 TPD is 100 Million with a land requirement of less than 1 acre excluding storage. The plant requires 30 people to operate who are combinations of very skilled and semi-skilled employees. The costs of establishment are shared by the ENSYN Corporation and feedstock partner through equity participation.[47]

Input Requirements	Wood chips <0.25"; <6% moisture[48]
Outputs	Bio-oil[49]
Waste	Bio char, combustible gases[50]

Efficiency	36%[51]

The products generated from this process are eligible for receiving financial incentives as part of EPA's Renewable Portfolio Standards through Renewable Identification Numbers (RINs) if used as transportation fuel or home heating fuels. Also if the products are used for electricity generation then they eligible for receiving renewable energy certificates (RECs). Also there several incentives available through federal government for financing like federal loan guarantee through USDA and cash exempt financing though Department of Energy.[52]

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27 ibid
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30 International Renewable Energy Agency, Renewable Energy Technologies: Cost Analysis Series, 2012 (Bonn: IRENA)

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5. QUALITATIVE ANALYSIS

Given the understanding of required plant size, available woody biomass, and a delineated range of potential conversion technologies, attention is turned towards a variety of qualitative factors to be considered to further hone in on a technology decision. Environmental, social, policy-based, and plant operational factors can be difficult to quantify and complex in their interrelationship, yet remain pivotal to the town's conversion technology decision.

Below is a review of these factors as they relate generally to biomass energy production. Within each larger qualitative grouping listed above, a number of sub-factors are further detailed.

To appropriately accommodate the range of qualitative factors and sub factors impacting the technology decision, a scoring mechanism was devised that places a value on each technology's relationship to each qualitative factor. If a technology performed well in its relationship to a qualitative factor, it was scored a three (3). If it performed poorly, it was scored a one (1). If performance was average, a score of two (2) was given. A technology's final score was derived by summing individual scoring on each qualitative factor.

The following sections attempt to comprehensively review the qualitative factors that affect a technology decision for the town of Berlin. However, only essential factors identified by the town itself or report authors were considered in the final "scoring matrix", and appear in the "Qualitative Scoring" portion of each section.

5.1 ENVIRONMENTAL FACTORS

The qualitative factors with perhaps the most impact on technology decision making are the environmental considerations. As we transition to a decarbonized economy, biomass has been touted as an important environmentally sustainable fuel source for heat and energy generation. [1] Bio-energy with Carbon Capture and Sequestration (BECCS) is generally considered a cost-effective renewable resource that can play a role in bridging the transition from carbon intensive energy solutions to renewable energy solutions.[2] However, biomass energy generation does not win unanimous environmental support. Opinions about related environmental impacts can differ greatly, some of which are further reviewed below.

5.1.1 AIR POLLUTION

Using woody biomass as a feedstock produces many types of emissions, dominant among them are carbon dioxide (CO_2) and particulate matter (PM).[3]

CARBON DIOXIDE EMISSIONS

Any power plant that burns fuel emits a wide range of air pollutants. When comparing emissions per unit of energy produced, burning biomass produces more pollutants than burning fossil fuel, as seen in Table 5-1.[4] This can be explained by two key factors.[5] First, the inherent composition of biomass is carbon rich but not particularly energy rich. This means that, biomass releases between 150% and 400% more CO_2 per unit energy produced than coal and natural gas, respectively. Second, biomass requires more energy to combust than fossil fuels such as coal and natural gas. This is due to the fact that biomass has a relatively high moisture content and it takes significant energy to dry the wood before useful energy can be generated.[6]

Table 5-1: Comparison of efficiency and CO_2 emissions[7]

Technology	Fuel CO_2 emissions (lb/MMBtu heat output)	Facility efficiency	MMBtu required to produce one MWh	lb CO_2 emitted by MWh
Gas combined cycle	117.1	45%	7.54	883
Gas steam turbine	117.1	33%	10.40	1,218
Coal steam turbine	206	34%	10.15	2,086
Biomass steam turbine	213	24%	14.22	3,029

PARTICULATE MATTER EMISSIONS

Particulate matter, also known as particle pollution or PM, is defined by the EPA as *"a complex mixture of extremely small particles and liquid droplets, made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles"*[8]. When it comes to PM, biomass power plants generate the same amount of PM as coal (Table 5-2), but because it is less efficient it produces more PM on an electrical output basis.[9]

Table 5-2: Biomass power's lower efficiency increases particulate matter emissions[10]

Fuel	Boiler Size (MMBtu/ hr)	Efficiency	Heat input (MMBtu /Yr)	PM rate (lb/MM Btu)	Particulate Matter (Ton/Yr)	Electricity Output (MWh /Yr)	Particulate Matter (lb/MWh)
Biomass	500	24%	4,380,000	0.012	26	307,999	0.17
Coal	500	33%	4,380,000	0.012	26	423,498	0.12

EMISSION RATES ALLOWANCE

As of today, air permits are written to allow biomass plants to emit more pollutants than fossil fuel plants.[11] Figure 5-1 compares emission rates from three recently issued permits in pounds per megawatt-hour.

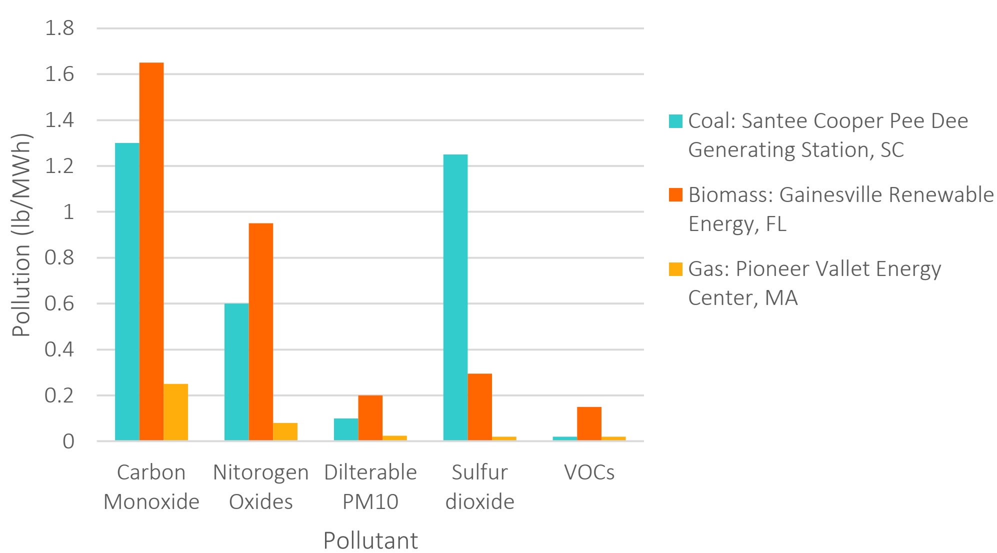

Figure 5-1: Emissions allowance[12]

5.1.2 EMISSION CONTROL MECHANISMS

Effective emissions control begins with the use of screened, dry sawmill residue wood chips blown directly into a trailer to minimize the introduction of ash-forming minerals that would contribute to fly ash in the combustion process. [13] Wood pellets of super-premium grade as classified by the Pellet Fuel Institute (PFI) limit the amount of ash content to 0.5%, however wood pellets as a feedstock have not been specifically included in this study. Use of high efficiency boilers with induced fans further reduces PM emissions.[14]

PM is categorized by the EPA in terms of size of the particulates released into the atmosphere by combustion.[15] Biomass furnaces tend to emit more particulate matter in the combustion process than most fossil fuels, with the exception of coal. Small particles less than 10 microns, known as PM10, and larger particles up to 25 microns, known as PM25, are regulated under the Clean Air Act (CAA).[16] PM10 is considered more harmful because the particles can be suspended in the air for longer periods of time and can more readily enter the respiratory stream.[17]

Another method of controlling and minimizing particulate matter emissions is through the use of emissions control technologies, which fall under three general categories: mechanical collectors (cyclones or multi-cyclones), fabric filters (bag houses), and electrostatic precipitators (ESPs).[18] More information on these control technologies can be found in Appendix 2.

Outside of supplemental emission control technologies, operating the plant under Best Management Practices, which incorporate both operational efficiencies and ongoing preventative maintenance to assure that all equipment is performing optimally, is required to minimize airborne pollutants. [19]

STACK HEIGHT AND SITING

Emissions not captured in any control technology will be dispersed into the environment through the smoke stack. Properly sizing and locating the stack will reduce ground level concentrations of PM and other pollutants.[20] Air dispersion studies model the effects of particulate dispersion in the atmosphere and should be conducted to properly capture the local conditions.[21] Weather, topography and surrounding structures all need to be considered in the correct sizing and location of the stack and the only way to achieve this is through the dispersion study.[22]

Exhaust flow rates and stack heads should allow the discharge gas to exhaust at a rate of 40 feet per second at a minimum regardless of weather conditions such as rain or snow that may otherwise impede air flow.[23] As a general rule, the stack should be a minimum of 1.5 times the height of the building and neighboring structures measured from ground level to minimize exhaust plume entrapment in eddies or wakes caused by adjacent obstructions.[24]

RECOMMENDATIONS FOR EMISSIONS CONTROL FOR BERLIN

Particulate matter control technologies would be required for a biomass facility in Berlin for several reasons. Although the town encourages use of its forest products and wood-based fuel is a dominant source for the community, the town's location within a valley subjects it to wind inversions and the emissions produce a haze within the community. A biomass energy plant will produce PM emissions that would contribute to this effect. Additionally, several financial incentives require emission control technologies be employed to qualify for the funding as discussed later in the report. The town would benefit from reduced emissions from the plant.

The emission control technologies mentioned here can each be employed separately, but several would only be effective if done in combination. Cyclonic separators by themselves would not be effective in reducing PM2.5 which would present the most deleterious emissions. [25] When coupled with a filter bag house, however, fine particulate emissions could be better controlled. Electrostatic Precipitators, though slightly less effective in removing PM for both PM10 and PM2.5, can work independently with less concern of filter clogging or fire potential. Although these precipitators require routine maintenance for cleaning, overall they require less maintenance. [26]

5.1.3 ENVIRONMENTAL REGULATIONS

The NY State Department of Environmental Conservation (NYSDEC) establishes air permitting regulations for the state and would govern air quality standards over the proposed facility in Berlin.[27] Berlin falls within a region identified as a moderate non-attainment area for nitrous oxide (NO_X) and volatile organic compounds (VOC).[28]

The biomass facility proposed in Berlin would be exempt[29] by definition of a stationary combustion installation only if it operates within a maximum rated heat input capacity less than one million Btu/hr burning coal or wood.[30]

Whether the proposed facility is exempt or not, the emissions from the facility must be included in the Potential to Emit (PTE) calculations for determining if the emission source is subject to Title V permitting under Subpart 201.6 and New Source Review (NSR) under Part 231 of the applicable regulations for a Major Stationary Source.[31]

A proposed facility is considered a Major Stationary Source for greenhouse gases if it directly emits or has the potential to emit 100 tons per year (TPY) or more of greenhouse gases, and 100,000 TPY or more of CO_2 equivalents.[32] Under such conditions, the facility would be subject to New Source Review requirements and Title V permitting requirements under Part 201 of the referenced regulations.[33]

CO_2 equivalent (CO_{2e}) describes different greenhouse gasses (GHG) in common measuring units based on their determined Global Warming Potential (GWP).[34] It is derived by multiplying the amount of the GHG by its GWP, which are provided in Table 5-3. CO_{2e} signifies the amount of CO_2 which would have the equivalent global warming impact.[35]

Table 5-3: Global Warming Potential of Greenhouse Gases[36]

Greenhouse Gas (GHG)	Global Warming Potential (GWP)
Carbon dioxide (CO2)	1
Methane (CH4)	21
Nitrous oxide (N2O)	310
Sulfur hexafluoride (SF6)	2,390
Hydrofluorocarbons (HFCs)	140 – 11,700+
Perfluorocarbons (PFCs)	5,210 – 9,200

When considering new power generating facilities, the EPA requires an evaluation for the Prevention of Significant Deterioration (PSD), which in effect would evaluate that any new facility does not add to pollution levels already present in the target area and each facility would need to employ Best Available Control Technology (BACT) to achieve that requirement.[37] Under the EPA's Clean Air Act Title V GHG Tailoring Rule, however, it considered that biogenic CO_2 emissions are distinct from other regulated pollutants. In its analysis, it considered that carbon sequestration in plant material outside the boundaries of the facility may counteract emissions from the facility itself, when considering the net atmospheric impact in its analysis.[38] Although not specifically required, BACT and the tailoring rule employed for biomass fueled power generating plants require a five step top down methodology that would require the following steps be taken:[39]

- Identify all available control technologies
- Eliminate technically infeasible options
- Rank remaining control technologies

- Evaluate most effective controls and document the results – this would entail a review of energy, economic and environmental impacts of the proposed technologies.
- Select BACT

Although BACT is not a requirement for a biomass facility as determined by regulations, an evaluation of environmental impacts should consider a Collateral Impact Analysis to evaluate the collateral effects emission pollution control technologies would have on other environmental concerns, including solid or hazardous waste generation, discharge of polluted water from a control device, visibility impacts, and demand on local water resources.[40]

In its enacting of the tailoring rule for GHG emissions for biomass facilities, the EPA considered that the cost of control technologies would offset incentives to use renewable fuel sources for fuel power generating facilities.[41]

The proposed new facility will produce additional pollutants and waste residue outside of those regulated under the CAA, including ash, PM and bio-char. The town has already indicated that current wood-burning stoves in residential use contribute to airborne particulates. Although not required under current regulations, the new facility should endeavor to mitigate PM in its emissions so the current local condition would not become worse. This would be consistent with the EPA's PSD requirements and certain control technologies could be employed to address these concerns.

5.1.4 OTHER ENVIRONMENTAL IMPACTS

In addition to emissions impacting air quality, a biomass plant can have other potential environmental impacts as well. Previously in the report, the environmental impacts of harvesting wood for the biomass plant were discussed. Another important consideration is the impact of the waste stream.

The burning of woody biomass in the form of wood chips or wood residue produces significant quantities of ash. Ash rates can vary between 5% to 15% (by weight) of biomass processed,[42] depending on the feedstock and technology being used for combustion. Ash may also contain varying concentrations of heavy metals depending on the feedstock used in combustion.[43] Due to the large quantities and varying levels of metal concentrations, operators of woody biomass energy plants must plan for the proper disposal of this ash waste. Fortunately, a number of potential applications for ash waste exist, as described below: [44]

Soil Amendment: Wood ash can be used in agricultural production to increase the pH of acidic soils, also called liming.

Fertilizers: Some mineral nutrients of the ash, particularly phosphorus and calcium, may increase nutrient contents when applied agricultural or forest soils.

Ingredients for Concrete: Ash contains many properties that are beneficial as a concrete ingredient, aiding in binding characteristics.

Landfill Alternative Daily Cover: Landfills are required to cover each day's intake of waste with a layer of material. Ash has shown potential to be an alternative to previously used daily covers.

Additional Fuel Source: Due to the presence of high unburned carbon content, research is being done to consider ash as a potential fuel source.

Based on the presence of regional agriculture and aspirations for increased construction (and increased use of concrete), ash residues generated from the combustion of woody biomass might come to benefit the town of Berlin and the surrounding area, if put to good use.

CASE STUDY: NATIONAL LIFE GROUP[45]

The National Life Group, located in Montpelier, VT installed a 3.5 MW Biomass energy facility in 2010. Included in their construction was an ash-collection silo that collected ash from the combustor and the ESP. As the National Life Group notes in the case study, the silo needs to be emptied about once a year. The ash from the silo is sent to a local farm, where it is commingled with manure and spread onto fields."

5.1.5 ENVIRONMENTAL FACTORS QUALITATIVE SCORING

Based on the above review of environmental factors, pollution control technology, waste generation, air pollution, and greenhouse gas emissions were chosen to be included in the qualitative scoring matrix. Below is an explanation of how technologies were scored, followed by the scoring itself.

POLLUTION CONTROL TECHNOLOGY

The relative complexity of pollution control technology required for abating emissions are dependent on the inherent cleanliness of the process used in each biomass energy technology. Combustion being the most primitive and relatively heavy polluting technology requires the most complex pollution control equipment for pollution abatement therefore receives the lowest score of one (1). CHP and ENSYN are inherently clean technologies and require the least complex pollution control equipment and consequently incur less pollution control costs; they therefore receive the highest score of three (3). Gasification scores in the mid-range of two (2).

WASTE GENERATION

All biomass plants produce ash, which must be disposed of properly in order to prevent contamination of the surrounding environment. Combustion and CHP technologies have waste water to deal with as well, giving them a ranking of two (2). Gasification does not have waste water, but produces tar in addition to ash. Because tar is difficult to prevent and even more difficult to discard properly, Gasification received a one (1) for this category in the scoring matrix.

AIR POLLUTION

Combustion has high uncontrolled emissions, as dust formation comes from incomplete combustion. Much of the total ash residue produced by a hog-fired grate equipped boiler is in the form of air borne particulate, called fly ash or furnace carryover.[46]

This poorly controlled system led to a ranking of one (1) for combustion. Although gasification systems are relatively more controlled, they still produce numerous air pollutants, including particulate matter, nitrogen oxides, carbon dioxide, and carbon monoxide. This leaves gasification with a score of two (2). CHP plants are equipped with enhanced combustion air systems to improve efficiency, increasing steam rates and carbon burnout. These two operational characteristics reduce the emitted concentrations of carbon monoxide, oxides of nitrogen (NO_x) and particulate matter, leaving them with a score of three (3). Despite being a closed-loop system, ENSYN releases some amount of air pollutants as well, giving it a median score of two (2) as well.

GREENHOUSE GAS EMISSIONS

Wood fuel combustion generates CO_2, a greenhouse gas and major contributor to global climate change. The CO_2 emitted is partially offset by the CO_2 absorption through photosynthesis by trees. The amount of CO_2 emitted per unit of energy generation depends on the efficiency of the biomass energy plant and the amount of carbon embedded in the solid waste generated. Therefore, the amount of greenhouse gas emitted by each technology varies and becomes a parameter for ranking of technologies. Combustion being the least efficient generates relatively high amount of greenhouse gases and therefore receives the lowest score of one (1). CHP being the most efficient technology receives the highest score of three (3). Gasification and ENSYN score in the mid-range score of two (2) owing to their relative efficiencies.

Table 5-4: Scoring of technologies based on environmental factors

Criteria	Combustion 2.5MW	Combustion 12.5MW	Gasification 2.5MW	Gasification 12.5MW	CHP 2.5MW	CHP 12.5MW	ENSYN (Biofuel)
Pollution control technology	1	1	2	2	3	3	3
Waste generation	2	2	1	1	2	2	2
Air pollution	1	1	2	2	3	3	3
Greenhouse gas emissions	1	1	2	2	3	3	2

5.2 POLICY-BASED INCENTIVES

Renewable energy and biomass energy have increasingly benefitted from many supportive policy incentives in the U.S. in recent years. The push for clean and renewable energy and the move towards a de-carbonized economy have resulted in a slew of measures, schemes and programs, at various governmental levels and by various departments in the country.[47] A myriad of policy incentives may apply to the proposed biomass facility, but the degree of applicability depends on a variety of factors including ownership type, eligibility criteria, cost of the plant, generation capacity and many more.

In determining the grants, loans and incentives potentially available, it is important to note that a combination of policy incentives may be relevant to the proposed plant; however, eligibility criteria must be carefully determined. While not intended to be an exhaustive list, major applicable federal and state policies and programs are listed in Table 5-5.

Table 5-5: Policy incentives

Department	Program/ Scheme	Incentive Type
Federal Policies		
Department of Energy (DOE)	Federal loan guarantees for renewable energy projects and efficient energy projects[48]	Loan guarantees
Department of Agriculture (USDA)	Rural Energy for America Program (REAP)[49]	Loan financing & Grants
	Rural Economic Development Loan and Grant (REDLG)[50]	Zero-interest loans & Grants
	Business & Industry Guaranteed Loans[51]	Loan guarantees
	Rural Business Enterprise Grants (RBDG)[52]	Grants
US Forest Service	Stewardship contracting[53]	Contractual incentives
Inter-agency	Small Business Innovative Research Grants (SBIR)[54]	Grants
	Modified Accelerated Cost-Recovery System Depreciation (MACRS)[55]	Depreciation deductions
	Biomass Research and Development Initiative (BRDI) financial assistance program[56]	Grants and Cooperative Agreements
	Wood Innovations Grant Program[57]	Grants
	Federal Renewable Energy Production Tax Credit[58]	Tax credits
	Biomass Utilization Grants (BUG)[59]	Grants
US Internal Revenue Service	Investment Tax Credit	Tax credits
State Policies		
New York State Energy Research and Development Authority (NYSERDA)	Clean Energy Fund[60]/ NY Green Bank[61]	Various financial arrangements
	Renewable Heat NY[62]	Installation incentives
	Cleaner, Greener Communities[63]	Grants
	New York Renewable Portfolio Standard[64]	Funds and incentives
Incentives pertaining to specific technologies		
NYSERDA	Combined Heat and Power Performance Program[65]	Performance-based incentives

Further information on policy incentives is presented in Appendix 3.

5.2.1 POLICY-BASED INCENTIVE QUALITATIVE SCORING

Based on the above review of policy based incentive factors, a single score was given to each technology type. Below is an explanation of how technologies were scored, followed by the scoring itself.

Both combustion and gasification technologies qualify for generic incentives and grants for wood boilers, both on the federal and state level, but there is often little differentiation between these two technologies. There are incentives for returning biochar to the land, as well as using specific types of feedstock, that exist for the ENSYN technology. The most available federal and state incentives and grants apply to CHP plants. There are state-based CHP gasification incentives for gas-fired reciprocating and turbine technologies, as well as specific grants for many types of CHP technologies. Since incentives and grants will be significant sources of funding for building a biomass plant, it is important to recognize that CHP has more funding options available than any other technology, giving it the highest score of three (3).

Table 5-6: Scoring of technologies based on incentives

Criteria	Combustion 2.5MW	Combustion 12.5MW	Gasification 2.5MW	Gasification 12.5MW	CHP 2.5MW	CHP 12.5MW	ENSYN (Biofuel)
Incentives	2	2	2	2	3	3	2

5.3 SOCIAL FACTORS

The impact of the proposed biomass power plant on the local community plays a critical role in determining its feasibility. Biomass energy plants have the potential to bring long-term benefits to the community in which they exist and have far-reaching, long-term positive and negative impacts on current and future residents. The Town of Berlin Land Use Regulations[66] stipulates specific requirements for proposed or existing development to protect both the environment and the quality of life in the town; these regulations may be indicative of some of the social factors that concern Berlin's residents.

While general social factors related to a biomass energy plant may be numerous, major social factors that must be considered are health and safety, job creation and aesthetic impacts, which are discussed below.

HEALTH AND SAFETY

Any new proposed energy plant can have multiple effects on the health and safety of local population.[67] Health issues can arise from particulate matter emissions and other pollutants generated during the plant's operations, as well as from traffic hazards due to movement of vehicles supplying raw material and finished products to and from the site. Safety issues like the risk of accidents during the operation of the power plant also need to be considered. A plant with higher health and safety issues associated may face opposition from the community. It is therefore important to consider a technology with least possible health and safety issues associated with it.[68]

JOB CREATION

Socio-economic impacts of a potential biomass energy plant are an important consideration for any community, but are especially crucial for Berlin. Specific economic factors are discussed in Section 6; however, an important socio-economic factor is the job creation potential of the plant. The number of jobs created by different technologies varies, with certain technologies creating a higher number of skilled jobs while others created higher number of unskilled or semiskilled jobs.

CASE STUDY: BIOPOWER IN EAST HELENA, MONTANA[69]

A Study Prepared by NREL in Partnership with the Environmental Protection Agency, 2014 by Kristi Moriarty

The case study is a feasibility assessment for reclamation of a brownfields site in East Helena, Montana for siting a biomass energy facility. To take advantage of the site to reenergize the community by developing jobs and using the natural forest resources to produce power. The project analysis looked into the feedstock availability, existing infrastructure and desire for social and community benefits of the proposed facility.

East Helena proposed a 10MW-20MW facility on an abandoned site with consideration for producing clean electricity. The study commented that according to their research bio power generates ten times the number of good-paying jobs found at a typical natural gas-fueled facility. Each dedicated biomass facility provides up to two jobs per one megawatt of plant capacity, with another two jobs created indirectly for the collection, handling and transportation of the organic fuels used by the plants.

AESTHETICS

Aesthetics or visual appeal of the proposed power plant will be an important consideration, especially in a small town like Berlin. Aesthetic impacts are often of particular concern to the local community, [70] where there is specific interest in understanding the type and degree of visual impact that may be associated with a proposed plant. Some factors often considered are the degree of visibility of the plant, the facilities' appearances from homes or scenic locations and overlooks such as wild and scenic rivers and state parks, the number of people who can see the plant, the amount of night sky disturbance from plant lighting or aircraft warning lights, and changes in visibility caused by plumes from stacks or cooling towers.[71] Generally, sites that are well-hidden or limited in visibility may be more desirable than sites that are highly visible, produce night lighting effects, or have plume impact potential[72]. However, it is difficult to quantify aesthetic impacts and consequently almost impossible to differentiate the available biomass technology options based on their aesthetic impacts. Therefore, aesthetics have not been scored as part of the qualitative ranking of social factors.

5.3.1 SOCIAL FACTORS QUALITATIVE SCORING

Based on the above review of social factors, as well as conversations with the town council, a score was given to each technology type based on the number of jobs that would be created by developing the individual technology. Similarly, overall health and safety impacts associated with each technology have been scored. Below is an explanation of how the technologies were scored, followed by the scoring itself.

HEALTH AND SAFETY

Health and safety considerations and scoring for each technology was based on a combination of three aspects: qualitative assessment of impacts associated with pollution (air and noise), increased risk to public safety due to traffic hazards from movement of trucks, and overall operational safety of a typical plant using that particular technology. Based on the overall assessment, it was found that except for combustion, all other technologies seem to weigh almost equally, when considering the combination of aspects considered for this scoring criterion. Combustion ranked the lowest (1) due to higher air pollution potential and higher traffic hazards associated due to increased movement of trucks; combustion's lower efficiency requires more feedstock to be utilized, implying an increased number of trucks to transport the feedstock to the plant site.

NUMBER OF JOBS

The number of potential jobs for each technology type was based on a combination of case study analyses and generalized metrics based on jobs per MW capacity for power generating plants. Although this may vary, power generating facilities would produce approximately 2 jobs for each 1 MW of power generated. For example, a 10 MW plant would equate to approximately 20 full time employees with an additional 10-20 jobs in the supply chain (forest services). More analyses on the potential number of jobs are presented in the Quantitative Analysis section of the report (Section 6.1). Plant size is a determinant in approximating the number of potential employees but a minimum is required regardless of size, including positions such as administrative, accounting, and maintenance technicians. Based on these criteria, every 12.5MW plant option was ranked higher than the 2.5MW plant option. The ENSYN technology creates significant employment as well, which is why it has a high ranking.

Table 5-7: Scoring of technologies based on social factors

Criteria	Combustion 2.5MW	Combustion 12.5MW	Gasification 2.5MW	Gasification 12.5MW	CHP 2.5MW	CHP 12.5MW	ENSYN (Biofuel)
Health and Safety	1	1	2	2	2	2	2
Number of jobs	2	3	2	3	2	3	3

5.4 SITING & INFRASTRUCTURE FACTORS

The location for the proposed biomass plant plays a crucial role in its effective and sustained operation. In determining the positioning and siting of the plant, many factors need to be considered, including physical and geographical requirements, community impacts, public safety and health concerns, environmental impacts, land use impacts, and economic impacts of siting.[73] In turn, based on where the plant is sited (or located), necessary infrastructure needs to be created around it, to ensure smooth inflow of raw material from forest sources and effective distribution of energy output to consumers. Table 5-8 provides the criteria used to decide the best possible location to site the biomass plant in the town.[74] Further information and detailed descriptions of the factors is available in Appendix 4.

Table 5-8 : Criteria categories and considerations for siting power plant

Criteria Categories	Consideration
Site Requirements	Ease of access Buffering Flood Plains Fuel Delivery Need for power Site expandability Site geography Site size Solid waste management Transmission Water discharge Water supply
Community Impacts	Aesthetics Costs to communities Number of relocations Public attitude
Public Health & Safety Concerns	Degradation of local air quality Attainment status Prevention of significant deterioration Sensitive populations Dust Electric and magnetic fields (EMF) Noise Operational odors Traffic safety Wastewater treatment

Environmental Impacts	Air quality Storm water runoff Wastewater treatment discharge Wildlife and natural lands Wildlife impacts from operation
Land Use Impacts	Industrial forests Land acquisition Land use compatibility Previous land use Prime agricultural land Recreational areas
Economic Impacts	Delivered cost of energy: Future development limitations Jobs and purchases Property values Transmission and distribution changes

Water plays a critical role in the operation of the power plant, finding itself in several aspects of the siting considerations listed above. Water is used for boiler feed, cooling, and emergency fire hydrant, as well as for dust suppression in a power plant. The water used for boiler feed needs to be demineralized to avoid scaling and hence adds significantly to the operational cost of the plant. It is therefore important to assess the water requirements of each technology as a separate category. Though the town of Berlin has an abundant water supply, the cost associated with demineralization and recovery rates make it an important qualitative consideration for selecting a particular technology.

5.4.1 SITING AND INFRASTRUCTURE FACTORS QUALITATIVE SCORING

Based on the above review of siting factors, a single “infrastructure required” score was given to each technology, as well as a “water requirement” score. Below is an explanation of how technologies were scored, followed by the scoring itself:

INFRASTRUCTURE REQUIRED

The main components required from an infrastructure standpoint are land area required, ease of connecting to loads (offtake grid for electricity and piped supply for heat) and quality of connectivity required for transportation of raw material and finished goods. Combustion and gasification plants require easy connectivity to local grid for electricity offtake along with a good transportation network for raw material; this earns each a score of three (3). CHP technology requires connectivity to local grid for electricity offtake as well as the appropriate infrastructure to distribute the heat and transportation network for raw material, which is why it is scored at two (2). The most complex technology is ENSYN, which would require the most amount of infrastructure in terms of good road connectivity for transporting raw material and finished product, strong local grid to supply electricity for plant operation as well local heat supply source to dry the wood to <6% moisture content. The fact that it is a patented technology could make it both difficult and expensive to obtain and install. For these reasons, ENSYN was given a score of one (1) in this category.

WATER REQUIREMENT

Among the technologies considered ENSYN is the most efficient with a score of three (3), as it requires the least amount of water and only for cooling, emergency fire hydrant and dust suppression. CHP that incorporates a district heating system is the least efficient, as the water supplied for district heating as steam is not recovered completely. This requires large quantities of water to be used as boiler feed continuously, giving it a low score of one (1). Combustion and gasification technologies have a higher efficiency compared to CHP because the boiler feed water can be recovered and recycled to an extent of more than 95% by condensing the steam used for running the turbine.

Table 5-9: Scoring of technologies based on infrastructure requirements

Criteria	Combustion 2.5MW	Combustion 12.5MW	Gasification 2.5MW	Gasification 12.5MW	CHP 2.5MW	CHP 12.5MW	ENSYN (Biofuel)
Infrastructure requirement	3	3	3	3	2	2	1
Water requirement	2	2	2	2	1	1	3

5.5 PLANT OPERATIONAL FACTORS

Operational factors related to feedstock requirements and feedstock variability which pertain to this section have been discussed earlier in Section 3 of the report. The efficiency of the plant is closely linked to the feedstock requirement and hence has also been used as a scoring factor here. Scoring of technologies based on these operational factors is explained in this section.

5.5.1 PLANT OPERATIONAL FACTORS QUALITATIVE SCORING

FEEDSTOCK REQUIREMENT

The feedstock requirement is based on the efficiency of the plant. This means the amount of feedstock required for a plant is inversely proportional to the conversion efficiency of the plant; if a plant is more efficient, it uses less feedstock to produce the same amount of energy as a less efficient plant. Since combustion is the least efficient technology, it has the highest feedstock requirement, resulting in a low ranking (1) because it puts more strain on the forest resources. Gasification is more efficient than combustion, earning it a slightly higher ranking (2). Both CHP and ENSYN are very efficient technologies, implying they require less feedstock and exert the least amount of stress on the surrounding forests.

PLANT EFFICIENCY

As discussed previously, each technology has a different efficiency, as defined by the ratio of input to output. CHP is the most efficient technology, with a range of 70-90%, because it is able to capture and reuse heat that would be lost in other biomass systems. While gasification technologies have a fairly large range of efficiency (15-45%), it is on average more efficient than combustion technologies, which are only 20-25% efficient. ENSYN only has three operational plants, all of which are approximately 36% efficient.

FEEDSTOCK VARIABILITY

Certain technologies are more equipped to handle less homogenous feedstock, while others require more specific, consistent inputs. The ability to have some flexibility in the type, size, and moisture content of the feedstock makes it easier for the logging companies providing the feedstock because they are able to utilize more wood in general. Gasification is able to use a larger variety of feedstock, with CHP similarly flexible. Combustion requires more specific homogenous wood. The most restrictive technology is ENSYN, which requires specific feedstock as an input.

Table 5-10: Scoring of technologies based on plant operational factors

Criteria	Combustion 2.5MW	Combustion 12.5MW	Gasification 2.5MW	Gasification 12.5MW	CHP 2.5MW	CHP 12.5MW	ENSYN (Biofuel)
Feedstock requirement	1	1	2	2	3	3	3
Plant efficiency	1	1	2	2	3	3	2

Feedstock variability	2	2	3	3	3	3	1

5.6 SELECTION OF TECHNOLOGY

A cumulative qualitative scoring matrix which sums the scores from each section to produce a final score and ranking for each technology was created. A representation of this cumulative qualitative scoring is presented below.

Table 5-11: Criteria based scoring of individual technology

Criteria	Combustion 2.5MW	Combustion 12.5MW	Gasification 2.5MW	Gasification 12.5MW	CHP 2.5MW	CHP 12.5MW	ENSYN (Biofuel)
Environmental Factors	5	5	7	7	11	11	9
Policy-based Incentives	2	2	2	2	3	3	2
Social Factors	3	4	4	5	4	5	5
Siting & Infrastructural Factors	5	5	5	5	3	3	4
Plant Operational Factors	4	4	7	7	9	9	6
TOTAL	**21**	**22**	**28**	**29**	**33**	**34**	**29**

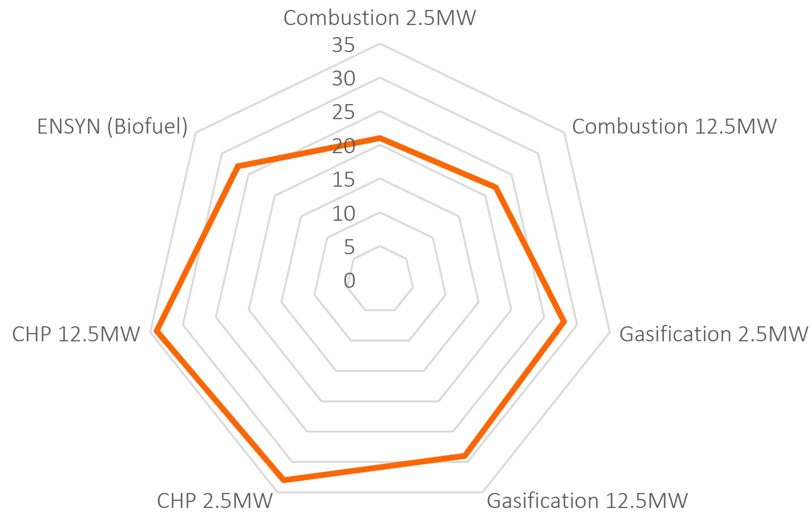

Figure 5-2 : Cumulative ranking of technologies

Based on this qualitative analysis, a 12.5 MW CHP biomass plant emerges as the best technology choice for Berlin. Although the 2.5 MW and 12.5 MW facilities were nearly tied within our scoring system, the town's primary goals of creating additional jobs and attracting new industry supported the 12.5 MW facility. The larger plant provides significantly more jobs and would support the development of the incoming aquaponics farm and other future industry. This preliminary qualitative analysis and resulting decision will be analyzed from a quantitative feasibility perspective in the following section.

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6. QUANTITATIVE ANALYSIS

Section 5 above detailed the many qualitative factors that play a crucial role in determining if a biomass plant is feasible for Berlin. This section will present the quantitative factors that are essential to understanding whether a biomass plant is viable for Berlin.

6.1 ECONOMIC IMPACT OF A BIOMASS ENERGY PLANT

One of the most important factors in Berlin's consideration of the construction of a local biomass energy plant is its potential positive impact on the community. Intuitively, the town board believes that such an initiative will contribute to, and encourage future growth of, economic activity in the region.

In order to quantify the potential impact in terms of employment and expenditures, this study utilizes an Input/output modeling and analysis. Input/output modeling is a generally accepted methodology for policy makers to analyze the benefits to a region of a particular stimulus.[1] In the case of this feasibility study, the stimulus or Input is the aggregate amount of capital investment required to build and operate the plant. The Output is the economic activity that results from the investment.

Economic activity in Input/output modeling can be divided into three categories: [2]

Direct Impact. The impact of resources directly employed at the plant both during construction and operation, including newly created jobs and on-site professional services.

Indirect Impact. The impact of incremental resources employed by supporting businesses in the supply chain for the plant, including hiring more workers in the feedstock/forestry sector to supply the plant with fuel and support services like outsourced plant maintenance, legal and accounting.

Induced Impact. The positive economic impact of additional hiring and spending by local businesses that will be needed to serve the increased activities from the direct impact and the indirect impact, including local restaurants, retail stores, health care and hotels.

Taken together, these three categories of increased activity create a Multiplier Effect on the local economy as spending is re-circulated through local businesses and employment. Diluting the multiplier effect are leakages from spending that occurs out of region and/or spending that is diverted into savings.[3]

The three most widely used Input/output models employ varied approaches to the way they project an economic impact, but all use U.S. Department of Commerce data as a foundation for building an iterative computer simulation.[4] This study uses a model developed by the National Renewable Energy Laboratory called Jobs and Economic Development Impact (JEDI) because it was specifically developed for renewable energy projects.[5] It is based on the Impact for Professional Planning (IMPLAN) software model, one of the three dominant systems, and can incorporate economic data by county, to customize results for specific regions.[6]

The JEDI model generates estimates of increased economic activity based on a specific set of project inputs applied to preset formulas, though the results are not intended to be interpreted as a precise forecast. It quantifies the direct, indirect and induced impacts both in terms of the number of additional jobs and the amount of additional income.[7]

In the case of the plant in Berlin, the inputs included the location, timing and duration of construction, plant size, generation technology, and feedstock type and capital structure. The results are summarized below (Table 6-1). The complete spreadsheet output can be found in Appendix 5.

Table 6-1: Economic impacts summery results

Construction period	Jobs	Impact
Direct Impact - On Site	56	$7,083,000
Indirect Impact - Supply Chain	10	$2,160,000
Induced Impact - External	17	$2,917,000
Total Impacts	**83**	**$12,160,000**
Annual Impact		
Direct Impact - On Site	15	$753,000
Indirect Impact - Supply Chain	13	$3,057,000
Induced Impact - External	5	$920,000
Total Impacts	**33**	**$4,730,000**

The JEDI model estimates that construction cost for a 12.5MW Biomass CHP plant would be $70.879 million. A total of 83 jobs would be created during the Construction Period, generating earnings locally of $8.3 million and leading to a one-time increase in local economic output of $12.16 million.

The three impact categories (direct, indirect and induced) are quantified above. On an annual basis the plant would support 15 direct employees earning an estimated aggregate total of $753,000. Not shown in the table, but built into the model by JEDI are assumptions that a 12.5MW plant will consume 80,000 tons per annum of biomass feedstock at $24.52 per ton. The additional indirect resources necessary to supply feedstock to the plant, plus employment in other supporting industries, are expected to create 13 new jobs. The induced effect on local businesses would create an additional 5 jobs, yielding a total annual increase employment of 33 and in economic output of $4.7 million.

REASONABLENESS OF JOB ESTIMATES

We have examined plant specifications, operating assumptions and resulting outputs of the JEDI model and have compared these with existing biomass energy plants in the Northeast United States (Table 6-2).[8] [9] [10]

Table 6-2: Jobs in biomass power plants in Northeast United States

Biomass Energy Plant	Capacity (MW)	Jobs
ReEnergy - Chateaugay NY	21	21
ReEnergy - Lyonsdale NY	22	22
GDF-Suez Ryegate VT	20	21
GDF-Suez Tamworth NH	22	20
GDF-Suez Bethlehem NH	15	25
PSEG Bridgewater NH	15	19
Indeck Energy Alexandria NH	16	15

The rate paid for feedstock has shown some volatility over the past few years, but the NREL assumption of $24.52/ton is in line with other market data. For example, the ReEnergy Lyonsdale plant recently lowered the rate it pays to foresters from $26.25/ton to $21.00/ton, but may need to raise it again to assure quality supply.[11]

Several comparable Economic Impact studies were examined, including one for a 30MW biomass energy and pellet manufacturing facility in nearby Bennington County, VT proposed by Beaver Wood Energy LLC in 2010. Northern Economic Consulting, Inc.

authored an impact study for the project and used Input/output simulation modeling to estimate that operations at the plant would support 45 direct jobs and an additional 120 indirect jobs in the county.[12] This compares in the same order of magnitude to the 15 direct jobs estimated by the JEDI model in Berlin, giving rise to an additional 33 jobs in supporting industries and local businesses.

6.2 FINANCIAL FEASIBILITY

Power generation projects obtain funding from various forms of invested capital: equity financing, recourse and non-recourse debt, and support from government programs such as loan guarantees, tax credits, subsidies and incentives (discussed in Section 5.2 above). Equity investors and lenders will focus on assessing and evaluating mitigating factors to key risks before committing to the project.[13] These include:

DEVELOPER, ENGINEERING FIRM AND GENERAL CONTRACTOR QUALIFICATIONS.

The reputation and past experience of these central players in coordinating the development and construction of the plant will be an important consideration. Strong qualifications will mitigate risks such as improper budgeting, construction delays and under-performance to design specifications.

POWER PURCHASE AGREEMENTS (PPA) AND INTERCONNECTION AGREEMENTS.

Long-term off-take contacts for the sale of energy at satisfactory prices and to assure interconnection with customers for the length of time covering debt terms, form the backbone of the financial structure for the project. Risk elements in such contracts, including conditions and counter party risk, will be critical elements in setting rate of return hurdles for equity investors and interest rates for lenders.

FEEDSTOCK PRICE AND AVAILABILITY RISKS

Hedging potentially volatile feedstock prices will be important for the project's long-term economic viability, as well as assuring stable supply quantities from multiple parties. Suppliers must be relied upon to deliver consistent quality for efficiency of operation.

ENERGY AND COMMODITY PRICE RISKS

Electricity price offerings from other suppliers to the New York Independent System Operator (ISO) present a risk to the portion of the proposed plant's revenue stream comes from non-PPA revenue. Those prevailing rates also influence PPA contract terms. Non-contracted heat/steam sales will also be at risk when alternative heating commodity prices are low, both of which will need to be factored into the projection model.

REGULATORY COMPLIANCE RISK

Financial institutions that consider backing power generation projects must be assured that all regulatory hurdles can be cleared in the development phase, and will require independent legal review of all permits, licenses and contracts to minimize regulatory risks. Such risks include facility siting according to local zoning, building codes and community precedent, state and federal environmental laws, and state power utility laws.

CURRENT MARKET CONDITIONS

Underlying the above risk analysis are market conditions affecting the energy sector generally and the biomass industry specifically. The current oversupply of domestic natural gas and low fossil fuel prices, coupled with the growth in generation capacity from other new renewable plants and distributed generation, all negatively affect the prospects for biomass power plants.[14] The wholesale price of electricity in most areas of the US has fallen well below the level at which biomass plants can viably operate without significant subsidies.[15]

YEAR-TO-DATE 2016 DEVELOPMENTS IN NORTHEAST US BIOMASS

- In January, Covanta announced the closure of two 25MW biomass plants in Maine and ReEnergy indicated that four other biomass plants in Maine are under review for closure. Both Covanta and ReEnergy cited low competing electricity supply rates and the phasing out of REC programs in Massachusetts and Connecticut.[16]
- In reaction to these announcements, the legislature in Maine passed a bill on April 14 making $13.4 million in direct taxpayer-funded subsidies to the plants remaining open. No assurances from the corporate owners were given that further closures would not occur.[17]
- In New York, ReEnergy warned in February that its 22MW Lyonsdale plant may shut down in 90 days and stated in March that it will not reopen its 21MW Chateaugay plant as had been planned.[18]
- The Lyonsdale plant received recent backing from U.S. Senator Charles Schumer for additional state support through the newly introduced Clean Energy Standard, though details on how this would apply to biomass have not been specified. This would be beyond what the plant had already been awarded in 2015 through an extension to its REC sales program.[19] The subsidy package, which amounts to $4.39 million annually, was less than the company had requested, but the maximum allowable by the Public Service Commission.[20]

6.2.1 FINANCIAL PROJECTION ANALYSIS

An Excel spreadsheet model was constructed to assess the financial feasibility of the Berlin biomass plant and understand how changes in key metrics may affect the outcome. Major inputs in the financial projection model include: plant generation capacity and performance metrics, plant capital costs, components and cost of capital structure, energy output pricing per kWh and Btu, operating costs and margins, and feedstock costs and utilization.

CONSTRUCTION COSTS, PLANT CAPACITY AND PERFORMANCE

NREL compiles estimates for plant construction costs using its database of past bio-power projects and feasibility studies. These cost estimates take into account plant capacity, power generation technologies, equipment cost averages and regional variables. As discussed above, a plant capacity for Berlin of 12.5MW was chosen. As outlined in the Economic Impact section above, the total cost of construction is estimated to be $70.879 million which has been used in the financial model as well. This figure does not include site acquisition costs or line/pipe extension costs from the plant. Separate financing would need to be arranged for these costs. It was determined that the plant would produce 93,075 MWh of power based on operating 7,450 hr/yr (85% system uptime availability factor per NREL).[21] This figure was used to calculate the yearly electricity revenue generated by the plant (discussed below: price of electricity per kWh time's number of kWh of operation).

PROJECT CAPITAL STRUCTURE

A newly formed commercial entity (Newco) will be responsible for financing and operating the proposed plant. The components of the capital structure of Newco needed to finance the $70.9 million in construction costs are assumed to be common equity (25%), and a blend of debt in the form of low interest (state supported) loans and traditional bank debt (75%). Grants could be used in place of portions of the equity or debt to lower the Weighted Average Cost of Capital (WACC). Since the WACC is used as the discount rate in calculating the Net Present Value (NPV) of the project, lowering the WACC is a desirable and effective way to raise the project's NPV. The makeup of the capital structure will also influence a corresponding measure of feasibility for equity investors: the Internal Rate of Return (IRR). Reducing the percentage of equity needed to fund the project through additional state guarantees and grants will raise the IRR for equity investors.

OPERATIONS AND MAINTENANCE

At the assumed level of operations for a 12.5MW plant, NREL estimates that the plant will consume 80,000 tons of woody biomass feedstock per year (same as used in the NREL-JEDI economic impact model above). Prices vary by region and quality (moisture content) but for the purposes of the base model, an assumed price of $24.52 per delivered ton was used, per NREL data. The NREL rate was kept as a base assumption and a sensitivity analysis was run on feedstock prices to demonstrate the effect of price fluctuations have on project NPV (see Table 6-5). Also based on NREL data, a minimum of fifteen full time employees would be required for this sized plant at a fully loaded compensation level of $80,000 per employee per year. Other variable and fixed operating costs were determined as percentages of plant output and size, respectively.

OUTPUT PRICING

The price of electricity per kilowatt-hour was the primary driver for the model. Annual revenue for the plant is determined by multiplying this price by the number of hours per year that the plant is generating electricity, times the plant's capacity in kilowatts. The cash flow resulting from this amount of revenue over a fifteen-year period drives calculations for the project's NPV and IRR. Factoring in the equity component of the capital structure yields the NPV and IRR to the equity investor(s), which are critical benchmarks in attracting an equity sponsor for the project. Separately, supplemental revenue from government subsidy programs can be added to enhance profitability. These take the form of Renewable Energy Credit sales or subsidized Power Purchase Agreements. The base case projection model assumes a combination of RECs at 25% of generation output, which was derived from NREL and NY State data. An assumption was made that the only use for the excess heat from the plant was to dry feedstock to sufficient levels to optimize efficiency. Some remaining portion of excess heat could be sold to one or more nearby customers.

Even with supplemental REC revenue, the model shows that the proposed plant, using defensible assumptions as noted above, cannot generate sufficient earnings to show clear financial feasibility (Project NPV of at least $0) if current wholesale electrical rates are imposed. The model requires an average wholesale rate of $0.10 per kWh to achieve breakeven NPV. Current price quotes from competitive retail energy providers are around $0.065 per kWh in Rensselaer County.[22]

Tables 6-3 – 6-5 provide a summary of the financial projection model assumptions, results and sensitivities. A full version of the model is in Appendix - 7.

Table 6-3: Summary of financial model results and sensitivity

Project Inputs			Pricing			$/kwh
Plant Capacity	12.5	MW	Industrial	60%	$0.10	0.10
Availability Factor	85%		Commercial	20%	$0.10	0.10
Annual Generation	93,075	MWh	Residential	20%	$0.10	0.10
Thermal Offtake	175	MMBtu	Average Rate		$0.10	0.10
			Thermal Sales		0	
Construction Costs	$ 000s		Operating Costs	$ 000s	Units	Cost
Generation Plant	70,879	100%	Salaries	1,200	15	80
Soft Costs	0	0%	Operations & Maintenance	1,780		
Grid Connection	0	0%	Feedstock	1,962	80	24.52
Pipe Extension	0	0%	Other	0		
Total Investment	70,879		Total	4,942		
Grants	0					
Net Investment	70,879					
Other Inputs			Capital Structure			$ 000s
Construction Time	1.5	Years	Equity & Grant %	25%	Equity	17,720
Collection Efficiency	98%		Required returns	15%	Grants	0
Distribution losses	5%		Loan Rate	5%	Debt	53,159
Rate Inflation	2.0%		Loan Grace Period	2		
Cost Inflation	2.0%		Loan Term	20		

Terminal value	5.0	times exit FCF	WACC***	6.4%		
REC rate	0.27	1				

Table 6-4: Project returns and recovery

Outputs		
Project Returns		
Project IRR	6.4%	
Equity IRR	19.2%	
Project NPV	$0	
Equity NPV	$3,655	
Cost Recovery		
Capital Investments	5,670	$/kW
Operating Costs	5.3	c/kWh
Capital Recovery	6.9	c/kWh
Total	12.2	c/kWh
RECs	2.7	c/kWh
Grants	0.0	c/kWh

The table below (Table 6-5) shows the effect on Project Net Present Value from $0.015 incremental changes in the price of electricity and from $5.00 changes in feedstock prices. The yellow portion of the table shows what combinations of electricity rates and feedstock prices result in positive NPV, where the discounted future earnings stream of the plant exceeds the required capital investment.

Table 6-5: Project Net Present Value

Electricity c/kWh	Project NPV ($,000)				
13.0	36,980	33,207	29,435	25,662	21,889
11.5	14,601	10,828	7,055	3,282	(491)
10.0	3,411	(362)	(4,135)	(7,908)	(11,680)
8.5	(13,374)	(17,147)	(20,919)	(24,692)	(28,465)
7.0	(45,250)	(41,477)	(37,704)	(33,931)	(30,158)
Feedstock	$20	$25	$30	$35	$40

The graph below (Figure 6-1) shows, according to the constructed financial model, what combinations of electricity supply rates and annual operating subsidies (either in the form of RECs or PPA contracts) will result in breakeven Net Present Value, where the discounted future earnings stream covers the plant's capital investment. The green line indicates that at $0.10 per kWh, $2.65 million of annual subsidies are required for NPV breakeven. The red line indicates that at the current market price of $0.065 per kWh, $6.05 million of annual subsidies are required. When comparing these subsidy levels to the recent situation for the 22MW plant in Lyonsdale, New York,[23] where the maximum level of subsidies achievable was $4.39 million, the implication is that any amount over $2.65 million for the potential 12.5MW plant is likely to be extremely challenging to obtain under current regulatory conditions.

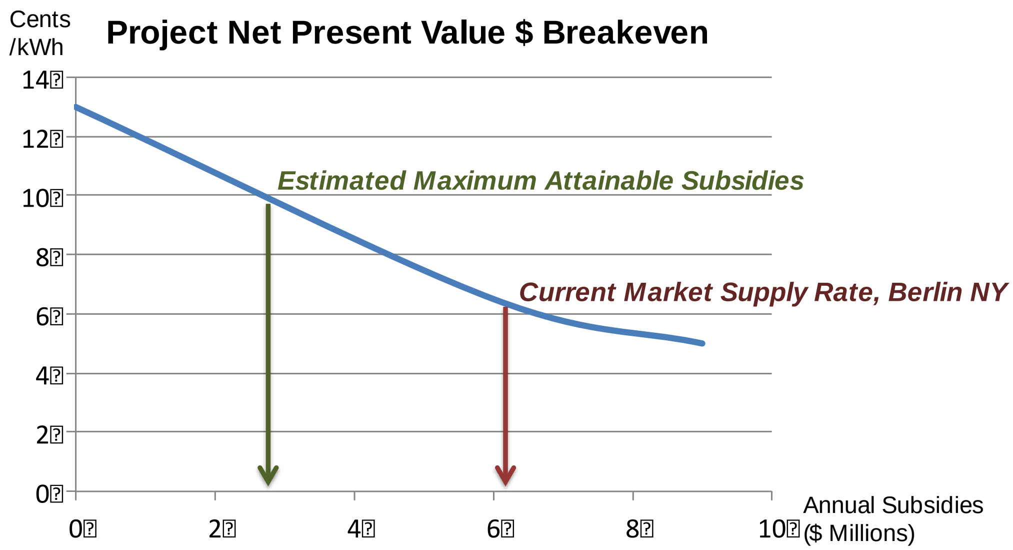

Figure 6-1: Electricity supply rates and annual subsidies

6.2.2 FINANCIAL FEASIBILITY SUMMARY

While the Excel spreadsheet model that was constructed required simplifying assumptions, the model clearly indicates that current electricity supply rates available in the Berlin region cannot support profitable biomass power generation. This is confirmed by the negative operating performance of existing industry participants, as described above. Even using optimistic amounts of annual subsidies in the model, challenging market factors outweigh any reasonable levels of government support to make the potential project financially feasible currently.

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7. CONCLUSION & RECOMMENDATIONS

The town of Berlin has expressed an interest in developing a biomass energy plant that creates jobs, supports the development of new industry, and follows sustainable forestry practices. Based on a full qualitative and quantitative feasibility analysis, the project would not be feasible under current market conditions.

A range of energy load and qualitative factor research showed that a combined heat and power (CHP) biomass energy plant with 12.5 MW of annual power generation in the form of electricity and heat would most appropriately fit the town's goals of creating jobs and supporting new industry.

According to the financial model, a 12.5 MW CHP plant in Berlin would require $70.879 million in capital investment for construction, with annual operating costs of $4.9 million. The resulting price of electricity supplied would need to be, at minimum, $0.10/kWh in order to produce positive project net present value. This takes into account a current feedstock price of $24.52 and added subsidies from federal and state incentive programs of 25% of generation capacity. This $0.10/kWh price represents a $0.035/kWh increase over the current market price of $0.065/kWh that residents of Berlin pay for electricity.

A variety of factors could affect the future feasibility of a Biomass Energy Plant in Berlin, NY. Perhaps the most prominent is the potential change in electricity prices. If market conditions shifted and electricity prices within the town of Berlin moved from their current price at $0.065/kWh to $0.10/kWh, while all other factors (feedstock price, incentives) remained the same, the proposed biomass energy plant would approach feasibility. A shifting policy landscape that favored biomass energy production could also move this project toward feasibility. Lowering the electricity price produced by the biomass plant from $0.10/kWh to $0.065kWh (the price residents currently pay) would result in $3.4 million in lost revenue in the first full year of operation. Consequently $3.4 million in additional governmental offsets would be necessary to justify the capital investment in the current market. Operating subsidies, either in the form of additional renewable energy credits (RECs) or in direct subsidies built into the power purchase agreements (PPAs) with large-scale customers could provide the necessary offsets. However, it is improbable that the plant would receive the level of subsidies needed in the current market based on case studies of similar plants.

If changing market and policy conditions created economic feasibility, Berlin would be well situated to develop a biomass energy plant. Woody biomass feedstock abounds in the surrounding area, with sufficient availability to support a 12.5 MW facility. Additionally, the estimated number of construction jobs (83) and long-term operating jobs (33) represents a significant potential increase in opportunity and economic impact on the town.

Environmental sustainability proponents will note that the proposed project has a variety of sustainability issues in relationship to carbon neutrality and emissions. Analysis shows that biomass energy production is not carbon neutral, and that emissions released by burning of biomass are not sufficiently sequestered by future biomass growth. Development of a Forest Management Plan (FMP) that reduces biomass removal while increasing regenerative growth, then, becomes paramount to environmental feasibility.

RECOMMENDATIONS AND NEXT STEPS

- Remain in close contact with federal (USDA) and state (NYSERDA) agencies in regards to changing policy and incentive landscape that could offset both production and operational costs
- Monitor forecasts for electricity prices, understanding that $0.10/kWh is the feasibility threshold for this particular plant and size
- Seek out private investment capital to offset construction capital costs
- Develop a Forest Management Plan (FMP) that contains best management practices (BMPs) that genuinely add to regenerative forest growth and have the ability to sequester at least 80% of carbon released as a result of the biomass plant
- Build in additional costs of emissions mitigation technology for the proposed plant to reduce particulate emissions and increase sustainability.

- Consider siting criteria for the proposed plant. Suggested site and considerations is provided in Appendix 4.
- Explore the possibility of developing a pellet plant, as opposed to a biomass energy plant. This facility would utilize the abundant local forest resources to provide a local source of pellets for town residents to use in their home heaters. For more information about pellet plants, see Appendix 6.

Although it is not recommended that Berlin pursue building a biomass energy plant in current conditions, it could be possible in the future as several market and policy factors change. It is therefore important for the town to understand the options available for this type of project and to revisit this topic again in the future.

*****

APPENDIX 1: BIOMASS PROCUREMENT: ADDITIONAL FACTORS

STAKEHOLDERS

Land owners: While the Forestland Group owns a large portion of the land surrounding Berlin, there would also be need for private land owners to collaborate with logging companies to allow for biomass extraction.

Land managers/forestry consulting firms: These land management companies work with logging companies directly to develop silviculture and management plans for the landowner. Some examples of firms in the Berlin area are Landvest, Prenstiss and Carlisle, and Forecon.

Logging companies: The physical harvesting of the woody biomass is performed by the logging companies under a management plan designed by the land management/consulting firm. In Berlin, the major logging companies include Sylvan Timber Harvesting, Inc., Lashway Forest Products, and Mid-Hudson Forest Products.

DELIVERY REQUIREMENTS

Biomass can be delivered to an end user in many forms, including round wood, ground wood, and whole tree chips, or variations of these three. Prices vary by mill specifications, the season, and market competition.

CASE STUDY: VØLUND GASIFIER PLANT AND TOWN OF HARBOØRE (JUTLAND, DENMARK)

The city of Harboøre built the Vølund Gasifier Plant as a way to convert wood (harvested from forests within a 10-20-miles radius of the plant) into electricity using an engine instead of a steam boiler. The 1.6 MW (electric) gasifier system converts woodchips into a gas that burns clean enough to fuel an internal combustion engine. Two engines in the plant burn that gas, producing rotary motion that drives a power generator. However, electricity is only the secondary product. The primary product is heat, coming from 3 sources: the heat that comes from the engines' coolant, the heat that is pulled from the engine exhaust, and the heat produced by the cooling process that cleans the gas from the gasifier. The product of all this heat capture is hot water for a district heating system that warms buildings in the Town of Harboøre a kilometer away. The total length of the Harboøre district heat network of buried piping is 10 kilometers (six miles). The Harboøre plant was commissioned in 2000, and after five years fine-tuning for optimal performance, the plant has been running smoothly more than 8,000 hours per year without requiring much maintenance.

CASE STUDY: BWSC BIOMASS PLANT – STOBART PARK

People in Revelstoke always had an interest in using the sawdust and other wood waste created by the local Downie cedar mill that otherwise were going up in smoke. In 2005, when the time came, they first created a wholly owned subsidiary of the city, the Revelstoke Community Energy Corporation (RCEC), to be managed by a volunteer board on which city staff and council members form the majority. Initially, they were planning to build a combined heat and power (CHP) plant, producing heat as well as power. However, electricity rates were so low at the time that planners developed just the district heating system: a 1.5 thermal MW (5.1 MMBtu/hour) biomass boiler with two kilometers of piping to major buildings in the city core. The heating plant was built for $6 million on the cedar mill's land. The mill supplies the feedstock and buys about half of the heat produced by the plant for use in its drying kiln, as well as providing staffing for the heating plant. Despite a few challenges and struggles with mixed-quality fuel, project leaders and community are absolutely satisfied by the project and are actually working on expanding it.

CASE STUDY: CITY OF REVELSTOKE (BRITISH COLUMBIA, CANADA)

BWSC is the acronym for Burmeister & Wain Scandinavian Contractors, a turnkey contractor based in Denmark specializing in developing energy and power generating projects. The case study referenced is for a component of a larger development site in the United Kingdom located in an industrial area called Stobart Park.

Plant characteristics include the development of a Combined Heat and Power (CHP) plant to generate renewable electricity and heat by combustion of wood fuel. The feedstock for the facility is based on approximately 145,000 tons per year of virgin and recycled wood to produce 20 MW of electricity for export to the National Grid. The facility will generate 3.5 Megawatts thermal (MWth) of thermal energy to local industry.

For the proposed facility, chipped Biomass material will be delivered to the site by trucks fitted with walking floors which allow the load to be moved inside the body of the vehicle. Each truck will be capable of delivering approximately 25 tons of ready chipped recycled wood fuel. Deliveries are anticipated to be two vehicles per hour scheduled between 7AM and 6PM daily with an additional three (six two way) trips for removing ash residue from the site. Additional traffic activity will be produced by plant employees. Rail delivery of feedstock to mitigate the high traffic potential is being considered but this option is precluded if the intent is to source the wood locally.

ADDITIONAL IMPACTS OF WOODY BIOMASS HARVESTING

As mentioned in Section 3.2, harvesting of woody biomass can have both beneficial and negative impacts. Some of the major impacts are described below.

BENEFICIAL IMPACTS

Managed correctly, woody biomass harvesting can have a wide range of benefits for forests, including:

Increasing Age-class diversity of trees: Because of historical patterns of land management over the last century, northern forests lack age-class diversity and, if left unmanaged, will uniformly grow old.[1] The result is a loss of habitat for specific species of trees that depend on early succession. Management practices that increase the rate of forest regeneration, such as woody biomass harvesting, will increase species diversity. [2]

Increased Bird Habitats: Throughout the Northeastern United States, growing concern surrounds the loss of early succession tree species that provide habitat to a variety of bird species. Biomass harvesting that promotes the growth of a wider diversity of tree species will indirectly promote a wider diversity of bird species. [3]

Increased Water Yields: Selective thinning of forests and other practices that reduce biomass, reduce ecosystem water use, therefore increasing water yield to local and regional surface and groundwater resources. Scientists therefore note that reduced biomass may prove useful in comprehensive water conservation strategies.[4]

Reducing risk of wildfire: Biomass harvesting can reduce risk of catastrophic forest fires by reducing the quantity of available fuel. A partial harvest or thinning can reduce the density of tree residue on the forest floor, therefore limiting the effects of a fire. [5]

NEGATIVE IMPACTS

However, not following Best Management Practices in Forest Management by overharvesting or by the misuse of harvesting equipment can have a number of negative impacts.

Although sustainable levels of biomass harvesting can positively impact biodiversity, overharvesting can decrease species habitat and diversity. Overharvesting of deadwood, for example, can have a direct impact on bird and insect species that depend on deadwood for habitat and nutrients.[6]

Woody biomass harvesting activities can also have a negative impact on both water quality and quantity. Heavy equipment used in harvesting can compact soil, increase erosion and runoff, and disrupt the flow of small streams and rivers. [7]

And finally, serious concerns exist around the amount of organic matter loss from woody biomass harvesting and the effect it could have on soil nutrient content. Levels of organic matter in soils directly impact the forest’s ability to regenerate, and by overharvesting woody biomass there is a potential for decreasing re-growth potential of forests.[8]

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7 ibid
8 ibid

APPENDIX 2: EMISSION CONTROL TECHNOLOGIES

Emissions Control Technologies fall under three general categories: mechanical collectors (cyclones or multi-cyclones), fabric filters (Bag Houses), and electrostatic precipitators (ESPs).

CYCLONES AND MULTI-CYCLONES

A cyclonic separator (cyclone) uses centrifugal force to separate particulate matter from the flue gas. The cyclone's body design uses the taper to allow particulate matter to fall by gravity into a collection hopper for disposal. A cyclonic separator uses high speed rotating airflow within a conical container to separate particulate matter from emissions. In a single cyclone, the air flows in a helical pattern, beginning at a wider radius of the container near the top and ends at the bottom, tapered end where it exits in a straight airstream through the center of the container and out the top. As the particles move down the conical container, they have too much inertia to follow the tighter radius, where they strike the inside wall and fall to the bottom of the container into a collection hopper. The conical shape helps to reduce smaller particles from the airstream.[1]

Multi cyclones utilize this same technology in numerous smaller conical containers to collect smaller particles and have greater efficiency in particulate emission reduction. Single cyclonic separators can achieve an efficiency of 50% while multi-cyclones range between 65%-95% efficient. [2]

Cyclone separators are more efficient in capturing larger particles (PM10) but ineffective in collecting smaller size particles such as PM2.5, which are the most harmful. Cyclone separators have no moving parts or filter media so operation costs are minimal. [3]

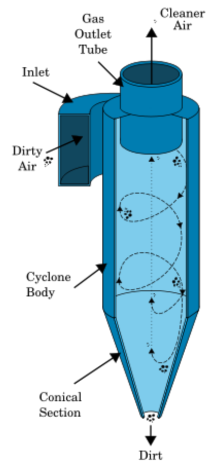

Figure 0-1: Cyclonic Separator, Source: Wikipedia (Cyclonic separation)

FABRIC FILTERS

Fabric filters can achieve particulate control efficiencies of 99% for total PM based on design and filter fabric selection. Highest efficiencies are achieved when large PM are first eliminated from the flue gas stream. This would require that large PM are first removed by cyclonic separators. This would improve the efficiency of the fabric filter to collect finer PM since the filter media is not compromised by the larger particulate matter. [4]

Fabric filters operating independent of a mechanical separator can be subject to particulate matter caking on the filter media as well as having a fire hazard potential if embers from the combustion stream are caught in the filter fabric. [5]

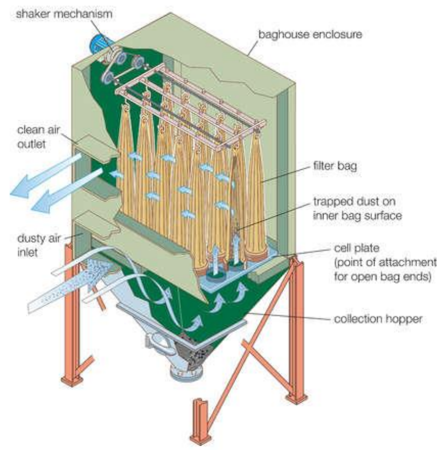

Figure 0-2: Shaker type baghouse, Source: illustrationsource.com

ELECTROSTATIC PRECIPITATORS

Electrostatic Precipitators (ESPs) use electric fields to collect particulate matter emissions in the flue gas stream. An ionizer imparts a positive electric charge to the PM which is subsequently collected on a negatively charge collection plate. The collection plate must be cleaned of the collected material by rappers, hammers or vibrators depending on the size of the collector plate. The removed PM is collected in bottom hoppers for waste removal. [6]

Electrostatic Precipitators can achieve efficiencies of 98% for PM 10 and nearly as much for PM 2.5. They are not prone to fire risk as filter fabric and can operate at temperatures over 570 degrees, allowing their installation closer to the boiler rooms. ESPs tend to require less maintenance than filter fabric and use less energy. Routine cleaning of the collection plates is required. [7]

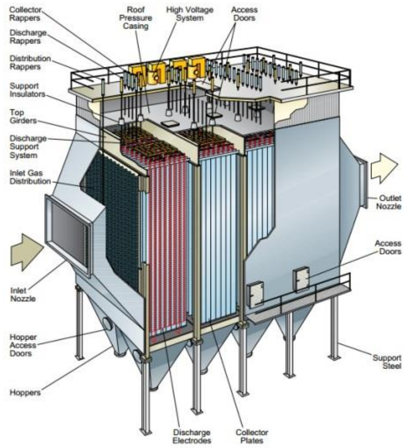

Figure 0-3: Electrostatic Precipitator, Source: Babcock & Wilcox

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[1] Biomass Energy Resource Center , Particulate Matter Emissions-Control Options for Wood Boiler Systems, 2011
[2] ibid
[3] ibid
[4] ibid
[5] ibid
[6] ibid
[7] ibid

APPENDIX 3: DESCRIPTION OF POLICY-BASED INCENTIVES FOR BIOMASS ENERGY PLANTS

FEDERAL POLICIES

DEPARTMENT OF ENERGY (DOE)

FEDERAL LOAN GUARANTEES FOR RENEWABLE ENERGY PROJECTS AND EFFICIENT ENERGY PROJECTS[1]

DOE offers up to $2.5 Billion in loan guarantee to finance projects located in the United States employing new or significantly improved technology such as renewable and/or efficient energy systems that avoid, reduce, or sequester anthropogenic emission of greenhouse gases.

DEPARTMENT OF AGRICULTURE (USDA)

All though some of the following grant options are for towns with population greater than 50,000 they have been included here in case future policy regulations change in favor of smaller towns.

RURAL ENERGY FOR AMERICA PROGRAM (REAP)[2]

REAP guarantees loan financing (up to 75% of total eligible project costs) and grant funding (up to 25% of total eligible project costs) or a combination of both. The funds may be used for the purchase, installation and construction of renewable energy systems, including biomass among others. Eligibility applies to agricultural producers and rural small businesses (situated in a city or town with a population of greater than 50,000 inhabitants) to purchase or install renewable energy systems or make energy efficiency improvement.

RURAL ECONOMIC DEVELOPMENT LOAN AND GRANT (REDLG)[3]

USDA provides grant funds (up to $300,000) or zero interest loan (up to $1 million) to local utility organizations which use the funding to establish revolving loan funds (RLF) to fund projects that will support businesses, public bodies and non-profits to create or retain rural jobs. Eligibility applies to current rural development electric programs borrowers situated in a city or town with a population of greater than 50,000 inhabitants.

BUSINESS & INDUSTRY GUARANTEED LOANS[4]

This program guarantees loans for rural businesses, allowing private lenders (with legal authority, sufficient experience, and financial strength) to extend more credit than they would typically be able to. Borrowers such as for-profit businesses, nonprofits and cooperatives, federally-recognized tribes, public bodies and individuals that are situated in a city or town with a population of greater than 50,000 inhabitants can use the funds to develop a business. Loan amount are guaranteed as follows: 80% for loans of $5 million or less, 70% for loans between $5 and $10 million and 60% for loans exceeding $10 million but up to $25 million maximum.

RURAL BUSINESS ENTERPRISE GRANTS (RBDG)[5]

RBDG provides grant funding to support targeted technical assistance, training and other activities leading to the development or expansion of small and emerging private businesses. Eligibility applies to towns, communities, state agencies, authorities, non-profit corporations, institutions of higher education, federally-recognized tribes and rural cooperatives situated in a city or town with a population of greater than 50,000 inhabitants. There is no maximum amount but higher priority is given to smaller request with grants generally ranging from $10,000 up to $500,000.

US FOREST SERVICE

STATEWIDE WOOD ENERGY TEAMS

Statewide Wood Energy Teams Cooperative Agreements[6] were started in 2013 in an effort to increase the knowledge and use of woody biomass for energy. The program goals include promotion of commercially proven wood energy systems, facilitation of market expansion for woody biomass based energy to support wildfire mitigation, forest restoration and other forest management goals. NY State has formed the New York Statewide Wood Energy Team (NYSWET)[7], which among other initiatives has enhanced two NY state programs: Green Bank and Renewable Heat NY.

STEWARDSHIP CONTRACTING

Harvesting and procuring of woody biomass from forests may be eligible for stewardship contracts, providing further incentive for utilization of this resource. Stewardship contracting helps achieve land management goals while meeting local and rural community needs, including contributing to the sustainability of rural communities and providing a continuing source of local income and employment8. It focuses on the "end result" ecosystem benefits and outcomes, rather than on what's removed from the land. Stewardship contracting allows private organizations or businesses to do the necessary thinning and removal of small trees and undergrowth; as partial payment, stewardship contractors are able to keep part of what they remove.[9]

INTERAGENCY PROGRAMS

SMALL BUSINESS INNOVATIVE RESEARCH GRANTS (SBIR)

The SBIR program provides funding to small, high-tech businesses to research, design, develop, and test new technology ideas related to specific needs defined in solicitations floated by federal agencies. The program stimulates technology innovation by funding new ideas that would otherwise be funded, and helps introduce small business solutions into the market and to meet a wide range of government research priorities from national defense to renewable energy systems to new medical or educational solutions.[10]

MODIFIED ACCELERATED COST-RECOVERY SYSTEM DEPRECIATION (MACRS)

MACRS allows businesses to recover investments in certain property through depreciation deductions through a set of class lives for various types of property, ranging from 3 to 50 years. A number of renewable energy technologies are classified as five-year property under MACRS, including combined heat and power. For biomass, the property class life is 7 years. Eligible biomass property includes assets used in the conversion of biomass to heat or to a solid, liquid or gaseous fuel, and to equipment and structures used to receive, handle, collect and process biomass in a water wall, combustion system, or refuse-derived fuel system which can create hot water, gas, steam or electricity.[11]

BIOMASS RESEARCH AND DEVELOPMENT INITIATIVE (BRDI) FINANCIAL ASSISTANCE PROGRAM[12]

Both DOE and USDA have been given responsibility to support the development of a biomass based industry in the United States. The objectives of this responsibility are specified in Section 9008(e) of FSRIA (Farm Security and Rural Investment Act of 2002) and the BRDI is developed based on the FSRIA. Three technical areas are eligible for guidance and assistance under BRDI: (A) Feedstock development, (B) Biofuels and bio-based products development, and (C) Biofuels development analysis. USDA anticipates awarding grants and DOE anticipates awarding Cooperative Agreements under this funding opportunity announcement. Anticipated award size ranges from $500,000 to $2 million per award.

All entities listed under Section 9008(e)(5) of FSRIA, as amended (7 U.S.C. 8108(e)(5)), are eligible to apply 13. Eligible entities are: (A) An institution of higher education; (B) A National Laboratory; (C) A Federal research agency; (D) A State research agency; (E) A private sector entity; (F) A nonprofit organization; or (G) A consortium of 2 or more entities described in (A) through (F) above.

WOOD INNOVATIONS GRANT PROGRAM

USDA Forest Service Wood Innovations Grant Program14 (formerly known as the Wood-to-Energy, and Woody Biomass Utilization Grant programs) is a national program that runs on an annual basis. The program seeks to substantially expand and accelerate wood energy and wood products markets throughout the United States to support forest management needs on National Forest System and other forest lands. Funding is granted under 2 separate categories: Category 1, Expansion of Wood Energy markets (includes 2 types of projects- Wood Energy Markets and Wood Energy Projects) and Category 2, Expansion of Wood Product Markets.

Previous Wood to Energy grant recipients have included CHP and pellet mill facilities and grants have ranged from $30,000 to $250,000. [15]

ENERGY POLICY ACT & ENERGY INDEPENDENCE AND SECURITY ACT (EPACT)

FEDERAL RENEWABLE ENERGY PRODUCTION TAX CREDIT

This production tax credit is an inflation-adjusted tax credit for electricity produced from qualifying renewable energy sources or technologies. Three different rates of tax credits are available for producers of energy from biomass, ranging from 0.9 cents to 1.9 cents, depending on the type of feedstock being used.[16]

BIOMASS UTILIZATION GRANTS (BUG)

The woody Biomass Utilization grant program is focused on creating markets for small-diameter material and low-value trees removed from forest restoration activities. The funds are targeted to help communities, entrepreneurs, and others turn forest residues into marketable forest products, including renewable energy. Grants range in size from $50,000 to $350,000.[17]

BIOMASS UTILIZATION RESEARCH AND DEVELOPMENT

This program authorizes $25 million for grants for research, development, demonstration, and commercial application of biofuel production technologies in states with low rates of ethanol production.

SMALL BUSINESS, TRAINING, AND OUTREACH GRANTS

Millions in dollars of grants have been awarded to small enterprises, universities, and research institutions to develop new uses for woody biomass, to explore policy issues, and to develop training and outreach programs.

INVESTMENT TAX CREDIT (ITC)

Federal incentive corporate tax credit is administered by the U.S. Internal Revenue Service. Incentive amounts include 30% for solar, fuel cells, small wind; 10% for geothermal, microturbines and CHP. Maximum incentives are dependent on the type of technology and are typically as follows:

- Fuel cells: $1,500 per 0.5 kW
- Micro turbines: $200 per kW
- Small wind turbines placed in service 10/4/08 - 12/31/08: $4,000
- Small wind turbines placed in service after 12/31/08: no limit
- All other eligible technologies: no limit.
- Eligible size for CHP is 50MW or less.

STATE POLICIES

New York State's ambitious and strong push for renewable energy has manifested into many programs, policies, incentives and support mechanisms. An overview of the major policies and programs is given throughout this section.

CLEAN ENERGY FUND

Reforming the Energy Vision (REV) is New York's strategy to develop a clean, resilient, and affordable energy system for all New Yorkers and supports the state's Clean Energy Standard commitment that will require 50% of electricity to be sourced from renewable energy sources by 2030. The Clean Energy Fund[18] is designed to deliver on New York State's commitment to reduce ratepayer collections, drive economic development, and accelerate the use of clean energy and energy innovation. NYSERDA, through the Clean Energy Fund, focuses its efforts in four distinct portfolios: Market Development, NY-Sun, Innovation and Research, and NY Green Bank.

NY GREEN BANK

NY Green Bank[19] works with a broad range of market participants such as energy service companies, developers, and equipment manufacturers. Rather than providing loans directly to the companies for pre-construction operations, NY Green Bank works in partnership with the participating financing entities, including banks and other private sector participants, to address existing market barriers and alleviate those in order to expand today's clean energy financing markets. The NY Green Bank assumes various roles, including but not limited to: providing credit enhancements (e.g. a reserve account or a junior interest), serving as a lender (e.g. senior, mezzanine or subordinated), or warehouse provider (with likelihood of being taken out by private sector third parties). These financial arrangements are targeted towards funding various clean energy projects that are economically viable but not currently financeable due to financing gaps in today's clean energy marketplace. While there is no maximum or minimum project size NY Green Bank will consider, the expected project range is between $5 million to $50 million.

RENEWABLE HEAT NY

Renewable Heat NY[20] (RHNY) provides incentives toward the installed costs of high-efficiency, low-emission wood heating systems for homeowners and businesses without access to natural gas. Incentives are available for different types of customers (residential, commercial – small and commercial-large). For the purpose of our study, Large Commercial Pellet Boilers are more suited. Incentives are available for high-efficiency, low-emission pellet boiler heating systems in new and existing facilities. Incentives are offered under this large commercial program[21] to offset the installed system costs for systems with thermal output over 300 MBtu/h (88 kW). Incentives of up to 45% of total installed cost and a maximum of $270,000 is available per facility. Incentives are based on the installed project costs. 80% of the incentive will be paid based on proof of installation and system commissioning. The remaining 20% will be paid at the end of the Measurement and Verification (M&V) period[22].

CLEANER, GREENER COMMUNITIES

NYSERDA offers Cleaner, Greener Communities grant funding [23] to private developers, local governments, nonprofit organizations and other public and private entities. The primary goal of the program is to encourage communities to create public-private partnerships and develop regional sustainable growth strategies in such areas as emissions control, energy efficiency, renewable energy, low-carbon transportation, and other carbon reductions.

Phase I of CGC provided funding to the 10 Regional Economic Development Council (REDC) regions in NYS for the development of Regional Sustainability Plans.

Phase II is a $90 million effort to fund implementation of large-scale, high-profile projects that support the goals of each region's sustainability planning efforts.

NEW YORK ENERGY EFFICIENCY PORTFOLIO STANDARD (EEPS)

New York's EEPS goal requires utilities to reduce both electricity and natural gas sales by 15% from forecasted levels by 2015. CHP is an eligible reduction technology. Renewable-fueled and fossil-fueled CHP systems are eligible under the EEPS. Waste heat to power systems may also be eligible, subject to approval.

NEW YORK RENEWABLE PORTFOLIO STANDARD

The RPS applies to investor-owned utilities and targets 30% of state electricity consumption by 2015 to come from eligible resources. The program provides funding for CHP systems through a combination of capacity- and performance-based incentives. Eligible technologies include, but are not limited to, CHP systems fueled by anaerobic digestion biogas and (in certain regions) systems fueled by renewable biogas (including systems co-fired with renewable biogas). Incentives can be based on either capacity (kW) or output (kWh) and are awarded through competitive solicitations.

New York's Renewable Portfolio Standard (RPS) includes two tiers used to meet the requirements. The *Main Tier* seeks to foster the development of additional renewable resources in New York and eligible resources include biomass and biofuels, among others. *Customer-sited tier* systems are generally limited to the size of the load at the customer's meter and eligible resources include digester gas-fueled CHP systems, among others.

Renewably-fueled CHP is eligible under the Main Tier; Digester gas-fueled CHP and fuel cell CHP using any type of fuel are eligible under the Customer Sited Tier (CST). Minimum Size CHP systems should be greater than 50 kW.

POLICIES AND PROGRAMS SPECIFIC TO CERTAIN TECHNOLOGIES

While many Federal and State policies and programs apply to biomass technologies in general and consequently, many of the technologies discussed in this study may be eligible for those programs, certain technologies benefit from specific focus and added incentives. This factor can potentially weigh in, in the choice of a technology option for the proposed plant in Berlin. Some major programs that apply only to certain technologies are detailed below.

COMBINED HEAT AND POWER PERFORMANCE PROGRAM

NYSERDA has made up to $36 million available to promote the installation of clean, efficient, and commercially available CHP systems. Owners of CHP systems with an aggregate nameplate generation capacity greater than 1.3 MW that provide summer on-peak demand reduction and are located in New York are eligible for this program.

Incentives are performance-based and correspond to the summer-peak demand reduction (kW), energy generation (kWh), and fuel conversion efficiency (FCE) achieved by the CHP system on an annual basis over a two-year measurement and verification (M&V) period. Systems will receive:

Upstate: $0.10/kWh + $600/kW.

Downstate: $0.10/kWh + $750/kW.

Base CHP Incentives are capped at the lesser of $2,600,000 per CHP project or 50% of total Project cost.

[1] US DOE, *Federal Loan Guarantee Solicitation & Supplements for: Renewable Energy Projects and Efficient Energy Projects*, US DOE Loan Programs Office, Updated December 4, 2015.
[2] "Rural Energy for America Program", USDA Rural Development, Accessed March 28, 2016 <http://www.rd.usda.gov/programs-services/rural-energy-america-program-renewable-energy-systems-energy-efficiency>
[3] "Rural Economic Development Loan Grant Program", USDA Rural Development, Accessed March 28, 2016 <http://www.rd.usda.gov/programs-services/rural-economic-development-loan-grant-program>
[4] "Business Industry Loan Guarantees", USDA Rural Development, Accessed March 28, 2016 <http://www.rd.usda.gov/programs-services/business-industry-loan-guarantees>
[5] "Rural Business Development Grants", USDA Rural Development, Accessed March 28, 2016 <http://www.rd.usda.gov/programs-services/rural-business-development-grants>
[6] "Wood Resource and Education Centre, New York", US Forest Service, Accessed March 28, 2016 <http://na.fs.fed.us/werc/swet/ny.shtm>
[7] ibid
[8] "Stewardship Contracting", US Department of Agriculture, Forest Service, Accessed on April 29, 2016,<http://www.fs.fed.us/restoration/documents/stewardship/stewardship_brochure.pdf>
[9] "Stewardship Contracting", Forests and Rangelands, Accessed on April 29, 2016 <http://forestsandrangelands.gov/stewardship/index.shtml>
[10] "Small Business Innovation Research program", SBIR, Accessed March 28, 2016 <https://www.sbir.gov/applicant>
[11] Patton-Mallory, Marcia, *"Incentives for Biomass Utilization at the Federal level",* U.S. Forest Service Presentation, February 21, 2008
[12] US Department of Energy, "Financial Assistance Funding Opportunity Announcement", US DOE, February 26, 2015
[13] ibid
[14] "Wood Innovations Grant Program", Woody Biomass Utilization, Accessed March 28, 2016 <http://ucanr.edu/sites/WoodyBiomass/Grants_2_142/Woody_Biomass_Utilization_Grant_190/>
[15] "Wood Resource and Education Centre, New York", US Forest Service, Accessed March 28, 2016 <http://na.fs.fed.us/werc/swet/ny.shtm>
[16] Rahmani, et. al., "Federal Policies and Incentives Promoting Woody Biomass Production and Utilization", extension, March 12, 2010, Accessed March 28, 2016 < http://articles.extension.org/pages/26559/federal-policies-and-incentives-promoting-woody-biomass-production-and-utilization>
[17] "Woody Biomass Utilization Group", Forests and Rangelands, August 2012, Accessed March 28, 2016 < https://www.forestsandrangelands.gov/Woody_Biomass/overview.shtml>
[18] "Clean Energy Fund", NYSERDA, Accessed March 28, 2016 <http://www.nyserda.ny.gov/About/Clean-Energy-Fund>
[19] "NY Green Bank", NYSERDA, Accessed March 28, 2016 <http://greenbank.ny.gov/About/Overview>
[20] "Renewable Heat NY", NYSERDA, Accessed March 28, 2016 <http://www.nyserda.ny.gov/All-Programs/Programs/Renewable-Heat-NY>
[21] "Large Commercial Pellet Bioler", NYSERDA, Accessed April 29, 2016, <http://www.nyserda.ny.gov/All-Programs/Programs/Renewable-Heat-NY/Large-Commercial-Pellet-Boiler>
[22] ibid
[23] "Cleaner Greener Communities", NYSERDA, Accessed March 28, 2016 <http://www.nyserda.ny.gov/All-Programs/Programs/Cleaner-Greener-Communities>

APPENDIX 4: SITING CONSIDERATIONS

Important siting criteria for a potential biomass plant have been discussed in Section 5.4. Using such criteria[1], an attempt to determine the ideal site for a potential plant in Berlin has been made.

Some assumptions used are: (1) the current power plant will be based on steam turbine (2) it will have a capacity factor of 85%, average electrical conversion efficiency of 32.5% and heat efficiency of 55% with the rest being waste heat.[2] The total land required for the power plant is approximately 3 acres considering the average moisture content of delivered wood to be 35% stacked to a height of 3 meters at the facility with a storage period of 30 days. The calculations are provided in the table below.

Table 0-1: Land requirement calculations

Area required for Power Plant Machinery	1	Acre
Calculation of storage Area		
Plant Size	12.5	MW
Capacity Factor	85%	
No. of Days in a Year	365	
No. of hours per day	24	
Operational Hours per Year	7446	
Electricity generation per Year	93075	MWh
Average Electricity generation efficiency	32.5%	

Average heat Generation efficiency	55.00%	
Total Plant Efficiency	88%	
Total energy required per Year	286385	MWh
Total energy required per Year	1030984615	MJ
Average calorific value of bone dry fuel	9300	MJ/Nm^3
Average moisture content of fuel	35%	
Amount of bone dry wood required per year	110859	Nm^3
Average Bulk Density of bone dry wood	500	Kg/m^3
Weight of dry wood required per year	55429280	Kg
Weight of moist wood required per year	85275816	Kg
Bulk density of moist wood	650	Kg/m^3
Volume of wood required	131194	m^3/Year
Storage required	30	Days
Stacking height	3	m
Storage Area required	3594	m^2
Storage Area required	1	Acres
Assuming area of physical plant	1	Acres
Total Land area required	1.9	Acres

Assuming 30% utility area	2.7	Acres
Total area required for plant	3	Acres
Average Truck Capacity	20	Tons
Number of Trips	4264	Per Year
Number of Trips	12	Per Day

Based on all the above considerations, it was determined the ideal lactation of the biomass energy plant would be on the north eastern part of the existing Green Renewable Inc. site, as shown in the map below (Figure 0-1). It is recommended to provide access to the site from the existing northern road instead of through the town. This will reduce impact of dust generation from the movement of trucks that transport the feedstock and machinery, along with increased safety and reduced traffic congestion. An electrical feed line of 15 MW capacity is available in this area, as noted during the site visit to Berlin. In addition, a water connection to the municipal system is available. The plant location within this industrial zone will allow for grid connection as well as heat distribution to the local residents.

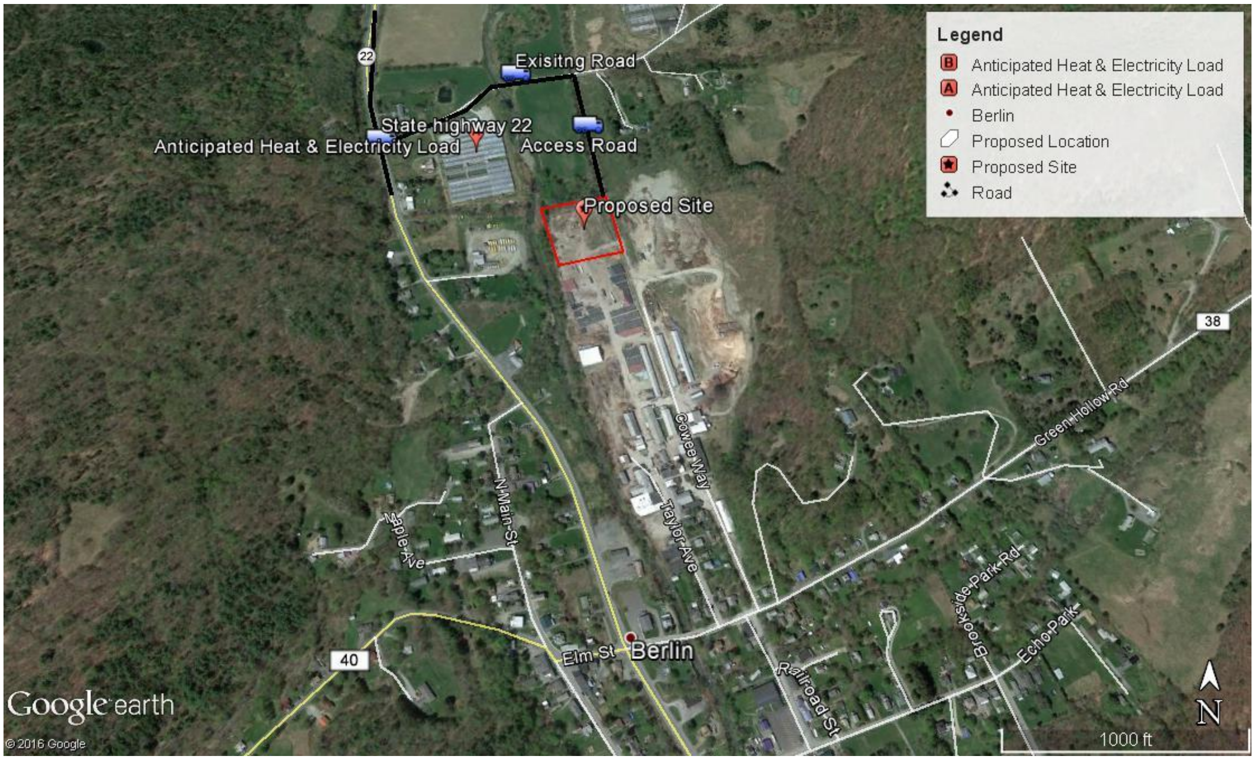

Figure 0-1 : Potential Site Location in Berlin

[1] Public Service Commission, *Common Power Plant Siting Criteria,* Public Service Comission, State of Wisconsin
[2] “Industrial Efficiency Technology Database”, Institute of Industrial Productivity, 2010, Accessed on April 07, 2016, < http://ietd.iipnetwork.org/content/combined-heat-and-power-chp-generation>

APPENDIX 6: PELLET PLANT

A pellet manufacturing plant has been considered as an alternative to a biomass plant or a complementary facility to the potential biomass plant in Berlin.

A pellet plant also uses woody biomass as the input material; pellets are used both as home heating fuels and as a feedstock for other biomass technologies. A pellet plant differs from the five types of biomass conversion technologies discussed throughout the report, in that it is not a biomass conversion technology on its own, but rather an intermediate step in biomass conversion. Pellets are often used as feedstock in different biomass technologies owing to their higher calorific value and efficiencies.

Pellets are also often being used in Berlin and neighboring towns for household heating needs and our research and anecdotal evidence suggests that there is a high demand for pellets in the cold months. A pellet manufacturing plant may be a potential industry in Berlin and can generate additional revenue for the community. Pellet manufacturing requires heat for drying the feedstock, as drying makes pellets more efficient in energy generation. Therefore, a pellet plant can be a feedstock provider to the biomass plant and also potentially be a buyer for the heat generated in a biomass (CHP-based) plant.

Hence, a pellet plant, in the context of this study, is being presented as an alternative or complementary option. As a stand-alone option, it can make use of Berlin's abundant biomass resources for pellet manufacturing. The pellets can then be marketed and sold for residential heating needs in Berlin and the surrounding counties. It can also be considered in combination with a CHP biomass energy generation plant, both as a feedstock provider to the plant and potential buyer for heat from the biomass plant, with the heat being used for drying the pellets. Further description of the technology and associated factors is presented below.

TECHNOLOGY OVERVIEW

Wood pellets are produced from woody biomass in a process of drying and densification of the raw material into a low-moisture, homogenous, hydrophobic capsule. Wood pellets have many benefits as a fuel: they provide an enhanced heating value for wood, produce lower ash and particulate emissions relative to other forms of woody biomass, and can be used in both small scale home heating stoves and large scale power generating plants.[1]

Depending on the type of material being processed, wood pellet manufacturing can involve numerous steps to produce the quality of pellet standard for efficient combustion. Pellet production involves four major steps: feedstock processing in a hammer mill, drying for moisture removal, pelletizing, and cooling. The first process in the pellet manufacturing process is to run the material through a chipper in a hammer mill. This reduces the feedstock to a more uniform dimension to facilitate ease of handling in through feeders and augers to subsequent processing equipment. The next step is drying; once the feedstock is reduced to a consistent size, it must be conditioned to remove moisture in the material from upwards of 50% moisture content for green wood to between 12%-17% moisture to facilitate processing efficiencies. Once the feedstock is milled and dried to the appropriate moisture content, the conditioned material is cooled, then pressed through dies at high pressure. The process of pelletizing causes the material to heat up as it is pressed through the dies. The heat generated in this process releases the material’s natural lignin that serve to bind the material together, eliminating the need to add supplemental binders.[2] The last step is cooling; the extruded pellets leave the mill as soft capsules between 200 and 250 degrees and hence must be cooled, usually in a cooling tower to allow the temperature to drop and the pellets to harden.

INPUT REQUIREMENTS

Pellets can be produced from raw wood, including round wood, as well as from wood waste, forest-thinning residue, mill waste sawdust and shavings, wood production by-products and construction debris. Other non-woody biomass can also be used in the production of pellets. Regardless of the feedstock used, pellets must meet a standard of production for manufacturing to align with the burning characteristics of manufactured stoves and boilers. The Pellet Fuels Institute identifies several audit agencies that monitor pellet quality and standards.[3] The Institute also sets the standards for bulk density, diameter, durability, fines, inorganic ash, moisture and chloride content.[4]

WASTE PRODUCTS

The use of pellets reduces emissions from either energy plants or small-scale pellet heaters. Since pellets are of consistent quality (relative to other wood fuels), they burn very cleanly as they do not contain any bark (white premium pellets). In addition, the pellets have very low ash contents of around 0.5% with consistent and low moisture of about 8%. Depending on the combustion technology, particulate emissions using pellets may be as low as 70 mg/m^3 and small-scale two-stage combustors (gasifiers) with as low as low emissions of 50-70 mg/m^3. The installed fabric filters or electrostatic precipitators are subject to intensive continuous maintenance to eliminate potential fire hazards.[5]

COST OVERVIEW

Upwards of 70% of the cost of pellet manufacturing is in feedstock procurement and the drying process.[6] Energy costs associated with the drying and pelletizing process make up a substantial portion of pellet production costs; other miscellaneous energy costs are associated with costs of material conveyance and handling, storage, packing and bagging the product.

Depending on the output capacity of the pellet manufacturing plant, capital expenditures must account for ancillary equipment that is not primary to the production process but are required for an efficient operation. In addition to capital outlay for a hammer mill, dryer and pellet mill, equipment such as conveyors, front end loaders, hoppers, storage bins and silos, shakers, boilers, bagging and distribution systems must also be part of the overall process. An assessment of capital expenses in a 2010 study of a

75,000 ton per year capacity pellet plant suggest that the most significant drivers were the cost of the biomass material itself followed by labor costs, others costs included marketing fees, incentives and maintenance costs in the described model.

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1 Pirraglia et al, "Wood Pellets Feasibility," BioResources, 2010, 5(4), 2374-2390
2 "How are pellets made?", Woodpellets, Accessed on April 29, 2016, < http://www.woodpellets.com/heating-fuels/pellet-processing.aspx>
3 "Accredited auditing agencies", Pellet Fuels Institute, Accessed on April 29, 2016 <http://www.pelletheat.org/accredited-auditing-agencies>
4 Spelter, H., Toth, D., North America's Wood Pellet Sector, US Department of Agriculture, August 2009, FLP-RP-656
5 British Columbia Ministry of Environment, Emissions from Wood Fired Combustion Equipment, Victoria, BC, June 2008
6 Biomass Energy Centre, Wood Pellets Production, Forest Research, 2011, Accessed on April 29, 2016, <http://www.biomassenergycentre.org.uk/project information note 15/08>

APPENDIX 7: FINANCIAL MODEL USED FOR QUANTITATIVE ANALYSIS

Inputs								
Project Inputs			Pricing			$/kwh		
Plant Capacity	12.5	MW	Industrial		60%	$0.10	0.10	
Availability Factor	85%		Commercial		20%	$0.10	0.10	
Annual Generation	93,075	MWh	Residential		20%	$0.10	0.10	
Thermal Offtake	175	MMBtu	Average Rate			$0.10	0.10	
			Thermal Sales			0		
Construction Costs	$ 000s		Operating Costs		$ 000s	Units	Cost	
Generation Plant	70,879	100%	Salaries		1,200	15	80	
Soft Costs	0	0%	Operations & Maintenance		1,780			
Grid Connection	0	0%	Feedstock		1,962	80	24.52	
Pipe Extension	0	0%	Other		0			
Total Investment	70,879		Total		4,942			
Grants	0							
Net Investment	70,879							
Other Inputs			Capital Structure					$ 000s
Construction Time	1.5	Years	Equity & Grant %		25%		Equity	17,720
Collection Efficiency	98%		Required returns		15%		Grants	0
Distribution losses	5%		Loan Rate		5%		Debt	53,159
Rate Inflation	2.0%		Loan Grace Period		2			
Cost Inflation	2.0%		Loan Term		20			
Terminal value	5.0	times exit FCF	WACC***		6.4%			
REC rate	0.27	1						

Outputs				
Project Returns				
Project IRR	6.4%			
Equity IRR	19.2%			
Project NPV	$0			
Equity NPV	$3,655			
Cost Recovery				
Capital Investments	5,670	$/kW		

Operating Costs	5.3	c/kWh			
Capital Recovery	6.9	c/kWh			
Total	12.2	c/kWh			
RECs	2.7	c/kWh			
Grants	0.0	c/kWh			
Schedule	1	2		3	4
Construction	67%	33%		0%	0%
Operations	0%	67%		100%	100%
Other Assumptions					
Depreciation period	15	Years			
Corporate Tax rate	34%				
Tax holiday	0	Years			
Electricity (c/kWh	Project NPV ($,000)				
13.0	36,980	33,207	29,435	25,662	21,889
11.5	14,601	10,828	7,055	3,282	(491)
10.0	3,411	(362)	(4,135)	(7,908)	(11,680)
8.5	(13,374)	(17,147)	(20,919)	(24,692)	(28,465)
7.0	(45,250)	(41,477)	(37,704)	(33,931)	(30,158)
Feedstock	$20	$25	$30	$35	$40

P&L $'000s	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Residual Value
Investment	$47,253	$23,626	$0	$0	$0											
Grants	$0	$0	$0	$0	$0											
Equity	$11,813	$5,907	$0	$0	$0											
Debt	$35,440	$17,720	$0	$0	$0											
Energy Rate (c/kwh)	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.13	0.13	0.13	
Energy Revenues	0	6,329	9,684	9,877	10,075	10,276	10,482	10,691	10,905	11,123	11,346	11,573	11,804	12,040	12,281	
REC Sales	0	1,738	2,659	2,713	2,767	2,822	2,879	2,936	2,995	3,055	3,116	3,178	3,242	3,307	3,373	
Operating Costs	0	3,360	5,141	5,244	5,349	5,456	5,565	5,676	5,790	5,906	6,024	6,144	6,267	6,392	6,520	
EBITDA	(47,253)	(18,919)	7,202	7,346	7,493	7,642	7,795	7,951	8,110	8,272	8,438	8,607	8,779	8,954	9,133	45,667
Margin%			58%	58%	58%	58%	58%	58%	58%	58%	58%	58%	58%	58%	58%	

APPENDIX 8: LIST OF CASE STUDIES

Sl. No.	Facility Name	Location	Capacity	Source
1	Albany Medical Center Hospital	Albany, NY	4.6MW	http://www.powerbycogen.com/albany-medical-center
2	Barre Town Elementary and Middle School Woodchip Heating System	Barre, VT	1.3MW (4.5 MMBtu/hr)	http://www.biomasscenter.org/resource-library/case-studies/schools/barre-town-elementary-and-middle-school
3	Beaver Wood energy	Fair Haven, VT	34 MW/110,000 tons/yr pellets	www.beaverwoodenergy.com
4	Bridgewater Power	Plymouth, NH	17 MW	
5	Buena Vista Biomass Power	Iona, CA	18 MW	http://ihipower.com/plants/buenavista.php
6	Burlington Electric	Burlington, VT	59.5 MW	https://www.burlingtonelectric.com/about-us/what-we-do/joseph-c-mcneil-generating-station
7	Burrston Energy Center	Utica, New York	3.6 MW	http://www.powerbycogen.com/burrstone-energy-center
8	Cayuga regional digester	Auburn, NY	625 Kw	http://www.cayugaswcd.org/digester.html
9	City of Charlottetown	Charlottetown, Canada	35 MW heat (120 MMBtu/hr); 1,200 kW electricity	http://www.biomasscenter.org/resource-library/case-studies/community-district-energy/city-of-charlottetown
10	City of Revelstoke	Revelstoke, British Columbia, Canada	1.5 MW (5.1 MMBtu/hr)	http://www.biomasscenter.org/resource-library/case-studies/community-district-energy/city-of-revelstoke
11	Community-Owned Pellet District Heating System	Mullsjø, Sweden	3 MW boilers totaling 9 MW (31 MMBtu/hr)	http://www.biomasscenter.org/resource-library/case-studies/community-district-energy/community-owned-pellet-district-heating-system
12	Concord Steam Corporation	Concord, NH	2 MW	http://www.concordsteam.com/index.html

13	Enovaenergy group	Plainfield, CT	37.5 MW	http://www.power-eng.com/articles/2015/07/sale-of-connecticut-biomass-power-plant-completed.html
14	Evergreen Community Power Plant	Reading, PA	30 MW	http://www.esitenn.com/project-case-studies/steam-generating-systems/biomass-conversion/evergreen-community-power/
15	Finch Paper	Glens Falls, NY	powers 11,614 households a year	http://www.finchpaper.com/environmental-stewardship/
16	Griffin Utility Services Corp.	Rome, NY	1 MW	
17	Gusc Energy Biomass Plant	Rome, New York	1MW	http://www.powerbycogen.com/gusc-energy-biomass-plant
18	Hartford Central School District	Hartford, NY	6.6 mmBTU gasifier / 7.0mmBTU boiler (2 MW)	https://csarch.wordpress.com/2010/01/11/new-york-state-alternative-energy-milestone/
19	Leavitte Area High School Woodchip Heating System	Turner, ME	1.3 MW	http://www.biomasscenter.org/images/stories/leavitt-high-school.pdf
20	Limlaw Pulpwood and Chipping	Topsham, VT		http://www.biomasscenter.org/resource-library/case-studies/businesses-and-industries
21	McNeil Station	Burlington, VT	55 MW	https://www.burlingtonelectric.com/about-us/what-we-do/joseph-c-mcneil-generating-station
22	Metropolitan Syracuse WWTP, Syracuse, NY	Syracuse, NY	32 MW	
23	Middlebury College	Middlebury, VT		http://sites.middlebury.edu/biomass/about/
24	Mitter Transporte Fuel Company	Linz, Austria	Two 49 kW (170,000 Btu/hr) boilers	http://www.biomasscenter.org/resource-library/case-studies/businesses-and-industries/mitter-transporte-fuel-company
25	National Life Group	Montpelier, VT	3.5 MW (12MMBtu /hr)	http://www.biomasscenter.org/images/stories/BERC_Case_Study_National_Life.pdf
26	New Hope View Farm / RCM International, Inc.	Homer, Cortland County, NY	70kW Microturbine & boiler	

27	Nordstrom Greenhouses	Narpio, Finland	800 kW total (2 400kW units)	http://www.biomasscenter.org/resource-library/case-studies/agricultural-facilities/nordstrom-greenhouses
28	Oakwood Beach Water Pollution Control Plant	Staten Island, NY	200kW	http://chp.nyserda.ny.gov/facilities/fulldetails.cfm?Facility=60
29	Pine Tree Power	Westminster, MA	17 MW	http://www.telegram.com/article/20140420/NEWS/304209958
30	Power pallet inc.	Schenectady, New York.	400 Kw	http://dataint.cdhenergy.com/Documentation/CHP%20Thumbnails/CHP%20Thumbnail--Power%20Pallet,%20Inc..pdf
31	Power Pallet, Inc.	Amsterdam, NY	400kW	http://chp.nyserda.ny.gov/facilities/details.cfm?facility=105
32	ReEnergy Lyonsdale	Lyonsdale, NY	22 MW	http://www.reenergyholdings.com/about-us/
33	Ridgeline Farm/RCM International Inc.	Clymer, NY	28 MW	
34	Roach Dairy Farm	Scipio Center NY	450 kW	http://www.manuremanagement.cornell.edu/Pages/General_Docs/Case_Studies/Roach_case_study.pdf
35	Ryegate	Ryegate, VT	22 MW	http://www.wcax.com/story/19599645/industrial-biomass-in-vermont
36	Schenectady Wastewater Treatment Plant	Schenectady, NY	28 MW	
37	Seneca Meadows Landfill	Waterloo, NY	17.6 MW	https://globenewswire.com/news-release/2015/03/25/718611/10126196/en/Aria-Energy-s-Seneca-Energy-II-Renewable-National-Gas-Facility-Receives-Project-of-the-Year-Award-From-U-S-EPA-Landfill-Methane-Outreach-Program.html
38	Spriengfield Power	George Mills, NH	19 MW	http://yesvy.blogspot.com/2011/10/energy-safari-visits-woodchip-plant.html#.Vsm7I4RvlJ8
39	Stefan Nordmyr Family Farm and Greenhouse	Narpio, Finland	3 MW (10MMBtu /hr)	http://www.biomasscenter.org/images/stories/nordmyr.pdf
40	Sullivan County Biomass Project	Sullivan, NH	40 kW	http://www.wilsonengineeringservices.com/Sullivan_NH_Fact_Sheet.pdf

41	Swiss Valley Farms	Warsaw, NY	30 MW	
42	Taylor Biomass Energy	Montgomery, NY	20 MW	http://www.power-technology.com/projects/taylorsmontgomerybio/
43	Town of Gjern Varmevaerk	Denmark	5 MW	http://www.biomasscenter.org/resource-library/case-studies/community-district-energy/town-of-gjern-varmevaerk
44	Vølund Gasifier Plant and Town of Harboøre	Jutland, Denmark	Heat :4 MW (14MMBtu /hr) Electrical Capacity: 1.6MW	http://www.biomasscenter.org/resource-library/case-studies/community-district-energy/v%C3%B8lund-gasifier-plant-and-town-of-harbo%C3%B8re
45	W.J. Cowee, Inc.	Berlin, NY	500 kW	http://chp.nyserda.ny.gov/facilities/details.cfm?facility=106
46	Walker Farms Anaerobic Digester (RCM)	Fort Ann, NY	32 MW	
47	Wastewater Treatment Plant	Auburn, NY	1.4 MW	http://www.cayugacounty.us/portals/0/planning/assets/energyplan.pdf
48	Wolf Ridge Environmental Education Center	Finland, MN	900 kW	http://www.biomasscenter.org/resource-library/case-studies/community-buildings/wolf-ridge-environmental-education-center