ECO-GRID, BIOMASS, DISTRICT CHP/HEATING AND COOLING SYSTEM FEASIBILITY STUDY
Final Report

Prepared for

THE NEW YORK STATE
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ABSTRACT

The goal of this project is to analyze the potential energy and economic benefits of a biomass-fired, district CHP/heating and cooling system for the city of Hudson, New York. A CHP/heating and cooling system could consist of several major elements: a biomass-fired cogeneration plant with fuel from wood residues; a low-temperature, hot water, district heating network to deliver thermal energy to Hudson customers; connection to buildings and conversion of existing systems to efficiently use hot water for heating. This report contains an engineering assessment prepared by VanZelm engineers, and a biomass availability study by Mesa Reduction Engineering & Processing, Inc. Equipment quotations were received from a number of vendors in the USA and Canada.

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SUMMARY

The goal of this project is to analyze the potential energy and economic benefits of a biomass-fired, district CHP/heating and cooling system for the City of Hudson, New York. A CHP/heating and cooling system could consist of several major elements: a biomass-fired cogeneration plant with fuel from wood residues; a low-temperature, hot water, district heating network to deliver thermal energy to Hudson customers; connection to buildings and conversion of existing systems to efficiently use hot water for heating. This report contains an engineering assessment prepared by VanZelm engineers, and a biomass availability study by Mesa Reduction Engineering & Processing, Inc. Quotations were received for equipment from a number of vendors.

Conclusions from Van Zelm's engineering report are that:

A. This preliminary design study indicates that there are no technical issues or "fatal flaws" that cannot be overcome in order to implement the Biomass CHP power plant and district energy system. Reasonable assumptions for project deployment have been applied in order to establish practical expectations for capital cost efficiency and constructability.

B. The project will reduce Hudson's dependence on fossil fuel, and in particular afford a conversion from draining the local economy to pay for this fuel, when instead a sustainable foresting enterprise could provide benefit to the local economy.

C. Conversion to renewably sourced energy will appreciably reduce environmental emissions. The Biomass CHP power plant will mark a positive step in neutralizing Hudson's carbon footprint, avoiding heating boiler emissions or external electric generation emissions chargeable to Hudson's import of electricity.

D. Power plant and district energy distribution equipment components and systems have been preliminarily selected based on demonstrated technology and proven performance.

E. The simple payback of the integrated Biomass CHP and district heating system is projected at six years. Adjustments favoring electric rate contracts above fuel rate increases will substantially reduce the payback of the investment and improve the rate of return of the project.

The Swiss energy-consulting firm Verenum reviewed Van Zelm's work. This was done in order to provide an assessment of air emissions and provide recommendations on technologies that exceed the stated biomass CHP technologies in cost and/or emissions. Verenum's work focused mostly on an assessment of Van Zelm's report. Verenum identified no new technologies. In Verenum's assessment "estimations on efficiency and economy reveal that the overall concept is presumably uneconomic." In response to this assessment, Van Zelm provided an additional two-page appendix.

Lessons Learned

R & D requires immense flexibility, endurance, persistence, and often depends on industry relationships for its success. The biomass field and industry, still emerging in the State of NY, responds with receptivity and competitiveness to inquiring minds, researchers, as its own building blocks are gathered and put in place. Generosity of time and spirit has underscored all of our alliances. In becoming advocates for the NY State Energy Research and Development Authority in the Hudson -Valley Region, we have had the distinct opportunity of becoming an example for other communities ---one that will outlast our work and the life of the study itself.

Our initial proposal to the NY State Energy Research ad Development Authority was ambitious in scope but short in timeline and funding. In the 3 years that we have spent completing "Eco-Grid Biomass-Fired District CHP/Heating and Cooling Systems" for the cities of Hudson and Greenport, NY, we have found ourselves organically expanding into the building phase, while still in R & D mode. Every new topic we unearthed afforded opportunities that required more time and exploration. Each one of these opportunities was developed into a brand-new addition to the global study, rounding out a template that may be utilized in other similar communities in the State of NY.

INTRODUCTION by Dr. Morris Pierce

The City of Hudson is located on the east shore of the Hudson River in Columbia County, New York, approximately 30 miles south of Albany, the state capital. Hudson was the eighth largest city in the United States in 1790 and as late as 1820 was the fourth largest city in New York State. Hudson has undergone several economic transformations, starting out as a bustling port for whaling and trade before transitioning to an industrial community in the mid-1800s with knitting and cotton mills, brickyards, and a factory that made paper-core railroad car wheels for George Pullman. Hudson has a rich architectural heritage, with hundreds of buildings listed or eligible for historical registers. According to US Census data, Hudson's population peaked in 1930 at 12,337 and estimated in 2006 to be 6,985. The population of the adjacent town of Greenport in 2000 was 4,810. The City of Hudson has moderately cold winters and warm, humid summers, with an average of 6,390 heating degree days and 587 cooling degree days. High summer humidity in the Hudson River Valley is of particular concern in maintaining comfortable indoor space conditions.

Existing Energy Infrastructure in New York State

Although New York has the second lowest per capita energy consumption in the nation, the state is hardly a model of energy efficiency, particularly in the commercial sector. Energy Information Administration data for 2004 shows that New York's residential and commercial energy costs to be among the highest in the nation:

Sector	Consumption (Btu per capita)	Rank	Expenditures ($ per capita)	Rank
Residential	63.2	5	$779.17	44
Commercial	72.8	45	$778.31	50
Industrial	27.8	3	$181.39	2
Transportation	57.4	2	$783.83	2
Total	221.3	2	$2,522.70	7

In addition to the direct economic impact on New York's energy consumers, nearly ninety percent of New York's primary energy was imported from outside the state at a cost of $29.3 billion, creating a significant drain on the state's fragile economy:

New York State 2005 Energy Use (Trillion Btus)	Primary Energy Consumption	%	In state Production	Imports	Imports % by fuel
Petroleum	1,777.1	40.9%	37.959	1,739.1	97.9%
Natural Gas	1,237.7	28.5%	56.539	1,181.2	95.4%
Nuclear	438.0	10.1%	-	438.0	100.0%
Coal	316.1	7.3%	-	316.1	100.0%
Hydro	238.2	5.5%	238.2	-	0.0%
Biofuels	120.0	2.8%	120.0	-	0.0%
Net imported electricity	219.7	5.1%		219.7	100.0%
Total	**4,346.8**	**100.0%**	**452.7**	**3,894.1**	**89.6%**

This bad situation is made even worse because more than one-fourth of this expensive primary energy (1,212 trillion Btus in 2005) was simply wasted in New York's inefficient electric infrastructure, primarily as heat rejected into the atmosphere through cooling towers or bodies of water. Interestingly, the amount of energy we waste is nearly equivalent to the 1,242 trillion Btus of non-electric primary energy used in residential and commercial buildings.

Existing Energy Infrastructure in the City of Hudson and Columbia County

Residential heating fuel use in Columbia County and the City of Hudson show a higher percentage of electricity and fuel oil than the state as a whole, as shown in the following tables of data from the 2000 Census:

Columbia County	Number	Percentage	NYS Percentage
Natural Gas	2,775	11.2%	52.0%
Electricity	3,661	14.8%	8.8%
Fuel oil	15,985	64.5%	33.6%
Propane	1,145	4.6%	3.2%

City of Hudson	Number	Percentage	NYS Percentage
Natural Gas	1,816	61.5%	52.0%
Electricity	689	23.3%	8.8%
Fuel oil	386	13.1%	33.6%
Propane	33	1.1%	3.2%

Town of Greenport	Number	Percentage	NYS Percentage
Natural Gas	674	37.9%	52.0%
Electricity	418	23.5%	8.8%
Fuel oil	616	34.7%	33.6%
Propane	54	3.0%	3.2%

No natural gas or oil resources are known to exist in Columbia County and according to the most recent NYISO data the only electric generating unit in the county is a 100 kW hydroelectric at Valatie Falls in the Town of Kinderhook. Hudson and Greenport are located in Zone F (Capital) of the New York Independent System Operator (NYISO), which operates the state's bulk electricity grid and administers New York's wholesale electric markets. Electric market prices in Zone F are generally higher than Zones A through E and lower than Zones G through K, as shown in the appendix..

National Grid (formerly Niagara Mohawk) provides regulated electricity and natural gas delivery service to Hudson and Greenport under tariffs approved by the New York State Public Service Commission. National Grid also supplies gas and electricity to customers who choose to remain with them rather than select another market provider. The existing natural gas delivery system in Hudson includes cast iron pipe 75 to 100 years old, steel pipes installed 50 to 60 years ago, and plastic pipes installed over the past 35 years. National Grid has recently began a project to replace 11,000 feet of existing steel and cast iron natural gas pipes with new plastic piping.

With few exceptions, heating and cooling apparatus in most buildings is old and inefficient. Nearly two-thirds of the households in the City of Hudson are rented, and many landlords are simply unable or unwilling to invest in energy efficiency improvements. Most new multi-unit buildings have individual utility meters for each unit, which simply eliminate any incentive for the landlord to address energy efficiency, while most tenants have few opportunities to do so. Overall, more than three-fourths of households in Hudson are in multi-unit buildings, greatly enhancing the ability to improve the overall energy efficiency of the community. Many multi-unit buildings in Greenport are located close to the City of Hudson, again offering additional opportunities.

Housing Units in Structure	Hudson		Greenport	
	Number	Percent	Number	Percent
1 unit, detached	755	22.6%	1,190	62.8%
1 unit, attached	202	6.0%	48	2.5%
2 units	881	26.3%	140	7.4%
3 or 4 units	746	22.3%	109	5.7%
5 to 9 units	357	10.7%	101	5.3%
10 to 19 units	137	4.1%	42	2.2%
20 or more units	253	7.6%	87	4.6%

A New Energy Infrastructure for Hudson, Greenport, and Columbia County

After the oil shocks of the 1970s, several European countries recognized that they simply could not afford to continue importing most of their energy and then wasting a large percentage of it. Denmark and other Scandinavian countries undertook a massive effort to replace their centralized electric generating plants and individual building heating systems with community-wide district energy systems. Today more than sixty percent of Danish households are connected to district energy networks supplied by combined heat and power plants and other low cost heat sources, many using local renewable resources such as wood chips, straw, and large solar thermal arrays. Implementing this proven technology in the City of Hudson and other Columbia County communities will deliver significant energy and environmental benefits.

Hudson, New York 50-Mile Wood Fuel Assessment

Hudson, New York 50-Mile Wood Fuel Assessment

Summary

- The assessment area includes 4.7 million acres of land. Of this amount, 3 million acres (63%) is categorized as timberland.

- Of the 6.5 billion cu/ft of the total net volume of live trees in the assessment area, 77% are hardwoods and 23% are softwoods. This works out to 153.1 million green tons of hardwoods and 33.5 million green tons of softwoods. The predominate species in the assessment area are primarily hardwoods: sugar maple, white/red oaks, cherry/ash, and red maple. Predominate softwoods are eastern hemlock and eastern white pine.

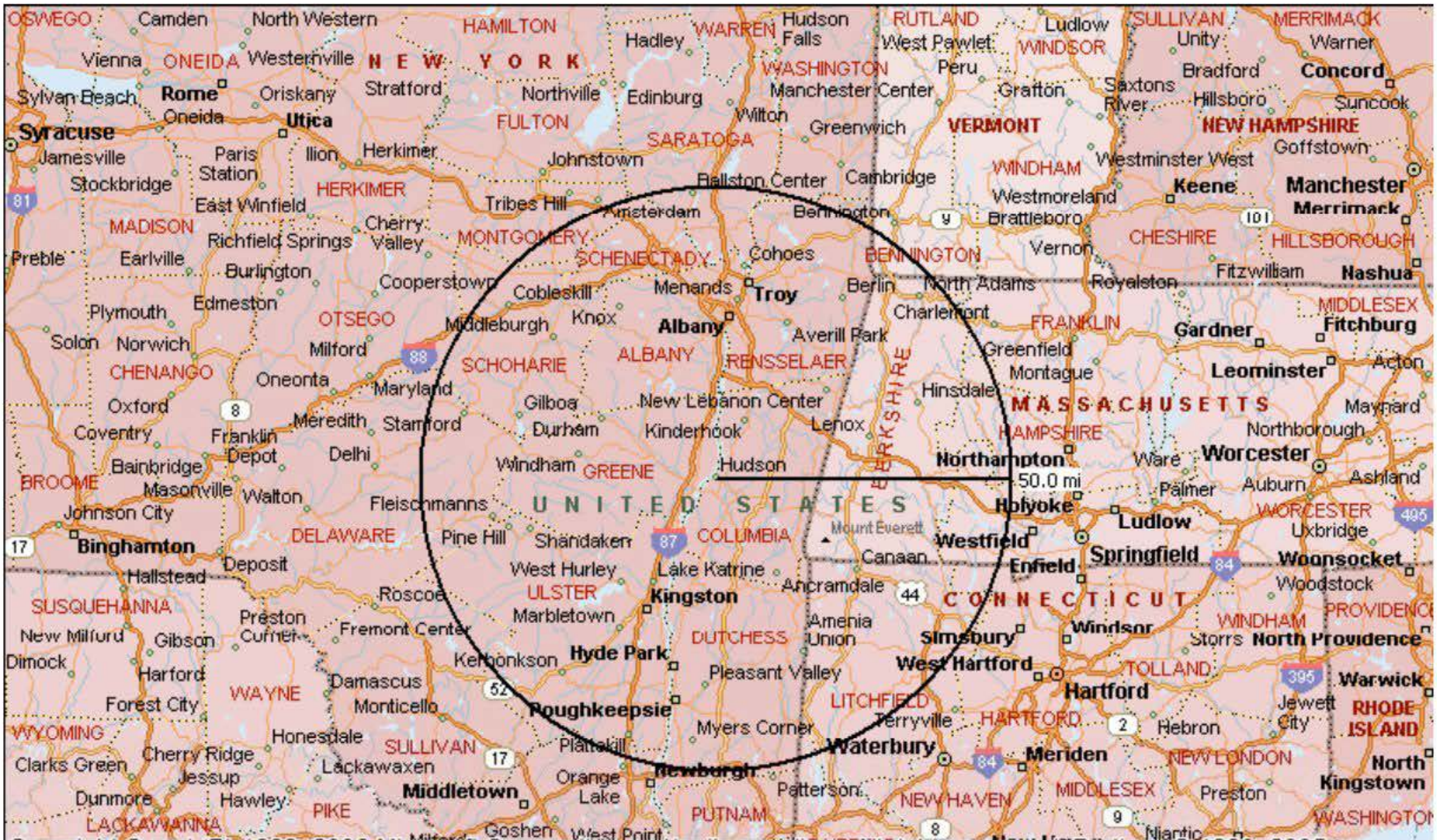
- The assessment area adds 68.4 million cu ft of growing stock every year. The majority of the stock is hardwoods at 40.8 million cu ft/year, followed by pine (10.7 million cu ft), soft hardwoods (8.8 million cu ft), and other softwoods (7.9 million cu ft). At the same time, there are 24 million cu ft of removals in the study area, 11 million cu ft of which are hardwoods.

- Subtracting removals from growth and applying availability adjustments for physical factors (slope, accessibility) and land size and owner attitudes provides an estimate of available excess growth of **35.5 million cu ft per year**, or just slightly more than 1 million green tons. This number suggests a fairly significant amount of wood resource available for fuel use.

- The assessment area produces 44.2 million cubic feet (cft) of roundwood products a year, or 1.2 million green tons. The largest segment of roundwood is for fuelwood with 19 million cft (41%), followed by sawlogs at 13.8 million cft (31%), pulpwood at 9.2 million cft (21%), veneer logs at 1 million cft (2.3%), and composite products (1.2%).

- There are over 6 million dry tons (dt) of mill residues generated in the assessment area. Of that amount, over 1.9 million dt/year are used as fuel by-product, and 1.4 million dt are used in fiber by-products. The data of most interest would be the mill residues that go unused – there are 404,000 dt/year of residues that are unutilized. This includes 109,000 dt of bark, 158,000 dt of coarse wood, and 137,000 dt of sawdust and veneer wastes. There are 39 primary wood processors in the assessment area.

- Registered construction & demolition (C&D) debris handlers in the assessment area handled 268,314 tons of waste wood, C&D debris, and other possible fuel materials in 2006. This number is likely a low estimate, given incomplete data reporting to DEC. A majority of this material is sent to western New York for landfilling, suggesting another possible fuel resource.



Hudson, New York 50-Mile Assessment Area

Hudson, New York 50-Mile Wood Fuel Assessment

This assessment analyzes forest resources in a 50-mile radius from Hudson, New York. The 50-mile study area includes all or part of the counties of Columbia, Greene, Ulster, Delaware, Orange, Sullivan, Dutchess, Albany, Rensselaer, Schenectady, Schoharie, Montgomery, and Saratoga counties, as well as Berkshire, Hampshire, and Hampden counties in Massachusetts; Litchfield County and a small portion of Hartford County in Connecticut; and a portion of Bennington County in southwestern Vermont. The area includes the Albany-Schenectady-Troy, Pittsfield, and Poughkeepsie metropolitan areas, but also includes large stretches of heavily forested lands, including some in the 287,000-acre Catskill Forest Preserve, as well as rural farmland.

Forest Land/Timber Assessment

The assessment area includes 4.7 million acres of land. Of this amount, 3 million acres (63%) is categorized as timberland. The USFS defines timberland as forest land that is producing or capable of producing in excess of 20 cubic feet of roundwood per acre, excluding reserved forest lands.

The largest concentrations of timberland by county are within 25 miles of Hudson, in Ulster, Dutchess, Greene, and Berkshire counties. Of the timberland in the assessment area, 2.5 million acres is privately-owned (85%), 324,000 acres (11%) is owned by state government (mostly Forest Preserve in the Catskill Park), 96,195 acres (3.2%) is owned by local government, and 28,501 acres (0.9%) in Dutchess County is owned by the National Park Service as part of the Roosevelt National Historic Site near Hyde Park.

The majority of timberland is categorized as large diameter stand size, over 2 million acres (69%), while 771,000 acres (25%) is medium-diameter, and 147,000 acres (5%) is small-diameter. Over 82% of the assessment area timberland is categorized as fully or medium-stocked (1.4 million and 1 million acres, respectively), while 340,000 acres (11%) is poorly-stocked and 144,000 acres (5%) is overstocked.

Of the 6.5 billion cu/ft of the total net volume of live trees in the assessment area, 77% are hardwoods and 23% are softwoods. Using volume to weight conversion factors developed by the New York State Department of Environmental Conservation (DEC), this works out to 153.1 million green tons of hardwoods and 33.5 million green tons of softwoods[1]. The predominate

[1] From Sloane Crawford, DEC. 1 cord equals approximately 85 cu.ft. of solid wood -- 2.6 tons per green cord for dense hardwoods such as maples, oaks, hickories, cherry, ash; 1.9 tons per green cord for softwoods and less dense hardwoods like aspen and basswood.

species in the assessment area are primarily hardwoods: sugar maple, white/red oaks, cherry/ash, and red maple. Predominate softwoods are eastern hemlock and eastern white pine (Source: Forest Inventory Mapmaker version 2.1, U.S. Forest Service, http://www.ncrs2.fs.fed.us/4801/fiadb/fim21/wcfim21.asp)

Wood Resources Availability

The assessment area adds 68.4 million cu ft of growing stock every year. The majority of the stock is hardwoods at 40.8 million cu ft/year, followed by pine (10.7 million cu ft), soft hardwoods (8.8 million cu ft), and other softwoods (7.9 million cu ft). At the same time, there are 24 million cu ft of removals in the study area, 11 million cu ft of which are hardwoods. Subtracting removals from growth and applying availability adjustments developed by DEC of 4% for physical factors (slope, accessibility) and 9% for land size and owner attitudes provides an estimate of available excess growth of 35.5 million cu ft per year, or just slightly more than 1 million green tons, using DEC conversion factors. Table 1 shows the data in greater detail.

Table 1: Estimated Available Excess Timber Growth

Net Growth of Growing Stock (cu ft)	Annual Growth	Physical Factors Adjustment (4%)	Land Owner Adjustment (9%)	Removals	Available Excess Growth
Pine	10,752,229	430,089	967,701	6,196,710	3,157,729
Other Softwoods	7,989,645	319,586	719,068	1,193,257	5,757,734
Soft Hardwoods	8,882,760	355,310	799,448	5,751,511	1,976,490
Hardwoods	40,867,253	1,634,690	3,678,053	10,939,119	24,615,391
Total	**68,491,887**	**2,739,675**	**6,164,270**	**24,080,597**	**35,507,345**
Source: U.S. Forest Service; Forest Inventory Data Online, 2005 survey					

Of that amount, 69% are hardwoods, followed by other softwoods at 16%, pine at 9%, and soft hardwoods at 5.6%. Both pine and soft hardwoods have a relatively greater rate of removals, which accounts for their relatively low rates of availability compared to hardwoods and other softwoods. The counties with the highest net growth in the 2005 survey were Dutchess, Rensselaer, and Berkshire, all within 30 miles of Hudson. The assessment area produces 44.2 million cubic feet (cft) of roundwood products a year. The largest segment of roundwood is for fuelwood with 19 million cft (41%), followed by sawlogs at 13.8 million cft (31%), pulpwood at 9.2 million cft (21%), veneer logs at 1 million cft (2.3%), and composite products (1.2%). Over 68% of the roundwood products are hardwoods, while 31% are softwoods. Slightly more than half, 22.5 million cft, of the roundwood products are categorized as non-growing stock, while sawtimber at 19.2 million cft (43%) and pole timber at 2.5 million cft (5.7%) make up the rest of the roundwood products categories. Table 2 shows the roundwood products numbers in greater detail.

Volume of roundwood products (cu ft)		% of Total
Fuelwood	*19,538,032*	44.1%
Sawlogs	*13,831,901*	31.2%
Pulpwood	*9,237,169*	20.9%
Veneer logs	*1,018,924*	2.3%
Composite products	*524,806*	1.2%
Misc	*127,793*	0.3%
Total	**44,278,625**	
Source: U.S. Forest Service Timber Products Output Mapmaker Version 1.0 2005 survey		

Table 2: Volume of Roundwood Products

There are a total of 14 million cft of logging residues generated each year in the assessment area, 83% of which is non-growing stock pole and sawtimber, the rest (2.3 million cft) is sawtimber residues. By definition, logging residues remain in the forest area and are not recovered. There are also over 6 million dry tons (dt) of mill residues generated in the assessment area. Of that amount, over 1.9 million dt/year are used as fuel by-product, and 1.4 million dt are used in fiber by-products (fiberboard). The data of most interest would be the mill residues that go unused – there are 404,000 dt/year of residues that are unutilized. This includes 109,000 dt of bark, 158,000 dt of coarse wood, and 137,000 dt of sawdust and veneer wastes. It should be noted that this data is from the U.S. Forest Service 1996 survey. Table 4 shows mill residue numbers for all categories of sources and uses.

Table 4: Mill residues by type and use

Mill residues by type (dt)	Fiber Byproduct	Fuel Byproduct	Misc	Unused	Total
Bark	46,000	317,000	717,000	109,000	1,189,000
Coarse Wood (slabs for chipping)	1,369,000	997,000	302,000	158,000	2,826,000
Fine Wood (sawdust/veneer clippings)	70,000	656,000	1,188,000	137,000	2,051,000
Total	**1,485,000**	**1,970,000**	**2,207,000**	**404,000**	**6,066,000**
Source: U.S. Forest Service Southern Research Service, Timber Products Output, 1996 survey					

According to various directories of primary wood processors (see Appendix A table for source listing), there are 39 primary wood processors in the study area, including three in Columbia County. While most of these processors handle less than 1 million board feet (MMBF) of softwoods or hardwoods, several processors handle significant amounts, as much as 5-10 MMBF. However, these larger facilities also make use of their sawdust and waste wood – both J&J Lumber in Dover Plains and W.J. Cowee in Berlin use their waste wood for on-site energy needs. Wastes from some of the smaller processors should be considered, as they would be more likely to send their wastes off-site than to use them for on-site energy needs. Appendix 1 shows the list of primary wood processors in the study area and their location.

Waste Wood/Construction & Demolition

In addition to forest and timber processing resources, there are also potential fuel sources in waste wood. These materials are typically post-consumer, post-processing wastes such as land clearing debris and yard wastes, construction and demolition (C&D) debris, and waste paper and cardboard that are not included by U.S. Forest Service data. If waste wood is regulated in a state, the responsibility often falls on the solid waste division of that state's environmental agency, as much of these materials are landfilled or recycled. However, with increasing interest in biomass-to-energy, states may have to begin tracking the myriad of waste wood categories and their disposition more closely.

In New York State, C&D is defined as uncontaminated debris "that is not mixed or commingled with other solid waste at the point of generation, processing or disposal, and that is not contaminated with spills of a petroleum product, hazardous waste or industrial waste" (6 NYCRR §360-16.2) and resulting from the construction, remodeling, repair and demolition of utilities, structures and roads, and uncontaminated solid waste resulting from land clearing. The DEC website expands the definition to include:

- bricks, concrete and other masonry materials;
- soil and rock;
- wood, including painted, treated and coated wood and wood products;
- land clearing debris;
- wall coverings, plaster, drywall, plumbing fixtures, non-asbestos insulation, roofing shingles and other roof coverings;
- any other types of non-hazardous solid waste.

This definition is consistent with other states (see Connecticut definition in CSA §22a-208x), in that the main distinction made in distinguishing amongst the many types of materials in the category is separating hazardous materials from non-hazardous. Solid waste debris from the same waste stream as C&D, such as asbestos waste, garbage, electrical fixtures containing hazardous liquids such as fluorescent light ballasts or transformers, or tires, is regulated separately. Also, if the waste has been processed in any manner that renders individual waste components unrecognizable, such as with pulverizing or shredding, it is not considered C&D. Since C&D is not considered "hazardous" and not regulated as solid waste is, the amount of C&D generated, handled, and processed and its disposition is more difficult to track.

In New York, C&D processors and handlers are permitted or registered by DEC, depending on the types of waste they handle. C&D processing facilities are registered if they handle materials of a more hazardous nature, such concrete, asphalt pavement, brick, soil or rock that has not been in contact with hazardous or industrial waste. All other C&D processing facilities are permitted. Since both types of C&D processing facilities can handle waste wood, they are both included in this analysis.

Materials can be separated from C&D debris to be recycled or to be reused for a specific use if approved by DEC, and what is not recovered is sent to a MSW or C&D debris landfill, many of which are located in central and Western New York. Both types of C&D processing facilities are required to submit annual operating reports, which include reporting on types and amounts of materials handled. In 2006, C&D processing facilities received 9.35 million tons of C&D debris and recovered 4.75 million tons of material (Source: NYS Department of Environmental Conservation, *Construction and Demolition Debris Processing Facilities,* www.dec.ny.gov/chemical/23686.html). While reporting requirements are not very stringent, as many individual reports often are incomplete or do not use consistent measurements (cubic feet, yards, and tons are all used), it is possible to obtain a picture of availability of the waste wood and C&D waste stream in the assessment are for fuel use.

There are 3 registered C&D facilities in the assessment area which handled 268,314 tons of waste wood, C&D debris, and other possible fuel materials in 2006. A number of transfer stations in Columbia County handle C&D and yard waste, including the Greenport, Kinderhook, Livingston, and Chatham transfer stations but most of the C&D is either sent to the eco/B3 transfer station in Canaan, where most of it ends up being sent to the Seneca Meadows landfill, or is directly sent to Seneca or Hayes Landfill in Steuben County. The material sent to landfill from these solid waste facilities represented an additional 68,000 tons per year of material. There are also 3 permitted facilities in the assessment area that handle C&D, however those facilities either did not submit reports to DEC or did not provide information on the amounts they handle and disposition. Table 4 shows these facilities and others outside the assessment area but within range of major transportation corridors, such as the Northway or Thruway.

Table 4: Eastern New York State C&D Handlers

Regulated C&D Processing Facilities **Facility**	**Location**	**County**	**2006 Amount (tons)**	**Material**	**Disposition**
Troy Transfer LLC	Troy	Rensselaer	51,176	mixed C&D debris	Albany landfill, western NYS
Taylor Recycling	Montgomery	Orange	86,854	C&D	wood recovered, some landfilled
County Waste & Recycling Services	Halfmoon	Saratoga	130,284	C&D, clean wood, cardboard	C&D landfilled, wood chips recovered
Permitted C&D Processing Facilities	**Location**	**County**	**(tons)**	**Material**	**Disposition**
Duffy Layton Contracting	Stanfordville	Dutchess	not listed	clean wood, pallets	not listed
Devitts Supply	Newburgh	Orange	not listed	clean wood, chips	not listed
Petruzzo Products Wood Processing	Corinth	Saratoga	not listed	clean wood	not listed
Solid Waste Facilities	**Location**	**County**	**(tons)**	**Material**	**Disposition**
Town of Bethlehem Landfill	Selkirk	Albany	2,396	mixed C&D, cardboard	cardboard recovered, rest landfilled
William Biers Inc	Albany	Albany	2,772	pallets, stumps, branches	processed for mulch
Columbia County Transfer Stations	various	Greene	4,406	C&D	sent to SM, Hayes, B3 landfill
MOSA - Root/Amsterdam Transfer Stations	various	Montgomery	12,431	C&D	sent to western NYS landfills
eco/B3 Transfer Station	Canaan	Columbia	49,041	C&D from Columbia County	sent to Seneca Meadows landfill
Outside Study Area But Accessible	**Location**	**County**	**(tons)**	**Material**	**Disposition**
Carter's	Schuyler Falls	Clinton	50	pallets, wood chips	chipped for ground cover
Harlow Excavating	North Elba	Essex	195	trees, stumps	not listed
JoRose Clean Wood Waste Recycling	Herkimer	Herkimer	3,730	not listed	Lyonsdale
French Mt Company	Lake George	Warren	5,176	clean wood, chips, stumps	most to Burlington Electric, Lyonsdale
North Country C&D Processing	Ft Ann	Washington	5,270	C&D, clean wood, stumps	C&D landfilled, wood chips burned
Waste Management of NewYork LLC	Ft Edward	Washington	not listed	C&D, clean wood, cardboard	not listed
Delczeg Lumber Processing	Johnsburg	Warren	not listed	not listed	not listed
Exit 18 Wood Recycling Center	Queensbury	Warren	not listed	not listed	not listed
Campbell Trucking Waste Processing	Saranac	Clinton	not listed	clean wood, pallets	not listed
Agri-Cycle Wood Processing Facility	Cambridge	Washington	not listed	not listed	not listed
Byrd Construction Company	Granville	Washington	not listed	clean wood	not listed
Central Timber C&D Processing Facility	Argyle	Washington	not listed	not listed	not listed
Pallets Inc. Wood Processing Facility	Ft Edward	Washington	not listed	not listed	not listed
Source: NYS Department of Environmental Conservation					

Massachusetts banned the landfilling of C&D waste materials, including wood, in July 2006. The ban was expected to have the most impact on wood, since other C&D materials like asphalt, brick, and concrete were already recycled at a high rate. While the Commonwealth had hoped to promote development of new processing outlets and end markets for C&D materials, the immediate effect of the ban has been shipment of C&D materials to landfills in other states, mostly to Maine and Ohio. Development of new biomass-to-energy plants in Connecticut (as many as 3 are planned in Connecticut) will likely tap into the clean waste wood stream. In 2006 after the landfill ban took effect, 590,000 tons of C&D a year out of the over 4.6 million tons generated were sent out-of-state landfills for disposal and 130,000 tons were landfilled in-state. Of the remaining wood waste, 120,000 tons were recycled, another 80,000 tons were used for fuel, and 790,000 tons were used as landfill cover material (Source: *2006 Solid Waste Data Update on the Beyond 2000 Solid Waste Master Plan,* Department of Environmental Protection, Commonwealth of Massachusetts; February 2008).

The two closest permitted C&D processing facilities in Massachusetts are located outside the study area: ABC&D Recycling in Ware, which handled 5,303 tons of material in 2006; and Western Recycling C&D Transfer Station in Wilbraham, which handled 110,324 tons of material in 2006. However, both of these facilities are located close enough to the Mass Pike that they should be considered as possible sources of material. Surprisingly, all 4 wood processing facilities in Massachusetts, which are permitted specifically to compost wood waste and handle over 27,000 tons of wood waste between them, are located on Cape Cod (Source: *Active Handling Facilities, Facility Master File*; Department of Environmental Protection, Commonwealth of Massachusetts; September 2007).

Given the preponderance of planned biomass-to-energy plants in Connecticut and their expected impact on waste wood streams in that state, Connecticut should not be considered a viable source of waste wood for fuel.

Conclusion

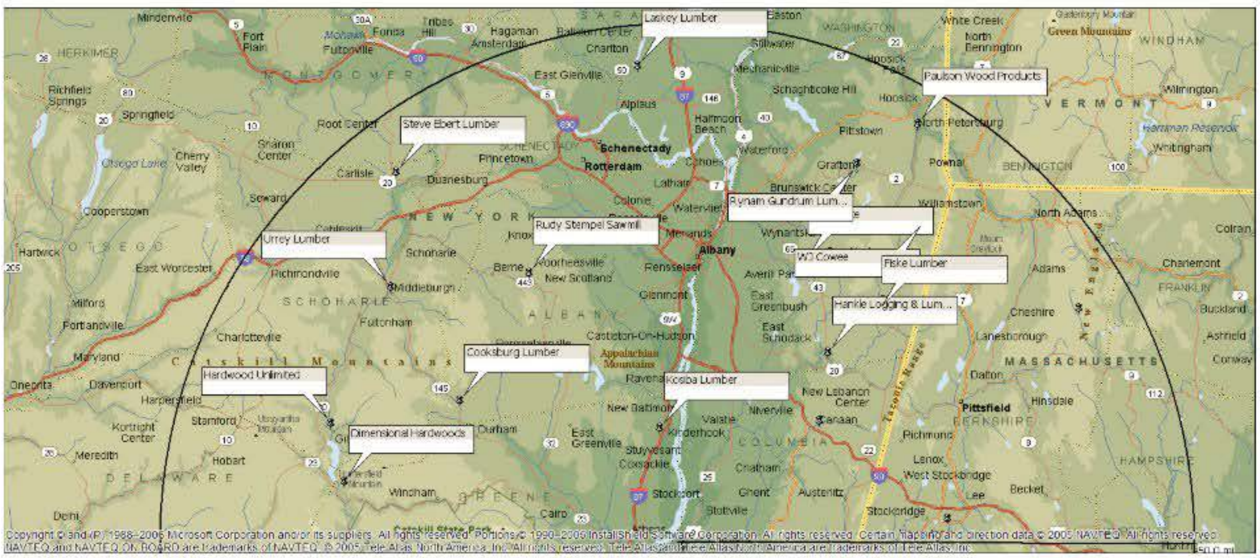
The assessment area is very productive in forest resources. The assessment area adds 68.4 million cubic feet of growing stock every year and has an estimated excess available growth of 35.5 million cubic feet every year, suggesting that significantly more timber resources could be sustainably harvested. Given that these resources are within a 50-mile range of Hudson, timber resources alone should be enough to support small on-site wood heating projects in the area. On top of this, there are significant waste wood resources in the area. A preliminary look at C&D waste wood streams suggests that significant amounts of potential fuel resources are being sent to landfills in central and western New York – capturing just a small part of this stream could provide fuel resources for district heating in Hudson. Finally, the assessment area is home to 39 primary wood processors in New York, Massachusetts, and Connecticut. While some of these processors, such as J&J Lumber in Dutchess County, already use their waste wood and sawdust in biomass boilers for heat and power, the sheer number of processors in the area should also provide a significant fuel resource.

Appendix A: Primary Wood Processors in Study Area

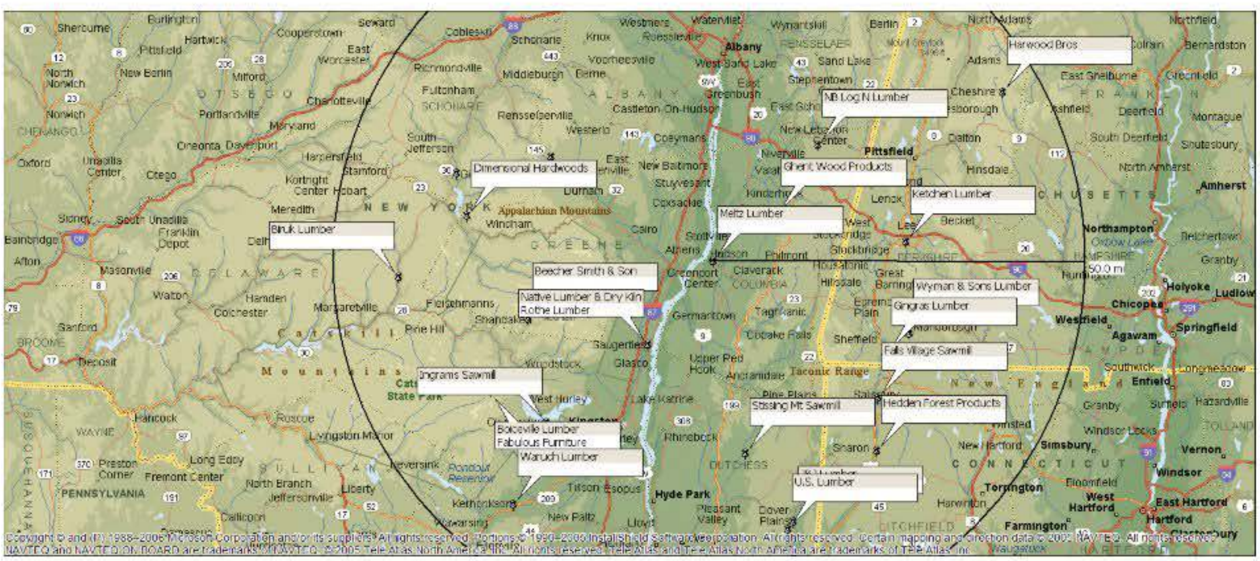
	Operation	Location	County	Products
1	Rudy Stempel & Family Sawmill	East Berne	Albany	Rough Lumber
2	Cooksburg Lumber Co	Preston Hollow	Albany	Rough Lumber
3	Gingras Lumber	Ashley Falls	Berkshire	Dimension, Rough Lumber, Boards, Timbers, Beams
4	Wyman & Sons Lumber	New Marlborough	Berkshire	Beams, Siding, Flooring
5	Harwood Bros Lumber	Savoy	Berkshire	Dimension, Flooring, Beams, Timbers
6	Ketchen Lumber	South Lee	Berkshire	Dimension, Fuelwood, Pallet stock, Beams
7	New Britain Log-n-Lumber	East Chatham	Columbia	Flooring, Rough/Planed Lumber, Shavings, Timbers
8	Ghent Wood Products	Ghent	Columbia	Rough, Planed, Bark, Chips, Shavings
9	Meltz Lumber	Hudson	Columbia	Boxes/Crates, Chips, Coarse Bark, Pallets, Shavings
10	Fruitful Furnishings	Arkville	Delaware	Dimension, Planed/Rough Lumber
11	Biruk Lumber	Halcottsville	Delaware	Dimension, Flooring, Rough/Planed Lumber
12	J & J Log and Lumber Co	Dover Plains	Dutchess	Chips, Coarse/Fine Bark, Planed/Rough Lumber/Shavings, Sawdust
13	U.S. Lumber Company	Dover Plains	Dutchess	Chips, Coarse Bark, Rough Lumber, Timbers
14	Stissing Mountain Sawmill	Stanfordville	Dutchess	Fencing, Firewood, Rough Lumber, Squares, Timbers
15	Beecher Smith & Son	Lanesville	Greene	Boxes/Crates, Pallets, Planed/Rough Lumber
16	Dimensional Hardwoods	Prattsville	Greene	Dimension, Squares
17	Kosiba Lumber	West Coxsackie	Greene	Planed/Rough Lumber
18	Falls Village Sawmill	Falls Village	Litchfield	Sawmill/Planed Lumber
19	South Norfolk Lumber Co	Norfolk	Litchfield	Sawmill/Planed Lumber
20	Hedden Forest Products	West Cornwall	Litchfield	Sawmill/Planed Lumber
21	LJ Valente	Averill Park	Rensselaer	Chips, Coarse Bark, Firewood, Flooring, Planed/Rough Lumber
22	Berlin Lumber	Berlin	Rensselaer	Chips, Coarse Bark, Dimension, Rough Lumber
23	WJ Cowee	Berlin	Rensselaer	Dimension, Squares, Stakes
24	Hankle Logging & Lumber	East Nassau	Rensselaer	Chips, Fencing, Fine Bark, Rough/Planed Lumber, Ties, Timbers
25	Rynard G. Gundrum Lumber	Grafton	Rensselaer	Cabin Logs, Chips, Fine/Coarse Bark, Sawdust, Rough, Timbers
26	Paulson Wood Products	Petersburg	Rensselaer	Cabin Logs, Planed/Rough Lumber, Ties, Timbers
27	Fiske Lumber	Stephentown	Rensselaer	Dimension, Planed/Rough Lumber, Poles, Squares, Ties, Timbers
28	Academy Lumber	Ballston Lake	Saratoga	Dimension, Fencing, Flooring, Planed/Rough Lumber, Timbers
29	Laskey Lumber	Ballston Spa	Saratoga	Dimension, Fencing, Planed/Rough Lumber, Timbers
30	Hardwood Unlimited	Gilboa	Schoharie	Cabin Logs, Firewood, Rough Lumber, Stakes
31	Urrey Lumber	Middleburgh	Schoharie	Cabin Logs, Planed/Rough Lumber, Ties
32	Steve Ebert Lumber	Sloansville	Schoharie	Flooring, Millwork, Planed/ Rough Lumber, Siding
33	Boiceville Lumber	Boiceville	Ulster	Cabin Logs, Chips, Coarse/Fine Bark, Rough Lumber, Ties, Timbers
34	Fabulous Furniture	Boiceville	Ulster	Furniture, Planed/Rough Lumber
35	Waruch Lumber	Kerhonkson	Ulster	Rough Lumber, Siding, Squares, Ties, Timbers
36	Ingrams Sawmill	Olivebridge	Ulster	Planed/Rough Lumber
37	Native Lumber & Dry Kiln	Saugerties	Ulster	Planed/Rough Lumber
38	Rothe Lumber	Saugerties	Ulster	Fine/Coarse Bark, Fencing, Planed/Rough Lumber, Sawdust, Timbers
39	Farmer Jones Barns	Shandaken	Ulster	Sheds, Barns Gazebos

Source: NYS Department of Environmental Conservation, Directory of Primary Wood-Using Industry in New York State; 2006
Massachusetts Department of Conservation & Recreation; University of Massachusetts at Amherst; Massachusetts Directory of Sawmills and Dry Kilns, 2003
Southern New England Forest Consortium, Inc. Directory of Connecticut Primary Wood Processors, 2006

Appendix Map 1: Primary Wood Processors: Northern Counties



Appendix Map 2: Primary Wood Processors: Southern Counties



VANZELM ENGINEERS

Biomass Combined Heat and Power District Heating Preliminary Design

for

Eco-Grid Hudson

(NYSERDA Agreement No. 10050)

ECO-GRID™

eco-grid

Hudson, NY

January 2010

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I. EXECUTIVE SUMMARY

A. Eco-Grid is a Hudson-based public benefit (non-profit) entity that provides technical, outreach and management leadership for the development of a renewable-energy sourced district energy system for Hudson, New York. Eco-Grid entered into a contract with the New York State Energy Research and Development Authority (NYSERDA), for the funding of a feasibility study to advance the development of a system. van Zelm Engineers, LLC was engaged by Eco-Grid to provide engineering services for the preliminary design of a biomass Combined Heat and Power (CHP) central plant and heating distribution system.

B. The mission of the feasibility study and the preliminary design effort is to investigate a shift to renewable energy such that Hudson can stabilize long term energy costs, and reduce costs over time to the benefit of the local economy and the environment.

C. Review of prior report data, field survey and subsequent analysis identified the conceptual approach outlined by the feasibility study as sound. In essence, the feasibility study identified:

- Candidate central power plant locations.
- Low Temperature Hot Water (LTHW) as the preferred heat distribution medium.
- Governmental, institutional and large commercial anchor thermal customers.
- Appropriate density of downtown districts for eventual connection of residential and small commercial thermal customers.

D. The findings of the preliminary design result in the following proposed system configuration:

- Biomass CHP plant location is proposed to be on state owned land on the Hudson Correctional Facility (HCF) campus, specifically abutting the existing central steam power plant. The biomass CHP plant will supply electricity to the power grid, steam to the Hudson Correctional Facility and LTHW to Hudson. The HCF central steam plant will be maintained in service to provide backup heating capacity for HCF as well as the Hudson LTHW distribution system.
- Biomass CHP plant is proposed to be constructed in a phased deployment, programmed for Phase I to install a nominal 2 MegaWatts electric (MW_e) and 40 Million British thermal units per hour (Btu/hr) of heat. The subsequent Phase II could be an in-kind addition or increased in size subject the rate of growth in connecting thermal customers.
- Biomass fuel receiving can be accomplished by railroad or truck delivery to CHP plant.
- Thermal distribution is proposed to be comprised of a combination of above ground and underground distribution piping, for maximum efficiency of initial capital utilization as well as for ease of system expansion to stimulate connection of new thermal customers.
- Biomass CHP Plant is expected to have 85% availability.

E. The following tabulation provides a proforma overview for this biomass CHP district heating project:

Eco-Grid Hudson Biomass CHP District Heating Project

Capital Costs					
Biomass CHP Power Plant					$ (10,000,000)
Thermal Distribution System					(8,000,000)
NYSERDA Incentive Funding (estimated)					2,000,000
				Capital Total	**$ (16,000,000)**
Revenues					
Electric:	Power to Grid (1.84 MW_enet)	125.00 $/$MW_e$h	13,701 MWh		$ 1,712,580
Thermal:	Thermal Energy to Hudson Customers (40 Million Btuh Peak 20 Million Btuh average)	15.00 $/MegaBtu	175,200 MegaBtu		2,628,000
				Revenue Total	***$ 4,340,580***
Expenses					
Fuel:	Wood Chips (50% MC)	(35.00) $/Ton	43,800 Tons		$ (1,533,000)
Power Plant Maint:	General, Administrative & Labor	(0.01) $/kWh	1, 712,580 kWh		(161,184)
				Expenses Total	***$(1,694,184)***
Summary					
				Total Capital Outlay	***$(16,000,000)***
				Net Annual Revenue	***$ 2,646,396***
				Simple Payback (Years)	***6.01***

Notes: 1. Redundant thermal supply by Hudson Correctional Facility (HCF) power plant.
2. Control room operation/supervision from HCF power plant.

II. THERMAL CUSTOMER ASSESSMENT

A. In order to successfully initiate the development of a district energy system, a critical mass of thermal customers must be aggregated, in particular those customers that can be negotiated with a group rather than seeking to negotiate with a great number of property owners. The term anchor customers is typically applied to those facilities that would serve to provide sufficient committed thermal sales to justify the capital investment in the Biomass CHP Plant and the thermal distribution piping.

B. Review of the initial feasibility study was conducted for familiarization, and subsequent field survey work was undertaken to identify and list the perceived best initial thermal customers, examining the largest thermal customers, and subsequently examining public or quasi-public entities as preferred initial customers.

C. The downtown district of Hudson has significant density of buildings and ultimately will afford much opportunity once a district energy system has been initiated. However, a number of large customers are at the outskirts of the downtown proper, but offer significant loads.

D. The following provides a summary of the downtown properties as were examined:

<u>Properties Within Downtown District:</u>

County Court House	405 Union/10 East Court Street
County Human Services	325 Columbia Street
Bliss Towers and Columbia Apartments	41 North 2nd Street
Providence Hall Apts	119 Columbia Street
Schuyler Court Apts	18 Columbia Street
Promenade Hill Day Treatment	11 Warren Street
County Office Building	69 North 3rd Street
CoARC	124 North 2nd Street
DMV/County Treasurer	560 Warren Street
Columbia Memorial Hospital	22-71 Prospect Avenue
Armory (Fine Art Antiques)	438 State Street
Hudson Public Library (steam)	400 State Street
County Administrative Offices (steam)	401 State Street

E. The following provides a summary of the properties that are in the outskirts of the city as were examined:

Properties On Outskirts of Downtown:

Correctional Facility (steam)	151 East Court Street
LB Furniture (former use)	99 South 3rd Street
Public Safety / County Jail	85 Industrial Tract
Edwards Elementary School	360 State Street
Montgomery C Smith Middle School	102 Harry Howard Ave
Firemen's Home and Museum	125 Harry Howard Ave
Hudson High School	211 Harry Howard Ave

F. The following provides a summary of a property in Greenport as was examined:

Property in Greenport:

Archer Daniels Midland	Route 23B

G. The above listed properties within the City of Hudson were seen to be viable as candidate anchor customers, with the expectation that at least half of the listed properties would be likely to agree to initially participate in the initiation of a Biomass sourced district energy system. The Greenport facility was examined but was determined to be perhaps appropriate for a second phase of system growth, rather than participate in the initial development.

III. THERMAL LOAD ANALYSIS

A. The selected thermal customers were tabulated into a spreadsheet for analysis. This is contained in Appendix D. Each of the potential customers was evaluated in a three stage process, whereby the preferred evaluation was to examine the actual as-installed heating equipment and operating history of heating load, especially fuel consumption records. Where this was not available and adequate building data could be found, then heat loss was estimated for the building envelope, and as a last resort, gross square footage was employed as had been derived in the prior "Hudson Heat Load Assessment" document.

B. The aggregate heat load of the selected anchor customers represents a total of almost 80 Million Btu per hour (Btuh) of peak heating load. Of this the Hudson Correctional Facility represents the largest thermal user at a peak load of 17 Million Btuh. This facility is a steam system that requires 40 pound per square inch gauge pressure (psig) steam and would be not be economic to convert the campus to hot water for purposes of enabling a single commodity LTHW thermal service to be accepted by HCF.

C. Of the selected anchor customers, virtually all were already low temperature hot water systems with the exception of two steam heated buildings, the Hudson Public Library and the County Administrative Offices at 401 State Street. These buildings would significantly benefit from modernization of their heating systems to convert to LTHW, and warrant separate examination for conversion. Additionally, the Montgomery C. Smith Middle School obtains roughly half of its heating from LTHW and the other half from a similarly dated steam heating system. However, its LTHW heating load is sufficient to justify connection to the district heating loop.

D. It is reasonable to expect that at least half of the twenty tabulated facilities could be realistically connected to the receive the biomass sourced district energy, and this is consistent with the Heating Load Duration Curve as was prepared during the feasibility phase of study (contained in Appendix E). As such it is expected that the initial distribution system capacity should be configured to have capacity for the delivery of a peak load of 40 Million Btuh.

IV. THERMAL DISTRIBUTION SYSTEM

A. The selected thermal customers were examined as to the most economic manner to route the LTHW heating distribution, as well as to configure the system for the best opportunity to expand and serve the numerous thermal customers afforded by the relatively high density of the downtown district.

B. The Hudson Correctional Facility abutting the biomass CHP plant will receive its energy as steam and return condensate to the CHP plant.

C. In order to enable lowest possible initial cost for installing the piping as well as to allow maximum ease of adding new thermal customers, where the piping could be installed above ground, this is the proposed approach. This would be primarily done for some major segments, the industrial area en route to the former LB Furniture, the railroad right-of-way to the Public Safety/County Jail complex, and the Prison Alley for its entire length. It is proposed that the Prison Alley segment be run at a uniform 14 feet above ground, and potentially also serve as a structure to carry the electric and communications aerial cables, eliminating the wooden poles. Along the railroad right of way, the height would be low to the ground, with loops added at any of the road crossings.

D. The piping sizes have been conservatively selected, especially for the distribution main from the biomass CHP plant into the center of the downtown district, and subsequent distribution to provide expansion for adding smaller thermal customers along the right of ways. In essence, the Prison Alley, railroad right-of-way and the Harry Howard Avenue segments enable practical access to connect numerous future thermal customers.

V. BIOMASS CHP POWER PLANT CONFIGURATION

A. Siting of the CHP plant was examined at each of the three candidate locations as were identified in the feasibility study. Of these three locations the preferred site quickly became the Hudson Correctional Facility campus, for the following reasons:

1. The HCF represents the single largest thermal customer in Hudson.

2. Its current heating system requires steam, which can be easily sourced from the biomass CHP plant, but would require duplicated thermal distribution if the biomass CHP plant were not on the HCF campus.

3. It has adequate capacity to serve as a redundant heating source in the event of a scheduled or forced outage of the Biomass CHP plant. Additionally, it could support expansion of the thermal customer base as a precursor to expanding the Biomass CHP capacity as the district energy system grows.

4. The plant has an existing compliment of trained steam plant operators that could provide shared oversight of the HCF plant and the Biomass CHP power plant.

5. The existing central steam power plant has a railroad spur (from its coal fueled days) which affords flexibility for the biomass fuel to be delivered by rail or by truck delivery.

6. For the above reasons and to assure no disruption to the HCF operations during the construction phase, it is proposed that the new Biomass CHP power plant be sited on the HCF property separate from but abutting the existing central steam power plant location.

B. Architectural

1. The areas and configuration of the buildings supporting the power plant that will be added to the HCF site and their estimated sizes include the following:

   a) Raw Wood Receiving Yard (150 ft x 150 ft) with railroad and truck unloading apron areas, and weigh scales as appropriate.
   b) Fuel Preparation Building (50 ft x 100 ft)
   c) Prepared Fuel Storage Building (100 ft x 150 ft)
   d) Power Plant Building Phase I (180 ft x 150 ft)
   e) Power Plant Building Phase II (180 ft x 150 ft)

2. Preliminary style of the buildings is suggested to be on basis of pre-engineered metal building construction, with the power plant building provided with supplemental reinforcement above that of the wind and snow loading, for accommodation of machinery and piping supports and other miscellaneous equipment not mounted at grade level.

C. Power Plant Mechanical

1. Fuel Handling

a) After being weighed at the scales at the entrance to the raw wood receiving yard, truck or rail delivered biomass material (chips, stumps, pallets, etc.) will be transferred to the to the Fuel Receiving Building for sorting and processing. Fuel will be processed in the Fuel Processing Building with a grinder or a combination stump crusher / grinder for conveyor transport to the Processed Fuel Storage Building. This building will be sized to maintain five days of power and pellet plant operation when at full storage capacity. The Fuel Storage Building will have conveying systems to selectively supply material to bins and a withdrawing system from the bins to transfer material to the power plant boiler fuel feed bins.

2. Boilers and Stack

a) Both wood gasification and stoker fired boiler combustor technologies were evaluated. A comparison of wood gasification vs. stoker fired is presented, below:

<u>Packaged Gasifier Boiler</u>

- Typically smaller in size, so more units must be operated in parallel
- Clean biomass fuels operate favorably with less complicated gasifier technology
- Significant experience in the forest products and wood fuel industry
- Combustors favor package water tube boilers rather than field erected boilers
- Ramp rates faster than fluidized bed units
- Refractory maintenance less burdensome

<u>Packaged Stoker Fired Boiler</u>

- Oldest technology, many years of proven operating history.
- Not as efficient as the gasifier-boiler combustion technology
- Fuel mineral content can sometimes be an issue relative to smooth operation of the stoker grate.
- Typically reflects smaller boilers
- Inertial mass to start and stop is more expensive to cycle

- Some consider stoker type boilers safer than updraft gasifiers

b) After extensive review of biomass combustion technologies and review of experiences with operating facilities, the scale of this installation favors biomass gasification in high pressure steam boilers and will provide the most desirable power plant operational flexibility with regard to fuel materials, sizing, moisture content, and emissions. Presently, the largest commercially available gasifier is capable of producing approximately 49,000 lb/hr of steam with 12% wood chip moisture content. Therefore, the basis of the power plant general arrangement includes a phased build-out with the Phase I to consist of two 21,500 pph boilers with biomass gasifiers in order to produce sufficient steam capacity for a 2 MW_e steam turbine generator. Steam conditions will be 600 psig / 750°F. Stack gas heat recovery will be accomplished with economizers on each boiler. Emissions controls will include one electrostatic precipitator, one selective catalytic reduction (SCR) system and one continuous emissions monitor system (CEMS) per two boilers. The flue gas outlet from the emissions controls will be directed to a common stack, estimated to be at 150 feet height. The free standing stack will consist of two carbon steel flues. The last 10 feet of the two flues prior to exit will be fabricated from stainless steel. The flues will be insulated with 3" thick mineral fiber. The Phase II build-out could be configured identically, or could potentially be capable of supporting up to 4 MW_e steam turbine generator. Hence, the Biomass CHP plant is planned for an initial capability of 2 MW_e and thermal export of up to 40 Million Btuh, and future expansion to a total of 6 MW_e and thermal export of up to 120 Million Btuh.

3. Selective Catalytic Reduction (SCR)

a) Flue gas clean up will include SCR systems designed for a minimum of 76% NOx reduction. The systems will come complete with aqueous ammonia storage, ammonia flow control unit, ammonia injection grid, reactor housing and NOx catalyst. An anhydrous ammonia system may also be considered. It should be noted that the majority of solid fuel burning applications in power plants has standardized on 19% aqueous ammonia, but anhydrous ammonia can lower on-site storage requirements. The ammonia handling and storage equipment will be common to both SCR systems and sized to handle the full capacity of all four boilers.

4. Steam Turbine Generator (STG)

a) The Phase I steam turbine generator is sized to match the steam conditions and combined capacity of the boilers with preliminary turbine sizing based on the following criteria:

1) 600 psig / 750 °F
2) 43,000 lb/hr
3) 4 psia vacuum
4) 40,000 lb/hr controlled extraction at 40 psig

b) The STG should produce a nominal 2 MW_e with these steam conditions. The steam turbine extraction conditions are based on a 40 psig steam demand that would allow matching the steam requirements of the Hudson Correctional Facility as well as to provide steam to heat exchangers to generate LTHW for the Hudson distribution system.

5. Condenser

   a) A shell and tube heat exchanger will be used to condense the steam after the turbine generator. The tubes and tubesheets will be 316 stainless steel and the water boxes and water box covers will be carbon steel coated with coal tar epoxy. The basis of design will be to condense the full steam flow rate at the turbine throttle to 4 psia (22" Hg VAC). The saturation temperature of the steam is approximately 150°F. The cooling water for the condenser will be a 50% propylene glycol mixture that will flow from the condenser to an air cooled cooler.

6. Air to Fluid Cooler

   a) When the thermal customers do not require heat, heat rejection cooling capacity will be provided by a fan forced fluid cooler. The air to fluid cooler will only be active during spring and fall seasons when the demand for thermal energy is at a minimum.

7. Deaerator

   a) The deaerator will be built in accordance with ASME code. It will be tray type of carbon steel construction. The deaerator will be sized for 80,000 lb/hr and come complete with storage tank. The storage tank will be fitted with injection quills for dosing with oxygen scavenging chemicals.

8. Feedwater Heater

   a) A feedwater heater will be added to the system to pre-heat the feedwater prior to entry to the boiler economizers in order to improve system efficiency. The heater will use 40 psig turbine extraction steam as the heating medium. The tubes will be 304 stainless steel and the shell and tube sheet will be carbon steel materials. The condensate will be returned to the deaerator.

9. Water Treatment

   a) A reverse osmosis and deionizer will be used to produce high purity water. A demineralized water storage tank will provide for reserve capacity so that the power plant can continue to operate if there is a temporary interruption to condensate flow, in particular from the HCF steam returns.

   b) A chemical feed and sampling system will be required for the addition of amines, sulfites and oxygen scavengers, as well as for testing of chemical concentrations and pH levels.

D. Power Plant Electrical

1. Substation / Interconnect

a) The Phase I steam turbine generator is planned to interconnect to the electric grid at the 13.8 kV line that feeds the HCF campus. It is anticipated that a disconnect with a visible break and/or a medium voltage power circuit breaker will be acceptable at the grid interconnect.

2. Medium Voltage Switchgear

a) The paralleling switchgear for the steam turbine generator will be at the 13.8 kV level. The power to the substation will be metered and be bi-directional. The 13.8 kV switchgear will also provide power to one (13.8 kV / 480 V) station service transformer.

3. Low Voltage Switchgear

a) 480 V switchgear will provide station service power to the CHP plant and its district LTHW pumping equipment.

4. Controls

a) The power plant will have a Supervisory Control and Data Acquisition (SCADA) system that will communicate on a control system architecture loop with two hot swappable programmable logic controller nodes and redundant uninterruptible power supplies (UPS). The SCADA system will be capable of communicating with vendor PLCs for the boiler burner management and combustion control systems, steam turbine generator, air cooler, substation, and switchgear mill equipment. There will be hard wired data points for monitoring and control of pump and fan motors, as well as for monitoring of system pressures and temperatures.

VI. COST ESTIMATES

A. The capital cost of the Biomass CHP plant, for the power generation island, is anticipated to be in the order of $4,000 per installed kW_e, based on experience with similar small scale projects. The LTHW heat exchangers, distribution pumping, and SCADA system for control and automation are estimated to increase the cost above that of the power island by an additional $ 2 Million. Hence, a combined cost of $10,000,000 for the Biomass CHP Plant.

B. The district heating thermal distribution system is estimated to require 15,000 linear feet of distribution piping at an estimated average cost of $400/l.f., or $6 Million, with work required for the connection of buildings estimated as $200,000 per each of an initial 10 connected buildings (50 % deployment of the twenty candidates) or $2 Million additional for an estimated total of $8 Million.

VI CONCLUSIONS

A. This preliminary design study indicates that there are no technical issues or "fatal flaws" that cannot be overcome in order to implement the Biomass CHP power plant and district energy system. Reasonable assumptions for project deployment have been applied in order to establish practical expectations for capital cost efficiency and constructability.

B. The project will reduce Hudson's dependence on fossil fuel, and in particular afford a conversion from draining the local economy to pay for this fuel, when instead a sustainable foresting enterprise could provide benefit to the local economy.

C. Conversion to renewably sourced energy will appreciably reduce environmental emissions. The Biomass CHP power plant will mark a positive step in neutralizing Hudson's carbon footprint, avoiding heating boiler emissions or external electric generation emissions chargeable to Hudson's import of electricity.

D. Power plant and district energy distribution equipment components and systems have been preliminarily selected based on demonstrated technology and proven performance.

E. The simple payback of the integrated Biomass CHP and district heating system is projected at six years. Adjustments favoring electric rate contracts above fuel rate increases will substantially reduce the payback of the investment and improve the rate of return of the project.

APPENDICES

A. Initial Findings Report (2 pages)

B. Field Report #1 (2 pages)

C. Field Report #2 (5 pages)

D. Thermal Load Estimate – selected anchor customers (1page)

E. Heating Load Duration Curve (1 page)

F. Thermal Distribution System – SK-1 (1 page)

G. Biomass Power Plant Site Plan – SK-2 (1 page)

H. Biomass Power Plant General Arrangement – SK-3 (1 page)

I. Biomass Power Plant Preliminary Heat Balance – SK-4 (1 page)

APPENDIX A
Initial Findings Report

1.0 Familiarization and Data Review

Overview

van Zelm Engineers has prepared this initial findings report as the first phase of a preliminary design sequence for the development of a biomass fired, CHP/district heating system. The basis of evaluation and findings of this phase of investigation is based on the following elements of study, as follows:

1. General familiarization with prior data collection, analysis and reports, as follows:

    a) District Energy Feasibility Study Narrative.
    b) Initial Development Financial Summary.
    c) Estimated Heating Load Duration Curve (Sep 15, 2008).
    d) Site Selection Analysis (Oct to Dec 2008).
    e) Summary of Large Buildings for which Utility Usage was Available.
    f) Initial System Development Map (Sep 14, 2008)
    g) Aerial Photographs (15 total) of potential customer facilites.
    h) KMW Energy Inc. Wood Fired Boiler Proposal (Jun 15, 2008)
    i) Heat Load Assessment (May 4, 2009)
    j) Spreadsheet Tabulation of Properties with Tax ID numbers.

2. Detailed review of Peak Load and Annual Totalized Heat Load projections data.

3. Detailed review of the proposed CHP electric and thermal generation for the as proposed steam cycle thermodynamic as well as physical equipment mix.

Data Analysis

1. The conceptual approach outlined in the feasibility study is well focused and though there are some alternatives discussed, the initial recommendation for system development appears to have a sound basis on the following points:

    a) The proposed central plant location at the Hudson Correctional Facility, an operating steam plant that was configured and constructed to receive store and combust solid fuel (formerly coal), is the optimum location to develop the initial plant location.
    b) Design basis of CHP heat generated as low temperature hot water, is an optimum means for initiation of a modern distribution system.
    c) Proposed anchor thermal customers as governmental and institutional facilities is altogether appropriate.
    d) Hudson's downtown density appears reasonable that routings of the district hot water distribution would prove synergistic with eventual connection of small residential and commercial heating customers.

<u>Findings</u>

1. There are a few concerns with the feasibility data, which indicate that it would be beneficial to revisit some of the criteria, inclusive of:

   a) The thermal load projections are comprised of three levels of source data for heating load projections. These are:

      - Utility Historical Billing Data
        (totalized natural gas fuel input / verifiable annualized and derived peak loads)

      - Square Foot Living Area and Building Load Coefficients for Building Envelopes
        (generic per square foot estimates / derived annualized and peak heating loads)

      - Building Tax Map Identifications
        (without square foot data / no data for heating load)

      A necessary verification of the actual installed fuel input capability and/or hydronic conversion and pumping capacity for the largest of the anchor thermal customers would be a prudent verification preparatory to the preliminary design selections of the CHP plant size and phasing of implementation.

   b) The suggested steam conditions of 900 psig / 900°F, though desirable from an operating efficiency perspective, are likely to burden the capital cost and hinder project economics.

      Preliminary design needs to evaluate if a reducing the steam conditions to 625 psig / 850 °F might afford greater benefit without the cost premiums for high alloy materials on the boiler and turbomachinery.

   c) Though it is desirable that Greenport be considered for the potential to be a part of the CHP district heating system, it is likely that the distribution investment would exceed the initial return on investment.

      Configuring the Hudson system and its anchor thermal customers as the initial basis of getting a viable system underway, should be evaluated with Greenport as a second phase of distribution expansion. It also affords an opportunity to provide source CHP Plant redundancy.

<u>Options</u>

1. In view of a number of sites that are likely "stranded asset" real estate, these locations offer some possibilities for locating relatively large solar thermal collector arrays, which could contribute a significant daytime heat source. The availability of large roof areas as well as paved areas are potentially suitable for serving as the civil works foundations for solar thermal collector arrays. In this case, the hot water supply temperature might be reduced from the suggested as 203°F and potentially lowered to hot water supply design temperature of perhaps 160°F.

APPENDIX B
Field Report #1

VAN ZELM ENGINEERS
VAN ZELM ENGINEERS, LLC
10 TALCOTT NOTCH FARMINGTON, CT 06032-1800
P:(860) 284-5064 F:(860) 284-5098

FIELD REPORT #1

Issue Date:	November 4, 2009
Project Name:	Eco-Grid Hudson Biomass CHP DHC Pre-Design
Project No.:	2009149.00
Field Location:	Eco-Grid Hudson Biomass CHP
Date of Visit:	October 29, 2009
Written By:	Joseph F. Camean, P.E.

Attendees:

Name	Company	Email
Matt de la Houssaye	Eco-Grid Hudson	mdelaho@yahoo.com
Maria Miller	Eco-Grid Hudson	maria@eco-grid.org

Distribution:

Name	Company	Email
Attendees		
Craig W. Parker, P.E.	van Zelm	CParker@vanZelm.com

Item No: **Observations and Determinations** **Action Item:**

1. Bliss Towers (Jeff First) Hudson Housing Authority HUD Project
   - Grade Elevation MER (2) DHW Heaters @ 900,000 BTU input each
   - Roof Penthouse MER (4) Patterson Kelly Hot Water Boilers @ 1,200,000 BTU output each of which maximum of 2 needed
   - Columbia Apartments – Low Rise Part of BLISS (~10-20 Units) with individual Hydronic Boilers ~50,000 to 100,000 Btu/Hr Input each and Gas Fired Domestic Hot Water Heaters ~ 50,000 Btu/Hr each

2. LB Furniture (Mary) – Property mostly vacant seeking tenants
   - 300,000 GSF Pre-engineered metal building
   - Natural Gas Vented Unit Heaters
   - Air Rotation Units

3. Providence Hall Apartments (Valerie) - Delaware Corp. is Owner
   - Grade Elevation Modular Hydrotherm
   - (5) Hydronic Heating @ 300,000 BTU input each
   - (4) Domestic Hot Water Heating @ 300,000 BTU input each

4. Schuyler Court (Nick) - Same Delaware Corp. as Providence Hall Apts.
   - Individual Gas service w/ meters to each of ~ 50 apartment units with individual Hydronic Boilers ~50,000 to 100,000 Btu/Hr Input each and Gas Fired Domestic Hot Water Heaters ~ 50,000 Btu/Hr each

5. Hudson Area Association Library
   - Gas fired steam boiler 1,968,000 Btu/Hr output
   - Building in need of major rehabilitation

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6. Hudson Correctional Facility – Boiler Plant
   - (2) Trifuel Coal-oil-natural gas three pass wet back (1983) @ 20,700 pph/each - one boiler at 40 PSIG supplies winter peak (200 PSIG MAWP)
   - (1) Cleaver-Brooks CB 200-250 10,461,000 BTU input (5/23/83) natural gas and #2 fuel oil only operates at 40 PSIG
   - 20,000 Gallon #2 fuel oil storage tank
   - Peak Winter Steam Load is 16-18,000 pph @ 40 PSIG
   - Brick Radial stack ~120 FT
   - Condensate return maximum of 2000 gallon make up per day
   - Electrical Service Switchgear with Emergency Generator (December 2005)

   - Eco-Grid will obtain Hudson Correctional Power Plant building and site plan drawings

7. Firemen's Home (Tony Schwartz)
   - 92 bed mostly retirees some dementia care (built 2007) with UBW Hydronic Hot Water Boilers All VAV Air Handling systems
   - (2) @ 4,800,000 BTU ouput
   - (1) @ 3,200,000 BTU output
   - (1) @ 500 ton Central Water Chiller

8. Waste Water Treatment Plant (Paul Lossi)
   - Building is unheated other than small office
   - Sludge hauled offsite 100 wet tons sludge (27% solids) per month at $84.00/ton as picked up

9. Columbia Memorial Hospital (Harold Castellanos)
   - Hospital is top of hill, cancer center and medical offices are in out buildings
   - (2) Cleaver-Brooks CB 655-300 @ 12,553,000 BTU input each (1970)
   - (2) Direct Fired Natural Gas Absorption Chillers @ 320 ton each
   - Steam Convertors supply LTHW for building hydronic heating
   - Steam for sterilizers and kitchen – laundry sent offsite

10. Columbia County (Bob Pinto)
    - Could not survey buildings (unforeseen emergency)

    - Eco-Grid will collect info for County building boilers (nameplate data input/output Btu/Hr., steam or hot water) and Central Chiller (nameplate data, tons-refrigeration) and operating regimen

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11. Elementary School (George Keeler)
    - (2) HB Smith 28A N2003-538 Hydronic Boilers @ 1,300,000 Btu/Hr. input each (2003?) 1 boiler carries full load dual fuel natural gas/ #2 fuel oil
    - AC for Admin and few small areas 12,000 s.f. of 90,000 s.f.

12. Middle School (George Keeler)
    - (2) Weil McLain hot water boilers model 1894 gross IBR output 4,940,000 BTU (1996) dual fuel natural gas and #2 fuel oil
    - (2) HB Smith 450 Mills Steam Boilers @ 1,300,000 – 5,180,000 Btu/Hr input each
    - Total of 153,000 sq. ft., 50% steam/50% hot water
    - AC McQuay Chiller
    - 5,000 s.f. main office / admin spaces AC by ground coupled heat pumps

13. High School (George Keeler)
    - (2) x Cleaver-Brooks CB 655-300 Hydronic Hot Water Boilers @ 4,640,000 to 12,550,000 BTU input each, dual fuel natural gas and #2 fuel oil (1960's boilers w/new burners in 2001?)
    - (1) HB Smith Hydronic Hot Water Boiler 750,000 to 2,100,000 BTU input summer boiler for pool heating
    - All hydronic circuits hot water/glycol?)
    - (1) Trane Electric Chiller @ 500 Ton

14. Columbia County Documents (Tax Maps) Office
    - Requested Parcel maps showing property lines and public right-of-ways for all of Hudson City limits.

- Eco-Grid will obtain updated AutoCAD files of parcel maps.

U:\2009\2009149.00\Meeting\091029 Field Report #1.doc

APPENDIX C
Field Report #2

FIELD REPORT

Project Name:	Eco-Grid Hudson Biomass CHP
Field Location:	Columbia County Buildings, Hudson, NY
Date of Visit:	December 3, 2009
Written by:	Matt de la Houssaye with citations included from a draft Flex Tech Report

---

1. <u>Columbia County Office Building, 401 State Street</u>

Year building built: 1935
Manufacturer: Weil McLain Co. Inc
Boiler Size: H-1094SI[1]
Year. 1993
2 identical boilers
Natural gas
Sq ft steam 8450 series 2
MBH water 2271
Lb/hr 2450
Location: Basement
Square feet 43600 (draft flex tech report)
Low pressure steam boilers provide steam to individual radiators located in the offices and hallways to warm the building (draft flex tech report)

Flex Tech Report:

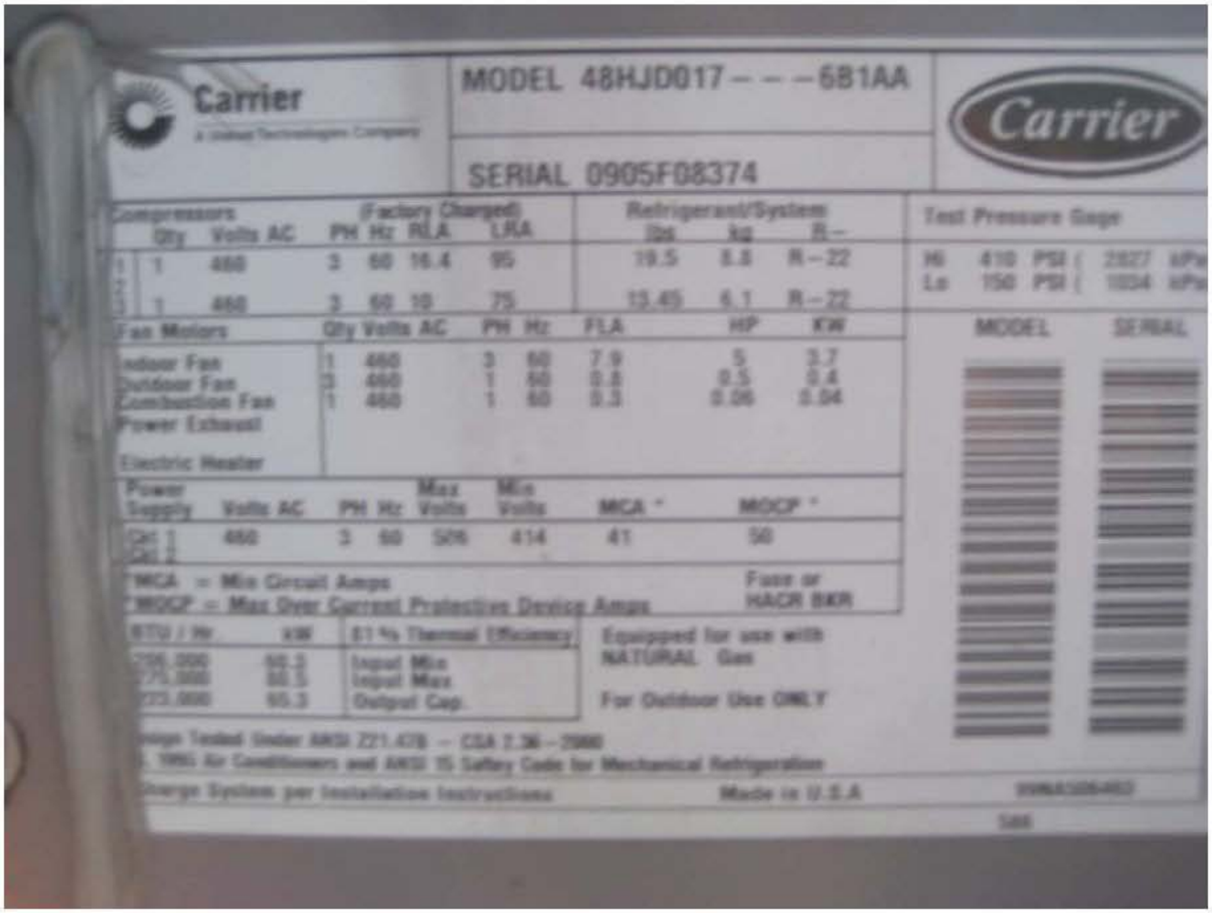
Existing System:
The 401 State Street Building currently has two (2) Weil McLain low-pressure steam boilers, each with a net output rating of 2,268,000 Btu/hr and a thermal efficiency of 72% (based on nameplate data). The unit is fired by a gas burner with a rated output of approximately 3,150,000 Btu/hr. The boilers deliver steam to two zones.

Peak Heating Load	1,959 MBH
Existing Boiler MBH rating output	2612
Estimated existing boiler efficiency	79%

[1] I looked on McLain's website and could not match this with the listed units.

2. Columbia County Department of Human Services. 401 Columbia Street

Year building built: 2005
2-story structure with lower level basement totaling 60,000 SF
Occupancy: Monday-Friday, approximately 30-50 people
Compressors Year 2005
Carrier Model 48HJD017[2]
Serial: 0905F08374
5 Compressors
1 “lobby” compressor
Location: Roof



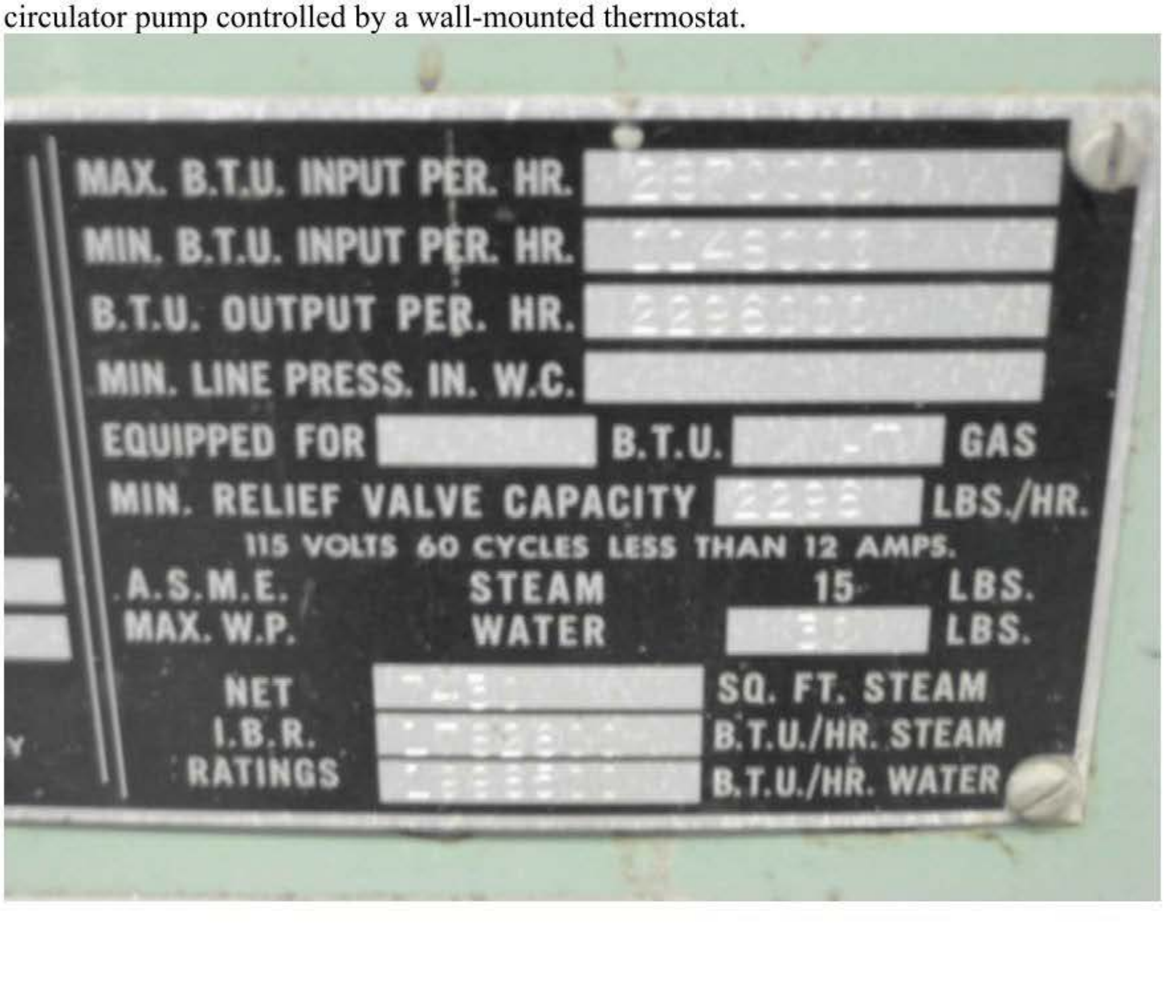
Second compressor nameplate below is for the Lobby Compressor (need to confirm)
MODEL 48HJD007-651HQ
Serial: 1505G30511

[2] Website description of this model:
www.commercial.carrier.com/commercial/hvac/product_description/1,3059,CLI1_DIV12_ETI434_MID157_PRD8,00.html

Carrier Lobby Compressor

3. Columbia County Courthouse
Year building built: 1907 (draft flex tech report)
Occupancy: Open Monday-Friday
2 Peerless Boilers, Same Size
Year of boilers: 1976
Natural Gas
Hot Water
Boiler #210-15-W-S
Serial#210-8941
Max BTU Input per hour 2,870,000
Min BTU input per hour 1,148,000
BTU output per hour 2,296,000
Net 7430 square feet steam
IBR 1782600 BTU/hr steam
1,996,500 BTU/hr water
Square feet: 23,500 (flextech report)

Flextech Report Description:
The County Courthouse currently has two (2) Peerless hot water boilers, each with a net output rating of 2,045,200 Btu/hr and a thermal efficiency of 62% (based on nameplate data). These units are fired by a gas burner with a rated output of approximately 3,200,000 Btu/hr. The boilers deliver hot water to three zones, each zone with a dedicated circulator pump controlled by a wall-mounted thermostat.



Columbia County Courthouse Boiler Room, Basement

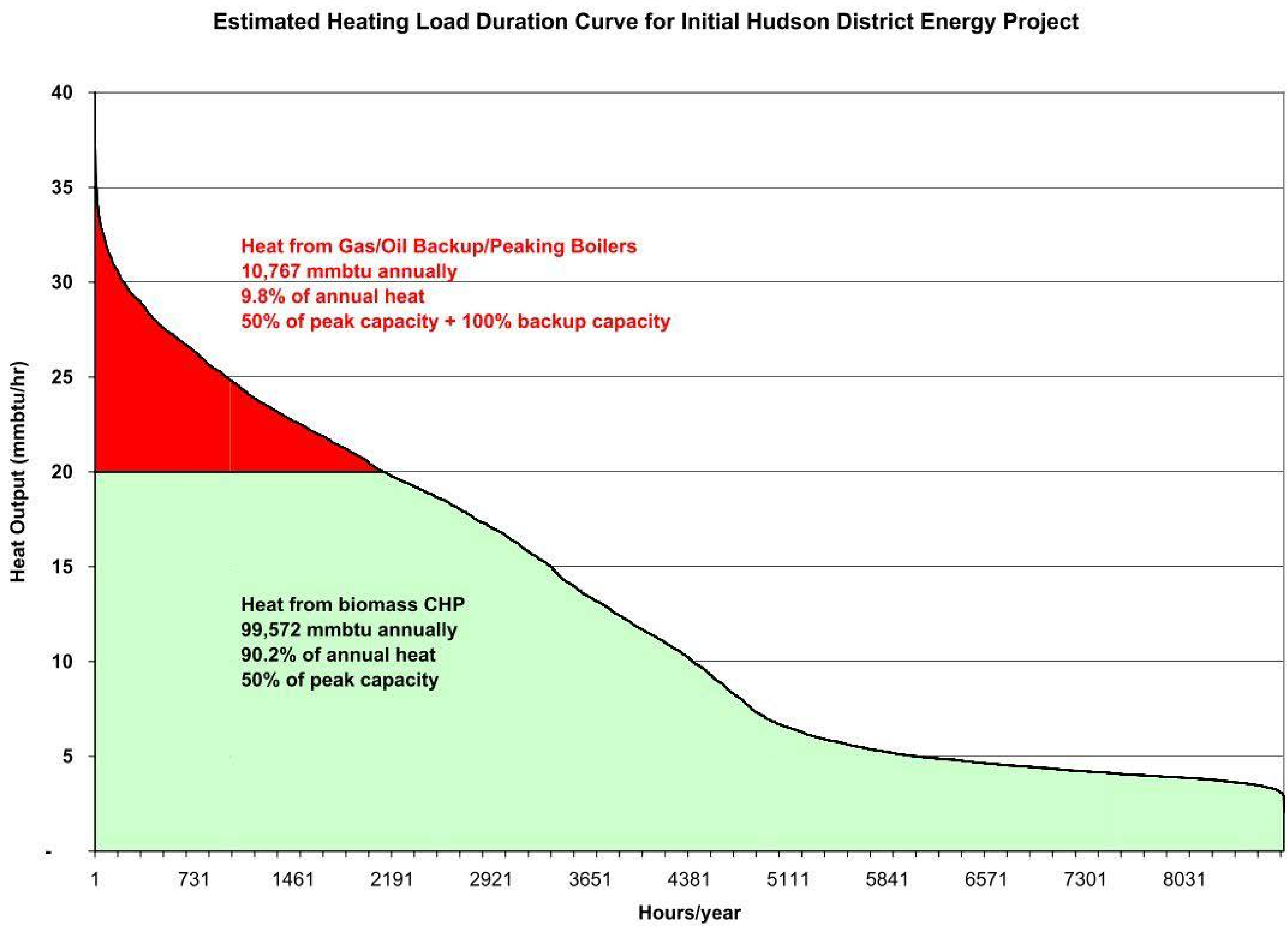
APPENDIX D
Thermal Load Estimate
(selected anchor customers)

Eco-Grid Hudson Biomass CHP District Heating

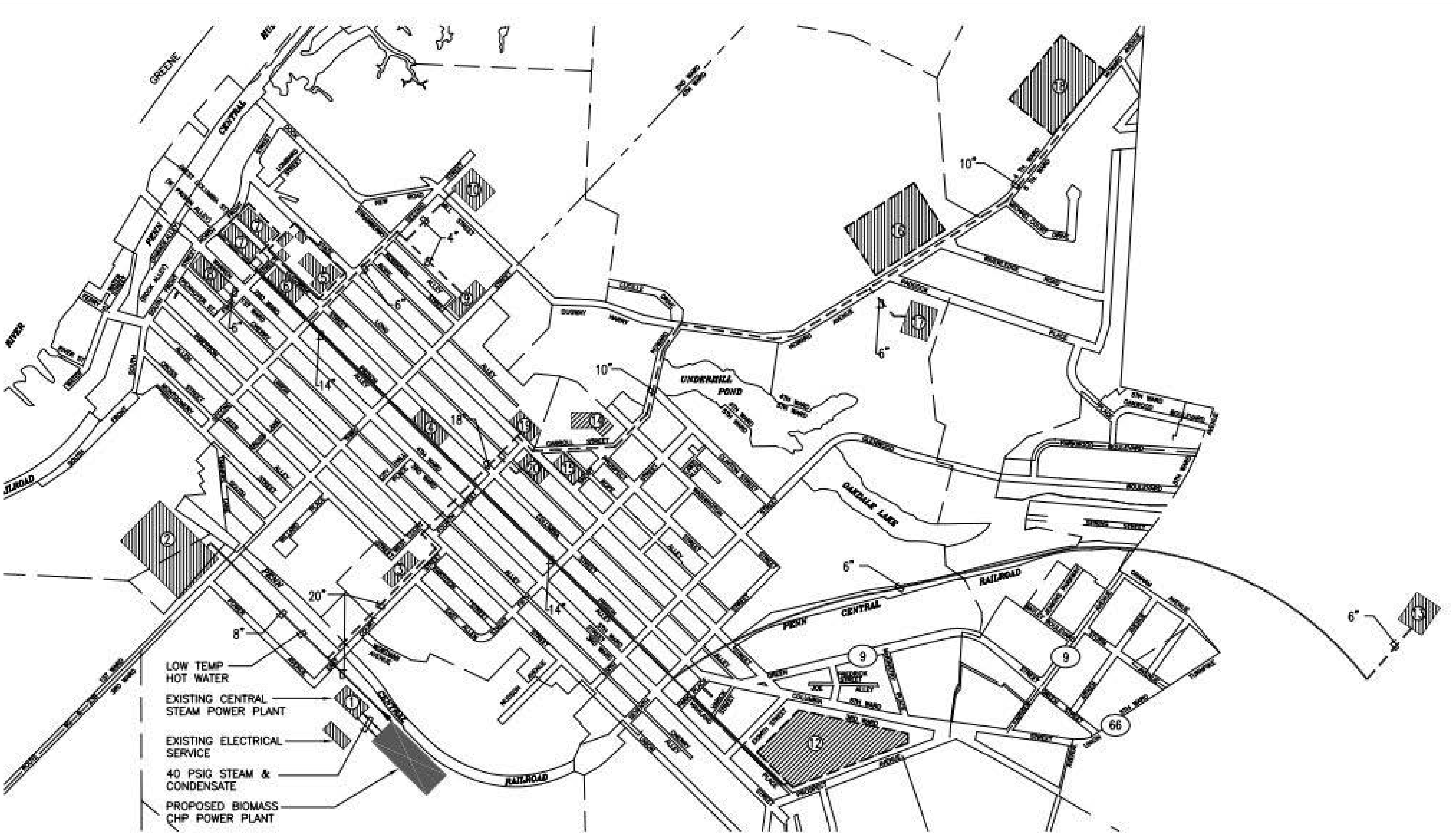
Thermal Load Estimate (selected anchor customers)

Building / Location				Winter Heating					Summer Heating			
Map Tag #	Property	Address	Building Size (gsf)	Existing Boiler Size (Kbtu/hr)	Peak Load Factor	Boilers Online at Peak	Estimated Peak Load (kBtu/hr)	Peak Load (gpm)	DHW Heater Size (kBtu/hr)	Peak Load Factor	Estimated Peak Load (kBtu/hr)	Peak Load (gpm)
1	Correctional Facility (steam)	151 East Court Street		20,000	0.85	1	17,000	N/A	573	1	287	N/A
2	LB Furniture (former use)	99 South 3rd Street	300,000				12,913	861				
3	County Court House	405 Union/10 East Court Street	23,000	2,045	0.85	1	1,738	116				
4	County Human Services	325 Columbia Street	60,000				1,320	88				
5	Bliss Towers and	41 North 2nd Street		1,200	0.8	2	1,920	128	900	1.2	1,080	72
	Columbia Apartments			1,125	0.7	1	788	53	600	0.7	420	28
6	Providence Hall Apts	119 Columbia Street		249	0.8	4	797	53	996	0.75	747	50
7	Schuyler Court Apts	18 Columbia Street		3,750	0.7	1	2,625	175	2,000	0.7	1,400	93
8	Promenade Hill Day Treatment	11 Warren Street					624	42				
9	County Office Building	69 North 3rd Street					830	55				
10	CoARC	124 North 2nd Street					590	39				
11	DMV/County Treasurer	560 Warren Street	30,300	348	0.85	1	296	20				
12	Columbia Memorial Hospital	22-71 Prospect Avenue	126,000	10,293	0.85	1	8,749	583	881	1	1,057	70
13	Public Safety / County Jail	85 Industrial Tract	61,300				1,349	90				
14	Edwards Elementary School	360 State Street		1,079	0.8	1	863	58				
15	Armory (Fine Art Antiques)	438 State Street					530	35				
16	Firemen's Home and Museum	125 Harry Howard Ave	110,000	4,800	0.8	2	7,680	512	1,520	0.8	1,216	81
17	Montgomery C Smith Middle School	102 Harry Howard Ave	46,899	4,940	0.8	1	3,952	263				
	Middle School (steam)		46,899	4,144	0.8	1	3,315	221				
18	Hudson High School	211 Harry Howard Ave	161,264	10,417	0.8	1	8,333	556				
	Hudson High School - Summer		Pool Htg	2,100	0.7	1					1,470	98
19	Hudson Public Library (steam)	400 State Street		1,968	0.75	1	1,476	98				
20	County Administrative Offices (steam)	401 State Street	43,600	2,268	0.7	1	1,588	106				
				Peak Heat Load (kBtu/hr)			79,275				7,677	
	Hot Water dT (degF) =	30		Peak LTHW flow (gpm)				4,152				493

APPENDIX E
Heating Load Duration Curve


Estimated Heating Load Duration Curve for Initial Hudson District Energy Project
Heat from Gas/Oil Backup/Peaking Boilers
10,767 mmbtu annually
9.8% of annual heat
50% of peak capacity + 100% backup capacity
Heat from biomass CHP
99,572 mmbtu annually
90.2% of annual heat
50% of peak capacity
Heat Output (mmbtu/hr)
40
35
30
25
20
15
10
5
-
1
731
1461
2191
2921
3651
4381
5111
5841
6571
7301
8031
Hours/year

APPENDIX F
Thermal Distribution System – SK-1



BUILDING LEGEND

TAG	PROPERTY	ADRESS	TAG	PROPERTY	ADRESS	TAG	PROPERTY	ADRESS	TAG	PROPERTY	ADRESS
1	CORRECTIONAL FACILITY (STEAM)	181 EAST COURT STREET	6	PROVIDENCE HALL APTS	119 COLUMBIA STREET	11	DMV /COUNTY TREASURER	560 WARREN STREET	16	FIREMAN'S HOME AND MUSEUM	125 HARRY HOWARD AVE
2	LB FURNITURE (FORMER USE)	99 SOUTH 3rd STREET	7	SCHUYLER COURT APTS	18 COLUMBIA STREET	12	COLUMBIA MEMORIAL HOSPITAL	22-71 PROSPECT AVENUE	17	MONTGOMERY C SMITH MIDDLE SCHOOL (STEAM)	102 HARRY HOWARD AVE
3	COUNTY COURT HOUSE	405 UNION/10 EAST COURT ST.	8	PROMENADE HILL DAY TREATMENT	11 WARREN STREET	13	PUBLIC SAFTY/COUNTY JAIL	85 INDUSTRIAL TRACT	18	HUDSON HIGH SCHOOL (SUMMER)	211 HARRY HOWARD AVE
4	COUNTY HUMAN SERVICES	308 COLUMBIA STREET	9	COUNTRY OFFICE BUILDING	69 NORTH 3rd STREET	14	EDWARDS ELEMENTARY SCHOOL	360 STATE STREET	19	HUDSON PUBLIC LIBRARY (STEAM)	400 STATE STREET
5	BLISS TOWERS AND COLUMBIA APTS	41 NORTH 2nd STREET	10	CoARC	124 NORTH 2ND STREET	15	ARMORY (FINE ART ANTIQUES)	426 STATE STREET	20	COUNTY ADMIN. OFFICE (STEAM)	401 STATE STREET

DRAWING LEGEND

———	ABOVE GROUND
- - - - -	BELOW GROUND
//////	EXISTING BUILDING
▩	PROPOSED BUILDING

PROJECT NAME
ECO-GRID HUDSON BIOMASS
CHP DISTRICT HEATING HUDSON, NY

DRAWING TITLE
LOW TEMPERATURE HOT WATER
THERMAL DISTRIBUTION SYSTEM

PROJECT NO.: 2009149.00
REVISION TO:
VER.: #
SCALE: NTS
DATE: 01/28/2010

SK-1
DWG. NO.

VANZELM ENGINEERS
MECHANICAL AND ELECTRICAL ENGINEERS
10 TALCOTT NOTCH FARMINGTON CT 06032-1800
(860) 284-5064 FAX (860) 284-5098

REMARKS:

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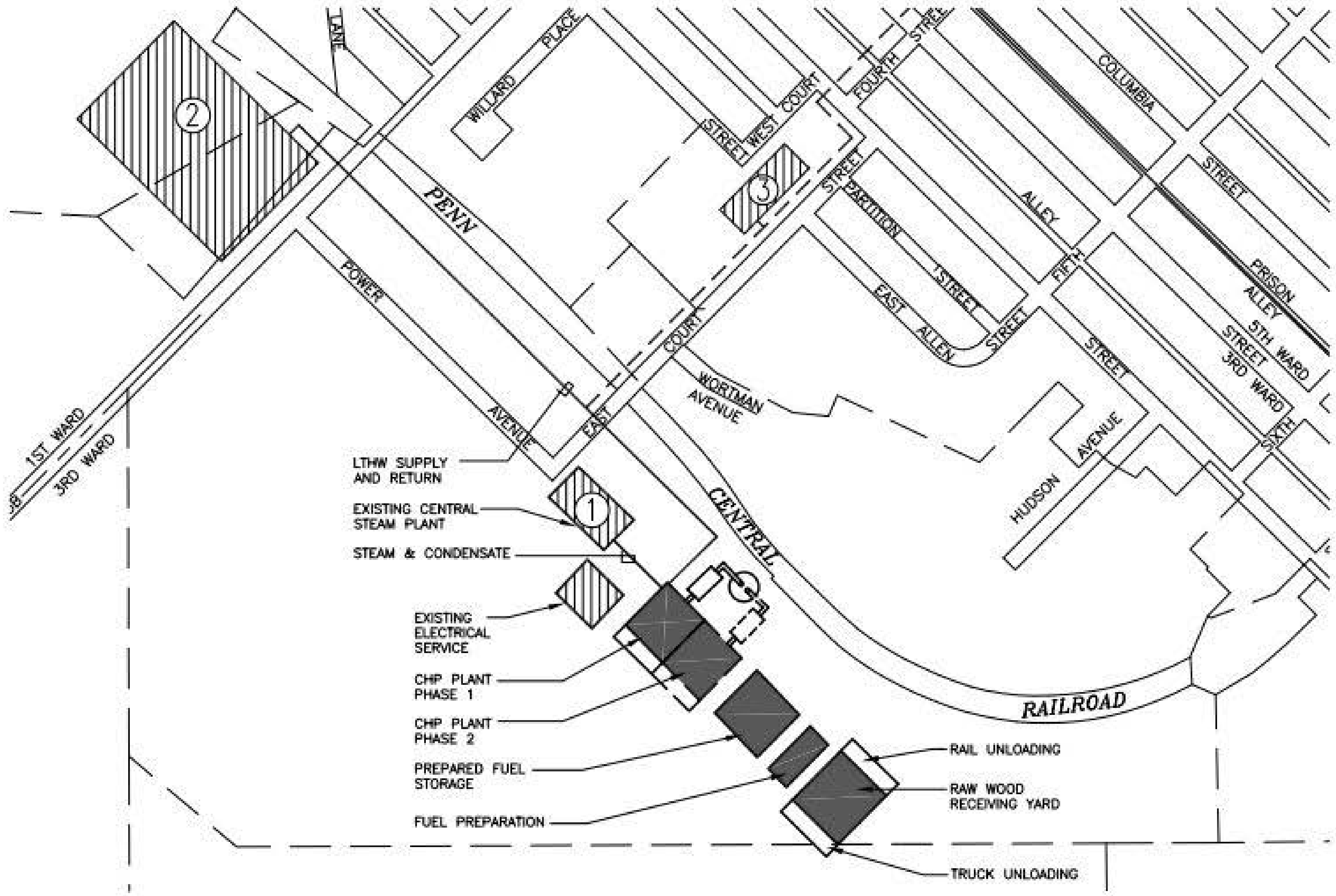
APPENDIX G
Biomass Power Plant
Site Plan – SK-2



BUILDING LEGEND

TAG	PROPERTY	ADRESS	TAG	PROPERTY	ADRESS	TAG	PROPERTY	ADRESS	TAG	PROPERTY	ADRESS
1	CORRECTIONAL FACILITY (STEAM)	181 EAST COURT STREET	6	PROVIDENCE HALL APTS	119 COLUMBIA STREET	11	DMV /COUNTY TREASURER	560 WARREN STREET	16	FIREMAN'S HOME AND MUSEUM	125 HARRY HOWARD AVE
2	LB FURNITURE (FORMER USE)	99 SOUTH 3rd STREET	7	SCHUYLER COURT APTS	18 COLUMBIA STREET	12	COLUMBIA MEMORIAL HOSPITAL	22-71 PROSPECT AVENUE	17	MONTGOMERY C SMITH MIDDLE SCHOOL (STEAM)	102 HARRY HOWARD AVE
3	COUNTY COURT HOUSE	405 UNION/10 EAST COURT ST.	8	PROMENADE HILL DAY TREATMENT	11 WARREN STREET	13	PUBLIC SAFTY/COUNTY JAIL	85 INDUSTRIAL TRACT	18	HUDSON HIGH SCHOOL (SUMMER)	211 HARRY HOWARD AVE
4	COUNTY HUMAN SERVICES	308 COLUMBIA STREET	9	COUNTRY OFFICE BUILDING	89 NORTH 3rd STREET	14	EDWARDS ELEMENTARY SCHOOL	360 STATE STREET	19	HUDSON PUBLIC LIBRARY (STEAM)	400 STATE STREET
5	BLISS TOWERS AND COLUMBIA APTS	41 NORTH 2nd STREET	10	CoARC	124 NORTH 2ND STREET	15	ARMORY (FINE ART ANTIQUES)	428 STATE STREET	20	COUNTY ADMIN. OFFICE (STEAM)	401 STATE STREET

DRAWING LEGEND

———	ABOVE GROUND
- - - -	BELOW GROUND
//////	EXISTING BUILDING
▨	PROPOSED BUILDING

PROJECT NAME

ECO-GRID HUDSON BIOMASS
CHP DISTRICT HEATING HUDSON, NY

DRAWING TITLE

BIOMASS POWER PLANT
SITE PLAN

PROJECT NO.: 2009149.00

REVISION TO:

VER.: #

SCALE: NTS

DATE: 01/28/2010

SK-2

DWG. NO.

VANZELM ENGINEERS
MECHANICAL AND ELECTRICAL ENGINEERS
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REMARKS:

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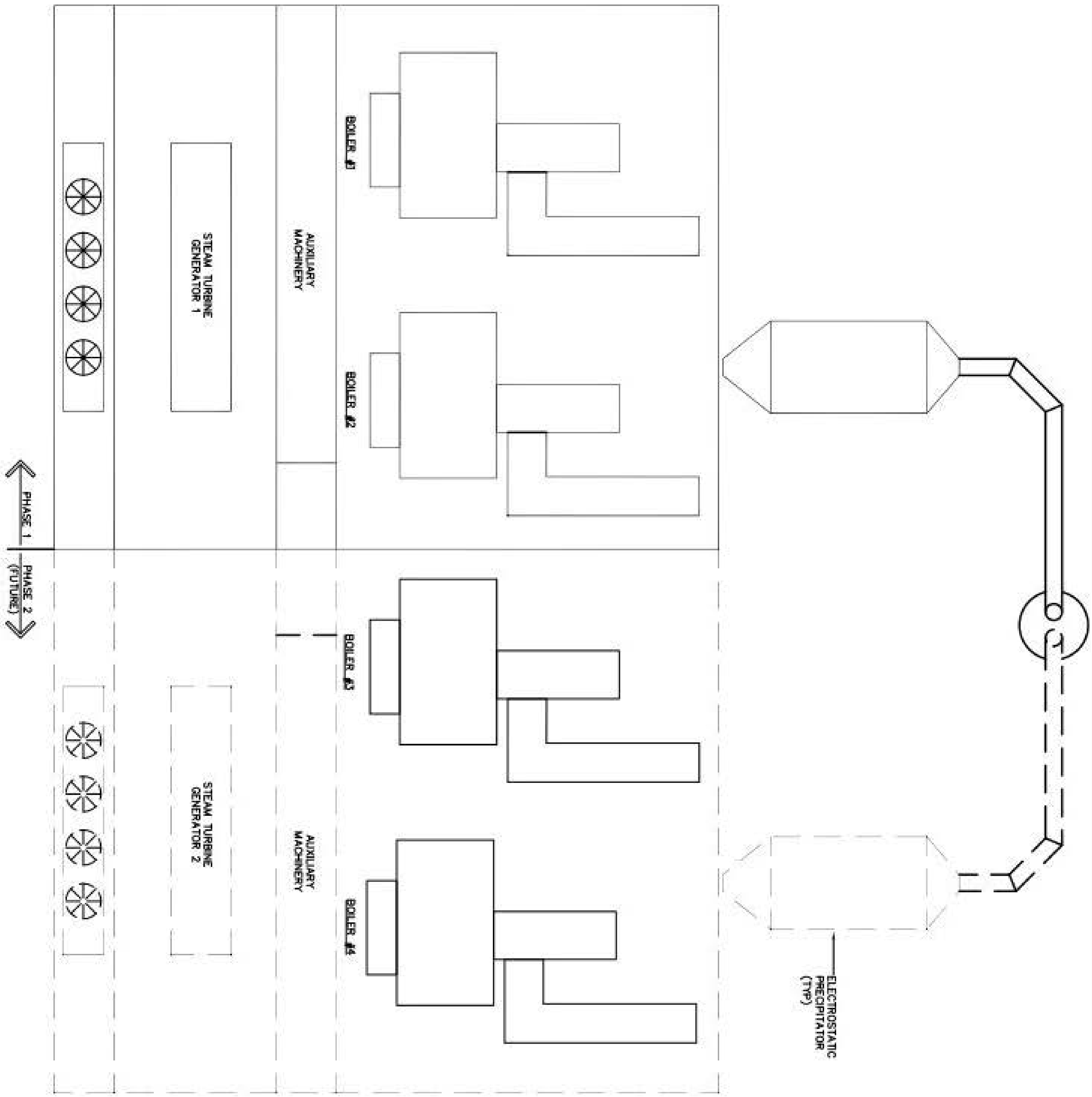
APPENDIX H
Biomass Power Plant
General Arrangement – SK-3



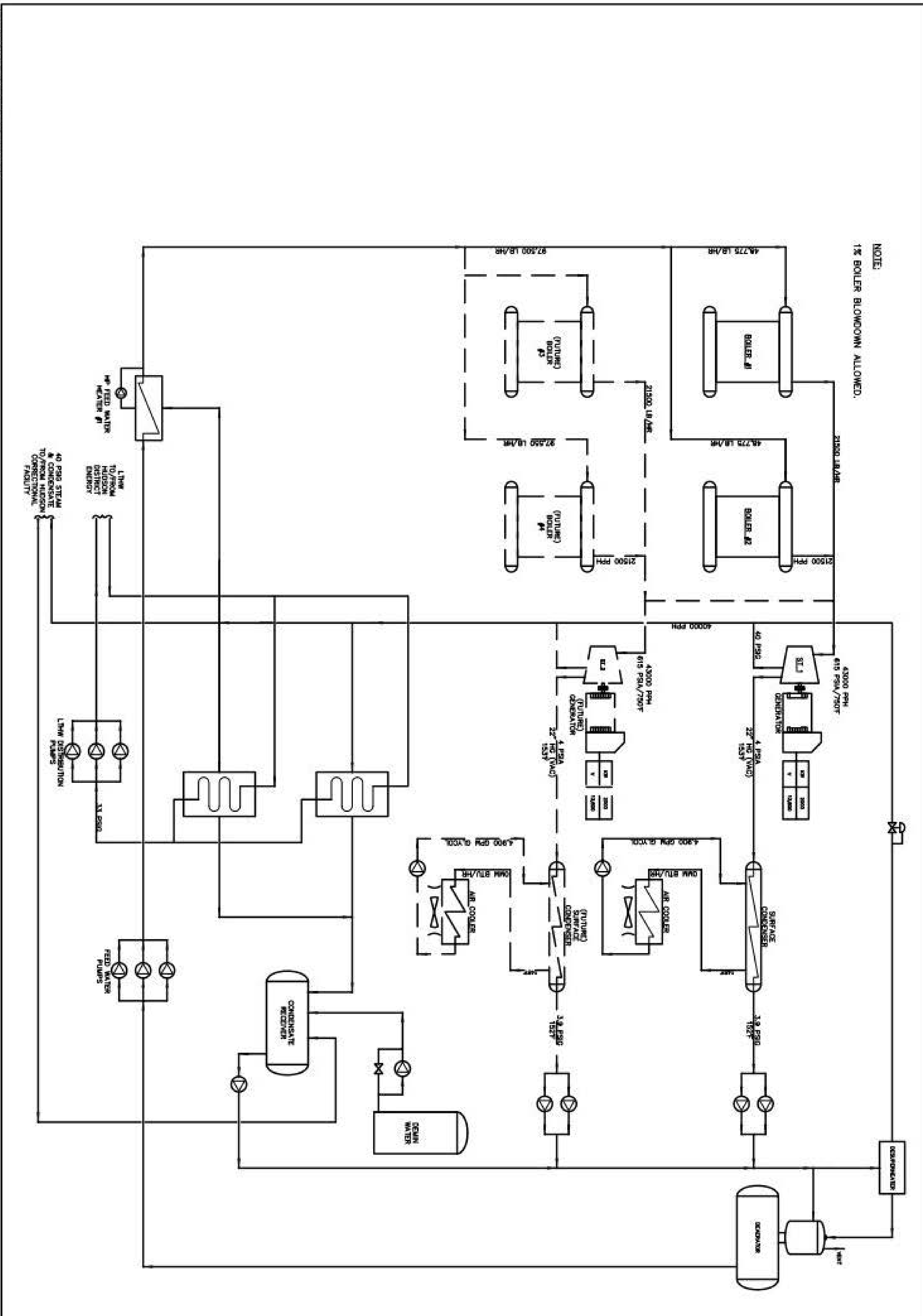
PROJECT NAME ECO-GRID HUDSON BIOMASS CHP DISTRICT HEATING HUDSON, NY	DRAWING TITLE BIOMASS POWER PLANT GENERAL ARRANGEMENT

VANZELM ENGINEERS
MECHANICAL AND ELECTRICAL ENGINEERS
10 TALCOTT NOTCH FARMINGTON CT 06032-1600
(860) 284-5064 FAX (860) 284-5098

PROJECT NO.: 2009149.00			SK-3
REVISION TO:		VER.: #	
SCALE: NTS	DATE: 01/28/2010		DWG. NO.

REMARKS:

APPENDIX I
Biomass Power Plant
Preliminary Heat Balance – SK-4



PROJECT NAME ECO-GRID HUDSON BIOMASS CHP DISTRICT HEATING HUDSON, NY	DRAWING TITLE BIOMASS POWER PLANT PRELIMINARY HEAT BALANCE

VANZELM ENGINEERS
MECHANICAL AND ELECTRICAL ENGINEERS
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(860) 284-5064 FAX (860) 284-5098

PROJECT NO.: 2009149.00			SK-4
REVISION TO: ####		VER.:	
SCALE: NTS	DATE: 01/28/2010		DWG. NO.

REMARKS:

Item	**Comment**
NYSERDA Review Comments:	
Page 1 – district cooling.	District cooling in Hudson would not be cost effective using a large scale piping network. Initial summer CHP load would be attained by adding LTHW motivated single stage absorption chillers at the larger facilities that already have chillers. Once a critical mass of heat customers are contracted, then grouping of buildings would be served by localized chillers and minimized runs of CHW piping.
Page 1 – "in-kind".	In-kind means that Phase II could be of identical size/configuration to Phase I
Page 1 – Summer Operation (85% availability) ?	Availability speaks to expected hours that the plant would be on line, minus scheduled or forced shutdowns, i.e., 0.85 x 8,760 hrs. = 7,446 hours. The CHP plant includes an extraction/condensing steam turbine, that would be capable of producing power even if there were no summer load, but it is expected that the system customer domestic water loads, as well as absorption chillers at several of the larger buildings would provide summer load.
Page 2 – NYSERDA Incentive Funding.	Anticipated to be funded as a R&D initiative.
Page 3 & 4 Facilities on Outskirts of City.	These are shown on the system map contained in Appendix F
Page 4 – Half of properties expected to connect to system.	This is based on approximately half of the suggested initial thermal customers having old, inefficient heating equipment nearing end of useful life.
Page 4 – What incentive to connect (and pay capital) by customers if existing heat still working?	In addition much aged heating equipment nearing end of useful life, the Biomass CHP system will make available renewably sourced energy that will likely be chosen by some amount of customers. Capital cost would have to be part of a rate based approach; no different than a natural gas utility offering a "free" boiler in return for a customer agreeing to use natural gas fuel.
Page 6 – Basis of distribution pipe routing.	Routings were configured such that the distribution would connect the largest thermal customers, and also run through the greatest extent of the City to allow lateral extension of services to new customers.
Page 6 – Citizen tolerance of above ground piping.	Intent is only to do so in alleyways, or along railroad right-of-way. Crooked utility poles with wires draped about have become part of the accepted background, displacing this with a neatly arranged conduit system is arguably more aesthetic. However, cost estimating for distribution piping was all factored at underground cost (in event that all ends up as underground).
Page 6 – Mapping of potential future customers.	Intent is any and all properties, commercial and residential.

Item	**Comment**
NYSERDA Review Comments Continued:	
Page 7 – HCF central steam plant as redundant capacity.	HCF peak steam requirement is 18,000 pph, and its existing central steam plant has 3 steam boilers with nominal capacity of (2) 21,000 pph and (1) 8,000 pph. If one of the Biomass CHP boilers is out of service, 21, 500 pph is needed. Hence, under normal conditions, the HCF plant can back up a single boiler outage.
Page 8 – Wood waste fuel acceptability.	The fuel preparation for waste fuels is intended to have the necessary equipment to separate non wood materials, and to size waste wood to avoid material handling problems.
Page 8 – Packaged Gasifier Boiler experience.	Forest products experience refers to sawmills and logging waste wood fuel streams. Wood fuel industry refers to hog fuel, and processed land clearing waste wood.
Page 9 – Gasifier capability at 49,000 pph at 12% moisture wood fuel.	The reference to 12% wood chip moisture content is in context with describing the largest commercially available {updraft} gasifier at 49,000 pph if fired on 12% moisture wood chips.
Page 9 – Why SCR?	Conventional boilers are now being fitted with SCR's. It is a logical extension that by the time project goes into service it will be expected for Biomass fired boilers as well.
Page 12 – Cost Estimate basis.	\$4,000/kW installed cost data from current steam turbine cycle biomass power projects that have been bid in Northeast (projects cannot be disclosed due to confidentiality). \$400/l.f. is the estimated average cost to go all underground, but was carried for the proposed above ground routing as well (as mentioned earlier – so all could be built for the budgeted cost if aboveground option not acceptable). Also, intent was this was in lieu of a contingency allowance.
Page 13 – Environmental emissions.	The emissions reductions are predicted to result in appreciably lower emissions on the following basis: Sustainably forested biogenic biomass, and avoided decomposition to methane of the wood waste fuel component drastically reduces carbon emissions. Also, biomass combustion occurs in nature on an ongoing cycle, i.e., forest fires, which emit uncontrolled NOx and PM. The ESP and SCR drastically reduce those emissions. Fossil fuels extraction and combustion is not a sustainable practice and adds to the total emissions in every respect.
Page 13 – Conservation study before connecting thermal customers to district energy.	Agreed, that this is appropriate for customer facilities, but is not part of study scope.

Item	**Comment**
General Comments:	
Capital cost for material handling.	Material handling represents approximately 20% of the CHP plant equipment and installation cost.
Why steam and no Organic Rankine Cycle.	The anchor thermal customer is Hudson Correctional Facility (HCF) with its campus served by 40 psig steam. Hence the plant is configured to serve this thermal stream as well as to produce Low Temperature Hot Water. Phase II could use ORC technology.
Page 8 reference to pellets.	This speaks to the onsite fuel preparation for waste wood, and need to provide uniform material for mixing with the primary wood chip fuel. Pellet used generically, preferred descriptor is "sized fuel".
Electricity Price.	The $125/MWh is based on electric power sold within the HCF campus and displacing retail purchased power at future value when CHP plant comes on line.
Cost comparison of above ground versus underground.	Intention was to install ~10,000 l.f above ground and ~8,000 l.f. underground, but estimated all piping at installed cost of $400/ linear foot. This reflects cost of direct buried, or architecturally treated aboveground conduit system. The above ground piping is proposed only in alleyways or along railroad right-of-way, intended to allow easy repetitive connection as the system expands. The alleyway piping would be in an architecturally treated conduit intended to also carry electric power and communications, eliminating the less aesthetic utility poles and wires.
CAD Drawings on disk.	Drawings can be plotted at any size from the pdf file.
Estimated CHP plant and LTHW pumping parasitic power.	Internal CHP electric loads for conveyors, steam cycle pumps, fans, etc. is a nominal 5% of gross generation. LTHW distribution pumping is estimated at a nominal 3% of gross generation.
Heat Load estimation.	Data was extracted from reports by others.
Biomass Fuel Cost.	The $35/ton at 50% moisture is current market price, fuel availability and pricing is by others.
Power Plant Maintenance Cost.	The $0.01/kWh (or $10/MWh) cost is based on industry experience for maintenance costs beyond normal operator staffing and incidental maintenance performed by operations staff.
Why not biomass heat only and not CHP.	Power is included in that the plant will be sited where the power is to be sold as avoided retail by HCF, additionally without the power sale revenues the payback is much less attractive.

Item	**Comment**
General Comments Continued:	
Duplicated Staffing.	The intent is for the same operator staff to operate both plants, employing Supervisory Control and Data Acquisition Technology and a central control room. with a control room operator and an equipment operator.
Importance of HCF as anchor customer.	Hudson does not enjoy the European approach of mandated district heating, and the system is not expected to immediately contract sufficient thermal customers to achieve financial viability without the significant and stable load of HCF.
Waste fuel impurities fouling combustion process.	The fuel preparation for waste fuels is intended to have the necessary equipment to separate non wood materials.
SCR location and RSCR option.	SCR placement would be after the ESP such that the flue gas stream is cleaned of particulates, and final design will accommodate required temperature zone, i.e., placing low temperature economizer downstream of ESP-SCR system. An RSCR or NSCR could be an option.
Environmental Emissions reduction.	The emissions reductions are predicted to result in appreciably lower emissions on the following basis: Sustainably forested biogenic biomass, and avoided decomposition to methane of the wood waste fuel component drastically reduces carbon emissions. Also, biomass combustion occurs in nature on an ongoing cycle, i.e. forest fires, which emit uncontrolled NOx and PM. The ESP and SCR drastically reduce those emissions. Fossil fuels extraction and combustion is not a sustainable practice and adds to the total emissions in every respect.
Thermal Load Estimates and middle school size.	Data was extracted from reports by others, and where there was no data unit estimates were made. The middle school heating is a combination of steam heated and hot water heated building wings. Only the hot water heated area will be supplied by the LTHW district heating energy. When the facility converts from steam to hydronic the LTHW service is adequate to serve the full building.
Reference to 12% moisture fuel.	The reference to 12% wood chip moisture content is in context with describing the largest commercially available {updraft} gasifier at 49,000 pph if fired on 12% moisture wood chips.
Electricity Price highly optimistic for Zone F.	Power is not direct to the grid, rather $125/MWh is based on electric power sold within the HCF campus and displacing retail purchased power at future value when CHP plant comes on line.
Plant Peak Output seems too high.	Plant is sized for future system capacity, but appropriate to system load duration curve prepared by others. Hence, 2 x 21,500 pph boiler arrangement.

Item	**Comment**
General Comments Continued:	
Peak Plant Output could serve 3 Million gsf.	Plant is sized for future system capacity.
Aboveground piping not aesthetic.	This is proposed for alleyways and railroad right-of-way. Intent is to provide architecturally treated conduit as a cleaner appearance than crooked poles and wires. This could change to underground as cost estimate is similar, but would not afford ease of repetitive tapping to add small (residential) customers.
Temperature differential not greater than 30 degF.	This is a conservative figure to assure that existing facilities (which currently are at 20 degF condition) can be successfully connected and operated. The DeltaT will then be progressively increased (with building system modifications if necessary to increase DeltaT. It is the long term intent for LTHW system DeltaT to be 60 to 80 degF.
Why condensing pressure at 4 psia and not 13 psia.	To provide capability to operate in summer season in electric priority the condensing pressure was selected at 4 psia. It is long term goal to progressively raise condensing pressure/temperature optimized to follow LTHW supply temperature requirements.
Thermal price at $15/MegaBtu.	Pricing is expected future price when plant comes in service. Thermal customers are mostly using firm natural gas in aged and inefficient heating equipment.
Why two boilers.	Two boilers are configured to provide redundancy as the availability is not 100%, and the long term intent is to provide district heating in winter as well as to continue to export heat in summer for driving absorption chillers. Hence, reliability of heating capability is required year round.
Why SCR.	Conventional boilers are now being fitted with SCR's. It is a logical extension that by the time project goes into service it will be expected for Biomass fired boilers as well.
30% soft costs should be allowed for.	This can be applied in the form of a contingency.

Item	Comment
Verenum Review Comments (Page/Section):	
4/1.1 Basis of assessment	Verenum review is inclusive of documents and data not provided by van Zelm Engineers, Comments are made only in regard to the van Zelm preliminary design report.
4/1.2 Air emissions was commented on as to be treated as a second step.	The proposed plant would include both particulate removal by electrostatic precipitator as well as a Selective Catalytic Reduction unit to control Particulates and Nitrogen Oxides from the flue gas stream. These are the Best Available Control Technologies for air emissions as are commercially available.
5/1.3 Heat Storage	It is acknowledged that heat storage in the way of a thermal accumulator tank improves system operational efficiency. In the interest of conserving capital for this developmental system, the initial strategy to accomplish this is to leverage the initial overcapacity of the distribution system mains, as are sized for future thermal customers. This volume will serve the thermal accumulation function by allowing elevation of water temperature in anticipation of thermal demand spikes.
6/2.2 Two Boilers vs. Single Boiler	It is anticipated that the operators for the Biomass CHP plant will be recruited locally. As there is no experience base with biomass fuel combustion, this was anticipated to provide necessary redundancy as well as be optimal for operating until the system grows in scale.
7/2.3 Gasifier Boiler	The proposed gasifier boilers have long term experience operating with woody biomass fuel at 6% to 60% moisture content.
7/2.4 Biomass CHP Plant Sizing	The proposed initial development anticipates approximately 50% of target customers being contracted to purchase thermal. The HCF Steam Boiler plant is planned to remain active as a backup steam supply, and for peaking in the event that system growth exceeds the two boiler units. It is also expected that the plant operators would provide operations for both the Biomass CHP and the HCF Steam Boiler Plant.

Item	Comment
Verenum Review Comments Continued (Page/Section):	
8/2.4 Energy Balance	The plant (phase I) has a design capability of 40 Million Btuh, but will initially serve a load of 20 Million Btuh. The preliminary design provides for reliably meeting the initial thermal load, forecast at 20 Million Btuh, with N+1 initial boiler capacity. This capacity will eventually be needed as the system grows to 40 Million Btuh, but will initially allow locally recruited plant operators to have the redundancy while they gain proficiency in operations. Relative to operating hours it is expected that the heating customer base will also quickly evolve to add absorption cooling to effect 7,450 operating hours for the system.
11/2.5 Economic Assessment	The preliminary design reflects 7,450 operating hours for the system. Hence the Verenum Case 3 does reflect the predicted system deployment. This is contingent on the project being launched, deployed and operating with popular public and private sector support. Hence, it is important that the fuel supply, plant and system construction and ongoing operations bring economic benefit to greater Hudson.
11/2.6 Potential of Improvement of Energy and Economy	Reduction of the initial capital cost would most likely be afforded by the availability of the HCF existing steam plant, and choosing to utilize a single biomass boiler. Modification of the steam pressure/temperature conditions, and the power cycle configuration would have to be addressed as part of final design.
13/2.7 Assessment of Hydraulic Integration and Heat Distribution	Heat storage will be initially accomplished by using the excess distribution piping volume, but it will be a worthwhile enhancement as the system expands to full customer base deployment. Use of a boiler condensing economizers was not included, as the minimum return temperature cannot be established until the largely existing thermal customer facilities can be optimized as part of the interconnection to the District Energy system.
15/2.8 Environmental Assessment of Air Emissions	The preliminary design includes Best Available Control technology, and the control efficiencies would be confirmed as part of the final design. This would be as required to meet the New York State Department of Environmental Conservation permit requirements to secure a permit to construct and operate.

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Technical and Economical Assessment of Concepts for Biomass Combined Heat and Power Plant and District Heating for Eco-Grid Hudson

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New York State Energy Research and Development Authority NYSERDA
NYSERDA Agreement 10050

Zürich, 24 June 2010

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1. Introduction

1.1. Data basis

The following documents provided by Eco-Grid are used as basis for the present assessment:

1. Van Zelm Preliminary Design Report for CHP plant based on steam cycle
2. Appendix to Van Zelm's Engineering Report
3. Envio Energi Budget Quote for CHP plant based on steam cycle
4. Vision Power USA budget quote for ORC plant
5. Information given by Eco-Grid in Email from 26.4.10: A total received price of $65 per MWh electricity is assumed if provided to the grid. If electricity is sold directly to the prison, then the assumed retail price of $125 per MWh
6. Additional information provided by Eco-Grid (Email from 11.6.1).

The following documents were also provided but are not specifically cited in the present report:

7. Mesa biomass availability study
8. Report by Dr. Morris Pierce with spreadsheet.

1.2. Target

The present report provides a technical assessment of the concepts for heat and power production from biomass of the Eco-Grid project. Due to the assignment of tasks initially defined by Eco-Grid, special focus should be given on the assessment of the ranges for key air emissions using the chosen technology and on recommendations on technologies that exceed the stated biomass CHP technologies in cost and/or emissions. After studying the provided documents, the priority of the present report was set on the plant design with respect to overall concept, plant economy and overall efficiency. In the present report, aspects of air emissions are treated in a second step. This is due to two reasons: First, own estimations on efficiency and economy reveal, that the overall concept is presumably uneconomic and hence a realisation of the proposed concept seems uncertain, and secondly, the fuel demand and consequently the total air emissions depend on the plant size and the annual full load hours. Hence the present report gives a generic assessment of the air emissions, while a detailed assessment of air emissions can be performed after initial decisions on the final plant size and design.

1.3. Comments on the data basis

Since several concept proposals are described in the above mentionned documents, the data available for the present assessment are of varying quality. In some cases it is unclear, which data are reference values and which are assumptions of the authors, since some of the available data are contradictory and heterogeneous (e.g. plant size, heat demand, full load operation). In addition, some of the data are given in incorrect dimensions. E.g. Envio Energi indicates power output in 2.25 MW/hr and 20.661 MW/yr respectively. Both dimensions are incorrect and hence need to be corrected to enable any calculations. Hence it is assumed that the correct meaning of the figures is 2.25 MW and 20.661 MWh/yr, since the given figures are physically incorrect. Furthermore, there are some inconsistencies in the Van Zelm Report between description in the text and the flow sheet, which do not fit together correctly or where the information is unprecise due to a quite generic flow sheet, which may lead to misinterpretation. Due to unclear data and inconsistencies in the documented data, the present assessment is related to respective uncertainties.

In addition, a comprehensive energy balance of the whole process is missing in all concepts. From the data by Van Zelm it has to be assumed, that input data are related to the process starting from heat available in steam provided to the turbine. Hence steam production efficiency needs to be considered additionally for the overall net efficiency, which is done in the present report.

Furthermore, transparent data indicating the net efficiencies are missing, both related to instantaneouos values (e.g. in MW or in kg/s) as well as indicated as annual mean values (e.g. in MWh/yr. or in tons/yr. and calculated as integrated values during 1 year). These data are crucial not only to assess the total energy yield, but also for the economic results of the plant, since the net efficiency directly influences the total fuel cost and the revenue for heat and power. Due to the lack of transparent data on the energy balance and the net efficiencies of the different process steps, the present assessment is related to high uncertainties and it is based on own assumptions which were introduced and needed due to missing data.

In addition, it is unclear if data on heat and power demand are given as peak values or as daily average values. In earlier days, the use of peak data was common as basis for plant design. However, this usually results in relevant over-dimensioning, since in case of several consumers, peak loads do not occur coincidently. In addition, heat storage tanks are usually implemented in district heating systems with a storage capacity of typically 1 hour of nominal heat load. Consequently, the dimensioning of heat capacities is nowadays favourably based on average daily values, thus resulting in considerably smaller plant sizes, enabling more constant operation of the plants and still avoid periods with energy shortage. With respect to investment cost, additional cost result from the heat storage tank, while relevant cost savings are due to a reduced size of the main boiler and CHP plant.

1.4. Conversion factors for phyisical data

In the documents provided above, different units are used for heat and power, which disables a direct comparison of heat and power and a direct calculation of efficiencies. In the present report, all data are converted into international standard units (SI units) by assuming the following conversion factors:

1 MMBtu/hr = 0.293 MW,	1 MW = 3.42 MMBtu/hr
1 lb = 0.454 kg,	1 kg = 2.20 lb

For evaluation of air emissions, the following conversion factors can be used:

1 mg/MJ based on LHV = 1.9 mg/m_n^3 at 11 Vol.-% O_2.

1 mg/m_n^3 at 11 Vol.-% O_2 = 0.525 mg/MJ based on LHV.

For simplification, the following conversion factors are also used to indicate rounded figures and orders of magnitude:

1 mg/MJ based on LHV = 2 mg/m_n^3 at 11 Vol.-% O_2.

1 mg/m_n^3 at 11 Vol.-% O_2 = 0.5 mg/MJ based on LHV.

2. Concept proposed by Van Zelm: Steam plant with extraction turbine

2.1. Concept description

The concept proposed by Van Zelm assumes a heat demand of approx. 11.7 MW peak with an annual heat demand distribution which is typical for heating applications, i.e., a short high peak, a relevant medium heat demand and a certain heat demand at low load.

The technical concept consists of two steam boilers providing steam at approx. 41 bar/400°C to an extraction turbine. The turbine enables steam extraction at approx. 2.7 bar to provide the steam demand of the HCF. In addition, 2,7 bar steam is used to provide the heat for the district heating at approx. 71° – 95°C depending on ambient temperature.

The low pressure part of the turbine expands steam to approx. 0.3 bar/70°C. The heat extraction for the low pressure steam is provided by an air cooler and a surface condenser.

The two flows of return water from the medium pressure and the low pressure steam are mixed in the condensate receiver. The feed water is pre-heated with medium pressure steam in a feed water heater before returned to the steam boiler.

2.2. General assessment of the plant concept

The concept of an extraction turbine is basically assessed as a reasonable opportunity for the present application, as it enables heat extraction for varying heat loads as typical for conventional heat consumers. In the specific situation, an extraction turbine enables to provide steam for HCF on-site and hot water to the district heating system.

In addition, feed water heating is applied as state-of-the art measure to increase the electric efficiency. To enable the operation of such a plant, part of the heat is being dispensed to the ambient, in the present concept by air coolers. The steam is provided by two wood boilers. The reason to split the combustion and steam production in two boilers is due to the choice of "packaged gasifier boiler" available at limited size only. On the one hand, two boilers are basically related to higher investment cost in comparison to one single boiler of double size. On the other hand, two boilers can be advantageous in case of part-load operation, which, however, is related to reduced electric efficiency of the turbine and not clearly foreseen in the description.

The design and operation of the plant as proposed in the present case results in a fairly low electric efficiency and in a low total annual efficiency by accounting heat and power. This is due to several reasons, some of them being typical for medium-scale steam applications and some of them indicating specific potential of improvement.

2.3. General assessment of the combustion principle

The report evaluates "wood gasification and stoker fired boiler combustor technologies" described as "packaged gasifier boiler" an "packaged stoker fired boiler". Both technologies are not further described with a schematic and technical specifications hence the detailed technology remains unclear. Here it is assumed, that "packaged gasifier" refers to gasification usually named "fixed bed gasifer" which are basically designed in downdraft and updraft versions. Downdraft gasifiers are mostly suited for dry wood pieces and applied for IC engine applications thanks to low tar concentration in the producer gas. Updraft gasifers exhibit a higher fuel flexibility and enable the utilisation of wet fuel at least up to a certain moisture content. For "packaged stoker fired boiler" it remains unclear, whether underfeed stoker boilers are considered or grate boiler operated with stoker feeding are meant.

According to experiences in Europe, moving grate boilers are most common for the considered size range. In case of approx. 12 MW total, usually one grate boiler might be considered if the CHP plant is operated at full load or from minimum 60% load and up. Moving grate boilers are available from different suppliers and capable to combust fuels with high ash content and with high moisture content, i.e., certainly up to 50% moisture content on wet basis. Depending on the plant size and the fuel characertistics, stoker feeding or feeding with a hydraulic piston is usually applied.

Under feed stoker boilers are common in the size range up to 2 MW and suited for limited ash content. Hence for the present application, under feed stokers are not recommended.

In the report by Van Zelm, biomass gasification is chosen, since gasification is assessed as being the most flexible technology. However, due to limited size of gasifiers available on the market, two boilers are needed to drive one turbine. In addition, the gasifier capacity is described for a moisture content of 12%. It is unclear, if this is given as an example, although wet fuel can be used in the gasifier, since dry fuel is not relevant for the Eco-Grid project, where fuel with a moisture content of 50% is supplied to the plant. In case that the gasifier is designed for dry fuel only, an additional fuel drying would be necessary thus increasing investment and operation cost, however not needed, if the gasifier is suited to safely combust fuel with up to 50%.

Besides, the application of fixed bed gasification is assessed as being promising with respect to low emissions in the raw gas (particulate matter, NOx, and unburnt pollutants), high combustion efficiency (operation at low oxygen content). Nevertheless, low emissions in the clean gas can also be achieved by grate boilers with respective flue gas cleaning (if efficient particle removal is applied, low PM in the clean gas is not necessary). In addition, it needs to be considered that long-term operation experience with fixed bed gasificaiton is scarce. Due to missing details on the chosen technology, a detailed evaluation is needed prior to the final decision of the combustion technology including potential need for additional fuel pretreatment.

2.4. Energy balance

The heat demand and the heat production data are partly inconsistent and it remains unclear, whether the plant is operated bivalent or monovalent and in case of a bivalent operation, how the bivalent heat production is provided.[1] Consequently, the concept proposal is assumed as monovalent plant design for the present evaluation.

[1] The Van Zelm Report states in the executive summary, that in Phase I the Biomass CHP plant is designed for an output of about 2 MW_e and 11.7 MW_{th} (40 MMBtu/hr). Appendix E (Report VZE) shows an estimated heating load duration curve with a peak load of the mentioned maximum peak load of 11.7 MW_{th} (40 MMBtu/hr). This diagram is in contradiction to the data given in the text, because it suggests, that only 50% of the peak load is provided by the biomass CHP plant (instead of 100% as described by the data given in the text) and that Gas/Oil Backup/Peaking boilers would provide the additional 50% or, in case of the biomass plant not operating, would provide a 100% backup of the peak load. Hence the real design proposed by Van Zelm remains unclear. We usually recommend a design value for the biomass CHP plant of approx. 50% of the total load. However, the biomass CHP plant seems to be designed for the maximum peak load, which we do not recommend due to economic and ecologigal reasons.

With this assumption, an estimation of the energy balance for the base case indicated as case 1 is given in the Appendix A, where an operation at full load during 7450 h/yr is assumed as being indicated by Van Zelm.

As an alternative, the energy balance for 4000 h/yr is displayed as case 2 in Appendix A.

In addition, case 3 shows the energy balance for an average heat demand as assumed by Van Zelm (which is assessed as being too optimistic based on the current heat demand curve).

The estimation of energy balance and economic assessment show the following trends:

Case 1 The base case operation at 7450 h/yr at full load achieves an estimated electric efficiency of approx. 12.1% based on the lower heating value (LHV) of the fuel input and an additional heat utilisation efficiency of approx. 25.5% resulting in a total efficiency of 37.6% if an average heat utilisation of 4.2 MW is assumed as estimated by Verenum from the available heat demand curve provided by Van Zelm. This operation is assumed as base case.

Case 2 In case of an operation during 4000 h/yr. at full load, the average heat utilisation is increased to approx. 6.0 MW (acc. to the heat demand curve). Consequently, the electric efficiency is slightly reduced to 10.9%, while the heat efficiency and the total efficiency considerably increase to 36.4% and 47.3% respectively.

Case 3 In case of 7450 h/yr. but with an average heat utilisation of 6.8 MW as assumed by Van Zelm, an electric efficiency of nearly 12.2% (in reality slightly reduced compared to case 1 which is not considered here) and a heat efficiency of 41.2% resulting in 53.5% total is achieved. This is assessed to be too optimistic based on the given heat demand curve, however, it might be achieved if considerable heat utilisation for thermal chillers during summer could be established.

Case 4 By application of part-load operation during phases with reduced heat demand, the electric efficiency might additionally be reduced, since part-load efficiency of small-scale turbines are typically as low as 60% of the full-load efficiency. However, the heat and total efficiency can be significantly increased. Case 4 is not further described by specific calculations in the appendix.

For the evaluation of the efficiencies, the current requirements for renewable electricity produced by biomass CHP plants in Switzerland are shown in Figure 1. The efficiency of heat and power has to exceed the red line indicated by the limits of a heat efficiency of 70% (in case of heat only) and an electric efficiency of 40% (in case of electricity only). These requirements can be fulfilled by energy efficient plants in case of heat driven operation.

As can be seen, the base case operation (case 1) of the CHP plant in the reference case is far below the requirements in Switzerland.

A significant improvement with respect to efficiency is possible by an operation during 4000 h/yr instead of 7450 h/yr, however still significantly below the minimum requirement in Switzerland (case 2).

In case of increased heat utilisation as assumed in the economic calculations by Van Zelm (case 3), which, however, is not in line with the heat demand displayed in the heat demand curve, the resulting efficiency approaches but still does not achieve the minimum requirements. Consequently, the higher feed-in-tariffs for renewable electricity were not applicable for a respective plant in Switzerland.

For case 4, a slightly reduced electric efficiency at significantly increased heat efficiency can potentially be achieved hence expecting to further approach the indicated target line.

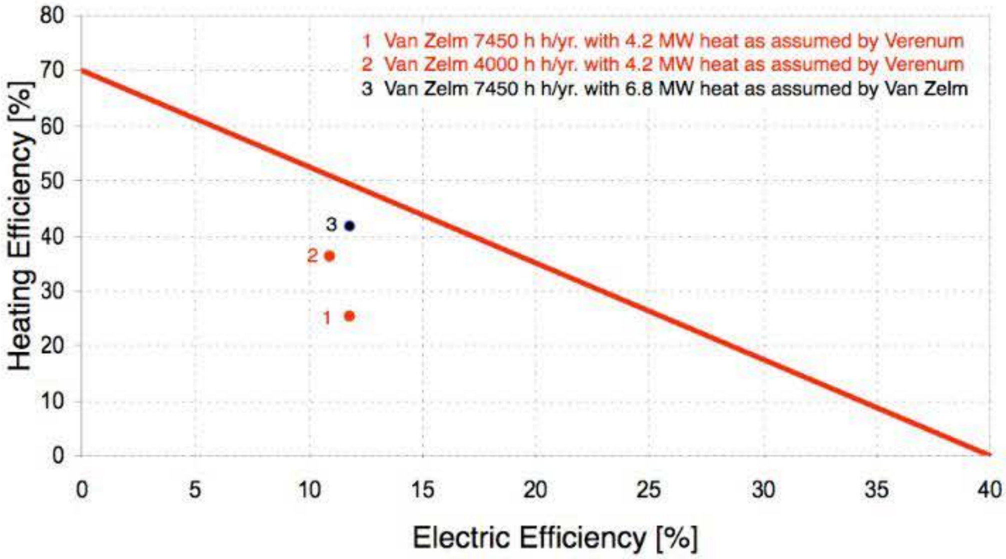

Figure 1 Heating efficiency as function of electric efficiency for CHP plant operation. The red line corresponds to the minimum requirements for feed-in-tarif for renewable electricity in Switzerland 2010 for values indicated as annual mean values.

2.5. Economic assessment

Based on the estimated energy balance, a simplified economic assessment reveals the data shown in Appendix B with the following parameters being varied to show the influence on the final result:

- Annuity for p = 5% per year for a calculation period of 15 years and 30 years.
- Electricity revenue of 65 USD/MWh (sold to the grid) and 125 USD/MWh (sold to HCF).
- Fuel price of **30 USD/t** and **60 USD/t**.
  According to Van Zelm, the fuel moisture content is assumed to be 50%, ranging from 45% to 55%. This value is assessed to be reasonable for the combustion design, hence to enable safe combustion even in case of wet fuel. With respect to typical forestry wood fuel, average moisture content between 40% to 55% are often found in practice and hence a calculation with 50% is on the safe side (i.e., pessimistic with respect to economy).
  The lower heating value (LHV) is expected as follows:

  Moisture content 50% (design value): LHV = 7.9 MJ/kg = **2.19 MWh/t**
  Moisture content 40% (most optimistic value): LHV = 10 MJ/kg = 2.77 MWh/t

  These values are valid in case of low ash content (< 2%), while at higher ash content, the weight

of the ash needs to be additionally considered in the calculation. The comparison between 40% and 50% moisture shows, that the fuel cost are reduced by more than 25% in case of 40% moisture at the same price per ton. This comparison does not yet take into account additional savings in case of reduced moisture content. However, due to the significant influence of the moisture content on the economy, fuel contracts should not be based on ton wet fuel without taking into account the moisture content. Hence the accounting for the fuel needs to be performed either by considering the fuel moisture and the ash content at fuel delivery or by accounting the heat production in the boiler and monitoring the boiler efficiency, thus enabling the fuel accounting by the delivered energy content. This alternative can only be applied in case of one single fuel supplier and is commonly applied in such cases in Switzerland.
For economic calculations, the fuel price based on LHV is assumed for the moisture content of 50%, referring to **13.7 USD/MWh** (30 USD/t) and **27.4 USD/MWh** (60 USD/t).

The fuel cost are calculated by the fuel input and directly influenced by the efficiency of the plant in case of a given energy output.

The investment cost are assumed to be 18 Mio USD in total as given from Van Zelm, of which 10 Mio USD are for the CHP plant and 8 Mio USD for the district heating system. Consequently, the specific investment cost for approx. 2'000 kWe are 5'000 USD/kWe for the CHP plant. The real cost not only depend on the technology and suppliers, but also on the specific situation and boundary conditions (e.g. cost of building and storage). However, the assumed investment cost are in a reasonable order of magnitude. For own calculations, approx. USD 6'500 per kWe are assumed for 2 MWe based on offers and experiences a few years ago in Switzerland. Target values for fundings of biomass CHP plants are usually significantly lower (< 4000 USD/kWe), while cost statements from finalized plants including all cost elements such as building, land, and planning, are in some cases even twice the amount as estimated by Van Zelm (however, high cost are often typical in case of plants being erected with high subsidies).

In the economic assessment, the total investment cost are considered including the district heating system. On the other hand, the full heat revenues are considered based on 51 USD/MWh. The selling price for district heat is low compared to typical applications in Switzerland, if no investment cost are covered by the consumer, since household heating devices are omitted with respective cost savings. However, the price for end consumers for district heat is usually correlated to the local price for natural gas and light fuel oil available for decentralized heating and hence the local situation needs to be evaluated.

In case of fundings of 2 Mio USD as expected in the project description, the capital cost for the project owner are reduced by 11% thus improving the internal cost calculations by 190'000 USD/yr for 15 years calculation and by 130'000 USD/yr for 30 years calculation period, which is not taken into account in the table given in the Appendix of the present report.

In addition to capital cost, relevant operation cost are expected for the biomass CHP plant, which may not be fully considered by the calculation proposed by Van Zelm or by Eco-Grid due to the situation, that operation staff is already available on the site. However, to enable a true economic evaluation, the full operation cost need to be taken into account, which depend on labour cost and number of employees needed to operate the plant. With increasing level of automatisation, operation cost can be reduced, however investment cost are increased. ! the higher the steam pressure, the higher the security-level needed and thus the higher the investment/operation costs' In Europe, it is important to decide, whether an unsupervised operation shall be enabled by the respective level of automatisation, thus avoiding fixed cost for 24 h supervision which demands for at least 7 licensed operators. In the economic assessment given in the Appendix, operation cost are estimated on a medium level.

The economic assessment shows the following trends:

1. The base case operation at 7450 h/yr. with an average heat utilisation of 4.2 MW (case 1) results in a net revenue of 53'000 USD/yr (hence close to zero when considering the high uncertainties) in case of fuel at 30 USD/t, an electricity revenue of 125 USD/MWh and a calculation period of 30 years. However, a calculation period of more than 15 years is unusual for industrial CHP applications and hence not assessed as a realistic assumption and the high electricity revenue will presumably not be achieved for all electricity.
   For a 15 years calculation period, the base case results in a loss of 500'000 USD/yr. In case of lower electricity revenues, the loss increases to 1.4 Mio USD/yr. An even more relevant influence is found, if the fuel price increases to 60 USD/t. If all pessimistic assumptions are combined, a loss of approx. 3 Mio USD/yr is expected.
2. With an operation of 7450 h/yr, the capital cost contribute from 23% to 44% of the total cost. At an operation of less 4000 h/yr (?case 2?), the relative contribution of the capital cost increases to 35% to 58%. Consequently, the economic and the energetic assessments are not congruent. While a reduction of the full load hours results in an improved energetic yield as described in figure 1, the economic performance is not improved accordingly or even worsened in case of high electricity revenues. Consequently, even by combining all optimistic assumptions, the operation at 4000 h/yr results in a loss.
3. In case of 7450 h/yr but with a heat utilisation of 6.8 MW as assumed by Van Zelm (case 3), additional revenues from heat of approx. 1.0 Mio USD per year (without additional cost) significantly improve the economic assessment. While at 30 years calculation period, a profit of approx. 1 Mio USD/yr results, even at 15 years calculation period, a profit of 0.5 Mio USD/yr is expected.

2.6. Potential of improvement of energy and economy

There are several options to improve the energetic and economic achievements of the plant. Each single measure exhibits a certain potential of improvement. However, in case of combining two or more measures, the added value of two measures does not correspond to the added of both measures if applied individually, hence the most economic solution is not found if all measures are applied. In addition, some of the individual measures do exclude some other measures, hence not all combinations are possible or technically feasible. However, there are basically two different strategies to improve the economy.

Strategy 1

The CHP plant can be downsized e.g. to meet 50% of the peak load to improve the total energetic yield by significantly improving the heat efficiency. At the given electric efficiency, heat driven operation needs to be aimed at. Consequently, measures to improve the electric efficiency are of second priority for this strategy. By downsizing the CHP plant, a bivalent operation is needed and therefore a second boiler to cover the heat demand for the district heating system and the HCF. A hot water boiler would be sufficient to supply the district heating system, while for HCF, currently a low-pressure steam boiler would be needed, which, however, has to be available in the existing energy supply of HCF.

Strategy 2

The electric efficiency of the plant could be improved. By application of the same plant size, the power-to-heat-ratio could be increased and consequently the total energetic yield and the revenues from electricity at identical fuel demand.

Depending on the chosen strategy, one or several of the following measures can be evaluated:

- The efficiencies (electric and heat) can be increased by reducing the temperature level of the heat extraction:
  In case of HCF, switching to hot water instead of steam enables a significant increase in efficiency. Except if there is a specific need e.g. for an industrial process heat, a retrofit of the heat distribution system at HCF is recommended as it enables significant improvements of the plant efficiency.
  For the district heating system, a temperature level of 70°–95°C to 54°–78°C is proposed by Van Zelm. We recommend
  a) to reduce the feed temperature to 70°–85°C, and
  b) to increase the temperature difference between feed and return to at least 30°C thus resulting in return temperatures of 40°–55°C.
- The air cooler is designed for heat extraction in the condenser at 70°C (approx. 0.3 bar). By increasing the surface of the air cooler (thus increasing investment cost) or by switchting to a more efficient but more costly cooling tower instead of air coolers, significantly lower temperatures can be achieved, thus enabling higher electric efficiency. In case of regularly planned operation in condensing mode (hence not for emergencies only), a significantly lower condensation temperature should be aimed at (i.e. preferably less than 0.1 bar/45°C) thus resulting in higher electricity yield.
- For the present design of the air cooler at 70°C (which, however, is recommended to be reduced) and reduced return temperature of the district heating system to 40°–55°C, the return water can be preheated by heat extraction from the low pressure steam leaving the turbine before entering the surface condensator. With this measure, waste heat can be used thus reducing the fuel consumption at identical heat utilisation. After re-design of the plant, this heat output can additionally be considered to reduce the boiler size.
- The steam cycle is based on relatively moderate data for the live steam of 41 bar/400°C. The choice of higher steam data (i.e. preferably > 60 bar/450°C) enables a significant increase in efficiency, however related to higher investment cost and choice. This measure is only reasonable for strategy 2.
- The turbine technology is not described in detail (supplier, number of stages, internal efficiency) and hence a detailed assessment is not possible. However, due to the estimation of the energy balance, it is assumed that the chosen turbine exhibits a relatively moderate efficiency of e.g. 65%. It is assumed that more efficient turbines at higher cost are available, thus enabling significantly increased electricity production (up to + 20% of the current electricity production) for the given steam flow. However, a final assessment is possible based on detailed design data only.
- By application of all available measures, the electric efficiency might be increased by up to 50% of the present value.

2.7. Assessment of hydraulic integration and heat distribution

2.7.1. Heat storage

In biomass heating plants operated for hot water only, we recommend to install a technical heat storage capacity of 1 hour of boiler operation at nominal heat load. This takes into account, that a biomass boiler cannot modulate the thermal load as quickly as a gas or oil fired boiler and hence increases operation flexibility. Furthermore, it enables a dimensioning of the boiler which does not need to take into account short peaks. Hence for district heating systems, the dimensioning is commonly performed according to the daily mean value instead ot the maximum peak value. This results in significantly smaller boiler design with reduced cost for the boiler but additional cost for the heat storage. In addition, it enables a smooth, continuous operation of the boiler, which prevents fast load changes and potential increase in air emissions due to this.

In the present situation, two gasifier steam boilers are used to drive one steam turbine. Since steam cannot be stored, load changes in the heat demand need to be compensated by the waste heat extracted by the air cooler, if the steam boilers are permanently operated at a load which is sufficiently high to cover potential peaks in heat demand. This type of operation may result in relatively high waste heat production and thus low total efficiency. To avoid high waste heat production, the CHP plant could be operated at part load. In this case, a heat storage tank for hot water (with a capacity of 1 h of nominal load) in the heat distribution system might be considered as an option. Here, the choice of packaged gasifier boilers might enable faster load changes than typcial grate boilers, hence the need for heat storage might be less important than with grate boilers. However, due to missing experience of the long-term operation of gasifiers, the option of heat storage should be evaluated based on the final specifications of the combustion principle.

2.7.2. Economiser and flue gas condensation

As described above, the return temperature of the district heating system should be reduced. The boiler should be equipped with an economiser section, that might be used for air preheating and/or preheating of the return water. This is a common measure to increase efficiency and foreseen according to the text of Van Zelm. In addition, flue gas condensation might be evaluated as an option, since fuel with high moisture content is planned as main fuel. Flue gas condensation is specifically attractive in case of low return temperature (e.g. 40°C) and can be applied in different ways (as economiser for air preheating and/or return water preheating). In case of flue gas condensation, wet electrostatic precipitation might be considered as an option.

2.7.3. Other design options

- As desribed above, the energy yield and the economy can be significantly improved if the saisonal heat demand of the district heating can be flattened and the annual demand increased by supplying absorption coolers. The biomass CHP plant could then be designed as proposed by Van Zelm and achieve far better economy as shown above.
- HCF is an important heat consumer. As HCF has its own steam generation plant, it seems to cover about 50% of the maximum peak load according to the available heat demand curve. This plant might be running as a bivalent energy supply during the about 90 days per year, when the heating load demand is greater than 6 MW (20 MMBtu/hr). The biomass CHP plant could then be designed to 50% of what is proposed in the VanZelm Engineers Report, i.e about 6 MW (20 MMBtu/hr).

- As an alternative, an independent operation of HCF steam production might be considered, thus enabling an independent biomass heating plant only for the district heating system or a biomass CHP plant designed to supply the district heating. For this concept, ORC can be an option, since hot water can easily be produced by an ORC plant, while ORC technology is not promising, if steam production for HCF is mandatory.

2.7.4. Assessment of heat distribution

Heat Distribution Density

Assuming that the Hudson Correctional Facility HCF would consume about 40% of the total annual heat demand (31'540 MWh/a / 107.700 MMBtu/yr), the consumers connected to the district heating would consume 18'920 MWh/yr / 64.620 MMBtu/yr). With a total linear length of 4.8 km / 15.000 linear feet, the specific annual heat consumption per meter of district heating length (fausse) is about 4.1 (MWh/yr)/m.

This specific value is an important performance parameter to assess a district heating distribution system. We usually recommend a specific annual heat consumption per district heating length or *heat distribution density* of at least 1.8 (MWh/yr)/m for all-the-year operated district heating distribution systems. If the customers really connect to the district heating, the performance of the district heating distribution system would be very high.

Thermal Distribution Loss

A second performance parameter of a district heating distribution system is the annual thermal loss in percentage of the annual thermal heat consumption of the consumers connected to the district heating, which should not exceed 10%. The thermal losses are influenced by the water temperature, the temperature and physical characteristics of the surrounding atmosphere (usuall ground, here air), the flow velocity, and the type of insulation. We miss indications about thermal losses of the district heating distribution system. District heating systems in western Europe are usually in the ground, hence there is few experience with piping above ground. Below ground, the annual mean temperature of the surrounding ground here is about 8°C (46°F). In winter, the air temperature may be far below zero, which also results in a danger of freezing if the water flow should be interrupted due to any technical problems. Hence the target value of 10% might be exceeded here, which, however, should be checked separately.

2.8. Environmental assessment of air emissions

The concept proposes a flue gas cleaning with one electrostatic precipitator (ESP) to reduce particle emissions and one selective catalytic reduction (SCR) to reduce NOx for both boilers. There are no indications about emission limit values to be met or target values to be achieved in the clean gas. However, for NOx, a reduction efficiency of more than 76% is postulated. Based on this information, only a generic assessment of the emissions is possible. However, the following estimations can be made for the regional air emissions:

- Since biomass combustion is related to significant emissions of particles and NOx in the raw gas, which cannnot be sufficiently reduced by primary measures, secondary measures for particles and NOx are reasonable and can be efficiently applied. Due to cost reasons, it is reasonable and technically feasible to combine the flue gas flows from both boilers to be treated in one single flue gas cleaning section. The emission of carbon monoxide (CO) - which is usually not relevant for the ambient air quality but acting as an indicator for other products of incomplete combustion (PIC), and volatile organic compounds (VOC) can be reduced by primary measures, i.e., near-complete combustion, in boilers of the considered size. In addition, CHP operation with long operation periods is advantageous compared to heat production only, as frequent peaks of PIC during start-up, shut-down and operation at low load are avoided.
- Due to missing emission levels to be guaranteed, it needs to be considered, that ESP can be designed for moderate separation efficiency (e.g. single-stage ESP) or high separation efficiency (multi-stage ESP with increased size and cost). For simple ESP, clean gas emissions of typically e.g. 50 mg/m^3 at 11 Vol.-% O_2 (approx. 25 mg/MJ based on LHV) are usually guaranteed, while for improved ESP, emission limit values of 20 mg/m^3 at 11 Vol.-% O_2 (10 mg/MJ) or 10 mg/m^3 at 11 Vol.-% O_2 (5 mg/MJ) can be met. In case of even lower emission limit values (5 mg/m^3 at 11 Vol.-% O_2 (2.5 mg/MJ) as necessary in case of urban waste wood in Switzerland, the size of ESP further increases and hence fabric filters are often applied instead of ESP. However, fabric filters are more sensitive to clogging by condensation (hence not well suited in case of wet fuels) and to destruction by glowing particles, while ESP are more robust and hence usually preferred, if fabric filters are not needed.
- Due to the plant size of more than 10 MW fuel input, low particle concentrations in the clean gas are state-of-the-art and should be required as design and guarantee values, i.e., e.g. 10 mg/m^3 at 11 Vol.-% O_2 (5 mg/MJ). Due to necessary safety spreads in ESP design, real-life emissions are usually significantly below the guarantee values, hence even lower emissions are expected during regular operation. Despite of these low emission levels, the installation of a biomass CHP plant exhibits significantly higher PM emissions than modern boilers with natural gas or light fuel oil, which exhibit typical emission factors on PM of 0.1 and 0.2 mg/MJ respectively[2]. However, a comparison of PM emissions from modern natural gas and light fuel boilers is not really relevant, since these type of installations do not contribute significantly to PM in the ambient. Since traffic is an important source of PM10, the comparison with this source category is more relevant. Diesel powered heavy duty vehicles have an allowable PM emission during type test according to EURO-3 (2000/2001) of 0.1 g/kWh, which corresponds to 28 mg/MJ. EURO-5 (2008/2009) demands for 0.3 g/kWh, which corresponds to 8.3 mg/MJ[3]. However, an emission factor of 14 mg/MJ is esti-

[2] Swiss Federal Office for the Environment, Arbeitsblatt Emissionsfaktoren 2005, Bern 2005

[3] Swiss Federal Office for the Environment: Luftschadstoff-Emissionen des Strassenverkehrs 1980-2030, Bern 2004, Schriftenreihe Umwelt Nr. 355

mated for the relatively modern fleet of Diesel trucks in Switzerland for 2008[4]. Hence the CHP plant can achieve emission factors with respect to particle mass significantly below those of modern Diesel trucks. Furthermore, the PM emissions from the wood fired CHP plant can also be compared to a reference case, where without installation of district heating systems, a shift from fossil fuels in house heating to residential heating based on wood combustion might occur in the next decades due to declining fossil fuels and increasing fuel prices. In this case, PM emission factors of approx. 20 mg/MJ are technically possible, if modern log wood boilers and modern pellet boilers are installed and 100% of all installations are operated properly all times. On the other hand, emission factors of more than 100 mg/MJ are expected in case of simple and typically operated wood stoves. In case of inappropriate operation of manually operated wood boilers and stoves, the emission factors can exceed 500 mg/MJ, which as example is expected for outdoor wood boilers (OWB) without heat storage tank as common in rural areas in New York State. Hence the combustion of 1% of wood fuel in badly operated stoves and boilers may result in comparable particle mass as the whole CHP plant. Beside primary PM emissions, inappropriately operated wood stoves and boilers exhibit high emission levels of VOC which act as precursors for secondary organic aerosols (SOA). Here, a reduction of close to zero is achieved in large automatic wood boilers for CHP instead of residential combustion.

In addition, the assessment of PM emissions from the CHP plant compared to Diesel and residential wood combustion does not take into account the different chemical properties of the particle types from these three source categories. Diesel soot is well known as being carcinogenic, while PM from incomplete combustion of wood as found in simple stoves additionally contains carbonaceous compound in the form of tar, which exhibit even higher toxicity and carcinogenity than soot. Compared to this, properly operated automatic wood boilers exhibit mainly inorganic PM resulting from ash constituents, while tar and other carbonaceous compounds are in very low concentrations, i.e., typically less than 5% of the total PM.

- For NOx, clean gas emissions depend on raw gas concentration and reduction efficiency of SCR technology. The raw gas concentration depends on the nitrogen content in the fuel. For natural forestry wood, which is low in nitrogen, typical raw gas emissions from grate fired boilers are in the order of 150 to 300 mg/m^3 at 11 Vol.-% O_2 according to approx. 80 to 160 mg/MJ based on LHV. In case of fixed bed gasification, the raw gas concentration can be lower than from grate boilers. By SCR with 76% reduction as described (and which seems reasonable), clean gas emissions of 20 to 40 mg/MJ are expected. This emission level is in the same order of magnitude as from modern, light fuel oil boilers with low-NOx technology as applied in Switzerland combusting high quality light fuel oil with low nitrogen content, for which an emission factor of approx. 30 mg/MJ is expected[3]. In comparison to old oil boilers or in case of low quality light fuel oil, higher NOx emissions result from residential heating with oil. In comparison to wood combustion in decentralised plants, the NOx emissions are reduced by the CHP plant thanks to the secondary measures. In comparison to Diesel engines, the emission factor after SCR is more than one order of magnitude lower than from modern engines, since EURO-5 (2008/2009) demands for 2.0 g/kWh or 555 mg/MJ. Old heavy duty Diesel engines exhibit up to a factor 100 higher NOx emissions. Consequently, the NOx emissions from the CHP plant are marginal on a regional scale.

[4] Swiss Federal Office for the Environment: Switzerland's Informative Inventory Report 2010 (IIR), Submission under the UNECE Convention on Long-range Transboundary Air Pollution, Submission of March 2010 to the United Nations ECE Secretariat in the ambient, Bern 2010

- In case of utilisation of natural wood, air emissions of other toxic substances such as SO_2, heavy metals, HCl, HF, and PCDD/F are typically on a low level and usually no specific additional measures are needed in case of natural wood. Hence it is crucial to decide in advance, if the plant operation is strictly limited to natural wood or if other fuel categories such as e.g. urban waste wood and demolition wood shall be combusted. In case of urban waste wood and demolition wood, the above mentionned additional air emissions can be present in relevant concentrations and hence need to be considered in the flue gas cleaning, e.g. by meeting more stringent limit values on particulate matter (typically e.g. 2.5 mg/MJ instead of 5 or 10 mg/MJ fuel input for natural wood) and by additional application of sorptive treatment e.g. in a fabric filter additional to the ESP or instead of the ESP.

Since no detailed emission limit values are foreseen so far, we strongly recommend to define guarantee levels at least for the following parameters in the clean gas prior to start the final plant design:

- CO
- VOC
- NOX
- PM
- in case that other fuels than strictly natural wood is foreseen, stringent emission limit values on different other substances such as heavy metals and halogenated compounds need to be defined.

In addition, limit values for the efficiency should be defined, preferably for both, boiler and combustion efficiency, hence maximum values for O2 and flue gas temperature should be agreed upon as well, since these parameters beside efficiency also influence the flue gas volume and the design of ESP.

Furthermore, we recommend to define detailed phyisical and chemical properties of the fuel as basis for the contracts with the plant provider *and* the fuel provider. All guarantees for the plant need to be based on detailed fuel specifications, which shall cover reasonable ranges for the main parameters as e.g. moisture content, ash content, fuel size, chlorine content, nitrogen content, ash slagging temperature, and other parameters. Hence, emission limits need to be guaranteed within the whole range according to the fuel specifications, while efficiency limits need to be related to specific fuel characteristics, e.g. a minimum efficiency for fuel at the lowest and highest allowable moisture content.

In summary, we expect that the main impact of the CHP plant on local and regional air emissions is related to PM, which, however, can be safely limited to a low level by defining strict requirements on emission limit values and control mechanisms to ensure that they are safely met in practical operation. This can be based on a monitoring scheme, which does not necessarily need a continuous PM analysis, but which can alternatively be based on a set of parameters enabling the assessment of the operation of the flue gas cleaning section. The impact on NOx and PIC is of second priority and expected to be not relevant compared to other sources. The potential of air emissions from contaminations such as heavy metals and halogenated compounds needs to be restricted by strict quality requirements of the fuel and limitation to natural wood or – in case of potential use of other fuel categories – can be limited by additional measures in the flue gas cleaning and the plant operation and monitoring.

Table 1 shows an estimation of the total annual air emissions in case of 7450 full load hours per year corresponding to case 1 shown in Appendix 1.

Table 1: Estimation of the total annual air emissions in case of 7450 full load hours per year, resulting in a total annual fuel input of 443 TJ/yr (Case 1).

Air emissions	Emission factor		Annual emissions	
	mg/MJ = kg/TJ		kg/yr	
	Min	Max	Min	Max
PM	< 2.5	< 10	< 1'106	< 4'425
NOx	< 20	< 40	< 8'851	< 17'701
CO	< 20	< 200	< 8'851	< 88'506
VOC	< 1	< 10	< 443	< 4'425

With respect to the resulting environmental assessment, it is important to notice, that the energetic yield of the plant is strongly influencing the resulting environmental impact. This is not expressed in emission factors indicated in mg per MJ end energy based on LHV, however, this can be calculated by dividing the emission factors based on fuel input by the efficiency. Hence the target to increase the electric and the total efficiency is crucial for both, economic and ecological reasons. To enable a final assessment in comparison to alternative supply chains e.g. based on fossil fuels by residential oil heating instead of district heat or a CHP plant based on fossil fuel, the resulting air emissions based on useful energy need to be compared. This is important, since the total efficiency is now estimated to be 38% only in the base case thus indicating, that with typical applications of fossil fuels as e.g. a natural gas driven CHP plant, considerably higher efficiencies are commonly achieved. Hence, a final assessment of the air emissions can be performed, if specific reference scenarios are defined.

3. Other concepts

3.1. Concept of Envio Energi: Backpressure plant

Envio Energi has offered a "budget price estimate" for a turnkey biomass CHP plant. The concept constists of a reciprocating grate boiler which is equipped with a baghouse filter for particle removal and SNCR for NOx abatement. The boiler is followed by a backpressure steam turbine and – as indicated in footnote 5 – a cooling tower if required.

The budget estimate of roughly 11 Mio USD is 10% higher than from Van Zelm, who calculate 10 Mio USD for the CHP plant without district heating system. However, the cost of a backpressure system should be significantly lower due to lower cost of the turbine and due to savings for the air cooler. However, the effect of the air cooler remains unclear, since a cooling tower is mentionned as an option in footnote 5.

The proposed combustion type is standard technology for wood fuels and a reasonable proposal for the present application.

With respect to air emissions, lower PM emissions in the clean gas can potentially be achieved by baghouse filters instead of ESP. However, baghouse filters are critical in practical operation in case of wet wood (and thus high humidity in the flue gas) and in case of discontinuous operation. Since a backpressure turbine is proposed here, there is an increased risk of discontinuous operation. Hence the proposal of baghouse filter needs to be evaluated in detail for the final decision, once the fuel characteristics, the boiler type, and the emission limit values are defined. In case of operation with urban waste wood and demolition wood, baghouse filter should be foreseen with sorptive treatment.

Backpressure turbines are well suited in case of uninterrupted, continuous heat demand, which enable a fully heat-driven operation. This type of operation results in relatively low electric efficiency but at high total efficiency. Thanks to lower investment cost and thanks to high total efficiency, backpressure turbines are advantageous, if these conditions are safely met. In the present situation, it is questionnable, if these conditions are fulfilled, since this is usually not the case for district heating. Hence, the utilisation of a cooling tower is mentionned as an option in the report of Envio Energi, which indicates, that proper operation of the backpressure system without cooling tower might be critical.

With respect to the economic estimation, we believe that the calculation of Envio Energi are too optimistic due to several assumptions. First of all, the production hours are assumed to be 8264 h/yr. This is a high value in case of an electricity-driven operation. However, in case of a heat-driven operation as typical for a backpressure turbine without cooling tower, this figure is far too high and had to be corrected for a realistic economic assessment based on the real heat demand curve, as done above for the Van Zelm concept. Secondly, the data on energy input and energy output refer to an electric efficiency which seems too optimistic for the given situation and consequently the figures on fuel consumption for the assumed energy production are too low. Consequently, economic estimations based on these assumptions might be significantly underestimating the cost and overestimating the revenues.

For a final assessment, detailed design data and offers for both concepts should be compared, however, the concept with an extraction turbine is regarded as advantageous for the present application due to its operational flexibility at variing heat demand.

3.2. Concept by Vision Power: Organic Rankine Cycle (ORC)

Vision Power describes two plant sizes for ORC plants, i.e.,

600 kWe and 2.35 MWth for 3.25 Mio USD and

2.2 MWe and 9.4 MWth for 5.95 Mio USD.

Compared to the offers with steam plants, the price of the comparable plant size is significantly, i.e., more than 40%, lower. However, important parts (flue gas cleaning and others) are missing in the price quotes, which, in case of Van Zelm are presumably included. Hence a final economic assessment is not possible, since all cost need to be considered for all concepts.

At the same time, the expected electric efficiency for the ORC plant is higher than the one estimated for the steam plant by Verenum (here, approx. 14.8% net efficiency are given by Vision Power).

Consequently, the ORC technology is economically promising in case that the heat demand can be covered by hot water. However, it is not possible to supply the current demand of HCF with steam, hence ORC is only feasible if HCF is initially being retrofitted to hot water instead of steam, or if the ORC plant is designed independently from HCF, which then might result in a smaller size plant than in the case including HCF.

In addition, the expected efficiencies from the ORC plant as described by Vision Power seem very challenging or too optimistic. Hence a detailed offer would be needed for a final evaluation enabling an assessment of the real net efficiency at practical operation.

With respect to air emissions, conventional grate combustion is foreseen, while no information is given on flue gas cleaning. However, secondary measures as particle removal and NOx abatement can be applied similarly as in the concepts described by Van Zelm and Envio Energi. Hence, there are no significant differences expected with respect to air emissions.

In comparison to steam plants, ORC plants exhibit an additional potential risk due to the need of an organic fluid in the primary cycle, which is either inflammable or which may contribute to the greenhouse effect or to ozone depletion in case of accidents. In case of proper operation, this aspect is of minor importance, however, long-term experiences on ORC mainly result from geothermal applications at lower temperatures, while experiences with biomass applications are scarce so far.

4. Appendix A - Energy balance

Case 1 - Energy balance 7450 h/yr

Case 1	Heat and Power in MW						Efficiency based on Fuel Input					
Annual Values for Full Load Operation	Q^*_{Fuel}	Q^*_{Steam}	P	Q^*_{useful}	$P+Q^*_{useful}$	Q^*_{waste}	Q^*_{Fuel}	Q^*_{Steam}	P	Q^*_{useful}	$P+Q^*_{useful}$	Q^*_{waste}
	MW	MW	MW	MW	MW	MW	%	%	%	%	%	%
Fuel Input	16.5						100%					
Steam Output		14.0						84.8%				
Boiler Losses						2.5						15.2%
Power Output			2.0		2.0				12.1%		12.1%	
Thermal Output after Turbine		12.0						72.7%				
Useful Heat Output to District Heat				4.2	4.2					25.5%	25.5%	
Thermal Output to Air Cooler						7.8						47.3%
Total	16.5	[redacted]	2.0	4.2	[redacted]	10.3	100%	[redacted]	12.1%	25.5%	[redacted]	62.4%
Total Power and Useful Heat					6.2						37.6%	

Total MWh/yr	122'925	[redacted]	14'900	31'290

Total MJ/yr 442'530'000

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Case 2 - Energy balance 4000 h/yr

Case 2	Heat and Power in MW						Efficiency based on Fuel Input					
Annual Values for mainly Thermal	Q^*_{Fuel}	Q^*_{Steam}	P	Q^*_{useful}	$P+Q^*_{useful}$	Q^*_{waste}	Q^*_{Fuel}	Q^*_{Steam}	P	Q^*_{useful}	$P+Q^*_{useful}$	Q^*_{waste}
Following Operation	MW	MW	MW	MW	MW	MW	%	%	%	%	%	%
Fuel Input	16.5						100%					
Steam Output		14.0						84.8%				
Boiler Losses						2.5						15.2%
Power Output			1.8		1.8				10.9%		10.9%	
Thermal Output after Turbine		12.2						73.9%				
Useful Heat Output to District Heat				6.0	6.0					36.4%	36.4%	
Thermal Output to Air Cooler						6.2						37.6%
Total	16.5		1.8	6.0		8.7	100%		10.9%	36.4%		52.7%
Total Power and Useful Heat					7.8						47.3%	

Total MWh/yr	66'000		7'200	24'000

Case 3 - Energy balance 7450 h/yr and heat demand as assumed by Van Zelm

Case 3	Heat and Power in MW						Efficiency based on Fuel Input					
Annual Values for Full Load Operation	Q^*_{Fuel}	Q^*_{Steam}	P	Q^*_{useful}	$P+Q^*_{useful}$	Q^*_{waste}	Q^*_{Fuel}	Q^*_{Steam}	P	Q^*_{useful}	$P+Q^*_{useful}$	Q^*_{waste}
	MW	MW	MW	MW	MW	MW	%	%	%	%	%	%
Fuel Input	16.5						100%					
Steam Output		14.0						84.8%				
Boiler Losses						2.5						15.2%
Power Output			2.0		2.0				12.1%		12.1%	
Thermal Output after Turbine		12.0						72.7%				
Useful Heat Output to District Heat				6.8	6.8					41.2%	41.2%	
Thermal Output to Air Cooler						5.2						31.5%
Total	16.5	[redacted]	2.0	6.8	[redacted]	7.7	100%	[redacted]	12.1%	41.2%	[redacted]	46.7%
Total Power and Useful Heat					8.8						53.3%	

Total MWh/yr	122'925	[redacted]	14'900	50'660

5. Appendix B - Economic assessment

Case 1 - Economy 7450 h/yr

Fuel Expenses			USD/t	30	60	30	60
			USD/MWh	13.7	27.4	13.7	27.4
Annuity for p = 5% p.yr.	–		–	0.0963 (15 yr.)		0.0656 (30 yr.)	
Investment			USD	18'000'000	18'000'000	18'000'000	18'000'000
Capital Expenses			USD/yr.	1'733'400	1'733'400	1'180'800	1'180'800
Operation Expenses	3%		USD/yr.	540'000	540'000	540'000	540'000
Fuel Expenses			USD/yr.	1'684'073	3'368'145	1'684'073	3'368'145
Total Expenses			USD/yr.	3'957'473	5'641'545	3'404'873	5'088'945
Electricity Revenue	65	USD/MWh	USD/yr.	968'500	968'500	968'500	968'500
Electricity Revenue	125	USD/MWh	USD/yr.	1'862'500	1'862'500	1'862'500	1'862'500
Heat Revenue	51	USD/MWh	USD/yr.	1'595'790	1'595'790	1'595'790	1'595'790
Total Revenue at	65	USD/MWh	USD/yr.	2'564'290	2'564'290	2'564'290	2'564'290
Total Revenue at	125	USD/MWh	USD/yr.	3'458'290	3'458'290	3'458'290	3'458'290
Net annual Revenue at	65	USD/MWh	USD/yr.	-1'393'183	-3'077'255	-840'583	-2'524'655
Net annual Revenue at	125	USD/MWh	USD/yr.	-499'183	-2'183'255	**53'418**	-1'630'655

Case 2 - Economy 4000 h/yr

Fuel Expenses			USD/t	30	60	30	60
			USD/MWh	13.7	27.4	13.7	27.4
Annuity for p = 5% p.yr.	–		–	0.0963 (15 yr.)		0.0656 (30 yr.)	
Investment			USD	18'000'000	18'000'000	18'000'000	18'000'000
Capital Expenses			USD/yr.	1'733'400	1'733'400	1'180'800	1'180'800
Operation Expenses	2%		USD/yr.	360'000	360'000	360'000	360'000
Fuel Expenses			USD/yr.	904'200	1'808'400	904'200	1'808'400
Total Expenses			USD/yr.	2'997'600	3'901'800	2'445'000	3'349'200
Electricity Revenue	65	USD/MWh	USD/yr.	468'000	468'000	468'000	468'000
Electricity Revenue	125	USD/MWh	USD/yr.	900'000	900'000	900'000	900'000
Heat Revenue	51	USD/MWh	USD/yr.	1'224'000	1'224'000	1'224'000	1'224'000
Total Revenue at	65	USD/MWh	USD/yr.	1'692'000	1'692'000	1'692'000	1'692'000
Total Revenue at	125	USD/MWh	USD/yr.	2'124'000	2'124'000	2'124'000	2'124'000
Net annual Revenue at	65	USD/MWh	USD/yr.	-1'305'600	-2'209'800	-753'000	-1'657'200
Net annual Revenue at	125	USD/MWh	USD/yr.	-873'600	-1'777'800	**-321'000**	-1'225'200

Case 3 - Economy 7450 h/yr and heat demand as assumed by Van Zelm

Fuel Expenses			USD/t	30	60	30	60
			USD/MWh	13.7	27.4	13.7	27.4
Annuity for p = 5% p.yr.	–		–	0.0963 (15 yr.)		0.0656 (30 yr.)	
Investment			USD	18'000'000	18'000'000	18'000'000	18'000'000
Capital Expenses			USD/yr.	1'733'400	1'733'400	1'180'800	1'180'800
Operation Expenses	3%		USD/yr.	540'000	540'000	540'000	540'000
Fuel Expenses			USD/yr.	1'684'073	3'368'145	1'684'073	3'368'145
Total Expenses			USD/yr.	3'957'473	5'641'545	3'404'873	5'088'945
Electricity Revenue	65	USD/MWh	USD/yr.	968'500	968'500	968'500	968'500
Electricity Revenue	125	USD/MWh	USD/yr.	1'862'500	1'862'500	1'862'500	1'862'500
Heat Revenue	51	USD/MWh	USD/yr.	2'583'660	2'583'660	2'583'660	2'583'660
Total Revenue at	65	USD/MWh	USD/yr.	3'552'160	3'552'160	3'552'160	3'552'160
Total Revenue at	125	USD/MWh	USD/yr.	4'446'160	4'446'160	4'446'160	4'446'160
Net annual Revenue at	65	USD/MWh	USD/yr.	-405'313	-2'089'385	147'288	-1'536'785
Net annual Revenue at	125	USD/MWh	USD/yr.	488'688	-1'195'385	**1'041'288**	-642'785

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PERMITTING

This section contains:

- Summary of the three scenarios presented by Eco-Grid to NYSDEC. Eco-Grid requested a response from NYSDEC on permitting for emissions for these three scenerios.
- Responses from NYSDEC

After reviewing by conference call, Eco-Grid presented the following three scenarios by e-mail to NYSDEC:

Scenario # 1 Heat-Only Option for Hudson Prison Site
A two-boiler system with a 16 MMBTu output new wood chip building that includes a boiler room and chip bin area. 2-boilers, with furnances, 8 MMBTu net output each boiler/ 16 MMBTu total net output, bin w/truck bridges, Bag house (also including single cyclone before bag house), 36*x75* free standing corten steel stack with stainless steel liner, breaching from boilers to stack, Traveling Carriage unloader and delivery system, with conveyor(s), metering bin, metering and stoker augers , control panel with program logic controller and modem, all wiring and piping between our control panel and our traveling carriage.

Scenario # 2 - 5W electric with 17 MW (heat) cogeneration.

Scenario # 3 10 MW electric with 17 MW (heat) cogeneration

In all 3 instances, we require threshold limits that we would need to stay under for these technologies for the most important pollutants (e.g. particulates and NOx) under NYS and Federal requirements.

The responses on the next two pages came by e-mail and conference call on January 22, 2009 from Michael Cronin, P.E., Environmental Engineer, NYSDEC Division of Air Resources, Bureau of Stationary Sources, Permiting and Compliance Section. 625 Broadway, 2nd Floor, Albany NY 12253, 518-402-8403.

RESPONSES FROM NYDEC

Scenario # 1

Two – 8 mmBtu/hr wood stoker boilers exhausting to one common stack. This is a steam-only system with a total output of 16 mmBtu/hr.

Controls: single cyclone and bag house. Cyclone precedes the bag house.

Assume wet wood

Assume 8,760 hrs/yr

Emissions:
Pollutant Emission Factors Maximum Potential to Emit
(for wet wood and controlled) (based on 8760 hr/yr)
PM 0.1 lb/mmBtu x 16 mmBtu/hr 1.6 lb/hr
NOx 0.22 lb/mmBtu 3.52 lb/hr
SO2 0.025 lb/mmBtu 0.4 lb/hr
CO 0.60 lb/mmBtu 9.6 lb/hr

*Note: Other emission sources, if any, at the facility must be accounted for when determining overall facility emissions, rule applicability, and level of permitting.

Applicable Regulations:
6 NYCRR Part 200, General Provisions
6 NYCRR Subpart 201-4

Permit depending on the need for emission limits
6 NYCRR Subpart 227-1 Opacity and PM limit (should easily be met with proposed controls)

No federal regulations appear to come into play

Scenario #2

5 MW wood-fired boiler system
Assume heat rate of 13,500 Btu/kW
Control: ESP
Assume wet wood
Assume 8,760 hrs/yr

Emissions:
Pollutant Emission Factors Maximum Potential to Emit
(for wet wood and controlled) (based on 8760 hr/yr)
PM 0.054 lb/mmBtu x 67.5 mmBtu/hr 3.65 lb/yr
NOx 0.22 lb/mmBtu 14.85 lb/yr
SO2 0.025 lb/mmBtu 1.69 lb/yr
CO 0.6 lb/mmBtu 40.5 lb/yr

RESPONSES FROM NYDEC ON EMISSIONS, CONTINUED:

*Note: Other emission sources, if any, at the facility must be accounted for when determining Overall facility emissions; rule applicability, and level of permitting.
Applicable Regulations:
6 NYCRR Part 200, General Provisions
6 NYCRR Subpart 201-6
6 NYCRR Subpart 227-1 Opacity only (PM standard in Subpart Dc is more stringent than that in 227-1)
40 CFR 60, Subparts A and Dc

Scenario #3

10 MW wood-fired boiler system
Assume heat rate of 135 mmBtu/hr; Control: ESP; Assume wet wood; Assume 8,760 hrs/yr

Emissions:
Pollutant Emission Factors Maximum Potential to Emit
(for wet wood and controlled) (based on 8760 hr/yr)
PM 0.054 lb/mmBtu x 135 mmBtu/hr 7.29 lb/yr
NOx 0.22 lb/mmBtu 29.7 lb/yr
SO2 0.025 lb/mmBtu 3.38 lb/yr
CO 0.6 lb/mmBtu 81.0 lb/yr

*Note: Other emission sources, if any, at the facility must be accounted for when determining overall facility emissions, rule applicability, and level of permitting.
Applicable Regulations:
6 NYCRR Part 200, General Provisions
6 NYCRR Subpart 201-6
and major for NOx (i.e., greater than 100 tpy)
6 NYCRR Subpart 227-1 Opacity only (PM standard in Subpart Db is more stringent than that in 227-1)
6 NYCRR Subpart 227-2, NOx RACT because major for NOx
6 NYCRR Part 231, New Source Review
40 CFR 60, Subparts A and Db
40 CFR 52.21 (Prevention of Significant Deterioration)

Considerations:
Is boiler system going in at an existing facility with other shutdowns or in a brand new facility?
Conservative emission factors were used above for heat rates, etc.
Can the facility accept a limit/cap on capacity?
To avoid NSR (PSD and non-attainment NSR), what about the use of CO catalyst 80% reduction for CO emissions? What about NOx controls achieving 0.16 lb/mmBtu which would yield 95 tpy?

Note that for locations outside of the New York City metropolitan area, the major source (Title V) threshold limits are as follows: PM 100 tpy, NOx 100 tpy, VOC 50 tpy CO 100 tpy SO2 100 tpy
For the NYC metro area, they are: PM 100tpy, NOx 25 tpy, VOC 25 tpy, CO 100 tpy, SO2 100 tpy

Site Selection Analysis

Introduction

Six potential sites have been identified for the biomass cogeneration plant in Hudson and Greenport, NY. These sites are:

1. ADM flour mill,
2. Hudson Correctional Facility,
3. Fosters Refrigeration
4. Columbia Memorial Hospital
5. Holcim Greenport
6. Holcim Hudson Waterfront
7. McGuire's

The existing Hudson Correctional Facility boiler plant appears to be the most suitable site, since it is located between the prison and near the thermal center of the district energy network, which will reduce the sizes and lengths of the hot water piping. This facility is also located adjacent to the active railway which once delivered coal to this plant and could be used to deliver biomass at some point.

Another potential site is at or near the existing ADM Mill boiler plant, which is located in a heavy industrial area. This site is the farthest from the thermal loads, but appears to be suitable if the prison plant is not available for any reason. It also is served by an active freight railway line and has significant open space for shipping and storage. Columbia Memorial Hospital also has a small boiler plant and enough space to install a small biomass plant, but the site is very constrained and would only allow construction of a small plant.

Space Needed: According to Dr. Morris Pierce, the site will need 2 to 3 acres for the plant itself that would include a three day supply of biomass. Ideally it would be sited on a larger site that could store all biomass supply to simplify storage and handling.

Table 1 illustrates evaluation criteria which ranked on a scale of 1 to 3.

***Table 1**: Evaluation of Site Selection According to Scoring (1=most favorable conditions and, 2= medium and 3= not applicable or not favorable conditions)*

	Rail Access	Proximity to Heat Loads	Proximity to Transformer(s)	Truck Access	Barge Access	Compatibility with nearby land use	Total Score
ADM	1	2	1	1	3	1	9
Correctional Facility	2	1	1	2	3	1	10
Hospital	3	1	1	3	3	3	14
LB	1	2	1	1	1	1	6
SLC - Hudson Waterfront	3	3	1	3	1	2	13
SLC - Greenport	3	3	3	1	3	1	10

The LB Site scores the highest by three points. A key factor in this high score is its rail and nearby water access. A tractor trailer carries 22 tons of wood. A railcar carries100 tons and a barge carries up to 1600 tons. These numbers illustrate the value of having larger rail or barge fuel deliveries. Aside from this high scoring, it should be noted that LB currently does not have a tenant that is immediately available to purchase thermal energy, however the property remains on the market.

This scoring evaluates all categories equally. Compatibility with nearby land use can be said to trump the other categories, therefore a score of '1' is significant and sites scoring a '3' are not optimal.

Other categories, while important, can be lifted by high scores in other areas. For example, if a transformer is not present nearby, high nearby heat loads and compatible land use create conditions for such improvements to be financed.

Saint Lawrence Cement Site in Greenport

Holcim (US) Ltd. owns a combined 1842 acres on in Hudson and Greenport. Holcim operates a warf on the Hudson river with substantial surface area. Part of this area is leased for use in transfer of bulk stone from mining inland to barges. Being on the river in an existing industrial zone and close to a rail line it is another potential site.

In Greenport Holcim owns over 150 acres of land along a major artery (Route 9). The former manufacturing building is still intact. The associated office facility was use until 2008.

Eco-Grid solicited the interest of both Holcim and the community to ascertain for both of these sites. A proposal was sent t o SLC in order to obtain two appointments (Albany, August 7; Greenport, August 20, reconnaissance visit to Greenport SLC site) with Director of Business Development at St. Lawrence Cement Joe Meadows. In addition, Eco-Grid met with the Hudson Long Range Waterfront Plan (LWRP) chairperson Linda Mussman. Eco-Grid submitted formal comments within the public comment period for consideration of a biomass plant or wood fuel storage facility at the Hudson Waterfront.

Columbia Memorial Hospital

Written in 2008, Eco-Grid principal advisor to this NYSERDA#10050 Dr. Morris Pierce, wrote that:

Viewed independently, the proposed biomass plant at the hospital would need about 2.6 tons/hour of wet wood chips (50% moisture content, 4800 btu/lb. This plant should have a fairly high load factor due to the absorption chillers, so the total annual fuel requirement would be around 15,000 to 18,000 tons of wet wood chips per year.

Eco-Grid has met with the hospital engineers and CEO (see outreach report, PBS segment). This ranks high as a potential heat customer; however its proximity to the urban area makes not desirable as the initial site in the Hudson area.

Archer Daniels Midland

Archer Daniels Midland (ADMMILL), Greenport NY: We conducted our first meeting with managers and operators of the site October 22, under the remote supervision of Energy Manager Bret Balke at ADM headquarters in Decatur, Il. A power substation is located on site, as is illustrate in figure 1 below.

Figure 1: ADM Plant and Substation

ADM Mill	

The Hudson facility is a flour mill which only uses natural gas for building heat. The natural gas consumed is roughly as follows. National gas usage is roughly uses 0-60 MMBtu per hour during the summer and fall, and a peak of 2300 MMBtu per hour in 2300.The plant operates normally on a M-S schedule which calculates 5.5/7 = 78% load factor. The peak demand is roughly 3,800 kw and the monthly usage is about 2,000,000 kwh; this calculates a load factor of 72%.

A high electricity consumption of this facility could match nicely with a medium sized biomass boiler.

NYS Correctional System[1]

The Hudson Correctional Facility has an existing "district heating" plant, serving 400 prisoners and 270 staff in18 buildings. There are three tri-fuel boilers generating steam for heat and domestic hot water. The location of the powerhouse (adjacent to rail and accessible by road without passing through the center of Hudson and central to a minimum distance pipe network) makes it a good choice for a central node to the Hudson district system.

Figure 2: Hudson Correctional Facility Boiler Plant

Hudson Correctional Facility Boiler Plant (former coal plant, rail unloading infrastructure still present)	

The boiler plant of the Hudson Correctional Facility appears to be an ideal location for a biomass combined-heat-and-power unit. This site is somewhat farther away from the initial heating loads but has room to grow into a much larger plant.

Additional advantages of the correctional-facility plant are the existence of a rail siding formerly used for coal deliveries, a large amount of open space around the plant, and the distance from residential neighborhoods.

[1] On 10 /26/07, we presented the NYS State Correctional System –David Williams, Asst. Commissioner PRESENTATION TO STATECORRECTIONAL AUTHORITIES, FACS, OGS, David Williams, Asst Commissioner, Keith Rupert, PE, Lead Engineer; and Maynard Porter, Director, Facilities Planning. ECO-GRID has received clearance by FCS/OGS in Albany to tour the power plant of the Hudson Correctional Facility on March 4, 2008, to ascertain the feasibility of an anaerobic-digestion site on the grounds of the Hudson Correctional Facility.

Citing a decline in the state prison population and a need to find funds for newly mandated programs, the state Department of Correctional Services announced earlier this month plans to close the medium security Hudson prison as well as three prison camps elsewhere in the state by January 2009. One reason given for the choice of HCF for closure was the anticipated capital improvements for 2008-201 of $21 million, which might be avoided if the prison were closed.

Energy Infrastructure

HCF's powerhouse produces steam which is distributed throughout the campus for heat and domestic hot water. There are three tri-fuel boilers in place at the HCF power house. Each of them can burn natural gas, oil or coal. The boilers were installed in 2000 and there was a major upgrade to the distribution system around the same period.

There are opportunities for improvement of the energy efficiency for the system although more study will be required. Two possibilities:

1) The combustion efficiency of the primary boilers is currently around 60% and this could be increased.

2) A pressure-reducing valve makes high pressure steam go into a lower pressure. At this point a small turbine could be installed to generate electricity.

Power Supply

There are two independent high voltage power lines at 13.2 kV serving HCF. One line runs directly from Germantown on Worth Ave and the other from Hudson entering the property from Court St. Transformers are located on the east and west ends of the property.

Potential for biomass gasification/combustion unit on the site

Siting with or without a change in prison use, the powerhouse should be seen as an asset for the property. The building and its critical services (high-voltage power supply, steam heating network, gas lines, smokestack, etc) could certainly accommodate some level of biomass powered boiler/steam turbine combination or, preferably biomass gasification/gas turbine. This plant could produce electricity from biomass (sufficient space for biomass storage may be available where compost bin is located now). Provided the correct interconnection with the local grid, excess electricity generation could be sold to the grid, while waste heat from generation could be used to support the existing steam heating network. Given the proximity of the powerhouse to the center of town in Hudson, establishing a district-heating network back to the powerhouse may be viable.

Finally, given that the existing boilers are (20) burning fossil fuels at relatively low-efficiency, such a biomass-powered cogeneration system located here would likely providean20emissions reduction as compared to the existing situation.. This may be the biggest advantage of siting the generation facility at the powerhouse, as permitting such a plant should be more straightforward than starting with a greenfield site.

LB Furniture Building and Site

Figure 3: LB Furniture

LB Furniture		

99 South 3rd st Hudson,New York 12534
Type: Industrial Distribution Warehouse

Type:	Industrial Distribution Warehouse
Total Space Available:	300,000 SF
Divisible To:	10,000 SF
Maximum Contiguous:	300,000 SF
Building Size:	300,000 SF
Date Last Verified:	10/13/2008
Property ID:	15710855

LB FURNITURE SITE HUDSON NY

Property Description:
Offered for lease @ $5.00 a sq ft. NNN is the 300,000 sq ft LB Furniture Distribution building standing in the city of Hudson, NY The County Seat of Columbia County, NY
Beautiful & very well lit, clean & accessible space with 17 ft ceiling height,
4 indoor heated drive in loading docks, 5 exterior accessed indoor docks as well as 3 drive in overhead doors. Rail siding available. Also zoned for manufacturing.
Plus available office & showroom space.

Location Description:
Located in Hudson, NY 1000 Feet From the Amtrak Hudson Train/Rail Station And The Hudson River. 2 Hours from NYC. Just 7 minutes From The NYS Thruway Exit 21
Has Entrance off of Route 9G & Second Entrance from Front St. Across from Train station.
Lot Size: 12.27 Acres Power is available: 2500 Amp 440/270 volts 3 phase

Fosters Refrigeration

The Foster Refrigeration facility is located at 119 North 2nd Street, in Hudson. The site is located in a mixed industrial and residential neighborhood; the nearest residence is located approximately 300 feet from the south-eastside of the building. The site property consists of an approximately three acre parcel as identified in the City of Hudson tax records. The former manufacturing building occupies most of the property. Figure 2 shows the details of the site. The Hudson River is approximately 3,000 feet to the north-west of the site. To the west and north is an area of undeveloped land comprised of woods, fields and wetland areas. A residential area is located to the east and an industrial area is located to the south of the site.

The Foster Refrigeration property was used for the manufacture of refrigerators between 1946 and 1994. The Site is occupied by a 62,652 square foot single-story industrial structure with metal siding and slab at grade concrete floors.

The land area surrounding the building is classified as a brownfield with lead contamination in the soil. Remediation has been arranged and will begin in 2008. While the premises are attractive for the short distance to the Hudson River, there are limits on potential truck traffic transiting the adjacent residential neighborhood.

McGuire's Site

This is a 130,000 square foot unused industrial building and property. The advantage of the location is its proximity to town, and its existing rail spur. The main entrance is on Hudson Avenue (off Union street.) There is also a back road off Court Street. There is no opening off the rail spur onto McGuire's. The rail spur might manageable with the approval of CSX and any other necessary approvals.

Anaerobic Composting Analysis for Eco-Grid and CEEP, INC.

Community Heating and Cooling Grid, Hudson, NY

Think 21, LLC

5/28/2008

The possibilities for siting an organic waste recycling facility for the production of renewable Biogas in Hudson, NY were investigated. Potentially available organic waste volumes were estimated using available data, and several sites were analyzed. It was determined that an organic waste recycling facility would not be supported by wastes available only from Columbia County, and that waste would have to be imported from surrounding counties.

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Disclaimer

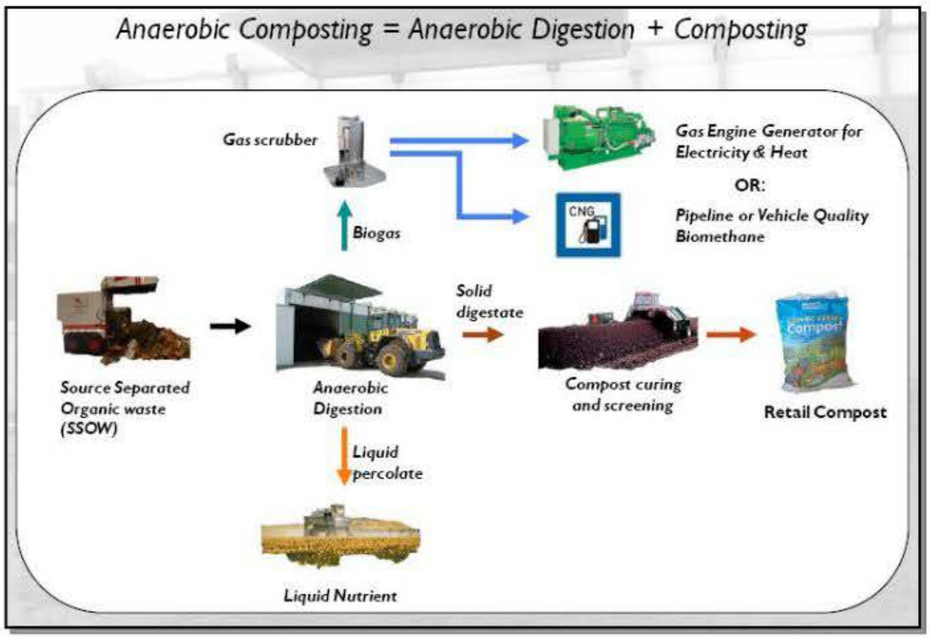
This report prepared for Recipients: Eco-Grid, CEEP, Inc., and the New York State Energy Research and Development Authority (NYSERDA). This report contains information and analysis related to Biogas production potential and site selection analysis proprietary to Think 21. Recipients of this document shall not disclose to any third party the Proprietary Data contained herein without written consent of Think 21.

This analysis is prepared from sources and data which Think 21 believes to be reliable, but we make no representation as to its accuracy or completeness. The report is provided solely for informational and analytical purposes and is not to be construed as providing endorsements, representations, or warranties of any kind whatsoever. Opinions and information provided are made as of the date of the report issue and are subject to change without notice.

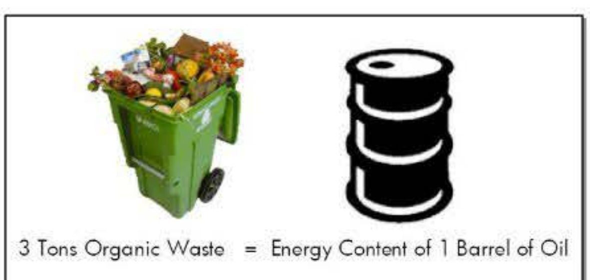
Introduction

Think 21 was retained as a technical assistance subcontractor to ECO-GRID and CEEP, Inc for their Hudson, NY regional heating and cooling study. Specific tasks included an assessment of theoretically available compostable wastes and the renewable Biogas energy potential of these wastes if utilized in a dry Anaerobic Composting process. In addition, several site opportunities in the Hudson, NY region were investigated. Given estimated waste volumes and project site potential, Think 21 generated conclusions regarding the potential for an Anaerobic Composting project to be part of Eco-Grid's proposed community heating and cooling grid.

Anaerobic Composting – *A carbon negative Industrial Ecology process that recycles food & other Source Separated Organic Waste (SSOW) to produce renewable Biogas energy & Compost.*



Plant revenues would be generated primarily from tipping fees (dumping fees) and energy sales. This method of organic waste management is dependent on Source-Separated Organic Wastes (SSOW), which must be separated from non-compostable Municipal Solid Waste (MSW) by commercial and residential customers. Anaerobic Composting is a common SSOW waste treatment method in Europe, and Think 21 is working to develop Anaerobic Composting projects using the BEKON Dry Fermentation System throughout the Northeast and in Northern California.



Summary of Columbia County SSOW

Columbia County SSOW Potential

Columbia County Per Capita Waste	.46 Tons/Person/Year	
2006 Population	63,000	
Total MSW	29,282 Tons/Year	
** Per Capita Data from Columbia County Solid Waste Plan*		
Columbia County Waste Only		
Average of National, State, & County Data		**<--Data Source**
Waste Type	% of Waste Stream	Total Annual Tonnage
Paper & Paperboard	39.30%	11,507 Tons/Year
Glass	5.44%	1,593 Tons/Year
Metals	5.00%	1,465 Tons/Year
Plastic	8.25%	2,417 Tons/Year
Yard Waste	**11.14%**	**3,263 Tons/Year**
Food Waste	**12.04%**	**3,526 Tons/Year**
Other	18.99%	5,560 Tons/Year

Figure 1 – Estimated Columbia County Waste Composition

Figure 1 shows that there is an estimated ***6,788 Tons Per Year (TPY)*** of compostable food and yard waste produced annually in Columbia County. Total annual Municipal Solid Waste (MSW) generation was estimated by multiplying the County population by per capita waste generation as per the Columbia County Solid Waste Plan (1994). The waste composition in Figure 1 was an average of National (www.epa.gov "Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2006, page 4, Figure 5), New York State (Western, Central, Eastern Rura (WCE-Rural)l estimates from New York State Solid Waste Management Plan 1999 – 2000 Update, page 7, Table 5), and Columbia County (Columbia County Solid Waste Plan of 1994) waste composition estimates.

Because Columbia County is relatively rural, yard waste can be dealt with in simple ways (dumping in the woods, backyard composting, etc.). Not all rural areas deal with yard waste in such a manner but we assume that this is the case because the Columbia County yard waste estimate was significantly lower (2.53%) than the national (12.93%) and New York State WCE-Rural (18.00%) data. In our analysis, we utilized the average yard waste composition (11.14%) in order to estimate the amount that we believe to be theoretically available if all yard waste was devoted towards an Anaerobic Composting project.

Later on in this report, we have estimated the breakdown of food waste from the commercial (2,561 TPY) and household (965 TPY) sectors. Assuming that 75% of commercial food waste can be collected; 50% of household food waste can be collected; and 100% of yard waste can be collected the potential recoverable organic waste in Columbia County is ***5666 TPY***.

Biogas Production Potential Using Columbia County SSOW

Biogas is a by-product of anaerobic bacterial degradation and consists of 50-80% methane plus 20-50% CO2 as well as traces gasses and water vapor. Biogas is a valuable fuel due to the methane content and can be utilized in a gas-engine electricity generator or boiler.

Considering the efficiency of Think 21's dry digestion technology, the biogas production potential from the 5,666 TPY of organic waste identified above is approximately:

460,000 cubic meters of Biogas

Assuming a Biogas methane concentration of 55%, the methane produced would be ***258,000 cubic meters*** with an energy value of:

8,500 MMBtu

If this fuel were used in an engine generator of 35% efficiency, the potential electricity production would be:

875,000 kWh, which after parasitic loads of the digester would offer the following surplus electricity for export to the grid or nearby user:

760,000 kWh

In addition, the following amount of waste heat could be recoverable:

4,200 MMBtu

In summary, an Anaerobic Composting plant that utilized Columbia County's theoretically available organic wastes could produce 8,500 MMBtu's of thermal energy in the form of direct gas or 4,200 MMBtu in the form of waste heat from a gas engine generator. Further analysis would need to be completed to determine how this could fit into Eco-Grid's proposed community heating and cooling grid.

Conclusion – Regional Project Would Be Required

In most viable markets in the US, Anaerobic Composting plants need at least 26,400 TPY of SSOW in order to function economically without subsidy. This is due to the batch-by-batch nature of the BEKON system and economies of scale. Because there is less than 6,000 TPY of SSOW theoretically available in Columbia County, a project could not function in Columbia County unless SSOW were imported from surrounding areas. According to Jolene Race, the Department of Public Works Director at Columbia County, regional waste projects have been discussed as a possibility amongst neighboring Counties. The next section analyzes the potential for a regional Anaerobic Composting facility.

Summary of Regional SSOW

Regional SSOW Potential

Blended Per Capita Waste	**.73 Tons/Person/Year**	
2006 Population	**1,043,000**	
Total MSW	**763,893 Tons/Year**	
**** Per Capita Data Average of New York State & Columbia County Estimates***		
Columbia County and Surrounding Counties		
Average of National, State, & County Data		**<--Data Source**
Waste Type	% of Waste Stream	Total Annual Tonnage
Paper & Paperboard	39.30%	300,179 Tons/Year
Glass	5.44%	41,566 Tons/Year
Metals	5.00%	38,219 Tons/Year
Plastic	8.25%	63,047 Tons/Year
Yard Waste	**11.14%**	**85,123 Tons/Year**
Food Waste	**12.04%**	**91,980 Tons/Year**
Other	18.99%	145,051 Tons/Year

Figure 2 – Estimated Waste Composition, Columbia and Surrounding Counties

Figure 2 shows there is an estimated ***177,00 TPY*** of compostable food and yard waste produced annually in Columbia, Greene, Dutchess, Ulster, Albany, and Rensselaer Counties. Total annual MSW generation was estimated by multiplying the population by per capita waste generation. The per capita waste generation (.73 tons/year/person) was an average of the per capita waste generation from The Columbia County Solid Waste Plan (.46 tons/year/person) and the per capita waste generation from the New York State Solid Waste Plan (1.00 tons/year/person from BioCycle Magazine, April 2006, "State of Garbage" page 30, Table 3). We decided to use a blended per capita rate to reflect the combination of rural and urban/suburban Counties that were examined.

The waste composition in Figure 2 was an average of National (www.epa.gov), New York State (Solid Waste Management Plan of 2000), and Columbia County (Columbia County Solid Waste Plan of 1994) waste composition estimates.

Because significant tonnages are available in the Mid-Hudson and Capital region of New York State, we can assume that minimum 26,400 TPY of SSOW is theoretically available for a regional Anaerobic Composting project.

Biogas Production Potential Using Regional SSOW

Considering the efficiency of Think 21's dry digestion technology, the biogas production potential from the **26,400** TPY of organic waste identified above is approximately:

2,275,000 cubic meters of Biogas

Assuming a Biogas methane concentration of 55%, the methane produced would be 1**,273,000 cubic meters** with an energy value of:

42,000 MMBtu

If this fuel were used in an engine generator of 35% efficiency, the potential electricity production would be:

4,311,000 kWh, which after parasitic loads of the digester would offer the following surplus electricity for export to the grid or nearby user:

3,700,000 kWh

In addition, the following amount of waste heat could be recoverable:

17,422 MMBtu

In summary, an Anaerobic Composting plant that utilized the Mid-Hudson and/or Capital Region's theoretically available organic wastes could produce **~42,000 MMBtu's** of thermal energy in the form of direct gas or **~17,000 MMBtu** in the form of waste heat from a gas engine generator.

Conclusion – Town of Hudson Not Ideal Location for Regional Project

While a regional project is a viable option, The Town of Hudson may not be the best location for a regional Anaerobic Composting project. The advantage of the BEKON Dry Fermentation system is that it can function at a smaller scale as compared to other commercially available technologies. This allows us to site closer to the waste stream and develop distributed projects that address local waste streams rather than large centralized facilities that import waste from far distances. As such, a location in the Northern part of Columbia County that is nearby the denser population areas in Albany and Rensselaer Counties may prove to be a better location.

Locations closer to major waste sources, but remote from Hudson, would negate the possibility of directly using biogas energy for the town of Hudson. However, should Hudson determine that the energy and economic benefits of an Anaerobic Composting facility were compelling; it would certainly be an option for such a plant to be located near Hudson (e.g. at the Newman Street Transfer Station). This scenario would require importation of at least 20,000 TPY of SSOW from surrounding counties.

Appendix A – Source-Separated Waste Analysis

Methodology for Estimating Organic Waste Potential in Columbia County and Surrounding Counties

1. Researched waste composition estimates from US Environmental Protection Agency (2006), New York State Solid Waste Plan (2000), and Columbia County Solid Waste Plan (1994)
2. Developed analytical tools to generate tonnage estimates based on various inputs.
3. Generated tonnage estimates based on population and waste per capita data from New York State Solid Waste Plan and Columbia County Solid Waste Plan.
4. Examined Columbia County commercial waste sources from US Census 2003 New York County Business Patterns, Columbia County Chamber of Commerce, yellow pages, and other sources.
5. Estimated potential tonnage available from specific organic waste generating sources using estimates from Cascadia Consulting Group's 2004 Sector Study conducted on behalf of California Integrated Waste Management Board.
6. Spoke with various local organic waste generating businesses and Columbia County Department of Public Works to review analysis and finalize study conclusions

Estimated Waste Available Based on National, New York State, and Columbia County Waste Composition Data

Columbia County Per Capita Waste	**.46 Tons/Person/Year**
2006 Population	**63,000**
Total MSW	**29,282 Tons/Year**

* Per Capita Data from Columbia County Solid Waste Plan

Environmental Protection Agency MSW Data (2006)		**<--Data Source**
Waste Type	% of Waste Stream	Total Annual Tonnage
Paper & Paperboard	33.90%	9,927 Tons/Year
Glass	5.30%	1,552 Tons/Year
Metals	7.60%	2,225 Tons/Year
Plastic	11.70%	3,426 Tons/Year
Yard Waste	**12.90%**	**3,777 Tons/Year**
Food Waste	**12.40%**	**3,631 Tons/Year**
Other	16.70%	4,890 Tons/Year

Figure 3 – Columbia County Organic Waste Estimates based on National Waste Composition Data

Figure 3 estimates and highlights the tonnage of organic waste available in Columbia County, NY using 2006 national Municipal Solid Waste (MSW) composition data from the EPA. Total MSW generated on an annual basis is estimated by utilizing per capita waste estimates of 0.46 tons/person/year from Columbia County's 1994 Solid Waste Plan.

Columbia County Per Capita Waste	**.46 Tons/Person/Year**	
2006 Population	**63,000**	
Total MSW	**29,282 Tons/Year**	
* Per Capita Data from Columbia County Solid Waste Plan		
New York State Solid Waste Management Plan (1999 - 2000)		**<--Data Source**
Waste Type	% of Waste Stream	Total Annual Tonnage
Paper & Paperboard	37.00%	10,834 Tons/Year
Glass	5.00%	1,464 Tons/Year
Metals	5.00%	1,464 Tons/Year
Plastic	8.00%	2,343 Tons/Year
Yard Waste	**18.00%**	**5,271 Tons/Year**
Food Waste	**13.00%**	**3,807 Tons/Year**
Other	14.00%	4,100 Tons/Year

Figure 4 – Columbia County Organic Waste Estimates based on New York State Waste Composition Data

Figure 4 estimates and highlights the tonnage of organic waste available in Columbia County, NY using Municipal Solid Waste (MSW) composition data from the New York State's 2000 Solid Waste Management Plan. Total MSW generated on an annual basis is estimated by utilizing per capita waste estimates of .46 tons/person/year from Columbia County's 1994 Solid Waste Plan.

Columbia County Per Capita Waste	**.46 Tons/Person/Year**	
2006 Population	**63,000**	
Total MSW	**29,282 Tons/Year**	
**** Per Capita Data from Columbia County Solid Waste Plan***		
Columbia County Solid Waste Plan (1994)		**<--Data Source**
Waste Type	% of Waste Stream	Total Annual Tonnage
Paper & Paperboard	46.99%	13,759 Tons/Year
Glass	6.02%	1,764 Tons/Year
Metals	2.41%	706 Tons/Year
Plastic	5.06%	1,482 Tons/Year
Yard Waste	**2.53%**	**741 Tons/Year**
Food Waste	**10.72%**	**3,140 Tons/Year**
Other	26.27%	7,691 Tons/Year

Figure 5 – Columbia County Organic Waste Estimates based on Columbia County Waste Composition Data

Figure 5 estimates and highlights the tonnage of organic waste available in Columbia County, NY using Municipal Solid Waste (MSW) composition data from Columbia County's 1994 Solid Waste Management Plan. Total MSW generated on an annual basis is estimated by utilizing per capita waste estimates of 0.46 Tons/Person/Year from Columbia County's 1994 Solid Waste Plan.

Columbia County Per Capita Waste		**.46 Tons/Person/Year**
2006 Population		**63,000**
Total MSW		**29,282 Tons/Year**
**** Per Capita Data from Columbia County Solid Waste Plan***		
Columbia County Waste Only		
Average of National, State, & County Data		**<--Data Source**
Waste Type	% of Waste Stream	Total Annual Tonnage
Paper & Paperboard	39.30%	11,507 Tons/Year
Glass	5.44%	1,593 Tons/Year
Metals	5.00%	1,465 Tons/Year
Plastic	8.25%	2,417 Tons/Year
Yard Waste	**11.14%**	**3,263 Tons/Year**
Food Waste	**12.04%**	**3,526 Tons/Year**
Other	18.99%	5,560 Tons/Year

Figure 6 – Columbia County Organic Waste Estimates based on Average Waste Composition Data

Figure 6 estimates and highlights the tonnage of organic waste available in Columbia County, NY using the average Municipal Solid Waste (MSW) composition data from Columbia County, New York State, and the EPA. Total MSW generated on an annual basis is estimated by utilizing a per capita waste estimate of .46 tons/person/year from Columbia County's 1994 Solid Waste Plan. This table shows what we believe to be the most accurate estimate of theoretically available SSOW in Columbia County.

Blended Per Capita Waste	**.73 Tons/Person/Year**
2006 Population	**1,043,000**
Total MSW	**763,893 Tons/Year**

* Per Capita Data Average of New York State & Columbia County Estimates

Environmental Protection Agency MSW Data (2006)		**<--Data Source**
Waste Type	% of Waste Stream	Total Annual Tonnage
Paper & Paperboard	33.90%	258,960 Tons/Year
Glass	5.30%	40,486 Tons/Year
Metals	7.60%	58,056 Tons/Year
Plastic	11.70%	89,376 Tons/Year
Yard Waste	**12.90%**	**98,542 Tons/Year**
Food Waste	**12.40%**	**94,723 Tons/Year**
Other	16.70%	127,570 Tons/Year

New York State Solid Waste Management Plan (1999 - 2000)		**<--Data Source**
Waste Type	% of Waste Stream	Total Annual Tonnage
Paper & Paperboard	37.00%	282,640 Tons/Year
Glass	5.00%	38,195 Tons/Year
Metals	5.00%	38,195 Tons/Year
Plastic	8.00%	61,111 Tons/Year
Yard Waste	**18.00%**	**137,501 Tons/Year**
Food Waste	**13.00%**	**99,306 Tons/Year**
Other	14.00%	106,945 Tons/Year

Columbia County Solid Waste Plan (1994)		**<--Data Source**
Waste Type	% of Waste Stream	Total Annual Tonnage
Paper & Paperboard	46.99%	358,938 Tons/Year
Glass	6.02%	46,018 Tons/Year
Metals	2.41%	18,407 Tons/Year
Plastic	5.06%	38,655 Tons/Year
Yard Waste	**2.53%**	**19,327 Tons/Year**
Food Waste	**10.72%**	**81,911 Tons/Year**
Other	26.27%	200,637 Tons/Year

Figure 7 - Organic Waste Estimates for Columbia, Rensselaer, Albany, Dutchess, Ulster, & Greene Counties

Figure 7 estimates and highlights the tonnage of organic waste available in Columbia County as well as surrounding counties using Municipal Solid Waste (MSW) composition data from the three sources cited in Figures 3 – 5. Total MSW generated on an annual basis is estimated by utilizing per capita waste estimates that average the New York State (1.00 tons/person/year according the BioCycle's State of Garbage 2006) and Columbia County numbers together to get .73 tons/person/year.

Blended Per Capita Waste	.73 Tons/Person/Year	
2006 Population	1,043,000	
Total MSW	763,893 Tons/Year	
** Per Capita Data Average of New York State & Columbia County Estimates*		
Columbia County and Surrounding Counties		
Average of National, State, & County Data		<--Data Source
Waste Type	% of Waste Stream	Total Annual Tonnage
Paper & Paperboard	39.30%	300,179 Tons/Year
Glass	5.44%	41,566 Tons/Year
Metals	5.00%	38,219 Tons/Year
Plastic	8.25%	63,047 Tons/Year
Yard Waste	**11.14%**	**85,123 Tons/Year**
Food Waste	**12.04%**	**91,980 Tons/Year**
Other	18.99%	145,051 Tons/Year

Figure 8 –Organic Waste Estimates for Columbia, Rensselaer, Albany, Dutchess, Ulster, & Greene Counties based on Average Waste Composition Data

Figure 8 estimates and highlights the tonnage of organic waste available in Mid-Hudson and Capital Regions in New York State using the average Municipal Solid Waste (MSW) composition data from Columbia County, New York State, and the EPA. Total MSW generated on an annual basis is estimated by utilizing the average per capita waste estimate of New York State and Columbia County, which is 0.73 tons/person/year. This table shows what we believe to be the most accurate estimate of theoretically available SSOW in Mid-Hudson and Capital region of New York State.

Columbia County Food Waste Generators by Category

Grocery Stores:

- 29 Grocery Retailers employing 756 people (US Census New York State County Business Patterns 2003, page 89)
- 1.54 Tons/Employee/Year of Food Waste (Waste Disposal and Diversion Findings For Selected Industry Groups, June 2006 Report for California Integrated Waste Management Board (CIWMB) produced by Cascadia Consulting Group, page 22)
- ~1,164 Tons/Year of food waste produced by Columbia County grocery stores

Restaurants:

- 125 Full & Limited Service Restaurants employing 1092 people (US Census New York State County Business Patterns 2003, page 90)
- 1.28 Tons/Employee/Year of Food Waste (Waste Disposal and Diversion Findings For Selected Industry Groups, June 2006 Report for California Integrated Waste Management Board (CIWMB) produced by Cascadia Consulting Group, pages 14, 18)
- ~1,397 Tons/Year of food waste produced by Columbia County restaurants

Food Processors:

Several small food process businesses are located in Columbia County. After a telephone survey of Beth's Farm Kitchen (jam producer), Tierra Farms (nut roaster), and Hudson Valley Farms, it was determined that these processers had limited food waste due to process efficiency and/or on-site solutions such as composting or animal feed.

Breakdown of Commercial and Household SSOW Potential:

When the commercial volume of 2,561 TPY is deducted from the 3,526 tons/year total estimated available food waste, a breakdown between commercial and residential waste generation is possible:

Commercial food waste generation = ~2,561 Tons/ year
Residential food waste generation = ~965 Tons/ year

Out of the 3,526 Tons/Year of food waste, we have assumed a theoretical recovery rate of 75% for both the restaurant and supermarket food waste as this fraction dominates their existing waste streams and are easily separable, given the proper economic incentives. Source-separation of organics from residential sources is more difficult, as it involves new separation infrastructure, education, and outreach. As such, we are assuming 50% recovery rate from residential sources.

Recoverable food waste is shown in the calculation below:

(2561 x 0.75) + (965 x 0.50) = 2,403 tons/year

Yard waste is either dealt with through on-site or natural methods or is dumped at the existing Newman St. Transfer Station in a clean condition, free from contaminants. For the purposes of this analysis, we have assumed a theoretically available yard waste stream of 3,263 TPY with 100% of this material being devoted to the SSOW mix.

Therefore the theoretical total recoverable SSOW volume is:

2403 + 3,263 = 5,666 Tons/year

Appendix B – Siting

Methodology for Assessing Siting Potential

1. Assessment of permitting requirements
2. Establishment of site criteria
3. Site search and analysis

Permitting Requirements and Site Technical Criteria

Anaerobic Composting Facilities receiving food and other organic wastes in sufficient quantity would require issuance of a Solid Waste Management Permit under NYS DEC Part 360-5 "Composting Facilities/Source-Separated Organic Waste Composting Facilities". Proposed facilities must also be reviewed under the State Environmental Quality Review Act (SEQRA). The SEQRA process carries the greatest potential difficulty in locating any recycling facility, as it is a public process and can be subjective in terms of "Determination of Significance".

The shortest pathway to permitting a viable site is for the project plan to achieve a determination of "Negative Declaration" or "Conditioned Negative Declaration" in which the local "Lead Agency", normally the town or county, concludes that the project will have no significant negative environmental impact. Location of a waste recycling project on a site already use-permitted for waste management activities is the most straightforward way of achieving a Negative Declaration. In addition, the site must not be located in or nearby to a wetland, or within 500 feet from residential areas. Perhaps the greatest single factor to achieving a use permit is whether or not the host community actively supports or opposes the project plan.

The best sites from a permitting standpoint will therefore be:

1. Located in heavy industrial zones;
2. Located on a site already use-permitted for waste management (e.g. an operating transfer station, landfill, or Materials Recovery Facility);
3. Supported by town and/or county government for use as an organic waste recycling facility.

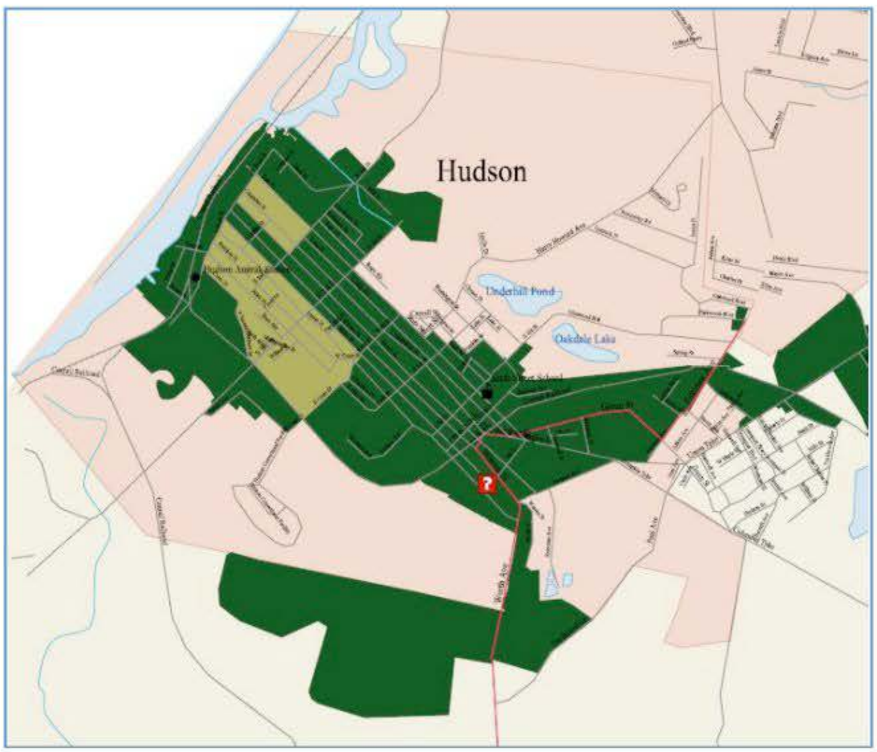
The technical requirements for locating an Anaerobic Composting Facility are not extensive, as the process is contained, highly managed, and rapid relative to conventional composting. The minimum project capacity is 26,400 TPY. Such a facility has a built footprint of less than 30,000 square feet, or about ¾ acre. Site access, circulation, truck scales and maintenance sheds bring the total site requirements to 60,000 sf or 1½ acres. Proximity to energy purchaser and major transport routes is also critical.

The best sites from a technical standpoint will therefore be:

1. At least 1½ acres (preferably rectangular);
2. Adjacent to large energy user or 3-phase electricity distribution feeder;
3. Easily accessible from major roadways.

Site Search and Analysis

As the Eco-Grid project is centered in the town of Hudson, a list of potentially suitable available sites in and around Hudson was created. Basic requirements included a minimum of 1.5 acres, zoned for Heavy Industrial usage or already in use for Waste Management activities. Tools used included the Empire State Development Corporation "Site Finder", Columbia-Hudson Partnership resources, and local real estate searches. Much of Hudson is within an Empire Zone, which would offer significant benefits for location of a new industrial facility.



Columbia County Area1Empire Zone

The only major transfer station in the Hudson area is located in-between Hudson and Greenport. This would be the most intuitive location for a new Anaerobic Composting Facility, and would be close enough to the Eco-Grid project area to consider waste heat use in the town of Hudson. Aside from the transfer station, no other sites were found meeting all site requirements listed above. Nonetheless, a list of additional candidate sites was identified.

Other Potential Sites:

1. Hudson Correctional Facility (Visited on March 4, 2008)
2. Former Refrigeration Plant
3. Cycletech

From the SSOW analysis, it can be seen that an Anaerobic Composting facility cannot be supported from the waste generated within Columbia County as the total estimated volume is less than 26,400 tons per year. However, the overall Mid-Hudson and Capital Region SSOW available would be more than sufficient to justify a plant. As per the preliminary analysis conducted for this study, the Newman Road transfer station would be the best candidate site in Hudson.

Outreach and Technology-Transfer Report

AUGUST 2007

PRESENTATION TO TOWN COUNCIL OF GREENPORT, NY: August 1, 2007. A ten-minute presentation on NYSERDA funding news and Statement of Work was delivered, with ample Q & A period. Presenters: Matt de la Houssaye, Maria Miller, with assistance from summer intern Sadie Coulter.

ECO-GRID WMHT TV (PBS) SEGMENT/CLEAR CHANNEL; HUDSON CHANNEL; ABOUT TOWN quarterly: WMHT's "NEW YORK NOW" Producer and host Susan Arbetter confirmed her plans to film the Eco-Grid team in Hudson in September – October 2008. In addition, Eco-Grid was featured in radio interview Clear Channel's "What's Going On" with Peggy Polenberg (tape of program available); was included in Hudson Channel Interview, Cable 25, Matt de la Houssaye (DVD of segment available). The September 2008 issue of ABOUT TOWN magazine will carry a story on Eco-Grid (NYSERDA funding, and Statement of Work).

ONLINE PRESENCE ... THE LAUNCH OF THE ECO-GRID WEBSITE: (www.eco-grid.org). Official press release issued with quote by Paul Tonko, President, NYSERDA, and news on NYSERDA funding with full version of the Statement of Work. The Q & A and Privacy-Policy Sections of the site are still in progress.

ECO-GRID NYSERDA STUDY ADVISORY GROUP: In formation. Responses from Jim Besha (conflict of interests with his NYPA board seat but wishes to remain abreast of progress); John Cody (yes, after the November election); positive response from Gary Schiro, Exec Director, Hudson Opera House.

SEPTEMBER 2007

PROJECT ADVISORY GROUP: Three community leaders have accepted participation. Realizing that it will probably be easier to conduct this task after the current enthusiasm over the mayoral elections subsides, we will continue our quest to form an eight-person Advisory Group after the November 2007 elections, with a goal to have one in place by Dec '07-March '08.

MEDIA OUTREACH: Eco-Grid shot a segment of "NEW YORK NOW" with Susan Arbetter (WMHT, Albany, PBS Station), with an emphasis on biomass and biomass availability/siting made possible by exterior shots of biomass samples at the Cornell Extention in Greene County (Acram, NY) as well as exterior shots of the Hudson Correctional Facility Power Plant and Columbia-Memorial Hospital in Hudson, NY.

OCTOBER 2007

PROJECT ADVISORY GROUP As of this week, Michael Greason, Forester (30-year experience), accepted to be part of the NYSERDA-prescribed Eco-Grid Advisory Group, adding the Advisory Group's current total number to four. Mike Greason has an impressive roster of clients in NY State, the majority of whose properties he manages under the 480-a Section of the Real Property Tax Law (www.orps.state.ny.us/ref/pubs/forestlaws/section1.htm). Our experience so far is that the formation of the Advisory Group has been a slow process, with steady interest from additional community leaders and experts …

MEDIA OUTREACH: THE ECO-GRID "NEW YORK NOW" TV SEGMENT AIRS: The Eco-Grid segment of WMHT's NEW YORK NOW with Susan Arbetter aired the weekend of Friday, 10-05/07, with replays in at least 10 PBS affiliates in NY State (and Toronto) on Saturday, 10-06, and on Sunday, 10/07, including WNET (Manhattan and Long Island). The 20-minute segment included a full interview with NYSERDA's President and CEO Paul Tonko. Here is a list of the stations and air times, which was also forwarded to Ray Hull of NYSERDA Communications**:** WMHT, Schenectady, Friday at 7:30pm and Sunday at 11pm; Think Bright Friday at 8pm Sunday at 12:30am; WNED, Buffalo & Toronto, Sunday at 9:30am; WXXI, Rochester and Sunday at 6:30pm; WCNY, Syracuse, Sunday at 1pm; WPBS, Watertown, Sunday at 7:30am; WSKG, Binghamton, Sunday at 6:30pm; WNET, New York City, Saturday at 1pm; WLIW, Long Island, Sunday at 6:30am; Mountain Lake Public Broadcasting, Plattsburgh, Saturday at 9:30am.

NOVEMBER 2007

PROJECT ADVISORY GROUP

We have confirmed our first Advisory-Group meeting for Monday, December 10, 2007, at 5:15 PM, at Eco-Grid headquarters in Hudson. Our confirmed Advisors are: Forester Mike Greason; Peter Rost (former owner of St Charles Hotel and now President of Merle Oil in Hudson and Board Member, Columbia-County School District); John T. Cody, ongoing advisor to the LWRP PLAN (Plans for Hudson Waterfront, since 2003; ties to HDPW) and now President of the Hudson Common Council; Gary Schiro, Director, nonprofit Hudson Opera House; Carrie Haddad, Owner and Director, Carrie Haddad Gallery (main-street business owner and Hudson Common-Council member). **We also have an additional 3-4 unconfirmed, but solicited members, in progress.**

TECHNOLOGY TRANSFER: Matt de la Houssaye and Eco-Grid intern Susan Robinson attended a conference hosted by Sustainable Hudson Valley on November 3. An effort was made at this event to recruit interest by stakeholders in other areas to conduct similar projects to Eco-Grid's study and/or other wood biomass projects such as modular boiler units for schools. Matt has supervised Eco-Grid intern Susan Robinson in creating a plan for additional outreach to stakeholders such as school superintendents. A database of contacts has been created which will be followed up by e-mail at the end of the study, to ascertain interest by potential collaborators.

DECEMBER 2007

PROJECT ADVISORY GROUP: Our first Advisory Group meeting took place on Monday, December 10, 2007. Confirmed members in attendance were forester Mike Greason, affiliated with Cornell Agro-Forestry Center in Greene County and 30-year EPA veteran; Merle Oil's President Peter Rost (also on the Board of Education, Columbia County); and Hudson-born John T. Cody, advisor to Hudson's Visioning Plan since 2003 (LWRP) and now President of the Hudson Common Council. We had reported meeting separately with Carrie Haddad on 11/30; Carrie is a Hudson Common Council Member and owner/director of the Carrie Haddad Gallery on our main street. Pending is acceptance of Craig Wittman, General Manager Firemen's Home, Hudson. Gary Schiro, Director, Hudson Opera House is also a confirmed member of the advisory group, absent from this past meeting due to travel. Three other "community leaders" remain to be confirmed in January 2008.

RELEVANT FINDINGS, ADVISORY GROUP MEETING: Forester Mike Greason will generate a list of woody-biomass resources in excess of that generated by MESA REDUCTION ENGINEERING, which we forwarded to NYSERDA with our November 2007 Report. Plans exist to combine both lists and survey/report results (which might together approximate nearly 50 woody biomass resources within the prescribed 50-mile radius of Hudson). All members of the advisory group have been asked for/will offer recommendations on all upcoming activities (most importantly, on the outreach portion of the study).

COMMUNITY OUTREACH: Eco-Grid's small community presentations are in progress. These initial presentations led by the Hudson-based Eco-Grid team (Maria Miller/Matt de la Houssaye) are being made to small, targeted groups in the community.

JANUARY 2008

PROJECT ADVISORY GROUP: Our second Advisory-Group meeting took place on Thursday, January 10, 2007. In attendance were Merle Oil's President Peter Rost (also Board of Education, Columbia County); Hudson-born John T. Cody, advisor to Hudson's Visioning Plan since 2003 (LWRP) and now President of the Hudson Common Council; Carrie Haddad, owner/director Carrie Haddad Gallery and one of the founders of the ArtsWalk in Hudson (Columbia County Council for the Arts); Gary Schiro, Executive Director, Hudson Opera House; and Imre Vilaghy, owner/operator of the Wunderbar Restaurant in Hudson, who developed and leads a small co-op for waste grease. Also present was the Eco-Grid core team.

More …

JANUARY 2008, CONTINUED

RELEVANT FINDINGS, ADVISORY GROUP MEETING: suggestions from the group included a) the use of bio-fuels for transport of woody biomass to plant b) widespread basic education on district energy/biomass as a pivotal step to establishing a plant locally ("Eco-Grid at the pulse of the community") c) the need to research other waste products as a source of fuel d) the possibility of using our website to gather energy information and e) the need to create a relative-comparison chart, with anchors and generalizations, and "propaganda," or direct-marketing slogans.

The Hudson-based Eco-Grid team (Matt de la Houssaye and Maria Miller) met several times to discuss a strategy for broader community outreach anchored in the Project Advisory Group. After conducting a series of presentations to the community, Matt and Maria felt that further outreach efforts could be most effective with multiple champions and spokespersons. The existing Project Advisory Group could be a great resource for this work. Matt and Maria presented this idea to the Project Advisory Group. The reaction from every member of the Project Advisory Group was receptive and enthusiastic, although they did not feel quite ready to deliver any presentations. The rest of the evening was spent with Matt and Maria answering questions on the study. At this time, key areas of the study such as the biomass availability section had not yet been completed.

The Hudson-based Eco-Grid team (Matt de la Houssaye and Maria Miller) concluded that the Project Advisory Group would not likely be ready for targeted outreach until the completion of the study.

FEBRUARY 2008

ECO-GRID WEBSITE UPDATES: We have updated the ECO-GRID™ website NEWSBRIEF PAGE to include the latest information on our feasibility-study tasks replete with a biomass survey, which can be downloaded and forwarded to Eco-Grid. Please visit **http://www.eco-grid.org/newsbrief.html.** This same link to the NEWSBRIEF PAGE was sent by email to the appropriate portion of the ECO-GRID™ media/industry/supporters e-database.

ECO-GRID INTRODUCTION TO NEW MAYOR OF HUDSON: On February 26, Matt de la Houssaye had a first meeting with the new Mayor of Hudson (Rick Scalera) to introduce **ECO-GRID** (mission, goals, history, team) as well as the NYSERDA-funded feasibility study for Hudson/Greenport. At the time of the meeting National Grid had offered the City of Hudson a proposal to bury power lines. Realizing the opportunity, Richard Cohen had met with the Mayor on several occasions to discuss the viability of coordinating this project with a district-energy project. Matt de la Houssaye attempted to close this conversation into some concrete numbers that could be incorporated into Eco-Grid's study. With a focus on the weekly priorities, the Mayor encouraged Matt to return when the district-energy project was ready to be constructed.

FEBRUARY-MARCH-APRIL-MAY 2008 were primarily devoted to research and development.

JUNE 2008

OUTREACH ASPECTS OF ENERGY-DATA COLLECTION

In the last 18 months, energy-data collection has evolved into a multi-faceted task, comprising equal amounts of outreach and relationship/trust-building activity, ranging from city/county buildings to the hospital, prison, and large manufacturing facilities in Hudson/Greenport. As of this report, it has taken Eco-Grid from 4-12 months to collect complete energy data that will permit a feasible citywide heat load calculation on the part of our engineers. This will be an ongoing activity in light of continuing demands.

APPROVED EXTENION TO THE STUDY by Ray Albrecht PE. One-Year Mark.

JULY 2008 – PRESENT* (under new Project Manager Nathan Russell)

SPREADING THE WORD; FORGING RELATIONSHIPS: Over the last 18 months, Eco-Grid has collected primary data for heat/electric usage, usually going back (typically) 2 years, for the following buildings or sets of buildings:

Volunteer NYS Fireman's Home
Hudson Correctional Facility
KAZ, Inc.
Columbia County (all properties owned and/or managed)
City of Hudson
Town of Greenport
Archer Daniels Midland (ADM)
Hudson Opera House
Amtrak Station
Hudson Area Library
Columbia-Memorial Hospital
209 Warren Street (residence)
417 Columbia Street (office/residence)
Hudson Housing Authority
Schuyler Court Apartments
Providence Hall Apartments
McGuire's
600 Warren (art gallery)

Questar

PRESS SUMMARY: In the last 18 months, The ECO-GRID NYSERDA-funded study has been featured in the Cover page of the Business Section of the Albany Times-Union; in District-Energy magazine; in ABOUT TOWN magazine; in the Register-Star and Independent Newspapers; in Susan Arbetter's NY NOW (WMHT PBS, also featuring an interview with Paul Tonko) which broadcasted in 11 PBS affiliates in the State of NY, including Manhattan and Long Island. The ECO-GRID NYSERDA study was also featured in a radio broadcast of "WHAT'S GOING ON" and in The Hudson Channel (interview with Matt de la Houssaye). These media outlets have also received our pitches for future placements: WNYT (Channel 13 Albany News); 60 Minutes; The New York Times.

SMALL GROUP PRESENTATIONS AND DAILY OUTREACH: During the study period, Maria Miller has made eight presentations to small groups of five or less people in Hudson. Matt de la Houssaye has served as a daily information source and liaison to community members on the prospects for biomass district heating in Hudson.

PROPOSAL / BUDGET QUOTES

TO: Eco-Grid
Hudson, New York

FROM: VisionPower USA

FOR: **Supply of ORC and Wood Combustion Equipment**
In Response to Request for Proposal (verbal)

DATE: February 19, 2010

In response to a request from Eco-Grid, this is a non-binding quotation for budget purposes only, for combined heat and power (CHP) equipment using Organic Rankine Cycle (ORC) technology, and for thermal-only wood-fired combustion system equipment. This quote is for the provision of equipment, excluding installation. This information in this quote may be used by Eco-Grid for any purposes that will advance its district energy project in Hudson, New York, but are not intended to be used for any other purposes.

I. Complete ORC System and Heat-only Equipment

The quotation provided herein is for a full set of equipment for a complete Organic Rankine Cycle (ORC) combined heat and power system (including wood fuel handling and combustion equipment, thermal oil heater, pumps and ORC equipment) for the Eco-Grid district energy project in Hudson, New York, and also for a complete wood combustion systems for the project at two scales:

	Nominal Electrical Capacity	Thermal Output Capacity
ORC System:	600 kW	8.0 MMBtu/hr
	2.2 MW	32 MMBtu/hr
Heat-only System:		8.0 MMBtu/hr
		32 MMBtu/hr

VP USA will provide ORC equipment manufactured by Turboden/Pratt & Whitney and wood combustion equipment will be supplied by Järnforsen Energi.

ORC System – Supplied Items:

Manufacturer: **Turboden / Pratt & Whitney Power Systems** **Shipping: ExW Hartford, CT**

a) Interface drawings
b) One-line wiring scheme (preliminary to the complete one included in the instruction manual).
c) 1 ORC turbogenerator
d) Organic fluid (in separate std. barrels)
e) SCADA supervision system based on a personal computer interfaced with the PLC
f) Supervision to unloading and positioning
g) Supervision to installation on site
h) Supervision to start-up of the turbogenerator
i) Instruction course for the local technicians
j) Maintenance and instructions manuals
k) Thermal oil inlet/outlet flange
l) Cooling water inlet and outlet flanges
m) Electric power terminals in the switch gear panel, and electric parallel breaker
n) Electric signal terminals in the control panel to interface with the plant (thermal oil 3-way valve)
o) Concrete supporting plate
p) Compressed air flanges
q) Outlet flange leak supervision system
r) Flanges for safety device discharge

Wood Combustion System & Thermal Oil Heater for ORC - Supplied Items:

Manufacturer: **Järnforsen Energi System AB** **Shipping:** **to Eastern US**

a) Feed equipment from silo (approx. 3-day storage)
b) Combustion equipment (furnace)
c) Gas-recirculation
d) Hot oil Boiler (thermal oil heater)
e) Soot removal equipment
f) Flue-gas cleaning equipment - multicyclone
g) Ash- and slag discharge to ash container
h) Controls and regulating equipment
i) Chimney
j) Platforms and ladders
k) Start up, trimming and commissioning
l) Instructions and documentation
m) Thermal oil pumping equipment (skid)

Exclusions, Wood Combustion System:

- Building and concrete work
- All embedment steel to be cast into the concrete by others - drawings supplied by Järnforsen
- Supply of fresh water connection inside boiler house
- Water treatment plant, if required
- Connection of 400 V power supply to distribution system and control cabinets
- Air-ventilation equipment for boiler house
- Electrical installation
- Piping Installation, delivery limit flange boiler
- Costs for performance test and PM testing
- Unloading of trucks and heavy lifts by mobile-crane, front-loaders and other lifting-facilities
- Cranes and transport
- Water, electricity and compressed air during installation and commissioning
- Necessary wood-material for brick-lining work
- Clothes changing facilities and accommodation for our supervisors and installation personnel
- Containers for waste material after installation

Exclusions, Thermal Oil Heater:

- Thermal oil for the system
- Installation of quoted thermal oil components
- Piping material for the thermal oil, fuel and hydraulic system
- Insulation of all heat carrying pipes and valves
- All inspection charges at customer site to be borne by customer
- All electrical wiring to and from the switchboard and equipment

Wood Combustion System - Supplied Items (for Heat-Only Alternates):

Manufacturer: **Järnforsen Energi System AB** **Shipping:** **To Eastern US**

a) Feed equipment from silo (approx. 3 day storage)
b) Combustion equipment (furnace and hot water boiler)
c) Gas-recirculation
d) Soot removal equipment
e) Flue-gas cleaning equipment - multicyclone
f) Ash- and slag discharge to ash container
g) Controls and regulating equipment
h) Chimney
i) Platforms and ladders
j) Start up, trimming and commissioning
k) Instructions and documentation

Exclusions, Wood Combustion System:

- Building and concrete work
- All embedment steel to be cast into the concrete by others - drawings supplied by Järnforsen
- Supply of fresh water connection inside boiler house
- Water treatment plant, if required
- Connection of 400 V power supply to distribution system and control cabinets
- Air-ventilation equipment for boiler house
- Electrical installation
- Piping Installation, delivery limit flange boiler
- Costs for performance test and PM testing
- Unloading of trucks and heavy lifts by mobile-crane, front-loaders and other lifting-facilities
- Cranes and transport
- Water, electricity and compressed air during installation and commissioning
- Necessary wood-material for brick-lining work
- Clothes changing facilities and accommodation for our supervisors and installation personnel
- Containers for waste material after installation

ORC unit: CHP **Turboden 22-**

ORC hot source:		thermal oil		
ORC thermal power input	11,600	kW	39,59	MMBtu/h
hot source nominal temperature in	300	°C	572	°F
hot source nominal temperature out	240	°C	464	°F
hot source flow rate	80	kg/s	634,921	lbs/h
cooling water temperature in	80	°C	176	°F
cooling water temperature out	95	°C	203	°F
cooling water flow	148.6	kg/s	1,179,003	lbs/h
thermal power to cooling water	9,378	kW	**32.00**	**MMBtu/h**

glycol in cooling loop	0	%
gross ORC active electric power output	2118	kWe
ORC captive consumption	96	kWe
net ORC active electric power output	**2022**	**kWe**
Electric generator		Synchronous, 3 phase, LV

ORC unit: Turboden 6-CHP

ORC hot source			thermal oil	
ORC thermal power input	2,907	kW	9.92	MMBtu/h
hot source nominal temperature in	300	°C	572	°F
hot source nominal temperature out	250	°C	482	°F
hot source flow rate	23.5	kg/s	186,508	lbs/h
cooling water temperature in	80	°C	176	°F
cooling water temperature out	95	°C	203	°F
cooling water flow	37.2	kg/s	294,912	lbs/h
thermal power to cooling water	2,344	kW	**8.00**	**MMBtu/h**

glycol in cooling loop	0	%
gross ORC active electric power output	538	kWe
ORC captive consumption	31	kWe
net ORC active electric power output	**507**	**kWe**
Electric generator	Synchronous, 3 phase, LV	

Järnforsen Energi Typical System: Technical Data and Guarantees
Typical Plant: Boiler plant for wood waste 7 MW thermal (24 MMBtu/hr)

Produced capacity from boiler at 55% moisture content in fuel	7 MW
Design pressure, boiler	6 bar
Design temperature, boiler	165°C
Calc.water temperature, boiler	120/100°C
Flue gas temperature after clean boiler, max	200°C
Total efficiency, boiler, min	86 %
O2-content	6 % (dry gases)
Dust emission limit, max	200 mg/Nm3 at 11 % O2-content
CO emission,max	150 mg/ Nm3 at 11 % O2-content
NOx measured as NO2 at, max	0.5%
Nitrogen in the fuel (normal sawmill fuel), max	250 mg/ Nm3 at 11 % O2-content
Fuel	Wood chips (Odd pieces max 300x50x25mm)
Fuel moisture content, guarantee data	40 %
Fuel moisture content max	45 %
Fuel moisture content min	30 %
Calorific value	19-20 MJ/kg Ts
Volume weight	250 – 400 Kg/m3
Ash melting point	> 1200°C
Production accessibility (plant availability)	98%

Note: Any required level of PM emissions can be achieved with ESP or condensation plant added.

II. Budget Price Quotes

1. ORC Combined Heat and Power System:

Budgeting Price, All Equipment	500 kW (600 kW nominal)	$3,250,000
	2.0 MW (2.2 MW nominal)	$5,950,000

2. Heat-only Wood Combustion System:

Budgeting Price, All Equipment	8.0 MMBtu/hr	$ 950,000
	32 MMBtu/hr	$1,470,000

III. Notes

- Over 100 Turboden ORC units in operation and 30 under construction
- Turboden availability history: over 98%, 2 million operating hours achieved
- Turboden ORC operator time requirement: 3-5 hrs/week
- Turboden ORC turndown: 10% of nominal load
- Delivery: 9-11 months from order, depending on production work load
- Codes: ASME pressure vessels, UL certification for electrical equipment
- Typical installation time: 12 weeks (2.2 MWe units)
- ORC system does not include building construction, grid connection
- Bid quote does not include insurance, taxes, permitting and import duties

EnvioEnergi
Renewable Energy Systems

November 3, 2010

Eco-Grid
339 Allen Street No. 3
Hudson, NY 12534

Re: Project No. NA10-764
Eco-Grid Hudson
Hudson, New York, USA

BUDGET PRICE ESTIMATE

ESTIMATE NO: NA10-764_C20_110310
ESTIMATE TYPE: Class20 (+/- 20%)

We are pleased to provide a Class20 Budget Price Estimate for a turnkey biomass Envio Energi combined heat and power (CHP) plant all inclusive per the Design Criteria, Scope of Supply and Exclusions listed below.

Design Criteria (Preliminary):

Plant Type:	Biomass CHP Plant Model TRT 6/24z Gasification/Combustion Furnace 12.1 MWth (41.4 MMBtu/hr)
Thermal Output:	30 MMBtu/hr to District Heating Network
Power Output:	2.4 MW/hr

Scope of Supply:

FUEL FEED SYSTEM – Individual combustion chamber fuel metering bin, feed chute and pusher assembly. Fuel from fuel yard to be received via customer's conveyor to fuel metering bin.

COMBUSTION CHAMBER/FURNACE – Gasification/combustion chamber model TRT 6/24z complete with reciprocating grate system, grate system drives, feed chute, sprinkler system, feed pushers, spreader rolls, individually isolated under air/ash chutes, carbon retention plate, main ash chutes, air and gas ports, water cooled grate support, hydraulic units for fuel bin and furnace, steel supports and structure and refractory lining.

AIR & FLUE GAS FANS - Primary and secondary air fans, ID flue gas fan and flue gas recirculation fan including motors and frequency controller/converter.

BOILER - Custom designed ASME certified high pressure water tube boiler with super-heaters, including economizer, soot blowers, pre-heater and independent steel support structure.

BAGHOUSE FILTER - Complete bag house filter, ash disposal and transportation system, structural steel and drives.

STACK – Steel, single pipe construction with outer shell of COR-TEN plate.

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Envio Energi LLC
P.O. Box 1195
Troy, Montana 59935

Southeast USA
Envio Energi LLC
P.O. Box 2629
Cleveland, Georgia 30528

ASH HANDLING SYSTEM – Bottom ash wet type scraper conveyor system for transfer of ash and slag from combustion chamber, boiler and economizer to separate ash container(s). Includes conveyors, containers and galvanized support structure.

ELECTRICAL & AUTOMATION - Control and monitoring systems and sub-systems for the combustion chamber, process water, turbine, flue-gas cleaning, flue-gas condensing, etc. with local control cabinets and individual PLC systems.

OPERATING SYSTEM - Operating system with Ethernet communication for combustion chamber. Operating system shall be type iFIX 3.5 iclient for Windows. Graphic interface to show actual measured data, set points, limits etc.

EMISSIONS INSTRUMENTATION SYSTEM - Emissions PLC and instrumentation system for collection and registration of emissions data.

CAT WALKS, STAIRS AND SUPPORT STEEL - All stairs, walkways, handrails and steel supports necessary for the support of assembly, construction, operation and maintenance of the facility.

TURBINE & GENERATOR – Complete back-pressure turbine, synchronous generator and hot water condenser.

PIPING & ASSECORIES - Includes piping systems for high and low pressure steam, compressed air, control air, condensate, make-up water, and feed water treatment, dosing and sampling and other necessary systems for operation of the plant. Piping systems, pressure vessels and equipments are designed according to applicable ASME and other pressure vessel and steam piping codes.

EMERGENCY DIESEL GENERATOR - Emergency diesel generator to supply power to pumps and control equipment to enable a safe shut down of the combustion process and boiler during a power outage. Standalone unit including fuel tank, cooler, starting battery and automatic synchronizing system.

ELECTRICAL - Complete supply and installation of all electrical services and systems for building and process equipment. Delivery limits shall be from new plant switch gear to outgoing turbine generator clips.

BUILDING AND FOUNDATION – Standard steel building to accommodate all process equipment including control room, designated maintenance area, necessary climate controlled motor control rooms and sanitary facilities for staff. Including standard concrete mat foundations for assumed minimum soil bearing pressure 2000 psf. Pilings, if required, are not included.

ENGINEERING & DESIGN – Process design and engineering including all turnkey construction documents, specifications and operation and maintenance manuals..

CONSTRUCTION – Complete turnkey construction and installation including project management, site coordination, safety oversight, etc.

START-UP, TRAINING & COMISSIONING - Site supervision, necessary on-site programming of automation and operating system and crew training.

Price:

C20 BUDGET PRICE ESTIMATE: $11,915,000 USD

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Cleveland, Georgia 30528

EnvioEnergi
Renewable Energy Systems

Exclusions:

Subject to other conditions stated in this estimate the following exclusions will apply:

1. Design, engineering, material or construction other than that encompassed within the building walls of the Envio Energi facility.
2. Cooling Tower – Cooling tower(s) including outside piping, pumps and water treatment.
3. Sales taxes, duties, other taxes and federal, state or local fees.
4. Project permitting, work permits or licenses.
5. Site preparation, infrastructure, construction, core drilling, etc.
6. Fuel yard and associated material handling and processing equipment.
7. Interconnection, controls and switching facilities for interconnection to the power grid.
8. External piping, connections and distribution lines.
9. External power units, transformers and substation.
10. Emergency power units other than what is included for emergency shutdown.
11. Any external water treatment or drainage ponds.

Terms and Conditions:

1. Price estimate and data provided are subject to more detailed design data including:
    a. Fuels analysis report on guaranteed fuel.
    b. Final determination of thermal (heat and steam) loads and cyclical demands.
    c. Verification of seasonable thermal condensing characteristics and climate.
2. Terms of payment are to be determined.
3. Project timeline and critical path are to be determined.
4. This budget price estimate is valid for 90 days from estimate date above.

Sincerely,

ENVIO ENERGI LLC

Jeff Staska
CFO

Northwest USA
Envio Energi LLC
P.O. Box 1195
Troy, Montana 59935

Southeast USA
Envio Energi LLC
P.O. Box 2629
Cleveland, Georgia 30528

EnvioEnergi
Renewable Energy Systems

Plant Operating Data [1]

Date:	11/3/2010		
Project No.	NA10-764		
Project	Eco-Grid Hudson		
Location	Hudson, New York, USA		
Plant Type	Biomass Combined Heat & Power Plant		
Plant Size	Total Plant Size (MWth)	MW	12.10
Combustor Type	Single Line	TRT	TRT 6/26z
Thermal Demand	Process Heat for District Heating	Btu/hr	30,000,000
		MW/hr	8.8
Power Output	Power Output @ Maximum Operation	MW/hr	2.40
	Power Output @ Generator Terminals	MW/yr	19,835
Production Hours [2]	Hours per Year at Maximum Output	hrs/yr	8,760.00
	Planned Maint. Outage - 10 Days (Average)	hrs/yr	(240.00)
	Uptime Rate (After Maintenance)	%	97.0%
	Production Hours per Year at Maximum Output	hrs/yr	8,264.40
Fuel Type	Woody Biomass	Mix %	100.0%
Fuel Values [3]	HHV	Btu/lb	8,650
	Heat Value @ Moisture Content (As Received)	Btu/lb	4,325
	Moisture Content - Range [4]	% WT	40% to 50%
	Moisture Content - Design	% WT	45%
Fuel Volume [1]	Fuel Consumption - Hourly	lbs/hr	12,159
	Fuel Consumption - Hourly	tons/hr	6.08
	Fuel Consumption - Annually	tons/yr	50,243
Power Consumption	Internal Power Consumption - Hourly	kw/hr	580
	Internal Power Consumption - Hourly	MW/hr	0.58
	Internal Power Consumption - Annually	MW/yr	4,793
Water Consumption	Boiler	gpm	7.9
	Cooling Towers [5]	gpm	TBD
	Water Consumption	gpm	7.9
	Water Consumption - Hourly	gal/hr	474
	Water Consumption - Annually	gal/yr	3,917,326

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Renewable Energy Systems

Plant Operating Data [1]

Date:	11/3/2010			
Project No.	NA10-764			
Project	Eco-Grid Hudson			
Location	Hudson, New York, USA			
Plant Type	Biomass Combined Heat & Power Plant			
Effluent Discharge	To City Sewer (Process Water)	gpm		2.2
	To City Sewer (Building Services)	gpm		1.0
	Effluent Discharge	gpm		3.2
	Effluent Discharge - Hourly	gal/hr		192
	Effluent Discharge - Annually	gal/yr		1,586,765
Ash Volume	Ash Volume (Dry)	lbs/hr		130
	Ash Volume (Dry)	tons/hr		0.065
	Ash Volume (Dry)	tons/yr		537
Water Treatment Chemicals	Boiler Feed Water (Pending water analysis)	$/hr	$	2.50
	Cooling Tower (Pending water analysis)	$/hr	$	-
	Water Treatment Costs	$/yr	$	20,661
Lime	Lime Additive for Baghouse	lbs/hr		NA
SNCR	NH4OH @ 25%NH3	lbs/hr		NA
Maintenance Costs	Parts & Consumables	$/yr	$	75,000
	Maintenance Outage Costs	$/yr	$	125,000
Direct Labor	Plant Technicians (2 @ 3 Shifts/Day)	Qua.		6.00

Notes

[1] Data supplied are prelimiary estimates and will be confirmed as detailed engineering is completed.

[2] Uptime rate is stated at 97% to allow for industry standard turbine/generator operating uptimes. Envio Energi steam train uptime is 98.5% +.

[3] Fuel values and moisture content are standard values for conifer woody biomass. Actual fuel values TBD.

[4] Denotes moisture content design range for optimum performance. Fuels of varying moisture contents up to 60% are acceptable.

[5] Cooling tower (if req'd) water usage TBD.

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CHIPTEC
WOOD ENERGY SYSTEMS

September 22, 2010

Mr. Matt de la Houssaye
Eco-Grid
339 Allen Street, No. 3
Hudson, N.Y. 12534

Dear Matt;

We are pleased to hear that your project is coming to fruition. The application to N.Y.S.E.R.D.A. is a big milestone in your journey. We are very pleased to have been part of the learning curve and the homework required to develop the sense of the project. We hope to continue to be involved and end up as the selected technology.

We have experience with Van Zelm, and with N.Y.S.E.R.D.A., as well as having obtained air quality permits, and acceptance in public school contracting, in New York State. We feel that this level of familiarity with the process there, and their familiarity with Chiptec and our technology, may facilitate those relationships and processes to every ones mutual satisfaction.

We are presently building two almost identical systems for a Honeywell project in Illinois, and have several other similar projects in project development. We are very comfortable with this scale, fuel, pressure, air quality, and fuel and ash handling. We are certain that we can be a successful and viable partner in the project/.

We look forward to hearing of success with your financing and being selected as your vendor of choice.

Regards.

Robert J Bender

Robert J. Bender
President

Matt de la Houssaye
Project Manager
Eco-Grid, 339 Allen Street, No. 3
Hudson, NY 12534

Dear Mr. De la Houssaye;

Per your request, Veolia Energy has reviewed the concept of a biomass district heating, cooling and generation facility in the town of Hudson, New York. Veolia is impressed by the motivation within the region to fulfill the concept of a renewable and sustainable energy facility and we applaud this efforts. To date; Veolia visited a few of the key sites within the town and reviewed the load information provided. Based on this initial review we feel a facility of this sort is well positioned for federal funds which are now starting to flow through the Department of Energy. Veolia also believes that although current commodity prices hinder a project of this sort, prices will rebound within the near future and projects of this type will be key components of our energy independence strategy.

Veolia has prepared comment on four specific issues surrounding this type of development; location, energy match, logistics and financials. Although each item is discussed below these comments are based on Veolia's initial review of the project. They are in no way expressed as definitive's. Projects such as this have many moving parts and change is constant, so the views expressed are intended only to assist and are not intended to categorically confirm or deny any position.

Location:
Based on the sites visited Veolia feels the most desirable location would be closer to the Correction Facility. This offers easy access to one of the major heat and electrical loads within the town. This location also offers more space for a biomass facility. Although the hospital is another potential anchor for this project, its congested location makes it a difficult site. Another advantage of locating the facility near the correctional facility is its proximity to the Hudson. Assuming the ultimate configuration includes electrical generation, the river water could be used for condensing. Specifically locating the facility on Power St. for example would enable the facility to have access to regional loads and resources.

Energy Match:
Based on the information provided Veolia sees that this facility is not well match with it's potential hosts. The Correctional Facility offers an appropriate match for 4-5 months of the year but offers no cooling load. The Hospital's loads are relatively small and would not justify the cost as an initial target host. Although other entities within the town would ultimately add to the customer base (ie. Municipal, commercial and residential buildings),

these should not be viewed as primary design targets because they offer only additional seasonal load and little financial support. Based on this unbalanced seasonal

load, Veolia recommends the inclusion of a condensing turbine to produce green electrons for regional benefit while targeting the Correctional Facility's thermal load.

Logistics:
Veolia recommends a multi-phase development approach. The first phase being a high pressure biomass boiler with a condensing turbine which includes multiple extraction points. This first phase would enable the project to capture renewable energy credits, applicable grants and attractive financing options. The first phase would also have to include the consideration of space for the additional phases, that being, space for additional district heating, cooling and generation equipment. The second phase would improve the overall economics of the first phase and enable further environmental benefit as the overall efficiency improves.

Financing:
Financing is the most difficult component for a project of this nature. Ultimately some entity would have to take responsibility for securing the off-take which would in turn secure the financing source. Veolia recommends first securing as much Federal support as possible. A goal for this project should be securing roughly 25% of the project cost. Ideally, the easiest route would be to secure a steam contract with the Correctional Facility. Contractually however, getting the State of NY to agree to a long-term steam contract would be very difficult. This would then leave the electricity as the only real securable off-take component. If the facility could convince a local leader to agree that a fixed price for commodity would greatly benefit the region even if the initial cost per kWh is greater than market rates, that contract would secure the overall financing of the project. Then additional thermal contracts could reduce the price per kWh to the Municipal leader.

Summary:
The development of these types of projects takes a considerable amount of time. Furthermore, the environment which these projects are measured against is always changing so it is worthwhile to continue the development effort of the biomass solution. The project is well positioned for federal DOE funds, some of which were just announce on Tues 6/2. The Hudson project will be a difficult one to complete because of the varied end users, they offer strength to the projects potential, but they also create a very difficult contractual landscape. Veolia would be happy to assist the continued development of this project in whatever form the group would like to pursue.

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