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EVER-GREEN ENERGY™

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About Ever-Green Energy

Ever-Green Energy is one of the country's foremost experts on the advancement of community energy systems, built upon decades of experience with system development, utility ownership and management, and engineering. Ever-Green was formed in 1998 by District Energy St. Paul to advance the national model established for Saint Paul's Community Energy System (CES). District Energy St. Paul is an internationally recognized energy system, receiving two International District Energy Association System of the Year Awards and a 2013 Global Climate Award. District Energy has been serving heating customers for over three decades and customers are paying less today for energy than they did 30 years ago (when adjusted for inflation).

The first major project launched by Ever-Green was the development of a biomass-fired combined heat and power (CHP) facility in St. Paul. The CHP facility was a key step in advancing Saint Paul's system, which was preceded by district heating, district cooling, and thermal storage and has been further advanced by solar thermal and hot water thermal storage. Drawing from the experience in Saint Paul and working with clients throughout North America, Ever-Green helps communities, colleges, universities, and government organizations advance the study, development, and operation of integrated energy systems. Ever-Green operates and manages two other community energy systems in Minnesota and also provides system advisory services to District Heat Montpelier in Montpelier, Vermont.

For the past 10 years, Ever-Green has owned and operated the biomass-fired combined heat and power facility in downtown Saint Paul, along with a biomass collection and processing business. On an annual basis, these facilities process over 250,000 tons of biomass to generate power and heat. In addition, the operation serves as a research facility for local biomass fuel producers looking to take their fuels to market. Ever-Green's biomass knowledge is sought after by many campuses and communities looking to develop similar biomass programs.

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Executive Summary

Introduction

The City of Burlington is well positioned to enhance the sustainability, efficiency, and effectiveness of its energy future by integrating its existing energy infrastructure and leveraging underutilized energy systems to develop a Community Energy System (CES). The McNeil Generating Station (McNeil) currently operates at an efficiency of approximately 25% while generating approximately 50 megawatts (MW) net of electricity. The collaborative (Collaborative) of the Burlington Electric Department; the University of Vermont (UVM); Fletcher Allen Health Care (FAHC); and the Burlington District Energy Service committee, a citizen group, was formed for the purpose of investigating the viability of implementing a CES that integrates McNeil's generation assets with the loads located at FAHC, selected UVM facilities, and the University of Vermont Trinity campus (Trinity).

The Collaborative has engaged Ever-Green Energy to examine the potential for McNeil to provide an affordable and sustainable energy option for FAHC and UVM, along with the greater Burlington community. A CES in Burlington could capture 50% or more of its required thermal energy from the flue gas stream at McNeil, which is currently exhausted to the atmosphere from the electricity generation process. The energy recovered from the flue gas, along with energy extracted from the steam turbine, could be distributed through a hot water system to the Burlington community for space heating and domestic hot water needs. Implementation of a CES would improve the overall efficiency of McNeil by increasing the amount of energy that is captured from the electricity generation process.

Ever-Green has identified a technically feasible plan for implementation of a district energy system that would manage against the increasing risk of natural gas price volatility. Implementation of an integrated energy plan that connects McNeil with the campuses identified in this report would establish a foundation for a future comprehensive energy program that could benefit the Burlington community for generations to come.

CES Customers

Establishing a CES is a capital intensive endeavor and an initial group of anchor customers would need to be connected to the system to support the initial capital investment. Given that all of the buildings analyzed within this report are owned by two partners within the Collaborative, Burlington is well positioned to develop an integrated energy system with relatively minimal customer development efforts. Once an initial system is developed, expansion to additional customers adjacent to the energy distribution system becomes much easier to implement.

System Integration

The success of the system depends on the detailed integration of customer usage needs, energy production, fuel management, and energy distribution. Integrating McNeil with the hospital and university campuses offers an excellent opportunity to develop a CES system to meet the future energy needs of the Burlington community.

District heating customers could be served primarily with energy recovered from McNeil's flue gas and supplemented with energy extracted from the steam turbine. Hot water would be distributed to customer buildings via a series of underground pipes running from McNeil to the Trinity, FAHC, UVM and University Health Center (UHC) campuses.

To optimize the energy generation assets currently in Burlington, Ever-Green has assumed that the UVM, Trinity, and FAHC campuses would utilize their existing central plants for redundancy to the system in the event of a service disruption at McNeil. UHC's boilers are at the end of their service life and replacement is currently under consideration.

Business Structure

With a possible CES conceptually defined, Burlington could focus on developing the business structure of the CES. Although many operational models are possible, Ever-Green recommends that the CES business is structured as a private, non-profit business, utilizing a cost-based rate structure. This structure would generate many benefits, including a positive reception from customers, the key stakeholders, and the community. This structure would also allow the business to operate separately from McNeil, while providing members of the Collaborative with the ability to guide the governance of the business and establish a program that bolsters the long-term viability of McNeil and reduce greenhouse gas emissions in the Burlington community.

Environmental Benefits

Implementation of a CES in Burlington will bring the community closer to its goals of greenhouse gas emission reduction. By integrating combined heat and power at McNeil, the Burlington community would be developing a local, renewable, and reliable energy solution that reduces carbon dioxide emissions by an estimated 14,400 tons per year. This reduction would equate to the elimination of 2,700 automobiles per year[1]. The recent contract award to McNeil allowing the sale of Connecticut Class 1 RECs supports the long-term viability of generating biomass-based energy in Burlington. McNeil will be available to provide efficient cogenerated thermal energy to the Burlington CES and the CES would provide McNeil with additional revenue streams, increase plant efficiency, and establish a long-term, resilient energy program for future generations.

Financial Benefits

Development of the CES would provide long-term stability to the Burlington energy market. In general, a natural gas rate of approximately $6.90 enables the biomass-powered CES to be competitive for the majority of the prospective system customers. Given that the primary cost of the CES is related to predictable debt service payments and energy costs are buffered from the volatile natural gas market, connecting to a district energy system would provide customers with a much more predictable energy rate. Historically, biomass rates reflect stable costs and this stability could be viewed by prospective CES customers as a competitive and operational advantage when compared with the price volatility of natural gas.

Financing Strategies

Once the business structure decision has been made, system financing strategies should be established. Partners within the Collaborative expressed hesitancy with investments into the CES; therefore Ever-Green recommends the establishment of a private district energy business to provide the most practical basis for financing the system. Financing would be secured in the private market

[1] Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010. Chapter 3 (Energy), Tables 3-12, 3-13, and 3-14. U.S. Environmental Protection Agency, Washington, DC. U.S. EPA #430-R-12-001

through securing long-term energy service agreements with the customers of the system. Prospective customers would not be required to make an investment in the CES development, although grants or other subsidies would help decrease the projected energy rate. Given the recent escalation in natural gas prices, it is projected that the CES would be competitive with the input of less than $2 million toward the initial system financing. This financial input would move development forward to serve the majority of the initial anchor customer load.

The Collaborative would need to provide financing to cover costs of the next phase of development, with repayment to occur at project financing. Based upon information gathered by Ever-Green, the expected capital investment required for implementation of the CES is approximately $31 million.

Conclusion

The City of Burlington, UVM, and FAHC all have climate goals that include reducing greenhouse gas emissions and leveraging local, renewable, and reliable energy sources to meet their long-term energy needs. The development of a CES in Burlington would provide the partners of the Collaborative with a platform to achieve those goals and invest in the greater good for the Burlington community. A CES that utilizes biomass as its primary fuel source would provide customers with a more stable cost of energy when compared to natural gas. Given the recent increases in the price of natural gas, connection to the CES could be viewed as economically compelling for prospective customers. Based on these findings, the system potential, and the economic conditions, it is recommended that additional steps are taken to prepare the system for project financing.

Introduction

Background

The McNeil Generating Station is a 50 megawatt (MW) net electric generating station located on the north side of the City of Burlington along the Winooski River. McNeil has operated since 1984 as a traditional biomass-fired condensing power plant, where biomass is combusted in a boiler and the resulting steam is utilized to generate electricity. The power plant currently does not capture its waste heat for any re-use and thus is operating less efficiently than is possible.

A number of studies have been performed in the past to research the technical and economic viability of capturing stranded energy at McNeil for utilization in a thermal energy system that could serve the Burlington community with a CES. All of these past studies have acknowledged the benefits of a Burlington CES and they provided a number of options for how it could be structured. These studies include:

- In 1994, a district heating and district cooling study was conducted for Burlington Electric Department by Joseph Technology Corporation Inc. The study was to determine the feasibility of a CES to serve six core customers as identified by Burlington Electric. The McNeil Generating Station was the proposed energy source for the district services.
- In 1998, a district heating study was conducted to explore service to the Greater Burlington area, which includes Hilltop, Downtown, and Waterfront customers for Burlington Electric by Joseph Technology Corp. Inc. McNeil is the proposed thermal energy source for the CES.
- In 2002, a validation study was prepared by RDA Engineering for the development of an area-wide district heating system for Burlington Electric.
- In 2011, Ever-Green performed a study that investigated the viability of connecting downtown Burlington to McNeil via a CES, with future growth to FAHC and UVM. The report is attached as Appendix A for reference.

In 2013 the Collaborative hired Ever-Green to "study the feasibility of converting waste heat discharged from McNeil into usable energy via a district energy utility project." This study was conducted in late 2013 and early 2014 and focused specifically on meeting the thermal energy needs of the FAHC campus, the Trinity Campus, the John Dewey Hall, Waterman building of UVM, and the UHC.

Purpose

Although a number of past studies have provided district energy development options that would improve the efficiency of McNeil, reduce local greenhouse gas emissions, and provide the basis for a CES in Burlington, implementation of a CES has not yet occurred. In October 2013, all members of the Collaborative met with Ever-Green to discuss each partners' individual goals and also to establish a common mission for the study. The following was agreed upon as the mission of this study:

- Develop a community energy plan that is implementable. Identify what distinguishes this plan from past studies
- Develop a plan that provides customers with stable and competitive energy rates
- To the greatest extent possible, utilize local, renewable energy sources to support the development of energy independence
- Reduce the carbon footprint for the Burlington community - when it makes sense, go carbon free

- Improve the overall energy efficiency of the community
- Develop a system that reliably meets the needs of the community and that can adapt to changing energy supply
- Establish an initial customer base that makes implementation of a CES feasible
- Provide guidance for system financing and development

The purpose of this study is to establish the framework for the initiation of a CES in Burlington that could capture underutilized energy and infrastructure in the community to economically meet the current and future energy needs of the community while reducing greenhouse gas emissions and improving the resilience of Burlington's energy program.

Process

In order to develop an implementable energy plan for Burlington, the Ever-Green team (Team) first needed to quantify the consumption profiles of the selected buildings in the study. Prior to on-site visits, a building survey was completed by each of the parties involved in the study. After initial data was received, phone interviews were conducted so the Team could better understand the thermal consumption of all of the buildings included within the study. Lastly, the Team performed on-site surveys of all identified buildings during a site-visit in October 2013 so data could be properly interpreted and CES connection costs could be estimated. The results of these examinations are included in this report.

Once the expected load of the selected buildings was quantified and the physical dynamics of each building was determined, the Team analyzed various opportunities for connecting those buildings to a CES. Options sought to balance cost-effectiveness with other primary goals of each customer. In addition, the Team met with management of McNeil to better understand its current and future expected operating parameters and how they may affect the development and operation of a CES.

Lastly, the Team evaluated the current market for natural gas, the recent rate changes, and the future projected market rates. Solutions provided in this report reflect that information and target the implementation mission, while maintaining the Collaborative's deference of primary risk for developing the CES.

After collecting all of the above referenced data, the Team presented its preliminary findings and potential options to the members of the Collaborative. That presentation is included as Exhibit H for reference. Members of the Collaborative provided their feedback, which helped shape the findings in this report.

Integrated Energy System

The vision for the Burlington CES is for it to become an integrated energy system that utilizes energy from multiple sources and multiple technologies in order to reliably meet the energy needs of the community. This diverse and flexible system increases local resilience and provides a buffer from the market volatility of individual fuels. An integrated energy approach evaluates all sources of energy within a community and optimizes its energy efficiency by reducing waste and establishing a conduit for serving the needs of the community through utilization of local resources. Figure 1 illustrates the function of an integrated energy system in a community.

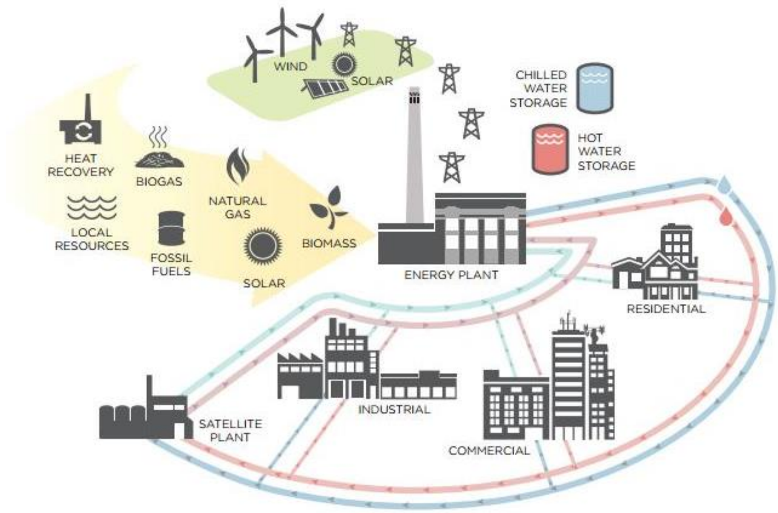


Figure 1. Integrated Energy System

Definitions and Abbreviations

The nature of this report requires the use of project specific and technical terminology. The following definitions and abbreviations are provided for those unfamiliar with energy system terminology:

Admission Steam	The high pressure steam from the boiler that is directed to the turbine inlet to drive the turbine.
AHU (Air Handling Unit)	An air handling unit is a piece of mechanical equipment used to move air through a building's distribution system and may contain heating and/or cooling coils to temper the air.
Backpressure Turbine	A type of turbine designed to allow steam at the outlet of the turbine to retain sufficient energy to be used to perform heating or other work.
Btu (British Thermal Unit)	A British thermal unit is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. The Btu is a small amount of heat equivalent to the heat released by a burning matchstick. For district heating systems, heat is often measured in million Btus (MMBtu) which is equivalent to one million Btus.
CCF (hundred cubic feet)	Unit of volume for measuring gas equal to one hundred cubic feet or approximately 100,000 Btu.
COP (Coefficient of Performance)	COP is the ratio of either heat removed (for cooling) or heat provided (for heating) in Btu per Btu of energy input.
Cogeneration	The simultaneous production of useable heat energy and electrical energy from a production facility.
Collaborative	The consortium of representatives from Burlington Electric, Fletcher Allen Health Care, the University of Vermont, and the BURDES group that initiated this study.

Diversified Load	The actual peak load for an energy system. The diversified load is less than the sum of the peak loads of individual users due to the difference in time of day that each individual user realizes their peak load.
Distribution system (hot water)	The underground piping network that delivers hot water from the production facility (the McNeil Plant) to the customer buildings. Hot water is circulated through a closed loop of supply and return pipes using pumps that are located at the production facility.
Domestic Water	Potable water heated for use in faucets, showers, laundry, and similar uses.
EIA (US Energy Information Agency)	The US Energy Information Agency is the principle US government agency that collects, analyzes, and disseminates energy information.
ETS (Energy Transfer Station)	An Energy Transfer Station connects the CES to the building systems and includes equipment such as temperature controls, metering and heat exchanger(s). The ETS can be field erected or shop fabricated and mounted on a steel base for easy installation.
FAHC	Fletcher Allen Health Care main hospital campus
Flue Gas	The hot combustion gases exhausted from a boiler via the flue gas stack.
Flue Gas Condenser	A heat recovery device that extracts heat from the flue gas as it leaves the boiler. The heat extracted is sufficient to cause the temperature of the flue gas to be reduced to the point that water vapor in the flue gas condenses into liquid.
Flue Gas Economizer	A heat recovery device that extracts heat from the flue gas as it leaves the boiler. A limited amount of heat is extracted such that the vapor in the flue gas remains vapor rather than being condensed to liquid.
Heat Pump	Machine used to increase the temperature of a low temperature heat source to a temperature that can be used for heating purposes through the use of external higher-grade energy, such as electricity or steam.
Heat Exchanger	A pressure vessel that contains plates or tubes and allows the transfer of heat through the plates or tubes from the district heating system water to the building heat distribution system. A heat exchanger is divided internally into two separate circuits so that the district heating system water and the building heat distribution system fluids do not mix.
Hot Water Supply and Return Lines	The district heating system piping that distributes hot water for heating purposes to customers (supply) and returns the cooler water to the plant for reheating (return).
Hot Deck/Cold Deck	A type of air handling unit used in older multi zone systems or dual duct HVAC systems. The air stream is split into two separate ducts and either heated or cooled by a coil. The air is then blended, right at the unit outlet in a multi-zone system or at the terminal unit in a dual-duct system. The system is currently

	considered energy inefficient.
kWh (kilowatt-hour)	A kilowatt-hour is normally a measure of electric energy. kWh_{te} refers to thermal energy that equals 3,413 Btus expended over one hour.
LTHW (Low Temperature Hot Water)	As used in this report, a low temperature hot water distribution system operating at less than 180°F supply temperature.
MW (megawatt)	A megawatt is normally a measure of electric capacity and equals 1,000 kilowatt. MW_{te} refers to thermal capacity equal to 3.413 MMBtu/hour.
MWh (megawatt-hour)	1,000 kilowatt-hours or 3.4 MMBtu.
MMBtu (million Btu)	Unit of measurement for thermal energy equal to one million Btu.
MMBtu/hour (million btu per hour)	Unit of measurement for thermal capacity equal to one million Btu per hour.
MTHW (Medium Temperature Hot Water)	As used in this report, a medium temperature hot water distribution system operating at less than 250°F supply temperature.
Non-diversified Load	The sum of the peak loads of individual users. This is a theoretical maximum system peak load.
PEX (Cross linked polyethylene)	Cross linked polyethylene plastic pipe and/or tube used in LTHW systems.
PSIA (pounds per square inch, absolute)	A measure of pressure from an absolute reference rather than being adjusted for atmospheric pressure.
PSIG (pounds per square inch, gauge)	A measure of adjusted for atmospheric pressure.
Service lines/piping	The segment of the district heating distribution system that extends from the main lines to the inside of the customer building. The service line is typically sized to meet the peak hot water flow requirements for the individual building served by the piping.
Steam Extraction	Steam that is diverted from a turbine to be used for heating purposes before its full energy and temperature have been utilized by the turbine.
Study Buildings	Buildings identified by the Collaborative to be included in this study.
Terminal Equipment	Heating equipment such as heating coils, radiators, unit heater, or air handling units that transfer heat from water to the building air.
Thermal Energy	Energy in the form of heat.
Thermal Storage	A tank or similar device filled with water that has been heated in order to retain thermal energy for later use.
UHC-FAHC	University Health Center, The old DeGoesbriands Hospital owned by UVM and operated by FAHC.
UVM	University of Vermont

Energy Supply

In order to evaluate the economic viability of the proposed CES, Ever-Green reviewed the present and historical costs for natural gas and biomass in Burlington.

Natural Gas

Supply

Vermont's sole gas supply is delivered from the Trans-Canada Pipeline system through a single interconnection point at the Philipsburg Gate Station. Natural gas production in the northeastern United States rose from 2.1 billion cubic feet per day (Bcf/d) in 2008 to 12.3 Bcf/d in 2013. This trend has increased the supply and reduced the cost of natural gas in the Northeast. The EIA projections do not include any shortages like those experienced in 2005 and 2008 when prices spiked. The surplus and regional environmental incentives have contributed to the greater use of natural gas as a fuel, especially for power generation, and reduced the net inflow of natural gas into the northeast region from the Gulf of Mexico, the Midwest, and eastern Canada.[2]

Rates

Natural gas is supplied to customers in Vermont solely through Vermont Natural Gas, a regulated public utility. There are several options for purchasing gas, depending upon customer's annual load. Rates are structured so that larger users typically pay a lower unit rate for energy than smaller users. Gas contracts can be purchased through firm service rates or through interruptible service rates with floating commodity costs. All rates are subject to review and approval from the Vermont Public Service Board and rate adjustments are made annually to adjust for changes in the energy marketplace. Vermont present gas rates and a five-year average are summarized in Table 1.

Vermont Gas Delivered Rates ($/MMBtu)		
Rates	Present (2013)	5-Yr Average
R	$ 11.8559	$ 13.3826
G1	$ 11.0592	$ 12.4563
G2	$ 9.9566	$ 12.3043
G3	$ 9.7739	$ 11.2568
G4	$ 7.8519	$ 9.3077
Interruptible	$ 5.5281	$ 6.3600
Note:		
(1) Present rates from 11/1/13 rate schedule.		
(2) Interruptible rate will vary monthly with commodity cost. Present Rate is for December 2013.		
(3) Interruptible Rate for large volume contracts. Rates R, G1, G2, G3, G4 are published fixed rate contracts.		

Table 1. Vermont Gas present and historic rates

[2] U.S. Energy Information Administration | Short-Term Energy Outlook December 2013, P. 6-7.

As the supply of natural gas increases, there is a downward pressure on the commodity price. The oversupply has depressed the natural gas commodity price and has forced rates down from highs experienced in 2005 and again in 2008. The EIA historic pricing for the Henry Hub spot market presented in Figure 2 reflects historic commodity price fluctuations of natural gas. As the Henry Hub is located in Louisiana, a transportation charge is added to the commodity cost to move the gas from the Henry Hub to the customer and the transportation charge is proportional to distance from the Hub. As Figure 2 shows, the commodity price of natural gas has declined from the five-year average and is presently trading at a lower cost than the five-year average.

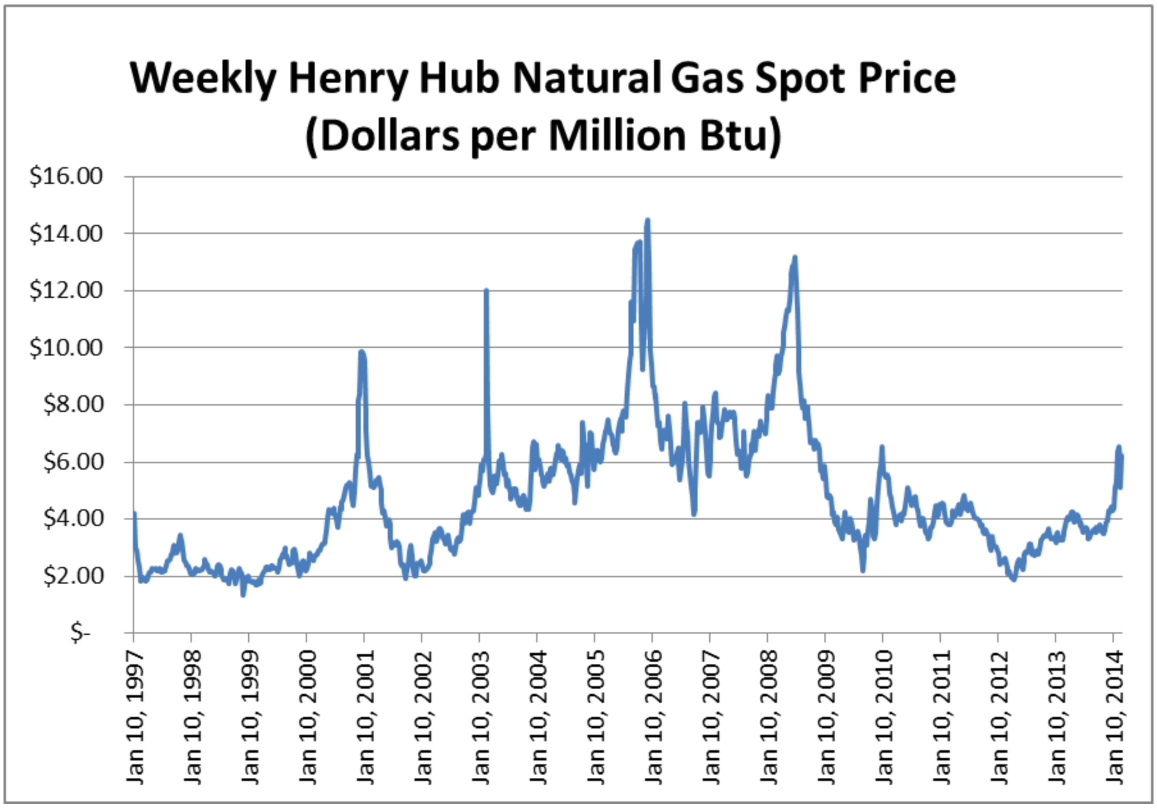


Figure 2. US natural gas spot market prices (source: EIA Henry Hub Spot Market Price)

Based on discussions with Vermont Gas, large volume interruptible customers should anticipate a slight increase in the average delivered cost of gas in 2014 and firm price customers in accordance with published rates. The December 2013 rate for interruptible gas was approximately $5.53/MMBtu delivered. This price reflects an increase in the commodity cost plus the impact of the recent tariff adjustment that moved the gas purchase point from the Empress Hub to the Parkway Hub. The point of purchase was approved by the Public Service Board and added to the Vermont Gas rates beginning November 1st. The 2013 average delivered natural gas rate for large interruptible customers of $4.92/MMBtu was used for purposes of modeling the CES presented in this report. Note that the natural gas market experienced significant volatility during the winter of 2014 and gas rates escalated above the anticipated thresholds to accommodate a sudden increase in the cost of natural gas. Interruptible customers were notified of steep cost increases due to supply constraints. This is discussed further in the section on volatility on page 17.

Biomass

Supply

Woodchips combusted at McNeil are presently harvested from managed forests in the form of forest residuals as a byproduct of logging activities and can be comprised of smaller diameter trees, tree tops and limbs, tree trimmings, stems, dead standing trees, and downed logs. A mature regional production and supply chain to furnish wood chips is already established to deliver the chips to end users.

The energy content of woodchips varies depending upon the moisture and ash content. Both moisture and ash content can vary depending on the origin, handling, and storage of the raw material. The moisture content of woodchips typically varies between 35% and 55%. The average energy content of the woodchips delivered to McNeil is approximately 10.5 MMBtu per ton.

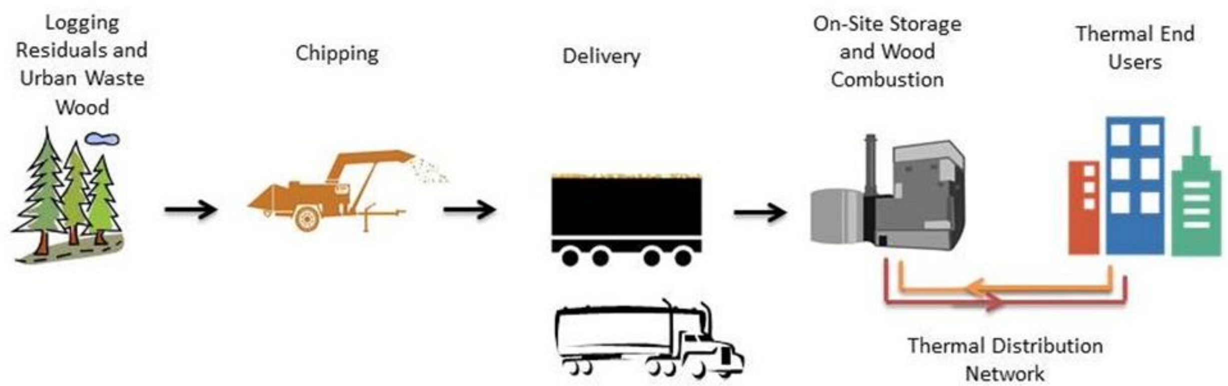


Figure 3. Typical biomass flow model

Rates

Woodchip costs usually depend on such factors as the distance from the point of delivery, the type of material, demand, and how the fuel is transported. McNeil receives approximately 75% of the woodchip fuel via railcar and 25% via truck. While railcar delivery is more expensive than delivery by truck due to the double handling of woodchips during rail transportation, the local community benefits by reduced truck traffic on local streets. The woodchips combusted at McNeil are sourced and harvested within a 60 mile radius from the Swanton railcar loading terminal and a 60 mile radius from McNeil for truck deliveries. McNeil's wood is harvested in a sustainable manner and the supply is secure for the foreseeable future. The pricing has been very stable over the last five years with variances based primarily on higher transportation fuel costs.

The five-year average cost for woodchips delivered to the plant is $3.34 per MMBtu.

Rate Volatility

The energy market in the northeast historically experiences seasonal and annual pricing fluctuations. These price fluctuations may be anticipated or unanticipated depending upon global markets. Historically the cost for fossil fuels tends to be fairly volatile compared to other energy sources. Figure 4 presents the 15-year average delivered cost for natural gas and biomass energy in the Vermont region. The graph indicates that biomass delivered to McNeil has averaged approximately \$2.97/MMBtu over the past fifteen years and the price has been relatively stable from year to year. Natural gas tripled in price from 2000 to 2006 followed by a consistent annual decline in cost from the 2008 peak to present with a fifteen year average cost of \$5.77 per MMBtu.

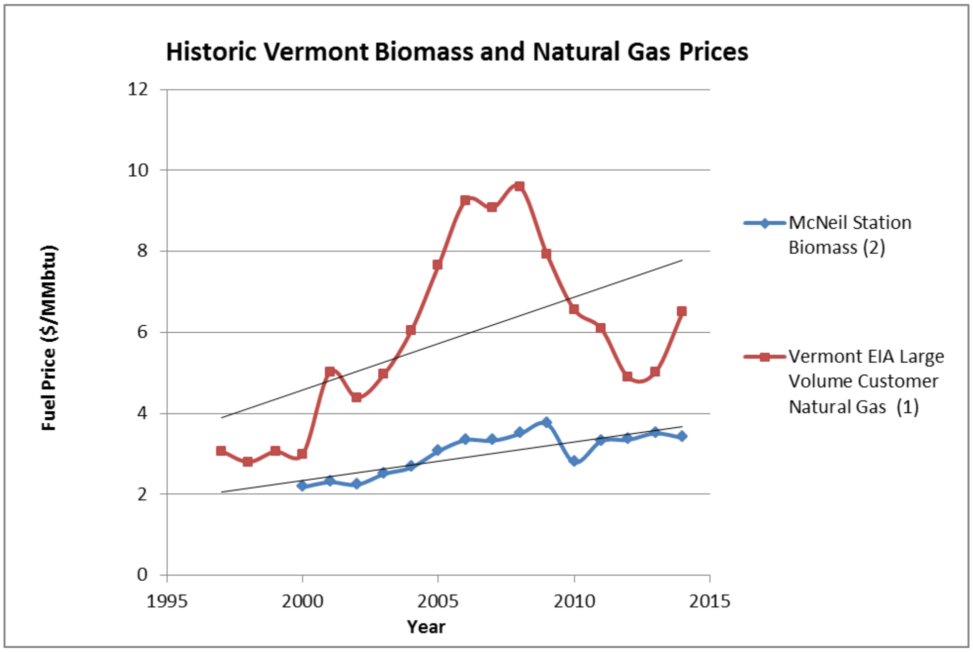


Figure 4. Historic energy rates (2014 average rate based on present natural gas futures market)

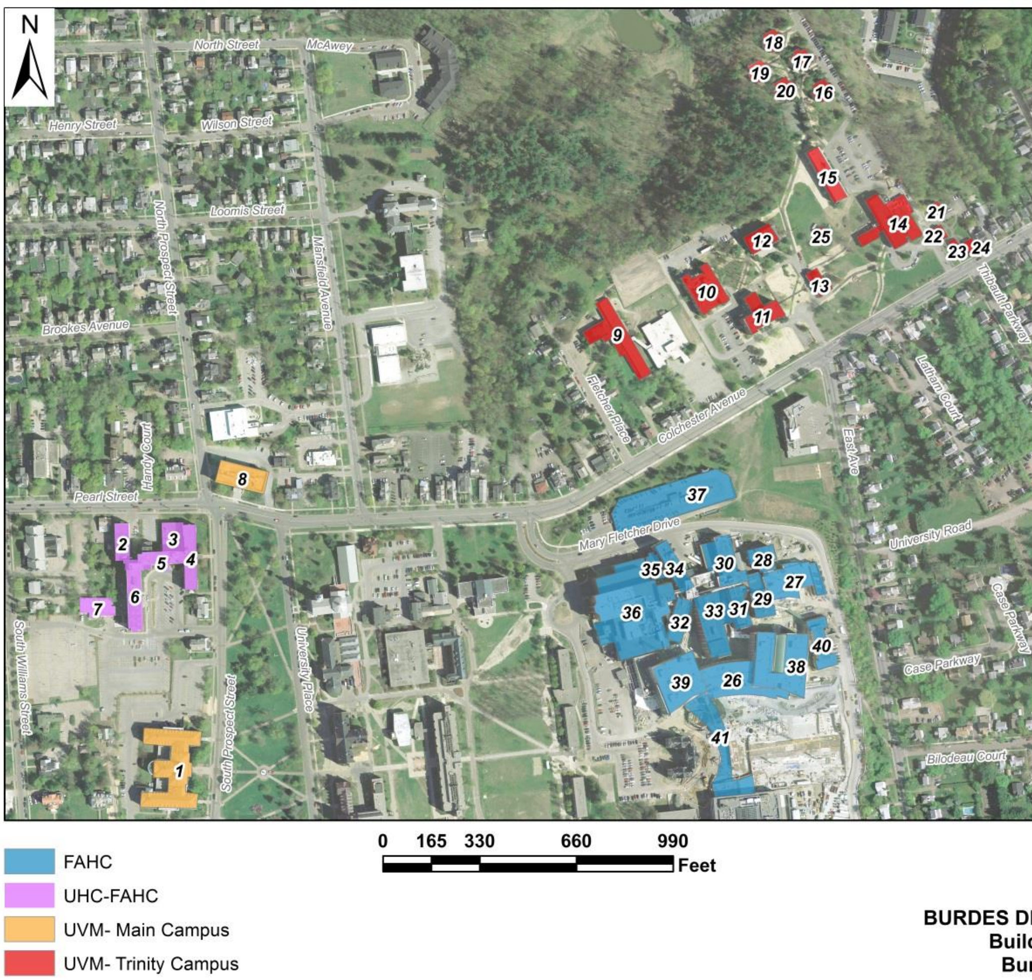
The winter of 2014 has proven to be highly volatile for natural gas prices. Cold winter weather, increased use of natural gas for power generation, and pipeline delivery constraints have increased the pricing volatility for natural gas. Interruptible customers in Vermont saw prices spike and reach as much as \$40 per MMBtu, with daily customer rate approval required due to the sudden high price of natural gas. The EIA reported that the trend of high natural gas prices is anticipated to continue and generate market increases throughout New England due to capacity constraints on the pipeline system and increased use of natural gas for power generation[3]. During the past two winters, New England natural gas winter prices have risen significantly. The average bid-week natural gas price reached a high of \$14.52/MMBtu for December 2013 and more than \$20/MMBtu for January 2014. The report concludes that the price volatility and supply constraints in New England will continue into the foreseeable future, particularly in the periods of the year when heating needs are high and gas consumption is the greatest. Present futures market projections for Vermont indicate an interruptible rate of \$6.51/MMBtu in the 2014/2015 heating season.

[3] EIA Report Issues and Trends: Natural Gas, "High prices show stresses in New England natural gas delivery system", Released: February 7, 2014, http://www.eia.gov/naturalgas/issuesandtrends/deliverysystem/2013/

Customers

General

As part of the evaluation process for a CES, the proposed customer loads required review and evaluation to properly size the system. Ever-Green surveyed and collected data for the buildings identified by the Collaborative as part of this study. Site visits to each building were completed over a four day period in October 2013. The purpose of the site visits was to evaluate the building loads, the type and condition of existing heating systems, the general condition of the buildings, and meet with building maintenance staff to discuss building operation. A summary of the buildings internal distribution system is included in Appendix B. In order to evaluate the overall thermal demand for a district system, Ever-Green reviewed three years of gas consumption data furnished by the end users for individual buildings or for entire campuses when a campus is served by a central boiler plant. Figure 5 presents the buildings included as part of this study.



Bldg_ID	Building Name
0	McNeill Station
1	Waterman
2	Rehabilitation
3	Clinic
4	Old Hall
5	St Joeseph's Pavillio
6	Arnold Pavillion
7	Boiler House
8	Dew ey Hall
9	Ira Allen
10	Delhanty
11	Mann Hall
12	Farrell Hall
13	The Villa
14	McAuley Hall
15	Mercy Hall
16	McCann Hall
17	Hunt Hall
18	Ready Hall
19	Sichel Hall
20	Richardson Hall
21	Cottage 1
22	Cottage 2
23	Cottage 3
24	Cottage 4
25	Boiler Plant
26	Main Pavilion
27	Central Plant
28	Fletcher
29	Engineering
30	Shepard North
31	Shepard South
32	Smith
33	Baird
34	Patrick
35	Mod B
36	McClure
37	Parking Garage
38	East Pavilion
39	West Pavilion
40	Garden Pavilion
41	Education Center

BURDES DISTRICT ENERGY STUDY
Building Location Plan
Burlington, Vermont

Figure 5. Building inventory map

UVM

Waterman

Waterman Hall is a mixed use masonry building containing offices and classrooms and was originally constructed in the early 1940s. It is listed on the National Register of Historic Places. The building is heated by steam, with boilers located in the basement. A packaged 6.4 MMBtu/hour boiler is used as the lead boiler to generate 15 psi steam for space heating and domestic hot water. Domestic hot water is generated by two domestic hot water heat exchanger skids. One of the two original 9.5 MMBtu/hour boilers is still used to meet peak demand and the other is abandoned in place. A pressure regulation station in the boiler room reduces the 75 psig steam to 15 psig steam for distribution in the boiler room and building. Perimeter radiation is supplied by cast iron steam radiators with local temperature control valves. There are several older air handling units with steam coils for reheat located throughout the building. The building is zoned and controls are a combination of electronic and pneumatic. The building is on interruptible gas service with oil back-up.

It is reported by the UVM operation staff that the steam and condensate piping system has corroded and requires replacement. The cost to replace the building's internal heating distribution system will be significant.

Dewey Hall

Dewey Hall is a mixed use masonry building containing offices, classrooms, and laboratories. It was originally constructed in 1905. It also is listed on the National Register of Historic Places. The building contains two 2.3 MMBtu/hour boilers generating 10 psig steam in the ground floor mechanical room. The boilers were replaced in 2011 when the mechanical room was reworked. Perimeter heating is provided by fin-tube hot water radiation supplied from the heat exchangers located in the mechanical room. Domestic hot water is provided by two hot water heaters with steam coils and electric backup. There are several cage washers and an autoclave supplied with steam from the boilers and located in laboratories that were not accessible during the site walk. The building is controlled by a Johnson Controls system located in the mechanical room. An air handling unit supplies make up air and is located in a closet adjacent to the auditorium. The building is on interruptible gas service.

Trinity Campus

The Trinity campus consists of 17 buildings. There are several dormitories, a geology building, a preschool building, and two classroom buildings. The buildings range in construction types from wood-framed to brick and vintages from the late 1800s to the 1980s. There is a central hot water boiler plant located in the center of the campus that presently serves three of the buildings: Farrell, McAuley, and Mercy Halls. There are two gas-fired boilers installed with a capacity of 6.3 MMBtu/hour each in the central plant. Internal heating systems for the other buildings vary from electric heat in the 'back five' dormitories (building numbers 16-20) to a hybrid system in Delhanty. Other buildings have their own hot water and steam boilers for heating supply. Domestic hot water in the buildings consists of gas fired units that are in the process of being replaced with ultra-high efficiency units. Ever-Green walked through all of the buildings on the Trinity Campus with the exception of The Cottages and The Villa, which were not accessible during the visit. The buildings are on various gas service rates depending upon each building's end use.

University Health Center

UHC is owned by UVM and operated by FAHC. The facility consists of six interconnected buildings originally named The DeGoesbriand Hospital. The original hospital was constructed in 1924 with several additions from 1940 through the 1960s. The buildings construction type is predominately masonry with a newer international style Rehabilitation Building constructed of glass and steel. Most of the windows are single pane glass. The buildings are served by a central boiler plant containing one 1972 6.7 – 16.7 MMBtu/hour modulating boiler and one 1953 3.5 MMBtu/hour dual-fuel boiler. Steam is generated at 30-40 psig and distributed to several mechanical rooms where heat exchangers serve perimeter hot water radiation loops. Domestic hot water is furnished by steam-heated heat exchangers in the winter and by local, ultra-high efficiency domestic hot water heaters in summer months when boilers are shut down. There are several small air handling units throughout the facility with steam coils to heat makeup air. Saint Joseph's building contains a hot deck/cold deck air handling unit. The Clinical Building contains heat pumps with a core loop. The boilers are old and maintenance personnel indicated that they are scheduled for replacement in the near future. The campus relies on interruptible gas service with #2 fuel oil as a backup fuel. The campus is generally occupied from 7 am to 7 pm.

Fletcher Allen Health Care Campus

Opened in 1879, the Medical Center Hospital of Vermont, formerly Mary Fletcher Hospital, is the largest hospital in Vermont. Construction has occurred continuously throughout the hospital's history with building ranging from the 1879 original Fletcher building to the Pavilion wings added in 2007. The facility contains 630 beds and there are approximately 3,000 people in the complex at any given time. The hospital today consists of 16 interconnected buildings served by a central boiler plant. The plant produces steam at 90 psig for distribution to the various buildings. The boiler plant contains five boilers able to provide a peak load capacity of 74 MMBtu per hour. Boilers are fired primarily on natural gas with #2 fuel oil as a backup fuel. The boiler plant is well maintained and continuously improved to maintain capacity and efficiency. The steam is distributed throughout the facility to local mechanical rooms overhead and through a series of underground tunnels. The local mechanical rooms contain steam to hot water heat exchangers to provide heating for domestic hot water and perimeter radiation. Hospital staff reported that there are ten domestic hot water generators located throughout the facilities' mechanical rooms.

The internal heating systems vary greatly depending upon each building's construction date. The newest Ambulatory Care Center (ACC), built in 2007, contains several large steam to hot water heat exchangers and air handling units located in penthouses. Hot water is generated for perimeter radiation and reheat as well as domestic hot water. The McLure Building (1985) contains a large hot deck/cold deck air handling unit that is scheduled for replacement with hot water terminal units to improve efficiency within the next few years. The Baird Building contains heat pump units and a core loop. A project to increase make up air to Baird and install heat recovery was in progress during the site visit and one of the two penthouse air handling units was also being upgraded. Both penthouses in Baird contained steam to water heat exchangers for domestic hot water. Shepardson and Baird have some remaining ceiling panel steam heaters. Shepardson South contained heat exchangers on each floor to serve air handling units. Patrick and Smith Buildings have PTAC (steam heat) units on the west walls and steam radiators on the east wall. The Fletcher Building contained heat exchangers serving air handling units located in the attic space.

Process loads in the hospital appear to be limited to humidification, some small kitchen loads, and a sterilization facility known as the CSR. The sterilizer was not inspected during the site visit but is reported to use eight to ten thousand pounds of steam per hour with condensate discharged to the sewer.

The heating systems were operating during the site walks. It was common for steam heated buildings to be overheated in certain areas and under-heated in other areas. Several of the end users expressed frustration with the level of comfort. Some of the older steam heating systems were installed when the buildings were initially constructed and have not been retrofitted.

The materials of construction vary with the age of the building. Older buildings are masonry and newer buildings are masonry and curtain wall. Single pane glass is common in the older buildings. A large utility tunnel runs along the south side of the ACC and contains space for district energy piping from McLure to the East Pavilion. Other utility tunnels were noted extending from the Patrick P32 mechanical room. The utility tunnels could provide access corridors to install hot water district heating pipes.

FAHC is continuously implementing energy efficiency improvements for the hospital campus. A heat recovery wheel is being added to the roof of the Baird building to recover the waste heat from the exhaust air to heat the incoming make up air. Flow meters are installed on the fuel oil lines to the boilers and on the steam lines to better track energy flow throughout the facility. The burner and controls on the 20 MMbtu per hour Johnston boiler were replaced with a higher efficiency unit with improved controls to manage and track energy consumption. The preliminary engineering for improving the efficiency of the McLure building hot deck/cold deck is also in progress.

FAHC is planning an expansion to the hospital. Their plan is to submit an application to the state for review and approval in early fall of 2014. Construction could begin in late 2015 with expected occupancy in 2018. Design has not progressed to a stage where building internal mechanicals would be identified, so this potential load has not been included in the model presented in this study. Adding this building to the CES, however, would further improve the economic and environmental benefits of the system.

Building Loads

Ever-Green calculated the loads for each of the study buildings based on fuel gas consumption data furnished by each facility operator and information gathered during the site visit. Fuel gas consumption for each building or campus facility for 2010, 2011, and 2012 was normalized to account for annual fluctuations in temperature and averaged to determine the normalized fuel gas consumption for each. The heat output from the boiler was then calculated with an assumed boiler efficiency of 75%. This existing building load is presented in Table 2. The complete building load inventory is included in Appendix C.

Existing Estimated Building Loads by Campus			
	Building Area	Estimated Building Peak Demand	Estimated Building Annual Energy Usage
	(sf)	(MMBtu/hr)	(MMBtu/Yr)
FAHC Hospital	1,494,394	76	190,000
UVM	234,603	10	20,000
UHC-FAHC	249,830	5	12,000
Trinity Campus	268,556	8	17,000
Totals:	2,247,383	99	239,000

Table 2. Existing estimated system loads

Connection to a CES

In order to be able to receive district energy service from the CES, many of the mechanical rooms of the surveyed buildings and central plants will require some modifications. The Team has identified a medium temperature hot water system as the preferred medium of energy transfer for the Burlington CES. As such, the following section provides a summary of the building conversions that would need to occur for the study buildings, along with the estimated costs of conversion.

Building Conversion

General

Based on Ever-Green's building surveys, conversion of the study buildings to hydronic systems has been found to be technically feasible. The majority of the buildings surveyed contain heat exchangers to convert steam to hot water for the perimeter radiation or they contain a complete hot water internal distribution system. In addition, several of the steam heated buildings should be readily convertible to operate on a hot water system through fairly simple conversion processes. A summary of projected conversion costs is provided in Table 3.

Converting the heating equipment throughout these buildings from steam to hot water will improve the efficiency of those buildings along with the comfort level experienced by the occupants. Hot water heating systems can operate at lower temperatures while consuming less energy. Hot water systems operate with lower heat losses and eliminate losses from condensate trap operation and other control losses. With the addition of controls on fans and radiators, the heating systems will respond better to the building loads and improve occupant comfort.

Building Interface with CES

Customer buildings could be connected to the CES with a short underground service lateral from the main distribution system to an energy transfer station located in each building. The energy metering, controls, and heat exchangers are commonly known as the energy transfer station. There are two types of connections in a district energy system, direct and indirect. A direct system connects the buildings distribution piping directly to the service lateral and an indirect connect system contains a heat exchanger to isolate the building's mechanical system from the district energy system. Direct connect systems offer the advantage of lower first cost as the heat exchanger is omitted. The disadvantage of a direct connect system is the potential for a problem to propagate from one building, creating an impact on the entire system. Direct connect systems are more common for cooling rather than heating systems and is not being considered for the Burlington CES. The energy transfer station consists of simple components that perform basic operating functions with limited moving parts. For heating applications, one or more heat exchangers are installed to transfer the thermal energy from the CES to the building heating and domestic hot water systems. A Btu meter is installed to measure and record the amount of energy that is delivered to the customer. A modulating control valve precisely regulates the amount of energy that is transferred by varying the water flow rate to the energy transfer station, depending upon the actual building demand.

Building Conversion

Transitioning buildings to receive hot water rather than steam will differ for each building depending upon the configuration of their existing mechanical systems. The objective is to reuse as much of the existing mechanical system as possible to minimize conversion costs. Buildings with central forced hot air, hydronic systems, two pipe steam systems, unitary heat pumps with a core loop, and new or proposed buildings designed to support a CES connection are all good candidates for conversion. One pipe steam systems are not convertible without major renovations. For purposes of this study, buildings have been classified in one of the categories listed below.

Hot Water Buildings

Buildings with internal hot water mechanical systems are the easiest buildings to convert to hot water district energy service. The conversion will be an indirect connection from the CES distribution system to the building system. This will require minor plumbing modifications, installation of the energy transfer station, and connection to the building system. Domestic hot water heat exchangers will need to be added to separate the district system from the domestic system, and double walled heat exchangers may be required by state building codes. Most of the existing buildings included in this study with internal hot water distribution service could be converted to hot water district energy service with relative ease, with modifications limited to the mechanical rooms of the buildings.

Steam Buildings

Buildings using steam service utilize steam for space heating in radiators, finned tube radiation units, cabinet unit heaters in entryways, and heating coils in ductwork or air handling units. In some cases, these systems can easily convert to hot water by completing minimal alterations at radiator control valves and utilizing existing piping systems, if in good condition and capacity is adequate. Piping and radiators will require pressure testing to verify that they are compatible with hot water system operating pressures. The major modification work should be confined to the basement or mechanical room to connect to a hot water system and adding temperature controls to regulate the building supply temperature. This will require minor plumbing modifications, installation of the energy transfer station, and connection to the district energy system. Domestic hot water heat exchangers will need to be added to separate the district system from the domestic system. Double-walled heat exchangers may be required by state building codes.

Conversion Cost

In estimating conversion costs for this study, Ever-Green categorized the building conversions into three levels of complexity: easy, moderate, and complex. Easy conversions are buildings that are presently heated by internal hot water distribution systems where modifications will be fairly limited. Moderately difficult buildings will require replacement of some of the buildings piping and air handling unit coils, along with conversion of existing radiators from steam to hot water operation. Complex buildings will require complete renovation of all mechanical system internals. All buildings are assumed to require indirect connection. Conversion estimates are calculated on a square footage basis and are based upon Ever-Green's past experience converting similar types of buildings.

Waterman

Waterman Hall will require an internal building conversion from steam to hot water to operate on a hot water based CES. Ever-Green believes that the building could conceivably be converted to operate on hot water fairly economically; however UVM representatives reported that the existing steam system has leaks and replacement is warranted. To connect to the CES, the present radiators would be replaced by fan coil units with a two-pipe heating and (future) cooling distribution system. The interior spaces would be served from central fans with heating and cooling coils serving VAV boxes. The building would likely require staged construction over several years if vacating is not possible.

Dewey

Dewey Hall contains steam boilers but the internal heating system is hot water. UVM representatives report that the steam is necessary for animal cage pressure washers and an autoclave. These loads could not be verified as the labs were not accessible. However, the steam is generated at 10 psig in the boiler room, which correlates to a saturated steam temperature of 240^0F. As the CES would operate at 240^0F in the winter months and 190^0F in the summer, it is possible that the cage washer can be served by a medium temperature hot water system if the cage washing can be accomplished with 180^0F hot water. The autoclave will likely require localized steam service or replacement with an electric autoclave. As the building is presently served by heat exchangers to generate hot water for space heating and air handling units use hot water, conversion can be accomplished by running service lateral piping into the mechanical room and connecting the supply and return hot water headers to an energy transfer station. Boiler equipment could be kept in operational condition at the discretion of the customer.

Trinity

The Trinity campus is comprised of multiple buildings operating with various types of mechanical systems. Mercy, Ferrell and McAuley are presently connected to a central hot water boiler plant and this will require a rather basic conversion at the boiler room. Ira Allen School and the Mann Hall are presently served by low pressure steam from on-site boilers. These buildings could be easily converted, with the internal distribution systems being pressure tested and reused for the hot water heating system. Steam traps internals will need to be removed and a valve or orifice will need to be added for balancing. Delhanty is a mix of hot water perimeter radiators, make-up air warmed by hot water and furnaces in the air handling units, and reheated by heat pumps and a core water loop. This building will require a supply and return header run up to the penthouse mechanical room through the existing chase for connection to hot water loops. Apart from running the headers up to the penthouse, this building should be easily converted. McCann, Hunt, Ready, Sichel, and Richardson Halls are all electric heat and will require complete mechanical system replacement, which are assumed to be fintube radiators with exposed piping. Since the conversion of the buildings requires replacement of internals, Ever-Green carried a conversion cost of $100,000 per building for the 'back five'. The other buildings on the campus were not available for inspection during the site walks and were not considered for conversion. The boiler at Trinity would need to be maintained in operating condition as backup for the system in the event that McNeil's biomass boiler is down.

UHC-FAHC

The University Health Center will be relatively easy to connect to a hot water system since much of the building is already served by hot water. The building is presently served from a central steam boiler plant that connects to several mechanical rooms. The two mechanical rooms located at or below the ground floor contain steam to hot water heat exchangers and centralized hot water piping that serve the perimeter radiators. There are additional smaller mechanical rooms located in the higher floors of the building that will require some piping modifications. An energy transfer station could be added in the boiler room and connection to the other mechanical rooms will require repurposing the steam pipe to supply hot water to ground floor mechanical rooms. The condensate return lines appear to be of adequate size to return the hot water to the energy transfer station. The upper mechanical rooms will require repurposing of the headers to supply hot water to the existing AHU coils.

FAHC

FAHC has expressed a specific desire to maintain redundant energy systems to the proposed CES. The existing steam boiler plant will remain in place and operational. In order to convert buildings to a hot water CES, a hot water distribution loop could be installed around the hospital through steam tunnels and direct burial in other locations. This loop will be fed from the CES or alternately, when the CES service is interrupted, the loop will be fed from a steam to water heat exchanger in the hospital's mechanical room. As buildings are converted to hot water internal distribution, they will be connected to the hot water loop and as the steam system load diminishes, boilers can be shut down. Buildings with hot water internal systems can be connected immediately.

The lateral connection from the loop to the building distribution system will be made in the existing basement mechanical rooms. It is assumed that the piping laterals will be run from the external loop to each of the mechanical rooms through existing tunnels, chases or overhead and connected to the existing building internal distribution system. The East and West Pavilion mechanical rooms are in the penthouse and will require conversion of existing steam risers or installation of new risers to carry the hot water to the penthouse. Other buildings with internal steam systems can be converted to hot water by connection to the main steam risers and condensate returns in the buildings. The conversion will require planning and coordination to implement but overall should be relatively easy to complete on a building by building basis.

Summary of Conversion Costs

The conversion of the buildings identified in this report will require: the installation of a service lateral, the installation and connection of an energy transfer station, and the conversion of internal systems to accept hot water. Table 3 summarizes the estimate of probable conversion costs for the project. Table 3 also includes an estimate of the replacement cost of the existing boiler equipment as a comparison.

	Service Laterals	Building Conversions	Energy Transfer Station	Equipment Replacement	Conversion (2)
FAHC Hospital	$ 125,000	$ 1,583,000	$ 617,000	$ 1,887,000	A
Trinity Building[1]	$ 346,000	$ 891,118	$ 198,000	$ 683,000	A
Dewey Hall	$ 141,000	$ 40,000	$ 73,000	$ 143,000	A
Waterman	$ 138,000	$ 4,029,000	$ 187,000	$ 415,000	C
UHC-FAHC	$ 44,000	$ 269,000	$ 168,000	$ 397,000	A
Totals:	$ 794,000	$ 6,812,118	$ 1,243,000	$ 3,525,000	

Notes:
1) Trinity service lateral cost includes PEX piping from FAHC mechanical room to the Trinity boiler room and to the individual buildings not currently connected. Estimated $500,000 conversion cost of McCann, Hunt, Ready, Sichel, and Richardson Hall (the back five) is included.
2) Conversion Complexity Rank: A - Easy; B- Moderate; C- Difficult

Table 3. Estimate of building conversion costs

Projected Load

To determine the building load on a hot water based system, all non-convertible process loads that require temperatures greater than 250° F and steam system distribution losses were deducted from the current boiler output. Non-convertible loads were found to be the cage washer, autoclaves, sterilizers at the hospitals, minimal kitchen equipment, and humidification. These loads were based on estimates furnished by building operators and, if equipment information was not available, calculated from ASHRAE load tables. Non-convertible process loads like sterilizers, autoclaves, and steam humidification will require a small steam supply if the buildings are converted to operate with a medium temperature hot water system. The next phase of development should include an evaluation of whether some of these devices could operate at lower temperatures. In campus settings, where a central boiler plant is currently serving multiple buildings, the total boiler production less non-convertible loads and distribution losses was allocated to each building based upon the ratio of the building area. Steam system losses were estimated to be 15% based on Ever-Green's operational experience. These losses include condensate losses, control losses and thermal losses through the insulation. Efficiency improvement gains in selected buildings were also deducted from the hot water system loads to account for the current owner's proposed efficiency improvement projects. Loads for the proposed CES hot water based system are summarized in Table 4.

Projected CES Hot Water Loads by Campus			
	Building Area	Estimated Building Peak Demand	Estimated Building Annual Energy Usage
	(sf)	(MMBtu/hr)	(MMBtu/Yr)
FAHC Hospital	1,494,394	48.8	120,000
UVM	234,603	8.2	16,000
UHC-FAHC	249,830	4.1	9,000
Trinity Campus	268,556	6.8	14,000
Totals:	2,247,383	68	159,000

Table 4. System loads for hot water community energy system

Future Customer Expansion

During the completion of this study, Ever-Green identified buildings that could be served by the CES system development. Potential buildings were identified based on building size, the proximity to the pipeline corridor, and load density. While not included in the findings of this report, it is likely that a number of additional buildings could be added to this proposed system to improve the economics of the system and enhance the environmental benefits for the community.

Buildings Adjacent to the Distribution Route

Additional potential loads adjacent to the proposed pipeline are shown in Figure 9. These loads include buildings along Mansfield Avenue, College Street, and Champlain College. The proposed loads were identified based primarily on square footage and close proximity to proposed distribution line routing. These loads will require additional review and vetting to determine load size and economics of connection to the system.

UVM

Based on discussions with UVM, there are multiple candidates for future expansion of a hot water system on campus. Buildings along Colchester Avenue include the Billings Lecture Hall, the Mansfield House, Perkins Hall, and the Fleming Museum. The proposed STEM project also presents an opportunity for CES hot water expansion as the proposed project will create or rebuild 300,000 sq. feet of science and technology classroom and lab space around Votey Hall. These buildings are believed to have hot water internal heating systems and are located adjacent to the proposed pipeline route.

Downtown

In 2011, Ever-Green completed a study including a load analysis to serve the downtown area. The loads were presented as Alternative 1 and Alternative 2 in the report. Alternative 1 contained loads in the Burlington's North End and Alternative 2 was the downtown business core. The total estimated downtown load from the 2011 report is summarized in Table 5.

	Route		Customer Load	Diversified Load
	From	To	MMBtu/hr	MMBtu/hr
Alternative 1	McNeil	Pearl Street	38	31
Alternative 2	Pearl Street	Main St	50	32
Total			88	63

Table 5. Downtown loads (extracted from the 2011 Ever-Green study)

These downtown loads are not included in the results of this study but they should be taken into consideration and further evaluated prior to implementation of the CES so that future potential expansion may be accounted for when deciding upon the proper size of the main distribution system leaving McNeil.

Distribution

There are two primary options to deliver thermal energy from McNeil to the study buildings, steam distribution or hot water distribution. Modern district heating systems are predominately constructed with hot water as the distribution media due to the simplicity, lower cost, safety, efficiency, and flexibility of the system. The benefits and drawbacks of both systems, along with recommendations, are provided below.

Steam Distribution

Steam district heating systems are common in the United States for cities, corporate campuses, and college campuses. Steam may be supplied at various pressures and temperatures. 150 psig pressure and 365° F supply temperature is a fairly common system design and would function well for a CES to furnish thermal energy to the study buildings. Steam systems provide thermal energy at higher supply temperatures than hot water systems. This is usually found in older buildings constructed with less sophisticated building envelopes. New construction and retrofitted buildings with tighter envelopes and better insulation typically do not require higher supply temperatures, unless there are specific process applications requiring higher temperatures.

Steam district energy distribution systems are more complex to construct and install than hot water systems and typically cost more per unit of delivered energy. The distribution system is generally welded steel pipe with a steam supply and condensate return. The piping is installed inside a casing pipe or in tunnels and expansion loops are required to accommodate the thermal expansion of the piping.

Maintenance of steam systems is more complex and more costly due to steam and air trap maintenance and the corrosive nature of the condensate returned for reuse. Equipment such as air vents and condensate traps are required at regular intervals and traps are required at all low points to drain condensate from the piping system.

Steam can be extracted from the McNeil plant turbine for cogeneration purposes. The extraction of steam would occur at a higher pressure for a steam-based distribution system than it would for a hot water system. This will reduce the power generation output from McNeil and reduce the overall efficiency of the CES.

Hot Water Distribution

A medium temperature hot water system could operate at a peak supply temperature of 250°F with a design differential temperature between supply and return of 90°F. The system generally operates at the peak supply temperature when the system load is at its maximum level; typically when the outside air temperature is at the design temperature for Burlington. The supply temperature normally has a sliding reset down to a minimum temperature of 180° F at a 40° F outdoor temperature. This outdoor air temperature reset schedule serves four primary purposes (1) to minimize the distribution pipe size required to meet peak loads since each gallon of water delivered for peak carries more thermal energy due to the higher temperature, (2) to reduce the pumping energy required to deliver sufficient flow to the customers during peak usage conditions, (3) to minimize the loss of heat through the insulation during off-peak operation since the lower supply temperature reduces the heat loss, and (4) increase the utilization of low-temperature heat sources.

Pre-insulated piping systems are commonly utilized in hot water distribution systems. The system consists of a thin-wall steel carrier pipe, polyurethane foam insulation, and a high-density polyethylene (HDPE) jacket. This system has demonstrated useful life of more than 50 years when properly installed and maintained. Heat loss is very low and the system requires minimal maintenance. This piping system also includes a detection system that can provide early warning of moisture in contact with the outside of the steel pipe to allow the problem to be addressed before the system is impacted by exterior corrosion. Valves can be direct-buried, which reduces the infrastructure required for valve chambers and underground vaults. This system also has the benefit of requiring limited provisions for thermal expansion, which simplifies installation. Lower operating temperatures also allow for the use of lower-cost plastic piping technologies, including PEX.

Hot water district heating pipes are typically placed underground at a depth of approximately three feet from the top of pipe to the ground surface. Figure 6 provides a typical section of hot water pipe installation. With structural protection, a more shallow installation for portions of the route can also be accomplished. Installation deeper than three feet underground, unless the depth is required to avoid other utilities in the area, is usually not necessary as cost of installation increases with increased trench depth.

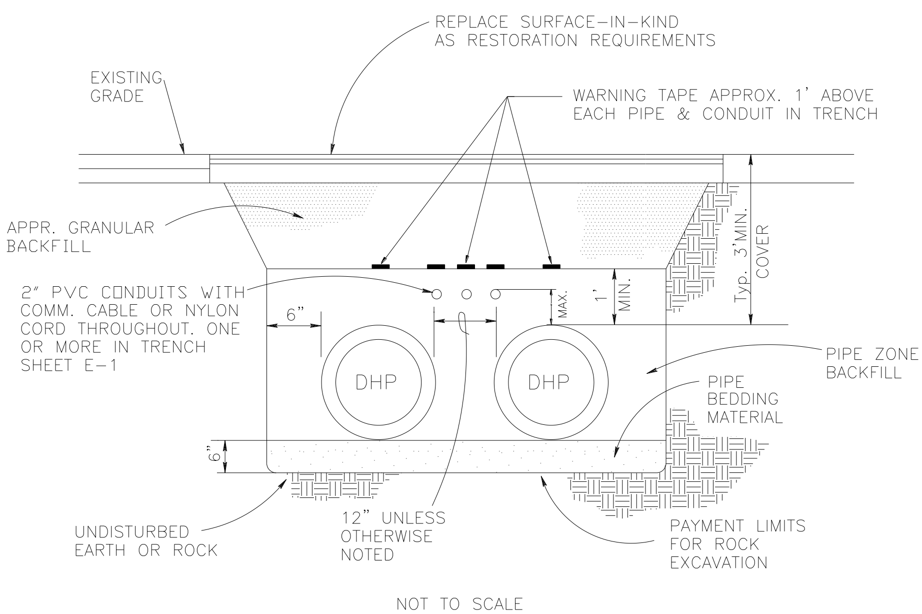


Figure 6. Typical hot water district energy system trench section

Distribution System Recommendation

The US Army Corp of Engineers Cold Regions Research and Engineering Laboratory (CRREL) researched and compared the performance of low and medium temperature hot water distribution and steam distribution systems on military bases. Their findings are published in the report titled "Efficiency of Steam and Hot Water Heat Distribution Systems." The report concludes that low temperature hot water systems have lower capital costs, lower maintenance costs, better performance and efficiency, a higher level of safety, better temperature control for end users, and offer more flexibility to incorporate low value thermal sources from alternate energy sources and emerging technologies. CRREL conclusions are aligned with the findings in this report.

Lower grade heat can be used to supply the thermal energy to district energy systems. In the case of heat supply from McNeil, this system could be fed primarily with heat recovery from stack flue gases which provides high overall system efficiency and is the most economical source of heat for the district system. The remainder of heat for the system can be fed from lower pressure turbine extraction, which improves the overall cogeneration process and maximizes the power output before the steam is extracted for thermal use.

Based on Ever-Green's experience operating and evaluating steam and hot water based distribution systems, a medium temperature hot water system is the appropriate choice for a CES in Burlington. A medium temperature hot water distribution system offers the highest merit for providing thermal energy to the individual buildings and campuses. A medium temperature hot water based CES operating at a design supply water temperature of 250°F at peak conditions and 180°F in the summer, with a design return temperature of 160°F offers the highest level of efficiency at the lowest operating and capital cost. The system will be on a reset schedule for reasons discussed previously. Overall the system will provide the safest, most flexible, and lowest life-cycle cost option to provide thermal distribution to the community.

McNeil Pipeline Alternatives

Proposed Alignment Alternatives

As part of the evaluation to serve the study buildings with district heating from McNeil, Ever-Green reviewed several route alignments to generate preliminary pipeline cost estimates. District energy systems typically are routed in the public right of way adjacent to potential building loads. Distribution piping is commonly installed in the street, under pedestrian sidewalks, in the grassy area between sidewalk and curb, or between traffic lanes. Green areas are preferred for installation of underground utilities since the disruption to traffic is minimized and the cost of restoration is usually lower than paved or concrete surfaces. For purposes of this study, three route alternates were studied to determine the preferred alignment. The topography and location of the study building loads constrains the options to routing along North Prospect Street, a partial cross country route to Trinity Campus, and an alternate along Willard Street. The proposed pipeline alignment alternatives for the initial phase of the project are presented in Figure 7.

North Prospect Street: This alignment follows Intervale Avenue to North Prospect Street, and then runs adjacent to Mansfield Avenue branching at Colchester Avenue to serve the study loads. The railroad will likely require a bored and cased installation in its right of way. The crossing of Riverside Avenue will be challenging due to traffic count and possible utility congestion and a bored and cased crossing may provide the best alternative. The hill on North Prospect is a topographic choke point and will require review to determine optimal alignment as utility congestion is likely. Several potential loads are located along North Prospect that should be evaluated for connection to the system. Installing the distribution pipe along North Street and Mansfield Avenue will provide the potential for service to larger building loads and it will reduce congestion along North Prospect Street during construction. Construction complexity is projected to be moderate with a significant portion in the public right of way.

Trinity Campus Overland Alternate: This alternate route follows Riverside Avenue to Hildred Drive and then adjacent to Hildred Drive and up the bluff to the Trinity Campus boiler house where the system would then follow the base alternate to serve the remaining study buildings. The advantage of this route is that a portion of the route can be installed in undeveloped areas along Hildred Drive and up to the Trinity Campus and avoid the congestion and traffic along North Prospect. The cost to install pipeline in undeveloped green space can be 20-30% less expensive than installation in congested urban neighborhoods. The section of construction up the steep bluff to the Trinity Campus could prove challenging due to the steep erodible slopes that would be disturbed by conventional open cut methods. As an alternative, the section up the bluff could be directionally drilled to avoid disturbing the slope. Construction complexity is estimated to be moderate to high with a portion in the public right of way and a short directional drill or steep slope construction.

North Willard Street Alternate: A third possible alignment is to route piping to the south from McNeil, across the rail road line, transit the adjacent privately owned parcels to intersect, and follow Riverside Avenue for a block. The alignment then turns and parallels North Willard Street turning east and following Pearl Street to the study buildings located at top of the hill. The railroad will likely require a bored and cased installation in its right of way. An easement will need to be acquired to cross the open lot and slope and possibly for the public housing development. Once on Riverside Avenue, the proposed pipeline will be constructed in the public right of way. Traffic on Riverside, North Willard and Pearl Street is anticipated to be heavy during peak hours. Construction complexity is estimated to be moderate with a significant portion in the public right of way.

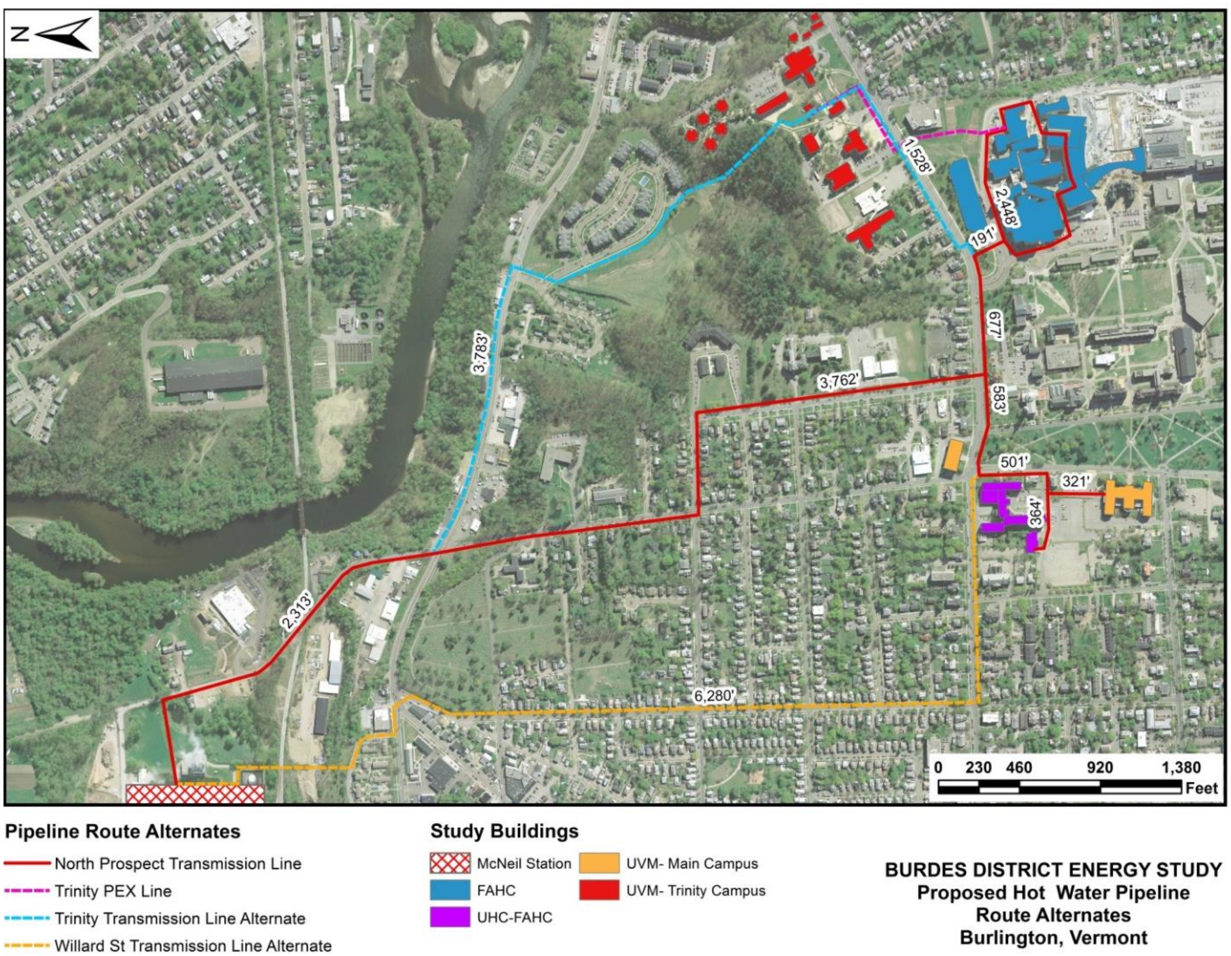


Figure 7. Hot water pipeline route alternates

Estimate of Probable Costs

Based on the proposed alignments, a probable cost estimate was generated for each of the route alternatives. Construction difficulty is believed to be moderately complex for all options with each alternate presenting unique challenges. Table 6 presents the estimate of probable cost for each routing alternate, including a 25% contingency. The hot water system estimates are based on a pre-insulated system supplied in forty-foot lengths and joined by welding in the field. The pre-insulated pipes typically have a wall thickness equal to approximately schedule 10, polyurethane insulation and a high density polyethylene an outer jacket. The main distribution pipes leaving the plant will be 10-inch diameter steel pipes with an outer diameter, including insulation and jacket, of 16 inches. The pipe sizes will be reduced to match downstream load. One section of pipe between FAHC and Trinity campuses will use PEX rather than steel pipe, with the ETS for Trinity located in the FAHC mechanical room.

Distribution System Alternates Estimate of Probable Cost			
Route Alternate	*Trench Feet*	*$/Foot*	*Total*
North Prospect Street	12,542	$ 843	$ 10,572,188
Trinity	12,015	$ 927	$ 11,141,125
North Willard Street	12,747	$ 854	$ 10,886,500

Table 6. Distribution pipeline estimates of probable cost

Based on the alignments evaluated for the hot water distribution system, the North Prospect Street alignment is the preferred alternate based upon estimated installed cost and additional potential customer loads on Mansfield Avenue that could be served by the CES, reinforcing the economics of this route selection. If the planned system expansion to downtown becomes a more heavily weighted selection criterion, the North Willard Street option may prove more attractive due to proximity to the downtown business district. Since this study is focused on FAHC and UVM as anchor customers, the North Prospect street alternate is preferred. This preferred route may change once discussions with Burlington Public Works occur.

Figure 8 shows the preferred alignment, pipe lengths, and proposed pipe sizes between branches. Pipe sizes are indicated in parentheses. For purposes of the evaluation, the piping is sized to supply only the study building loads. Expansion of the system would require larger pipe sizes and final sizing and alignment should be reevaluated during the next phase of system development. It has been assumed that there is physical space available in the alignments shown to accommodate the proposed facilities.

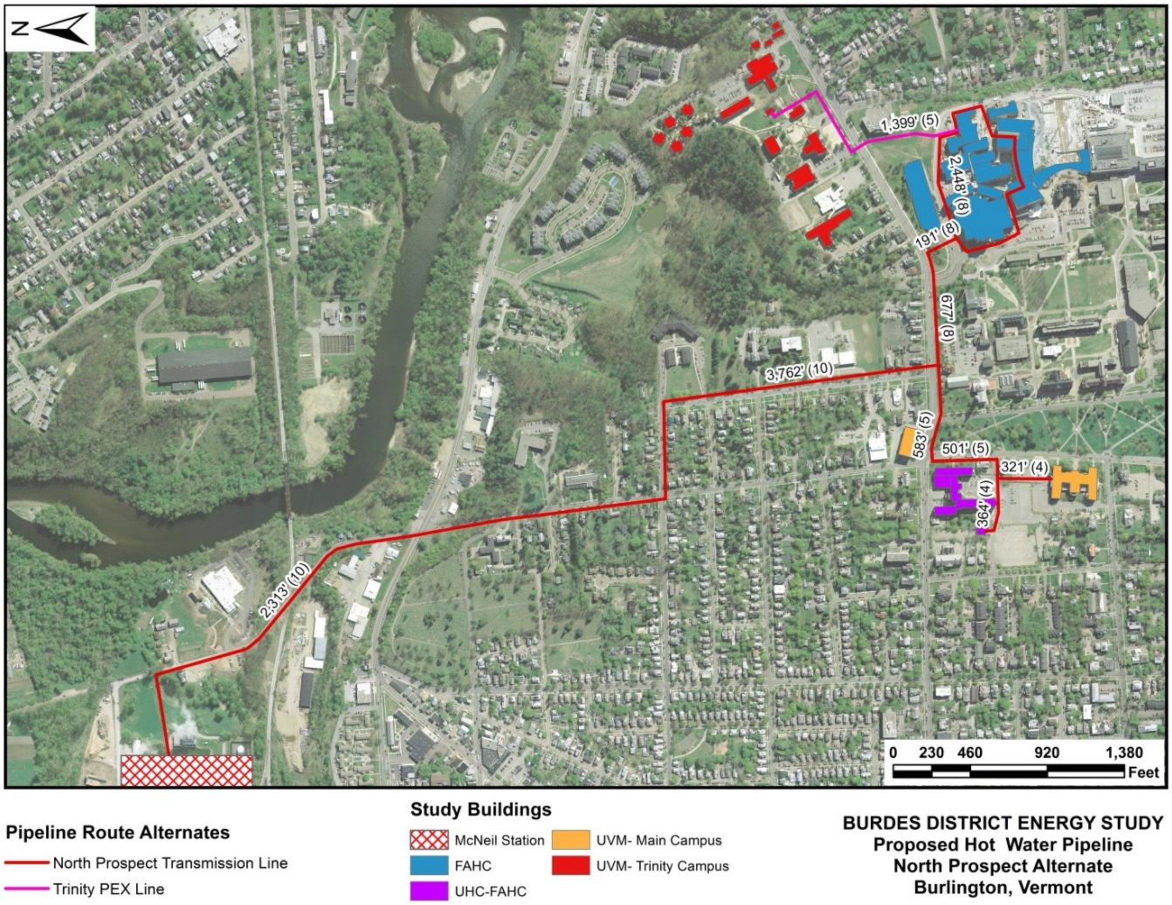


Figure 8. Least cost alignment - Prospect Street alternate

FAHC Loop

Fletcher Allen Health Care Hospital is the regional flagship hospital for Northern Vermont. The building presently contains a central boiler plant supplying steam to the buildings on its campus. To convert the facilities internal distribution system from steam to hot water and allow for the sequential conversion of the buildings, a perimeter hot water loop can be installed outside of the building footprint and in existing tunnels. This loop will be operated in parallel with the existing steam system and will provide the necessary flexibility to convert the hospital gradually over to hot water-based district energy.

Existing Utilities

Pipeline installation cost is directly related to the level of construction effort. In order to select an open corridor for pipeline routing during the design phase, the proposed pipeline alignment alternates are reviewed with maps of existing utilities. Coordination with Burlington Public Works was not possible during this phase of study. The recommendations presented in this report will need validation from Public Works prior to proceeding to the next phase of development.

System Growth

The basis of this report is to evaluate the construction and implementation of a CES connecting the study building loads to McNeil. Expansion of the system will extend the benefits of the system to other customers. System development begins with connection of large anchor customers that elect to participate in the CES. Once the service is established, development can first occur adjacent to the distribution pipeline and as the confidence in the system increases, the system can expand beyond the original limits, reaching new customers and additional service areas. For the Burlington CES, the anchor loads are considered to be the study buildings. Figure 9 presents one possible system expansion scenario that includes potential customers in the downtown area, the hospital expansion, Champlain College, and facilities adjacent to the proposed distribution pipeline alignment. Additional growth on the UVM campus to buildings presently not connected to the UVM steam system is also possible. Desired expansion will need to be closely evaluated during the next phase of system development to determine a prudent level of investment in the distribution network via oversizing of lines and expansiveness of the network.

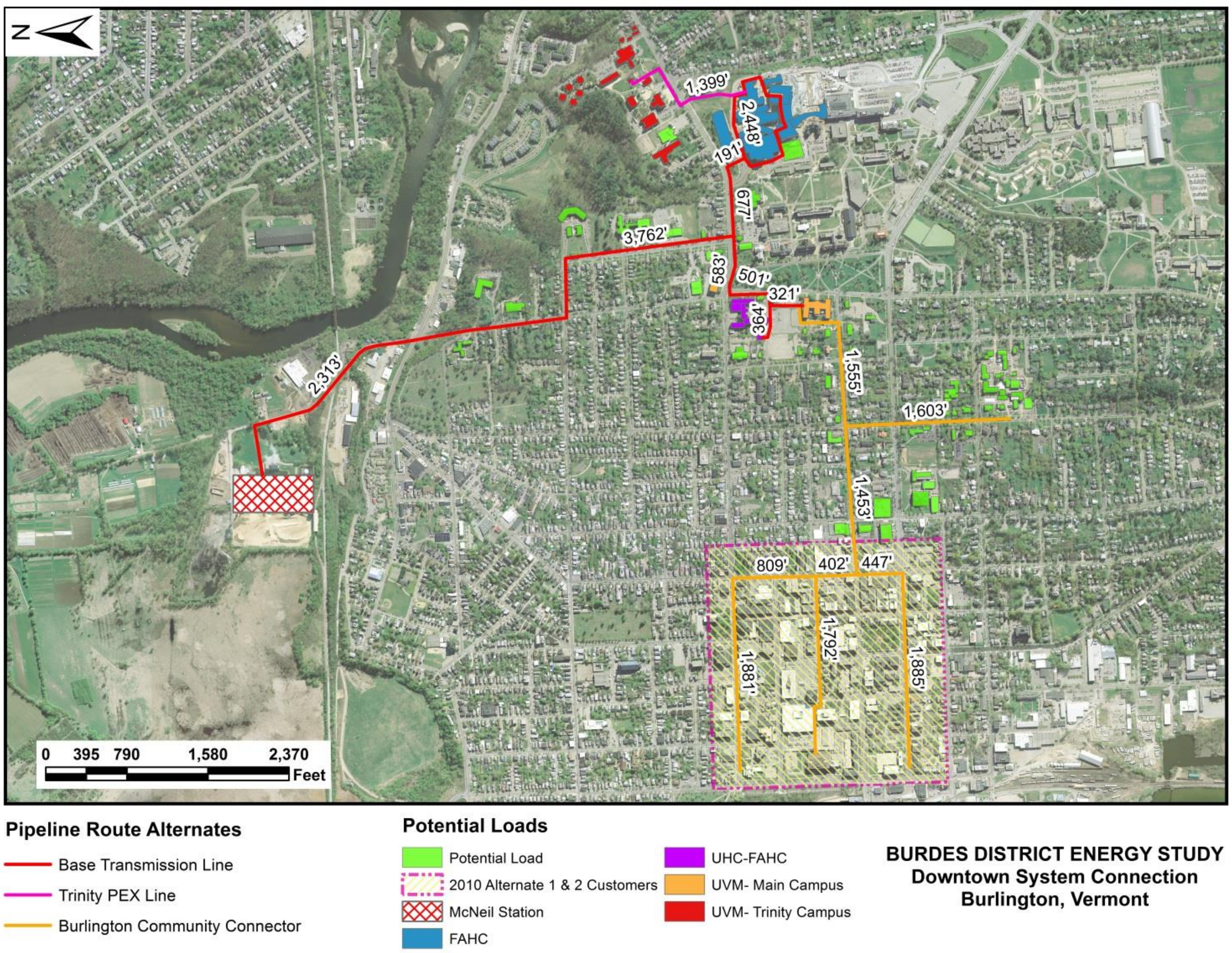


Figure 9. Downtown pipeline expansion

Production

General

McNeil Generating Station is a 50 MW net biomass (wood-fired) electric generating station located in Burlington's Intervale. It is connected to the New England power grid (NE-ISO) and its ownership is divided between Burlington Electric Department (50%) and other Vermont utilities (50%). The plant design incorporated cogeneration with approximately 100 MMBtu/hr of heat extraction being supplied from the turbine to serve the CES. Additional thermal supply is available from stack gas heat recovery and potentially from extraction through other ports on the turbine. Currently, McNeil does not utilize the designed cogeneration potential and discharges the low-grade thermal energy from the cold condenser to the atmosphere without any further benefit.

Heat Supply from McNeil

Heat supply configuration at McNeil was evaluated with a goal of maximizing the use of renewable thermal energy from the biomass boiler while keeping capital and energy costs as low as possible. Two possible options have been evaluated based upon findings in the 2011 Ever-Green report.

For Option 1, the heat production system consists only of a heat exchanger that transfers heat to the hot water distribution system from steam extracted from the McNeil steam turbine. Based on the assumption that McNeil will continue to operate 24 hours per day, seven days per week, a thermal storage system is not included. Except for planned or forced outage periods, all thermal energy would be provided through steam extracted from the steam turbine. The remaining thermal energy to the system would be provided by two natural gas-fired (with fuel oil backup), 14 MMBtu/hr hot water boilers also installed on the McNeil site. Those boilers would be sufficiently sized to provide the capacity needed for the full system during normal planned outages and 100% of the capacity needed for UVM during peak conditions. At a forced outage during peak winter conditions, UHC and UVM will be provided with heat from McNeil's backup boiler, while FAHC and Trinity would be utilizing their own boilers for backup.

In Option 2 a flue gas economizer is employed in conjunction with steam extraction from the McNeil turbine. The flue gas economizer captures heat that would otherwise be exhausted to the stack as waste heat. The resulting energy price is very low and consists solely of the cost of capital and maintenance on the economizer. No additional fuel is consumed at McNeil to supply heat through this economizer, yet more than 50% of the annual demands of the Burlington system could be derived from this low-cost flue gas heat recovery. The remainder of the thermal energy would be supplied from extraction from the McNeil turbine (approximately 46% of the total heat to the system) and natural gas/fuel oil from a pair of backup 14 MMBtu/hr natural gas-fired (with fuel oil backup) boilers (4% of the total heat to the system).

Option 1: Steam Extraction

Steam can be extracted from the existing steam turbine at five different pressures, although electric generation loss is lower at lower extraction pressures (i.e. extraction at a point after which the steam has been used to produce more electricity). For a medium temperature hot water system as proposed for Burlington, the optimal extraction pressure is approximately 35 psia in order to achieve the design maximum temperature of 250°F for the CES without utilizing peaking boilers.

The cost of energy to the district heating system based on extraction from the existing steam turbine is assessed in Tables 7 and 8 (see also Appendices D and E). The thermal energy price in the tables is based on the lost power revenue compared to normal condensing power production. The Coefficient of Performance (COP) for the steam extraction varies from 2.4 for admission steam to 10.6 for port 1. With a mix of extraction from ports 3 and 2, to be able to achieve a 250°F district heating supply temperature, the thermal energy price will be in the range of $4.10/MMBtu to $6.90/MMBtu based on an electricity price of $80/MWh. The steam turbine is, however, designed to be able to supply steam from ports 4 and 5 and the quantity of steam that can be extracted from ports 2 and 3 requires additional evaluation by the turbine manufacturer to determine the available amount. It is Ever-Green's experience that additional extraction is typically available after detailed analysis by the manufacturer.

It should be noted that the extraction COP is calculated on gross electric output. If calculated on net electricity sold to the grid, the COP would increase and the cost for steam extraction would theoretically decrease. However, an associated cost for plant auxiliary electricity usage attributable to the steam extraction would then have to be added to the cost for the extracted steam. Both methods will yield similar results and are merely alternatives for how the extracted steam can be priced.

During part-load operation, McNeil has excess steam capacity available and steam can be used directly from the boiler to generate thermal energy for the CES. Thermal energy generated in this scenario is priced only for the additional fuel usage. Based on a biomass price of $37.00/ton and a boiler efficiency of 70%, the thermal price based on fuel usage would be $5.00/MMBtu (see Table 9).

McNeil at 50,000 kW gross								
	Inlet	Extraction					Condenser	Total
		5	4	3	2	1		
Steam pressure (psia)	1265	392	208	86	13.0	3.9	1.0	
Steam temperature (F)	950	660	522	356	206	152	101	
Enthalpy steam (Btu /lb)	1,468	1,342	1,280	1,206	1,082	1,021	963	
Saturation temp (F)	574	443	385	317	206	152	101	
Enthalpy water (Btu /lb)	581	422	359	287	174	120	67	
Extraction steam flow (lb/hr)	11,529	26,449	25,116	28,948	19,009	9,574	291,411	
Steam flow to next stage (lb/hr)	400,621	374,172	349,056	320,108	301,099	291,525	114	
Gross power (kW)		14,803	6,770	7,606	11,687	5,324	4,950	51,140
Gross power per lb/hr steam (W)[1]	148	111	93	71	35	17	0	
Gross power per lb/hr steam (W)[2]	128	97	85	69	34	17	0	
DH per lb/hr steam (Btu/lb)[3]	1,059	933	871	797	672	612	554	
DH per lb/hr steam (W)	310	273	255	234	197	179	162	
COP DH extraction[2]	2.4	2.8	3.0	3.4	5.8	10.6		
DH energy price ($/MMBtu')[4]	9.6	8.3	7.8	6.9	4.1	2.2		

Notes

1) Only based on enthalpy difference from port to condenser without compensation for preheater steam flow

2) With compensation for preheater steam flow based on turbine heat balance

3) DH condensate enthalpy 410* Btu/lb. *DH condensate enthalpy based on boiler feedwater enthalpy after HP preheater.

4) At electricity price 80.0 $/MWh

5) The 11,529 lb/hr labeled as "extraction steam flow" at the turbine inlet is the sum of 2,578 lb/hr in "dummy piston leakage steam" flow, 8,351 lb/hr in "dummy piston relief" flow and 600 lb/hr in "ejector steam" flow according to BBC's turbine balance.

6) In the calculations of the system performance, it has been assumed that steam will be extracted from port 4 to a steam to hot water heat exchanger but the thermal energy price is based on additional fuel usage cost at $5.00/MMBtu.

Table 7. Cost of steam extraction - McNeil at 50,000 kW gross

McNeil at 25,000 kW gross								
	Inlet	Extraction					Condenser	Total
		5	4	3	2	1		
Steam pressure (psia)	1265	199	107	45	7.0	2.3	1.0	
Steam temperature (F)	950	570	445	294	177	132	101	
Enthalpy steam (Btu/lb)	1,468	1,307	1,250	1,182	1,067	1,014	984	
Saturation temp (F)	574	381	333	275	177	132	101	
Enthalpy water (Btu/lb)	581	355	304	244	144	100	67	
Extraction steam flow (lb/hr)	6,629	11,695	11,341	11,774	9,071	892	164,573	
Steam flow to next stage (lb/hr)	209,428	197,733	186,392	174,618	165,547	164,655	82	
Gross power (kW)		9,888	3,288	3,728	5,909	2,554	1,444	26,810
Gross power per lb/hr steam (W)[1]	142	95	78	58	24	9	0	
Gross power per lb/hr steam (W)[2]	128	86	73	57	24	9	0	
DH per lb/hr steam (Btu/lb)[3]	1,123	962	905	837	721	669	639	
DH per lb/hr steam (W)	329	282	265	245	211	196	187	
COP DH extraction[2]	2.6	3.3	3.6	4.3	8.8	22.4		
DH energy price ($/MMBtu')[4]	9.1	7.1	6.5	5.4	2.7	1.0		
1) Only based on enthalpy difference from port to condenser without compensation for preheater steam flow								
2) With compensation for preheater steam flow based on turbine heat balance								
3) DH condensate enthalpy 346 **Btu/lb.** ***DH condensate enthalpy based on boiler feedwater enthalpy after HP preheater.***								
4) At electricity price 80 $/MWh								
5) The 6,629 lb/hr labeled as "extraction steam flow" at the turbine inlet is the sum of "dummy piston leakage steam" flow, the "dummy piston relief" flow and "ejector steam" flow according to BBC's turbine balance.								

Table 8. Cost of steam extraction - McNeil at 25,000 kW gross

Total Wood Fuel Cost 2013	**37.00**	**$/ton**
Heat Content	10.556	MMBtu/ton
Boiler Efficiency	70%	
Thermal Energy Price	5.0	$/MMBtu
Gross Steam Turbine Heat Rate	8,531	Btu/kWh
Electrical losses and aux.	15%	
Net Plant Heat Rate	14,337	Btu/kWh
Power Energy Price	50.3	$/MWh

Table 9. Steam price based on fuel cost and boiler efficiency

Option 2: Flue Gas Economizer

A flue gas economizer has been evaluated as a primary heat source to the district heating system. The economizer is the one option for low-grade heat recovery at McNeil that does not require a heat pump to make the waste heat useable by the CES.

While a flue gas economizer does not have the same dramatic effect on flue gas conditions as a flue gas condenser would, the impact of this cooling of the flue gas on stack exit conditions must be fully evaluated. McNeil completed an ambient air quality model and analysis in August of 2011 to evaluate the effect of reduced stack gas temperature from thermal recovery. The model was run at temperatures down to 140^{o}F to determine if there was an impact on regulated emissions. The model results indicated that compliance with National Ambient Air Quality Standards and Hazardous Ambient Air Standards for all heat recovery scenarios. This report is included as Appendix G. Stack emission dispersion modeling results and McNeil's air permit may require updating if a flue gas economizer is deployed.

Figure 10 shows the potential heat recovery in a flue gas economizer depending on flue gas exiting temperature and boiler load. The flue gas will start to condense at a certain temperature, depending upon moisture content in the fuel and the excess air. Based on 45% fuel moisture content and 6% excess air for the McNeil plant the flue gas will start to condense at approximately 140°F. At full load the flue gas exit temperature from the boiler is approximately 330°F and at 25% load 280°F.

By reducing the flue gas temperature to 212°F, approximately 20 MMBtu/hr could be recovered at 100% plant load and 5 MMBtu/hr at 25% plant load. With an assumed 160°F return temperature in the district heating system, the outlet temperature from the flue gas economizer would be approximately 190°F at 20 MMBtu/hr heat recovery and full distribution flow. The system temperature would then be increased in the steam heat exchanger to up to 250°F, depending on heating load. Since the potential output from a flue gas economizer is heavily dependent on the dispatched capacity of McNeil as shown in Figure 10, the steam extraction equipment will need be sized to provide almost the entire district heating system capacity. In the following calculations, a relatively low-cost economizer has been assumed with a maximum output of 15 MMBtu/hr and an average capacity of 12 MMBtu/hr. Even at the relatively low capacity, equal to about 20% of the peak heating demand, the economizer will be able to provide about 50% of the energy required for the system (see Figure 11). The size of the economizer should be optimized in the next phase of the CES development based on heating load and dispatch of McNeil.

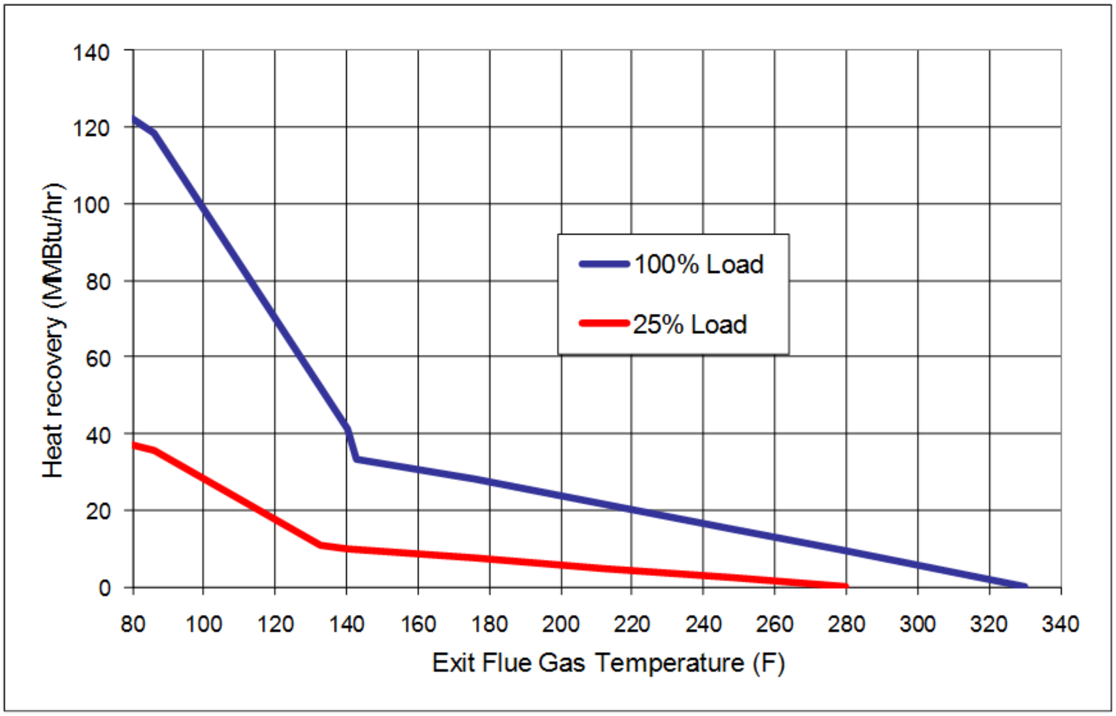


Figure 10. Flue gas heat recovery potential as a function of exiting flue gas temperature and plant load

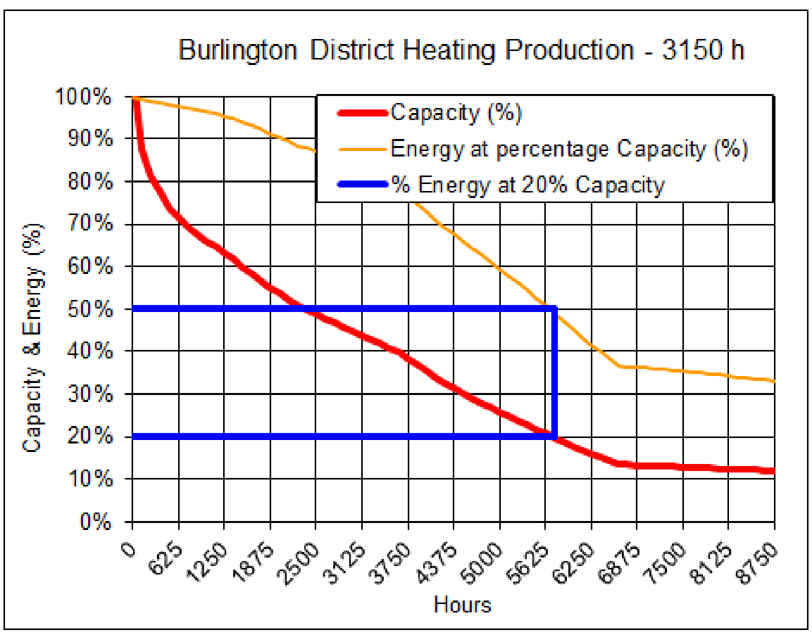


Figure 11. Burlington load duration and energy curve

Hot Water Storage

Hot water storage could be used to maximize the amount of cogenerated renewable energy derived from the McNeil biomass boiler. In a hot water application, the use of storage helps to level the customer load profile between night and day, which reduces the dependence on expensive peaking boilers that operate on fossil fuels. If McNeil would be cycled on and off, thermal storage would also be able to cover heat demand during off periods. When McNeil is operating, the customer's demand for heat is met using extraction or flue gas recovery (depending on the selected option) and, at the same time, heat is stored in the thermal storage system for use when it is offline. This enables the CES to be supplied with renewable energy from McNeil even when it is not currently in operation. The storage of this heat also minimizes the amount of natural gas and/or fuel oil that is needed to supplement the system energy demands.

The thermal storage system for a hot water system is generally an atmospheric tank. As such, hot water would be stored at a temperature of approximately 200°F. The system temperature would then be increased in the steam heat exchanger up to 250°F, depending on system heating load.

While McNeil is assumed to continue to operate 24/7, a thermal storage has not been considered in this model. Changes in the dispatch of McNeil or increasing district heating demand could however justify an installation of a thermal storage tank.

Capital Cost

Tables 10 and 11 summarize the necessary production equipment and probable cost estimates for the two proposed options. A P&ID for the option with a flue gas economizer is provided in Appendix F. In each option, provisions have been made in the capital costs for a building to house the production and thermal energy conversion equipment at McNeil. It is likely that a preferred location would be in an unused area at McNeil in order to minimize the length of piping required to connect the production system components, however this should be further researched during the next phase of CES development.

	Size		Units	Unit price	Total
Package hot water boiler	14	MMBtu/hr	2	140,000	$280,000
Steam heat exchanger	55	MMBtu/hr	1	230,000	230,000
Flue gas economizer	15	MMbtu/hr	0	2,000,000	0
Hot water storage tank	2,500,000	gal	0	2,000,000	0
Distribution pumps	1,500	gpm	2	30,000	60,000
Steam turbine extraction modifications			1	100,000	100,000
Piping & insulation			1	470,000	470,000
Valves, strainers, etc			1	140,000	140,000
Oil transfer pumps			2	5,000	10,000
Oil storage tank above ground w/ containment	5,000	gal	0	45,000	0
Water softener incl installation			1	15,000	15,000

Chemical feed equipment incl installation			1	4,000	4,000
Insulated stack w/ breeching	60	ft	1	120,000	120,000
Transformer/MV switchgear			1	100,000	100,000
Motor control centers w/ installation			1	150,000	150,000
Controls			1	87,500	87,500
Building	7,000	sq.ft	7,000	150	1,050,000
SUBTOTAL					2,816,500
Engineering	10%				281,650
Contingency	25%				774,538
TOTAL					$3,872,688

Table 10. Production equipment summary and estimate of probable cost for Option 1 (Steam extraction)

	Size		Units	Unit price	Total
Package hot water boiler	14	MMBtu/hr	2	140,000	$280,000
Steam heat exchanger	55	MMBtu/hr	1	230,000	230,000
Flue gas economizer	15	MMBtu/hr	1	2,000,000	2,000,000
Hot water storage tank	2,500,000	gal	0	2,000,000	0
Distribution pumps	1,500	gpm	2	30,000	60,000
Steam turbine extraction modifications			1	100,000	100,000
Piping & insulation			1	620,000	620,000
Valves, strainers, etc			1	180,000	180,000
Oil transfer pumps			2	5,000	10,000
Oil storage tank above ground w/ containment	5,000	gal	0	45,000	0
Water softener incl installation			1	15,000	15,000
Chemical feed equipment incl installation			1	4,000	4,000
Insulated stack w/ breeching	60	ft	1	120,000	120,000
Transformer/MV switchgear			1	100,000	100,000
Motor control centers w/ installation			1	180,000	180,000
Controls			1	112,500	112,500
Building	7,000	sq.ft	7,000	150	1,050,000
SUBTOTAL					5,061,500
Engineering	10%				506,150
Contingency	25%				1,391,913
TOTAL					$6,959,563

Table 11. Production equipment summary and estimate of probable cost for Option 2 (economizer and extraction steam)

Energy Cost

The load duration curves for each option are shown in Figures 12 and 13. In these curves, the sources of heat expected to be utilized through the year are detailed. Load duration curves are based on aggregate customer loads and the typical climate conditions for Burlington. In each case, a natural gas price of $4.92 per MMBtu is assumed. Note that the black band in Figures 12 and 13 represent the usage of the backup gas boilers, considered for installation at McNeil, during the planned spring and fall power plant maintenance outages. System heat load during those outage months is greater than during the middle of the summer, therefore Figures 12 and 13 represent the actual load that is estimated to be served by the backup boilers during the outages.

Energy Production by Source				
	Energy Production		Energy Price	
	MMBtu	%	$/MMBtu	$
Flue gas economizer	0	0%	0.0	$0
Steam extraction	167,814	96%	5.0	$840,296
Backup boilers[1]	6,982	4%	6.2	$42,939
Total	174,797		5.1	$883,236
1) Based on gas price	*4.92*	*$/MMBtu and eff.*		*80%*
2) Peak capacity of 54.3 MMBtu/hr				

Table 12. Option 1 production sources and cost

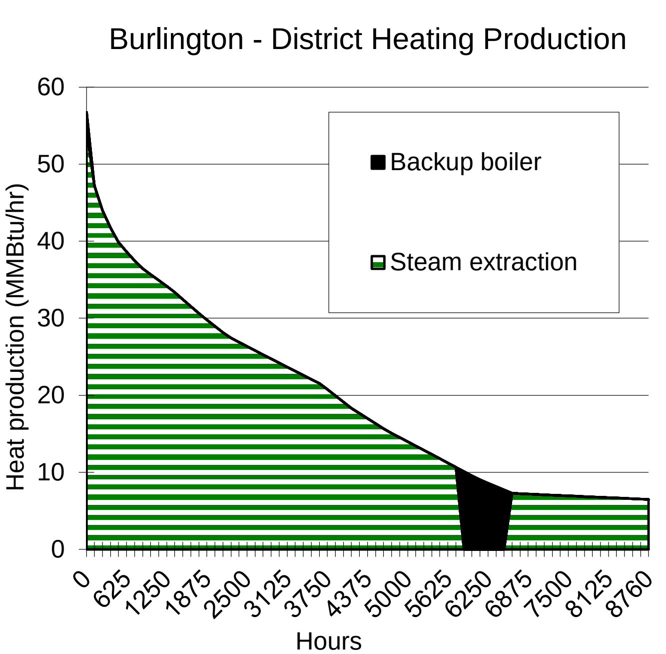


Figure 12. Option 1 load duration curve and production sources (note that the black band represents backup boiler use during spring and fall maintenance outages)

Energy Production by Source				
	Energy Production		Energy Price	
	MMBtu/Year	%	$/MMBtu	$
Flue gas economizer	86,812	50%	0.0	$0
Steam extraction	81,149	46%	5.0	$406,338
Backup boilers *1	6,835	4%	6.2	$42,035
Total	174,797		2.6	$448,373
1) Based on gas price	*4.92*	*$/MMBtu and eff.*		*80%*
2) Peak capacity of 54.3 MMBtu/hr				

Table 13. Option 2 production sources and cost

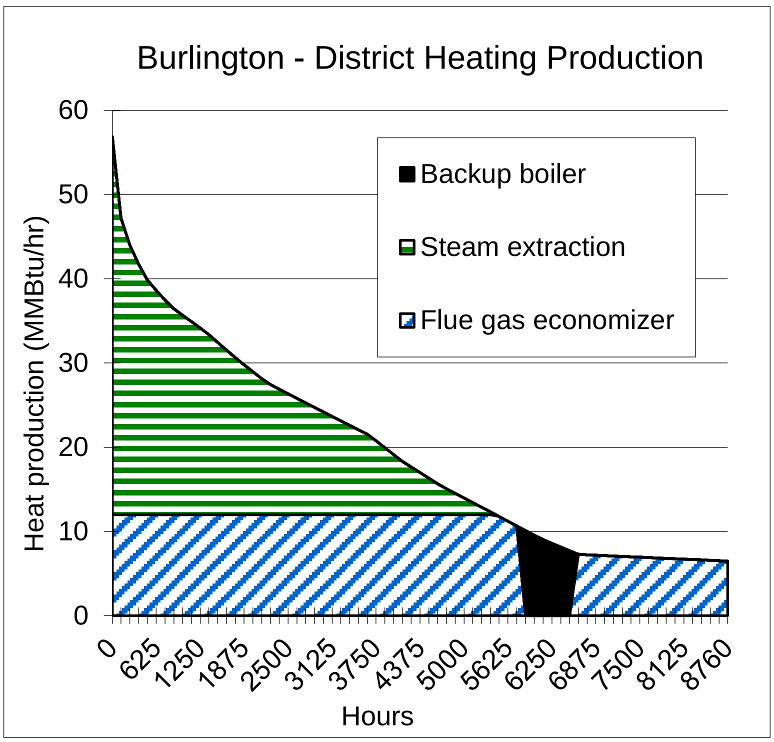


Figure 13. Option 2 load duration curve and production sources (note that the black band represents backup boiler use during spring and fall maintenance outages)

Renewable Energy Certificates

In the document "Renewable Energy Certificates" published by the EPA's Green Power Partnership, renewable electricity is defined as electricity produced from resources that do not deplete when their energy is harnessed, such as biomass, sunlight, wind, waves, water flow, biological processes such as anaerobic digestion (e.g., landfill gas), and geothermal energy and Renewable Energy Certificates (RECs) represent the environmental and other non-power attributes of renewable electricity generation and their associated financial value. RECs are measured in single megawatt-hour increments and are created at the point of electric generation. Businesses and utilities purchase RECs to meet their internal or state mandated renewable energy portfolio standards. The purchase of RECs is used to account for and credit that their electrical power consumption is generated in a renewable fashion. Buyers can select RECs based on the generation resource (e.g., biomass, wind, solar, geothermal), when the generation occurred, as well as the location of the renewable generator. RECs are the currency of renewable electricity and green power markets. RECs are not constrained by physical bottlenecks on the power grid and may be sold to buyers at locations beyond the service territory of the generator and local grid.

McNeil generates RECs for each megawatt-hour of electricity generated and for the past several years sold the RECs in the state of Connecticut to meet renewable energy portfolio standards. McNeil RECs are traded as Class 1 RECs in Connecticut and have a market value of approximately $54/MWH as reported by BED. BED currently sells McNeil's Class 1 RECs and purchases lower cost Class 2 RECs to attain their renewable objectives. In June of 2013, the Connecticut legislature enacted Public Act 13-303, which calls for a decrease of Class 1 RECs for biomass plants starting in 2015 unless the generator was awarded a contract in response to the RFP issued by the Connecticut Department of Energy and Environmental Projection (DEEP). BED and GMP were notified in January 2014 that they were successful in securing a contract to sell RECs to Connecticut utilities for a ten year period. The award of the contract exempts McNeil from the decrease for the life of the contract and allows them to continue to sell RECs in the Connecticut market through 2025.

Environmental

The Team investigated the environmental implications related to the Burlington CES. The following summarizes what was learned through analysis of the system, fuel choice, and system construction.

GHG Emissions Reduction

Utilization of McNeil to serve the Burlington CES will provide environmental benefits to the Burlington community. Although natural gas, considered one of the cleanest fossil fuels, is currently the primary fuel source for the buildings surveyed, it still releases emissions such as carbon dioxide (CO_2) into the atmosphere. By replacing natural gas with energy from McNeil, the calculated emissions of CO_2 would be drastically reduced.

The biomass emissions are calculated in accordance with the US EPA Combined Heat and Power Partnership document, "Fuel and Carbon Dioxide Emissions Savings Calculation Methodology for Combined Heat and Power Systems" dated August 2012. This is based on the commonly accepted approach that the combustion of biofuels does not contribute to a net addition of CO_2 to the atmosphere. The biomass cycle is a closed loop over the 40-60 year growing and harvest cycle. While CO_2 is emitted from the combustion of the biomass, the trees are concurrently synthesizing the CO_2 to generate more biomass. Provided that the forests are harvested sustainably, as is the case for McNeil's biomass fuel, CO_2 nets out to zero on a local basis.

A comparison of CO_2 emissions between business as usual and the proposed CES is shown in Table 14. Under the proposed CES, some non-convertible steam load will still require steam for process loads. Even with the non-convertible loads fired on natural gas, a CES integrated with McNeil will reduce the present CO_2 emissions by approximately 14,400 tons per year.

	Carbon Dioxide Emissions			
	Existing System		Hot Water DE System	
	Fuel Usage	CO_2[1]	Fuel Usage[2,3]	CO_2[1]
	MMBtu/yr	tons/year	MMBtu/yr	tons/year
Natural Gas[4]	319,457	18,528	71,822	4,166
Biomass[4]	-	-	115,927	0
Totals		18,528		4,166
NOTES:				
1) CO_2 lb/MMBtu	Gas:	116	Biomass:	0
2) Assumes onsite natural gas fired steam boiler for non-convertible process loads and a natural gas fired hot water boiler at McNeil to cover UVM load during unscheduled outages.				
3) Assumes a 50% reduction of campus steam distribution losses				
4) Boiler Efficiency	*Onsite customer gas:*	*75%*	*Biomass:*	*70%*
	McNeil gas:	*80%*		

Table 14. Emission comparison between natural gas and biomass for Option 2

The IBM Smarter City Challenge identified greenhouse gas emission reduction as one of the primary objectives to strengthen and improve the City of Burlington's economic and financial position.

Burlington's Climate Action Plan reported a total community CO2 emission value of 405,000 tons for 2010. Implementation of the proposed CES encompassing the study buildings will lower the overall community CO_2 emissions by 14,400 tons and expansion of the CES to the broader community will net further GHG reductions.

Air Permitting

Review of the McNeil emissions permit will be required during the project development phase to verify if any permit modifications or major amendments will be required to incorporate proposed operating changes required to develop the CES. This work should be performed by Burlington Electric Department's consultant in conjunction with the engineer for the CES.

Business Considerations

Summary of Capital Cost for District Heating

Based upon the load identified in this report and the expected system costs, the overall capital investment needed for the CES is estimated to be approximately $31 million. This opinion of probable cost for the entire Burlington CES, as shown in Table 15, includes both construction and development costs and is based upon Ever-Green's experience with developing, operating and managing similar district energy systems. A complete presentation of the project costs is presented in the economic model section and is based upon the McNeil integration Option 2, which includes a flue gas economizer along with some steam extraction.

Item	Cost ($1000)
Building Conversions	$6,812
Service Laterals	$794
Energy Transfer Stations	$1,243
Distribution	$10,572
Production	$6,960
Total	$26,381

Table 15: Summary of capital costs

The cost for the continued operation of steam boilers to serve non-convertible loads will require review during the next phase of system evaluation. Ever-Green believes that most of the loads can be converted to operate on a medium temperature hot water system. It has been assumed that FAHC will maintain its boilers to manage its own load in the event that the CES were to fail during peak conditions. Natural gas-fired boilers have been included at McNeil to manage all other system load in the event of a McNeil outage.

Opportunities for cost reduction

Cost reductions for the project can be attained through coordination with other work in the buildings, the distribution system construction, work at the power plant, and through the use of newer technologies.

Since the construction of a CES system in Burlington will be primarily in the public right of way, excavation of existing sidewalks and roadways is inevitable. Coordination with street reconstruction projects, water and sewer installation projects, or other projects that disturb streets and sidewalks reduces the installation cost of the distribution pipeline up to 35%.

To the greatest extent possible, pipelines should be installed in the green space or median areas where repair of streets, sidewalks, curb, gutter, etc. is not required. This can reduce distribution piping costs up to 25%. These opportunities should be further investigated during the next phase of development to keep project costs at a minimum. New technologies can also reduce project costs. Historically, thermal energy distribution systems are installed with welded steel pipe. Pre-insulated PEX piping has been on the market in Europe for a decade and is presently being introduced into the North American market. PEX piping is supplied on coils of 300 feet or more, with insulation and an outer jacket installed. It is available in diameters up to the equivalent of four inch NPS. The pipe is installed in a trench and is joined using a proprietary metal compression fitting. The ditches can be open and closed quickly and daily production is much higher per unit man-hour. Costs to install PEX can be up to 50% less than for pre-insulated steel pipe.

Building conversion costs could be further reduced through coordination of the building mechanical system conversions with other renovation work.

Proposed Organizational Structure

Structure Options

Before a CES may be fully developed, its organizational structure will need to be established. The structure may follow a number of different variations, depending upon the interests of the key stakeholders involved in the development of the system. The partners of the Collaborative have communicated that they would prefer for the system to be privately financed and managed by an outside party. Therefore, the primary organizational structures evaluated for the Burlington system are private non-profit and private for-profit. The two structures are discussed below:

Private Non-Profit

Under this structure, the business would be established as a non-profit, private organization. The business would operate much like a cooperative, establishing a board that oversees the activities of the organization and enters into an operations and management (O & M) contract with a company experienced in operating district energy systems. The efforts of the O & M provider would be overseen by the board of the CES. Rates could be cost-based, with provisions for necessary reserves and approvals required by the board. Board membership could be comprised of key stakeholders, including customers, City of Burlington appointees (recommend non-political), community group representatives, and other stakeholders as appropriate. Including local stakeholders on the board will help gain community support and trust of the customers as the business is developed and operated.

Under this structure, the Collaborative could fund the up-front capital needed for the development of the system, with development funding repaid upon 100% debt financing, which could be obtained through revenue bonds in the private markets. The private non-profit would make debt service payments based upon revenue received from energy service agreements with customer buildings. Construction and operational financing would likely be in the form of 20 to 25-year revenue bonds but other types of financing could be considered. The private non-profit may secure some equity in the form of grants and forgivable loans, among other options, to help in the financing of development and construction of the system.

The benefits of such a structure include:

- Long-term customer contracts (e.g. 25 years) would be required for financing purposes.
- Replication of a public-private partnership model that has been successfully implemented in Saint Paul over the last thirty years.
- Customer and community involvement in the establishment and management of the business.

- Allow the Collaborative partners to remain focused on their core businesses.
- Transparent, cost-based rates that should be more stable than the market volatility of natural gas and electricity.

Concerns with this structure include:

- Lack of equity investment could require 100 percent debt financing.
- Interest rates obtained may be more expensive than if one or more of the partners secured financing.
- Lack of an investor will require the Collaborative to fund the next phase of development so that project financing may be secured.
- Customers will be required to sign long-term energy service agreements.

Private For-Profit Company

Under this scenario, the Collaborative would be looking to an outside entity to take over the development, management, operation, and ownership of the CES. This structure would require a privately held company to invest in the development of the business, along with the overall financing of the system. Debt and equity would be raised based upon long-term customer contracts or the investors' balance sheet. In addition to debt service and operating costs, rates would also include a return for the equity investors and costs may not be as transparent. Governance of this structure would be as directed by the equity investors and might mirror other traditional utility structures. Contract terms would also be as required by equity investors, and would likely be for a 20 to 25-year term unless the investor decided to invest speculatively. Development and operation of the system would be managed by the for-profit company, or whomever they hire as their service provider. The for-profit model would allow for the benefits of accelerated depreciation in order to allow the business to be more profitable early in its development.

The benefits of such a structure include:

- Debt and equity raised by others.
- Arms-length transaction allows for each entity to focus on core business.

Concerns with this structure include:

- Potential lack of transparency.
- Uncertainty of serious interest by outside parties.
- Required return on equity may cause the required customers' rate to be too high.
- The Collaborative will likely not have a say in the governance, operation or management of the system and future interests of the system may be in contradiction with the goals of McNeil and the community.

Base Case Scenario

For purposes of the model in this report, a private non-profit structure has been adopted. This model has been successfully implemented in Saint Paul, MN, where customers pay less today for energy (adjusted for inflation) then they did thirty years ago (see Figure 14). The private non-profit model allows for a competitive, cost-based energy rate structure while also allowing key customer and community stakeholders to provide guidance to the operation and management of the business. It is important to select the structure that works best for the City of Burlington, the Collaborative partners, customers, and the overall business. One commonality for any successful system is a strong partnership between building owners, the local community, and the local government entities.

In the event that one of the partners decides that they would prefer to own, operate and manage the CES, this recommendation should be reevaluated.

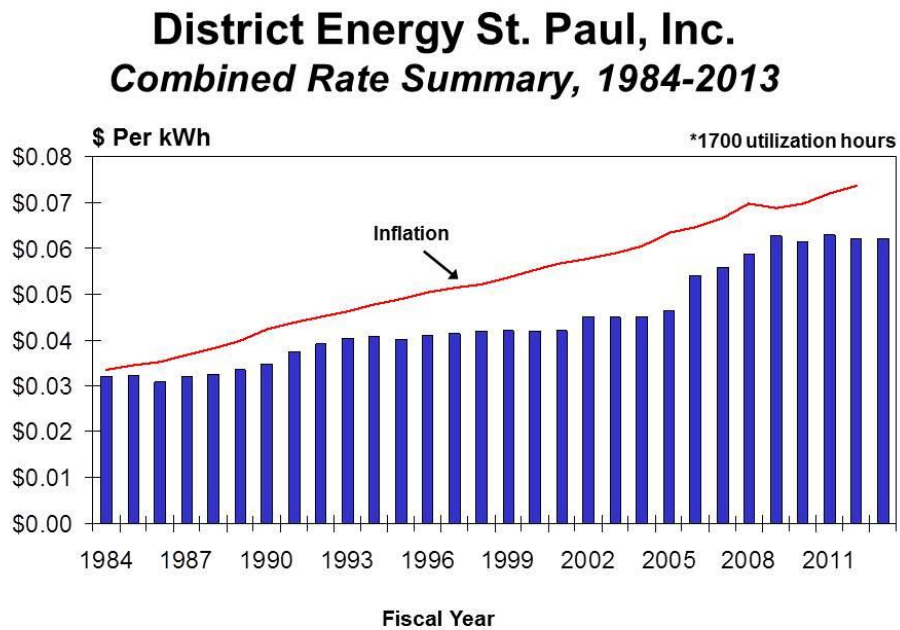


Figure 14. Historic rates for District Energy Saint Paul

Economic Modeling

The Ever-Green Team utilized the estimated costs and energy consumption presented in this report to estimate the energy rate that all buildings connected to the proposed Burlington CES would pay for district energy services. It should be noted that this model does not differentiate sources of funds for the various costs. Rather, it is assumed that all capital costs (McNeil modifications, distribution system, service laterals, building connections, and building conversions) are paid for by the CES. In addition, the model also assumes no grant funding or supplemental funding for the CES is acquired. All costs are assumed to be funded through revenue bonds, which would be secured with long-term (25-year) energy service agreements between the CES and the building owners. To the extent that some of the costs are paid by entities other than the CES, the projected aggregate energy rate would be reduced.

The CES business is assumed to follow the recommended private non-profit structure and energy rates are expected to be cost-based. This financing model has been successfully implemented in a number of communities across North America, including District Energy Saint Paul.

Assumptions and Cost Inputs

The following specific assumptions have been taken into consideration as part of this modeling:

Project Assumptions	Value
Construction Costs	$26,349,000
Total Project Costs	$31,017,000
Construction Schedule (Months)	18
Revenue Bond Interest Rate	5.0%
Revenue Bond Term (Years)	25
Annual Debt Service	$2,200,732
Annual Interest Earnings	($66,041)
Net Financing Cost	$2,134,691
Input Variables	
Inflation	3.0%
Energy Cost Escalation	2.0%
Interest Earnings Rate	3.0%
Building Square Footage	2,247,383

In addition, the following CES operating costs have been included in the model:

Annual Non-Energy Operating Costs	
Management & Staffing	$340,000
Maintenance & Repairs	225,000
General & Administrative	15,000
Total Non-Energy Operating Costs	$580,000
Annual Operating Costs	
Energy Costs	$466,000
Non-Energy Costs	580,000
Total Operating Charges	$1,046,000
Net Financing Cost Subtotal	$2,134,691
Total Annual Costs	$3,180,691

Included within the modeled costs is the assumption that approximately 50% of the energy will come from a flue gas economizer at McNeil and an additional 46% of the needed energy will come from steam extraction at the McNeil turbines. An annual payment to McNeil of over $400,000 has been included in the model.

Aggregated Energy Rate

Based upon the above listed assumptions, the initial users of district energy are expected to pay an aggregated rate for thermal energy as follows:

Calculated Results	
Total Cost ($/MMBtu)	$20.00
Cost Per Square Ft	$1.42

Life Cycle Cost Comparison

The Team completed a life cycle cost comparison to evaluate the aggregate CES energy rate compared with the comprehensive life-cycle costs of on-site generation for each of the proposed customers based on current rate conditions. The life cycle cost comparison allows for the direct evaluation of on-site generation to CES supplied energy by incorporating all of the costs of facility ownership on an equivalent annual basis. A macro-level comparative cost concept is presented in Figure 15. These costs include the capital cost of equipment amortized over a specified period and rate of return (25 years and 5% for this project), the annual cost of fuel consumed to service the facility, the equipment operational costs (labor), and the maintenance and upkeep costs. The estimated equipment capital costs are based on the RS Means commercial cost database and the operating costs are from ASHRAE's "Owner and Operating Costs" and are based on building use. Given the present market conditions, onsite generation using natural gas is the preferred alternative for all of the study buildings except for the Trinity Campus (note that Trinity's aggregate natural gas rate is higher due to purchase of natural gas at fixed rates in majority of buildings). In order for a CES to be economically competitive for all of the study buildings, the Team completed a break-even cost analysis for each facility to determine the natural gas rate that would create a competitive market for the CES. The break-even analysis determines the natural gas rate that will equal the cost of a CES system based on the calculated CES aggregate energy rate. Table 16 provides that side-by-side comparison for FAHC, Trinity, and UHC campuses and estimated break-even natural gas rate. A sample calculation for break-even rate is presented in Appendix I.

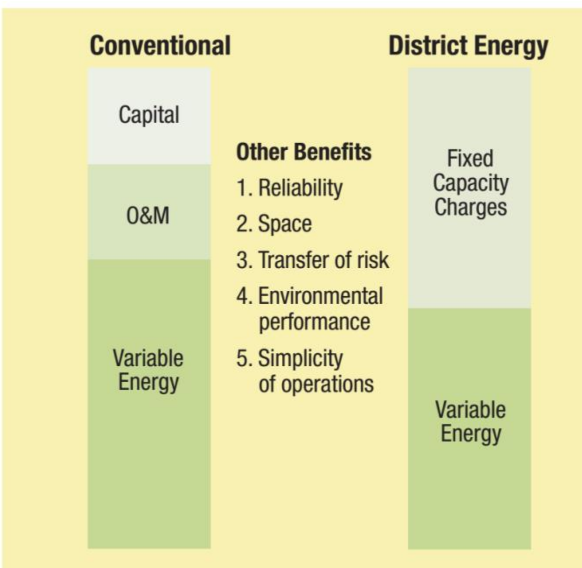


Figure 15. Comparative costs of on-Site and CES Thermal costs (Source: Summit Magazine, March 2008, Purchasing district energy services, a case for life cycle analysis, Richard Damecour)

There are common misconceptions when comparing and evaluating rates for a hot water CES with on-site steam generation. System efficiency, the boiler efficiency, the life cycle cost for equipment, operating costs for system, and maintenance cost must be included on an equivalent basis for an effective direct comparison. Energy rates cannot be compared side by side. When purchasing energy from a CES, the customers purchase only the energy used in the building whereas operation of an on-site boiler has efficiency losses during non-peak circumstances.

For comparison between a CES and on-site generation, the operating efficiency of the boiler has to be included to determine fuel gas costs. A 75% efficient on-site boiler burning one million Btu of fuel per hour produces only 750,000 Btus of energy at the boiler outlet and the remaining energy is lost, typically up the stack. For this example, thirty-three percent more fuel is required for on-site thermal generation to deliver the same MMBtu from the CES. It is also important to understand that the boiler nameplate efficiency is for boilers operating at full load condition. Since boilers typically cycle on and off and rarely operate at full load, the efficiency is diminished and will not typically attain nameplate efficiency numbers. Even the most efficient condensing boilers achieve their rated efficiency only when operating at design conditions. Additional efficiency gains are achieved through economy of scale by operating one large boiler and pumping equipment at maximum efficiency. Building staff can also be used more efficiently, as their responsibility to on-site boiler management would be decreased by connecting to a CES. Staff and resources could be redirected to other daily tasks or energy efficiency projects.

Table 16 provides a natural gas price break-even analysis for each of the proposed customers of the CES. This is a macro-level analysis and the model currently spreads all projected capital costs across the entire customer base. If desired during the next phase of development, the details of the model can be adjusted to assign building conversion costs to each customer and also offset projected capital costs with funds from other sources.

	Estimated Present Equivalent Annual Cost [6]		Natural Gas Rates	
	On-Site[2,3,4]	CES[5]	Present[1]	Break-Even[7]
	($/Year)	*($/Year)*	*($/MMBtu)*	*($/MMBtu)*
UVM Waterman Hall	$208,800	$284,995	$4.92	$8.90
UVM Dewey Hall	$61,812	$94,618	$4.92	$10.00
UVM Trinity Campus	$332,353	$310,841	$7.88	$6.90
UHC	$185,861	$191,769	$4.92	$5.30
FAHC	$2,060,973	$2,515,236	$4.92	$6.70
Note:				
1) Based on a natural gas rate average for 2013 Large Interruptible User except for Trinity Campus which is based on an aggregated rate for all meters.				
2) Opportunity cost of capital for installed equipment. Interest rate of 5% and service life of 25 years.				
3) Backup fuel (oil) use for previous 3 years was minimal and is not considered.				
4) Operating costs based on ASHRAE "Owner and Operating Costs", Chapter 37.				
5) Non-convertible loads are assumed to utilize natural gas and costs are included in CES cost.				
6) Estimated operating costs include labor and administration, maintenance and repairs, energy costs, and opportunity cost of capital.				
7) Break-even is the minimum rate that natural gas will have to equal in order for the biomass-fuelled district heating option to become economically attractive.				

Table 16. Life Cycle Cost Comparison

Under the current economic conditions, it is not economically feasible to connect all of the proposed customers to the CES. Excluding the Trinity Campus, each entity is paying less for heating service through site generation with natural gas prices at their current level. However, if natural gas prices were to increase to levels identified in Table 16, a CES could become more economically compelling for Burlington. Recent market data has indicated that the future (2015) interruptible natural gas rate will be $6.51/MMBtu. At that rate, the CES would be competitive with the input of $2 million toward the initial system financing.

Due to the higher aggregate cost of gas, connection of the Trinity Campus buildings to create an energy island presently shows favorable economics and should be evaluated further.

Waterman Renovation

Included in these projected costs is a significant cost for converting the Waterman building to hot water. This cost has been estimated to be in excess of four million dollars. During the Team's survey of Waterman, it was learned that this building may be renovated in the next three to five years, regardless of the direction of the CES. In the event that renovation of Waterman occurs prior to implementation of the CES and this cost is borne by an entity other than the CES, the estimated aggregate rate for CES customers could be reduced to $18.75/MMBtu and connection to the CES could be more economically attractive for the majority of prospective customers at a natural gas rate of $6.30/MMBtu.

Other Considerations

The customer load assumed for the system was limited to the specific buildings identified by the Collaborative. During the October survey of all buildings, the Team found a number of other buildings that would be adjacent to the proposed distribution system which could be connected to the CES. In the event that development of the system proceeds, these prospective customer buildings should be further investigated as their addition would likely decrease the cost of energy for all buildings connected to the system.

In addition, the Team has not placed any value on greenhouse gas emission reduction, enhanced RECs for the addition of combined heat and power at McNeil or the increased efficiency that McNeil will experience as a result of its integration with a CES. In the event that a value is placed upon these improvements, the economics of the system could be improved further.

Lastly, Ever-Green has assumed that no grants would be obtained or other investments would be made in the CES. In the event that this changes, the debt service would be decreased for the system and the energy rate for customers could also be decreased.

Recommendations and Proposed Path Forward

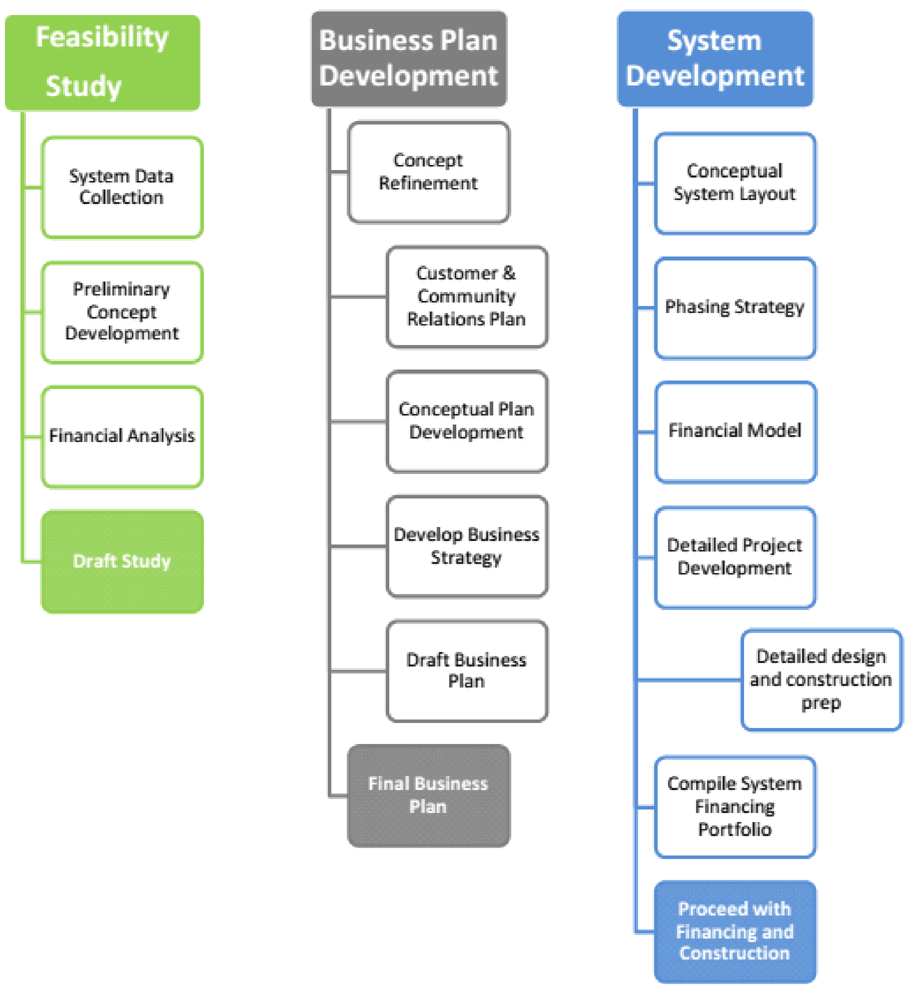
Summary

After detailed analysis, implementation of a CES for the Burlington community would reduce greenhouse gas emissions in the greater Burlington community, enhance the economic stability of McNeil, and provide building owners with the opportunity to connect to a sustainable, local, and reliable energy source. As compared to the current volatility of natural gas and the predicted future increases in its cost, the CES would provide customers with competitive, stable, and predictable energy costs for the foreseeable future.

In the event that the cost of natural gas further increases, the economic comparison could change. At a natural gas rate of $6.90, a CES capturing waste heat from McNeil is cost competitive with natural gas for the majority of prospective customers. Further increases in the cost of natural gas enhance the competitiveness of the CES. The following steps could be taken to prepare for the acceleration of natural gas prices and to prepare to secure project financing for the Burlington CES.

Business Plan and System Development

Implementation of a CES in Burlington would provide the community with a reliable, resilient, sustainable, and environmentally sensible energy solution for decades to come. Implementation would also improve the efficiency of McNeil and provide it with additional sources of revenue, particularly if the RECs were to be modified in the future. The next stage of development proposed in the Feasibility Study will prepare the system to begin construction and involves finalizing the business plan and system development. The work flow provided in Figure 16 represents the typical process



followed for the development of community energy systems.

Figure 16. Ever-Green Energy system development work flow

The recently completed Feasibility Study identified the preferred anchor customers for the initial system. In order to secure financing for the development of this initial system, the next step of development can be classified as Business Plan Development. The goal of Business Plan Development will be to focus on those items that may have the greatest impact on the success of system development, and establish a comprehensive plan for obtaining project financing.

During Business Plan Development, the early focus should be on establishing the structure of the business, refining the conceptual design of the system, verifying with Burlington Public Works that the preferred distribution system routing is feasible and securing anchor customers. This early focus will allow members of the Collaborative to gain greater confidence that the system can serve the presumed anchor customers and that the projected energy rates are still competitive with the market. Once the system concept has been refined, the project team should then focus on securing costs for the design of the system, identifying needed permits for the system and the expected plan for obtainment, verifying that the preferred organizational structure will comply with Vermont law, developing a system financing plan, establishing an energy service agreement that is agreeable to the anchor customers, and understanding any franchise or easement requirements that may exist. In parallel, a community outreach program should be developed and initiated so that the greater community can understand the benefits of the CES and become supporters of its development. This outreach program is also important to understand any local concerns with the CES so that they can be appropriately addressed. At the conclusion of Business Plan Development, a full system development plan can be expected, which includes a detailed budget and schedule to obtain full project financing, commence construction, and ultimately provide district energy services.

Business Plan Development is an important step to take in this development process so that investment in System Development may be made with greater confidence of success and reimbursement at construction financing. During System Development, the following areas will all require more significant focus so that the business may be funded in the private markets, based upon the long-term energy service agreements signed by the anchor customers:

Business Structure, Operating Model and Business Plan: The organizational structure of the business will need to be decided upon and established. Governance of the business and how it will be operated and managed will also need to be established. A business plan forming the strategic direction of the business should also be developed.

Financing Strategy: The financing plan for the business needs to be created so that development period activities may be geared toward the needs of prospective financing entities. Included in this strategy will be a financing report and a rating for the system.

McNeil Integration: Integration with McNeil is a comprehensive program that needs development. Operating protocols, a steam purchase agreement with the CES and a McNeil steam supply plan also needs development. McNeil will also need to evaluate how this development will affect the obtainment of RECs and other incentives.

Customer Contracts: The structure of the energy rate and the term of the agreements will need to be set. The energy service agreements will also need to be drafted and signed by all system customers in order to facilitate project financing in the private markets.

System Expansion Plan: The Collaborative should determine what a prudent growth strategy might be for the system beyond the initial anchor customers.

Design: System design needs to reach a threshold that supports the securing of permits, easements, and lump-sum construction prices, which are all required to support project financing.

Franchise or Easements: The system will require approvals to route the distribution lines through public right of ways. Coordination with Public Works and the City of Burlington need to occur to facilitate this need and support the design of the system.

Construction Contracts: Contracts for all equipment and construction will need to be signed prior to project financing being secured.

Community Outreach: The system should develop a positive relationship with the local community and advance an outreach program that maintains the community stakeholders as partners in the system development and operation.

Conclusions

Implementation of a CES in Burlington would provide the community with a reliable, resilient, sustainable, and environmentally sensible energy solution for decades to come. Implementation would also improve the efficiency of McNeil and provide it with additional sources of revenue, particularly if the RECs were to be modified or eliminated in the future. The next stage of development proposed in this report will prepare the system to begin construction. Although the current cost of natural gas offers some economic challenges in today's market to advance the proposed system in today's market, if natural gas increased to $6.90 per MMBtu, the CES would become a cost-competitive alternative to natural gas and would provide the Burlington community with a more sustainable and resilient energy program.

In the short-term, steps could be taken to prepare the Burlington community for the development of a CES. Currently, UVM's Trinity Campus is paying more for natural gas than FAHC. Burlington could interconnect those two campuses and utilize the FAHC energy center to meet the base-load needs of both campuses. The Trinity boilers could also be maintained to manage peak conditions in the coldest parts of the winter (and for redundancy in the event that there is a shutdown of the FAHC boilers).

Such an interconnection would increase the efficiency of the FAHC boilers and would provide UVM with lower long-term energy costs at Trinity Campus. The short-term savings could be used to pay back the initial capital investment for interconnecting the campuses. It is estimated that this payback could occur in approximately five to six years. Interconnecting the two campuses could be financed in the private markets in the current economic conditions and would establish an initial CES for Burlington that could expand as other opportunities arise.

Acknowledgements

The Ever-Green team would like to express our gratitude to Burlington Electric Department, Fletcher Allen Health Care, The University of Vermont, the City of Burlington, and the members of the BURDES committee. We appreciate the contributions of these and other stakeholders as we worked toward the completion of this study. We recognize the value of each of these contributions and understand that the success of this endeavor will be predicated upon the ongoing support of these parties.

Appendix A

EGE 2011 Burlington Renewable District Heat Final Report

Burlington Renewable District Heating FINAL REPORT

May 2011

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1 Executive Summary

The City of Burlington, VT presents a unique opportunity to initiate a district heating system based on a readily-available source of renewable thermal energy at the wood-fired McNeil Generating Station. A district heating system uses heat from a central source, in this case the wood-fired McNeil Generating Station, to provide building heat and heat for domestic hot water via hot water distribution through underground pipes. Burlington is a community that values conservation, effective resource utilization, and local solutions – the same principles that make the recovery and deployment of underutilized thermal energy at McNeil a compelling opportunity. This underutilized heat from McNeil is more than sufficient to meet the full space heating and hot water heating needs of the businesses and residents of downtown Burlington. This energy is an untapped resource for a community energy system modeled after successful systems elsewhere in the US and in countries such as Denmark and Sweden where conservation and environmental stewardship are high priorities. Such a community energy system will place Burlington among a small group of forward-looking communities that enjoy the benefits that result from the use of locally-derived renewable energy sources. These benefits include:

- Reduction in dependence on fossil fuels for meeting the heating needs in the community. This tends to improve energy price stability and energy security.
- Expenditures for energy stay in the local community with the associated economic and employment benefits. These are dollars that would otherwise leave the community for imported natural gas or oil or other fossil fuels.
- Environmental benefits of reduced greenhouse gas emissions and other emissions as a result of switching to renewable fuel and thermal energy recovery which reduces the amount of natural gas and heating oil consumed for building heating.

A medium temperature hot water system is technically feasible for the City of Burlington. The economic analysis depends on how such a system is implemented such as the scope of the system, the market penetration achieved, the rate at which the district heating system expands and the density of customer load during that expansion, and the credit and financing availability and other capital sources.

In the report three alternative systems are evaluated, not as exclusive options, but as examples of the various sizes of systems that are possible. The actual system scope and location will be established later based on customer interest and other factors evaluated in the report. If the hot water district heating system could achieve substantial market penetration such as is outlined in Alternative 2 or Alternative 3, there is sufficient load under these alternatives to support a district system without subsidy. In fact, the economics of Alternatives 2 and 3 compare favorably with successful systems such as the one in St. Paul, Minnesota. The economics of Alternative 1, a small system with many of the buildings along Pearl Street to serve as “anchor customers” for a later expansion cannot be accomplished without outside subsidy in the form of loan guarantees, grants or favorable financing. However, the opportunity of a system such as is described in Alternative 1 should not be ignored as the customer profile in that area would serve very well as a starting point for a more expansive system that could be self sufficient economically. There is a distinct economy of scale in district heating systems. Therefore, the economics of the larger systems evaluated are often more attractive than the economics of a smaller system. As more heating load is added to the system, the operation and maintenance costs for the system are spread over a larger customer base, which lowers the cost per unit of energy delivered. As would be expected, as these operation and maintenance costs are spread over a larger base, and the average cost per unit of energy is reduced, the district service becomes more compelling to other prospective customers. This dynamic suggests that pursuit of Alternative 1 and finding a way to overcome the early deficit in financing could result in a system that expands rapidly as the costs are shared by more and more customers.

The analysis determined that the maximum anticipated peak load for any of the three alternatives could be served using extraction from the McNeil turbine. Such an approach has the drawback of reducing the amount of electricity produced by McNeil. To minimize this impact and to address the cyclic nature of the McNeil electric dispatch, the steam extraction is supplemented with thermal storage in each of the Alternatives. In Alternatives 2 and 3, much of the production for the district system is provided via a flue gas economizer that extracts waste heat from the flue gases leaving the stack at the McNeil plant. A flue gas economizer is a simple solution that extracts a substantial amount of heat without the complexities associated with collecting heat through condensing of the flue gas. The amount of energy available from flue gas condensation in a wood-fired boiler is substantially higher than the heat available from a flue gas economizer since the heat of vaporization of the flue gas moisture is recovered. In this case, the complexities and operation and maintenance costs associated with condensing the flue gas can be avoided since peak customer loads anticipated for the Alternatives do not warrant a flue gas condenser. This conclusion should be reevaluated for Alternative 3 if Alternative 3 is the selected Alternative.

Development of a medium temperature hot water system accomplishes a number of goals for the Burlington community:

- Reduce fuel consumption in the Burlington community as underutilized renewable energy from the McNeil Generating Station is used to offset or displace natural gas and fuel oil combustion for heating buildings.
- Tap a local energy resource to stabilize energy costs and to keep energy dollars in the local economy.
- Reduce fossil fuel use and emissions of pollutants and greenhouse gases.

This study concludes that there is an opportunity to supply competitively-priced, renewable energy from McNeil Generating Station via a hot water district system at current and projected natural gas and heating oil prices in Burlington. Next steps include (a) additional verification of the suitability of customer buildings to accept district heating service, especially for the buildings in Alternatives 2 and 3, (b) initiation of discussions with FAHC and UVM/Trinity Campus regarding technical suitability and intent to utilize district energy services to establish feasibility of Alternative 3, (c) perform more detailed business planning and establish a structure for the organization of the district heating entity/utility, (d) perform detailed analyses on the steam available from each of the extraction ports of the McNeil turbine and on the effects of a flue gas economizer on flue gas exit conditions, and (e) begin the process of community engagement throughout the Burlington community to gain support for this exciting project. As these next steps progress, a decision to invest in the detailed engineering design activities for the system will follow.

2 Introduction

The Burlington District Energy Service (BURDES) Committee was formed to evaluate the opportunity to deploy the underutilized heat from McNeil as a resource for a community district energy system. BURDES contracted with Ever-Green Energy to perform an evaluation of the potential for and logical scope of a district system in Burlington. Ever-Green Energy has substantial experience in operation of a renewable-based community energy system in Saint Paul, Minnesota. The system in Saint Paul is recognized nationally and internationally as a model for community energy systems. A summary of the backgrounds of the Ever-Green Energy staff involved in the project is included in Appendix I.

At the inception of the study, members of the Ever-Green Energy team visited Burlington to gather information and to involve key stakeholders in the study. Meetings held with a limited group of stakeholders at the inception of Ever-Green Energy's effort were very encouraging. All attendees were supportive of the BURDES Committee initiative. There was unanimous willingness to support the data collection and evaluation process during the study by Ever-Green Energy.

Several studies have been performed that offer a sound technical basis regarding the merits of a district system. All acknowledge the benefits of such a system. These studies include:

- In 1994, a District Heating and District Cooling Study was conducted for Burlington Electric Department (BED) by Joseph Technology Corporation Inc. The study was to determine the feasibility of district energy system to serve six core customers as identified by BED. The McNeil Generating Station is the proposed energy source for the district services.

- In 1998, a District Heating Study was conducted to serve the Greater Burlington area, which includes Hilltop, Downtown and Waterfront customers for BED by Joseph Technology Corp. Inc. The McNeil Generating Station is the proposed thermal energy source for the district energy system.

- In 2002, a validation study was prepared by RDA Engineering for the Development of an Area-Wide District Heating System for BED.

It is the goal of the BURDES Committee to build on the insights gained in the previous studies and to work with Ever-Green Energy to identify a practical solution that leads to the creation of a renewable-fuelled community energy system in Burlington using the plentiful and underutilized thermal energy from the McNeil Station. The group of entities that own McNeil Generating Station support the evaluation of the feasibility of a district heating system based on thermal energy from McNeil. This owners group includes Burlington Electric Department with a 50% ownership stake, Central Vermont Public Service with a 20% ownership stake, Vermont Public

Power Supply with a 19% ownership stake, and Green Mountain Power Corporation with an 11% ownership stake.

Definitions

The nature of this report necessitates the use of technical terminology. The following definitions are provided for those unfamiliar with energy system terminology:

Admission Steam – The high pressure steam from the boiler that is directed to the turbine inlet to drive the turbine.

Backpressure Turbine – A type of turbine designed such that the steam at the outlet of the turbine retains sufficient energy to be used to perform heating or other work.

Boulevard area/Greenbelt – The grassy area between sidewalk and curb or between traffic lanes. These areas are preferred for installation of underground utilities since the cost of restoration is usually lower than paved or concrete surfaces.

British Thermal Unit (Btu) – The amount of heat required to raise the temperature of one pound of water 1degree Fahrenheit. The Btu is a small amount of heat equivalent to the heat released by a burning matchstick. For district heating systems, heat is often measured in million Btus (MMBtu) which is equivalent to one million Btus.

BURDES – Burlington District Energy System is a committee of citizens in Burlington promoting the use of district heating in Burlington using heat from the wood-fired McNeil Generating Station.

Coefficient of Performance (COP) - COP is the ratio of either heat removed (for cooling) or heat provided (for heating) in Btu per Btu of energy input.

Cogeneration – the simultaneous production of useable heat energy and electrical energy from a production facility.

Community Energy System – a thermal energy delivery system that connects a significant portion of a community and permits technologies and energy sources to be deployed on behalf of the entire community as a result of economies of scale of the system and the adaptability advantages of the distribution network.

Condensing Turbine – A type of turbine in which the steam at the outlet of the turbine is not used for additional useful energy transfer but, instead, is condensed from vapor back to liquid condensate. The outlet of such a turbine typically operates at a vacuum (negative pressure).

Customer conversion – The equipment in a customer building mechanical room that transfers thermal energy from the district heating system to the building systems to allow the heat to be distributed throughout the building. The customer conversion usually consists of heat exchangers, pumps, piping, control sensors, and control valves to enable heat to be efficiently transferred from the higher temperature district heating system to the lower temperature building system.

Differential Temperature (dT, delta T) – the difference between the supply temperature and return temperature of the district heating water delivered to users. This is an indication of the amount of energy delivered to the customer.

District Energy – a thermal energy delivery system that connects energy users with a central production facility.

Diversified Load – The actual peak load on an energy system. The diversified load is less than the sum of the peak loads of individual users due to the difference in time of day that each individual user realizes their peak load.

Dual Pipe – a district energy system that consists of a two-pipe distribution network **-** a supply pipe that carries hot water to the customer and a return pipe that returns the cooler water to the production facility for reheating.

Distribution system – The underground piping network that delivers hot water from the production facility (the McNeil Plant) to the customer buildings. Hot water is circulated through this distribution system using pumps that are located at the production facility.

Domestic Water – Potable water that is heated for use in faucets, showers, laundry, and similar uses.

Finned Tubes – a heat exchanger with a surface that includes fins that increase the surface area of the tube and, consequently, increase the heat transfer rate.

Flashing of Hot Water – converting hot water to steam through the addition of heat to the hot water until the water reaches the point of vaporization.

Flue Gas – the hot combustion gases exhausted from a boiler via the flue or stack.

Flue Gas Condenser – a heat recovery device that extracts heat from the flue gas as it leaves the boiler. The heat extracted is sufficient to cause the temperature of the flue gas to be reduced to the point at which water vapor in the flue gas condenses into liquid.

Flue Gas Economizer – a heat recovery device that extracts heat from the flue gas as it leaves the boiler. A limited amount of heat is extracted such that the vapor in the flue gas remains vapor rather than being condensed to liquid.

Heat exchanger – A pressure vessel that contains plates or tubes and allows the transfer of heat through the plates or tubes from the district heating system water to the building heat distribution system. A heat exchanger is divided internally into two separate circuits so that the district heating system water and the building heat distribution system fluids do not mix.

Heat Pump – A machine that is used to collect heat from a low temperature source and increases the temperature so that the heat can be used for heating purposes.

Heating coil – A heating element made of pipe or tube that is designed to transfer heat energy to a specific area or working fluid.

Hot Water Supply and Return Lines – the district heating system piping that distributes hot water for heating purposes to customers (supply) and returns the cooler water to the plant for reheating (return).

KiloWatt-hour thermal (KWhT) – A measure of thermal energy that equals 3,413 Btus.

Non-diversified Load – The sum of the peak loads of individual users. This is a theoretical maximum system peak load.

PSIA (Pounds per square inch- absolute) – a measure of pressure that is measured from an absolute reference rather than being adjusted for atmospheric pressure.

Service line/Service piping – The segment of the district heating distribution system that extends from the main lines to the inside of the customer building. The service line is typically sized to meet the peak hot water flow requirements for the individual building served by the piping.

Steam Extraction – steam that is diverted from a turbine to be used for heating purposes before its full energy and temperature have been utilized by the turbine.

Terminal Equipment – Heating equipment such as heating coils, radiators, unit heater, or air handlers that transfer heat from water to the building air space.

Thermal Energy – energy in the form of heat.

Thermal Storage – a tank or similar device filled with water that has been heated in order to retain thermal energy for later use.

3 Customer Demand and Distribution System

3.1 General

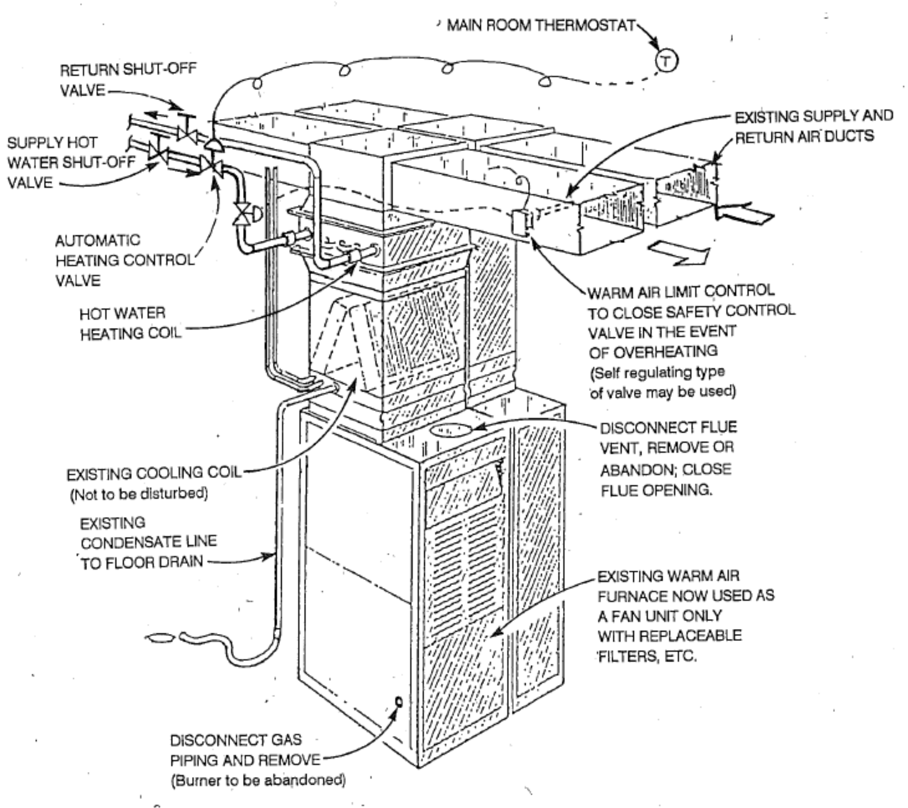
The most efficient community thermal energy systems employed globally today utilize hot water as the means for transferring heat from the location where the heat is produced to the location of the end user of the thermal energy. Hot water can be more effectively controlled at the customer building to ensure optimal energy transfer. Hot water is also more easily delivered to the end user through the distribution pipeline with fewer losses than are experienced in a system that uses steam as the means of transporting thermal energy. In a steam distribution network, the higher temperatures, difficulties in controlling and containing the gaseous steam, and losses of condensate at the point of delivery of heat to the customer all are disadvantages when compared to the hot water distribution alternative.

Due to the comparatively high system efficiencies of a hot water distribution network, as well as a long service life of the piping and related infrastructure, such a hot water district heating system is recommended for the City of Burlington. Specifically, a medium-temperature hot water distribution network is well suited for a community energy system such as the one that could serve the City of Burlington. Such a medium-temperature district system operates at a maximum supply temperature of 250 ºF during peak usage conditions (with a reset schedule that limits supply temperature to 190 ºF in summer) and a return temperature of not higher than 160 ºF. Such a hot water system is extremely effective for utilizing low grade thermal sources, combined heat and power, and renewable sources. A hot water distribution system such as this also allows buildings to meet the Code-required temperatures for building systems with no additional boosting of temperature using supplemental means.

Building internal space heating systems are typically designed to operate at hot water heating temperatures from 130 ºF to 180 ºF for human comfort. Building domestic water heating systems typically operate at a temperature of 120 ºF to 140 ºF and commercial properties with food service and cleaning systems typically will use domestic hot water heating to a maximum of 160 ºF. All of these systems are well-suited to use of medium temperature hot water as the source of thermal energy for the building. During a data-gathering visit by Ever-Green Energy staff, each of the buildings visited by Ever-Green Energy to observe the internal heating distribution were found to have water heating systems as described above and each is well suited to use of the proposed hot water district heating services. This provides some optimism that the energy systems in the broader existing building stock will prove readily compatible with a hot water district system. Compatibility with existing building systems provides the potential for low-cost conversion of building systems to utilize the district energy service, although conversion costs will vary widely depending on the building compatibility, building load, and mechanical room location and other routing and logistical issues.

While only a limited sample of the buildings in Burlington were visited to confirm compatibility with a hot water district heating system, there are good options for providing heat from a hot water system to a wide variety of buildings. Many residential buildings such as those in the neighborhoods around the Burlington downtown area, both single family or multiple unit dwellings, utilize a heating system that distributes warm air throughout the dwelling. Even buildings such as these are readily compatible with a hot water district heating system. In fact, the heating system in the building is simplified when served by hot water from the district system rather than direct gas combustion in the furnace. In the case of a warm air distribution system through a building, the conversion interface to utilize the district heating system is as shown in the diagram below (Figure 1). A hot water heating coil is mounted in the discharge air plenum of the furnace to replace the natural gas burner as the heat source. The hot water heating coils are a common type of construction that consists of multiple-rows of finned tubes or coils. These types of coils are very commonly used in the terminal units in apartment buildings, condominiums, and hotels. Often, the same coils are used to provide air conditioning to the building during the warmer months of the year by introducing chilled water to the same coils as are used with the hot water for heating during the colder portion of the year.

Figure 1 Typical conversion of warm-air furnace to hot water heating



3.2 Alternative 1

Alternative 1 consists of a district system that serves a substantial load center around Pearl Street that includes buildings owned and occupied by a number of State and Federal government entities. The system is served by a hot water supply and return pipeline of eight inch diameter. The pipeline follows a route that is very direct so as to minimize pipeline costs and anticipates connecting buildings along the pipeline route from McNeil to the downtown business district.

As shown in the Alternative 1 tables and related figure below, this case anticipates connecting the buildings located on either side of Pearl Street. This system has an anticipated peak load of 11,315 kilowatts thermal (non-diversified). Total pipeline length (dual pipes) is 12,342 feet.

Alternative 1 was chosen for potential implementation first for the following reasons:

A. The information on many of the buildings was readily available from the building owners, including the building energy usage to estimate the district heating loads.

B. Many of buildings on both sides of Pearl Street are owned by the Federal and State Governments and the Burlington Housing Authority which have goals (if not mandates) to utilize renewable energy and to meet other environmental requirements.

C. The high interest displayed by the owners, managers, and operations personnel and the participation in the informational meeting during Ever-Green Energy's visit to the sites.

D. The compatibility of the buildings heating systems with the proposed hot water district services which will likely result in low capital investments by potential customers to connect to the district system.

The scope of the system contemplated as Alternative 1 is listed in Table 1. The actual system scope and location will be established later based on customer interest and other factors evaluated in the report.

Table 1 Alternative 1 heating loads

MAP ID	TYPE	HEATING SYSTEM	BUILDING AREA SF	HEATING LOAD KW *1	HEATING LOAD MWH
1	Residential	Warm air	14,210	70	133
2A	Residential	Hot water	6,056	30	57
2B	Residential			80	152
3	Clinic	Hot water	53,788	350	665
4	Res./Com.	N/A	36,583	400	760
5	School	Steam	43,845	325	618
6	Residential	N/A	21,951	100	190
7	Res./Com.	Hot water	20,954	110	209
8	Res./Com.	N/A	22,687	120	228
9	School	Steam	50,760	400	760
10	Church	Steam	42,289	400	760
11	Res./Church	Hot water	32,392	150	285
12	Res./Com.	Multiple	54,548	250	475
13	Res./Com.	Hot water	52,207	250	475
14	Com./Res./Church	Hot water	29,357	200	380
15A	Residential	Hot water	53,997	250	475
15B	Office	Hot water	119,561	900	1,710
16A	Res./Com./Off.	Warm air	43,975	240	456
16B	Office	Hot water	7,842	60	114
16C	Residential	Hot water	44,074	300	570
16D	Residential	Multiple	21,762	100	190
17	Res./Com.	Multiple	27,854	125	238
18A	Church	Warm air	23,422	225	428
18B	Residential	Hot water	89,382	1,200	2,280
18C	Office	Hot water	164,356	1,200	2,280
18D	Office	Hot water	22,134	160	304
18E	Office	Hot water	19,220	140	266
18F	Res./Coffice	Warm air	13,779	70	133
19	Com./Church	H.w/warm air	27,786	200	380
20A	Office	N/A	262,301	1,500	2,850
20B	Office	Hot water	40,958	220	418
20C	Com./Office	Warm air	27,519	150	285
20D	Com./Office	N/A	62,043	350	665
21A	Office	Hot water	44,871	250	475
21B	Com./Office	Warm air	14,312	80	152
21C	Com./Office	Warm air	35,505	200	380
21D	Com./Office	Warm air	29,075	160	304
TOTAL			1,677,355	11,315	21,499

**1 Heating loads are estimated from building area, surveys and gas bills*

Table 2 Alternative 1 distribution system pipe size and length

Route From	To	Customer Load kW	Market Load kW	Diversified Load kW	Pipe Size inch	Length ft
McNeil	Riverside Ave	11,315	11,315	9,052	8	1,241
Riverside Ave	N Winooski Ave	930	930	744	3	982
Riverside Ave	North Street	10,385	10,385	8,308	8	2,038
North Street	Pearl Street	9,730	9,730	7,784	8	1,636
Elmwood Ave	Park St	5,170	5,170	4,136	6	1,246
Elmwood Ave	N Winooski Ave	3,610	3,610	2,888	5	599
Customer connections		23	23	23	3	4,600
TOTAL		11,315	11,315	9,052		12,342

dT = 90 F

Figure 2 Alternative 1 customers and distribution system route

The actual system scope will be established later based on factors described in the report.

This route from McNeil, in addition to being the most direct and therefore least costly route, also has the advantage of passing in close proximity to a number of substantial potential customers along the route, many of whom could benefit from the availability of a cost-effective, renewable energy resource. While a complete inventory of these buildings is beyond the scope of this report, a general survey of the density and types of buildings along the route was made by Ever-Green Energy staff during the data gathering phase of the report.

Many of the buildings considered for Alternative 1 were more thoroughly evaluated. Many of the building mechanical rooms were evaluated and load capacities of the building mechanical systems verified. Fuel consumption data for years 2008 and 2009 was also provided which enabled detailed evaluation of building peak loads and energy use profiles. All of this information increases the validity and level of detail of the evaluation for this group of buildings. As was previously mentioned, many of the buildings inspected are readily compatible with a hot water district system since the buildings already use hot water as the means for distributing heat throughout the building. This compatibility will result in a reasonable cost for the customer conversion needed to utilize the renewable energy from the district system.

3.3 Alternative 2

Alternative 2 consists of a more extensive system that includes much of the commercial district in Burlington including the Church Street Marketplace/Downtown Mall area. The pipeline and extent of the system are shown in the tables and figure below. In this alternative a gross customer load of 25,865 kilowatts of thermal is available. With an 80% market penetration of the specific buildings for Alternative 2, a customer connected load of 22,955 kW thermal is anticipated (non-diversified). The pipeline length expands to 21,695 feet (dual pipe). A 10 inch supply and return pipe is routed from McNeil to the Downtown Business District to provide thermal energy. This alternative could be built out in segments to reach its full potential over time with some additional investment at the outset to size the pipeline from McNeil adequately to meet the anticipated load of the full system. In fact, this organic growth from a smaller initial system to a community-scale system is typical of district heating systems.

In Table 3, the twenty city blocks within the expanded area of the hot water district heating system in Alternative 2 are shown with an estimated heating load based on the site observations and the assistance of aerial three dimensional views of the buildings. Estimating the additional building area that could potentially be served by the district heating system in this way yields a rough estimate of approximately 2,600,000 square feet for the heated area in the eighteen blocks. This estimate correlates well with the estimate of heated areas as identified by BURDES previously. The actual system scope and location will be established later based on customer interest and other factors evaluated in the report.

Table 3 Alternative 2 heating loads

MAP ID	TYPE	HEATING SYSTEM	BUILDING AREA SF	HEATING LOAD *1 KW	MWH
22	Com./Res.			400	760
23	Commercial			600	1,140
24	Commercial			800	1,520
25	Office			700	1,330
26	Office			800	1,520
27	Retail			1,300	2,470
28	Hotel/Condo	Hot water		2,200	4,180
29	Entertainment			500	950
30	Commercial			700	1,330
31	Commercial			600	1,140
32	Commercial			900	1,710
33	Municipal			750	1,425
34	Commercial			600	1,140
35	Library			800	1,520
36	Com./Warehouse			600	1,140
37	Commercial			600	1,140
38	Commercial			400	760
39	Commercial			500	950
40	Commercial			400	760
41	Commercial			400	760
TOTAL				14,550	27,645
Alternative I Buildings				11,315	21,499
GRAND TOTAL				25,865	49,144

**1 Heat loads shown with block I.D. numbers are estimated based on visual observation from the 3-dimensional Google Map and visual observation during site visit.*

Table 4 Alternative 2 distribution system pipe size and length

Route From	To	Customer Load kW	Market Load kW	Diversified Load kW	Pipe Size inch	Length ft
McNeil	Pearl St	25,865	22,955	18,364	10	4,915
Riverside Ave	N Winooski Ave	930	930	744	3	982
Elmwood Ave	Park St	5,170	5,170	4,136	6	1,246
Elmwood Ave	N Winooski Ave	18,160	15,250	12,200	8	599
Pearl St	Bank St	14,550	11,640	9,312	8	860
Bank St		5,000	4,000	3,200	5	1,750
Bank St	Main St	8,550	6,840	5,472	6	845
Main St	Battery St	6,350	5,080	4,064	6	1,898
Customer connections		43	43	43	3	8,600
TOTAL		25,865	22,955	18,364		21,695

dT = 90 F

Figure 3 Alternative 2 customers and distribution system route

The actual system scope will be established later based on factors described in the report.

Alternative 2 achieves a community scale for the district heating system with much of the main business and commercial district enjoying the benefits of the hot water district heating system. The routing of the system piping also creates an opportunity for installing a snowmelting system in the Church Street Marketplace/Downtown Mall area. A snowmelt system would reduce the maintenance required for snow removal in the area, improve the experience for visitors to the area, and reduce the tracking of snow and ice melting chemicals into the local shops and restaurants. This snowmelting is accomplished using a network of tubing under the Mall area that keeps the surface at a temperature that prevents snow from accumulating. Such a snowmelting system has not been included in the capital budget estimates in this report.

A priority in further evaluating the feasibility of Alternative 2 is the gathering of specific building mechanical system and load information. Without this information it is difficult to ascertain the ease of system interface with the district heating system and the extent of the customer conversion work required. Further future investigation will determine the potentials for the actual system size and capacity.

3.4 Alternative 3

This alternative is a high-level review of a system expansion that includes other substantial loads that are believed to be compatible with the hot water district system with a maximum 250 ºF supply temperature and which are in proximity to the proposed downtown system evaluated in Alternative 2. The addition of load at the Fletcher-Allen Health Care (FAHC) complex and at UVM/Trinity Campus would more than double the connected load on the system as well as doubling the annual energy delivery via the hot water community energy system. While a thorough evaluation of the compatibility of these loads with the district system is beyond the scope of this report, the effects on system economics will be evaluated so as to guide the decision regarding undertaking a more thorough evaluation of this opportunity. Preliminary investigation based on the findings of prior reports (Joseph Technologies, 1998) indicates a total customer load under this scenario of 56,865 kW thermal. With an 80% market penetration of the specific buildings for Alternative 2, a customer connected load of 53,955 kW thermal is anticipated (non-diversified). The distribution pipeline diameter increases proportionately to serve the additional load and the length of the pipeline increases to an estimated 27,495 feet (dual pipe).

Table 5 Alternative 3 heating loads

MAP ID	TYPE	HEATING SYSTEM	BUILDING AREA SF	HEATING LOAD KW	MWH
42	Hospital	h.w.&steam	1,279,826	25,500	48,450
43	School	Hot water		5,500	10,450
TOTAL				31,000	58,900
Alternative II Buildings				25,865	49,144
GRAND TOTAL				56,865	108,044

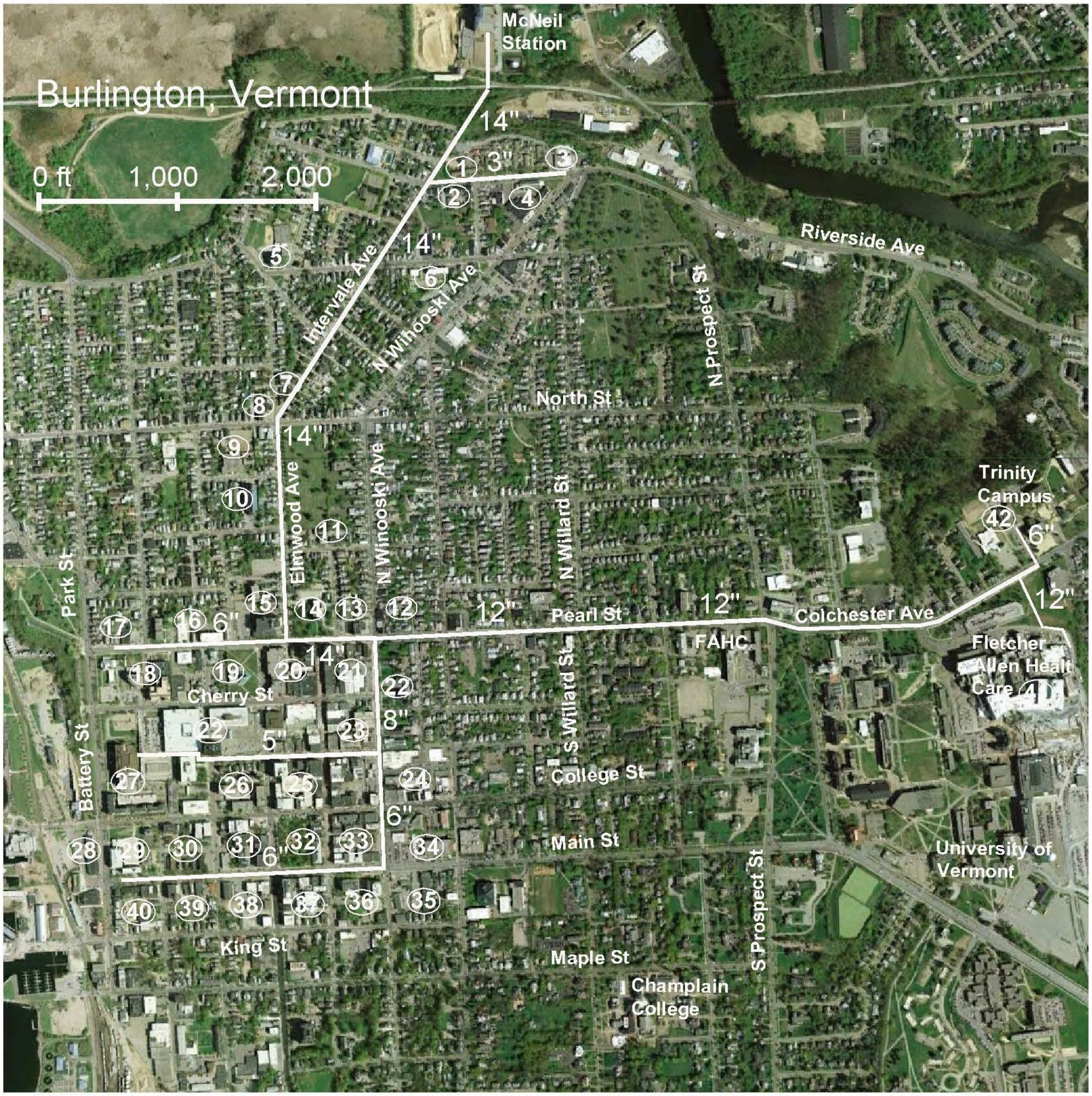
Note: Heating systems in buildings and heating loads are taken from Greater Burlington District Energy Study, dated March 1998 by JosephTechnology Corporation, Inc.

Table 6 Alternative 3 distribution system pipe size and length

Route		Customer Load	Market Load	Diversified Load	Pipe Size	Length
From	To	kW	kW	kW	inch	ft
McNeil	Pearl St	56,865	53,955	43,164	14	4,915
Riverside Ave	N Winooski Ave	930	930	744	3	982
Elmwood Ave	Park St	5,170	5,170	4,136	6	1,246
Elmwood Ave	N Winooski Ave	49,160	46,250	37,000	14	599
Pearl St	Bank St	14,550	11,640	9,312	8	860
Bank St		5,000	4,000	3,200	5	1,750
Bank St	Main St	8,550	6,840	5,472	6	845
Main St	Battery St	6,350	5,080	4,064	6	1,898
N Winooski Ave	FAHC conn.	31,000	31,000	25,500	12	4,630
Colchester Ave	FAHC	25,500	25,500	25,500	12	692
Colchester Ave	Trinity Campus	5,500	5,500	5,500	6	478
Customer connections		43	43	43	3	8,600
TOTAL		56,865	53,955	43,164		27,495

dT = 90 F

Figure 4 Alternative 3 customers and distribution system route



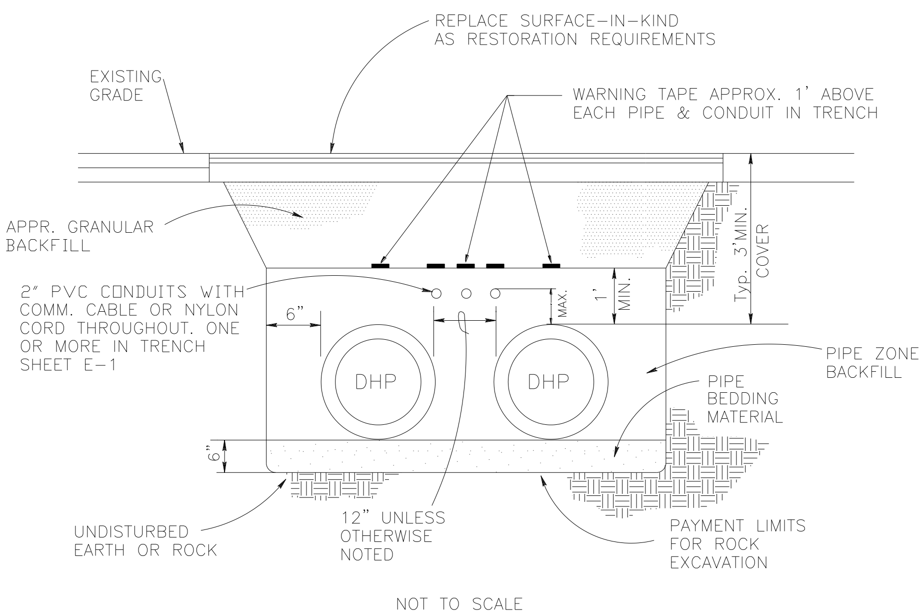
The actual system scope and location will be established later based on customer interest and other factors evaluated in the report.

3.5 District Heating Pipes and System Design Considerations

The distribution piping system is anticipated to be a pre-insulated piping system such as is commonly utilized in hot water distribution systems (refer to Appendix B). This system has been used effectively in such systems for several decades. The system consists of a thin-wall steel carrier pipe, polyurethane foam insulation, and a high-density polyethylene (HDPE) jacket. This system has demonstrated useful life of more than 30 years when properly installed and maintained. Heat loss is very low and the system requires minimal maintenance. This piping system also includes a detection system that can provide early warning of moisture in contact with the outside of the steel pipe to allow the problem to be addressed before the system is impacted by exterior corrosion. Valves can be direct-buried which reduces the infrastructure required for valve chambers and underground vaults. In fact, it is possible to install the entire system without a single valve chamber or manhole. This system also has the benefit of requiring limited provisions for thermal expansion which simplifies installation.

Hot water district heating pipes are typically placed underground at a depth of approximately three feet from the top of pipe to the ground surface (see Figure 5). With structural protection, a more shallow installation for portions of the route can be accomplished. Installation more than three feet underground, unless the depth is required to avoid other utilities in the area, is usually not necessary. Cost of installation increases with increased trench depth. Considering the permitting costs for placing piping in the street right of way and in order to minimize the costs of surface restoration following pipeline construction, Ever-Green Energy recommends that the hot water district heating pipeline be installed in the sidewalk or boulevard/greenbelt areas wherever possible. Such a placement has the added benefit of upgrading the neighborhood sidewalks along the pipeline route while at the same time minimizing the cost of installation and right of way access fees. It should be noted that sidewalk installation can prove challenging in areas where mature trees are encountered in the boulevard/greenbelt areas due to the potential for damaging the existing trees as a result of disturbing the root structure of a mature tree. Prior to installation of the district heating pipeline, a thorough assessment of the potential for district cooling should be completed since there is a cost savings if both heating and cooling pipes are installed in the same trench at the same time.

Figure 5 Typical trench section



The parameters selected for the temperatures and pressures for the district system are established to ensure an efficient overall system with adequate static pressure throughout the system to prevent flashing of the hot water at temperatures above 212 ºF. A peak supply temperature of 250 ºF with a design differential temperature between supply and return of 90 ºF are key design parameters for establishing the size of the distribution piping. The system typically operates at the peak supply temperature when the system load is at its maximum level; typically when the ambient outside air temperature is at the design temperature for Burlington. The system is operated such that the supply temperature is reduced by one degree for each degree increase in outdoor air temperature to a minimum supply temperature of not less than 180 ºF. This adjustment is called the outdoor air temperature reset schedule and serves three primary purposes (1) to minimize the distribution pipe size required to meet peak loads since each gallon of water delivered on peak carries more thermal energy due to the higher temperature, (2) to reduce the pumping energy required to deliver sufficient water to the customers during peak usage conditions, and (3) to minimize the loss of heat through the insulation during off-peak operation since the lower supply temperature reduces the potential for heat loss.

Although steam district heating systems are common in the United States for cities and corporate and college campuses, the medium temperature hot water distribution recommended for Burlington has other advantages that a steam distribution system does not provide. Specifically, lower grade heat can be used to supply the thermal energy to the system. In the case of heat supply from McNeil, the efficiency of supplying heat to the system is improved since turbine extraction can be done at a lower pressure which improves the overall cogeneration process and maximizes the power output before the steam is extracted for thermal use. This system is also compatible with heat recovery from stack flue gases which provides even better overall system efficiency and is the most economical source of heat for the district system. Hot water distribution has other advantages over steam distribution including:

- Steam systems typically have higher installation costs than a hot water system, and
- Maintenance of steam systems is more complex and more costly due to steam trap maintenance and the corrosive nature of the condensate returned for reuse.

The hot water is delivered through the hot water distribution pipes via a redundant pumping system controlled by a variable-frequency drive (VFD). The pump output is controlled in response to a differential pressure signal on the pipeline that provides constant feedback to the VFD and causes the pump speed to increase or to decrease in response to the differential pressure throughout the system. This design also serves to reduce energy use in the system since the pump output, and therefore electrical input to the pump motor, are controlled to the lowest possible level to meet customer demand.

4 Heat Supply

A heat supply configuration was established for each Alternative with a goal to maximize the use of renewable thermal energy from the biomass boiler at McNeil Generating Station while keeping capital and energy costs as low as possible.

For Alternative 1 the heat production system consists of a heat exchanger that transfers heat to the hot water distribution system from steam extracted from the McNeil steam turbine. In order to maximize the amount of renewable thermal energy derived from the McNeil biomass boiler, a thermal storage system is employed. The thermal storage system is a 2,500,000 gallon insulated storage tank at atmospheric pressure that can be charged with hot water while McNeil is dispatched for electric production on its normal production schedule. Using thermal storage in this manner allows the McNeil biomass boiler to supply a predicted 95 percent of the total energy delivered to the hot water system. This high percentage is achieved despite a conservative assumption for the electrical dispatch at McNeil being only during weekday peak hours and offline during weekends. The remaining thermal energy to the system is provided by natural gas with fuel oil backup and is combusted in a 10 MW hot water boiler also installed on the McNeil site. This boiler provides peaking capacity and backup to the system if the McNeil Generating Station is offline for longer periods.

Alternative 2 also achieves a total energy supply from the McNeil biomass boiler to the hot water distribution system in excess of 95 percent. However, due to the larger customer load associated with Alternative 2, additional capital equipment is needed to collect low grade heat from the McNeil electric production process. In this case a flue gas economizer is employed in conjunction with steam extraction from the McNeil turbine and thermal storage. The flue gas economizer captures heat that would otherwise be exhausted to the stack as waste heat. The resulting energy price is very low and consists solely of the cost of capital and maintenance on the economizer. No additional fuel is consumed at McNeil to supply heat through this economizer, yet more than half of the annual demands of the Burlington system under Alternative 2 would be derived from this low-cost flue gas heat recovery. The remainder of the thermal energy is supplied from extraction from the McNeil turbine (a predicted 40 percent of the total heat to the system) and natural gas/fuel oil from a pair of backup 10 MW boilers (4 percent of the total heat to the system). Again, through the extraction of heat from the McNeil electric production process in conjunction with thermal storage almost all of the heat for the district heating system is supplied by renewable fuel at McNeil. In the Alternative 2 scenario, a second 2,500,000 gallon thermal storage tank is included in the capital costs for production in order to maximize the renewable thermal energy derived from McNeil. A tank of this volume that is 100 feet in diameter would be approximately 45 ft tall. The electric dispatch for the McNeil Station for this case is again assumed to be only during weekday peak hours.

For the cursory review done for Alternative 3, a system similar to the one used for Alternative 2 is assumed. In Alternative 3, the heat derived from the McNeil boiler remains at a predicted 92 percent of the total. However, only 30 percent of this total comes from the flue gas economizer since the system load is now proportionately larger than the economizer can be scaled.

In each case, other sources of heat were evaluated and each, in turn, determined to be not a viable solution. The case for installing a second backpressure turbine was investigated and concluded that the increased cost of the turbine coupled with higher O&M costs result in this option being removed from further consideration given that the new backpressure turbine provides no advantage from an overall efficiency or cost of thermal energy delivered to the district heating system compared with extraction from the existing turbine. Cooling tower heat recovery using electric-driven centrifugal heat pumps was also investigated and dismissed (Refer to Section 4.2.4). High capital cost required for the installation of the heat pumps coupled with the fact that there is a significant ongoing energy input cost due to the electric power required to operate the heat pump. Lastly, heat pump technology has not yet advanced to the point where the output from the heat pump can be used to directly supply a medium temperature hot water system due to output temperature limitations.

Table 7 District heating system input assumptions

	Alternative I	Alternative II	Alternative III
Market Penetration *1	100%	80%	100%
Diversification	80%	80%	80%
Energy Loss	10%	10%	10%
Daily Average Load	90%	90%	90%

**1 For buildings in each alternative*

4.1 Steam Extraction

Steam can be extracted from the existing steam turbine at five different pressures. The electric generation loss is lower at lower extraction pressures (i.e. extraction at a point after which the steam has been used to produce more electricity). For a medium temperature hot water system such as is proposed for Burlington, the optimal extraction pressure is approximately 20 psia in order to achieve the design maximum temperature of 250 ºF for the hot water distribution supply temperature.

4.1.1 Existing Steam Turbine

The cost of energy to the district heating system based on extraction from the existing steam turbine is assessed in Tables 8 and 9 (see also Appendixes C and D). The thermal energy price in the tables is based on the lost power revenue compared to normal condensing power production. The Coefficient Of Performance (COP) for the steam extraction varies from 2.4 (i.e. 1 kWh of electricity is lost for every 2.4 kWh thermal energy generated) if admission steam is used up to a COP of 10.6 for port 1. With a mix of extraction from ports 3 and 2 to satisfy temperature requirements for the district heating system, the thermal energy price will be in the range of $4.10/MMBtu to $6.90/MMBtu based on an electricity price of $80/MWh. The steam turbine is, however, designed to be able to supply steam from ports 4 and 5 and the quantity of steam that can be extracted from ports 2 and 3 requires additional evaluation by the turbine manufacturer to determine the available amount. It is Ever-Green Energy's experience that additional extraction is typically determined to be available upon detailed analysis by the manufacturer.

While the McNeil plant has sufficient boiler steam capacity the thermal energy can also be priced on only the additional fuel usage. Based on a biomass price of $34.55/ton and a boiler efficiency of 70%, the thermal price based on fuel usage would be $5.00/MMBtu (see Table 10).

In the calculations of the system performance it has been assumed that steam will be extracted from port 4 to a steam to hot water heat exchanger but the thermal energy price is based on additional fuel usage at $5.00/MMBtu.

Table 8 Cost of steam from existing steam turbine extraction at 50 MW electric output

50,000 kW - 100%	Inlet	Extraction					Condenser
		5	4	3	2	1	
Steam pressure (psia)	1265	392	208	86	13.0	3.9	1.0
Steam temperature (F)	950	660	522	356	206	152	101
Enthalpy steam (btu/lb)	1,468	1,342	1,280	1,206	1,082	1,021	963
Saturation temp (F)	574	443	385	317	206	152	101
Enthalpy water (btu/lb)	581	422	359	287	174	120	67
Extraction steam flow (lb/hr)	11,529	26,449	25,116	28,948	19,009	9,574	291,411
Steam flow to next stage (lb/hr)	400,621	374,172	349,056	320,108	301,099	291,525	114
Gross power (kW)		14,803	6,770	7,606	11,687	5,324	4,950
Gross power per lb/hr steam (W) *1	148	111	93	71	35	17	0
Gross power per lb/hr steam (W) *2	128	97	85	69	34	17	0
DH per lb/hr steam (btu/lb) *3	1,059	933	871	797	672	612	554
DH per lb/hr steam (W)	310	273	255	234	197	179	162
COP DH extraction *2	2.4	2.8	3.0	3.4	5.8	10.6	
DH energy price ($/MMBtu') *4	9.6	8.3	7.8	6.9	4.1	2.2	

**1 Only based on enthalpy difference from port to condenser without compensation for preheater steam flow*
**2 With compensation for preheater steam flow based on turbine heat balance*
**3 DH condensate enthalpy (btu/lb) 410*
DH condensate enthalpy based on boiler feedwater enthalpy after HP preheater
**4 At electricity price ($/MWh) 80*

Table 8 Cost of steam from existing steam turbine extraction at 50 MW electric output

Table 9 Cost of steam from existing steam turbine extraction at 25 MW electric output

25,000 kW - 50%	Inlet	Extraction					Condenser
		5	4	3	2	1	
Steam pressure (psia)	1265	199	107	45	7.0	2.3	1.0
Steam temperature (F)	950	570	445	294	177	132	101
Enthalpy steam (btu/lb)	1,468	1,307	1,250	1,182	1,067	1,014	984
Saturation temp (F)	574	381	333	275	177	132	101
Enthalpy water (btu/lb)	581	355	304	244	144	100	67
Extraction steam flow (lb/hr)	6,629	11,695	11,341	11,774	9,071	892	164,573
Steam flow to next stage (lb/hr)	209,428	197,733	186,392	174,618	165,547	164,655	82
Gross power (kW)		9,888	3,288	3,728	5,909	2,554	1,444
Gross power per lb/hr steam (W) *1	142	95	78	58	24	9	0
Gross power per lb/hr steam (W) *2	128	86	73	57	24	9	0
DH per lb/hr steam (btu/lb) *3	1,123	962	905	837	721	669	639
DH per lb/hr steam (W)	329	282	265	245	211	196	187
COP DH extraction *2	2.6	3.3	3.6	4.3	8.8	22.4	
DH energy price ($/MMBtu') *4	9.1	7.1	6.5	5.4	2.7	1.0	

**1 Only based on enthalpy difference from port to condenser without compensation for preheater steam flow*
**2 With compensation for preheater steam flow based on turbine heat balance*
**3 DH condensate enthalpy (btu/lb) 346*
DH condensate enthalpy based on boiler feedwater enthalpy after HP preheater
**4 At electricity price ($/MWh) 80*

Table 10 Steam price based on fuel cost and boiler efficiency

Base Wood Fuel Cost	27.93	$/ton
Maintenance Cost	0.57	$/ton
Ash Handling Cost	0.23	$/ton
VT Fuel tax	0.03	$/ton
Rail Cost	3.83	$/ton
Fuel Yard Cost	1.96	$/ton
Total Wood Fuel Cost	34.55	$/ton
Heat Content	9.794	MMBtu/ton
Boiler Efficiency	70%	
Thermal Energy Price	5.0	$/MMBtu
Gross Steam Turbine Heat Rate	8,531	btu/kWh
Electrical losses and aux.	15%	
Net Plant Heat Rate	14,337	btu/kWh
Power Energy Price	50.6	$/MWh

4.1.2 New Backpressure Steam Turbine

A new backpressure steam turbine can be installed in parallel to the existing steam turbine and be designed to supply heat at an optimal temperature to the district heating system thereby increasing the COP compared to the existing steam turbine. However, with a steam turbine designed for a 20 psia backpressure the performance is marginally better than extracting from ports 2 and 3 from the existing steam turbine (see Table 11 and Appendix E). At present the McNeil power station has sufficient boiler capacity not to have to reduce the power output even if steam is extracted from the existing steam turbine. To add additional capital cost and maintenance cost for a new backpressure steam turbine to the district heating project is therefore not advisable at present.

Table 11 New backpressure steam turbine performance

Existing Steam Turbine Efficiency		
Inlet steam	1,468	btu/lb
Port No. 2	1,082	btu/lb
100% internal efficiency	1,035	btu/lb
Actual internal efficiency	89%	
New Backpressure Steam Turbine- Inlet Steam		
Inlet steam	1,468	btu/lb
20 psia backpressure/100% internal efficiency	1,065	btu/lb
Enthalpy at 80% internal efficiency	1,146	btu/lb

4.2 Heat Recovery

4.2.1 Heat Pump

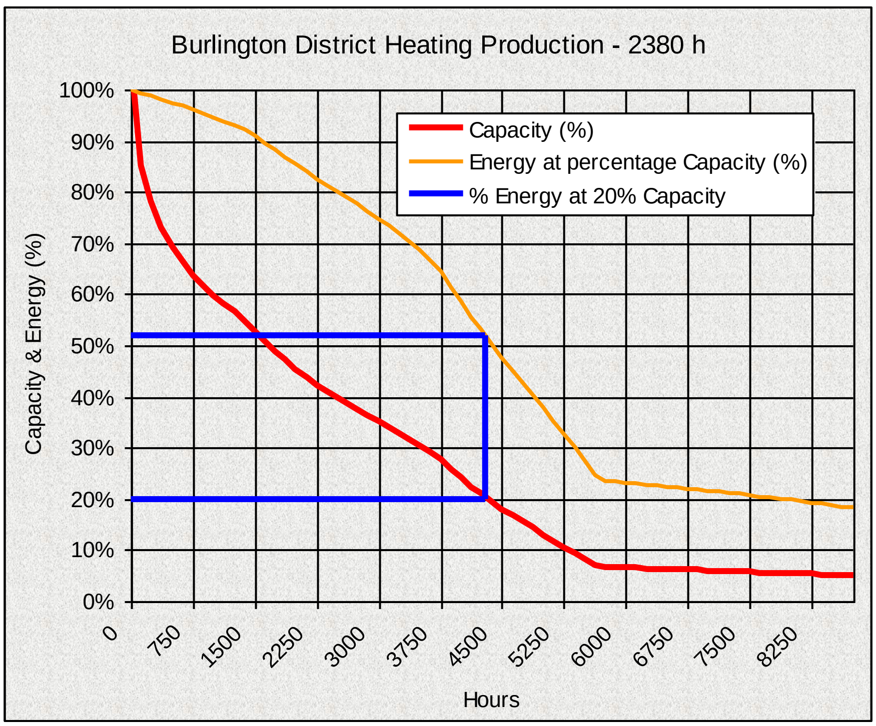
In order to recover heat from the McNeil cooling tower water a heat pump is needed to make the energy available at a temperature level suitable for a district heating system.

The maximum temperature from a heat pump using R134a refrigerant is in the range of 180 °F due to refrigerant critical pressure/efficiency considerations (see Appendix F). Most large heat pumps on the US market, however, are based on heat recovery from chillers for domestic hot water production and tend to have a maximum temperature below 160 °F and with a less than optimal Coefficient Of Performance (COP) in heat pump mode. With a district heating return temperature in the 160 °F range without significant capital improvements of the customer's on-site heating systems, a heat pump needs to provide a temperature up to about 180 °F to be able to provide a reasonable amount of energy into the system and are available on the European market.

Assuming a district heating system with a return temperature of 160 °F and a supply temperature of 180 °F in the summer and up to 230 °F in the winter, a heat pump with a 180 °F maximum temperature will be able to provide up to 20% of peak capacity and about 50% of the annual energy usage (see Figure 6). The capacity around 40 °F ambient temperature (at about 4,000 hrs) can be somewhat restricted however when the supply temperature normally starts to be increased above the base 180 °F.

With a 170 °F maximum temperature the heat pump can only provide 11% of the maximum capacity at peak conditions and 50% of the energy during periods with maximum 180 °F supply temperature, resulting in that only about 20% of the annual energy can be provided from a heat pump application.

Figure 6 Burlington load duration curve and energy usage



The temperature of both a flue gas condenser and cooling tower water is in the 80 °F range. With 180 °F maximum output temperature a heat pump could achieve a COPh of about 4 assuming an "inefficiency factor" compared to Carnot's ideal formula similar to a chiller (see Table 12).

Table 12 Estimated chiller and heat pump efficiency

Chiller and heat pump perfomance	Chiller	Heat Pump	Chiller	Heat Pump
	Degree F		Degree K	
T1 = Condenser	95	180	308	355
T2 = Evaporator	42	80	279	300
COPc T2/(T1-T2), COPh T1/(T1-T2)			9.5	6.4
"Carnot efficiency"			***0.62***	0.62
COP actual *1			5.9	4.0
**1*			*0.60*	*kW/ton*

4.2.2 Flue Gas Economizer

A flue gas economizer has been evaluated as a primary heat source to the district heating system. The economizer is the one option for low-grade heat recovery at McNeil that does not require a heat pump to make the waste heat useable by the district system. As can be seen in Table 13, the comparative cost of energy from such a system is in the range of $2.20 per MMBtu. This analysis is based on the annualized capital cost at a six percent cost of capital and an assumption of one percent per year operation and maintenance costs ($20,000 per year) on the economizer. Other options for heat recovery such as cooling tower water and flue gas condensing have the added burden of capital costs and continuous energy input of electricity to operate the heat pumps. As a result, the comparative cost per MMBtu is $10.50 per MMBtu for flue gas condensation (Refer to Table 14) and $8.30 per MMBtu for cooling tower heat recovery. This makes the case for flue gas economizer at $2.20 per MMBtu a compelling advantage. It should be noted that the amount of energy available from a flue gas economizer or condenser may be limited by the need to maintain a minimum temperature out of the stack for flue gas dispersion purposes. This minimum temperature is specific to McNeil and will need to be determined through a separate study and analysis.

While a flue gas economizer does not have the same dramatic effect on flue gas conditions as a flue gas condenser would, the impact of this cooling of the flue gas on stack exit conditions must be fully evaluated. Stack emission dispersion modeling results may require updating if a flue gas economizer is deployed.

Figure 7 Flue gas heat recovery potential as a function of exiting flue gas temperature

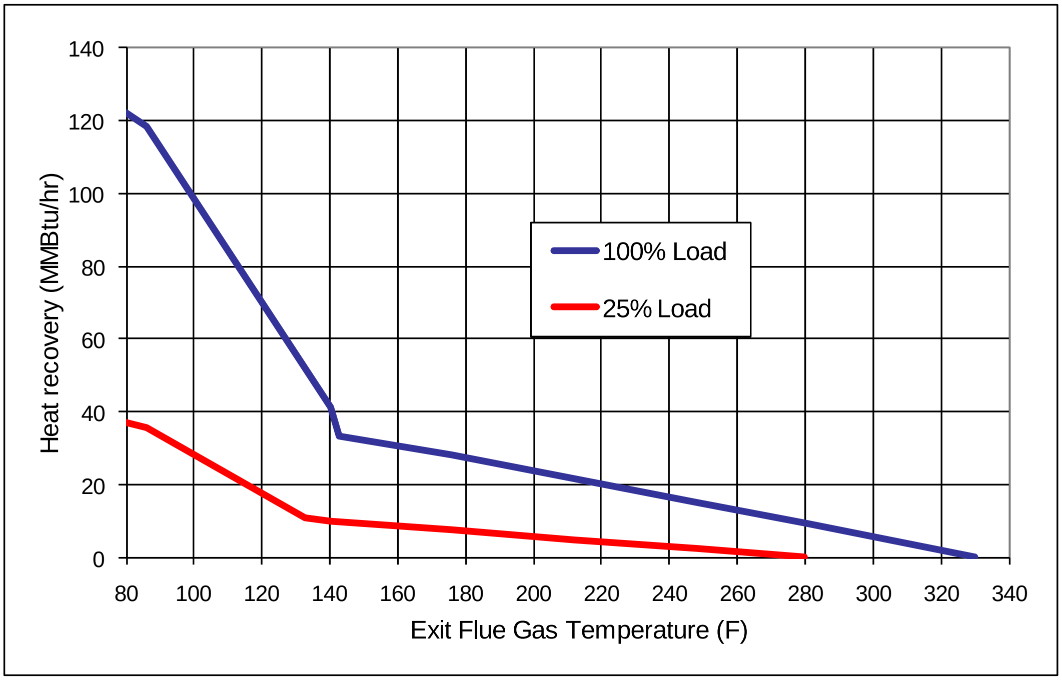


Table 13 Estimated cost for flue gas heat recovery

Flue gas economizer	2,000,000	$ /	15.0	MMBtu/hr =>	133,333	$/MMBtu/hr
Capital cost	6%	interest	20	years =>	8.7%	annuity factor
O&M cost	1%	on flue gas economizer				
Capital cost	11,625	$/MMBtu/hr				
O&M cost	1,333	$/MMBtu/hr				
DH utilization	2,240	equivalent full load hours				
Economizer utilization	20%	of peak demand =>			53%	of annual energy
Economizer utilization hours	5,936	equivalent full load hours				
Economizer production cost	2.2	$/MMBtu				

4.2.3 Flue Gas Condenser

The complexity of a flue gas condensing system, to a large part due to the heat pump needed, results in increased capital and O&M costs as well as added electricity cost to operate the heat pump compared with the flue gas economizer. The added cost to install, operate and maintain a flue gas condenser with a heat pump to make the thermal energy useable by the district heating system results in a total energy cost of $10.50/MMBtu.

Table 14 Estimated cost for energy from flue gas condensation

Chiller installation w/o cooling tower	1,000	$/ton				
HP capacity cost adjusted with COP	1,480	$/ton	420	$/kW	123,000	$/MMBtu/hr
Heat recovery heat exchanger	2,000,000	$ /	15.0	MMBtu/hr =>	133,333	$/MMBtu/hr
Capital cost	6%	interest	20	years =>	8.7%	annuity factor
Electricity cost	8.0	cent/kWh				
O&M cost	3%	of HP capital cost			1%	on heat recovery HX
Capital cost	22,348	$/MMBtu/hr				
Electricity cost	5.9	$/MMBtu				
O&M cost	5,023	$/MMBtu/hr				
DH utilization	2,240	equivalent full load hours				
HP utilization	20%	of peak demand =>			53%	of annual energy
HP utilization hours	5,936	equivalent full load hours				
HP production cost	10.5	$/MMBtu				

4.2.4 Cooling Tower Water Heat Recovery

Cooling tower water can be another heat source for a heat pump providing thermal energy to a district heating system. However, even if the heat recovery is less complicated compared to a flue gas condenser, the added cost of electricity input to operate the heat pump to make the thermal energy useable by the district heating system results in a total energy cost of $8.30/MMBtu.

This lower-grade heat from cooling towers remains suitable for such direct uses as heating of greenhouses as has been considered for the Intervale Center. The heat from the cooling tower remains fully available for such uses since it will not be utilized for the district heating system.

Table 15 Estimated cost for heat pump using cooling tower water

Chiller installation w/o cooling tower	1,000	$/ton				
HP capacity cost adjusted with COP	1,480	$/ton	420	$/kW	123,000	$/MMBtu/hr
Capital cost	6%	interest	20	years =>	8.7%	annuity factor
Electricity cost	8.0	cent/kWh				
O&M cost	3%	of capital cost				
Capital cost	10,724	$/MMBtu/hr				
Electricity cost	5.9	$/MMBtu				
O&M cost	3,690	$/MMBtu/hr				
DH utilization	2,240	equivalent full load hours				
HP utilization	20%	of peak demand =>			53%	of annual energy
HP utilization hours	5,936	equivalent full load hours				
HP production cost	8.3	$/MMBtu				

4.3 Hot Water Storage

Hot water storage is used to maximize the amount of cogenerated renewable energy derived from the McNeil biomass boiler. In a hot water application, the use of storage helps to level the customer load profile between night and day which reduces the dependence on expensive peaking boilers that operate on fossil fuels. In the case of the McNeil Generating Station, the cyclic nature of the electrical production dispatch is also able to be overcome with properly-sized thermal storage. When McNeil is operating, the customer's demand for heat is met using extraction or flue gas recovery (depending on the selected Alternative) and, at the same time, heat is stored in the thermal storage system for use when the McNeil Station is offline. This enables the Burlington hot water district system to be supplied with renewable energy from McNeil even when McNeil is not currently in operation. The storage of this heat also minimizes the amount of natural gas and/or fuel oil that is needed to supplement the system energy demands.

Figure 8 shows typical daily load curves for a district heating system with similar load pattern for the 5 weekdays and 4 weekend days depicted. For the sizing of a hot water storage a typical daily load as shown in figure 9, with an average load of about 90%, is used for both weekdays and weekend.

For Alternative 1, the storage is sized to be optimal for the size of the system at 2.5 million gallons. The production capital assumption for Alternative 2 includes 5.0 million gallons of hot water storage (two 2.5 million gallon tanks) which is the optimal storage size for Alternative 2. The assumption that Alternative 2 would use 2 tanks allows for the storage to be expanded as customer load increases over time rather than requiring all of the storage to be installed at the inception of the system. A similar approach was taken when planning the thermal storage requirements for the Saint Paul, Minnesota district cooling system which now employs two large storage tanks, installed at separate times as customer demand grew, to meet optimal storage capacity. For Alternative 3, an optimal storage of 11.7 million gallons is indicated. Due to the excessive space required for such a storage arrangement, the analysis for Alternative 3 was performed using the same storage volume as is used in Alternative 2 which is 5.0 million gallons. Further analysis of the practicality of additional storage volumes for Alternative 3 is appropriate if Alternative 3 becomes a likely arrangement. Additional storage in Alternative 3 could increase the percentage of the energy supplied using renewable fuel compared with the case analyzed in this study.

The thermal storage system considered here is an atmospheric tank. As such, hot water would be stored at a temperature of approximately 200 degrees F. At times of year when supply temperature of greater than 200 degrees is needed, the temperature of the water in the tank is increased by means of a heat exchanger as it is drawn from the tank and before being pumped to the system supply. An alternative to be reviewed during detailed engineering is whether the tank can be sized in such a way that its height provides sufficient static head for system pressurization.

Storage was selected due to the positive impact on McNeil's overall efficiency. Storage most effectively maximizes McNeil's overall average efficiency and fuel economy. There could be scenarios in a high thermal load (winter) period when natural gas prices are disproportionately higher than wood fuel during which it would be beneficial to the system to operate McNeil in out-of-economic dispatch to ensure continuous supply of thermal energy from wood fuel. This is the case where storage is expected to be exhausted due to high load which would require gas to supplement. In this case, a real-time pricing model which considers real-time electric power pricing, natural gas price, and projected HW customer load will be able to effectively guide such a decision to maintain McNeil in operation on wood fuel despite non-economic generation from an electric sales standpoint.

Figure 8 Examples of daily district heating load curves

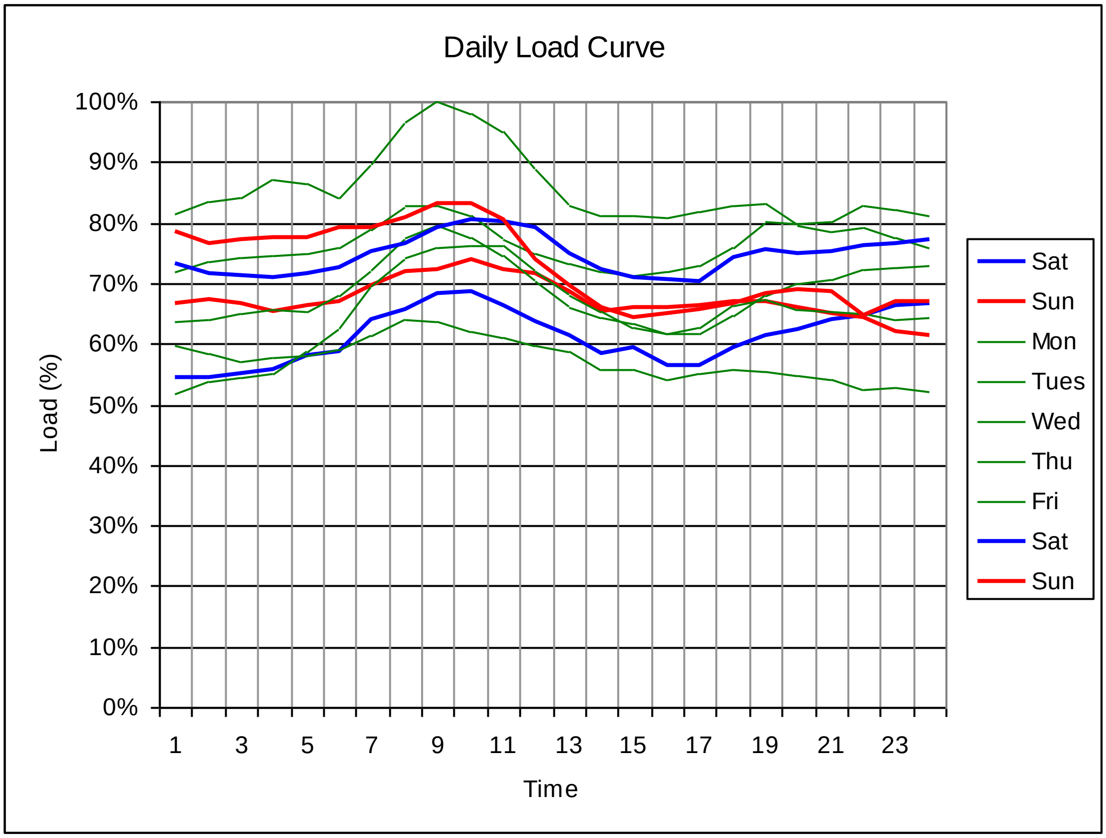


Figure 9 Typical daily district heating load curve

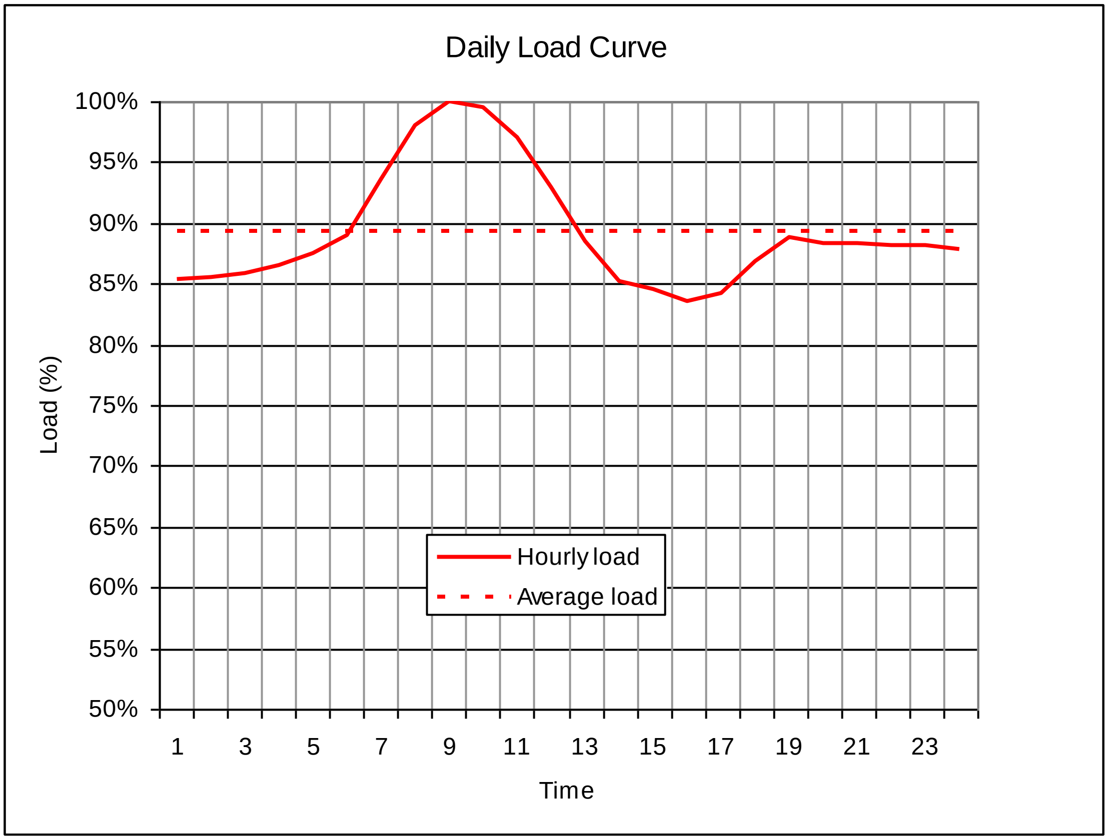


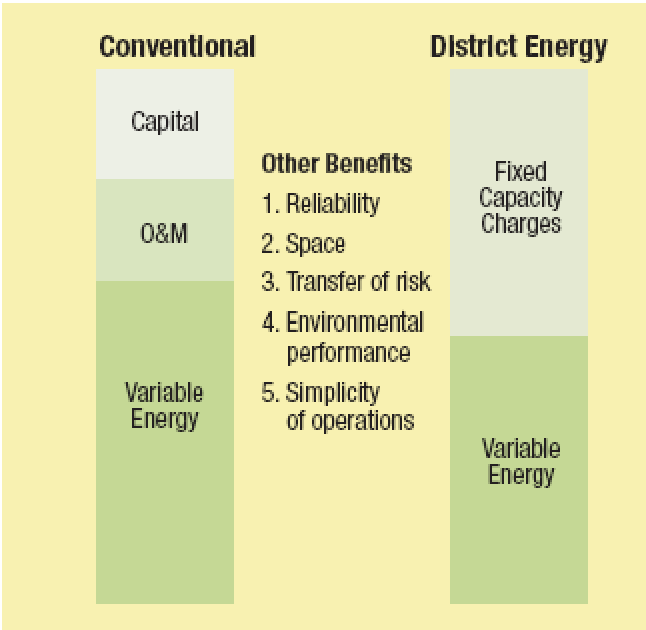
Table 16 Hot water storage system optimal volume analysis

	Alternative I	Alternative II	Alternative III
Peak Customer load (kW)	11,315	22,955	53,955
Peak Production Load (kW)	9,052	18,364	43,164
Daily Average Load (kW)	8,147	16,528	38,848
Max Load from Storage (kW) *1	3,621	7,346	17,266
Max energy from storage (MWh) *2	217,248	440,736	1,035,936
Net Storage Size (gal)	2,221,855	4,507,527	10,594,800
Gross Storage Size (gal) *3	2,447,806	4,965,920	11,672,237
**1 Supply temperature (F)*	*250*		
Return temperature (F)	*160*		
Max temperature from storage (F)	*200*		
Max load from storage (%)	*44%*		
**2 Friday 9 pm to Monday 9 am (hrs)*	*60*		
**3 Volume efficiency loss (%)*	*9%*		

5 Capital and Energy Cost for District Heating

Evaluating the cost of district energy services compared to using conventional onsite building systems requires the use of life-cycle analysis. That is to evaluate all of the costs associated with producing space heating and domestic hot water on-site (natural gas or fuel oil, operation and maintenance and capital) over a 20 to 30 year period compared to the cost of using district energy services.

Typically, customers of district energy services are charged a demand or fixed capacity charge, based on the actual heating and cooling capacity needs of the building, and a variable energy charge that varies by the actual energy utilized by the building.



The demand or capacity charge is generally fixed and is the same cost month to month and normally increases based upon CPI or some other mechanism.

For building owners to determine how much capital can be avoided by connecting to a district energy system, consideration should also be given to the space and infrastructure that on-site heating and domestic hot water boilers require that could be used for other purposes.

Comparing the total cost of conventional services is highly dependent upon the building specifics.

5.1 *Capital Cost*

Capital cost estimates provided in the report are estimates of probable cost based on Ever-Green Energy's experience with similar projects. Financing costs, including interest during construction, were assumed to be ten percent (10%) of the direct construction cost for each case.

For this feasibility evaluation, no cost for customer conversions has been considered. Typically, the customer is responsible for the cost of converting the building mechanical systems to utilize the district heating system. During the business planning phase of the Burlington project, consideration should be given to providing a credit to offset conversion costs for buildings that are considered crucial to allow the development of the system to proceed. These credits have not been included in the capital cost estimates.

5.1.1 Distribution

The tables below summarize the estimated cost of the distribution pipeline for each of the three Alternatives. Engineering of the pipeline can be expected to cost approximately five percent (5%) of the installed cost. These engineering costs can be considered included in the estimates of probable costs in the following tables (Tables 17 to 19).

Table 17 Estimate of probable cost for distribution pipeline for Alternative 1

Pipe Size inch	Length ft	Cost $/ft	Cost $1,000
8	4,915	700	3,441
6	1,246	600	748
5	599	550	329
3	5,582	450	2,512
TOTAL	12,342		7,029

Customer connections: 200 ft/each
Cost estimate:
50 $/in + 300 $/ft

Table 18 Estimate of probable cost for distribution pipeline for Alternative 2

Pipe Size inch	Length ft	Cost $/ft	Cost $1,000
10	4,915	800	3,932
8	1,459	700	1,021
6	3,989	600	2,393
5	1,750	550	963
3	9,582	450	4,312
TOTAL	21,695		12,621

Customer connections: 200 ft/each
Cost estimate:
50 $/in + 300 $/ft

Table 19 Estimate of probable cost for distribution pipeline for Alternative 3

Pipe Size inch	Length ft	Cost $/ft	Cost $1,000
14	5,514	1000	5,514
12	4,630	900	4,167
10	692	800	554
8	860	700	602
6	4,467	600	2,680
5	1,750	550	963
3	9,582	450	4,312
TOTAL	27,495		18,791

Customer connections: 200 ft/each
Cost estimate:
50 $/in + 300 $/ft

5.1.2 Production

The tables below summarize the production equipment and estimate of probable cost for each of the three Alternatives (see Appendix G for P&ID for each alternative). In each case, provisions have been made in the capital costs for a building to house the production and thermal energy conversion equipment at McNeil. It is likely that a preferred location would be in an unused area at the McNeil plant in order to minimize the length of piping required to connect the production system components. For Alternatives 2 and 3, the extent of the equipment required to produce the energy for the hot water system is sufficiently large as to require more space than is readily available within the existing buildings at the McNeil Station. Provision for construction of additional building space is included in the capital costs.

Table 20 Production equipment summary and estimate of probable cost for Alternative 1

	Size		Units	Unit price	Total
Package hot water boiler	10	MW	1	350,000	$350,000
Steam heat exchanger	15	MW	1	200,000	200,000
Flue gas economizer	0.0	MW		0	0
Hot water storage tank	2,500,000	gal	1	2,000,000	2,000,000
Distribution pumps	1,000	gpm	2	20,000	40,000
Piping & insulation			1	540,000	540,000
Valves, strainers, etc			1	200,000	200,000
Oil transfer pumps			1	5,000	5,000
Oil storage tank above ground w/ containment	0	gal		0	0
Water softener incl installation			1	15,000	15,000
Chemical feed equipment incl installation			1	4,000	4,000
24" insulated stack w/ breeching	60	ft	1	120,000	120,000
Motor control centers			2	100,000	200,000
Controls			1	200,000	200,000
Building	5,000	sq.ft	5,000	150	750,000
SUBTOTAL					4,624,000
Engineering	10%				462,400
Contingency	25%				1,271,600
TOTAL					6,358,000

Table 21 Production equipment summary and estimate of probable cost for Alternative 2

	Size		Units	Unit price	Total
Package hot water boiler	10	MW	2	350,000	$700,000
Steam heat exchanger	30	MW	1	350,000	350,000
Flue gas economizer	4.4	MW	1	2,000,000	2,000,000
Hot water storage tank	2,500,000	gal	2	2,000,000	4,000,000
Distribution pumps	1,500	gpm	2	30,000	60,000
Piping & insulation			1	975,000	975,000
Valves, strainers, etc			1	330,000	330,000
Oil transfer pumps			2	5,000	10,000
Oil storage tank above ground w/ containment	0	gal		0	0
Water softener incl installation			1	15,000	15,000
Chemical feed equipment incl installation			1	4,000	4,000
24" insulated stack w/ breeching	60	ft	1	120,000	120,000
Motor control centers			3	100,000	300,000
Controls			1	300,000	300,000
Building	7,000	sq.ft	7,000	150	1,050,000
SUBTOTAL					10,214,000
Engineering	10%				1,021,400
Contingency	25%				2,808,850
TOTAL					14,044,250

Table 22 Production equipment summary and estimate of probable cost for Alternative 3

	Size		Units	Unit price	Total
Package hot water boiler	25	MW	2	730,000	$1,460,000
Steam heat exchanger	30	MW	2	350,000	700,000
Flue gas economizer	4.4	MW	1	2,000,000	2,000,000
Hot water storage tank	2,500,000	gal	2	2,000,000	4,000,000
Distribution pumps - MT	3,500	gpm	2	40,000	80,000
Piping & insulation			1	1,060,000	1,060,000
Valves, strainers, etc			1	375,000	375,000
Oil transfer pumps			2	5,000	10,000
Oil storage tank above ground w/ containment	0	gal		0	0
Water softener incl installation			1	15,000	15,000
Chemical feed equipment incl installation			1	4,000	4,000
24" insulated stack w/ breeching	60	ft	1	120,000	120,000
Motor control centers			4	100,000	400,000
Controls			1	300,000	300,000
Building	9,000	sq.ft	9,000	150	1,350,000
SUBTOTAL					11,874,000
Engineering	10%				1,187,400
Contingency	25%				3,265,350
TOTAL					16,326,750

5.1.3 Total Capital Cost

Table 23 Total capital cost for Alternatives 1 to 3

District Heating Summary				
Alternative I				
Energy Usage				
Customer Load	11,315	kW	1.09	ft/kW
Customer Energy	21,499	MWh	0.57	ft/MWh
Plant Load	9,052	kW		
Plant Energy	23,648	MWh		
Capital Cost				
Distribution	$7,029	$ 1,000	$621	$//kW
Production	$6,358	$ 1,000	$562	$//kW
Customer conversions	$0	$ 1,000	$0	$//kW
Interest during construction, etc	$1,339	$ 1,000	$118	$//kW
Total Capital Cost	$14,726	$ 1,000	$1,301	$//kW
Alternative II				
Energy Usage				
Customer Load	22,955	kW	0.95	ft/kW
Customer Energy	43,615	MWh	0.50	ft/MWh
Plant Load	18,364	kW		
Plant Energy	47,976	MWh		
Capital Cost				
Distribution	$12,621	$ 1,000	$550	$//kW
Production	$14,044	$ 1,000	$612	$//kW
Customer conversions	$0	$ 1,000	$0	$//kW
Interest during construction, etc	$2,667	$ 1,000	$116	$//kW
Total Capital Cost	$29,332	$ 1,000	$1,278	$//kW
Alternative III				
Energy Usage				
Customer Load	53,955	kW	0.51	ft/kW
Customer Energy	102,515	MWh	0.27	ft/MWh
Plant Load	43,164	kW		
Plant Energy	112,766	MWh		
Capital Cost				
Distribution	$18,791	$ 1,000	$348	$//kW
Production	$16,327	$ 1,000	$303	$//kW
Customer conversions	$0	$ 1,000	$0	$//kW
Interest during construction, etc	$3,512	$ 1,000	$65	$//kW
Total Capital Cost	$38,630	$ 1,000	$716	$//kW

- Above table does not include cost for customer building conversions.
- 80% market penetration for the area encompassed by Alternative 2 is assumed.
- Financing costs and debt service, including interest during construction, assumed to be ten percent (10%) of the direct construction cost for each case.
- Cost of all production-side modifications at McNeil included, including building space cost.
- Alternative 1 requires favorable financing or other subsidy to achieve break-even.

5.2 Energy Cost

The load duration curves for each alternative are shown below. From these curves, the sources of heat expected to be utilized through the year is detailed. Load duration curves are based on aggregate customer loads and the typical climate conditions for Burlington. In each case, a natural gas price of $12.00 per MMBtu is assumed (equivalent to heating fuel oil price of approximately $1.70 per gallon).

Figure 10 Alternative 1 load duration curve and production sources

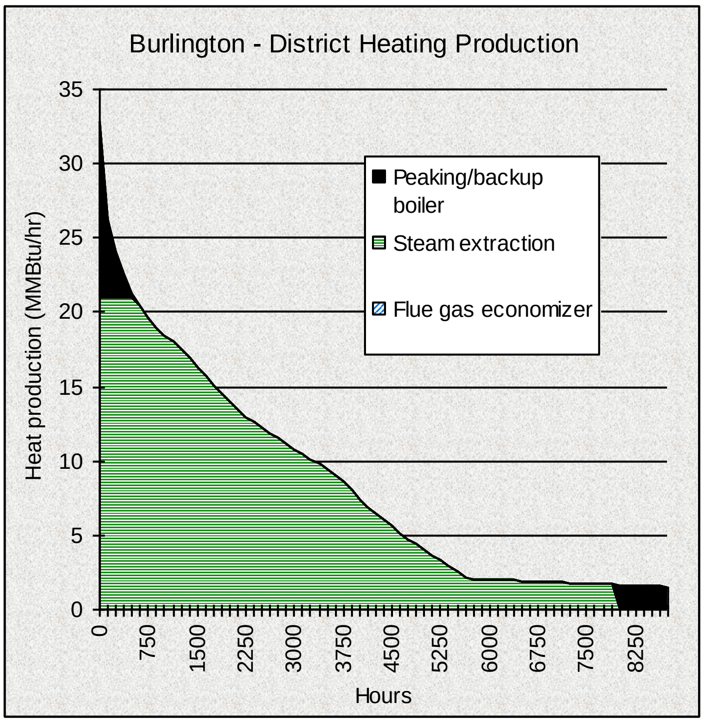


Table 24 Alternative 1 production sources and cost

Peak capacity (MMBtu/hr)	30.9			
	Energy Production		Energy Price	
	MMBtu	%	$/MMBtu	$
Flue gas economizer	0	0%	0.0	$0
Steam extraction	76,992	95%	5.0	$387,947
Peaking/backup boilers *1	3,649	5%	15.0	$54,734
Total	80,641		5.5	$442,681

**1 Based on gas price 12 $/MMBtu and eff. 80%*

Figure 11 Alternative 2 load duration curve and production sources

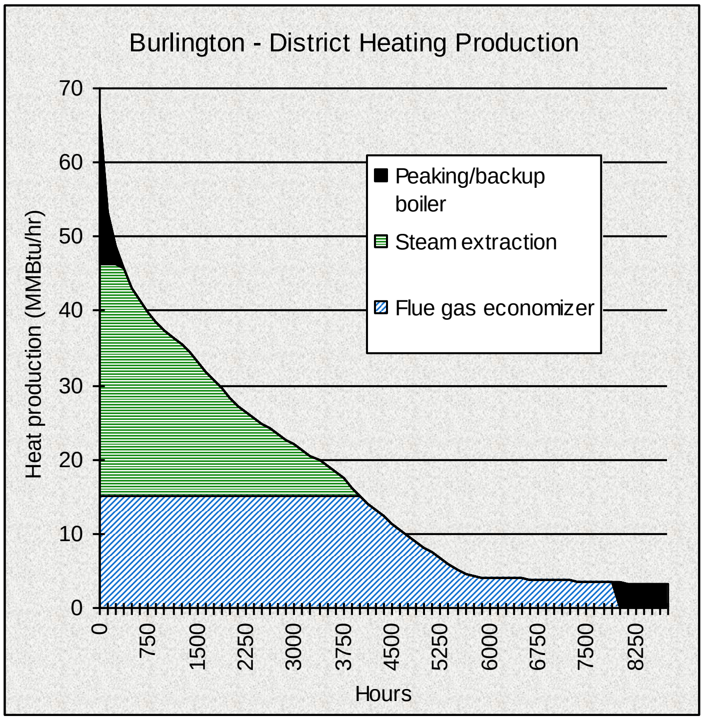


Table 25 Alternative 2 production sources and cost

Peak capacity (MMBtu/hr)	62.6			
	Energy Production		Energy Price	
	MMBtu	%	$/MMBtu	$
Flue gas economizer	92,396	56%	0.0	$0
Steam extraction	65,624	40%	5.0	$330,666
Peaking/backup boilers *1	5,577	3%	15.0	$83,654
Total	163,598		2.5	$414,320

**1 Based on gas price 12 $/MMBtu and eff. 80%*

Figure 12 Alternative 3 load duration curve and production sources

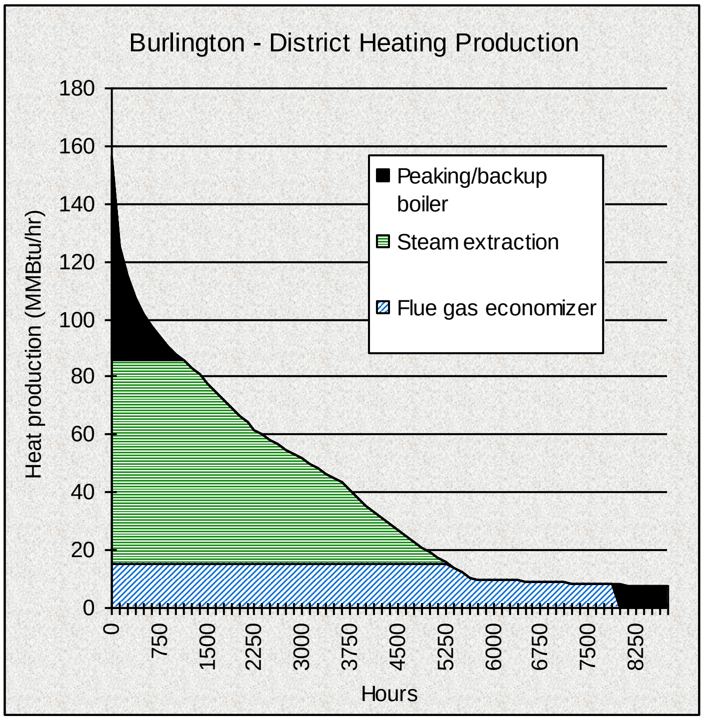


Table 26 Alternative 3 production sources and cost

Peak capacity (MMBtu/hr)	147.2			
	Energy Production		Energy Price	
	MMBtu	%	$/MMBtu	$
Flue gas economizer	114,588	30%	0.0	$0
Steam extraction	239,900	62%	5.0	$1,208,810
Peaking/backup boilers *1	30,044	8%	15.0	$450,658
Total	384,532		4.3	$1,659,468

**1 Based on gas price 12 $/MMBtu and eff. 80%*

5.3 Total Capital and Operating Cost

The tables in this section summarize the overall cost per unit of energy delivered to the customer for each Alternative. The evaluation includes a comparison to a baseline cost for a building to provide its own heating using firm natural gas in an on-site boiler or furnace. A natural gas price of $12.00 per MMBtu was selected for the comparison (equivalent to heating fuel oil price of approximately $1.70 per gallon). See Appendix H for gas price sensitivity analysis.

Table 27 Alternative 1 annual overall cost for district heating compared to customer avoided cost

Annual District Heating Cost	
Annual capital cost *1	$1,283,897
Staffing *2	400,000
O&M *3	98,727
Fuel	442,681
Total annual cost	$2,225,305
Total $/MMBtu	30.4
Customer Avoided Cost ($/MMBtu)	
Fuel cost *4	17.6
Non-fuel cost *5	6.0
Total avoided $/MMBtu	23.6

**1 20 years 6% interest => 8.7% annuity factor*
**2 4 employees at 100,000 $/year*
**3 1% on production capital 0.5% on distribution capital*
**4 12 $/MMBtu gas price and 68% seasonal boiler efficiency*
**5 6 $/MMBtu for avoided on-site labor, maintenance, capital, etc.*

Table 28 Alternative 2 annual overall cost for district heating compared to customer avoided cost

Annual District Heating Cost	
Annual capital cost *1	$2,557,287
Staffing *2	500,000
O&M *3	203,548
Fuel	414,320
Total annual cost	$3,675,155
Total $/MMBtu	24.7
Customer Avoided Cost ($/MMBtu)	
Fuel cost *4	17.6
Non-fuel cost *5	6.0
Total avoided $/MMBtu	23.6

**1 20 years 6% interest => 8.7% annuity factor*
**2 5 employees at 100,000 $/year*
**3 1% on production capital 0.5% on distribution capital*
**4 12 $/MMBtu gas price and 68% seasonal boiler efficiency*
**5 6 $/MMBtu for avoided on-site labor, maintenance, capital, etc.*

Table 29 Alternative 3 annual overall cost for district heating compared to customer avoided cost

Annual District Heating Cost	
Annual capital cost *1	$3,367,917
Staffing *2	500,000
O&M *3	257,224
Fuel	1,659,468
Total annual cost	$5,784,609
Total $/MMBtu	16.5
Customer Avoided Cost ($/MMBtu)	
Fuel cost *4	17.6
Non-fuel cost *5	6.0
Total avoided $/MMBtu	23.6

**1 20 years 6% interest => 8.7% annuity factor*
**2 5 employees at 100,000 $/year*
**3 1% on production capital 0.5% on distribution capital*
**4 12 $/MMBtu gas price and 68% seasonal boiler efficiency*
**5 6 $/MMBtu for avoided on-site labor, maintenance, capital, etc.*

6 Conclusions and Recommendations

As stated in the BURDES Request for Proposal, "The goal of this study is to evaluate the technical potential of combinations of these and other options and to assess their costs and benefits; and to determine, based on financial viability, whether or not to begin the detailed engineering, financial and legal implementation of one of these options."

A significant supply of underutilized heat from the McNeil Station coupled with the expressed desire of the members of the BURDES team to develop a community asset in the form of a district heating system that positions Burlington to have as its primary source of heat the renewable energy from McNeil provides a strong opportunity to the Burlington community.

As would be expected, the economies of scale of Alternative 3 result in a system that provides an energy price to the end user that is a substantial economic savings over the consumption of natural gas in on site boilers or furnaces. The energy cost to the customer is estimated to be $16.50 per million Btu which is a reduction of 30 percent over the alternative, natural gas combustion in an on site boiler or furnace. Given this preliminary conclusion, it is recommended that, as a first step, the technical compatibility of the FAHC campus be fully evaluated regarding specific energy system requirements. Also, effort should be made to determine the intentions of the FAHC with regards to utilizing the Burlington hot water district heating system as the primary energy source for the FAHC campus.

Alternative 2, at eighty percent market penetration for the area encompassed by Alternative 2, is an economically viable system and achieves the economies of scale necessary to be an essentially break-even cost per unit of energy consumed by the customer when compared to natural gas as an alternative fuel. The cost to the customer of the district heating system under Alternative 2 is an estimated $24.70 per million Btu. The system also provides the opportunity to introduce a snowmelting system in the Church Street Marketplace/Downtown Mall area with the associated benefits of reduced maintenance of the Mall area and less wear and tear on the Mall and the local merchant stores from ice melting chemicals that are currently used to remove ice and snow.

Alternative 1 is a technically viable system. It is also a logical starting point for a system that covers a broader swath of Burlington. However, Alternative 1 does not achieve the economies of scale that make for an economically viable system without some amount of subsidy to offset initial capital costs. The total cost to the end user of energy under Alternative 1 is $30.40 per million Btu energy consumed. This is $6.80 per million Btu (29 percent) higher than the avoided cost of heating the same building with natural gas with on-site equipment The capital subsidy required to achieve a break-even cost structure for a typical customer under Alternative 1 is approximately five and one-half million dollars ($5.5 million). If a subsidy through a grant, loan guarantee, or interest-free financing or similar mechanism can be achieved, then it is recommended that efforts be focused on developing Alternative 1 with the main distribution pipe from McNeil along Intervale and Elmwood Avenues upsized to meet the peak load of either Alternative 2 or Alternative 3. Alternative 1 requires a main distribution pipe of eight inch diameter to meet peak loads with an estimated cost for that portion of the pipe of $3.44 million. Alternative 2 requires a 10 inch pipe to meet peak loads at an estimated cost of $3.9 million. Alternative 3 requires a 14 inch main pipe from McNeil to meet peak loads at an estimated cost of $5.5 million. To preserve the option to expand the system to Alternative 2, an additional investment of an estimated $600,000 is required during the development of Alternative 1. An additional capital investment of an estimated $2.1 million is required during development of Alternative 1 to preserve the option to expand the system to the scope considered in Alternative 3. If such an additional investment is made at the outset to size the pipes for future expansion, then the system can be expanded incrementally and gradually over time from the initial scope to a community-wide system. Such organic growth is typical of such district energy systems in which there is a rapid initial buildout to reach the necessary economy of scale and subsequent incremental growth over a number of years. In such a scenario, this incremental growth is accomplished through a series of expansions to new areas and connections of additional customers, the economics of each weighed on its own merits.

7 Next Steps

A key step in the successful development of a district heating system is to communicate the prospects and advantages to the larger community and to potential customers. Effectively communicating the current advantages of developing a hot water district heating system in the community as well as the positioning of Burlington for a future of sustainable and stable energy supplies must build excitement within the Burlington community. An effective communication plan will lead key stakeholders to embrace this better approach for providing energy to the community. Ever-Green Energy recognizes the importance of communicating the vision of accomplishing the development of a community energy asset and knows that this is a very labor- and time-intensive community education process.

In the short-term, an underutilized renewable energy source at McNeil is deployed to improve the price stability and availability of energy in the community since the investment in the district heating system reduces dependence on natural gas and fuel oil. Over time, the hot water district heating system becomes the basic infrastructure that allows new, renewable and sustainable energy solutions to be deployed for the benefit of the community. With the hot water distribution pipeline in place, the opportunity to deploy emerging technologies such as commercial solar thermal, fuel cells, and waste heat recovery technologies at a community scale is made possible. These opportunities are far less likely to succeed in a community that does not have the advantage of a hot water distribution system to allow these new sources of energy to be produced where and when they are available and delivered to where the energy is needed on a continuous basis.

In parallel with this critical step of educating the Burlington community about the benefits and opportunities created by the development of the district heating system, a series of practical items must be pursued that will guide how such a project can proceed. Primary among these practical next steps are:

- Initiate discussions with FAHC regarding the prospects for connecting the FAHC campus to the hot water district heating loop. The outcome of those discussions will drive capital and financing needs as well as early stage design engineering activities such as distribution pipe sizes and production equipment location, sizing and arrangement at McNeil.

- Initiate a detailed inventory of the buildings and the building energy systems for the areas in blocks 22 through 41. This information is critical in establishing likely market penetration in this area of the City and the relative ease with which the buildings can be converted to use the hot water energy source for space heating and for domestic hot water heating.

- Evaluate the structure for the entity that will operate and maintain the hot water district heating system. Also determine the sources of funding, both capital and debt and associated terms of this financing, available to the entity. This information will enable refinement of the annualized costs of the district heating system investment. Favorable financing or capital sources have the potential to make the overall economics much better than the estimated costs established in this report.

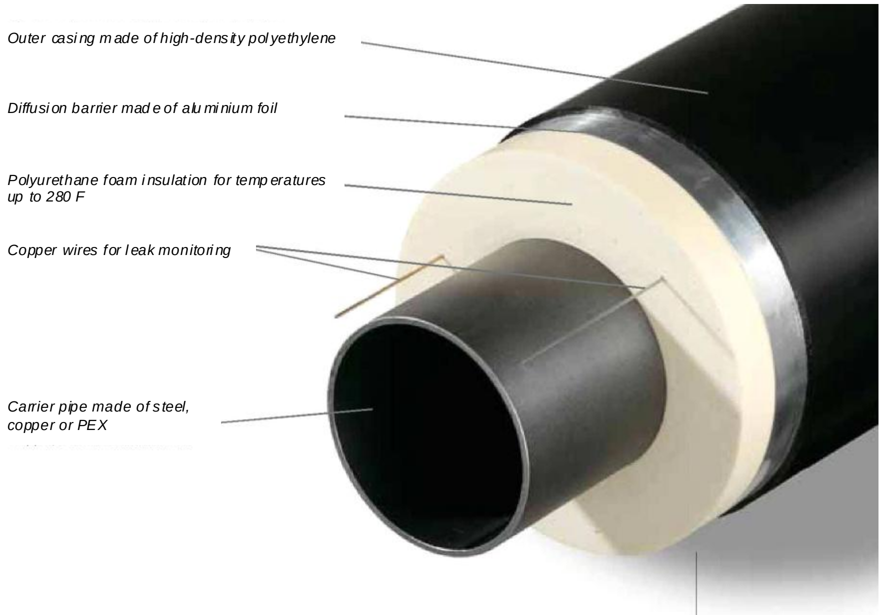
- Perform a detailed analysis of the effects of the flue gas economizer on McNeil's flue gas exit conditions. Have the manufacturer of the McNeil turbine assess the maximum amount of steam available from each of the extraction ports to serve the district heating system.

Resources for those interested in more information about district energy systems and the positive outcomes of such systems in other communities include:

- *www.districtenergy.com* the website for District Energy St. Paul, Inc. and the system that serves the community of St. Paul, Minnesota.
- *www.districtenergy.org* the website for the International District Energy Association which includes as members many of the district energy systems throughout North America and beyond.
- *www.dbdh.dk* the website for the Danish Board of District Heating which is an excellent resource for district heating in Europe and by European companies.
- *www.iea.org/files/CHPbrochure09.pdf* describes the case for Combined Heat and Power (CHP)
- *www.cdea.ca* Canadian District Energy Association website

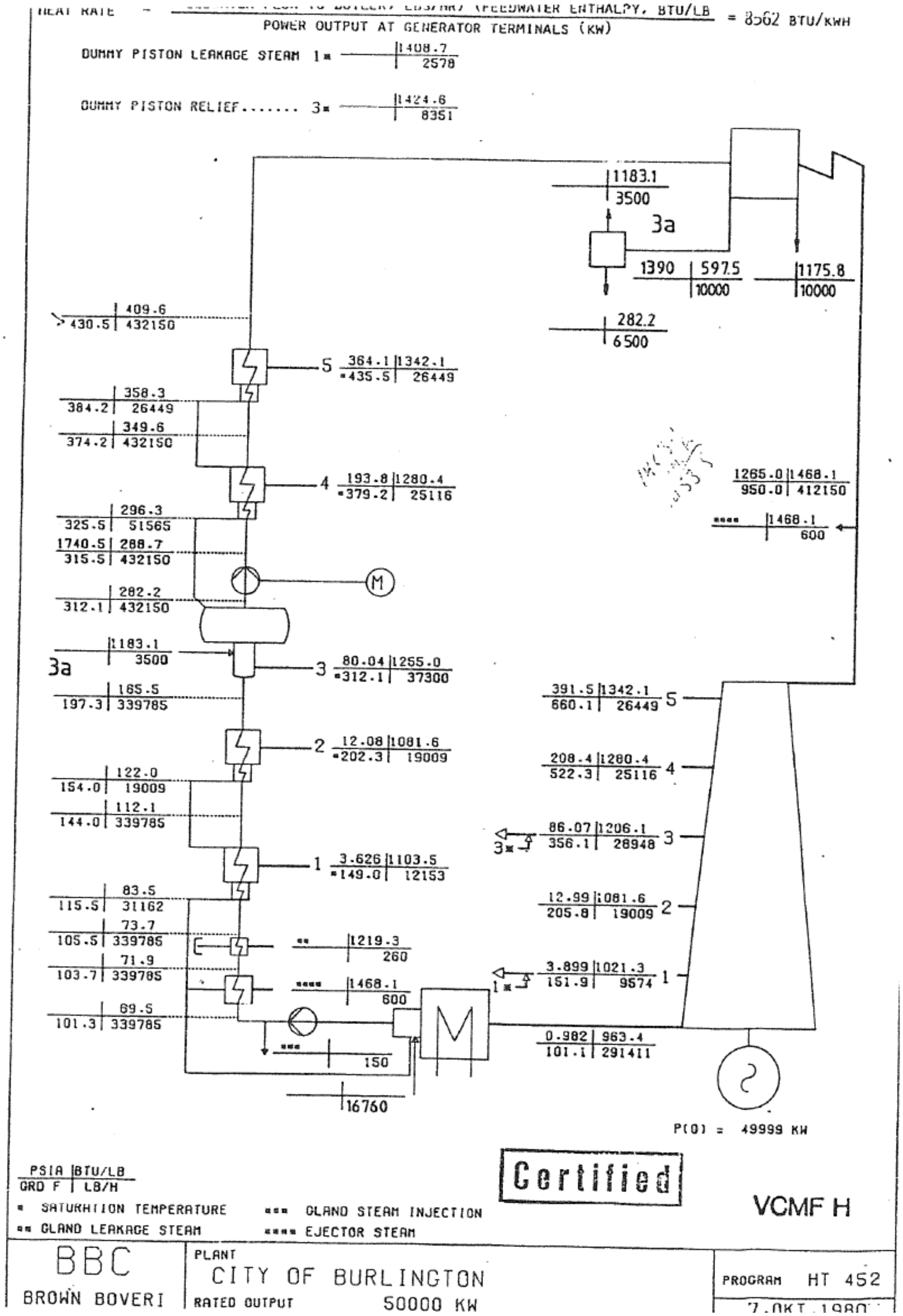
APPENDIX A – Not Applicable

APPENDIX B – District Heating Pipes

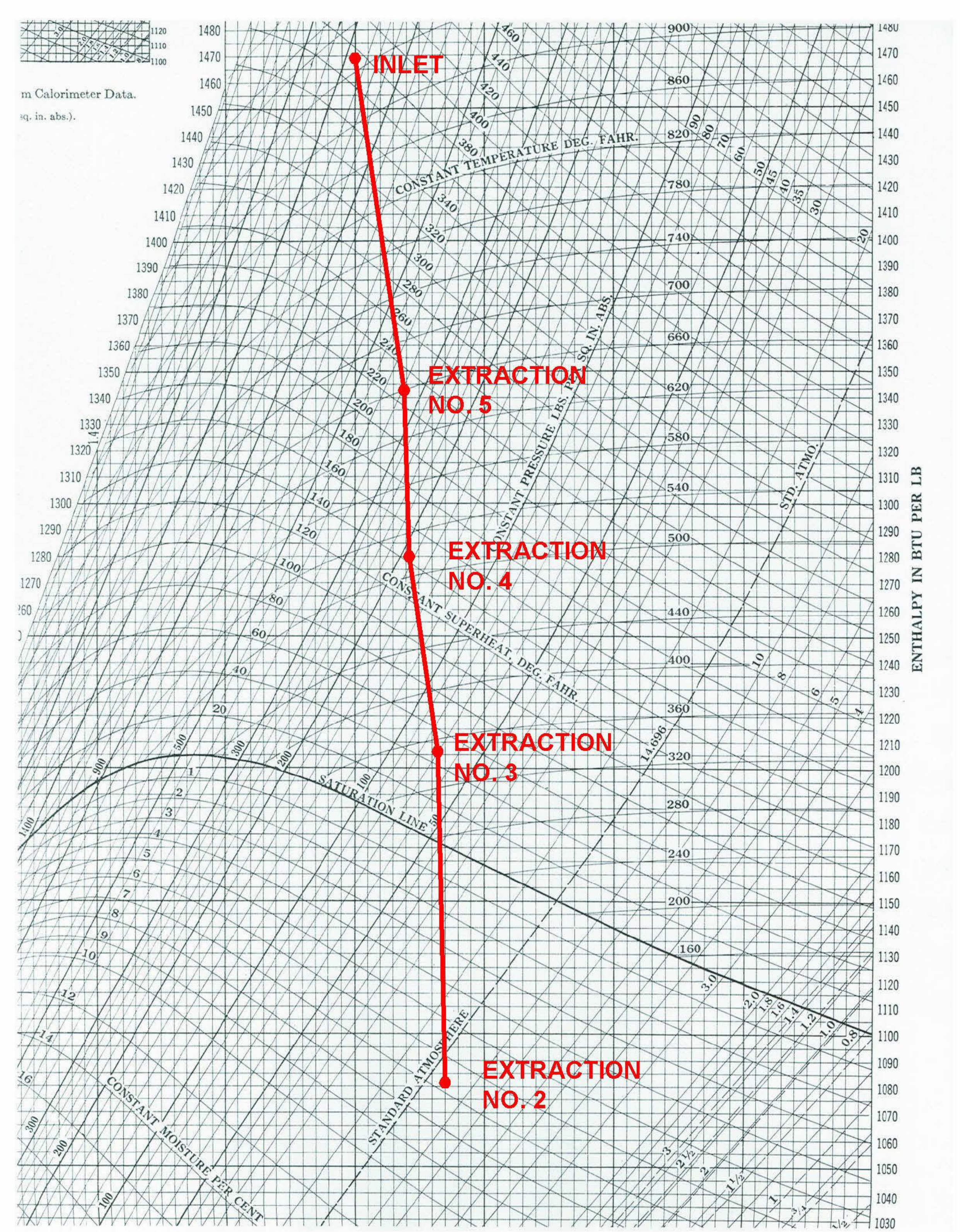


Laying method	Advantages	Disadvantages
1. **Compensated with elbows and compensators** Typical application: main and branch pipelines.	Axial stresses are reduced. The trench can be covered before heating.	Extra cost for compensating elements. All parts of the pipeline may move in the soil.
2. **Heat prestressed** Typical application: large transmission pipelines outside urban areas.	Reduced axial stresses at restrained part. Easy installation. No expenses for extra expansion facilities. Long restrained part where pipes do not move.	The trench has to be open during pre-heating.
3. **Heat prestressed with start-up compensators** Typical application: large transmission pipelines in urban areas.	The trench can be partly covered before pre-stressing. Reduced axial stresses at restrained part. Easy installation. Long restrained part where pipes do not move.	Extra cost for start-up compensators.
4. **System 4** Typical application: main and branch pipelines.	The trench can be covered before heating. Reduced axial stresses at restrained part. Easy installation. Long restrained part where pipes do not move.	Extra cost for relievers.
5. **Cold laying** Typical application: transmission and main pipelines.	Easy installation. No expenses for pre-heating or extra expansion facilities. Long restrained part where pipes do not move.	High axial stresses. First time expansion is high in expansion zones. Not possible for high temperatures at large diameters. Care must be taken by parallel trenching.

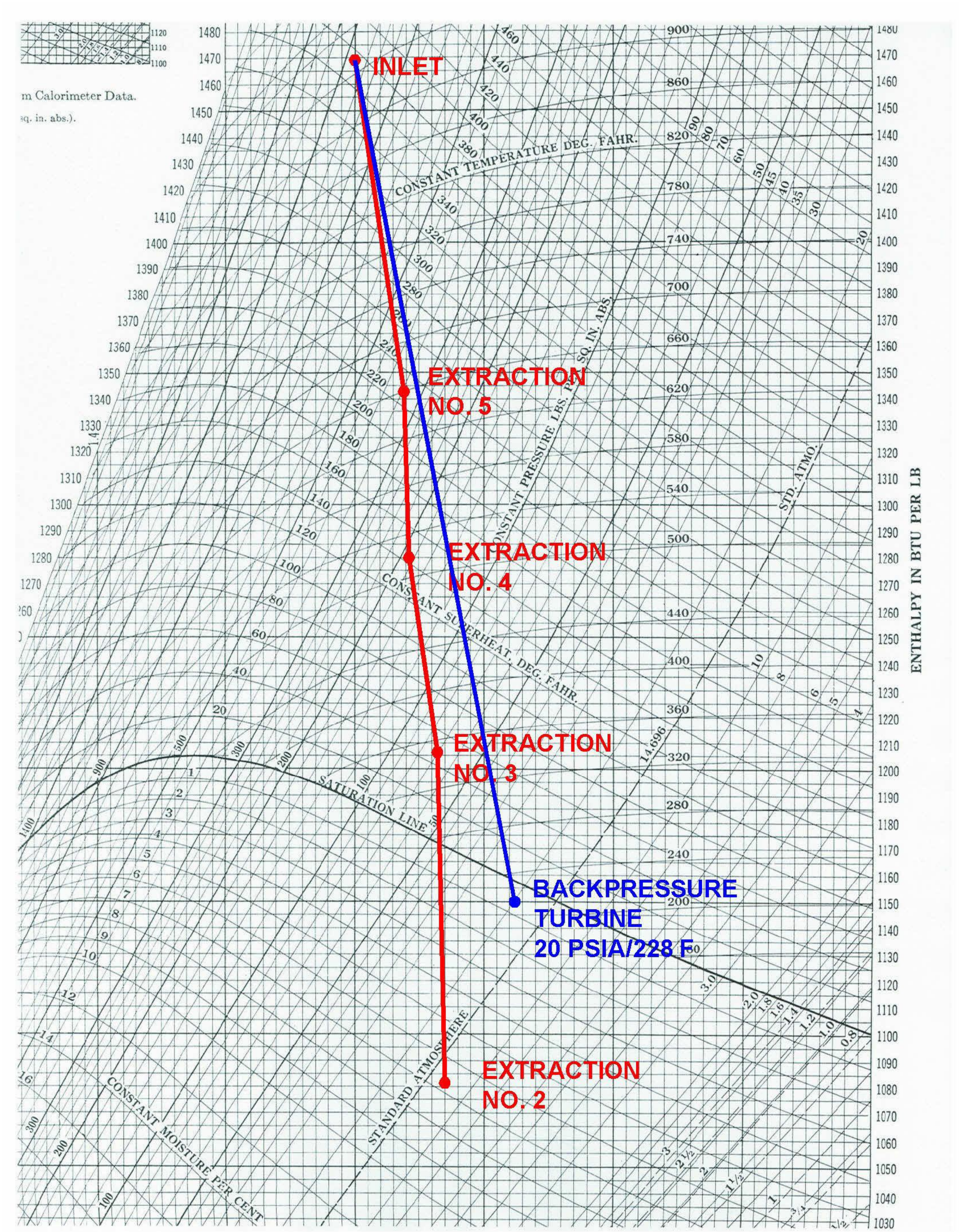
APPENDIX C – Steam Turbine Performance @ 50 MWe Gross



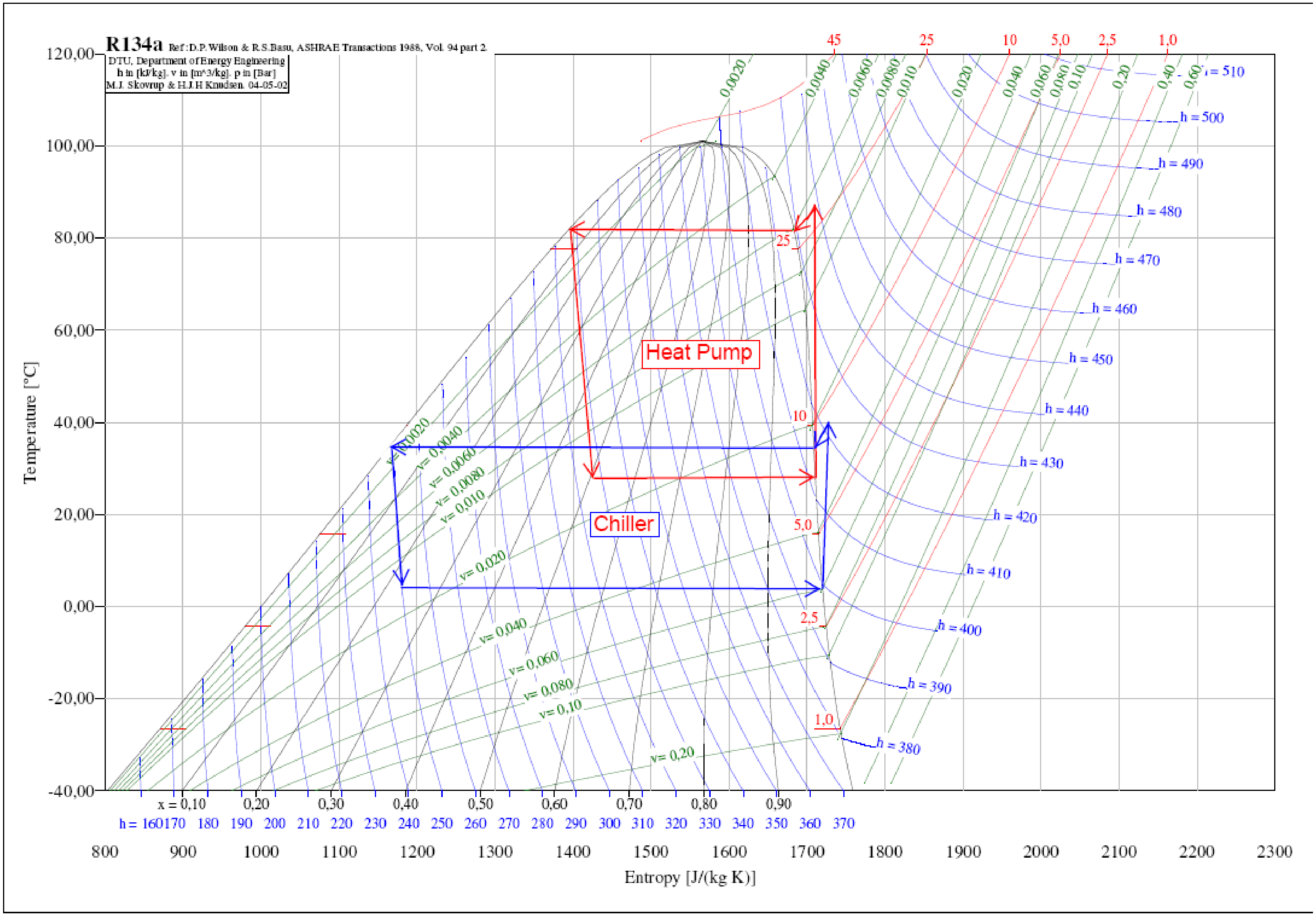
APPENDIX D – Steam Turbine Performance @ 50 MWe Gross



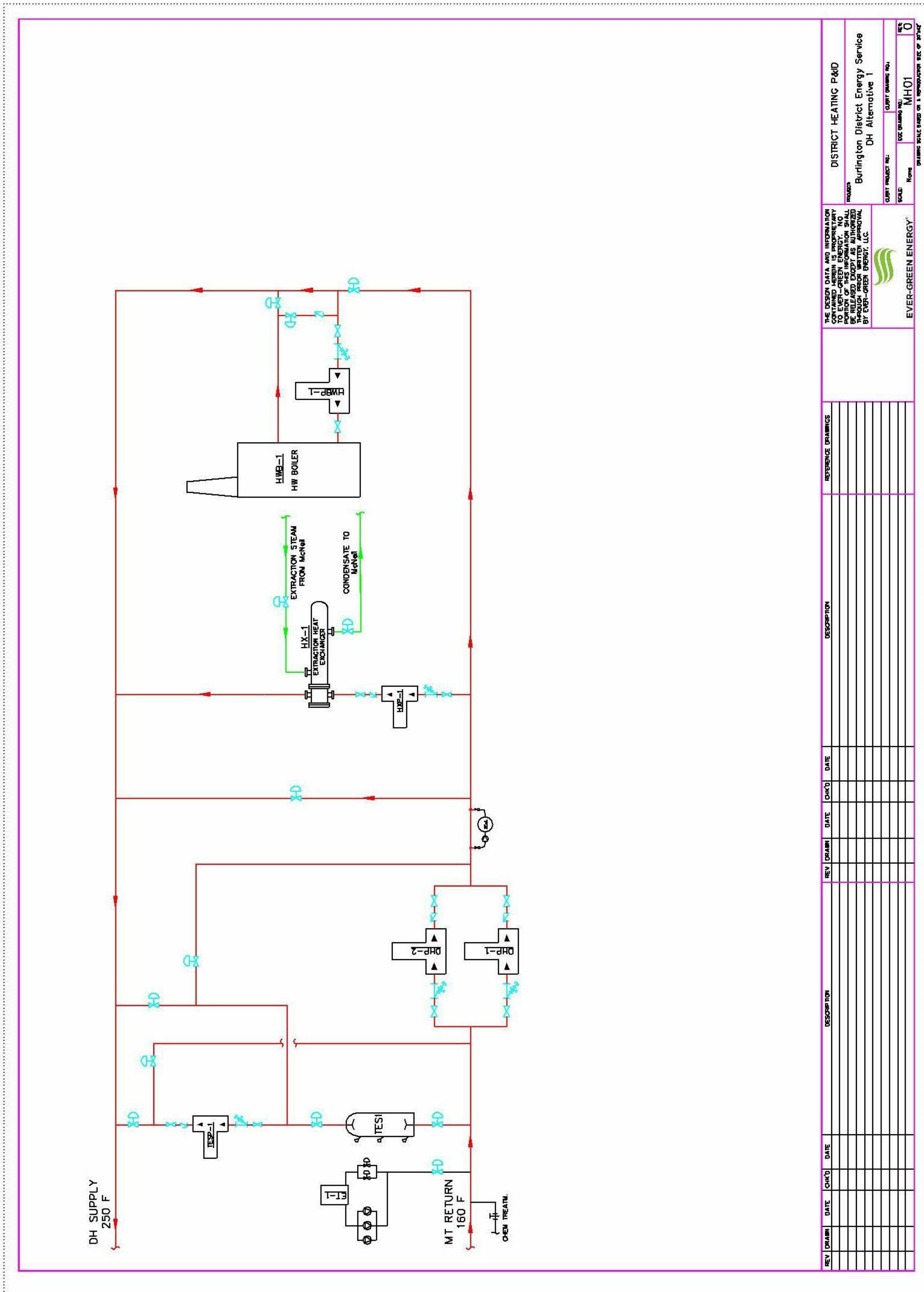
APPENDIX E – Backpressure Steam Turbine

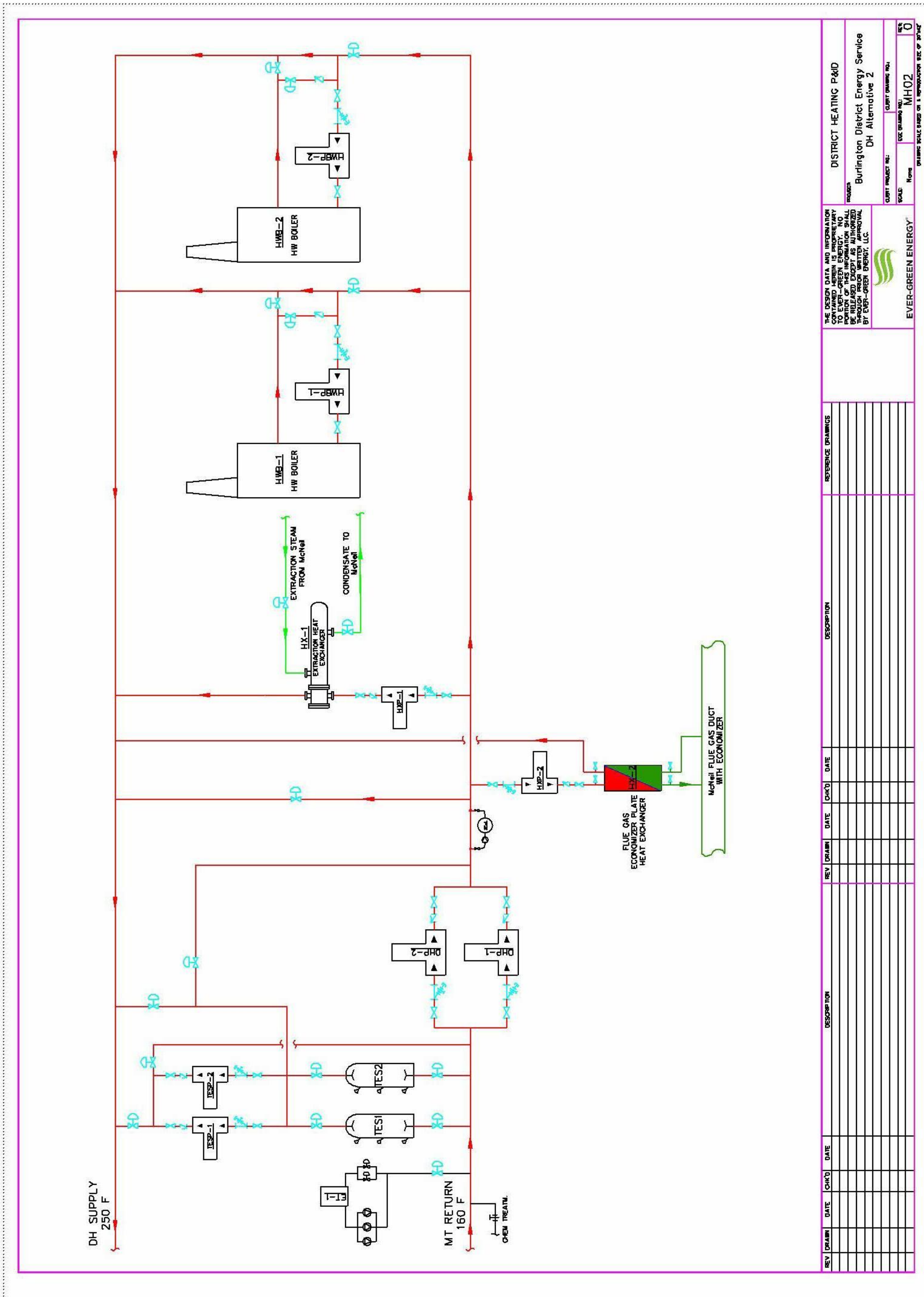


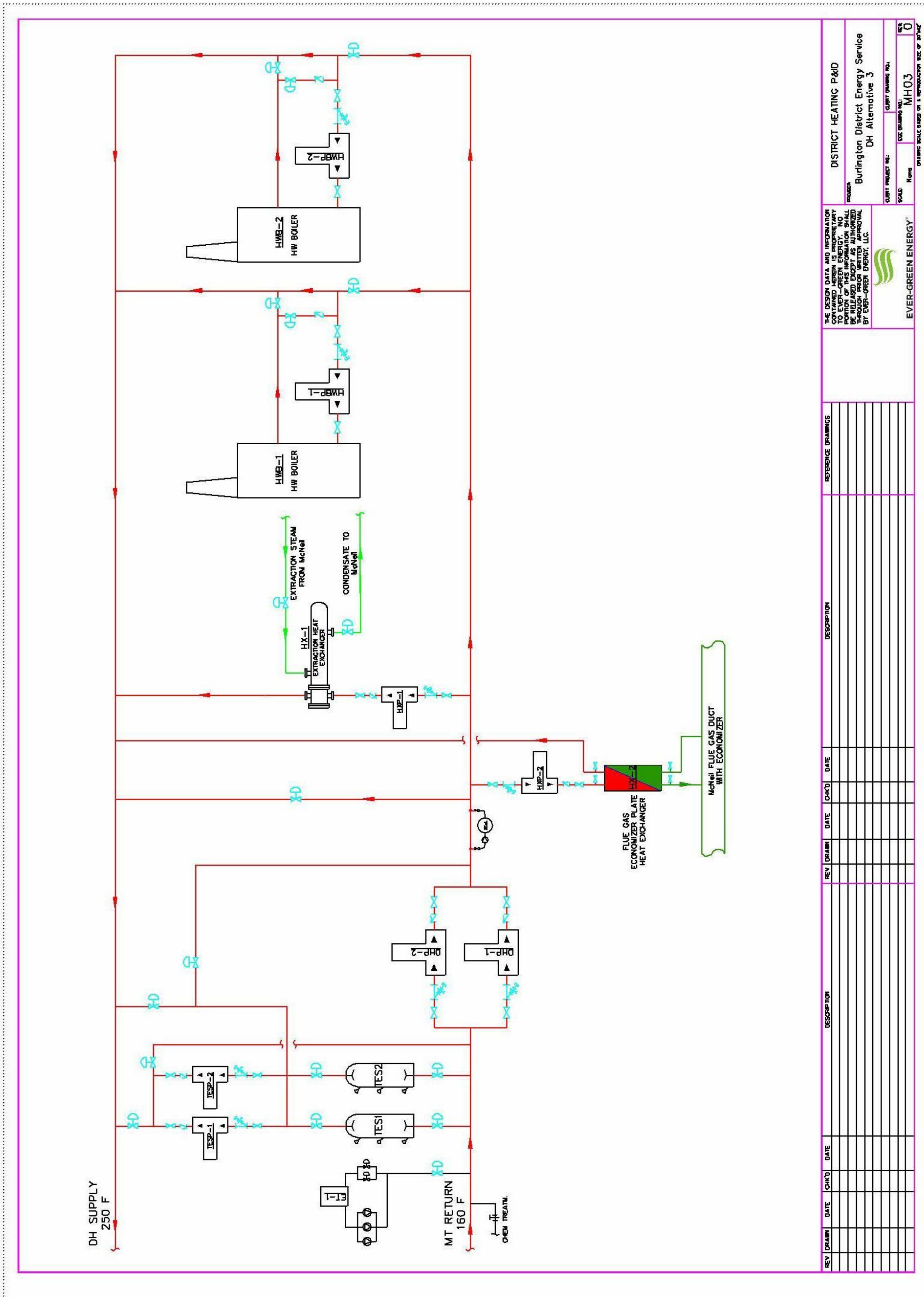
APPENDIX F – R134a TS-Diagram



APPENDIX G – District Heating P&ID




DISTRICT HEATING P&ID
Burlington District Energy Service
DH Alternative 2
MH02
EVER-GREEN ENERGY
DH SUPPLY
250 F
MT RETURN
160 F
HWB-1
HW BOILER
HWB-2
HW BOILER
HWBP-1
HWBP-2
HX-1
EXTRACTION HEAT EXCHANGER
EXTRACTION STEAM FROM McNeil
CONDENSATE TO McNeil
HXP-1
HXP-2
HX-2
FLUE GAS ECONOMIZER PLATE HEAT EXCHANGER
McNeil FLUE GAS DUCT WITH ECONOMIZER
DHP-1
DHP-2
TES1
TES2
TESP-1
TESP-2
ET-1
CHEM TREATM.


DISTRICT HEATING P&ID
Burlington District Energy Service
DH Alternative 3
MH03
EVER-GREEN ENERGY
HWB-2
HW BOILER
HWB-1
HW BOILER
HWBP-2
HWBP-1
EXTRACTION STEAM FROM McNeil
CONDENSATE TO McNeil
HX-1
EXTRACTION HEAT EXCHANGER
HXP-1
HXP-2
HX-2
FLUE GAS ECONOMIZER PLATE HEAT EXCHANGER
McNeil FLUE GAS DUCT WITH ECONOMIZER
DHP-1
DHP-2
TES1
TES2
TESP-1
TESP-2
ET-1
DH SUPPLY 250 F
MT RETURN 160 F
CHEM TREATM.
REFERENCE DRAWINGS
DESCRIPTION
REV
DRAWN
DATE
CHK'D
DATE

APPENDIX H – Gas Price Sensitivity Analysis

20% Lower Gas Price

Alternative I	
Annual District Heating Cost	
Annual capital cost *1	$1,283,897
Staffing *2	400,000
O&M *3	98,727
Fuel	431,734
Total annual cost	$2,214,358
Total $/MMBtu	30.2
Customer Avoided Cost ($/MMBtu)	
Fuel cost *4	14.1
Non-fuel cost *5	6.0
Total avoided $/MMBtu	20.1

**1 20 years 6% interest => 8.7% annuity factor*
**2 4 employees at 100,000 $/year*
**3 1% on production capital 0.5% on distribution capital*
**4 9.6 $/MMBtu gas price and 68% seasonal boiler efficiency*
**5 6 $/MMBtu for avoided on-site labor, maintenance, capital, etc.*

Alternative II	
Annual District Heating Cost	
Annual capital cost *1	$2,557,287
Staffing *2	500,000
O&M *3	203,548
Fuel	397,589
Total annual cost	$3,658,424
Total $/MMBtu	24.6
Customer Avoided Cost ($/MMBtu)	
Fuel cost *4	14.1
Non-fuel cost *5	6.0
Total avoided $/MMBtu	20.1

**1 20 years 6% interest => 8.7% annuity factor*
**2 5 employees at 100,000 $/year*
**3 1% on production capital 0.5% on distribution capital*
**4 9.6 $/MMBtu gas price and 68% seasonal boiler efficiency*
**5 6 $/MMBtu for avoided on-site labor, maintenance, capital, etc.*

Alternative III	
Annual District Heating Cost	
Annual capital cost *1	$3,367,917
Staffing *2	500,000
O&M *3	257,224
Fuel	1,569,337
Total annual cost	$5,694,477
Total $/MMBtu	16.3
Customer Avoided Cost ($/MMBtu)	
Fuel cost *4	14.1
Non-fuel cost *5	6.0
Total avoided $/MMBtu	20.1

**1 20 years 6% interest => 8.7% annuity factor*
**2 5 employees at 100,000 $/year*
**3 1% on production capital 0.5% on distribution capital*
**4 9.6 $/MMBtu gas price and 68% seasonal boiler efficiency*
**5 6 $/MMBtu for avoided on-site labor, maintenance, capital, etc.*

20% Higher Gas Price

Alternative I	
Annual District Heating Cost	
Annual capital cost *1	$1,283,897
Staffing *2	400,000
O&M *3	98,727
Fuel	453,627
Total annual cost	$2,236,251
Total $/MMBtu	30.5
Customer Avoided Cost ($/MMBtu)	
Fuel cost *4	21.2
Non-fuel cost *5	6.0
Total avoided $/MMBtu	27.2

**1 20 years 6% interest => 8.7% annuity factor*
**2 4 employees at 100,000 $/year*
**3 1% on production capital 0.5% on distribution capital*
**4 14.4 $/MMBtu gas price and 68% seasonal boiler efficiency*
**5 6 $/MMBtu for avoided on-site labor, maintenance, capital, etc.*

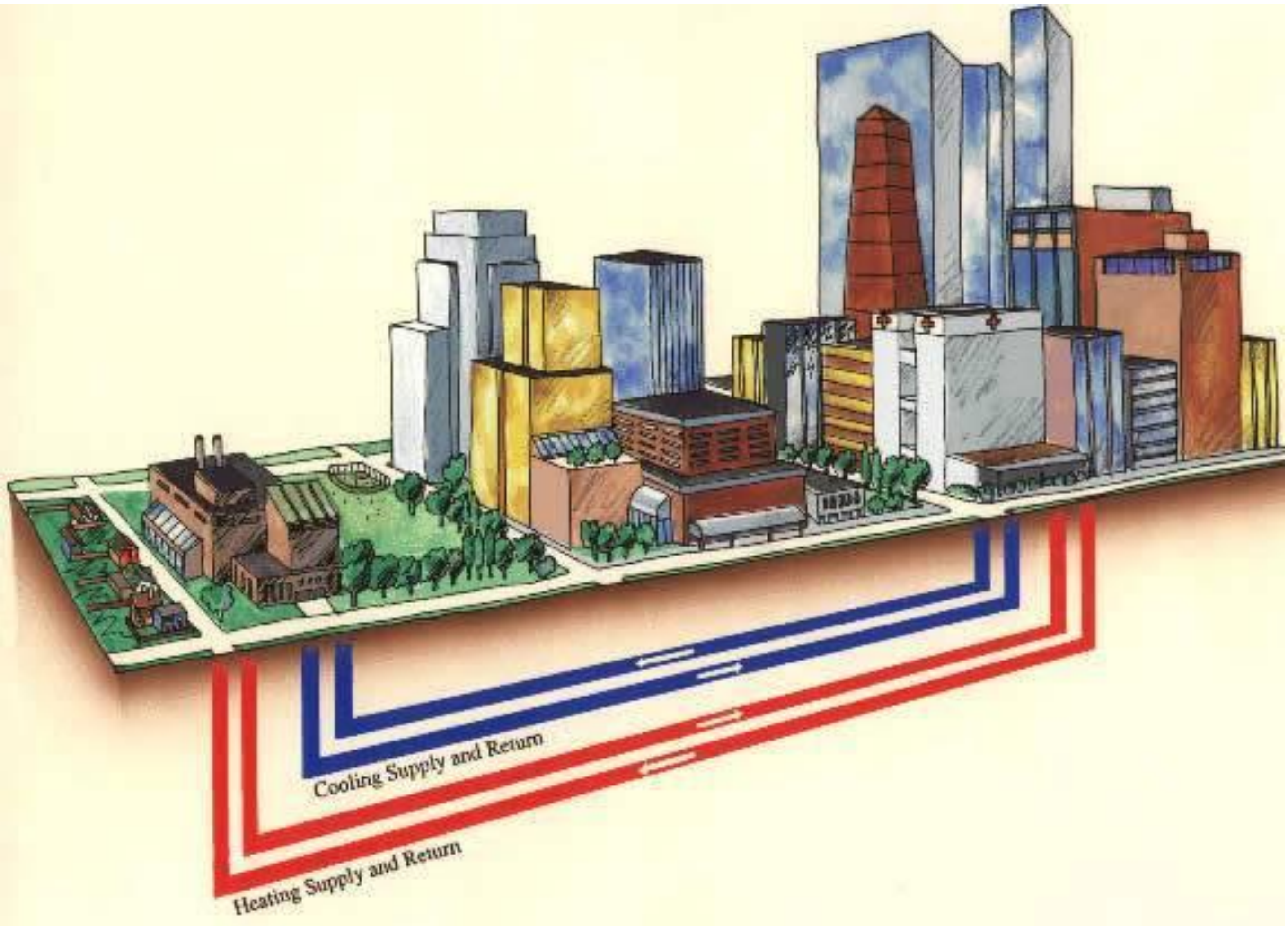
Alternative II	
Annual District Heating Cost	
Annual capital cost *1	$2,557,287
Staffing *2	500,000
O&M *3	203,548
Fuel	431,050
Total annual cost	$3,691,886
Total $/MMBtu	24.8
Customer Avoided Cost ($/MMBtu)	
Fuel cost *4	21.2
Non-fuel cost *5	6.0
Total avoided $/MMBtu	27.2

**1 20 years 6% interest => 8.7% annuity factor*
**2 5 employees at 100,000 $/year*
**3 1% on production capital 0.5% on distribution capital*
**4 14.4 $/MMBtu gas price and 68% seasonal boiler efficiency*
**5 6 $/MMBtu for avoided on-site labor, maintenance, capital, etc.*

Alternative III	
Annual District Heating Cost	
Annual capital cost *1	$3,367,917
Staffing *2	500,000
O&M *3	257,224
Fuel	1,749,600
Total annual cost	$5,874,740
Total $/MMBtu	16.8
Customer Avoided Cost ($/MMBtu)	
Fuel cost *4	21.2
Non-fuel cost *5	6.0
Total avoided $/MMBtu	27.2

**1 20 years 6% interest => 8.7% annuity factor*
**2 5 employees at 100,000 $/year*
**3 1% on production capital 0.5% on distribution capital*
**4 14.4 $/MMBtu gas price and 68% seasonal boiler efficiency*
**5 6 $/MMBtu for avoided on-site labor, maintenance, capital, etc.*

APPENDIX I – Basic District Heating Schematic



APPENDIX J – Staff Qualifications

The following are the resumes of the key members of our team that will serve as consultants on the project.

Anders J. Rydaker

Experience Summary

- President of District Energy St. Paul, District Cooling St. Paul and Ever-Green Energy from 1993 through 2010.
- More than 35 years of experience in the district energy field.
- Developed the SWAC cooling system for Stockholm, Sweden and was involved in the deep lake/SWAC systems in the Swedish cities of Jonkoping, Upplands Vasby, Solna, Sollentuna and Sodertalje.
- Developed the renewable energy combined heat and power project in Saint Paul utilizing clean urban waste wood.
- In 2003, he received Sweden's Prestigious Energy Prize for the development of numerous district cooling systems in the country.
- In 2004-05, Rydaker served as Chairman of the International District Energy Association.

Recent Relevant Project Experience

North Loop Renewable Energy District Study, Hennepin County, MN

South Loop District Energy Feasibility Study, Bloomington, MN

Flue Gas Condensation Feasibility Study, District Energy St. Paul

Renewable Energy Facility Study, Saint Paul Port Authority, St. Paul, MN

Prior Project Experience

Vice President, FVB District Heating Engineering Inc., Stockholm area and the USA market

General management responsibilities for the branch office in Stockholm. Developed and marketed FVB's new branch office including market strategies, marketing, sales, customer relations and employee motivation and development. Member of the company board and was responsible for FVB's consulting services to the district energy market in the United States.

- Introduced district cooling to the Swedish market 1990.
- Developed and commissioned the first district cooling system (5700 tons) in Västerås, Sweden.
- Conducted district cooling feasibility studies and marketing in over ten larger cities in Sweden.
- Established FVB **(**Fjärrvärmebyrån) as the leading consultant firm in the district cooling field in Sweden.
- Project manager for a $10 million hot water transmission line connecting two existing district heating systems in the Stockholm area.

- Provided design expertise for an 80 MW hot water district heating system at Deer Island, Boston.

Vice President, FVB branch office in St. Paul, Minnesota, USA

- Provided on-site district heating expertise during the construction of the St. Paul hot water distribution system and conversion of the old steam plant.
- Provided district energy consultation services for Willmar Municipal Electric Company, Willmar, Minnesota.
- Provided consulting services for Kent County in Grand Rapids, Michigan regarding expansion of the existing district heating system including cooling and co-generation of electricity.

Uppsala Kraftvärme AB, Sweden. A utility which has an installed production capacity of 900 MW heat, 200 MW electricity, an annual energy production of 1,750,000 MWh and a total installed length of 190 miles of distribution pipes.

Project Manager, new construction projects

- Construction Manager for a 21 MW wood chip fired heating plant.
- Construction Manager for a 39 MW heat pump project, extracting waste heat from sewage water.
- Construction Manager for a 25 MW addition to a refuse incineration facility.

Education

Uppsala Technical College – B.S., Mechanical Engineering, Uppsala, Sweden

Kenneth W. Smith, P.E.

Experience Summary

- President of District Energy St. Paul, District Cooling St. Paul and Ever-Green Energy since 2010.
- Professional experience since 1985 in the feasibility analysis, design, and construction of a wide variety of facilities including energy, institutional, commercial, aviation, government, industrial, and complex, high-tech/mission-critical facilities.
- Project and Engineering Management experience on multiple projects of varying size and complexity with responsibility for budget and schedule control, contractor tendering, client liaison, contract administration, issuing change orders, evaluating and mitigating claims, preparing reports, and quality control/assurance.
- Technical experience includes central energy plants (heating, cooling and power generation), medium- and low-voltage generation and distribution systems; UPS systems; data and communication systems; complex grounding systems; control systems for HVAC, chillers, boilers and power generation; and industrial and commercial lighting design.
- Global project experience includes several significant domestic and international projects including New Pentagon Heating & Refrigeration Plant, Washington DC, and New Ben Gurion International Airport, Israel.

Recent Relevant Project Experience

North Loop Renewable Energy District Study, Hennepin County, MN

South Loop District Energy Feasibility Study, Bloomington, MN

Flue Gas Condensation Feasibility Study, District Energy St. Paul

Renewable Energy Facility Study, Saint Paul Port Authority, St. Paul, MN

Prior Project Experience

Pentagon Central Heating and Cooling Plant; Washington, D.C.--Lead Electrical Engineer.

New Ben Gurion International Airport Terminal; Tel Aviv, Israel--Lead Electrical Engineer and Assistant Project Manager.

Steam Distribution Replacement; Picatinny Arsenal, NJ--Project Principal

250 MW Combined Cycle Power Plant; Faribault, MN—Principal

Substation and Primary Electrical Distribution System Upgrade for Pentagon Reservation; Washington, D.C.--Lead Electrical Engineer

Main Terminal Building Design; Denver International Airport; Denver, CO--Electrical Engineer

Utility Plant Boiler Replacement; Minnesota State University, Mankato; Mankato, MN—Principal

Central Plant Upgrade; University of Minnesota, Crookston -- Principal

Central Plant Expansion for 3M World Headquarters -- Principal.

Chilled Water Distribution System Upgrade; O'Hare Airport; Chicago, IL--Project Manager

Education

North Dakota State University - B.S., Electrical Engineering
University of St. Thomas - Master of Business Administration

Ingvar K. Larsson

Experience Summary

- Senior Engineer for Ever-Green Energy.
- More than 25 years of experience in the fields of district heating, district cooling and combined heat and power in Sweden and North America.
- Extensive applied knowledge in design, construction, financial analysis, technical and business management of district energy systems.
- Experience includes systems within the range of 1-600 MW of heating load and 1-200 MW of cooling load.
- Experience with the design, purchase, installation and commissioning of absorption chillers, electric chillers, combined chiller and heat pumps, chilled water storages and deep lake and seawater cooling systems.
- Experience with the design and installation of hot water and chilled water distribution piping and customer connections.
- Involved in the deep lake/SWAC systems in the Swedish cities of Stockholm, Jonkoping, Upplands Vasby, Sollentuna and Sodertalje.

Recent Relevant Project Experience

North Loop Renewable Energy District Study, Hennepin County, MN

South Loop District Energy Feasibility Study, Bloomington, MN

Flue Gas Condensation Feasibility Study, District Energy St. Paul

Prior Project Experience

Telge Energi AB, Södertälje, Sweden

Project Manager
Conducted feasibility study, design, purchase, construction and commissioning of a district cooling system with deep lake water-cooling. The project encompasses deep lake water cooling from a depth of 135 feet, polyethylene lake water piping with a diameter of 40 inches and a length of about 20,000 feet. The pumping capacity is 26,000 gal/min and with a potential cooling capacity of 17,000 ton.

Sollentuna Energi, Sollentuna, Sweden

Project Engineer
Involved in design, purchase, construction and commissioning of a lake water cooling system utilizing an aquifer storage.

Västerås Energi o Vatten, Västerås, Sweden

Project Engineer
Conducted feasibility study, design and construction of the first district cooling system in Sweden. The system was initially designed for about 5,700 tons utilizing heat pumps and a chilled water storage.

EMR/Canmet, Ottawa, Canada

Technology transfer of Swedish district energy experience. Energy plans and technical, economical and environmental feasibility studies regarding district energy for several cities in Canada such as Toronto (including lake water cooling from Lake Ontario), Halifax, Saskatoon, Ottawa and Montreal.

CERREY, S.A. DE C.V., St Felicien, Canada

Lead Consultant
Status assessment of a 21 MWe biomass fired condensing/combined heat and power plants in St Felicien, Canada supplied by Cerrey.

Uppsala Energi AB, Uppsala, Sweden

Planner and Analyst
The work at the district energy company in Uppsala included feasibility studies, design, purchase, construction, financial analysis, etc. including:

- Building connections
- Distribution systems for hot water and steam (peak demand about 600 MW)
- Steam and hot water boilers utilizing wood waste, peat, coal, oil and garbage
- Solar energy plant
- Large heat pumps (45 MW)
- Solid fuel fired combined heat and power plant (200 MWe/300 MWth)
- Daily and seasonal hot water storages (25,000-100,000 m3)
- Emission reduction measures
- Energy plan for the city of Uppsala
- Customer rate structures

Örebro Energi AB, Örebro, Sweden

Lead Consultant
Technical, economical and environmental feasibility studies regarding adding gas turbines to existing boiler fired steam cycles and adding a flue gas condensing plant to an existing biomass fired combined heat and power plant for a district heating system with a peak demand of 450 MW.

Sala-Heby Energi AB, Sala, Sweden

Technical support during design and installation of a 10 MWe/22 MWth biomass fired combined heat and power plant at the district heating plant in Sala, Sweden.

Sala-Heby Energi AB, Sala, Sweden

Lead Consultant, Combined Heat and Power Plant
Technical, economical and environmental feasibility study, purchase and technical support during installation of a 8 MW flue gas condensing plant connected to a biomass fired 10 MWe/22 MWth combined heat and power plant.

International Energy Association, IEA

Co-author of Reports
Report "Optimization of Cool Storage and Distribution"
Report "Design Guide for Integrating District Cooling with Combined Heat and Power"
the beginning of 2000.

Education

Fyrisskolan (Uppsala, Sweden) - B.S. in Mechanical Engineering

Royal Swedish Institute of Technology (Kungliga Tekniska Högskolan, KTH), Stockholm, Sweden - Mechanical Engineer (M.Sc) Specialization: Heat and Power

Andrew E. Kasid

Experience Summary

- Senior Vice President of Finance for Ever-Green Energy.
- Provided financial management to District Energy St. Paul since 1990.
- Responsible for financial management, project finance, financial strategic planning, financial analysis of business opportunities, forecasting and budgeting, financial risk management, energy rate setting and analysis, energy futures contracts, analysis of energy purchases, investment analysis and investment management.
- Provided analysis and financial modeling for the feasibility studies conducted by the companies on energy projects including district heating, district cooling, combined heat and power, and renewable energy projects.
- Extensive experience with commercial and investment banking projects including several under development, tax-exempt and taxable bonding revenue bond financings representing multiple project phases totaling over $95 million, fixed and variable rate debt financings utilizing letters of credit, fixed rate financings, equity financings, and the use of interest rate risk management products including interest rate swaps and caps.
- Earned the chartered financial analyst (CFA) designation.

Recent Project Experience

- **North Loop Renewable Energy District Study, Hennepin County, MN**
- **South Loop District Energy Feasibility Study, Bloomington, MN**
- **Flue Gas Condensation Feasibility Study, District Energy St. Paul**
- **Renewable Energy Facility Study, Saint Paul Port Authority, St. Paul, MN**

Prior Experience

Financial Analyst, Cherry Tree Ventures, Minneapolis, Minnesota

Provided research, analysis, financial modeling and forecasting to the due diligence process in investigating investment opportunities in growth companies for the venture capital firm. Developed financial models, budgets, forecasts and reports for the portfolio companies. Provided the research, analysis and financial modeling for investment opportunities.

Education

Gustavus Adolphus College – B.A., Financial Economics
University of Minnesota Carlson School of Management – M.B.A., Finance

Michael J. Burns

Experience Summary

- Senior Vice President of Operations for Ever-Green Energy.
- More than 18 years of engineering and managerial experience in all aspects of energy facility operations and project implementation from large electric utility generating units to renewable energy and CHP installations.
- Responsible for the operation and maintenance of the energy generation facilities and distribution systems for District Energy St. Paul, District Cooling St. Paul, Energy Park Utility, and St. Paul Cogeneration.
- Instrumental in implementation of a 33 MW biomass-fired Combined Heat and Power facility, development of the renewable fuel market for the plant and integration of this facility into the local energy delivery system.
- Led District Energy and District Cooling operations to achieve best-in-class reliability while experiencing rapid rates of growth.

Recent Project Experience

- **North Loop Renewable Energy District Study, Hennepin County, MN**
- **South Loop District Energy Feasibility Study, Bloomington, MN**
- **Flue Gas Condensation Feasibility Study, District Energy St. Paul**
- **Renewable Energy Facility Study, Saint Paul Port Authority, St. Paul, MN**

Prior Project Experience

EXELON CORPORATION/ComEd, Chicago, Illinois. Exelon is a $15 billion electric utility and energy services company.

System Engineering Manager

Led a staff of 73 through improvement initiative in the systems and operations engineering area. Responsible for system performance monitoring, engineering program development and equipment reliability improvement. Participated as one of 12 senior-level managers who worked to recover troubled 2200 MWe generating station, revamped processes, operating procedures and interfaces with other functional areas to improve department performance.

System Engineering Group Leader

Supervised various engineering groups with staffs of 10 to 12 engineers who had responsibility for solving equipment reliability and operational performance problems. Determined and implemented solutions to plant operational issues. Led groups through challenge of four major plant overhauls and return to service.

General Engineer, ComEd, Downers Grove, Illinois

Selected to participate on a corporate team assembled to assist troubled organization to achieve extensive equipment reliability and process improvements. Assessed work processes and improved to industry standards. Coordinated activities and budgets of architect/engineering firms on several projects.

System Engineer, ComEd, Byron Generating Station, Byron, Illinois

Responsible for testing and monitoring performance of plant systems and machinery. Recommended appropriate maintenance based on condition trending and observed deficiencies. Investigated and resolved system problems, established and implemented corrective actions.

Education

University of Notre Dame - B.S. in Mechanical Engineering
Northwestern University's Kellogg Graduate School of Management - M.B.A.

Alexander H. Sleiman

Experience Summary

- Provided engineering, customer relations and marketing services to the District Energy St. Paul for over 20 years.
- Referred to as "Mr. District Energy" by customers.
- Specify, selection and monitoring of district energy system metering and cost allocation systems to ensure the adequacy, accuracy and proper maintenance of metering equipment and provide monitoring of monthly energy billings.
- Broad technical knowledge concerning building conversions, the design and operation of building heating and cooling systems; ability to respond to customer problems in a creative and cost effective manner.
- Developed the written standards and guidelines for designing building heating and cooling HVAC systems to interface with the district energy systems.
- More than 35 years of experience in energy management engineering, specializing in the design, specification and construction supervision of heating, ventilating and air-conditioning systems.
- Authored the "Guidelines for Converting Building Heating Systems for Hot Water District Heating" for the International Energy Agency (AIE) in 1990.
- Member of the American Society of Plumbing Engineers and the American Society of Heating, Refrigeration, and Air Conditioning Engineers.

Recent Project Experience

- **North Loop Renewable Energy District Study, Hennepin County, MN**
- **South Loop District Energy Feasibility Study, Bloomington, MN**

Education

Bradley University - B.S. in Industrial Technology

Appendix B

Study Building Internal Systems

Study Building Load Table

BURDES Customer Data					Estimated Energy Demand and Annual Load			
Bldg ID	Bldg Name	Address	Use	SF	Heating Load Hot Water System		Heating Load Steam System	
					(kW)	(MWh)	(kW)	(MWh)
1	Waterman	UVM	Classroom	189,556	1,810	3,430	2,290	4,340
2	Rehabilitiation	UHC-FAHC	Hospital_Outpatient	29,872	140	330	180	430
3	Clinic	UHC-FAHC	Hospital_Outpatient	21,139	100	230	130	300
4	Old Hall	UHC-FAHC	Hospital_Outpatient	47,340	220	520	280	680
5	St Josephs Pavilion	UHC-FAHC	Hospital_Outpatient	55,821	250	610	330	800
6	Arnold Pavilion	UHC-FAHC	Hospital_Outpatient	88,972	410	970	530	1,280
7	Boiler House	UHC-FAHC	Boiler House	6,686	30	70	50	100
8	Dewey Hall	UVM	Classroom	45,047	600	1,150	760	1,450
9	Ira Allen	Trinity building	Classroom	18,526	190	370	240	460
10	Delehanty	Trinity building	Laboratory	40,470	640	1,350	810	1,700
11	Mann Hall	Trinity building	Office	35,892	200	390	260	490
12	Farrell Hall	Trinity building	Classroom	16,520	110	210	140	270
13	St Josephs Villa	Trinity building	Office	8,800	50	90	-	-
14	McAuley Hall	Trinity building	Residential	44,785	300	660	380	830
15	Mercy Hall	Trinity building	Residential	33,138	270	590	340	740
16	McCann Hall	Trinity building	Residential	10,665	50	90	10	30
17	Hunt Hall	Trinity building	Residential	10,665	50	90	10	20
18	Ready Hall	Trinity building	Residential	10,665	50	90	10	20
19	Sichel Hall	Trinity building	Residential	10,665	50	90	10	20
20	Richardson Hall	Trinity building	Residential	10,665	50	90	10	20
21	Cottage_1	Trinity building	Unknown	4,000	-	-	-	-
22	Cottage_2	Trinity building	Unknown	2,800	-	-	-	-
23	Cottage_3	Trinity building	Unknown	4,100	-	-	-	-
24	Cottage_4	Trinity building	Unknown	3,200	-	-	-	-
25	Trinity Boiler House	Trinity building	Boiler House	3,000	20	50	-	-
26	Main Pavilion	FAHC Hospital	Hospital_Outpatient	140,325	1,560	3,750	2,200	5,270
27	Central Plant	FAHC Hospital	Boiler House	65,231	830	1,740	1,170	2,450
28	Fletcher	FAHC Hospital	Office	24,222	340	650	480	910
29	Engineering	FAHC Hospital	Office	29,596	420	790	590	1,110
30	Shepardson North	FAHC Hospital	Hospital_Inpatient	58,860	540	1,570	760	2,210
31	Shepardson South	FAHC Hospital	Hospital_Inpatient	61,213	560	1,640	790	2,300
32	Smith	FAHC Hospital	Hospital_Outpatient	73,835	590	1,420	1,160	2,770
33	Baird	FAHC Hospital	Hospital_Inpatient	158,757	1,050	3,050	2,060	5,970
34	Patrick	FAHC Hospital	Office	61,682	870	1,650	1,220	2,320
35	Modular_B	FAHC Hospital	Office	11,209	-	-	-	-
36	McClure	FAHC Hospital	Hospital_Inpatient	365,541	2,420	7,020	4,740	13,740
37	Parking Garage	FAHC Hospital	Garage	-	-	-	-	-
38	East Pavilion	FAHC Hospital	Hospital_Outpatient	191,930	2,140	5,130	3,010	7,210
39	West Pavilion	FAHC Hospital	Hospital_Outpatient	192,396	2,140	5,140	3,010	7,230
40	Garden Pavilion	FAHC Hospital	Classroom	24,000	340	640	470	900
41	Education Center	FAHC Hospital	Classroom	35,597	500	950	700	1,340
							-	-
Total				2,247,383	19,900	46,600	29,100	69,700

Appendix C

Study Building Load Table

Study Building Load Table

BURDES Customer Data					Estimated Energy Demand and Annual Load			
Bldg ID	Bldg Name	Address	Use	SF	Heating Load Hot Water System		Heating Load Steam System	
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5	St Josephs Pavilion	UHC-FAHC	Hospital_Outpatient	55,821	250	610	330	800
6	Arnold Pavilion	UHC-FAHC	Hospital_Outpatient	88,972	410	970	530	1,280
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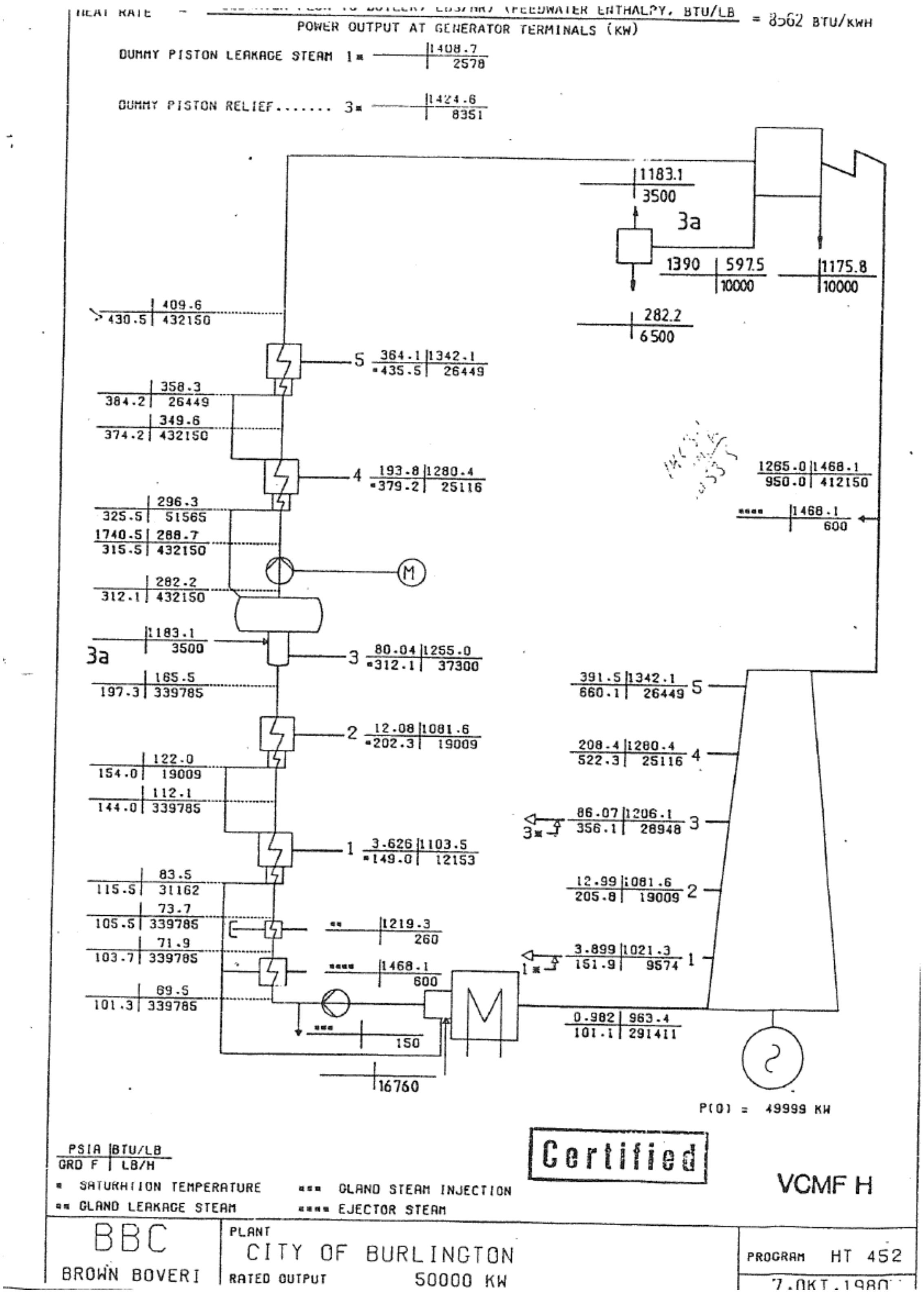
22	Cottage_2	Trinity building	Unknown	2,800	-	-	-	-
23	Cottage_3	Trinity building	Unknown	4,100	-	-	-	-
24	Cottage_4	Trinity building	Unknown	3,200	-	-	-	-
25	Trinity Boiler House	Trinity building	Boiler House	3,000	20	50	-	-
26	Main Pavilion	FAHC Hospital	Hospital_Outpatient	140,325	1,560	3,750	2,200	5,270
27	Central Plant	FAHC Hospital	Boiler House	65,231	830	1,740	1,170	2,450
28	Fletcher	FAHC Hospital	Office	24,222	340	650	480	910
29	Engineering	FAHC Hospital	Office	29,596	420	790	590	1,110
30	Shepardson North	FAHC Hospital	Hospital_Inpatient	58,860	540	1,570	760	2,210
31	Shepardson South	FAHC Hospital	Hospital_Inpatient	61,213	560	1,640	790	2,300
32	Smith	FAHC Hospital	Hospital_Outpatient	73,835	590	1,420	1,160	2,770
33	Baird	FAHC Hospital	Hospital_Inpatient	158,757	1,050	3,050	2,060	5,970
34	Patrick	FAHC Hospital	Office	61,682	870	1,650	1,220	2,320
35	Modular_B	FAHC Hospital	Office	11,209	-	-	-	-
36	McClure	FAHC Hospital	Hospital_Inpatient	365,541	2,420	7,020	4,740	13,740
37	Parking Garage	FAHC Hospital	Garage	-	-	-	-	-
38	East Pavilion	FAHC Hospital	Hospital_Outpatient	191,930	2,140	5,130	3,010	7,210
39	West Pavilion	FAHC Hospital	Hospital_Outpatient	192,396	2,140	5,140	3,010	7,230
40	Garden Pavilion	FAHC Hospital	Classroom	24,000	340	640	470	900
41	Education Center	FAHC Hospital	Classroom	35,597	500	950	700	1,340
							-	-
Total				2,247,383	19,900	46,600	29,100	69,700

Appendix D

Steam Turbine Process Flow Diagram 50 MWe

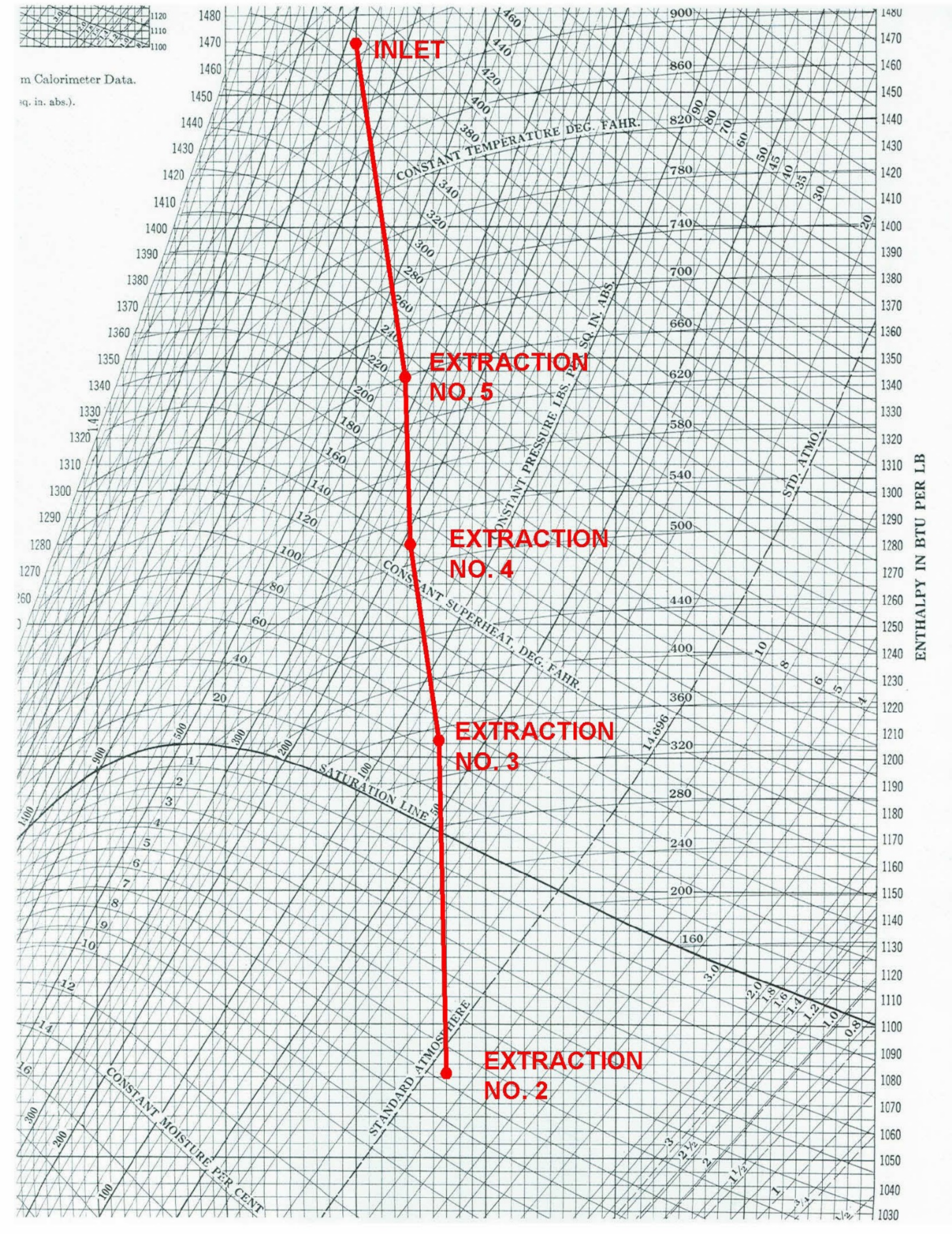
Steam Turbine Process Flow Diagram @ 50 MWe Gross



Appendix E

Steam Turbine Enthalpy Diagram @ 50 MWe Gross

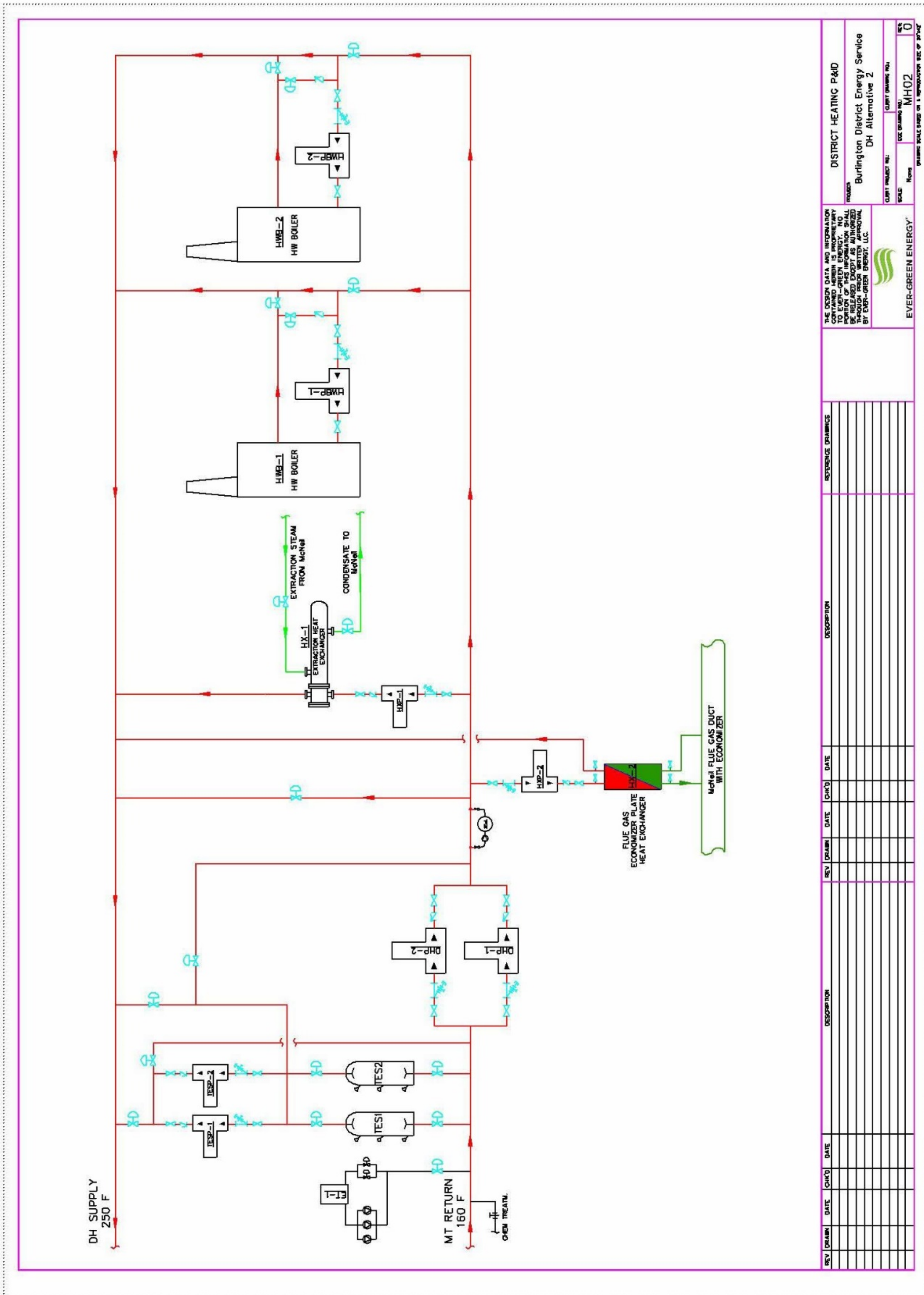
Steam Turbine Enthalpy Diagram @ 50 MWe Gross



Appendix F

District Heating PID

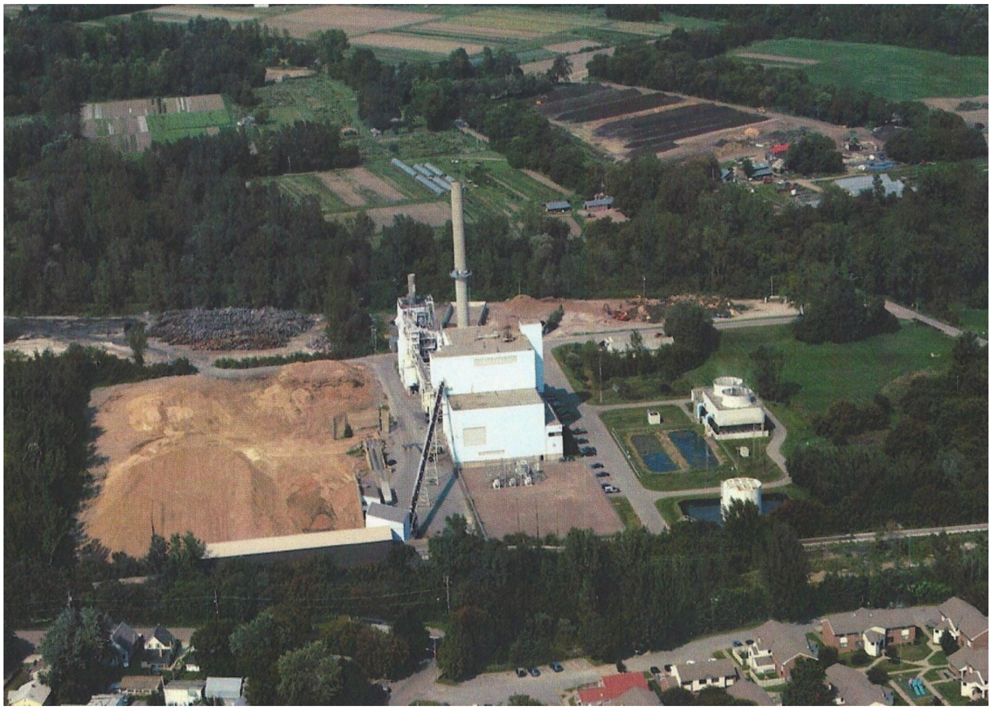
District Heating P&ID



Appendix G

BED Ambient Air Quality Modeling Report

Ambient Air Quality Modeling Analysis for Boiler Exhaust Heat Recovery



Burlington Electric Department Joseph C. McNeil Generating Station

Burlington, Vermont

August 10, 2011

Prepared for:

Burlington Electric Department
Joseph C. McNeil Generating Station
111 Intervale Road
Burlington, VT 05401

Prepared by:

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Boston, MA 02110

TETRA TECH EC, INC.

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1.0 Project Description

The Burlington Electric Department's Joseph C. McNeil Generating Station is an approximate 50 MW (net) wood fired power generating facility located in Burlington, Vermont. The site is located approximately 1.5 miles north of the Burlington city center adjacent to the Winooski River at 111 Intervale Road (see Figure 1-1: General Location Map). Figure 1-2 provides an aerial view of the facility. Burlington Electric Department is considering a project which would recover heat from the main boiler exhaust to provide district heating to various end-users in the City of Burlington.

This project is expected to have substantial net air quality benefits from net region-wide emissions reductions of criteria pollutants and carbon dioxide greenhouse gas emissions. Reductions would occur in end-user emissions through the replacement of emissions-producing boiler heating with district heating. However, at McNeil Station, while emissions would not be influenced by the recovery of heat in the boiler exhaust which is currently wasted, stack plume characteristics would be adversely affected by lower plume rise from lower stack exhaust exit temperature and stack exhaust exit velocity. For this reason, Burlington Electric Department retained Tetra Tech to conduct ambient air quality dispersion modeling of the modified stack exhaust to determine compliance with state and federal ambient air quality standards, focusing on the most critical new 1-hour NO_2 standard.

The following sections of this report present the emissions and plant operating scenarios modeled and the methodology and results of the dispersion modeling analyses.

FIGURE 1-1: Burlington Electric – Joseph C. McNeil Generating Station – General Location Map

FIGURE 1-2: Burlington Electric – Joseph C. McNeil Generating Station – Aerial View of Site

2.0 Project Emissions / Operating Scenarios

Five combinations of boiler fuel, operating load, and exhaust temperatures were analyzed in the dispersion modeling analysis to bracket all reasonable operating scenarios after the heat recovery project for district heating. One of the five cases represents the existing conditions for the main boiler and this is used for comparative purposes. The five cases analyzed are as follows:

- Case W-1 = Main boiler at full load on wood (750 mmBtu/hr heat input) with boiler exhaust 330 degrees F (existing full load conditions)
- Case W-2 = Main boiler at full load on wood (750 mmBtu/hr heat input) with boiler exhaust 230 degrees F (full load moderate heat recovery for district heating)
- Case W-3 = Main boiler at full load on wood (750 mmBtu/hr heat input) with boiler exhaust 160 degrees F (full load maximum heat recovery for district heating)
- Case W-4 = Main boiler at 33% load on wood (250 mmBtu/hr heat input) with boiler exhaust 140 degrees F (lowest normal operating load and maximum heat recovery for district heating)
- Case G-1 = Main boiler at full load on gas (675 mmBtu/hr heat input) with boiler exhaust 140 degrees F (full load gas firing and maximum heat recovery for district heating)

Very conservative (low) exhaust gas flows at standard conditions (scfmw) were assumed and were adjusted for the corresponding exhaust stack exit temperature of each case analyzed above. The flows selected were 200,000 scfmw for full load on wood and 100,000 scfmw for 33% on wood which are approximately 10% to 20% below typical corresponding exhaust flows derived from CEMS data. For natural gas firing, a conservative full load exhaust flow of 150,000 acfm at 140 degrees F was selected.

Except for SO_2, conservatively high emissions rates for each pollutant were based on maximum short term limits specified in the current Title V Operating Permit. For SO_2, a conservative emission rate based on 0.02 lb/mmBtu (15 lb/hr at maximum load) was used for wood firing. This is less than the 100 lb/hr emission limit in the permit because that permit limit is more representative of worst case on oil firing which is not expected under normal operations in the future. The specific emissions rates selected and the basis for these emission rates are shown in the spreadsheet and footnotes to the spreadsheet included in Attachment A.

3.0 Air Quality Dispersion Modeling Analysis

This section describes the procedures that were used for conducting the air quality modeling analysis, including the models which were employed, the model input options used, and the supporting data. The purpose of the air quality impact analysis is to assess the McNeil Station's predicted ground level pollutant concentrations plus background concentrations against applicable state and federal ambient air quality standards.

3.1 Model Selection

In accordance with VTDEC guidance, the refined modeling was conducted using the EPA AERMOD modeling system (dated 11103). The analysis was conducted in accordance with the AERMOD and AERMET users guides, EPA's *Guideline on Air Quality Models (revised) (40 CFR 51 Appendix W) and* VTDEC's *Air Quality Impact Evaluation Guidelines.* The AERMOD model system was used to evaluate potential impact concentrations from the McNeil Station main boiler stack at receptor locations representative of all terrain (simple, intermediate, and complex) surrounding the facility.

3.2 Land Use

A land use determination was made following the classification technique suggested by Auer (Auer 1978). The classification determination was conducted by assessing land use categories within a 3-km radius of the proposed site. Visual inspection of USGS topographic maps and aerial photos indicates that the majority of land use is characterized as rural. Therefore, rural dispersion coefficients were used for the air quality modeling.

3.3 Background Air Quality

The VTDEC collects air quality data (ambient pollutant concentrations) at numerous monitoring stations throughout the state. The highest values measured over the most recent 3 years (2008-2010) are summarized by the VTDEC in their table "Background Air Quality Monitoring Data for Use in Air Quality Impact Evaluations". Data from monitoring sites in Burlington (CO, NO_2, $PM_{2.5}$) and Rutland (SO_2) are proposed as representative of background air quality for the project site area.

3.4 GEP Stack Height and BPIP Analysis

A Good Engineering Practice (GEP) Analysis was performed in accordance with EPA and VTDEC guidelines. The controlling building structure at the facility is the main boiler building, which is 116.4 feet above grade. Since this is a squat building, the calculated GEP height for the stacks nearby is equal to 2.5 times the structure height. Thus, the calculated GEP height is 291 feet (2.5 x 116.4 feet). The boiler stack height (257 feet) is less than GEP height. Therefore, EPA's Building Profile Input Program (BPIP-Prime) was used to define the height and projected width of the "controlling" structures (as a function of flow vector) for each of the non-GEP stacks. The BPIP-Prime results were used in conjunction with the AERMOD dispersion model to evaluate the wind direction specific building downwash effects for each stack. BPIP-Prime input and output data are provided in Attachment B.

3.5 Meteorological Data

The AERMOD system includes a meteorological data processing program called AERMET which combines surface and upper air weather observations with surface characteristics based on land use to develop local dispersion parameters. For this analysis, the VTDEC (Dan Riley via email on 7/26/11) provided ready-to-use, preprocessed meteorological data files (in the form of .SFC and .PFL files) for the Burlington International Airport. The files incorporate land use data centered on the meteorological monitoring site (i.e., airport weather tower), so surface characteristic data processing by the applicant using AERMET is not necessary. This surface data, which has been processed along with Albany, NY upper air data for the years 2006-2010, was used in the modeling analysis.

3.6 Receptors

The dispersion modeling was completed for receptors surrounding the facility in a nested Cartesian grid. This grid was based on the following receptor intervals and distances:

- At 50 meter intervals from the main stack out to 200 meters;
- At 100 meter intervals from 200 to 1000 meters;
- At 200 meter intervals from 1,000 to 2,000 meters;
- At 500 meter intervals from 2,000 to 5,000 meters; and
- At 1,000 meter intervals from 5,000 to 20,000 meters.

Schematic diagrams of the receptor grid are provided in Attachment C. Terrain elevations at receptors were obtained using BEE-Line Software's BEEST program and USGS digital terrain data. BEEST implements the AERMAP model which includes processing routines that extract National Elevation Dataset (NED) data (the four nearest points surrounding receptor) to determine receptor terrain elevations (by interpolation) for air quality model input.

3.7 Emission Source Parameters

Table 3-1 summarizes stack characteristics for the main boiler. The emissions and source parameters used for this modeling analysis are summarized in Section 2 and are detailed in Attachment A.

3.8 AERMOD Modeling Results

The worst case AERMOD model results for the main boiler are summarized in Table 3-2. Detailed results for all load conditions evaluated are provided in Attachment D. Model-predicted concentrations are summed with ambient background concentrations and the total concentrations are compared the corresponding National Ambient Air Quality Standards (NAAQS). The model results indicate that the McNeil main boiler will be in compliance with all NAAQS for all exhaust temperature and flow conditions evaluated (current and after heat recovery for district heating is implemented). Maximum AERMOD-predicted annual concentrations for ammonia (NH_3) are presented in Table 3-3. The results indicate that maximum NH_3 impacts are well below the corresponding Hazardous Ambient Air Standard (HAAS). The electronic modeling files will be provided to the VTDEC upon request.

The model results also indicate that the McNeil main boiler will be in compliance with all PSD increments including the Vermont increment consumption policy for an individual source of a maximum of 25% of the full increment for annual concentrations and 75% of the full increment for shorter averaging periods. This is true for all exhaust temperature and flow conditions evaluated. For example, for the annual NO_2 increment of 25 micrograms per cubic meter, the Vermont allowable increment consumption is 6.25 micrograms per cubic meter. The maximum impact predicted from the McNeil main boiler is 1.2 micrograms per cubic meter, well within the allowable increment consumption.

Maximum impact concentrations shown in Table 3-2 for all criteria pollutants and averaging periods are predicted under the operating scenario case W-3 (100% load, wood fired, 160^{o}F). Maximum impact concentrations shown in Table 3-3 for ammonia are predicted under the operating scenario case W-4 (33% load, wood fired, 140^{o}F).

Table 3-1: Stack Characteristics for the Main Boiler

Parameter	Boiler
Base Elevation, msl (feet/meters)	115/35.05
Stack Height (feet/meters)	257/78.33
Inside Stack Diameter (feet/meters)	10/3.05
Number of Stacks	1
Predominate Land Use Type	Rural
Stack Location (UTM NAD83 zone 18) UTM-E (m) UTM-N (m)	 642453 4928251

Table 3-2: Maximum AERMOD Predicted Concentrations for the Main Boiler Compared to the NAAQS

Pollutant	Averaging Period	Rank	Maximum Concentration (µg/m^3)	Ambient Background (µg/m^3)	Total Concentration (µg/m^3)	NAAQS (µg/m^3)
NO_2	1-Hour	H8H	75.1 *	77.1	152.2	188
	Annual	H	1.2	17.5	18.7	100
$PM_{2.5}$	24-Hour	H	0.9 *	21.6	22.5	35
	Annual	H	0.1	7.3	7.4	15
SO_2	1-Hour	H4H	12.5 *	70.7	83.2	196
	24-Hour	H2H	1.5	44.5	46.0	365
	Annual	H	0.2	7.6	7.8	80
CO	1-Hour	H2H	1142.5	3092	4234.5	40,000
	8-Hour	H2H	269.3	1603	1872.3	10,000

H = highest; H2H = highest second highest

* Consistent with the recent EPA guidance, the 1-hour NO_2 concentration is based on the maximum 5 year average of the highest eighth highest (H8H) daily maximum concentrations (equivalent to 98th percentile values), the 24-hour $PM_{2.5}$ concentration is based the 5-year average of highest 24-hour concentrations, and the 1-hour SO_2 concentration is based on the maximum 5 year average of the highest fourth highest (H4H) daily maximum concentrations (equivalent to 99th percentile values).

Table 3-3: Maximum AERMOD Predicted NH_3 Concentration for the Main Boiler Compared to the HAAS

Pollutant	Averaging Period	Rank	Maximum Concentration (µg/m^3)	HAAS (µg/m^3)
NH_3	Annual	H	0.05	100

ATTACHMENT A

Emission and Exhaust Gas Calculations

Burlington Electric McNeil Station
Expanded emissions table for Main Biomass Boiler
Combustion technology : Stoker; Stack Height : 257 ft; Stack Diameter: 10 ft
Air quality controls : Good combustion practice / RSCR / Multiclone /ESP
Rev : C (Aug 4, 2011)

	Wood				Natural Gas
Case number	W-1	W-2	W-3	W-4	G-1
Approx load - exh temp	100% Hi	100% Med	100% Lo	33% Lo	100% Lo
Heat input	750	750	750	250	675
Controlled emissions factors (lb/mmBtu) (1)					
NOx	0.1933	0.1933	0.1933	0.23	0.13
PM	0.0129	0.0129	0.0129	0.0129	0.0076
CO	1.500	1.500	1.500	1.500	0.084
SO_2	0.02	0.02	0.02	0.02	0.0006
NH_3					
Controlled emissions at stack (lb/hr) (1)					
NOx	145.0	145.0	145.0	57.5	87.8
PM	9.7	9.7	9.7	3.2	5.13
CO	1125.0	1125.0	1125.0	375.0	56.7
SO_2	15.0	15.0	15.0	5.0	0.4
NH_3	3.00	3.00	3.00	3.00	
Stack temperature (°F)	330	230	160	140	140
Stack volume (acfm) (2)	303,846	265,385	238,462	115,385	150,000
Stack Area for 10 ft diam (ft2)	78.54	78.54	78.54	78.54	78.54
Exit Velocity (ft/s)	64.48	56.32	50.60	24.49	31.83
Exit Velocity (m/s)	19.65	17.17	15.42	7.46	9.70
Stack Temp (K)	438.7	383.2	344.3	333.2	333.2
Emissions, g/s					
NOx	18.3	18.3	18.3	7.2	11.1
PM	1.2	1.2	1.2	0.4	0.6
CO	141.8	141.8	141.8	47.3	7.1
SO_2	1.9	1.9	1.9	0.6	0.1
NH_3	0.4	0.4	0.4	0.4	

(1) NOx emission factor from max hourly rate of more stringent of 0.23 lb/mmBtu or 145 lb/hr specified in Title V permit. Actuals are below 0.075 lb/mmBtu on quarterly avg.
Gas NOx emissions from Title V limit of 88 lbs/hr and 0.13 lb/mmBtu
PM rate based on 9.7 lbs/hr limit in Title V permit. Actual emissions avaeraged only 0.11 lb/hr from Oct 2010 stack test (filterable only)
CO rate based on approx. lbs/hr equivalent of 1500 ppm 1 hr limit in Title V permit
SO2 rate based on conservative estimate of wood fired max. This is significantly less than 100 lb/hr limit in Title V permit.
Ammonia rate based on approximate lb/hr equivalent of 8 hr rolling avg limit of 20 ppm (6% 02).

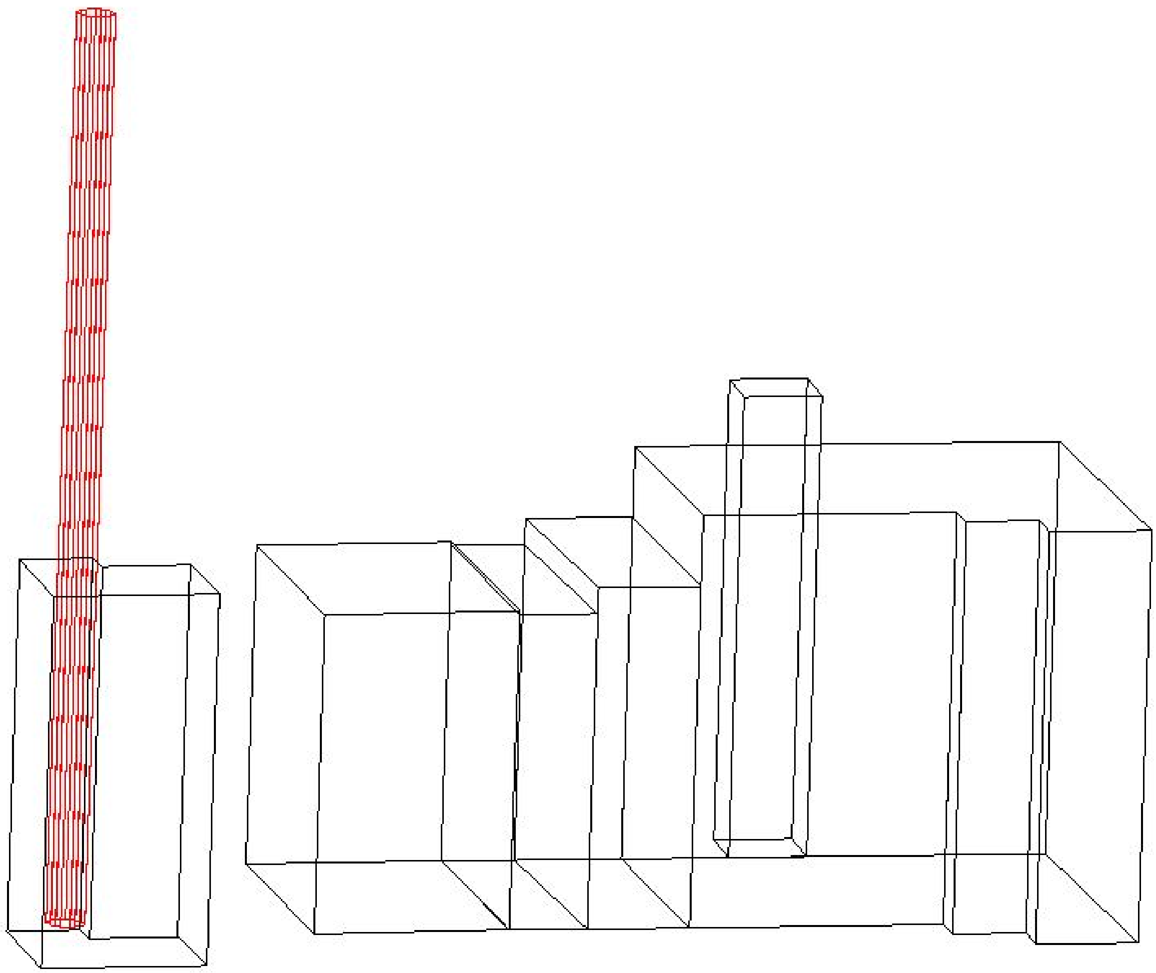
(2) 100% Load Wood Exhaust Flow Assumed	200000	scfmw	For conservatism, this is 10% to 20% below typical CEMS data at full load (56 MW net)
33% Load Wood Exhaust Flow Assumed =	100000	scfmw	For conservatism, this is 10% to 20% below typical CEMS data at approx 33% load (20 MW)

ATTACHMENT B

BPIP-Prime Data

```
'C:\Documents and Settings\Ted.Guertin\Desktop\Burlington Elec\AERMOD\BE2_2006.BST
BEESTWin BPIP-Prime Files 8/4/2011 5:19:41 PM'
'P'
'METERS'      1.0
'UTMY'        0
 6
'MAIN1'        1            35.36
 8            35.47872
642475        4928162.5
642440        4928162
642440        4928170.4
642444.5      4928170.4
642444        4928176.9
642447.9      4928176.9
642447.4      4928198.5
642474.5      4928199.
'MAIN2'        1            35.36
 4            29.4132
642474.5      4928199
642447.4      4928198.5
642447.4      4928207.5
642474.5      4928208
'MAIN3'        1            35.36
 4            27.1272
642447.4      4928207.5
642474.5      4928208
642474.5      4928214.5
642447.4      4928214
'MAIN4'        1            35.36
 4            27.432
642474.5      4928214.5
642447.5      4928214
642446.5      4928231
642474        4928231.5
'GASIFIER'     1            35.36
 6            32.004
642446        4928243
642434.5      4928242.5
642434        4928256.5
642448.5      4928257
642449        4928250.5
642445.5      4928250.5
'MAIN5'        1            35.36
 4            39.624
642474.8      4928183
642474.7      4928190
642481.7      4928190
642481.8      4928183
 5
'BLR_W1      '               35.052         78.3336       642453.       4928251.
'BLR_W2      '               35.052         78.3336       642453.       4928251.
'BLR_W3      '               35.052         78.3336       642453.       4928251.
'BLR_W4      '               35.052         78.3336       642453.       4928251.
'BLR_G1      '               35.052         78.3336       642453.       4928251.
```

3D View of Structures Input to BPIP



```
                        BEE-Line Software Version: 9.95

                         Input File - BE2_BPIP.PRW
                         Input File - BE2_BPIP.PIP
                        Output File - BE2_BPIP.TAB
                        Output File - BE2_BPIP.SUM
                        Output File - BE2_BPIP.SO


                             BPIP (Dated: 04274)
DATE : 08/04/2011
TIME : 05:19:41 PM
C:\Documents and Settings\Ted.Guertin\Desktop\Burlington Elec\AERMOD\BE2_2006.

============================
BPIP PROCESSING INFORMATION:
============================

  The P  flag has been set for preparing downwash related data
         for a model run utilizing the PRIME algorithm.

  Inputs entered in METERS     will be converted to meters using
   a conversion factor of    1.0000.  Output will be in meters.

  The UTMP variable is set to UTMY.  The input is assumed to be in
    UTM coordinates.  BPIP will move the UTM origin to the first pair of
    UTM coordinates read.  The UTM coordinates of the new origin will
    be subtracted from all the other UTM coordinates entered to form
    this new local coordinate system.

  Plant north is set to   0.00 degrees with respect to True North.


C:\Documents and Settings\Ted.Guertin\Desktop\Burlington Elec\AERMOD\BE2_2006.
```

PRELIMINARY* GEP STACK HEIGHT RESULTS TABLE
(Output Units: meters)

Stack Name	Stack Height	Stack-Building Base Elevation Differences	GEP** EQN1	Preliminary* GEP Stack Height Value
BLR_W1	78.33	-0.31	89.00	89.00
BLR_W2	78.33	-0.31	89.00	89.00
BLR_W3	78.33	-0.31	89.00	89.00
BLR_W4	78.33	-0.31	89.00	89.00
BLR_G1	78.33	-0.31	89.00	89.00

```
  * Results are based on Determinants 1 & 2 on pages 1 & 2 of the GEP
    Technical Support Document.  Determinant 3 may be investigated for
    additional stack height credit.  Final values result after
    Determinant 3 has been taken into consideration.
 ** Results were derived from Equation 1 on page 6 of GEP Technical
    Support Document.  Values have been adjusted for any stack-building
    base elevation differences.

    Note:  Criteria for determining stack heights for modeling emission
    limitations for a source can be found in Table 3.1 of the
    GEP Technical Support Document.
```

```
                             BPIP (Dated: 04274)
DATE : 08/04/2011
TIME : 05:19:41 PM


C:\Documents and Settings\Ted.Guertin\Desktop\Burlington Elec\AERMOD\BE2_2006.

 BPIP output is in meters


    SO BUILDHGT BLR_W1     35.48   35.48   27.43   27.43   27.43   27.43
    SO BUILDHGT BLR_W1     27.43   27.43   27.43   27.43   27.43   27.43
    SO BUILDHGT BLR_W1     27.43   35.48   35.48   35.48   35.48   35.48
    SO BUILDHGT BLR_W1     35.48   35.48   27.43   27.43   27.43   27.43
    SO BUILDHGT BLR_W1     27.43   27.43   27.43   27.43   27.43   27.43
    SO BUILDHGT BLR_W1     27.43   35.48   35.48   35.48   35.48   35.48
    SO BUILDWID BLR_W1     35.84   38.25   32.50   32.06   30.64   56.62
    SO BUILDWID BLR_W1     53.32   48.39   43.00   42.52   40.75   28.41
    SO BUILDWID BLR_W1     30.44   50.21   48.38   45.07   40.40   41.80
    SO BUILDWID BLR_W1     35.84   38.25   32.50   32.06   30.64   56.62
    SO BUILDWID BLR_W1     53.32   48.39   43.00   42.52   40.75   28.41
    SO BUILDWID BLR_W1     30.44   50.21   48.38   45.07   40.40   41.80
    SO BUILDLEN BLR_W1     42.43   46.57   28.41   30.44   31.55   31.70
    SO BUILDLEN BLR_W1     33.36   36.99   40.50   47.18   52.42   32.50
    SO BUILDLEN BLR_W1     32.06   45.32   44.98   43.27   40.25   37.00
    SO BUILDLEN BLR_W1     42.43   46.57   28.41   30.44   31.55   31.70
    SO BUILDLEN BLR_W1     33.36   36.99   40.50   47.18   52.42   32.50
    SO BUILDLEN BLR_W1     32.06   45.32   44.98   43.27   40.25   37.00
    SO XBADJ    BLR_W1    -89.91  -88.08  -34.79  -31.88  -28.00  -23.26
    SO XBADJ    BLR_W1    -20.29  -19.69  -19.00  -19.67  -19.74    4.37
    SO XBADJ    BLR_W1      7.88   36.62   42.67   47.42   50.73   52.00
    SO XBADJ    BLR_W1     47.48   41.51    6.39    1.44   -3.55   -8.44
    SO XBADJ    BLR_W1    -13.06  -17.29  -21.50  -27.51  -32.69  -36.87
    SO XBADJ    BLR_W1    -39.93  -81.94  -87.64  -90.69  -90.98  -89.00
    SO YBADJ    BLR_W1    -19.11  -31.82  -20.62  -23.90  -26.46  -14.05
    SO YBADJ    BLR_W1    -14.99  -15.48  -15.50  -16.13  -16.28  -20.59
    SO YBADJ    BLR_W1    -16.66  -42.06  -31.57  -20.12   -8.06    7.90
    SO YBADJ    BLR_W1     19.11   31.82   20.62   23.90   26.46   14.05
    SO YBADJ    BLR_W1     14.99   15.48   15.50   16.13   16.28   20.59
    SO YBADJ    BLR_W1     16.66   42.06   31.57   20.12    8.06   -7.90


    SO BUILDHGT BLR_W2     35.48   35.48   27.43   27.43   27.43   27.43
    SO BUILDHGT BLR_W2     27.43   27.43   27.43   27.43   27.43   27.43
    SO BUILDHGT BLR_W2     27.43   35.48   35.48   35.48   35.48   35.48
    SO BUILDHGT BLR_W2     35.48   35.48   27.43   27.43   27.43   27.43
    SO BUILDHGT BLR_W2     27.43   27.43   27.43   27.43   27.43   27.43
    SO BUILDHGT BLR_W2     27.43   35.48   35.48   35.48   35.48   35.48
    SO BUILDWID BLR_W2     35.84   38.25   32.50   32.06   30.64   56.62
    SO BUILDWID BLR_W2     53.32   48.39   43.00   42.52   40.75   28.41
    SO BUILDWID BLR_W2     30.44   50.21   48.38   45.07   40.40   41.80
    SO BUILDWID BLR_W2     35.84   38.25   32.50   32.06   30.64   56.62
    SO BUILDWID BLR_W2     53.32   48.39   43.00   42.52   40.75   28.41
    SO BUILDWID BLR_W2     30.44   50.21   48.38   45.07   40.40   41.80
    SO BUILDLEN BLR_W2     42.43   46.57   28.41   30.44   31.55   31.70
    SO BUILDLEN BLR_W2     33.36   36.99   40.50   47.18   52.42   32.50
    SO BUILDLEN BLR_W2     32.06   45.32   44.98   43.27   40.25   37.00
    SO BUILDLEN BLR_W2     42.43   46.57   28.41   30.44   31.55   31.70
    SO BUILDLEN BLR_W2     33.36   36.99   40.50   47.18   52.42   32.50
    SO BUILDLEN BLR_W2     32.06   45.32   44.98   43.27   40.25   37.00
    SO XBADJ    BLR_W2    -89.91  -88.08  -34.79  -31.88  -28.00  -23.26
    SO XBADJ    BLR_W2    -20.29  -19.69  -19.00  -19.67  -19.74    4.37
    SO XBADJ    BLR_W2      7.88   36.62   42.67   47.42   50.73   52.00
    SO XBADJ    BLR_W2     47.48   41.51    6.39    1.44   -3.55   -8.44
    SO XBADJ    BLR_W2    -13.06  -17.29  -21.50  -27.51  -32.69  -36.87
    SO XBADJ    BLR_W2    -39.93  -81.94  -87.64  -90.69  -90.98  -89.00
    SO YBADJ    BLR_W2    -19.11  -31.82  -20.62  -23.90  -26.46  -14.05
```

```
SO YBADJ    BLR_W2    -14.99  -15.48  -15.50  -16.13  -16.28  -20.59
SO YBADJ    BLR_W2    -16.66  -42.06  -31.57  -20.12   -8.06    7.90
SO YBADJ    BLR_W2     19.11   31.82   20.62   23.90   26.46   14.05
SO YBADJ    BLR_W2     14.99   15.48   15.50   16.13   16.28   20.59
SO YBADJ    BLR_W2     16.66   42.06   31.57   20.12    8.06   -7.90


SO BUILDHGT BLR_W3     35.48   35.48   27.43   27.43   27.43   27.43
SO BUILDHGT BLR_W3     27.43   27.43   27.43   27.43   27.43   27.43
SO BUILDHGT BLR_W3     27.43   35.48   35.48   35.48   35.48   35.48
SO BUILDHGT BLR_W3     35.48   35.48   27.43   27.43   27.43   27.43
SO BUILDHGT BLR_W3     27.43   27.43   27.43   27.43   27.43   27.43
SO BUILDHGT BLR_W3     27.43   35.48   35.48   35.48   35.48   35.48
SO BUILDWID BLR_W3     35.84   38.25   32.50   32.06   30.64   56.62
SO BUILDWID BLR_W3     53.32   48.39   43.00   42.52   40.75   28.41
SO BUILDWID BLR_W3     30.44   50.21   48.38   45.07   40.40   41.80
SO BUILDWID BLR_W3     35.84   38.25   32.50   32.06   30.64   56.62
SO BUILDWID BLR_W3     53.32   48.39   43.00   42.52   40.75   28.41
SO BUILDWID BLR_W3     30.44   50.21   48.38   45.07   40.40   41.80
SO BUILDLEN BLR_W3     42.43   46.57   28.41   30.44   31.55   31.70
SO BUILDLEN BLR_W3     33.36   36.99   40.50   47.18   52.42   32.50
SO BUILDLEN BLR_W3     32.06   45.32   44.98   43.27   40.25   37.00
SO BUILDLEN BLR_W3     42.43   46.57   28.41   30.44   31.55   31.70
SO BUILDLEN BLR_W3     33.36   36.99   40.50   47.18   52.42   32.50
SO BUILDLEN BLR_W3     32.06   45.32   44.98   43.27   40.25   37.00
SO XBADJ    BLR_W3    -89.91  -88.08  -34.79  -31.88  -28.00  -23.26
SO XBADJ    BLR_W3    -20.29  -19.69  -19.00  -19.67  -19.74    4.37
SO XBADJ    BLR_W3      7.88   36.62   42.67   47.42   50.73   52.00
SO XBADJ    BLR_W3     47.48   41.51    6.39    1.44   -3.55   -8.44
SO XBADJ    BLR_W3    -13.06  -17.29  -21.50  -27.51  -32.69  -36.87
SO XBADJ    BLR_W3    -39.93  -81.94  -87.64  -90.69  -90.98  -89.00
SO YBADJ    BLR_W3    -19.11  -31.82  -20.62  -23.90  -26.46  -14.05
SO YBADJ    BLR_W3    -14.99  -15.48  -15.50  -16.13  -16.28  -20.59
SO YBADJ    BLR_W3    -16.66  -42.06  -31.57  -20.12   -8.06    7.90
SO YBADJ    BLR_W3     19.11   31.82   20.62   23.90   26.46   14.05
SO YBADJ    BLR_W3     14.99   15.48   15.50   16.13   16.28   20.59
SO YBADJ    BLR_W3     16.66   42.06   31.57   20.12    8.06   -7.90


SO BUILDHGT BLR_W4     35.48   35.48   27.43   27.43   27.43   27.43
SO BUILDHGT BLR_W4     27.43   27.43   27.43   27.43   27.43   27.43
SO BUILDHGT BLR_W4     27.43   35.48   35.48   35.48   35.48   35.48
SO BUILDHGT BLR_W4     35.48   35.48   27.43   27.43   27.43   27.43
SO BUILDHGT BLR_W4     27.43   27.43   27.43   27.43   27.43   27.43
SO BUILDHGT BLR_W4     27.43   35.48   35.48   35.48   35.48   35.48
SO BUILDWID BLR_W4     35.84   38.25   32.50   32.06   30.64   56.62
SO BUILDWID BLR_W4     53.32   48.39   43.00   42.52   40.75   28.41
SO BUILDWID BLR_W4     30.44   50.21   48.38   45.07   40.40   41.80
SO BUILDWID BLR_W4     35.84   38.25   32.50   32.06   30.64   56.62
SO BUILDWID BLR_W4     53.32   48.39   43.00   42.52   40.75   28.41
SO BUILDWID BLR_W4     30.44   50.21   48.38   45.07   40.40   41.80
SO BUILDLEN BLR_W4     42.43   46.57   28.41   30.44   31.55   31.70
SO BUILDLEN BLR_W4     33.36   36.99   40.50   47.18   52.42   32.50
SO BUILDLEN BLR_W4     32.06   45.32   44.98   43.27   40.25   37.00
SO BUILDLEN BLR_W4     42.43   46.57   28.41   30.44   31.55   31.70
SO BUILDLEN BLR_W4     33.36   36.99   40.50   47.18   52.42   32.50
SO BUILDLEN BLR_W4     32.06   45.32   44.98   43.27   40.25   37.00
SO XBADJ    BLR_W4    -89.91  -88.08  -34.79  -31.88  -28.00  -23.26
SO XBADJ    BLR_W4    -20.29  -19.69  -19.00  -19.67  -19.74    4.37
SO XBADJ    BLR_W4      7.88   36.62   42.67   47.42   50.73   52.00
SO XBADJ    BLR_W4     47.48   41.51    6.39    1.44   -3.55   -8.44
SO XBADJ    BLR_W4    -13.06  -17.29  -21.50  -27.51  -32.69  -36.87
SO XBADJ    BLR_W4    -39.93  -81.94  -87.64  -90.69  -90.98  -89.00
SO YBADJ    BLR_W4    -19.11  -31.82  -20.62  -23.90  -26.46  -14.05
SO YBADJ    BLR_W4    -14.99  -15.48  -15.50  -16.13  -16.28  -20.59
SO YBADJ    BLR_W4    -16.66  -42.06  -31.57  -20.12   -8.06    7.90
SO YBADJ    BLR_W4     19.11   31.82   20.62   23.90   26.46   14.05
SO YBADJ    BLR_W4     14.99   15.48   15.50   16.13   16.28   20.59
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SO YBADJ    BLR_W4     16.66   42.06   31.57   20.12    8.06   -7.90


SO BUILDHGT BLR_G1     35.48   35.48   27.43   27.43   27.43   27.43
SO BUILDHGT BLR_G1     27.43   27.43   27.43   27.43   27.43   27.43
SO BUILDHGT BLR_G1     27.43   35.48   35.48   35.48   35.48   35.48
SO BUILDHGT BLR_G1     35.48   35.48   27.43   27.43   27.43   27.43
SO BUILDHGT BLR_G1     27.43   27.43   27.43   27.43   27.43   27.43
SO BUILDHGT BLR_G1     27.43   35.48   35.48   35.48   35.48   35.48
SO BUILDWID BLR_G1     35.84   38.25   32.50   32.06   30.64   56.62
SO BUILDWID BLR_G1     53.32   48.39   43.00   42.52   40.75   28.41
SO BUILDWID BLR_G1     30.44   50.21   48.38   45.07   40.40   41.80
SO BUILDWID BLR_G1     35.84   38.25   32.50   32.06   30.64   56.62
SO BUILDWID BLR_G1     53.32   48.39   43.00   42.52   40.75   28.41
SO BUILDWID BLR_G1     30.44   50.21   48.38   45.07   40.40   41.80
SO BUILDLEN BLR_G1     42.43   46.57   28.41   30.44   31.55   31.70
SO BUILDLEN BLR_G1     33.36   36.99   40.50   47.18   52.42   32.50
SO BUILDLEN BLR_G1     32.06   45.32   44.98   43.27   40.25   37.00
SO BUILDLEN BLR_G1     42.43   46.57   28.41   30.44   31.55   31.70
SO BUILDLEN BLR_G1     33.36   36.99   40.50   47.18   52.42   32.50
SO BUILDLEN BLR_G1     32.06   45.32   44.98   43.27   40.25   37.00
SO XBADJ    BLR_G1    -89.91  -88.08  -34.79  -31.88  -28.00  -23.26
SO XBADJ    BLR_G1    -20.29  -19.69  -19.00  -19.67  -19.74    4.37
SO XBADJ    BLR_G1      7.88   36.62   42.67   47.42   50.73   52.00
SO XBADJ    BLR_G1     47.48   41.51    6.39    1.44   -3.55   -8.44
SO XBADJ    BLR_G1    -13.06  -17.29  -21.50  -27.51  -32.69  -36.87
SO XBADJ    BLR_G1    -39.93  -81.94  -87.64  -90.69  -90.98  -89.00
SO YBADJ    BLR_G1    -19.11  -31.82  -20.62  -23.90  -26.46  -14.05
SO YBADJ    BLR_G1    -14.99  -15.48  -15.50  -16.13  -16.28  -20.59
SO YBADJ    BLR_G1    -16.66  -42.06  -31.57  -20.12   -8.06    7.90
SO YBADJ    BLR_G1     19.11   31.82   20.62   23.90   26.46   14.05
SO YBADJ    BLR_G1     14.99   15.48   15.50   16.13   16.28   20.59
SO YBADJ    BLR_G1     16.66   42.06   31.57   20.12    8.06   -7.90
```
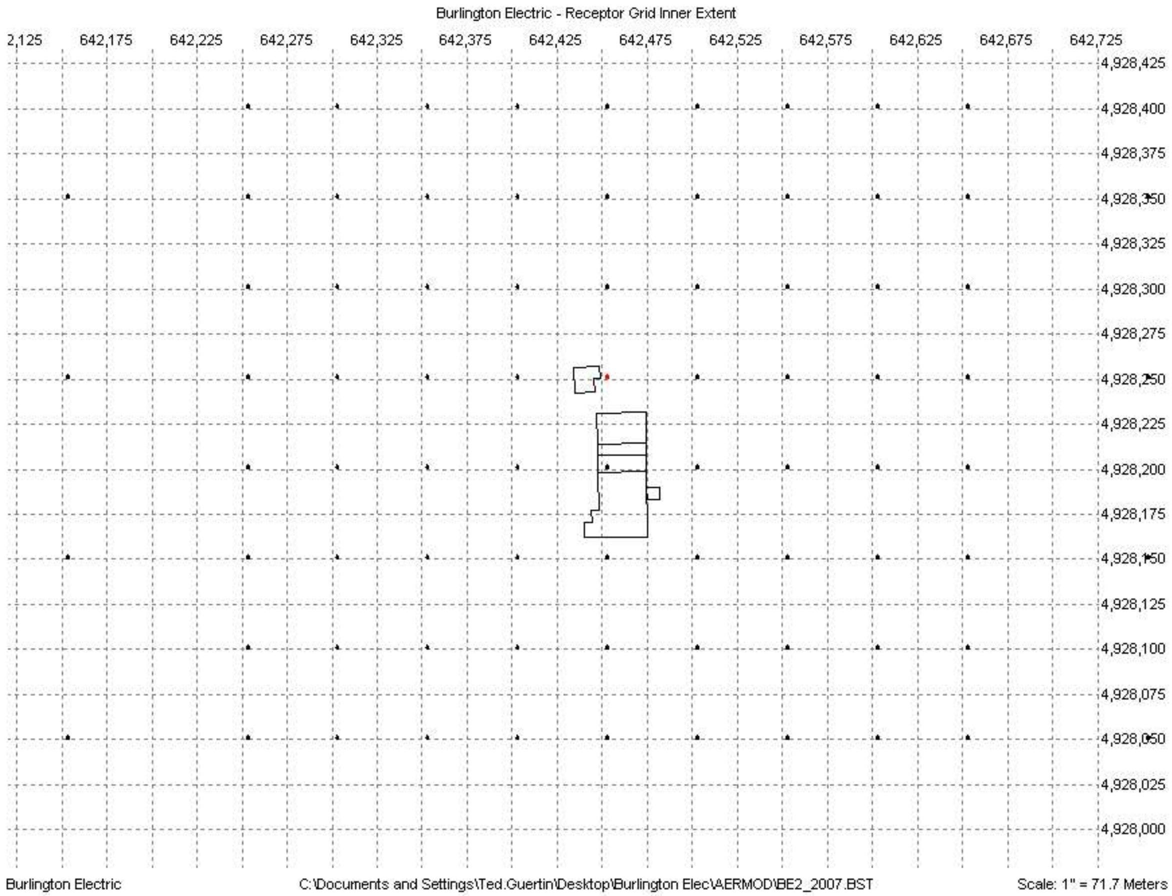
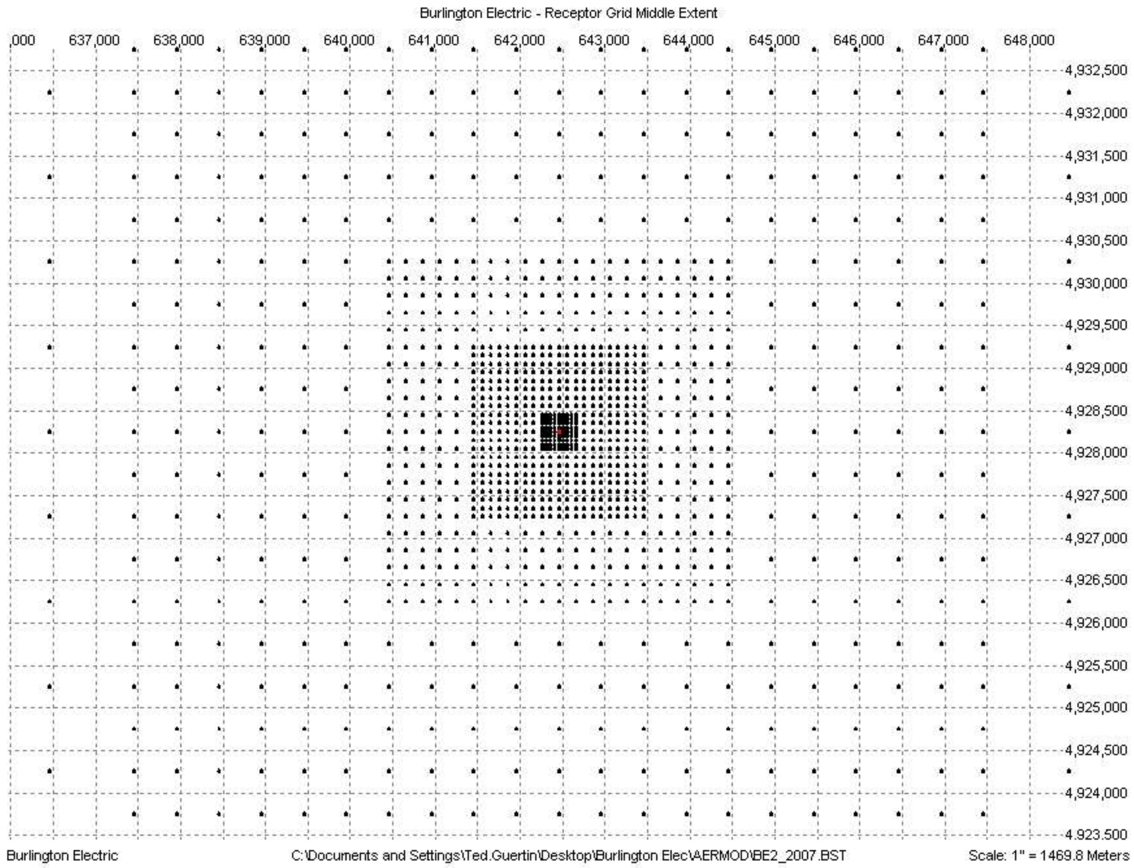

ATTACHMENT C

Receptor Grid Diagrams

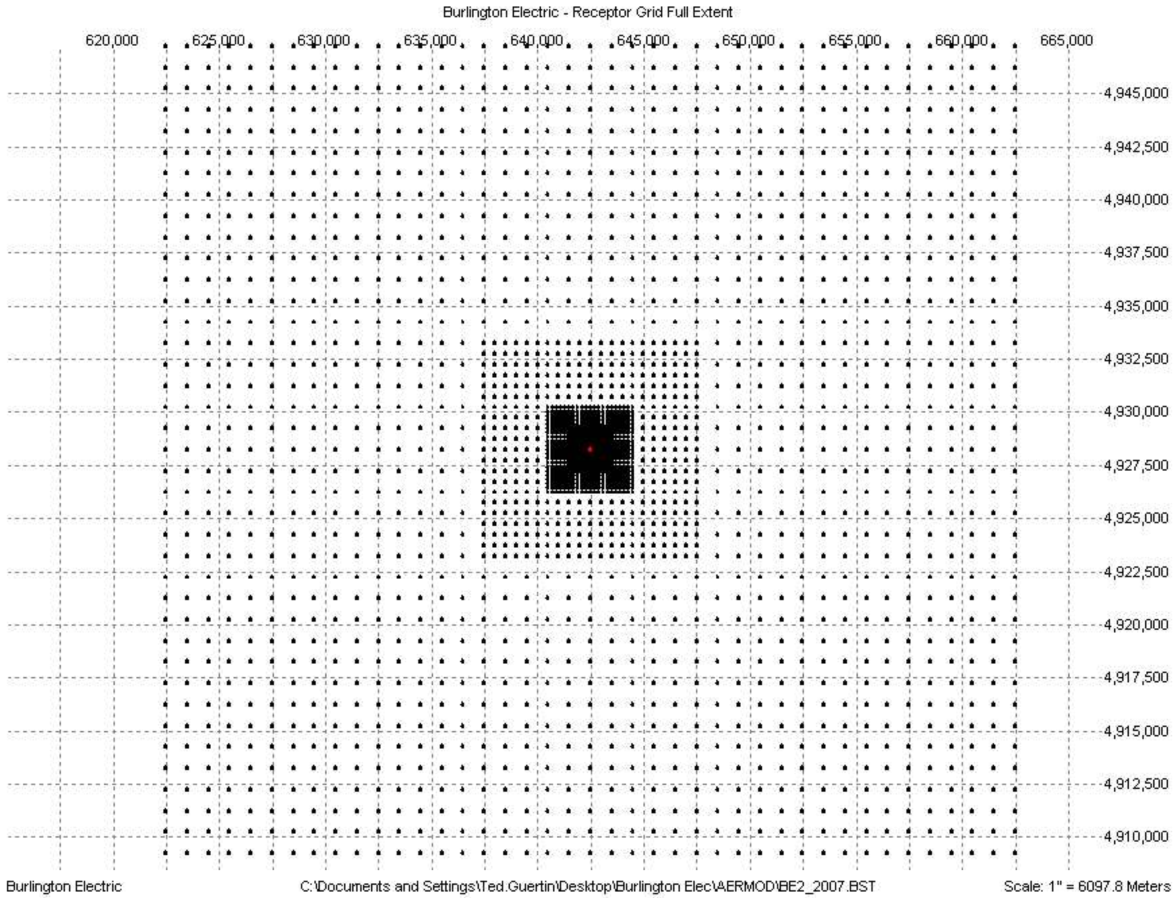
Inner Portion of AERMOD Receptor Grid



Middle of Receptor Grid



Outer Portion of Receptor Grid



ATTACHMENT D

AERMOD Detailed Results Summary

Emissions, g/s

	Wood				Natural Gas	
Case number	W-1	W-2	W-3	W-4	G-1	G-2
NOx	18.27	18.27	18.27	7.25	11.06	
PM	1.22	1.22	1.22	0.41	0.65	
CO	141.75	141.75	141.75	47.25	7.14	
SO2	1.89	1.89	1.89	0.63	0.05	
NH3	0.38	0.38	0.38	0.38		

AERMOD Results for Unit Emissions (1g/s) - 2006

		W-1	W-2	W-3	W-4	G-1
Annual	H	0.044	0.06	0.081	0.14	0.12
1-hr	H	5.02	6.48	8.68	15.24	13.76
	H2H	4.26	6.23	7.32	11.98	9.99
	H4H	3.86	5.02	7.29	10.14	9.16
	H8H	3.71	4.54	4.82	8.63	8.09
3-hr	H	2.17	2.69	3.29	5.08	4.59
	H2H	1.85	2.55	3.26	4	3.45
8-hr	H	1.11	1.61	2.24	2.49	2.35
	H2H	0.92	1.17	1.43	1.83	1..67
24-hr	H	0.44	0.56	0.75	0.93	0.8
	H2H	0.37	0.44	0.56	0.75	0.67
	H8H	0.25	0.34	0.42	0.65	0.57

AERMOD Results for Unit Emissions (1g/s) - 2007

		W-1	W-2	W-3	W-4	G-1
Annual	H	0.043	0.058	0.078	0.13	0.12
1-hr	H	5.5	6.99	8.92	14.8	12.27
	H2H	4.64	5.89	7.85	12.82	12.26
	H4H	3.75	5.73	7.37	9.59	9.13
	H8H	3.51	4.64	6.16	7.51	7.51
3-hr	H	2.72	3.38	3.68	5.27	4.44
	H2H	2.16	2.87	3.09	4.46	4.1
8-hr	H	1.37	1.53	1.96	2.42	2.21
	H2H	1.08	1.33	1.9	2.1	2.12
24-hr	H	0.53	0.68	0.78	1.02	0.91
	H2H	0.45	0.55	0.64	0.81	0.74
	H8H	0.27	0.34	0.46	0.62	0.54

AERMOD Results for Unit Emissions (1g/s) - 2008

		W-1	W-2	W-3	W-4	G-1
Annual	H	0.047	0.063	0.085	0.14	0.13
1-hr	H	5.1	6.97	9.74	10.91	11.06
	H2H	4.93	6.71	8.06	10.23	8.65
	H4H	3.88	5.05	7.28	8.75	7.9
	H8H	3.72	4.81	6.02	7.99	6.94
3-hr	H	2.48	2.77	3.35	4.38	3.93
	H2H	2.32	2.75	3.08	3.56	3.31
8-hr	H	1.62	1.96	2.08	2.6	2.43
	H2H	1.29	1.44	1.52	2.23	2.05
24-hr	H	0.72	0.91	0.94	1.13	1.16
	H2H	0.55	0.71	0.79	0.98	0.92
	H8H	0.3	0.36	0.41	0.62	0.54

AERMOD Results for Unit Emissions (1g/s) - 2009

		W-1	W-2	W-3	W-4	G-1
Annual	H	0.044	0.06	0.081	0.14	0.12
1-hr	H	6.05	7.83	9.13	11.57	9.98
	H2H	4.08	5.29	6.13	10.36	9.21
	H4H	3.91	4.98	5.75	9.69	7.98
	H8H	3.61	4.89	5.38	7.41	6.73
3-hr	H	2.56	3.29	4.18	5.09	4.6
	H2H	2.42	3.28	3.41	4.67	4.24
8-hr	H	1.58	2.12	2.36	3.31	3.03
	H2H	1.31	1.62	1.77	2.38	2.16
24-hr	H	0.6	0.71	0.9	1.45	1.34
	H2H	0.49	0.56	0.71	0.91	0.79
	H8H	0.36	0.45	0.47	0.65	0.57

AERMOD Results for Unit Emissions (1g/s) - 2010

		W-1	W-2	W-3	W-4	G-1
Annual	H	0.044	0.057	0.074	0.12	0.11
1-hr	H	5.52	7.8	8.91	13.42	11.53
	H2H	4.65	6.62	7.18	12.9	10.14
	H4H	4.52	5.51	6.14	10.93	8.48
	H8H	3.63	4.94	5.29	7.85	7.38
3-hr	H	2.93	3.26	3.92	5.29	4.76
	H2H	2.26	2.61	3.07	4.48	3.84
8-hr	H	1.72	2.27	2.21	2.94	2.92
	H2H	1.41	1.68	1.84	2.32	2.16
24-hr	H	0.63	0.8	0.75	1.01	0.98
	H2H	0.58	0.76	0.74	0.97	0.96
	H8H	0.28	0.38	0.42	0.68	0.58

AERMOD Results for Unit Emissions (1g/s) - Max 2006-2010

		W-1	W-2	W-3	W-4	G-1
Annual	H	0.047	0.063	0.085	0.14	0.13
1-hr	H	6.05	7.83	9.74	15.24	13.76
	H2H	4.93	6.71	8.06	12.9	12.26
	H4H	4.52	5.73	7.37	10.93	9.16
5-yr avg	H4H	3.87	5.15	6.61	9.55	8.53
	H8H	3.72	4.94	6.16	8.63	8.09
5-yr avg	H8H	3.64	4.71	5.14	7.88	7.28
3-hr	H	2.93	3.38	4.18	5.29	4.76
	H2H	2.42	3.28	3.41	4.67	4.24
8-hr	H	1.72	2.27	2.36	3.31	3.03
	H2H	1.41	1.68	1.9	2.38	2.16
24-hr	H	0.72	0.91	0.94	1.45	1.34
5-yr avg	H	0.55	0.71	0.74	0.98	0.89
	H2H	0.58	0.76	0.79	0.98	0.96
	H8H	0.36	0.45	0.47	0.68	0.58

Scaled Pollutant Impacts, ug/m3

Pollutant	Averaging Period	Rank	100% Wood 330°F W-1	100% Wood 230°F W-2	100% Wood 160°F W-3	33% Wood 140°F W-4	100% Gas 140°F G-1	Max	Ambient	Total	NAAQS
NO2 *	Annual	H	0.69	0.92	1.24	0.81	1.15	1.24	17.5	18.7	100
	1-hr	H8H	54.36	72.19	90.02	50.02	71.56	90.02	77.1	167.1	188
5-yr avg	1-hr	H8H	53.19	68.83	75.11	45.67	64.39	75.11	77.1	152.2	188
SO2	Annual		0.09	0.12	0.16	0.09	0.01	0.16	7.6	7.8	80
	1-hr	H	11.43	14.80	18.41	9.60	0.70	18.41	70.7	89.1	196
	3-hr	H2H	4.57	6.20	6.44	2.94	0.22	6.44	73.3	79.7	1300
	24-hr	H2H	1.10	1.44	1.49	0.62	0.05	1.49	44.5	46.0	365
5-yr avg	1-hr	H4H	7.32	9.74	12.49	6.02	0.44	12.49	70.7	83.2	196
PM2.5	Annual	H	0.06	0.08	0.10	0.06	0.08	0.10	7.3	7.4	15
	24-hr	H	0.88	1.11	1.15	0.59	0.87	1.15	21.6	22.7	35
5-yr avg	24-hr	H	0.67	0.86	0.90	0.40	0.58	0.90	21.6	22.5	35
CO	1-hr	H2H	698.83	951.14	1142.51	609.53	87.59	1142.51	3092	4234.5	40000
	8-hr	H2H	199.87	238.14	269.33	112.46	15.43	269.33	1603	1872.3	10000

* Note that NO2 impact concentrations include a 80% NOx to NO2 conversion factor

Scaled Ammonia (NH3) Impacts, ug/m3

Pollutant	Averaging Period	Rank	100% Wood 330°F W-1	100% Wood 230°F W-2	100% Wood 160°F W-3	33% Wood 140°F W-4	100% Gas 140°F G-1	Max	HAAS *
NH3	Annual	H	0.02	0.02	0.03	0.05	0.00	0.05	100

* Hazardous Ambient Air Standards

Appendix H

Preliminary Findings Presentation

BURDES

Community Energy System Feasibility Study

Interim Progress Report

EVER-GREEN ENERGY™

December 6, 2013

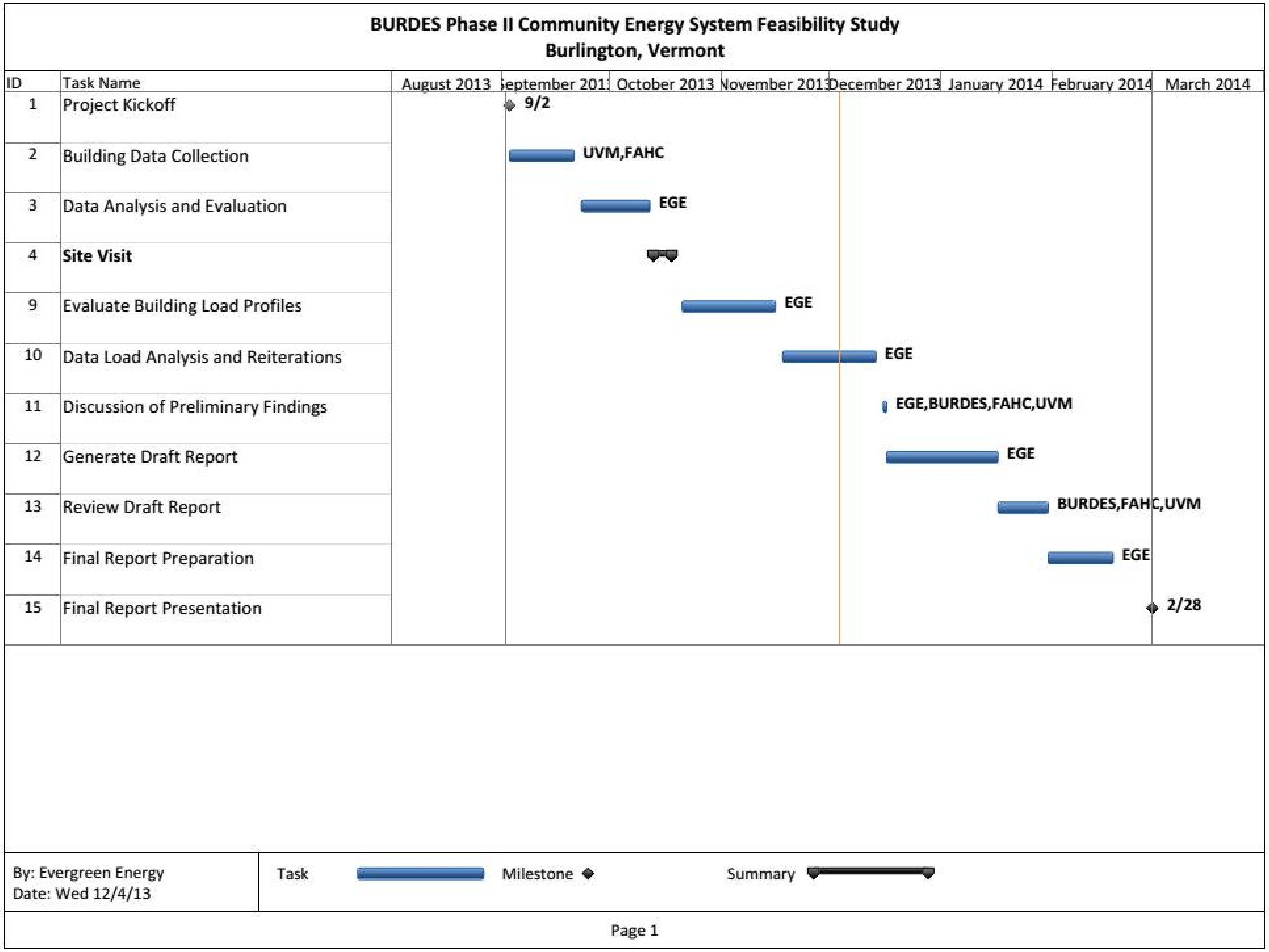
Meeting Agenda

- Introductions
- Study Mission Review
- Study Schedule
- Consumption
- Fuels
- Production
- Review of Options
- Next Steps
- Questions and Answers

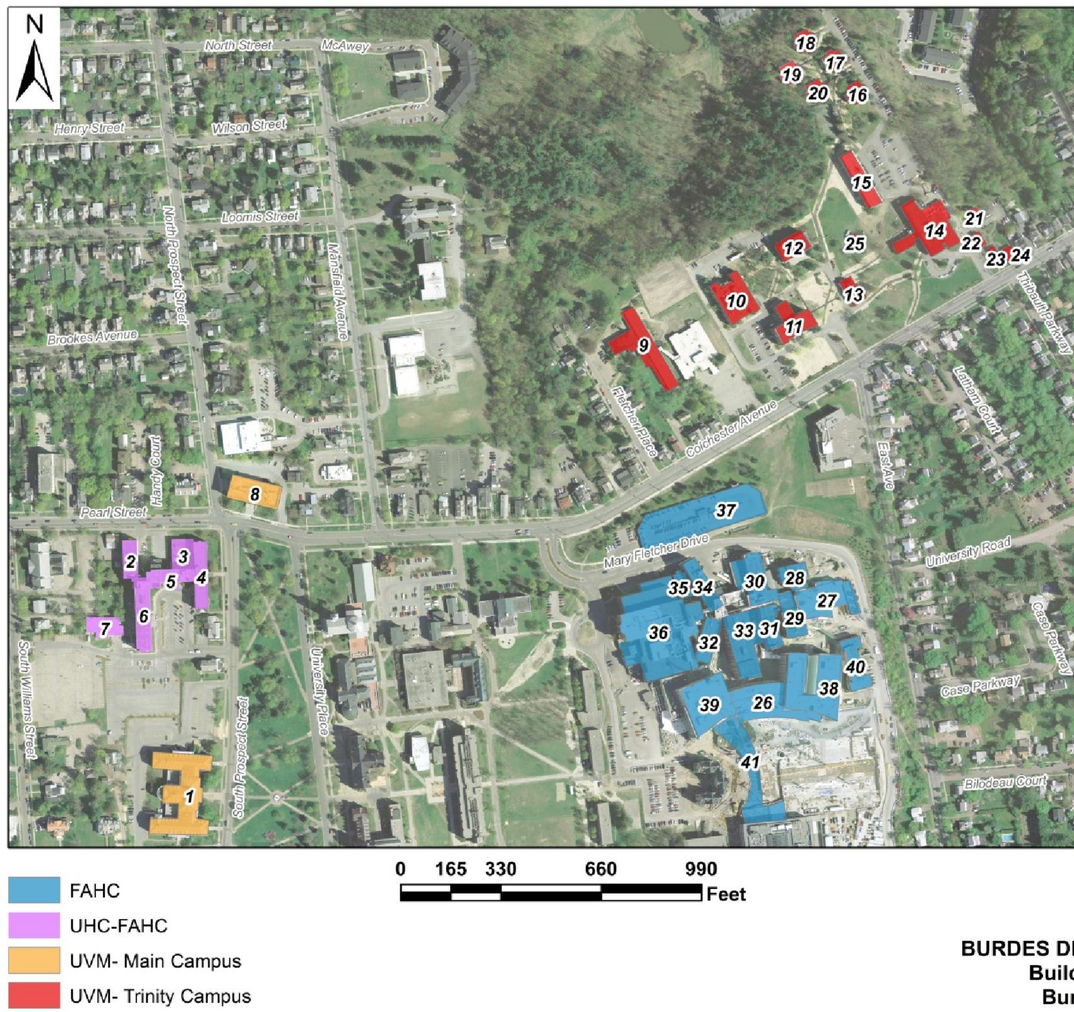
Burlington Study Mission

- Develop a community energy plan that is implementable. Identify what distinguishes this plan from other past studies
- Develop a plan that provides customers with stable, competitive energy rates
- To the greatest extent possible, utilize local, renewable energy sources to support the development of energy independence
- Reduce the carbon footprint for the Burlington community - when it makes sense, go carbon free
- Improve the overall efficiency of the community
- Develop a system that reliably meets the needs of the community and that can adapt to changing energy supply
- Establish an initial customer base that makes implementation of a community energy system feasible
- Provide guidance for system financing and development

Study Schedule



Consumption- Study Buildings



Bldg_ID	Building Name
0	McNeill Station
1	Waterman
2	Rehabilitation
3	Clinic
4	Old Hall
5	St Joeseph's Pavillio
6	Arnold Pavillion
7	Boiler House
8	Dewey Hall
9	Ira Allen
10	Delhanty
11	Mann Hall
12	Farrell Hall
13	The Villa
14	McAuley Hall
15	Mercy Hall
16	McCann Hall
17	Hunt Hall
18	Ready Hall
19	Sichel Hall
20	Richardson Hall
21	Cottage 1
22	Cottage 2
23	Cottage 3
24	Cottage 4
25	Boiler Plant
26	Main Pavilion
27	Central Plant
28	Fletcher
29	Engineering
30	Shepard North
31	Shepard South
32	Smith
33	Baird
34	Patrick
35	Mod B
36	McClure
37	Parking Garage
38	East Pavilion
39	West Pavilion
40	Garden Pavilion
41	Education Center

BURDES DISTRICT ENERGY STUDY
Building Location Plan
Burlington, Vermont

Consumption - Loads

❖ Existing Steam System Loads

- Peak Load - 100 MMBtu/hr
- Peak Load less non-convertible loads- 73 MMBtu/hr
- Annual Demand - 240,000 MMBtu/yr
- Annual Demand less non-convertible loads- 176,000 MMBtu/yr

❖ Non Convertible Loads

- Loads are located primarily at Fletcher Allen
- Sterilizers- 15,000 MMBtu/yr
- Humidification- 11,500 MMBtu/yr
- Kitchen equipment- minimal
- Non Convertible loads estimated based on information provided by FAHC and ASHRAE standard loads

Natural Gas and Biomass

5-Year Historic Prices

	McNeil Station Biomass ($/Ton)	(btu/ton)	($/mmbtu)	Vermont EIA Large User Natural Gas ($/mmbtu)
2008	$36.48	10,448,000	$ 3.49	$ 9.60
2009	$38.51	10,292,000	$ 3.74	$ 7.93
2010	$32.27	11,552,000	$ 2.79	$ 6.57
2011	$33.24	10,036,000	$ 3.31	$ 6.09
2012	$34.98	10,454,000	$ 3.35	$ 4.89
2013	$37.00	10,556,000	$ 3.51	$ 4.61

(1) EIA Vermont Pricing, Industrial User. Source:
http://www.eia.gov/dnav/ng/ng_pri_sum_dcu_svt_a.htm
(2) Source : Data from McNeil Plant. 2013 btu/ton value based on average or previous 5 years.

- ❖ Biomass prices are relatively stable over long term
- ❖ Natural gas prices fluctuate significantly over time.

Natural Gas Rates

	Normalized Annual Consumption (mmbtu(2))	Vermont Gas Rate Schedule	2013 Average Rate ($/mmbtu)	5 yr Average (2008-2012) ($/mmbtu)
Fletcher Allen Hospital	255,548	Interuptible	$ 4.7384	$ 7.3445
UHC	16,362	Interuptible	$ 7.0089	$ 9.1412
UVM Waterman and Dewey	26,362	Interuptible	$ 4.5505	$ 4.7647
Trinity (1)	21,006	Int., G1-G4, and R	$ 6.5737	$ 7.3287

(1) Aggregate rate for all meters based on volume consumed

(2) HHV= 1,013 btu/scf

(3) Prices as low as $3.85/mmbtu were noted in 2013.

- Interruptible customers are charged on a different rate schedule from posted rates, which represents a significant discount to the firm rates
- Interruptible rate is negotiated specifically for each customer based on their usage

Production-Installed Capacity

- McNeil- Biomass, 90 MMBtu/hr Extraction Steam from Port 4 available
- FAHC- Natural Gas, 74 MMBtu/hr
- UHC- Natural Gas, 20 MMBtu/hr
- Trinity- Natural Gas, 6.1 MMBtu/hr

- Existing production predominately steam
- Existing production is predominately natural gas fired interruptible service
- Excess boiler capacity exists at UHC and Trinity
- UHC main boiler near end of service life and second boiler is oversized.

Building Conversions

- Most of the buildings surveyed can be converted to Hot Water systems with relative ease
- Hospital presently converts steam to hot water for many end users, some coil change out required in air handling units
- Hydronic Loop around hospital to allow for phased conversion of buildings to hot water system
- Waterman appears to be convertible to hot water, however, reported issues with existing system may require major renovations to heating system
- Steam sterilizers and humidification loads are not convertible to a Hot Water system and will require alternate local thermal supply

Conversion of Loads

❖ Proposed Hot Water System Loads

- Peak Load - 68 MMBtu/hr (~7% decrease)
- Annual Demand –160,000 MMBtu/yr (~9% decrease)

❖ Hot Water System Benefits

- Efficiency gains from reduced distribution and standby losses
- Lower system operating temperature and pressure
- Medium Temperature Hot Water system operates between 190^0F and 250^0F
- Enhanced control at the buildings
- Lower energy consumption
- Ever-Green Energy's experience suggests significant efficiency gains will be realized with conversion to hot water
- Longer system life

Proposed Options

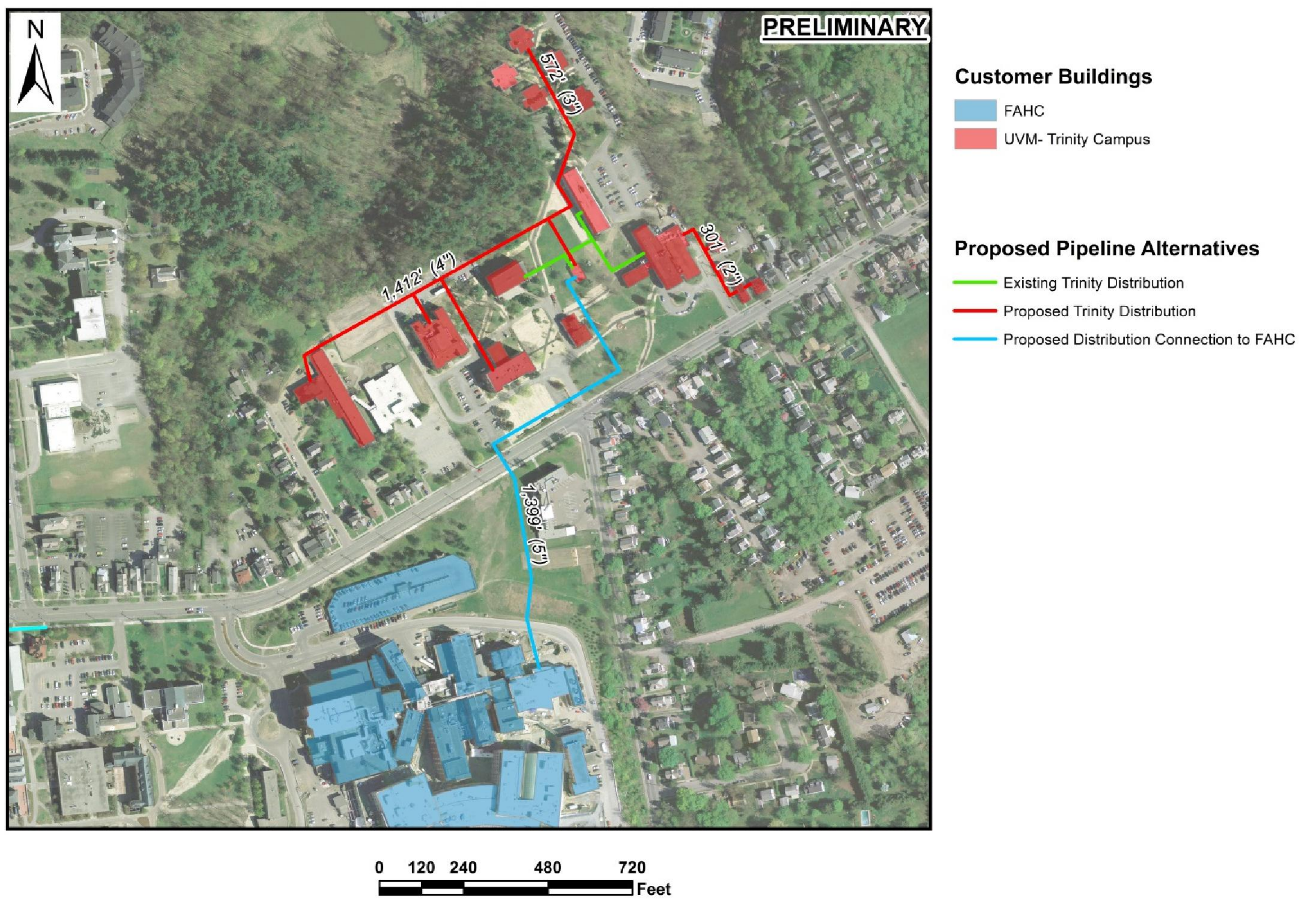
Looking for something implementable:

- Opportunity to tie Trinity and FAHC together
  - Establish an initial district energy system
- Biomass capacity is available at McNeil to power system
  - Unsure of the long-term direction of McNeil due to REC's uncertainty
- Possible biomass boiler near the FAHC/Trinity Campus
  - Current natural gas prices make this challenging

Option 1– Create Energy Islands Connect Trinity and FAHC

- Serve Trinity load with FAHC boilers
- Establish an energy island that can be the platform for a future district-wide system
- Leverage the purchasing power of a larger load to reduce energy costs for both campuses
- Utilize the Trinity boilers for peak management
- Investigate second energy island with UHC, Waterman and Dewey
- Ownership and operation strategy requires further discussion

Option 1 – Connecting Trinity and FAHC

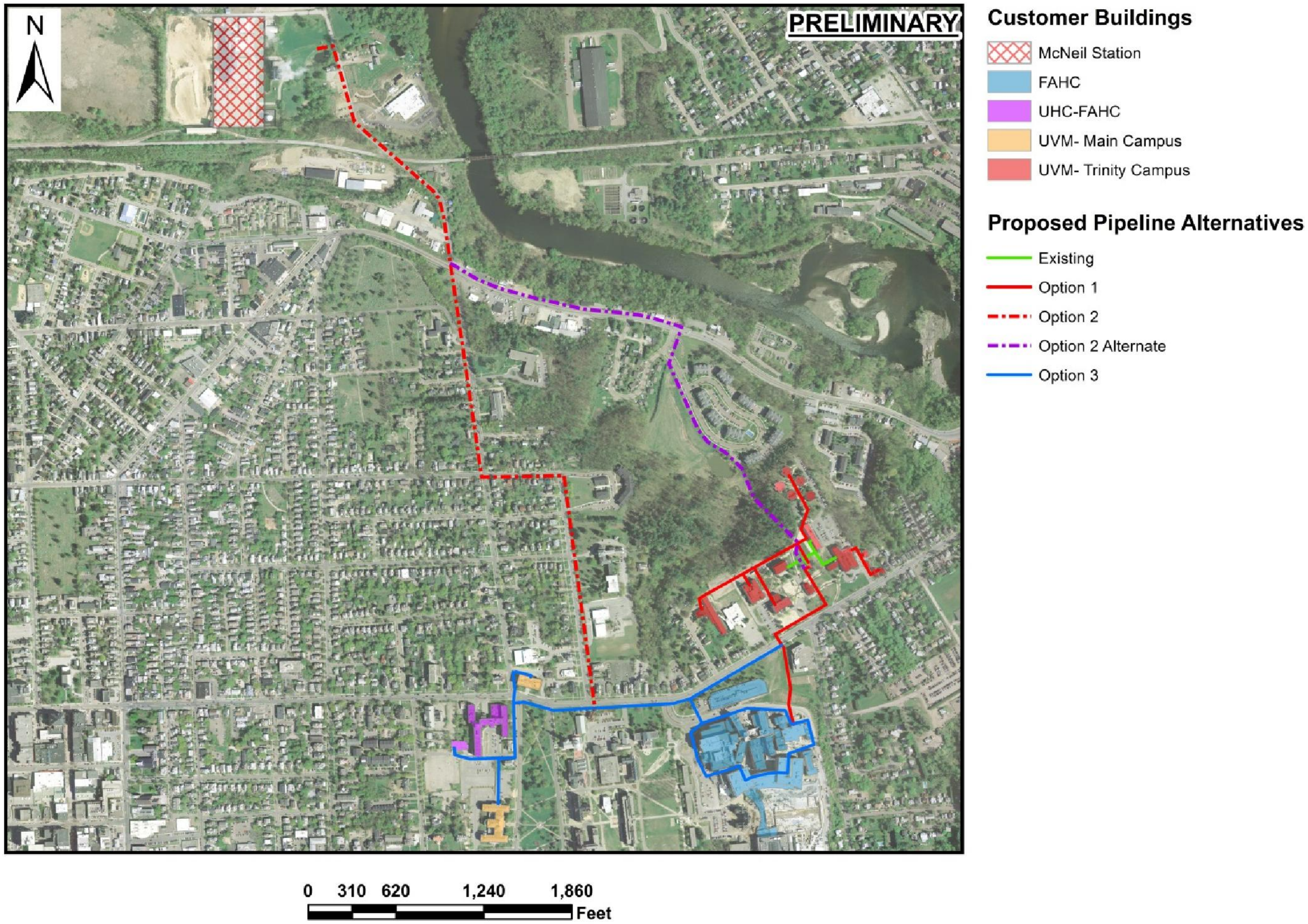


BURDES DISTRICT ENERGY STUDY
Conceptual Energy Island Layout
Burlington, Vermont

Option 2 – Connecting McNeil

- Capture thermal energy from McNeil to serve the base load for FAHC, Trinity and UHC
- Back-up/peak management from FAHC boilers
- Potentially add other buildings adjacent to the system
- Ever-Green to identify the price that natural gas needs to be at to cost justify this solution
- REC's need to be resolved and the future McNeil operating plan needs to be established

Option 2 – Connecting McNeil

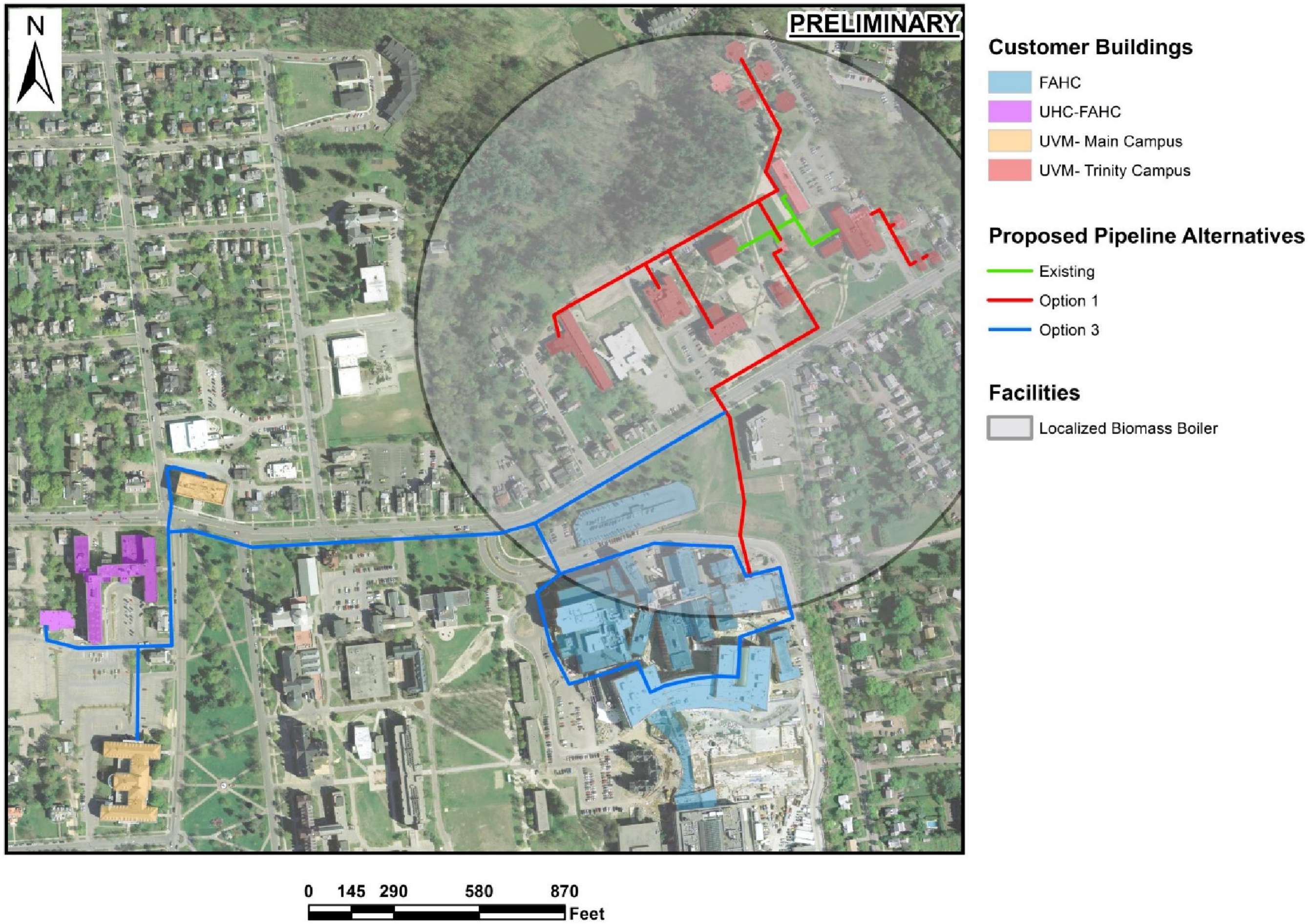


BURDES DISTRICT ENERGY STUDY
Conceptual Energy Island Layout
Burlington, Vermont

Option 3 – Localized Biomass

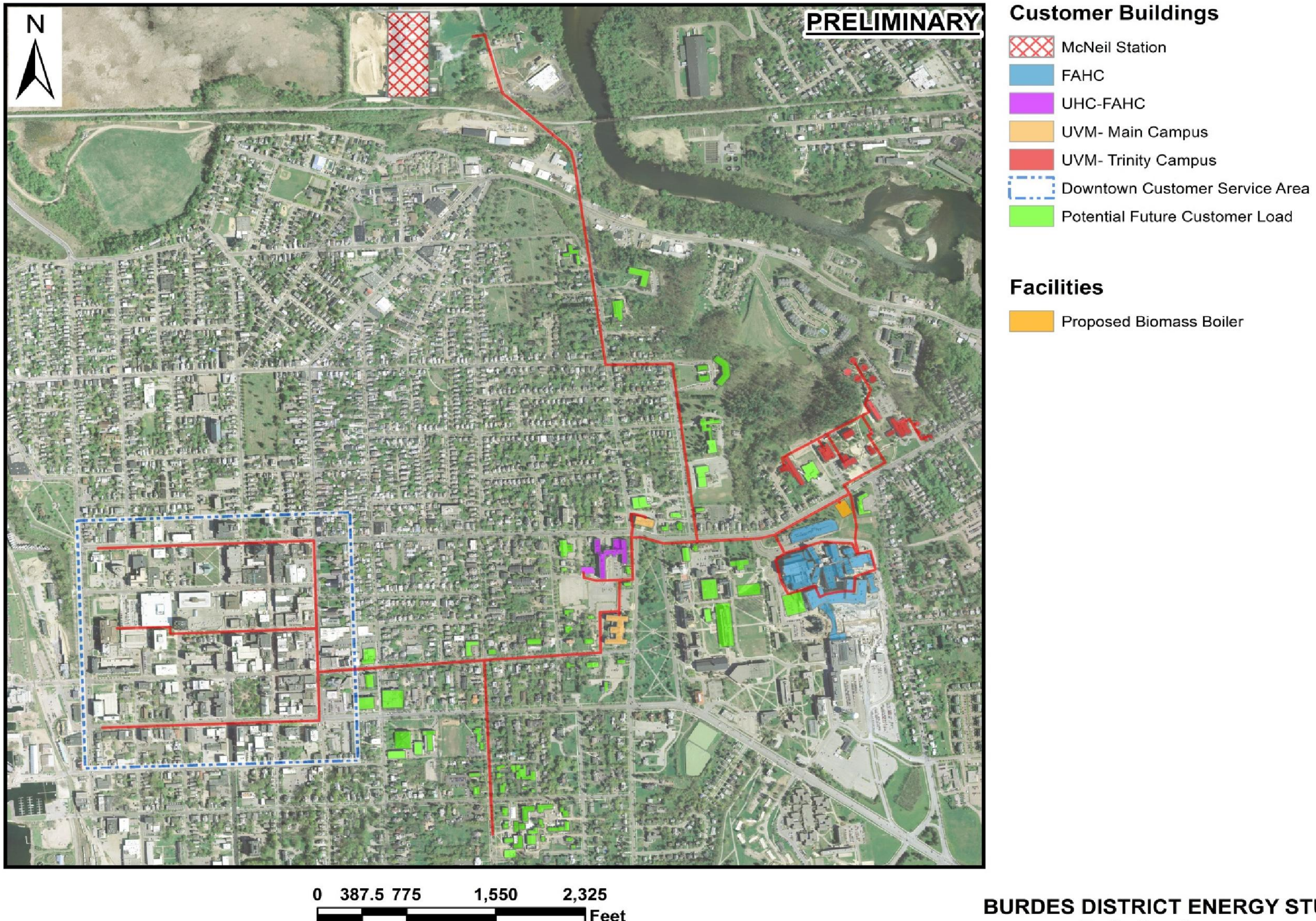
- Site a biomass-fired plant near the Trinity/FAHC campuses to serve that load with a hot water system
- Utilize a local, renewable, reliable fuel source to meet the base-load energy needs for Trinity and FAHC
- Small, thermal only, no power generation
- Limited truck traffic, less than 10 trucks per day during peak season
- New biomass boilers could be repurposed to serve base load steam needs of the UVM campus
- FAHC boilers as back-up/peak management
- Ever-Green to identify the price that natural gas needs to be at to cost justify this solution

Option 3 – Localized Biomass



BURDES DISTRICT ENERGY STUDY
Conceptual Energy Island Layout
Burlington, Vermont

Future Consideration - Downtown



BURDES DISTRICT ENERGY STUDY
Built Out System
Conceptual Energy Island Layout
Burlington, Vermont

Next Steps

- Feedback from the Burlington team
- Public Works discussion
- System structure discussion
- Finalization of phased approaches
- Cost estimates
- Economic modeling
- Draft report and review
- Report finalization and presentation

Questions?

Thank You

Appendix I

Example District Energy Proposal with Life-Cycle Cost Comparison

SAMPLE
Service Offer to

Customer XYZ

September 2013

Note:

This is a generic sample proposal for heating service from a district energy company. It is provided to enhance the understanding of district energy and to exhibit the methodology for cost calculation for DE when compared to on-site. Further educational reading on the subject of life cycle costs and analysis can be found in the following resources:

- Inside Insights, “Benefits of Economic Analysis (part 2): Real-world examples” by Steve Tredinnick, PE, Vice President of Energy Services, Syska Hennessy Group
- Summit March/April 2008, “Purchasing district energy services, A case for life cycle analysis” by Richard Damecour.

Background

In the late 1970s, Saint Paul and its building owners faced a major decision about how to secure a reliable energy source for the future. The concern was triggered by the second worldwide oil crisis. Much like today, oil and gas prices were at an all-time high. Research into alternative heating methods ensued, and a proven technology implemented in Sweden was chosen as the best way for Saint Paul to meet its heating requirements. That technology is hot water district heating. Capital was raised and agreements were put in place to build a hot water district heating system that began serving customers in 1983. The successful startup of district heating service prompted construction of a district cooling system a decade later.

District Energy was formed as a result of an extraordinary collaborative effort by public and private stakeholders including local, state and government representatives, community groups, the Saint Paul Building Owners and Managers Association (BOMA) and the University of Minnesota. This spirit of cooperation influenced the company's structure, mission and method of billing. BOMA worked with the company to set up a unique rate structure that offers significant benefits to customers. These benefits, along with the overall advantages of district heating and cooling, are highlighted throughout this proposal.

From the beginning, we have understood the importance of competitive pricing. Furthermore, we have adopted a much larger mission − environmental stewardship. A combined heat and power plant operated by an affiliate burns a renewable resource, wood residuals, resulting in significant environmental improvements and helping the community solve a local wood disposal problem. Our customers benefit from reduced costs, yet another fuel source, and the knowledge that they are using an environmentally sustainable source of "green" energy to heat and cool their buildings.

Awards & Recognition

- **2010 System of the Year Award** from the International District Energy Association
- **Inspiring Efficiency Innovation Award** from the Midwest Energy Efficiency Alliance recognizes District Energy's "Green Energy Program"
- **Environmental Initiative Award** from the Minnesota Environmental Initiative for operation of a biomass-based combined heat and power plant
- **Engineering Excellence Award** from the American Council of Engineering Companies of Minnesota for the design and construction of the 10th Street chiller plant
- **Prestigious Energy Prize** awarded to District Energy President Anders Rydaker for pioneering district cooling technology in Sweden and for his achievements in energy conservation
- **1993 System of the Year Award** from the International District Energy Association

Our Mission

Be the preferred provider of community energy services that benefit our customers, the community, and the environment.

District Energy Heating and Cooling Customers

Residential
- City Walk Condos
- Lowertown Commons
- Lowertown Lofts
- Mears Park Place
- Naomi Family Center
- Great Northern Lofts

Government
- Warren E. Burger Federal Building
- Eugene J. McCarthy Post Office
- State of Minnesota Capitol Complex

Hospitality
- Embassy Suites
- Crowne Plaza
- Saint Paul Hotel

Retail
- Macy's

Commercial Office
- Bremer Bank
- Degree of Honor
- Fifth Street Center Tower
- First National Bank
- Securian Financial Group

Health Care
- St. Joseph's Hospital
- United Hospital
- Phalen Specialty Clinic

Entertainment
- Minnesota Children's Museum
- Ordway Center
- Science Museum of Minnesota
- Xcel Energy Center

Industrial
- Ecolab
- Molex Copper Flex Products, Inc.

District Energy heats more than 190 buildings, representing 31.8 million square feet; and cools more than 100 buildings, representing more than 19 million square feet.

Summary of Benefits

There are several important decisions to make during the design of XYZ **COMPANY** project that will affect the success of the development. One of the decisions that will have a lasting impact on your financials and your tenants is who you choose to provide the energy needed to heat and cool your facility. According to data gathered by BOMA from its members, heating and cooling are generally the major expenses associated with operating a building.

Unlike many cities, you have a ***real*** choice in Saint Paul. While many building owners are facing rapidly escalating energy costs and the ever-increasing cost of HVAC equipment ownership, District Energy's customers are experiencing stable energy costs, outstanding customer service and significant financial savings. **BURDES** too can receive these benefits by using District Energy's heating and cooling services at **STUDY BUILDINGS**. By connecting the BURDES heating system, you will eliminate the need to design, install and operate on-site boilers, maintain the boiler, and avoid the associated environmental permits. You will also eliminate the noise and mechanical space required by having an on site boiler. BURDES will also cover the total service piping costs to **STUDY BUILDINGS**.

District Energy's heating system will also significantly reduce your annual operation and maintenance expenses.

Additional benefits you will receive by selecting District Energy to provide your heating and cooling services:

- **Fuel Flexibility and Rate Stability.** Our energy generating facility is designed to use several different fuel sources. Our primary fuel is clean wood residuals, a renewable energy resource, with natural gas as a back-up fuel. However, we can also use natural gas and oil to meet our customer's energy needs. The average annual overall rate increase from FY 1984 to FY 2013 for our heating customers is 2.3 percent, while inflation has averaged 2.9 percent. The average annual overall rate increase from FY 1993 to FY 2013 is 1.9 percent for our cooling customers while inflation has averaged approximately 2.5 percent during this same time period. ***By closely managing our fuel purchases, we mitigate the impact of an increasingly volatile fuel market. This results in stable rates and lower energy costs for our customers.***

"We've never had any problems with District Energy. We appreciate the reliability, customer service, and the environmental benefits of the new biomass plant. As we've watched the price of other energy sources go through the roof, we know that we made the right decision in choosing District Energy."

Kristel Hansen, The Markham Company, regarding the Hamm Building

> *"We like District Energy because we can budget a year ahead and don't need to worry about fluctuating natural gas prices. District Energy is good for the environment and has an unlimited supply of waste wood to use as fuel. We also appreciate the excellent communication and customer service."*
>
> *Ken Zahradka, St. Paul Travelers*

- **Outstanding System Reliability and 24/7/365 Customer Service.** District Energy's customers enjoy outstanding service reliability. Both our district heating and cooling services are over 99.999 percent reliable based on customer service hours. ***In addition to reliable heating and cooling services, our professional staff is available 24/7/365 to make sure services are available to your facility.***

- **Bulk Purchasing Power and Competitive Energy Rates.** District Energy aggregates the heating needs of 31 million square feet of building space in St. Paul to one central system. This provides the purchasing power needed to receive the lowest possible energy rates from fuel suppliers on behalf of our customers. As a result, our energy rates are consistently well below what our customers normally would be required to pay. ***Being a non-profit corporation, all savings are passed directly to our customers.*** The variety of fuels that can be used allows District Energy to select the economical choice.

- **Environmental Benefits.** District Energy believes that economic growth and environmental stewardship go hand in hand. By using wood waste, we have significantly reduced our use of coal with a clean, renewable energy source. Our use of this renewable energy has reduced a local wood disposal problem while keeping energy dollars in the local economy. Replacing fossil fuels with a renewable fuel has also significantly reduced particulate and greenhouse gas emissions. ***Your purchase of our services makes these benefits to our community possible.***

> *"We are a socially responsible development company and District Energy really fits with this mission, especially with its use of green energy. We chose District Energy and District Cooling for many reasons: the predictability of operating costs, energy efficiency, and the lower capital cost compared with new on-site systems."*
>
> *Colleen Carey, The Cornerstone Group, regarding Great Northern Lofts*

Summary of Service Options

The following graphs compare the initial capital cost and the annual operating costs for District Energy's heating service to an on-site heating system:

Initial Capital Cost Comparison

	On-Site Boiler Plant	District Heating
Initial Cost	**$683,000 (1)**	**$0 (2)**

Notes:

(1) Cost estimates are based upon replacement of existing boilers and complete installation costs.

(2) District Energy will extend its heating service to the building. DE will also provide the heat exchanger for the primary building heat. Mechanical room equipment, piping, pumps, etc, to be provided by the customer.

Annual Heating Operations and Maintenance Costs Comparison

Item	On-Site Boiler Plant [$]		District Heating [$]	
Labor and administration	$113,000	(1)	$4,300	
Water make-up, and treatment	$1,000		$500	
Maintenance, repairs	$4,600	(2)	$300	
Firm natural gas*	$166,000	(3)	$0	
District heating demand charges*	$0		$250,000	(4)
District heating energy charges*	$0		$42,000	(5)
Opportunity cost of capital	$48,500	(6)	$0	(7)
TOTAL ANNUAL COST	**$333,100.00**		**$297,100.00**	

** City fee and sales tax not included*

Notes:

(1) On-site operating costs include labor cost allocations during the heating season for a daily boiler check and maintenance of log data at $40/hour and management costs equal to 10% of labor costs (32 weeks, 1 hour/day, plus 20 additional hours for boiler tube cleaning). Includes operator's license and insurance. Numbers are based on ASHRAE "Owner and Operating Costs".

(2) Based upon two emergency and ten regular boiler/burner service calls; insurance; inspection fee; parts, grease, oil, after hours monitoring, and preventative maintenance (does not include replacement of major parts). Numbers are based on ASHRAE "Owner and Operating Costs".

(3) Based on 210,000 ccf (annual) of gas, for building heating only, at average gas rate of $0.78/CCF; at 75% seasonal efficiency.

(4) FY 2013 District Energy demand rate of $10.76 per kW per month at the contract demand of 1950 kW, adjusted annually after 2 years.

(5) FY 2013 District Energy's energy charge of $10.02/MWh for 4200 MWh.

(6) Based on an estimated capital costs of $683,000 for the replacement of all boilers and reconnection to existing distribution piping at an opportunity cost of capital of 5% over 25 years.

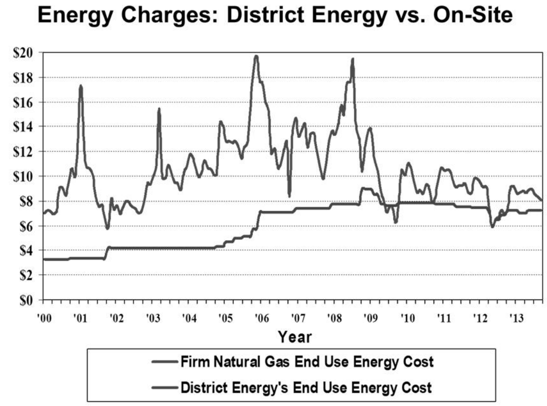
(7) The estimated capital cost for the heating system interface, valves, and related piping is $200,000 at an opportunity cost of capital of 5% over 25 years. Cost is included in CES costs and is not passed through.

This proposal expires May 31, 2014.

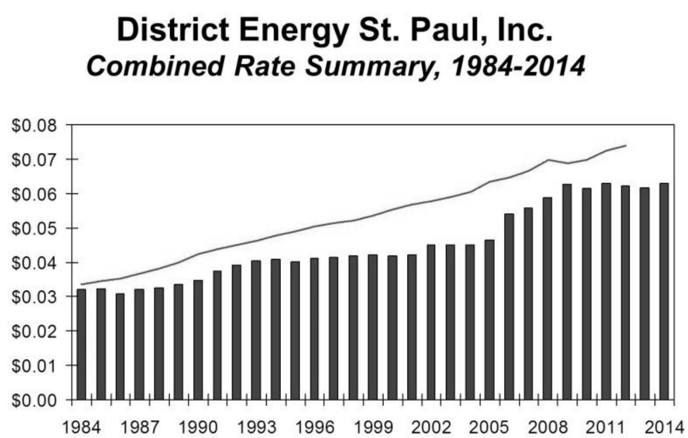
District Energy's Unique Rate Structure

District Energy's charges are made up of two parts: an energy rate and a demand rate. The energy rate, expressed in dollars per megawatt-hour (MWh), is based on our cost of fuel—there is no markup in the rate. Our large customer base and fuel flexibility allow us to pay lower fuel prices than those paid by individual building owners. We pass these savings directly on to you.

The demand rate, expressed in dollars per kilowatt (kW), covers District Energy's fixed costs for providing a service that allows customers to save money by eliminating the purchase and installation of major fixed equipment and associated maintenance, administration, operation and repair costs.



District Energy's rate increases over the years have been minimal; in fact, for the tenth consecutive year, the demand rate has remained the same. Fuel flexibility and our use of biomass renewable energy have enabled us to maintain stable rates for our customers despite unprecedented volatility in energy prices.



The Contract Demand for the **STUDY BUILDINGS** is estimated at 68 MMBtu/hr based upon anticipated fuel consumption, operations and function. The Contract Demand is adjusted yearly based upon normalized energy usage and 1,700 utilization hours.

The following compares the features of District Energy's heating services to on-site systems.

Heating Feature Comparison

Item	On-Site Boiler Plant	District Heating
Building Space	Space for boilers, pumps, and associated equipment	Minimal space required for heat exchanger and pumps
Energy Supply Options	Limited - Natural gas	Hot water generated primarily by clean wood residual, a renewable source of energy. We also use natural gas, coal and oil as back-up fuel sources depending upon economics and availability.
Heating Availability	When equipment is operational	24 hours a day, 365 days a year
On-site Combustion	Natural gas	None
Environmental Permitting Requirements	Boiler emissions	None
Operation and Maintenance Skill Level	Boiler experience a must	Minimal
Equipment Issues	Boiler installation, fixed capacity; reliability; maintenance, repair & noise	None