Burlington District Energy Study

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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

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[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.

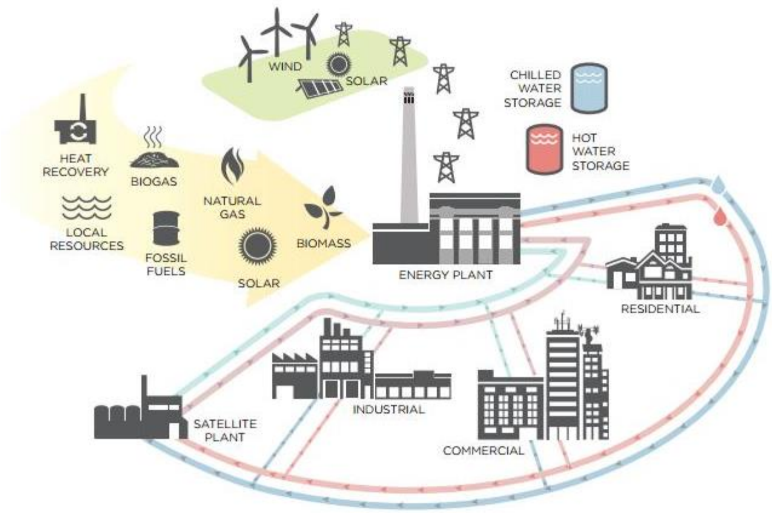


Figure 1. Integrated Energy System

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.

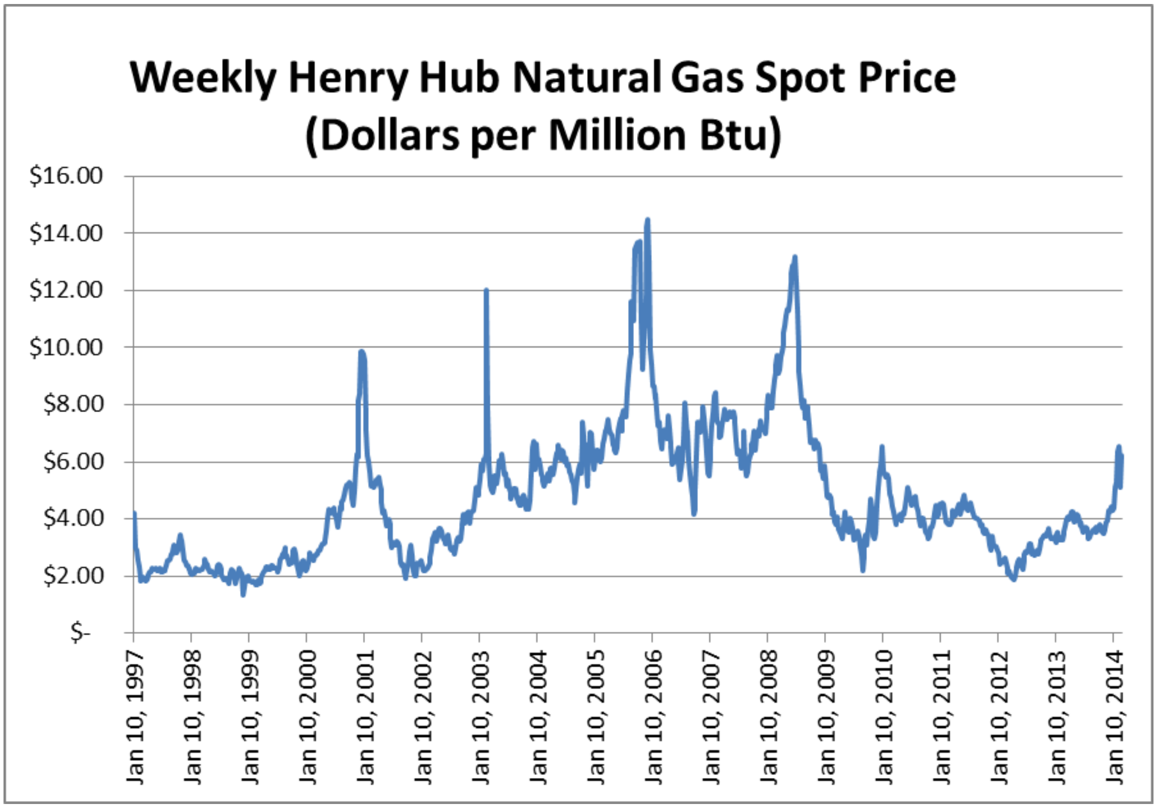


Figure 2. US natural gas spot market prices (source: EIA Henry Hub Spot Market Price)

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.

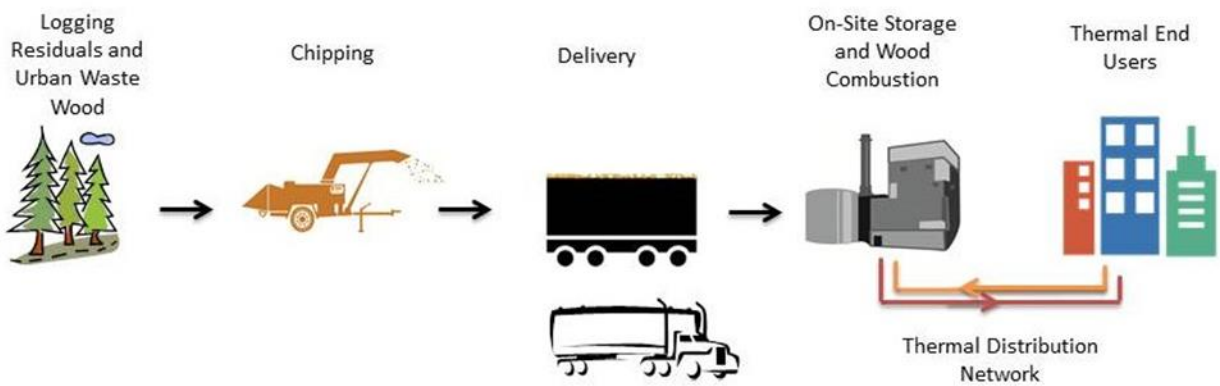


Figure 3. Typical biomass flow model

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.

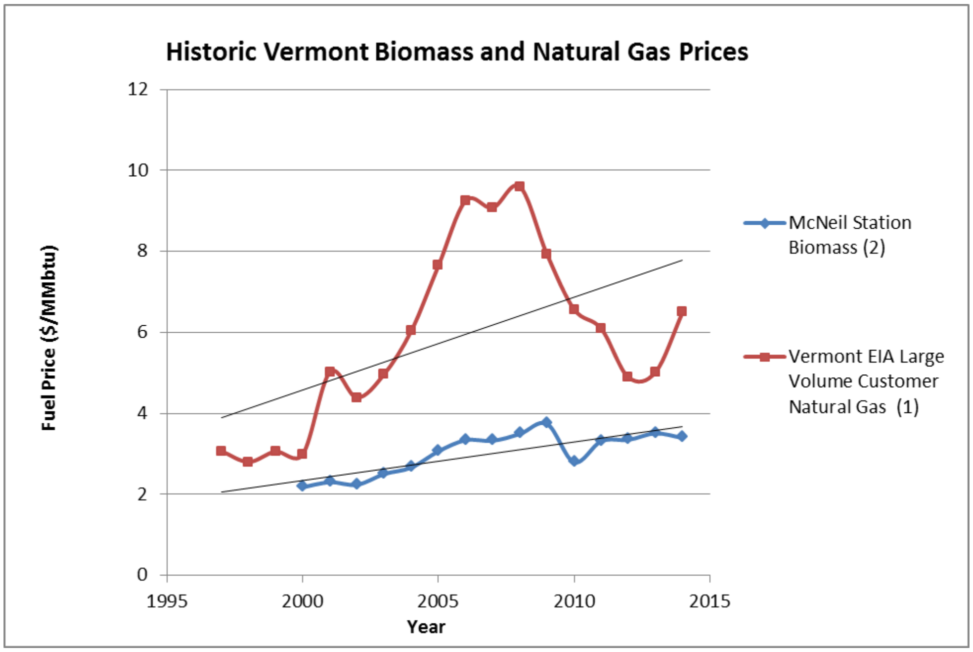


Figure 4. Historic energy rates (2014 average rate based on present natural gas futures market)

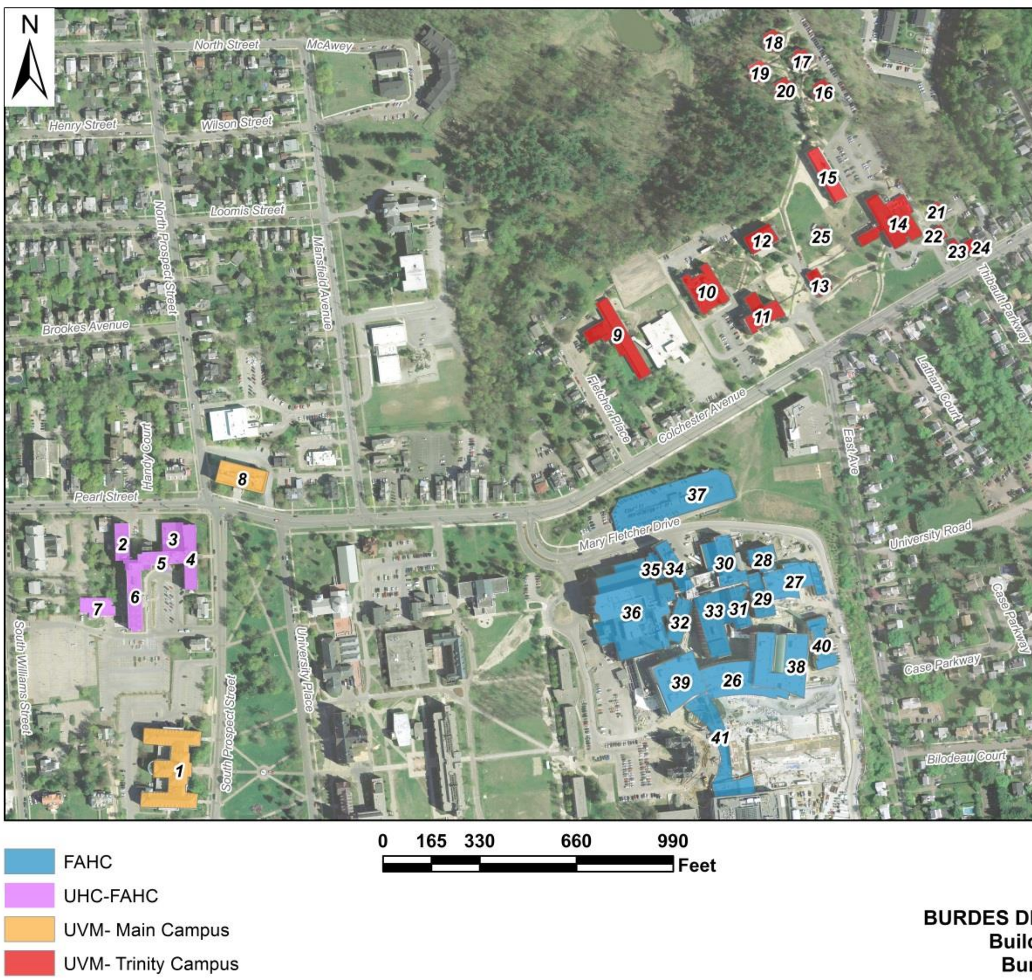
The winter of 2014 has proven to be highly volatile for natural gas prices. Cold winter weather, increased use of natural gas for power generation, and pipeline delivery constraints have increased the pricing volatility for natural gas. Interruptible customers in Vermont saw prices spike and reach as 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	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

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.

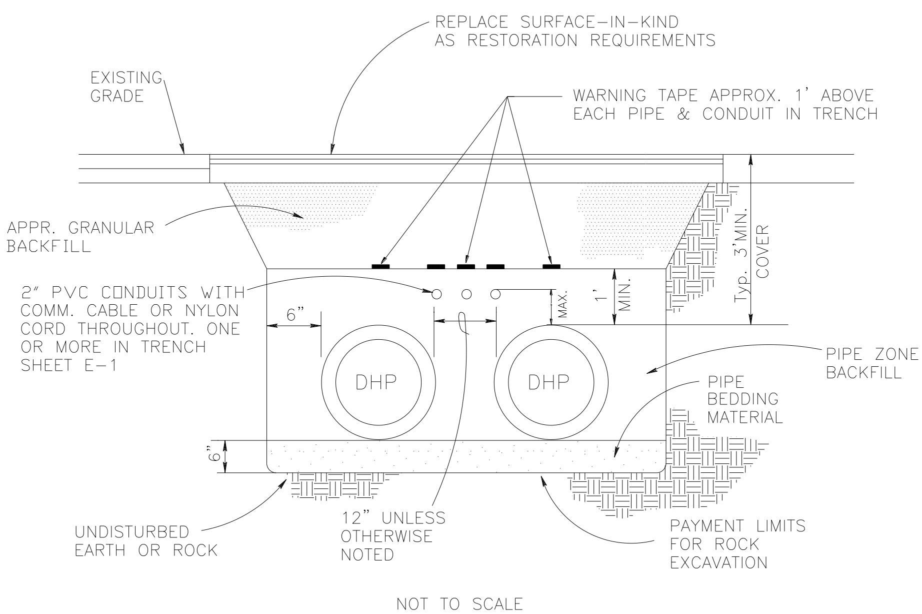


Figure 6. Typical hot water district energy system trench section

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.

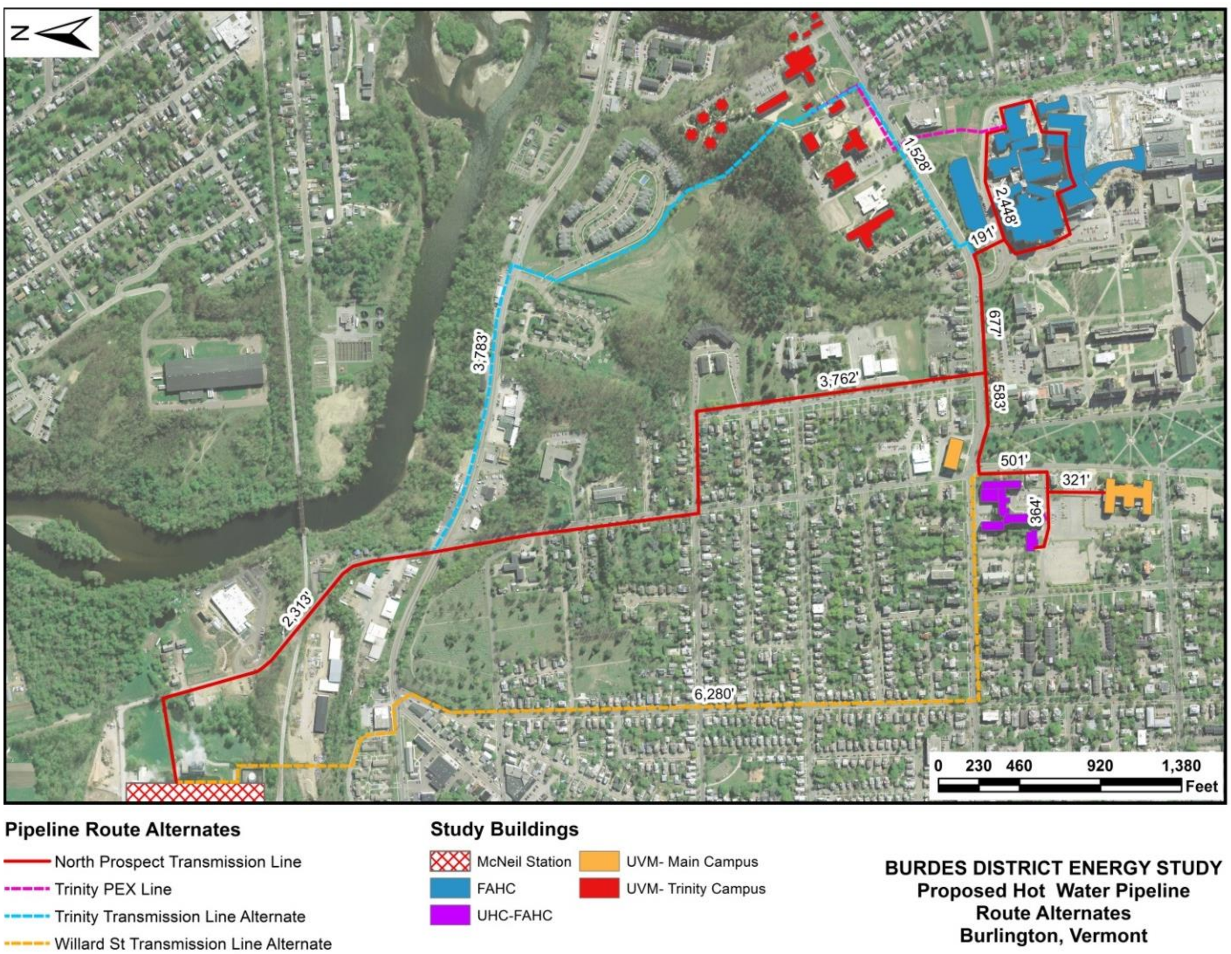


Figure 7. Hot water pipeline route alternates

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.

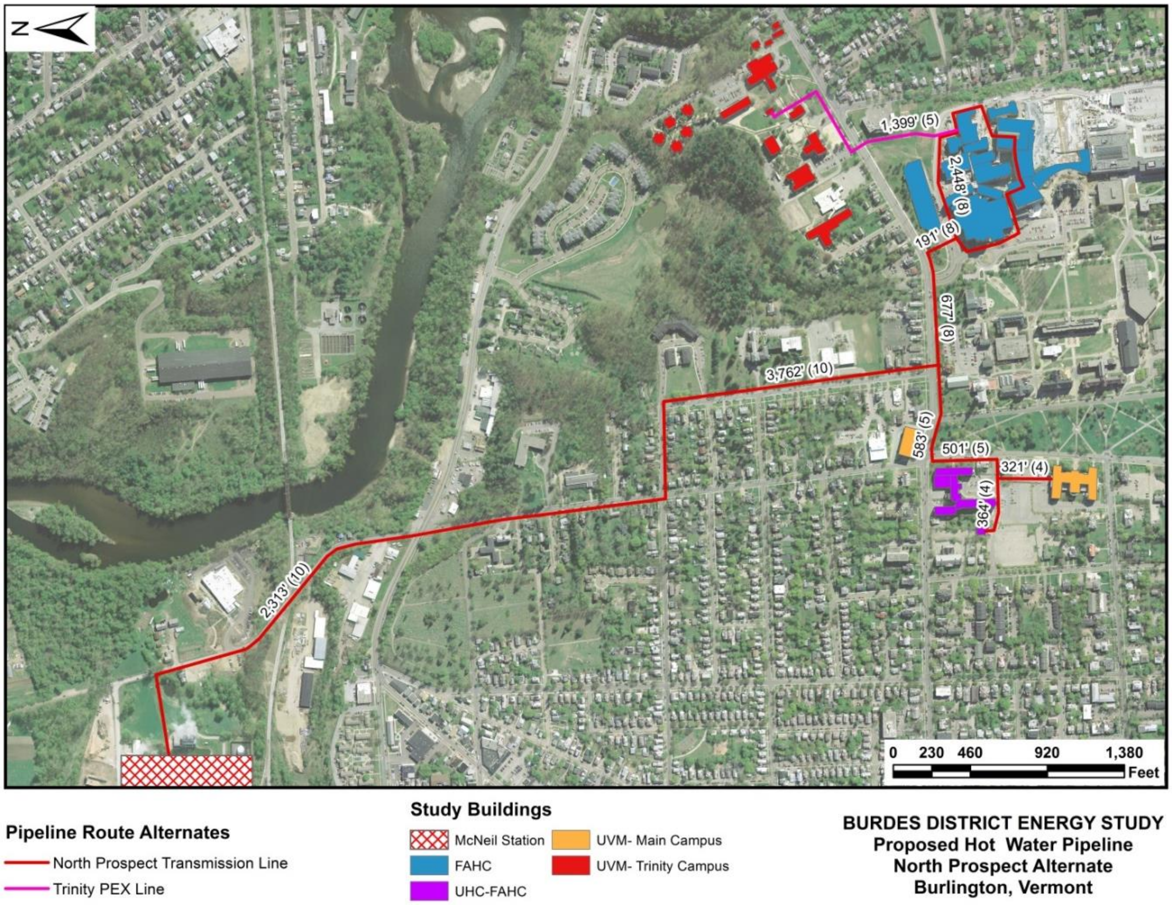


Figure 8. Least cost alignment - Prospect Street alternate

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.

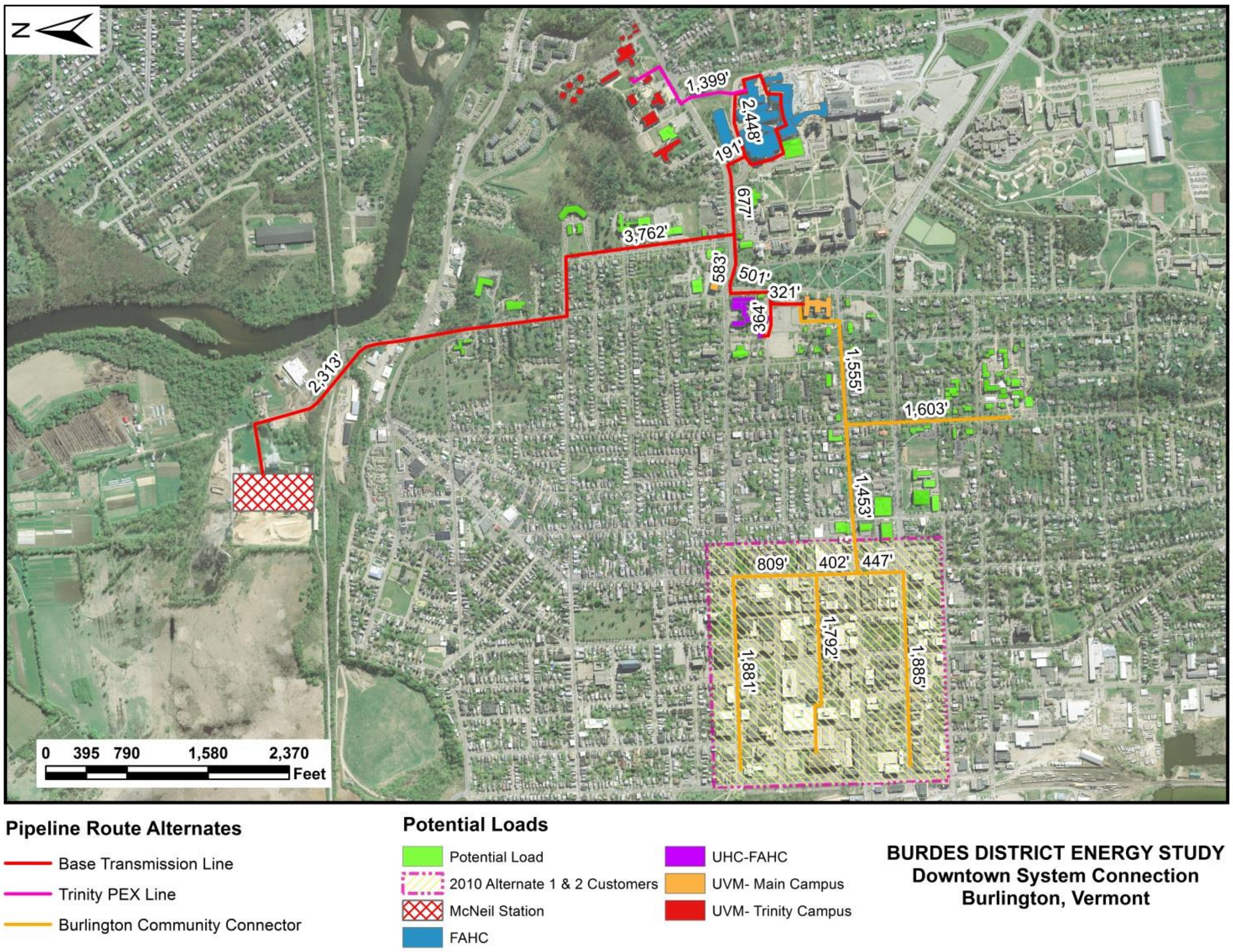


Figure 9. Downtown pipeline expansion

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°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.

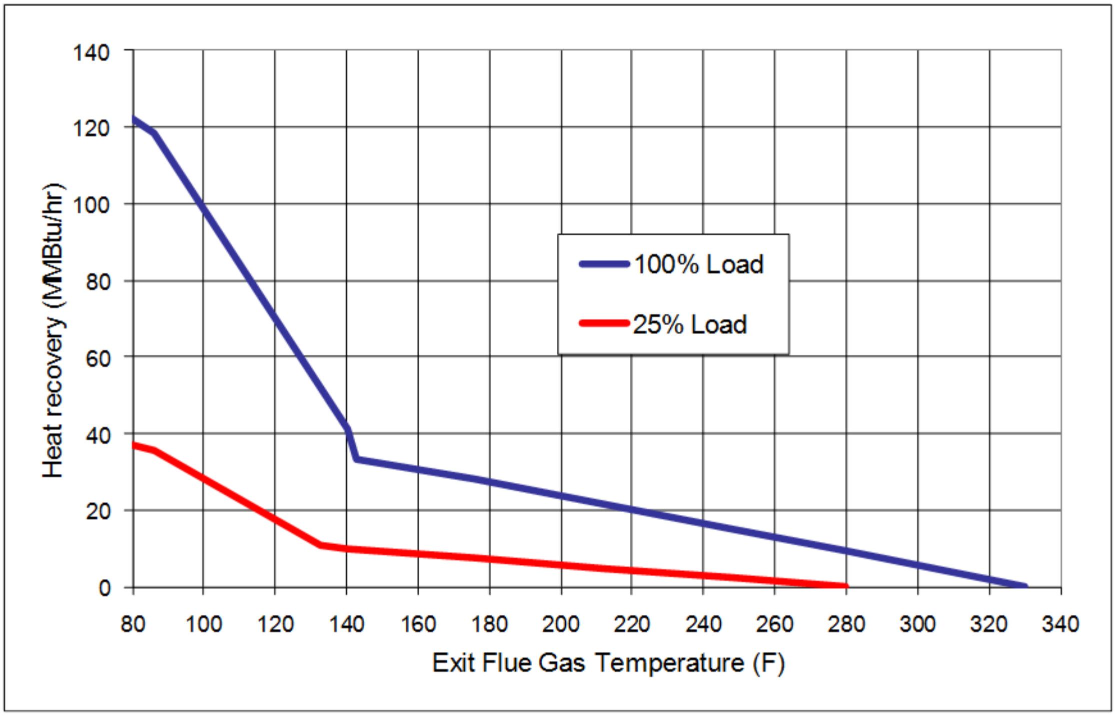


Figure 10. Flue gas heat recovery potential as a function of exiting flue gas temperature and plant load

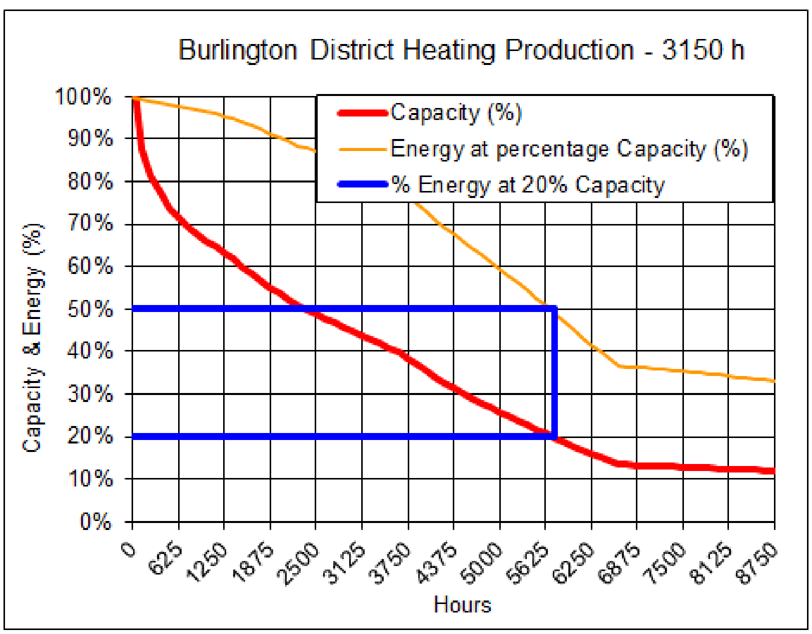


Figure 11. Burlington load duration and energy curve

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

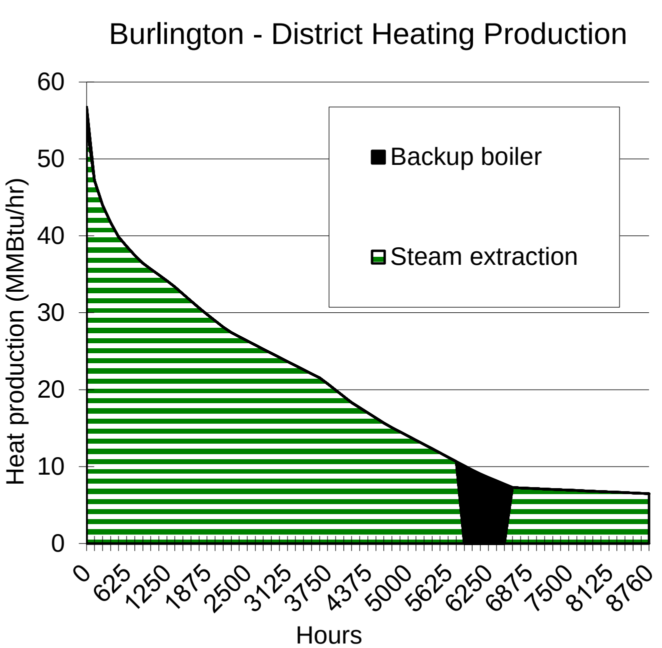


Figure 12. Option 1 load duration curve and production sources (note that the black band represents backup boiler use during spring and fall maintenance outages)

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

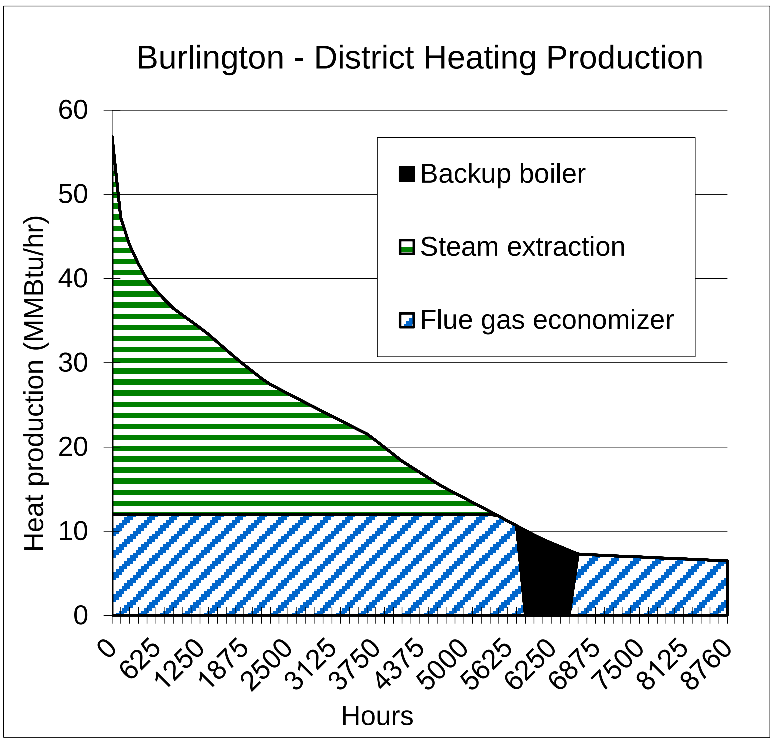


Figure 13. Option 2 load duration curve and production sources (note that the black band represents backup boiler use during spring and fall maintenance outages)

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.

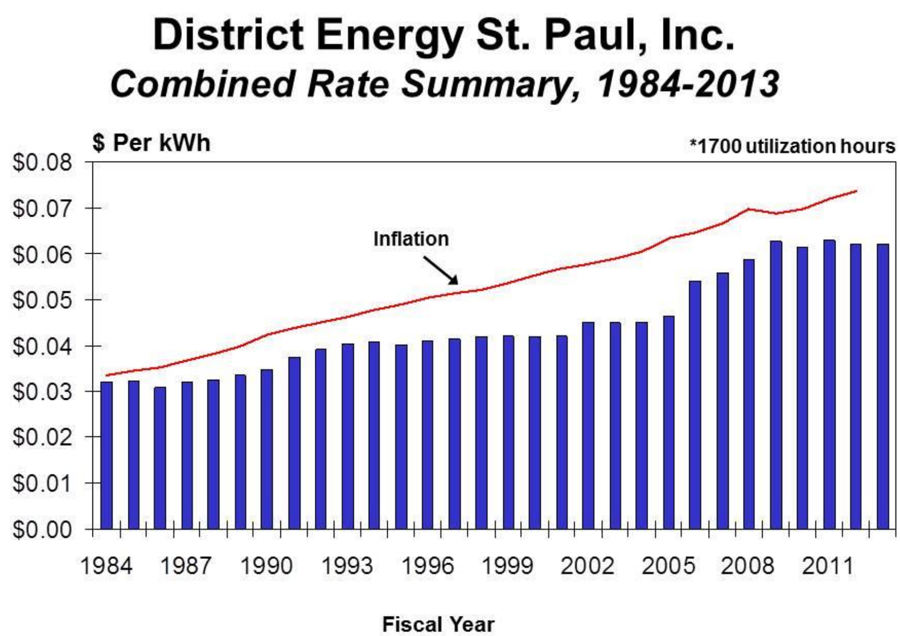


Figure 14. Historic rates for District Energy Saint Paul

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.

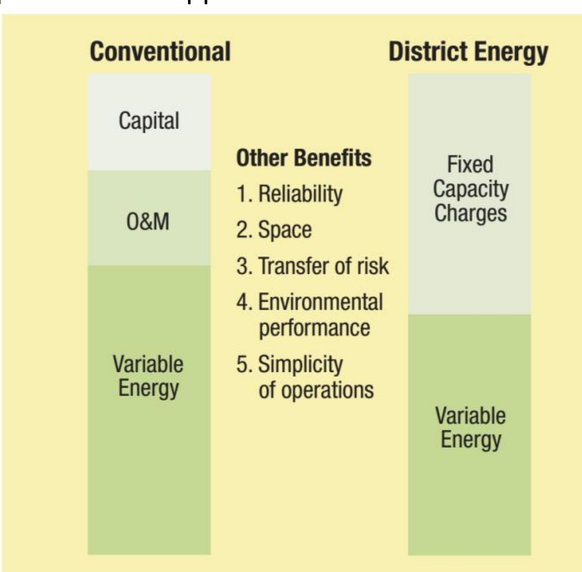


Figure 15. Comparative costs of on-Site and CES Thermal costs (Source: Summit Magazine, March 2008, Purchasing district energy services, a case for life cycle analysis, Richard Damecour)

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

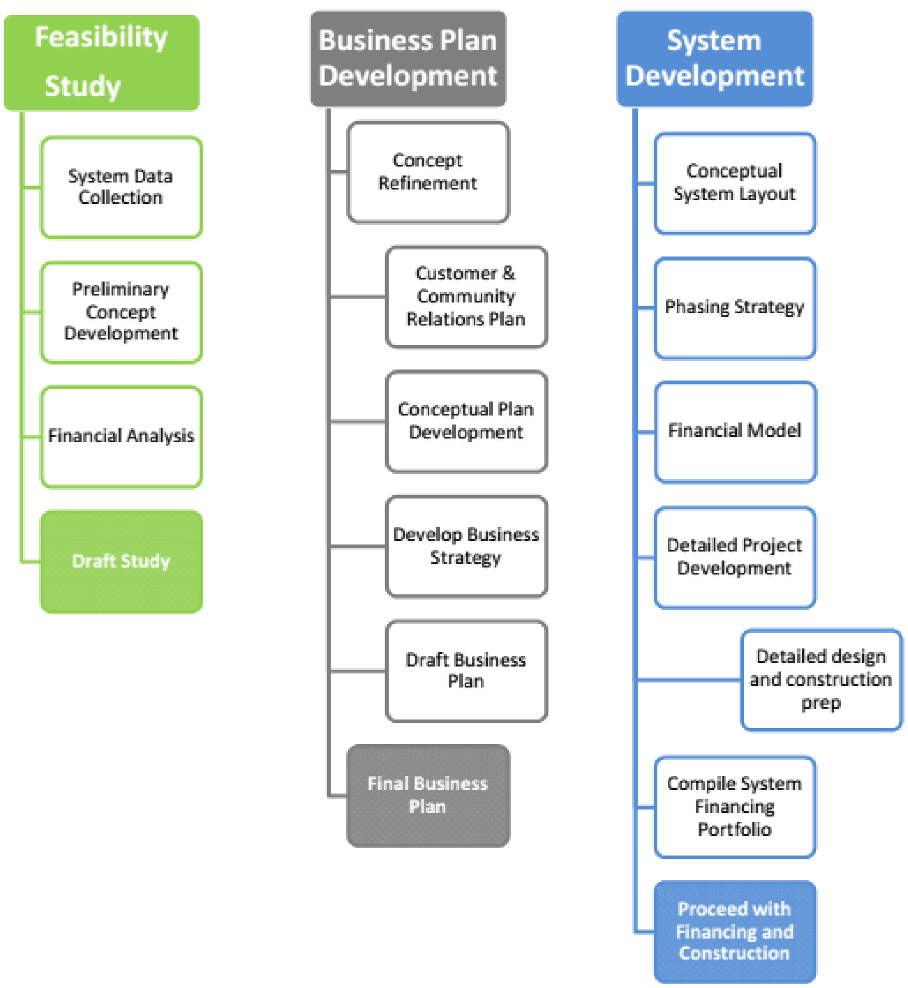
Summary

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.