DULUTH STEAM MASTER PLAN

EVER-GREEN ENERGY™

Duluth Steam
Master Plan Brief

Background

Duluth Steam was established as an affiliate of the City of Duluth in 1979 when the city purchased the Duluth Steam system to keep the system viable. This system has reliably served the downtown Duluth community for the last 81 years by meeting the energy needs of individual buildings through a community energy system. To ensure that the Duluth Steam system remains a robust, reliable, and resilient provider of energy services to its customers, the City of Duluth commissioned Ever-Green Energy (manager of the Duluth Steam system) to prepare a Five-Year Master Plan. This Master Plan is to serve as a guideline for improving Duluth Steam's methods for meeting the needs of the Duluth community with a focus on (1) the efficiency of the system, (2) enhancing environmental stewardship for Duluth Steam operations, (3) maintaining or improving cost competitiveness, and (4) identifying opportunities for growth and advancement.

The study was recently completed and a series of community forums were held to present the findings of the study. Generally, the recommendations that emerged from the study and community forums are:

- Implement hot water heating to select areas currently served by steam, and
- Add customers within the current boundaries of the system, and
- Enhance the flexibility of the fuel mix by integrating the use of locally-derived biomass

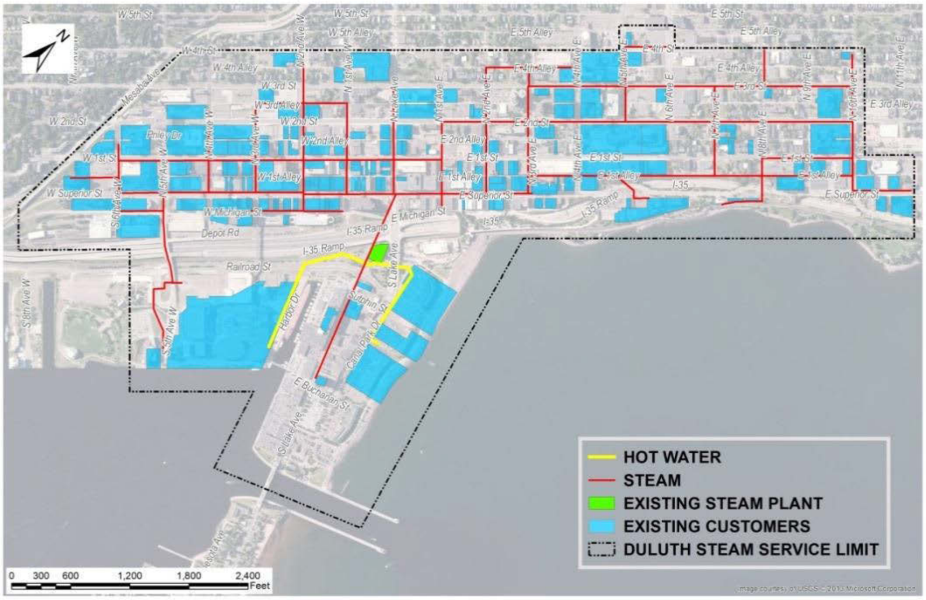
By pursuing these recommendations opportunistically (for example, as street renovation work is being implemented) the work can be completed cost-effectively and the following benefits will be realized:

- Efficiency of the system will be enhanced through reduced system trap losses and more efficient use of thermal energy in the customer buildings,
- Water use is reduced by approximately 80 million gallons per year with a commensurate reduction in water treatment at the WLSSD,
- Emissions of CO2 and sulfur dioxide are reduced by 25%,
- Fossil fuel combustion is reduced by over 25% through a combination of distribution system efficiency improvements that reduce condensate losses and use of locally-derived biomass fuel.

Current System (Outlined in Section 2.6)

Energy production for the system occurs at the Duluth Steam plant on the north end of the Canal Park district. The primary fuel source for the plant is western coal, and it is utilized to generate both high-pressure steam and hot water. The steam and hot water generated at the plant are then distributed via an underground network of pipes that run throughout Canal Park and the central business district (CBD) in downtown Duluth.

Once the steam and hot water are delivered to customer buildings through the distribution network, the customers utilize the energy for ventilation, radiation, domestic hot water and process needs of their buildings. Steam users then discharge condensate to the city sanitary and storm sewer system while hot water customers return the water to the Duluth Steam plant though a closed loop piping system so that it can be reheated and redistributed.



***Downtown Duluth* >> SYSTEM OVERVIEW**

Duluth Steam also owns a small chilled water system on the west end of the Central Business District (CBD). This system generates chilled water through a steam absorption chiller and distributes the chilled water to several customers on the west end of town through a closed-loop piping network.

The system currently serves over 180 buildings in the CBD and the Canal Park district. This constitutes approximately forty percent of the building stock in the CBD.

Developing an Integrated Energy System

The City of Duluth has expressed interest in improving the overall efficiency of the system and investigating opportunities for integrating renewable energy sources into its energy portfolio. While the system operates reliably, several efficiency improvements are recommended for the system. Each improvement will have its own influence on the overall efficiency and result in environmental benefits for the community. Improving the overall efficiency of the system, stabilizing the cost of energy for customers, and reducing greenhouse gas emissions are the goals of the community and are achievable on a community-wide basis through improvements at the Duluth Steam system.

Implementation of these improvements will likely be accomplished through a phased approach over a number of years. One advantage to having a detailed Master Plan in place is that these improvements can be implemented opportunistically in conjunction with other work, which has the benefit of reducing the overall cost. In order to understand and improve the operations, Ever-Green analyzed each individual component (fuel, production, distribution, etc.) and the system as a whole. The following is a summary of these findings and recommendations. The detailed analysis can be found in the main Master Plan document.

Distribution System (Outlined in Section 4)

Canal Park has a hot water distribution network that serves several hotels, a brewery, a convention center, and an arena. The buildings are all indirectly connected, using a heat exchanger to separate the distribution network from each building's internal heating loop. The hotels use the system's hot water service for domestic water heating, pool and spa heating, snowmelt, and laundry purposes. The brewery uses the hot water for in-floor heat and to preheat brewing water. The convention center (DECC) and arena use hot water for space heat and domestic hot water.

The chilled water loop exclusively serves buildings within the western portion of the CBD. The majority of the chilled water customers on the network are federal, city, or county buildings.

Ever-Green Energy's study of the Duluth Steam system and analysis of the opportunities for its advancement have determined that it is possible that parts of the distribution system could be converted to a hot water distribution network that would more efficiently serve the heating needs of buildings in downtown Duluth and Canal Park for future generations. A small number of customers with significant steam needs on the east end of the CBD will have ongoing steam needs, which could be met by localized steam generation. A number of other customers would not be able to receive hot water in the short-term due to constraints with their internal building mechanical systems. These buildings could be converted to hot water in coordination with future building renovations or as a part of the system upgrade project. It will be important to coordinate system transformation with the needs of these and all buildings in Duluth.

Recommendations for Improved Distribution

- Convert the Canal Park district to hot water using a two-phased approach. The first phase would be to convert existing steam users to hot water and improve the efficiency of the largest current hot water customer. The second phase would be to expand service to all buildings in the district, including the proposed Pier B Development.
- Install a hot water loop on the west end of downtown. Many of the buildings in this area already utilize hot water for internal building systems, allowing for an easier conversion to a hot water system. This initial loop could serve as the basis for hot water expansion in downtown as other buildings become compatible with a hot water network. Efforts could be coordinated with upcoming work planned for Superior Street and 1st Street to reduce construction costs. Over time, this loop could grow to serve all of the hot water needs of the CBD.
- Initiate a hot water loop on the east end of downtown, being served by an energy transfer station on that end. This loop would enhance the efficiency of the distribution to some current customers and also serve several customers that currently are not connected to the system.

Building Consumption – Customer Efficiency (Outlined in Section 3)

The customers of Duluth Steam receive thermal energy through hot water or steam. Hot water customers transfer energy through heat exchangers to internal hot water loops in their mechanical rooms and then circulate this hot water throughout their mechanical systems in the building. Steam is utilized in one of three applications in the customer buildings, with the type of usage split evenly between customers; full steam, steam and hot water, or hot water.

Existing Customers	MMBtu/yr
Steam	442,199
Hot Water	86,584

Many of the current customer buildings are readily compatible with a hot water distribution network. Clusters of customers on the western edge and eastern edge of the CBD could make the transition to hot water and would be the focus for the efficiency gains from a hot water distribution conversion.

	Number of Buildings	Annual Usage (MMBtu/yr)
Internal Steam	84	81,439
Internal Hot Water	52	180,139
Internal Steam and Hot Water	47	243,205
	183	504,783

Energy conservation is an important function for the plant, distribution system, and the end users. For building conservation, many key principles are applicable independent of their use of steam or hot water service. Connection to a district energy service delivers ease of operation and range of control, making it possible for the end user to achieve a high degree of energy conservation. In particular, the energy consumption in buildings is often reduced in transitioning from steam to hot water due to the enhanced control that can be achieved using hot water. When coupled with the improvements described in the Distribution Section of this report (Section 4), system efficiency improves by 11%.

Recommendations for Improved Building Consumption

- Improve the efficiency of the system by working with existing customers to implement energy conservation measures and building operation best practices, leading to a more effective utilization of hot water or steam, improved building efficiency, and improved system efficiency.
- Work with the city and other partners to improve building code planning and implementation to optimize design construction for a building's heating and cooling system.
- Implement system and building best practices for operation and maintenance, producing immediate reductions in energy consumption and cost savings. Potential building improvements include weather stripping, window replacements, and increased thermal insulation as well as in-building energy distribution systems. Additional energy conservation best practices are detailed in the Master Plan.

Plant Operations – Assets and Improvements (Outlined in Section 5)

Steam is currently produced at the main plant in Canal Park primarily via pulverized coal fired boilers. The steam is distributed to customer buildings through a once-through steam distribution system and is also used in the plant for steam turbine drives of equipment such as pumps, coal pulverizers and fans. The plant was built in 1932 and the four boilers have been maintained and repaired to keep them reliable and efficient. Other plant equipment such as forced draft fans, feed pumps, and steam turbine drives have been upgraded over the years.

The boilers produce steam only for the purposes described above and no electricity is generated. However, the plant includes a standby generator and two emergency generators to operate equipment in the event of an electrical interruption. The primary fuel for the steam boilers is pulverized sub-bituminous (western) coal, although bituminous (eastern) coal can also be used. Natural gas is used as backup fuel for two of the boilers and the plant is also permitted to burn No. 2 fuel oil.

Hot water is produced by capturing steam from the exhaust of the steam turbine drives at the plant and then is distributed to Canal Park customers. The plant is generally operating in an efficient manner. In order to improve overall production efficiency, the following actions could be taken.

Considerations and Recommendations for Improved Plant Operations

- The DECC loop heat exchanger in the plant is leaking and will require replacement. The estimated cost of this work is approximately $100,000. The Master Plan's requirement of additional heat exchanger capacity should be considered in this replacement.
- EPA Boiler Maximum Achievable Controls Technology Standards (MACT/GACT) may put additional restrictions on the plant. Short-term measures could include substitution of biomass to replace coal usage and reduce mercury emissions.
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- Long-term improvements include expanding the hot water production equipment and introducing alternative fuels in the Plant fuel mix.
- Currently, there are two separate systems with heat exchangers and distribution pumps for hot water distribution to the Canal Park area. In an effort to simplify the production system, the systems should be consolidated and expanded as proposed in the Master Plan.
- Additional equipment for biomass firing could also be installed based on evaluation of the economics of new or used biomass equipment.
- Meet the summer needs of the system through alternative means. Currently, the system meets the summer load of its customers by operating the large coal boilers at a lower capacity. The summer load could be served more effectively through utilization of smaller, natural gas-fired boilers placed within the system, potentially within an existing customer building.

Chilled Water Production (Outlined in Section 5.3)

The system's chilled water loop is served from a stand-alone production plant located at 414 W First Street, which is the old Water and Gas building located between the Duluth New Tribune storage building and the Duluth News Tribune administrative offices and presses.

The system currently operates without sufficient backup production capabilities. If the 800 ton absorption unit were to experience a mechanical failure, customers may not receive reliable chilled water delivery.

Considerations and Recommendations for Improved Chilled Water Production

- Duluth Steam should investigate the possibility of adding N+1 redundancy to the chilled water production system so that the system customers may continue to receive reliable service.
- With a long-term expansion of a hot water distribution system, substituting the existing steam system, two-stage absorption chillers will only be used at the plant where steam can continue to be provided.
- Expanded cooling service through cooling islands will likely be most cost-effective, using electric drive chillers in lieu of one-stage hot water absorption chillers. However, at each installation, the effect of the electric demand increase should be evaluated.
- Consideration of renewable energy cooling from Lake Superior. Deep water cooling has been an effective fuel and technology adaptation in other areas with similar climate. The Master Plan reviews the potential and important considerations to the lake temperature and ecology. Significant analysis would be necessary to proceed with this application.

Fuel Diversification (Outlined in Section 5.2)

For purposes of the Duluth Steam System, the team evaluated two options for biomass integration, sawdust and woodchips. Biomass sawdust would primarily be wood residual material from a sawmill or other wood manufacturing processes such as furniture, cabinet, and pallet making. Biomass woodchips could be derived from wood residuals from logging operations or possibly trees removed due to storm damage, disease, and urban development. Initially, it is believed that the system could supplement up to 25% of its fuel mix with sawdust. The potential percentage will need to be verified through test-firing and approved through the permitting process.

Sawdust

Without any changes to the existing coal boiler fuel preparation system, sawdust is the only possible fuel that could be co-fired with coal. Sawdust is also a possible design fuel for some used biomass boilers that are currently on the secondary market, such as the Georgia Pacific boiler.

This Master Plan recommends that Duluth Steam should integrate both co-fired sawdust and a used 50 MMBtu biomass-fired boiler system to the production capabilities so that system coal consumption may be reduced. The team further recommends that the longer-term System Vision increase biomass-based production to 100 MMBtu as the hot water system is expanded.

Woodchips

Biomass in the form of woodchips can be used in a new biomass boiler. Woodchips can potentially also be used for co-firing in the existing boilers to broaden the fuel supply if a hammer mill is installed in series with the existing roller mills.

With a system vision of 100 MMBtu/hr biomass boiler capacity installed, the coal usage will be down to less than 10% of the total fuel usage. With all 100 MMBtu/hr biomass boiler capacity designed for woodchips, up to 660,000 MMBtu/yr of woodchip biomass will be needed.

Natural Gas
The city of Duluth owns, operates, and maintains the municipal gas utility, Comfort Systems, to provide natural gas to approximately 26,300 customers. The price of natural gas follows supply and demand trends. Currently, natural gas commodity prices are trending upwards, although the recent increase in supply has stifled that trend. Natural gas could be utilized as a primary or secondary fuel in the plant; however the cost of gas per MMBtu is much higher than that of either coal or biomass. If market conditions for these fuels change gas could be considered as a more substantial fuel source.

Cogeneration or Combined Heat and Power
Cogeneration, or combined heat and power, is recognized internationally as a mechanism for improving the energy profile for a community and maximizing the energy efficiency of electrical generation. Cogeneration captures the waste heat from the production of electricity to be used in a thermal system, such as a district energy system, nearly doubling the efficiency of electric generation facilities. Cogeneration also allows district energy businesses such as Duluth Steam to incorporate electrical production more effectively and create affordable, stable price structures for its customers.

Waste Heat
In 2013, Minnesota adopted a new law (HF 729), which addresses the issue of waste heat in Minnesota's current energy system. The law expands the definition of "energy conservation improvement" and adds "waste heat recovery used as thermal energy." Through the addition of this language, the Minnesota legislature opened the door for the recovery and reuse of waste heat from existing machinery, buildings or industrial processes, including combined heat and power, for heating and cooling. This provides greater opportunities for the integration of waste heat for Duluth Steam.

Thermal Storage
Implementing hot water thermal energy storage at the Duluth Steam plant would allow more utilization hours of the turbine exhaust heat source. Essentially increasing the capacity of the hot water network by storing thermal energy when it is not needed and dispatching it in times where the waste steam source cannot meet the demand load.

Solar Thermal
Solar thermal has been increasing in scale and efficiency in recent years, allowing utilities, colleges, and industrial applications to explore large-scale solar thermal integration. When integrated with a hot water district heating system, excess heat from solar energy generation can be exported into the hot water loop to be utilized by other customers. This integration serves as a thermal "smart grid" for energy sharing and allows highest-best use of the available solar energy.

Possible System Growth (Outlined in Section 3.6)

With minor expansion of the distribution network, the system could increase its heating customer base by over 50% merely through connecting customers adjacent to the existing distribution infrastructure. With future planned development in the CBD and Canal Park, the customer base could be increased by 135 buildings (2.4 million square feet).

This expansion is a relatively inexpensive way to grow the customer base, spreading operating costs over more customers, and should enable customers to experience lower, more stable costs for their energy. Growth of the customer base will also support the financing of system improvements. As many of the improvements will require some type of financing, a broader system customer base and the associated revenue stream will provide a stronger business case for project financing.

Funding Profile and Options (Outlined in Section 10)

The current average customer steam system cost is approximately $17/MMBtu. Based on the system growth outlined in the five-year Master Plan, improved system efficiency and overall customer charges averaging $17/MMBtu, the system can support approximately $30 million of additional revenue bond financing. Security of the financing would be through customers signing long-term customer agreements. Below is a summary of the annual incremental funding sources and revenue bond funding based upon a 20-year revenue bond with an interest rate of 5%.

Additional Incremental Revenues	Annual Usage (MMBtu/yr)	Total Funding
Potential Customers	74,241	$1,262,097
Efficiency Savings	51,506	$164,106
Additional Customer Revenues	62,584	$524,483
Available for Debt Service Revenues		$449,030
Additional Incremental Funding		$2,399,717
Revenue Bond Debt		$29,905,774
Annual Revenue Bond Debt Service (20 year, 5%)		$2,399,717

Funding Options

Funding of the five-year Master Plan would be developed from a variety of sources. A majority of the funding of the five-year Master Plan will be from the issuance of revenue bonds or could be supplemented with tax-exempt facility bonds, also classified as Private Activity Bonds. Additionally, funding could be generated through New Market Tax Credits, private foundations, the Conservation Improvement Program, or grant and program funding through the Department of Energy or the State of Minnesota Department of Commerce, Division of Energy Resources. Funding is anticipated to be supported by customer revenues under long-term contracts.

Detailed Next Steps (Outlined in Section 12)

Review of Master Plan and System Vision - The technical and operational improvements recommended should now be further developed to verify their ease of implementation and also any considerations that may impact the success of these possibilities. Further development should entail a review of the Master Plan by management in order to identify those that can be opportunistically implemented.

Once those concepts have been identified, the possible future load should be evaluated so that a realistic customer load can be established for the first phase of advancement of the system.

Customer Outreach and Cost Estimation - If the hot water system transitions are viewed favorably, this would require meeting with existing and potential customers to gain a better understanding of their willingness to convert from steam to hot water, and also establish more detailed cost estimates for conversion of those buildings. Duluth Steam should also meet with existing customers either currently on hot water or proposed to convert to hot water to establish connection standards and identify energy conservation measures to support the efficient operation of the hot water district system.

Conceptual Design for Production and Distribution - Once the revised load is established for the enhanced system, a conceptual design should then be performed for both the system production as well as the new distribution network. With the production system, fuel sources should be researched as well as existing permit allowances for alternative fuel integration. An integration plan should also be established for any new equipment in the existing facility, along with necessary alterations that will need to be made at any satellite production facilities that may serve the load.

For the distribution network, collaboration with Duluth Public Works will be important so that the installation of the new hot water supply and return pipes may be coordinated with other infrastructure projects in the area. The work should be planned to occur in conjunction with other street work to minimize the cost of the installation and to continue a strong working relationship with City staff.

Draft Business Model - As portions of the Master Plan are implemented, an updated business model should be established to verify the financial feasibility of the refined plan. The model should include a financing plan for the project with possible funding sources, along with possible rate structures that provide customers with competitive energy rates while still managing the debt service requirements for Duluth Steam.

Business Plan Development - With the approval of the refined concept for system advancement or portions thereof, the team should then focus on completing the business plan for the system advancement. Some of the focus in business plan development should include detailed plans for design development, permits, financing, customer contracts and construction contracts. The business plan should also lay out the schedule and budget for completion of the development plan for System advancement along with a development budget. Lastly, the business plan should address significant risks of the development plan along with the proposed mitigations. With this expanded and more-specific business plan for the portions of the plan that are ready for implementation, Duluth Steam will be prepared to inform and to pursue approval of Duluth City Staff and Council.

Implementation of Detailed Development - Upon approval of the business plan, detailed development should commence to prepare the project for full financing and implementation.

Conclusion

With the completion of this stage of analysis, Ever-Green is confident that there are many opportunities and options for the improvement of the Duluth Steam system. Moving forward, it will be crucial to prioritize next steps to improve system efficiency and optimize services for existing and potential customers. To accomplish these goals and remain cost-effective, the following three areas of focus are recommended:

- Implement hot water heating to select areas currently served by steam, and
- Add customers within the current boundaries of the system, and
- Enhance the flexibility of the fuel mix and integrating the use of locally-derived biomass

As noted throughout the brief and the full report, the pursuit of these options will deliver the following benefits to the system and the greater community.

- Efficiency of the system will be enhanced through reduced system trap losses and more efficient use of thermal energy in the customer buildings,
- Water use is reduced by approximately 80 million gallons per year with a commensurate reduction in water treatment at the WLSSD,
- Emissions of CO2 and sulfur dioxide are reduced by 25%,
- Fossil fuel combustion is reduced by over 25% through a combination of distribution system efficiency improvements that reduce condensate losses and use of locally-derived biomass fuel.

Over the coming months, Ever-Green will be sharing findings and recommendations with stakeholders from the City of Duluth, St. Louis County, the System Advisory Board and Duluth Steam customer base, community and environmental organizations, and academic institutions, including the University of Minnesota Duluth and the College of St. Scholastica. Additionally, Ever-Green will partner with the City of Duluth to explore the best options for proceeding with system improvements, including financing mechanisms and broader support from local, regional, state, and federal organizations.

For more information regarding any of the aforementioned recommendations, research, or findings, please reference the Duluth Steam Master Plan report.

Quick Guide to Duluth Steam Master Plan (full report)

Duluth Steam Master Plan

Involved Entities

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4. Distribution

1. Executive Summary

1.1 Background

Duluth Steam was established as an affiliate of the City of Duluth in 1979 when the City purchased the Duluth Steam system to prevent decommissioning. This system has reliably served the downtown Duluth community for the last 81 years by meeting the energy needs of individual buildings through a community energy system. As the needs of the community and the buildings in downtown Duluth change, the system must also adapt to provide robust, reliable, and resilient energy services to its customers while serving the community and being a good steward of the environment. The following Five-Year Master Plan is intended to be a guideline for improving the efficiency of the system and preparing it for growth and advancement.

1.2 Current System

Energy production for the system occurs at the Duluth Steam plant on the north end of the Canal Park district. The primary fuel source for the plant is western coal, and it is utilized to generate both high-pressure steam and hot water. The steam and hot water generated at the plant are then distributed via an underground network of pipes that run throughout Canal Park and the central business district (CBD) in downtown Duluth.

Once the steam and hot water are delivered to customer buildings through the distribution network, the customers utilize the energy for ventilation, radiation, domestic hot water and process needs of their buildings. Steam users then discharge condensate to the city sanitary and storm sewer system while hot water customers return the water to the Duluth Steam plant though a closed loop piping system so that it can be reheated and redistributed.

Duluth Steam also owns a small chilled water system on the west end of the CBD. This system generates chilled water through a steam absorption chiller located at 414 W First Street and distributes the chilled water to several customers on the west end of town through a closed-loop piping network. After the customers utilize the chilled water for their cooling needs, it is returned to the First Street plant where it is re-cooled and redistributed to customers.

The system currently serves over 180 buildings in the CBD and the Canal Park district. This constitutes approximately forty percent of the building stock in the CBD.

1.3 Integrated Energy System

The City of Duluth has expressed interest in improving the overall efficiency of the system and investigating opportunities for integrating renewable energy sources into its energy portfolio. While the system operates reliably, several efficiency improvements could be applied to the system. Each improvement would have its own influence on the overall efficiency, and result in environmental benefits for the community. Improving the overall efficiency of the system, stabilizing the cost of energy for customers, and reducing greenhouse gas emissions is the goal of the community and is achievable for the Duluth Steam system.

Implementation of these improvements will likely need to occur over several years and through a phased approach. It will be important to determine the long-range vision for the system and then identify the steps that should be taken to achieve that vision. This Five-Year Master Plan proposes a series of improvements that could be implemented over the next five years in pursuit that vision. Prior to implementation, the suggested steps will require further evaluation and affirmation. These initial steps are outlined in the following pages for specific areas of improvement.

1.4 Possible System Growth

With minor expansion of the distribution network, the system could increase its heating customer base by over 50% merely through connecting customers adjacent to the existing distribution infrastructure. With future planned development in the CBD and Canal Park, the customer base could be increased by 135 buildings (2.4 million square feet).

This expansion is a relatively inexpensive way to grow the customer base, spreading operating costs over more customers, and should enable customers to experience lower, more stable costs for their energy. Growth of the customer base will also support the financing of system improvements suggested in this document. As many of the improvements will require some type of financing, a broader system customer base and the associated revenue stream will provide a stronger business case for project financing.

1.5 System Vision

Ever-Green Energy's study of the Duluth Steam system and analysis of the opportunities for its advancement have determined that it is possible that the distribution system could be converted to a hot water system that would efficiently serve the heating needs of buildings in downtown Duluth and Canal Park for future generations. A small number of customers with significant steam needs on the east end of the CBD will have ongoing steam needs and those needs could be met by localized steam generation in that area of the system. A number of other customers would not be able to receive hot water in the short-term due to constraints with their internal building mechanical systems. These buildings could be converted to hot water in coordination with possible building renovations. It will be important to coordinate system transformation with the needs of these and all buildings in Duluth. This Five-Year Master Plan provides one possible road map that could be followed to improve efficiency of the system in the immediate future, while also positioning it to achieve a longer-term vision of an extended hot water system with localized steam production for steam-based customers

In the scenario outlined, conversion of these segments of the system to hot water would improve the efficiency of the system, including the following outcomes:

- *Reduce* greenhouse gas emissions.
- *Improve* the energy efficiency of customer buildings.
- *Allow* for easier integration of alternative energy technologies such as cogeneration, solar thermal, and waste heat recovery.

- *Allow* for easier integration of alternative fuel sources.
- *Reduce* water consumption.
- *Provide* Duluth with the necessary infrastructure for an advanced integrated energy system to reliably and efficiently serve Duluth.
- *Improve* overall efficiency to over 50% (refer to section 6.4).

1.6 Five-Year Master Plan

Accomplishing the System Vision will take time to achieve and will need to be implemented in a phased approach so that the current and future needs of the customer buildings are being met efficiently and reliably. Although a timeline has not been established in this Master Plan for achieving the broader vision, it is assumed that this would take more than five years. Initial steps may be taken by Duluth Steam to move toward the vision while also improving the reliability and efficiency of the system, and establishing a platform for future system transition.

Ever-Green Energy suggests that the following steps could be taken in the short-term to improve the system's efficiency and prepare it for achieving its vision:

- *Improve the efficiency of the system* by working with existing customers to implement energy conservation measures. This would lead to a more effective utilization of hot water and/or steam, improve their building's efficiency, and improve the efficiency of the system.
- *Convert the Canal Park district to hot water* with a two-phased approach. The first phase would be to convert existing steam users to hot water and improve the efficiency of the largest current hot water customer. The second phase would be to expand service to all buildings in the district, including the proposed Pier B Development.
- *Meet the summer needs of the system* through alternative means. Currently, the system meets the summer load of its customers by operating the large coal boilers at a lower capacity. The summer load could be served more effectively through utilization of smaller, natural gas-fired boilers placed within the system, potentially within an existing customer building.
- *Install a hot water loop on the west end of downtown.* Many of the buildings in this area already utilize hot water for internal building heating, ventilation, and air conditioning (HVAC). This allows for an easier conversion to a hot water system. This initial loop could serve as the basis for hot water expansion in downtown as other buildings become compatible with a hot water network. Duluth Steam could also coordinate a large part of the construction of this hot water loop with upcoming Public Works efforts that are planned for Superior Street and 1st Street, which could reduce cost of this construction. Over time, this loop could grow to serve all of the hot water needs of the CBD.
- *Initiate a hot water loop on the east end of downtown*, being served by an energy transfer station on that end. This loop would also serve several customers that currently are not connected to the system.
- *Integrate biomass as a fuel source in the Duluth Steam plant.* Initially, it is believed that the system could supplement up to 25% of its fuel mix with sawdust. The potential percentage will need to be verified through test-firing and approved through the permitting process.

- *Introduction of a biomass boiler* to the plant as a base-load management asset, completed over the long-term, as energy production assets need to be replaced. Replacing coal with biomass will significantly reduce greenhouse gas emissions, would introduce the utilization of local fuel resources, and would provide greater fuel diversity for the system.
- *Continue discussions* with local utilities, higher education institutions, and industry partners to identify opportunities for collaboration and integration. Collaboration could range from merging procurement negotiations to locating a combined heat and power facility near the system for possible integration as a joint asset.

Implementing these steps, both purposefully and opportunistically, will improve the efficiency of the system and reduce greenhouse gas emissions in the short-term. They will also properly prepare Duluth Steam to achieve the long-term vision of a comprehensive community energy system that utilizes local resources for fuel, provides affordable and reliable service to its customers, and minimizes the amount of greenhouse gas emissions to the environment.

2. Introduction

2.1 Background

The City of Duluth is a unique community, serving as a harbor to Lake Superior and a gateway to the industry and natural resources of the North Shore. Since 1932, Duluth Steam has supplied a steady flow of energy to its customers who have come to rely on its efficiency and dependability.

Duluth has owned the steam plant and distribution system since 1979, when the city purchased it from General Waterworks. The former utility was planning to decommission the system, rather than invest in air quality improvements required by the Clean Air Act. The city's purchase of the system saved it from decommissioning and provided for the air quality improvements needed to continue operations. System decommission would have forced local businesses, building managers, and health-care facilities to make major investments in individual space heating and process heating systems. The decommissioning of the system would also have made it difficult for Duluth to establish a modern district energy system. The city was able to maintain this public asset and help stabilize the energy costs for the customers.

The Duluth Steam system currently serves more than 180 buildings in Canal Park and the CBD. Steam from the central plant heats and cools many local buildings, in addition to providing thermal energy for hot water heating, humidification, sterilization, dry cleaning, kitchens, and microbrewing. The diverse customer base includes St. Mary's medical clinics, St. Luke's Hospital, Fitger's, the Great Lakes Aquarium, US Bank, The Inn on Lake Superior, Washington Art Space, Duluth Entertainment and Convention Center and Gateway Towers. All of these facilities rely on dependable steam energy or hot water from Duluth Steam.

For buildings utilizing steam from the district system, reducing stations take the place of building-specific furnaces or boilers. As steam enters a building, the reducing station changes the steam pressure from 150 pounds to a lower pressure that is distributed in the building. In some cases, the lower pressure steam heats a building water loop that is then used to heat the building.

Connection to the Duluth Steam system provides customers with a choice for heat delivery systems in their building. Some buildings use steam radiators or less obtrusive hot water baseboard heaters. Other building designs include air handlers to take heat from steam and direct it through the building. Many medical facilities use the Duluth Steam system to maintain a constant temperature that is important for sensitive medical equipment. Data centers cooled with steam absorption chillers maintain temperatures that are essential for the operation of servers and data storage devices.

2.2 About Ever-Green Energy

Ever-Green Energy ("Ever-Green" or "EGE") is one of the country's foremost experts on the advancement of community district 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. 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 knowledge base of the team that has developed, operated and managed the flagship system in Saint Paul, Ever-Green's industry-leading experience helps communities, colleges, universities, and government organizations advance the study, development, and operation of integrated energy systems.

In 2012, the City of Duluth selected Ever-Green Energy-Duluth to manage the city-owned Duluth Steam system. The Ever-Green team includes Duluth Steam personnel and Ever-Green is responsible for managing all aspects of system operations, including production, distribution, fuel procurement, customer service, billing and accounting, communications, and community outreach.

2.3 Purpose of Document

As part of a five-year Energy System Management Services Agreement, Ever-Green was requested to develop and present to the (Duluth City) Council a Five-Year Master Plan that describes potential operation and development opportunities for the system. The Plan will identify and assess opportunities to improve the efficiency of the system's existing heating and cooling plants, and the steam, hot water, and chilled water distribution systems."

The Ever-Green Energy Master Planning team worked with the Duluth Steam operations and management team to develop a Master Plan that not only describes potential advancements for the system over the next five years, but also envisions what the community energy system might look like for all of downtown Duluth in the long-term. Ever-Green analyzed all of the thermal energy needs of downtown Duluth so that the System Vision takes both the broad and specific needs of the Duluth community into consideration.

2.4 The Process

The Ever-Green team spent a considerable amount of time meeting with customers and researching the consumption profiles and mechanical systems of buildings within or adjacent to the current Duluth Steam system, as well as other potential customers in or near the CBD of Duluth. The Ever-Green team generated survey forms that were mailed or hand delivered to all buildings that are currently taking district energy services. After meeting with a number of customers, approximately 50 surveys were returned by customers. The team then performed site visits at over 40 customer buildings, with the majority of those buildings having over 100,000 square feet of heated area. This process helped the team gain a better familiarity of the internal heating systems of the buildings.

Building consumption data was then estimated and aggregated all buildings in the system's service area so that the Master Plan could be developed with a holistic approach, analyzing opportunities for system development beyond how it is structured today. The Ever-Green team also evaluated energy conservation measures that were possible for the various buildings currently being served by the system, as well as non-customer buildings in the area.

After establishing baseline customer information, the team analyzed the current energy production assets. Particular attention was given to the efficiency of the energy production system, possible diversification of input fuel sources, and the viability of integrating locally-derived renewable fuels into the system. Analysis of the heating distribution system also included the examination of the potential for and feasibility of improving the efficiency of the current distribution network through a steam to hot water conversion in portions of the network.

The Ever-Green team has also participated in city initiatives, including the Local Energy Action Plan (LEAP) process and application for the Bloomberg Mayor's Challenge. The LEAP process was initiated in 2012 to help the city create a roadmap for energy improvements and efficiencies, including the development of new technologies, metrics, economic development opportunities, and processes to help various sectors reach their greenhouse gas emission reduction goals.

The planning process also included a variety of activities to evaluate the regulatory environment, collaboration with community partners, and financing options for the implementation of the Master Plan and longer-term system vision. Increasing collaboration with community partners included conversations with the University of Minnesota Duluth, the College of Saint Scholastica, and various non-profit, business and industry partners. Lastly, the team evaluated financing options that Duluth Steam could pursue in implementing the Master Plan, as well as the longer-term System Vision.

Downtown Duluth ▶▶ SYSTEM OVERVIEW

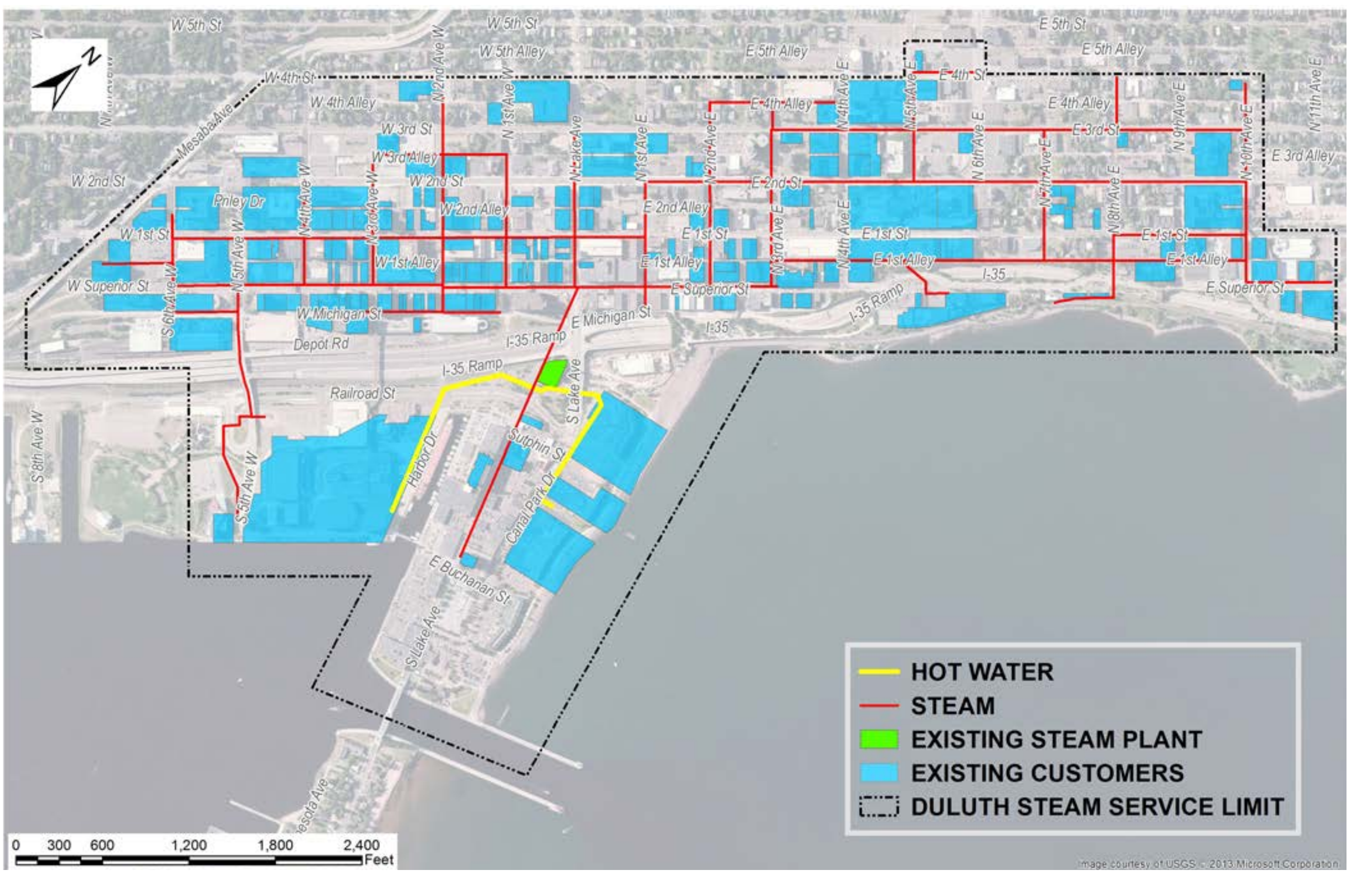


Figure 2.1 System service area

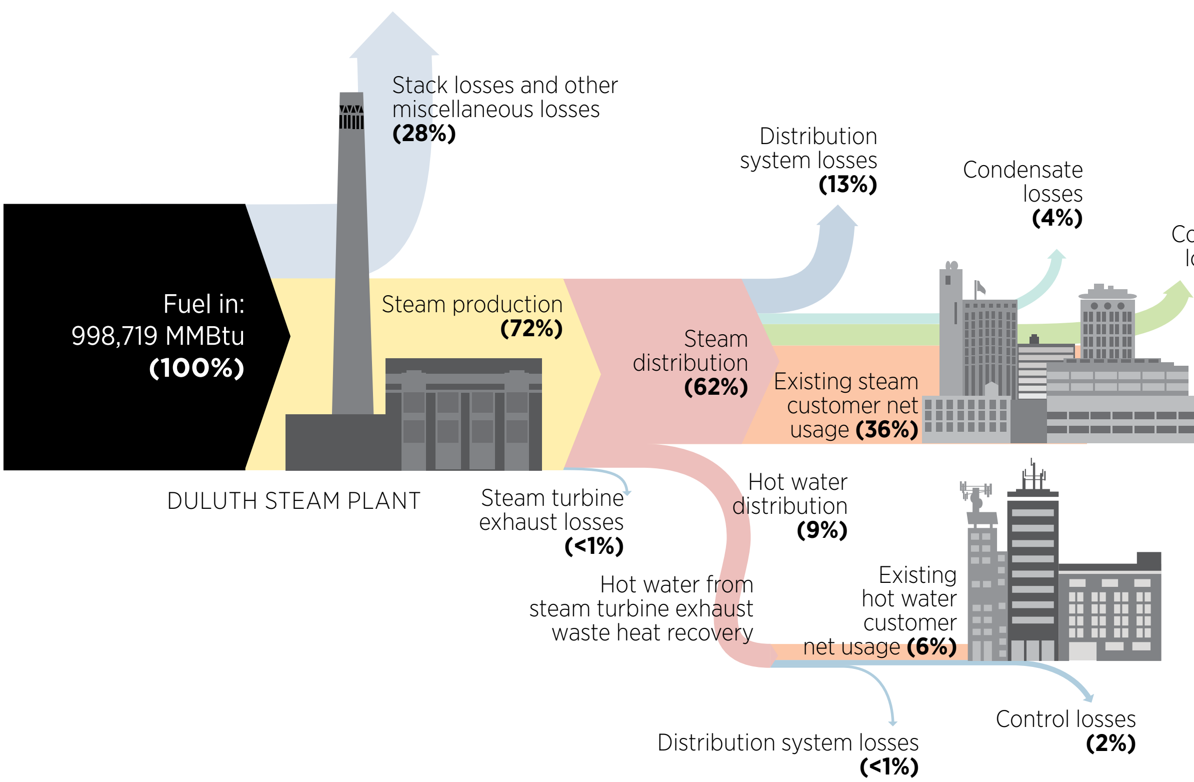
2.5 The System

The Duluth Steam System serves the CBD of Duluth, including the Canal Park area. The system meets the heating and cooling needs of approximately 180 buildings in Duluth, which includes hospitals, hotels, office buildings, government services centers, transit stations breweries, retail stores, and residential towers. The service territory of the system is shown in Figure 2.1.

Although the system serves many of the buildings in Duluth, a number of buildings in the district continue to meet their heating needs through on-site generation of hot water or steam with natural gas-fired boilers. Several of those buildings were previously connected to the system, but have since disconnected from the network. The system network traverses the entire area shown in Figure 2.1 and non-customer buildings would be able to connect to the system with relatively little cost.

The Duluth Steam central plant is located in the Canal Park district of Duluth. Western coal is transported into the plant from Wyoming, Montana, and North Dakota and is combusted in pulverized coal steam boilers. Steam at 366°F and 150 psi is then distributed through a network of underground steam pipes to the customer buildings. The customer buildings utilize the steam to heat their buildings and meet any process heat loads. Once the energy has been extracted from the steam, the steam condensate is then discharged from the customer buildings through the City storm and sanitary sewer systems, where it is either treated or discharged directly into Lake Superior. This process of utilizing steam without returning condensate to the steam source is known as a once-through steam system and is shown in Figure 2.2.

Figure 2.2 Energy flow diagram for the present system



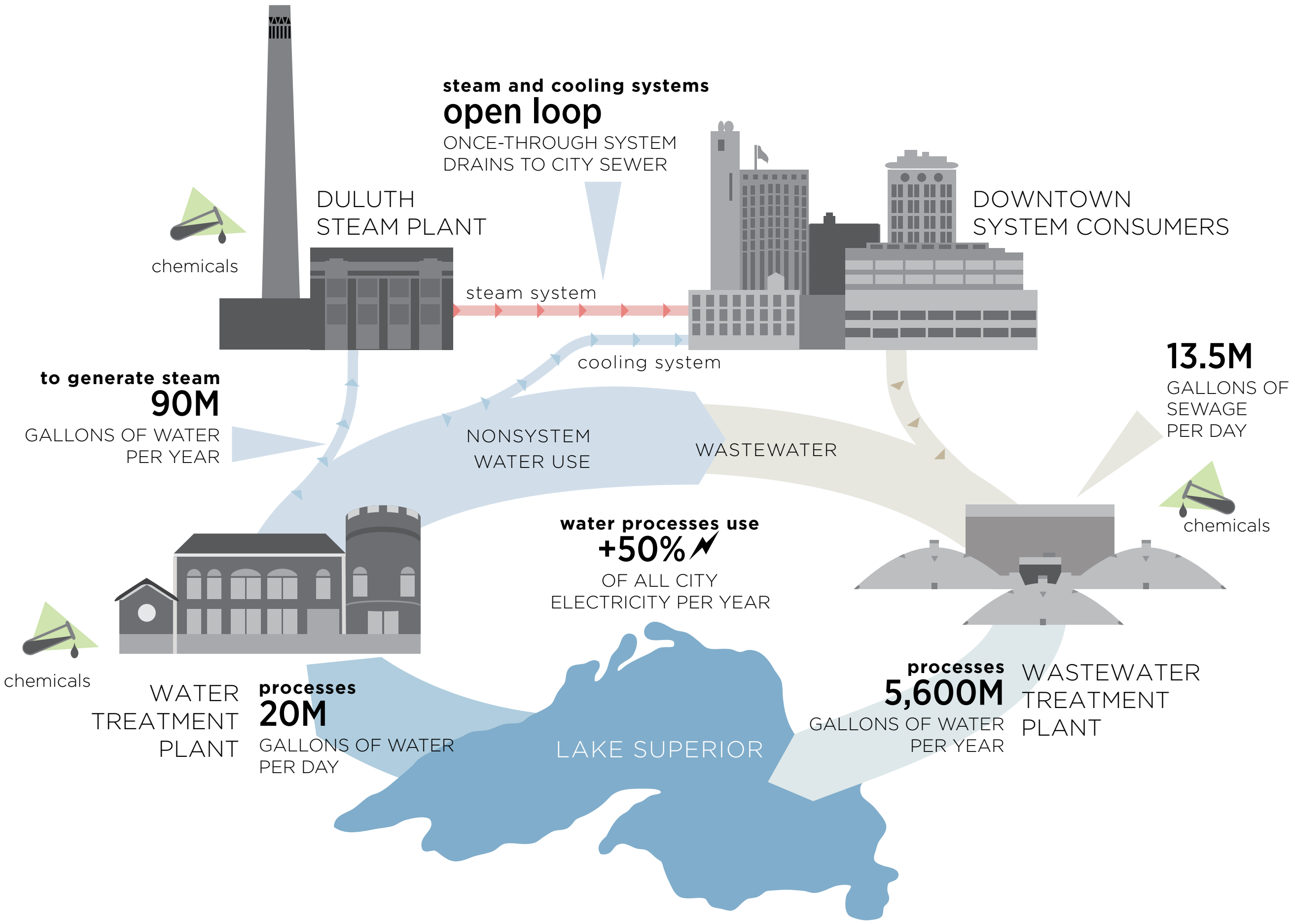


Figure 2.3 Current system for thermal energy transmission in Duluth

Water consumption needs of the system are currently being met through the City of Duluth water system and operate in an open-loop manner. The Duluth Steam plant receives cold make-up water from the Duluth water system; it is then treated and converted to steam. Corrosion inhibitors are added to the steam and the steam is transported to customer buildings where energy is then extracted from the steam. The resulting steam condensate is discharged into the city storm and sanitary systems. Condensate discharged through the storm system is then treated at the local wastewater treatment plant before it is discharged into Lake Superior.

Along with an extensive steam distribution network, Duluth Steam has a smaller hot water network in Canal Park. Hot water is generated by utilizing exhaust steam from Duluth Steam's turbine drives located throughout the plant. The exhaust steam is sent to heat exchangers so the thermal energy from the steam can be extracted and transferred to the hot water loop. The hot water is then pumped through two separate loops in Canal Park. This hot water provides space heating and process heating for entertainment facilities, hotels, and a brewery.

Duluth Steam also serves a small number of buildings with a closed-loop chilled water system. Under the closed-loop structure, chilled water is produced at the Duluth Steam chilled water plant and distributed through an underground pipe network to the buildings it serves. Once the customer buildings reject their building heat into the chilled water loop, the warmed water is returned to the chilled water plant where it is then cooled again and returned to the customer buildings once again. A minimal amount of city water is consumed by the plant for makeup water for the chilled water loop and for the cooling tower, although the chiller is a steam absorption chiller and the resulting condensate is also discharged to the city sewer.

Alternatively, some buildings not connected to Duluth Steam's chilled water plant utilize city water for cooling purposes, either as a direct cooling source or for condenser water cooling on their chillers. Once the city water is used by those customers for cooling, it is then discharged into city sewer for treatment and then returned to Lake Superior.

The life cycle of energy-based water consumption in Duluth is shown in Figure 2.3.

2.6 Canal Park Definition

Duluth Steam currently has two separate hot water networks within the district, one serving three hotels and the Canal Park Brewery and the other serving the DECC and AMSOIL Arena. The Team decided to include the DECC, AMSOIL Arena, the Great Lakes Aquarium and the potential future Pier B Development in this study due to their proximity to Canal Park and the possible benefits that could be gained by operating one combined Canal Park hot water network. For the purpose of this Study all of the shaded area in Figure 2.4 should be considered part of the Canal Park district.

Figure 2.4 Canal Park District

In January, 2013, Ever-Green Energy conducted a study for the City of Duluth, with support from the U.S. Department of Energy and the Minnesota Department of Commerce, Division of Energy Resources ("Canal Park Study"). The Canal Park Study investigated the technical feasibility of connecting all buildings within the Canal Park District to a hot water district energy system, and the environmental benefits that could be achieved by way of such a conversion. The Canal Park Study is attached as Appendix D and some of the findings of the Study are referenced in detail in this document, particularly as it pertains to proposed energy consumption improvements at Duluth Entertainment Convention Center (DECC).

2.7 Duluth Climate

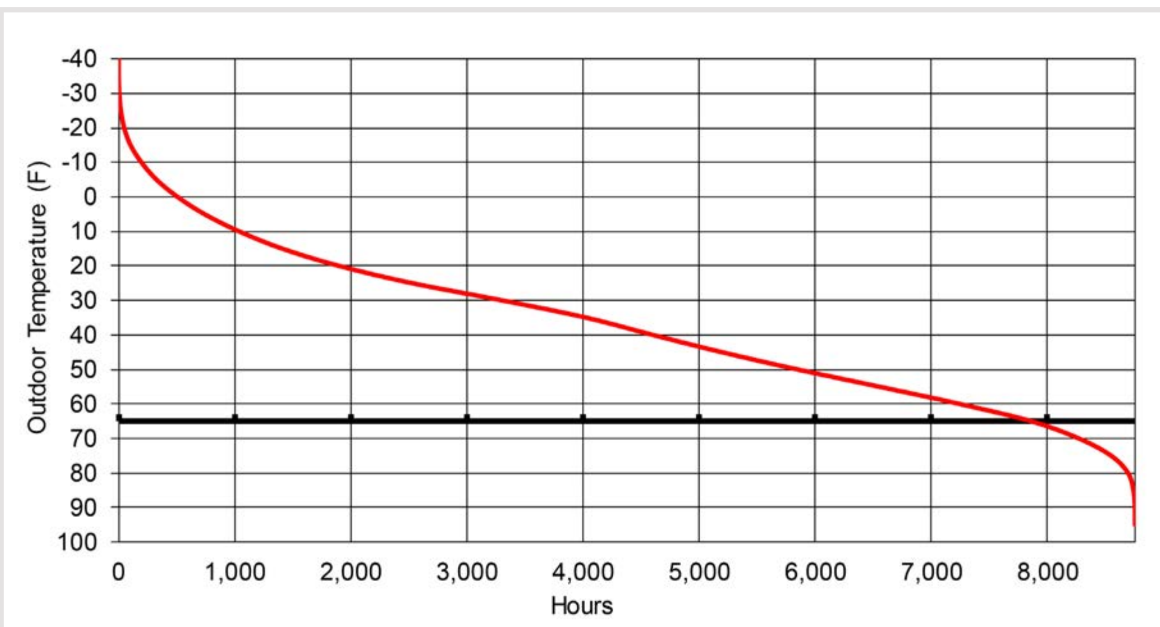
When designing heating and cooling systems, the ambient temperature plays a key role in design decisions for buildings' mechanical systems. The American Society of Heating, Refrigerating and Air Conditioning Engineers ("ASHRAE") 99.6% heating design outdoor temperature is -19.5 °F for Duluth. The ASHRAE 99.6% design temperature refers to the outdoor dry bulb temperature that is exceeded at least 99.6% of the time during a normal weather year.

The ASHRAE design temperature is used to design building HVAC equipment. Actual outdoor temperatures in Duluth can be significantly colder than this design temperature, as low as -30 °F. Since HVAC equipment is not designed for the coldest possible outdoor temperatures, indoor temperatures will start to decrease during extended cold spells.

Operators of district heating systems typically commission their systems to be able to provide sufficient capacity even at the coldest temperatures.

Similar to the ASHRAE heating design temperature there is an ASHRAE 0.4% cooling design outdoor temperature (84.5 °F in Duluth), i.e. the outdoor dry bulb temperature. This threshold is exceeded 0.4% of the time during a normal weather year.

Figure 2.5 Temperature distribution based on ASHRAE Bin data



While the coldest and warmest outdoor temperatures define the system capacity requirements, the temperature distribution over a year will indicate the heating and cooling energy needs. Figure 2.5 shows the temperature distribution based on ASHRAE Bin data. The area above and below the 65 °F line and the temperature distribution curves provides a good indication of the energy needed for heating and cooling. As can be seen in Figure 2.5, the temperature in Duluth is above 65 °F approximately 1,000 hours per year, thereby making district cooling a less sought after service in Duluth.

Heating and cooling degree days are another indication of the energy needed for heating and cooling. A degree-day is the difference between the outdoor mean temperature and a base temperature (normally 65 °F) over a 24-hour day.

Figure 2.6 shows the actual annual heating degree days for Duluth as well as the normal degree days. Normal degree days are the average degree days over a 30 year period and recalculated every 10 years.

As can be seen in Figure 2.5 the number of annual heating degree days has been trending downward since 1978. As a result, the normal heating degree days for the 30-year period of 1981 to 2010 are lower than the normal heating degree days for the period of 1961-1990 (9,443 compared to 9,818, a decrease of approximately 4%).

Duluth's annual cooling degree days have been increasing over the past 15 years. The normal cooling degree days for the 30-year period of 1981 to 2010 are 205 compared to 180 for the 30-year period of 1961-1990, which amounts to an increase of about 14% (see Figure 2.7).

Cooling has not been a significant service provided by the system in the past, but should be considered in the system's future plans, particularly if the trend shown in Figure 2.7 continues.

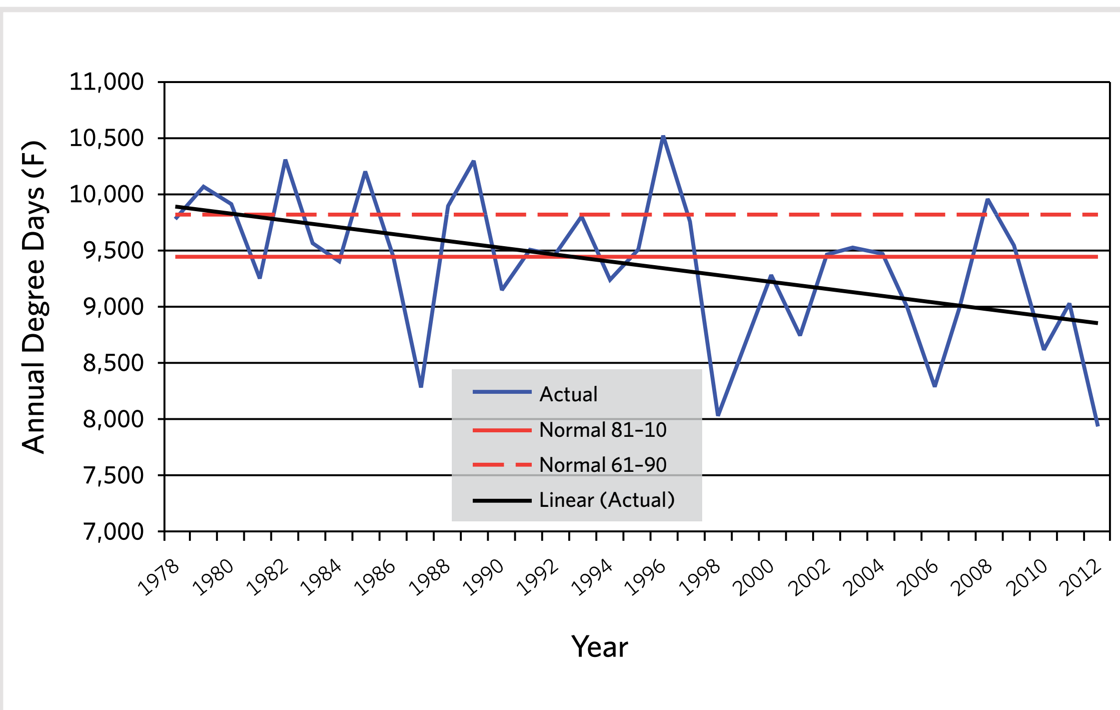


Figure 2.6 Normal and actual heating degree days for Duluth (65 F)

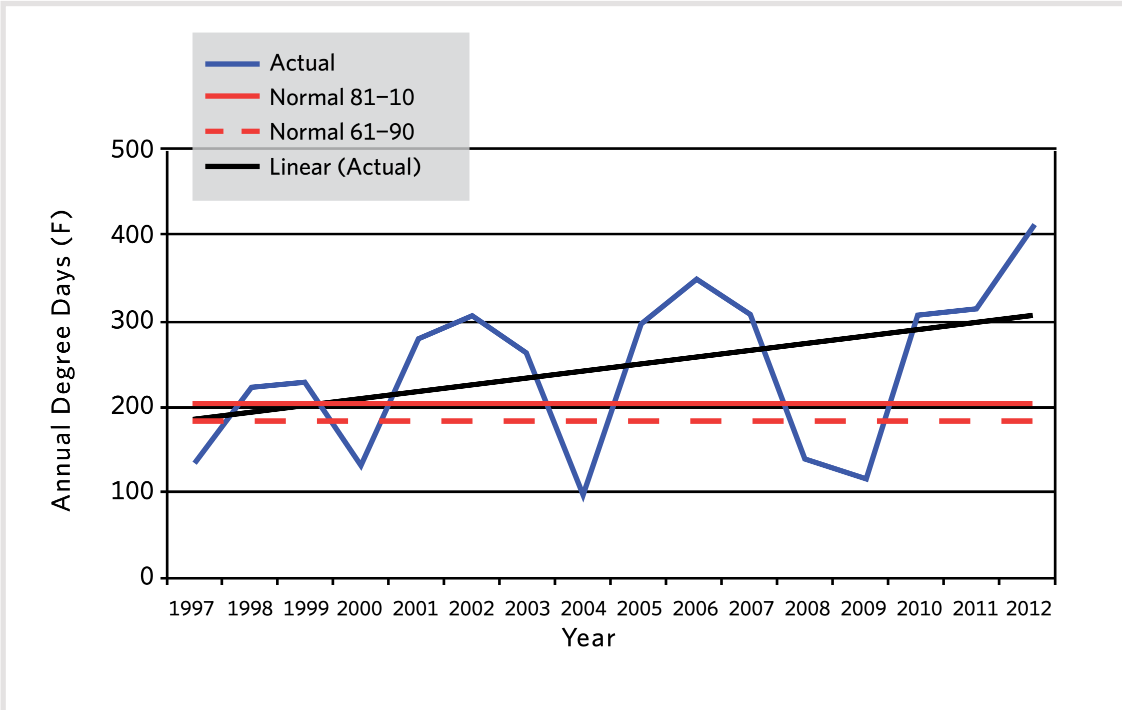


Figure 2.7 Normal and actual cooling degree days for Duluth (65 F)

2.8 Duluth Demographics

The 2006 Duluth Comprehensive Plan Demographic Profile provides an in-depth analysis of population and housing trends for the City of Duluth and surrounding suburban communities. The 2006 Demographic Profile was developed from the 2000 U.S. Census. A review of comparable data from the 2010 U.S. Census reveals minor changes in previously reported demographic information.

The total population in the City of Duluth has decreased slightly since 2000. The major employers continue to be in the categories of education, health care, retail, arts, recreation, and food service. Other professional categories and manufacturing remain generally stable in numbers reported in the 2010 census. The economic challenges facing all communities may have had an impact not captured by this data set.

Downtown Duluth continues to be a destination for tourists and offers a strong retail presence. The institutions of higher education continue to be a strong presence in the community and draw a large number of young adults to the community.

Housing needs continue to trend toward individual or non-family, owing to empty nesting and the large number of young adults. The downtown area is almost fully built-out and development in the downtown is limited but focused.

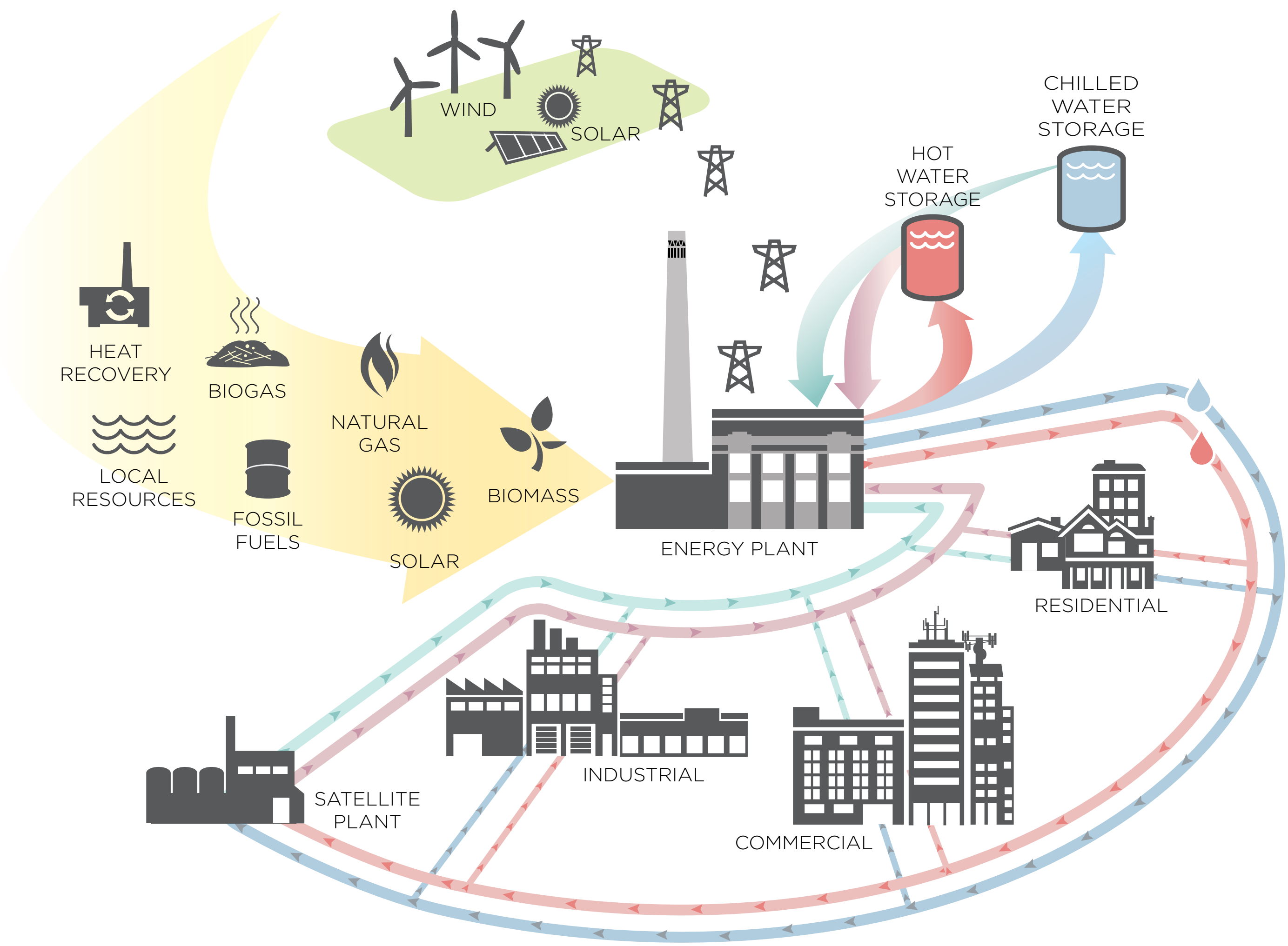
The City of Duluth does not project to realize significant growth in the downtown area; however it also does not expect to realize any significant decline. A stable population within the system's service area should allow for a predictable customer base and a sound business case for system investment and advancement.

2.9 Integrated Energy System

The vision for the Duluth Steam system is for it to become an integrated energy system that utilizes energy from multiple sources and multiple technologies. This integration will lead to a more reliable energy system meeting the needs of the community and providing a buffer from the market volatility of individual fuels. An integrated energy approach evaluates all sources of energy within a community and optimizes the efficiency of that community by reducing waste and establishing a conduit for serving the needs of the community through utilization of local resources. Figure 2.8 provides a visual representation of how an integrated energy system could function within a community.

By transitioning to a hot water heating system and expanding the chilled water cooling system, Duluth Steam could position itself to optimize the localized resources of biomass, cold lake water and stranded energy to serve the energy needs of the community.

Figure 2.8 Integrated Energy System



2.10 Definitions

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

ASHRAE Bin temperature data Temperature frequency in 5 F intervals available from American Society of Heating, Refrigerating and Air-Conditioning Engineers.

British Thermal Unit (Btu) The amount of heat required to raise the temperature of one pound of water 1 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 Btu's.

Coefficient of Performance (COP) Ratio of work or useful output to the amount of work or energy input, both represented in the same unit. Used generally as a measure of the energy-efficiency of chillers and heat pumps.

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

Condensate Water produced by the condensation of steam

Cooling Degree Days A degree day is the difference in temperature between the outdoor mean temperature over a 24-hour day and a given base temperature. Cooling degree days occur when the outdoor mean temperature is above 65 F.

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

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

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

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

Downtown East The downtown section of Duluth to the east of Lake Avenue.

Downtown West The downtown section of Duluth to the east of Lake Avenue.

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

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

Domestic hot water Potable water heated for use in faucets, showers, laundry, and similar uses.

Energy transfer station Equipment installed at the point of customer connection to the district energy system. The energy transfer station is utilized to transfer and measure the thermal energy delivered from the district energy distribution network to the customer's building(s) or other thermal loads.

Equivalent Full Load Hours Annual energy usage divided by the peak capacity used.

Flue Gas The gaseous by-product generated from the combustion of fossil or other fuels with air in a boiler or other stationary combustion device(s). Flue gases are emitted from a chimney or stack elevated above grade and surrounding structures to disperse the by-products into the atmosphere. The by-products vary depending upon combusted fuel but are predominately comprised of nitrogen, carbon dioxide, water vapor and oxygen with traces of other compounds.

Heating Degree Days A degree day is the difference in temperature between the outdoor mean temperature over a 24-hour day and a given base temperature. Heating degree days occur when the outdoor mean temperature is below 65 F.

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.

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

Hot water supply and return lines The district heating system piping that distributes hot water for heating purposes to customers (supply) and returns the cooler water to the Plant for reheating (return).

Medium temperature hot water Thermal heat transferred via hot water at a temperature between 190 °F and 250 °F.

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

Normalized Adjusted annual data of monthly building usage values measured on different monthly heating degree scales to a common scale prior to averaging.

N+1 Redundancy A measure of system component redundancy to provide backup in the event of failure of any one component. N+1 refers to the number of units installed to carry normal load plus one additional unit as backup. For example, if a system has three chillers to achieve the total design load, each is rated at 33% of the total load, or N=3. For this example, an N+1 system will have a total of four chillers of 33% capacity for a total installed capacity of 133% with one chiller providing backup in the event of failure of any one chiller.

PSI An abbreviation for pounds per square inch. PSI is a unit of pressure measurement.

Service line/service piping/customer connection 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.

Terminal equipment Heating equipment such as heating coils, radiators, unit heaters, or reheat coils that transfer heat from steam or hot water to the building air space.

Thermal energy Energy that is generated and measured in the form of heat.

Variable frequency drive An electronic controller that controls the speed of an electric motor by modulating input frequency and voltage to match motor speed to the specific demands of the work being performed.

3.
Duluth Energy Market

3.1 Existing Customers

Unless otherwise noted, all energy consumption data presented in this section is normalized.

3.1.1 CUSTOMER DATA

The system serves a wide variety of customer buildings throughout the Canal Park district as well as the CBD. Buildings served include hotels, medical facilities, entertainment venues, office buildings, residential buildings, and restaurants. The current Duluth Steam customers are shown in Figure 3.1 below.

Downtown Duluth ▶▶ EXISTING CUSTOMER LOADS

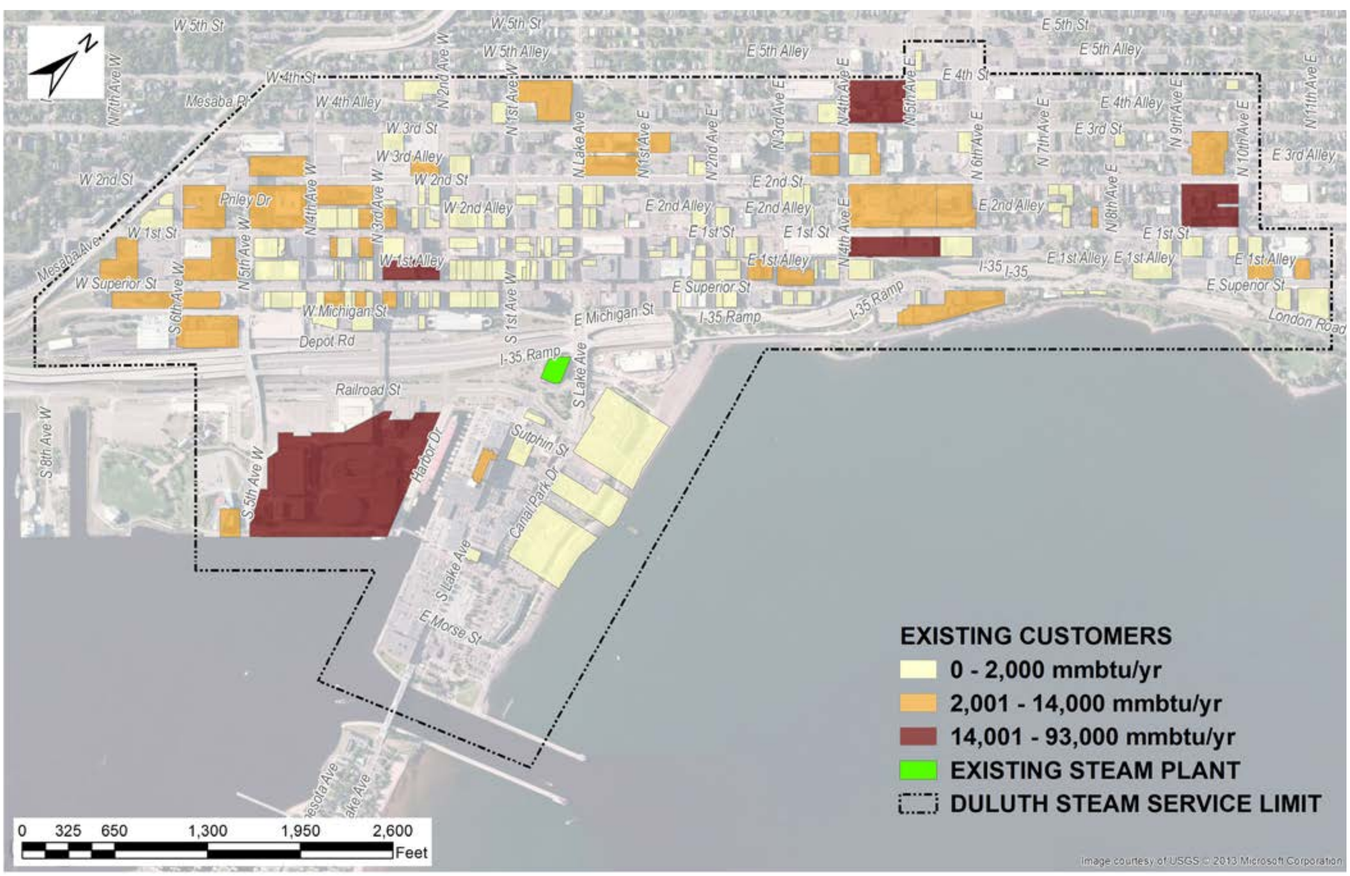


Figure 3.1 Current Duluth Steam customers

3.1.1.1 Steam vs. Hot Water Consumption

Duluth Steam serves its customers via steam and hot water systems. Some buildings that receive steam exchange the energy to a hot water loop that runs through the building. Other buildings circulate the steam throughout their buildings for heat or process load. The CBD customers are all currently served with steam, while Canal Park is served by both steam and hot water. Table 3.1 provides a summary of the total consumption for each type of energy delivery.

Table 3.1 Energy consumption summary

EXISTING CUSTOMERS	MMBtu/yr
Steam	442,199
Hot Water	86,584

Although section 3.1.1.3 provides a greater description of how each type of building owner utilizes energy from the system, Figure 3.2 provides a visual representation of the Duluth Steam customers of and their use of steam and hot water within their buildings.

Downtown Duluth EXISTING CUSTOMER HEATING SYSTEM TYPE

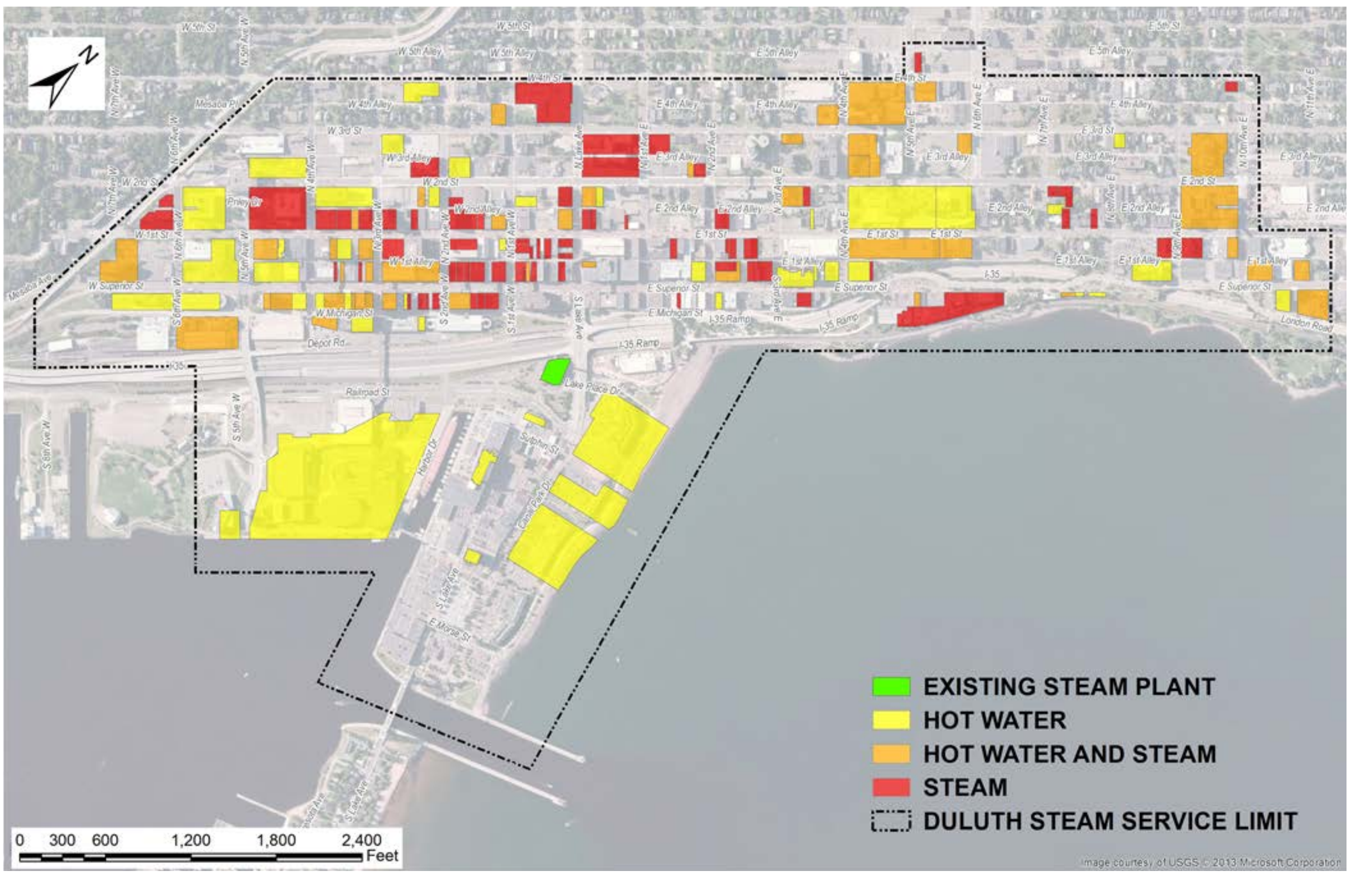


Figure 3.2 Current customer steam and hot water use

3.1.1.2 Summer Consumption

Summer steam and hot water consumption is significantly lower than winter usage and is predominantly driven by process loads, domestic hot water usage, steam absorption cooling, and HVAC reheat. The summer load customers are primarily made up of hospitals, hotels, and cleaners, with minor domestic hot water usage in residential buildings and offices. The summary of summer consumption is shown in Table 3.2.

Table 3.2 Average annual summer consumption of existing customers for years 2009 to 2012

SUMMER MONTH	STEAM SOLD (MMBtu)	HOT WATER (MMBtu)	ABSORPTION COOLING (MMBtu)	TOTAL LOAD (MMBtu)
June	17,376	1,846	1,064	20,286
July	12,214	1,234	1,632	15,079
August	13,498	1,361	1,928	16,787
September	15,439	2,503	994	18,936
Total	58,527	6,944	5,618	71,089

NOTES Numbers based on normalized meter data.
Summer consumption numbers assume DECC improvements have been made to reduce annual usage by approximately 24,000 MMBtu

The customers consuming energy during summer months are spread out throughout Canal Park and the CBD, however the significant load is coming from the hospitals, hotels, and entertainment venues, primarily due to domestic hot water and process load. The locations of summer consumption are shown in Figure 3.3.

Downtown Duluth ▶▶ CUSTOMER ANNUAL LOADS

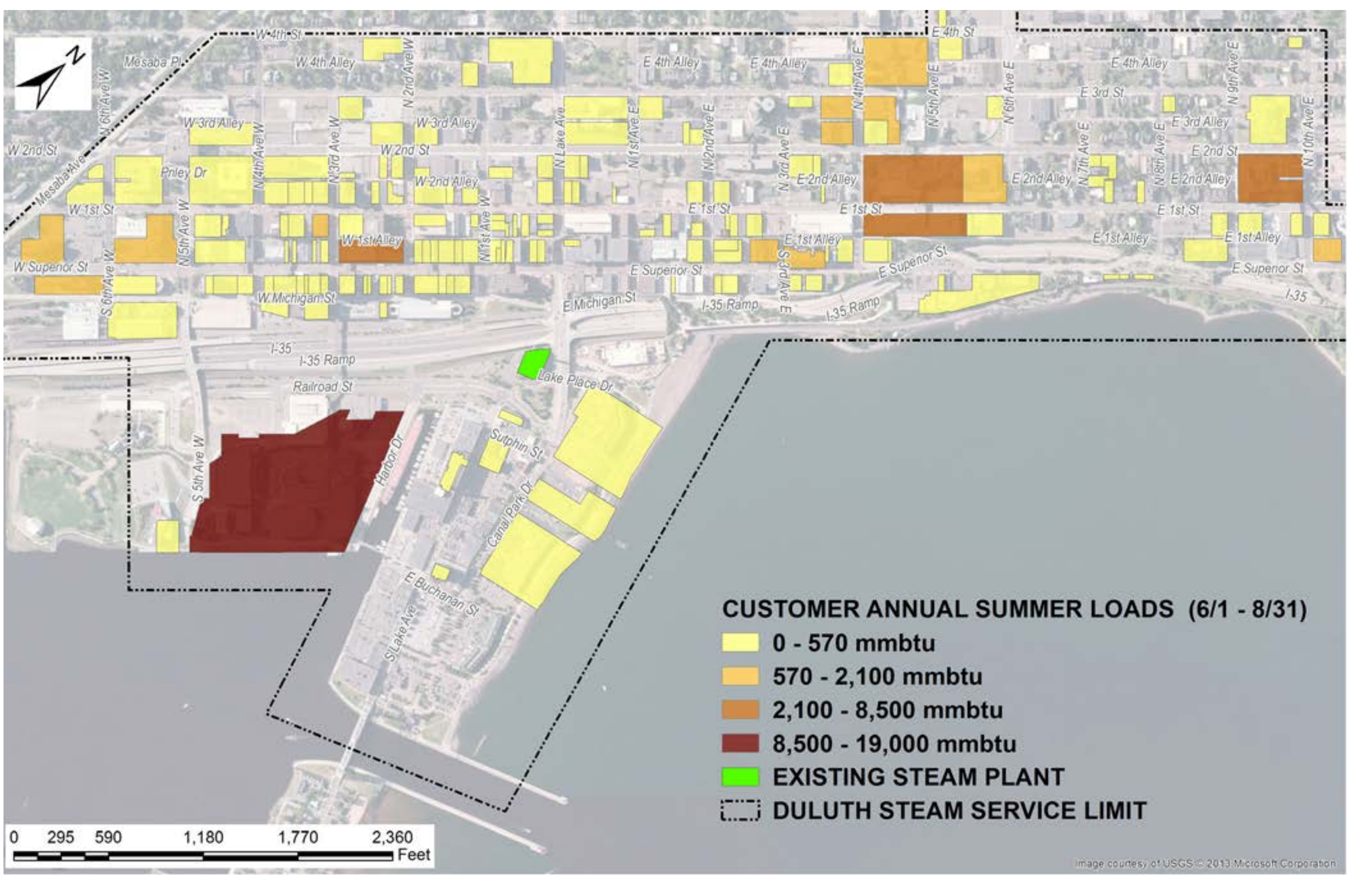


Figure 3.3 Current customer summer energy consumption

3.1.1.3 Internal Building Usage for Existing Customers

The customers of Duluth Steam receive thermal energy through hot water or steam. Hot water customers transfer energy through heat exchangers to internal hot water loops in their mechanical rooms and then circulate this hot water throughout their mechanical systems in the building. Steam is utilized in one of three applications in the customer buildings.

3.1.1.3.1 *Full Steam*

In this application, the building is utilizing steam throughout their entire building. The high pressure steam service is typically reduced from 150 psi through a pressure reducing valve and distributed throughout the building at a much lower pressure of 5 to 10 psi. The low pressure steam commonly serves radiators in entryways and under windows, in unit heaters in garages or mechanical rooms, and in air handling units. In the latter occurrence, thermal energy from the steam is transferred to incoming air passing through a steam coil. Other uses for steam include domestic water heating, HVAC reheat systems, and process loads such as steam kettles, building humidification, and medical sterilization equipment. The steam condenses after the heat is extracted, forming condensate. The condensate is piped and discharged to the sewer system.

The buildings in this category include residential, offices and institutional buildings with internal distribution as an open loop steam system. In general, our team found that buildings utilizing steam for all of their heating needs had been constructed prior to the 1960s. Very few of these examined buildings had modified, upgraded or converted their heating systems.

3.1.1.3.2 *Steam and Hot Water*

Steam and hot water customers utilize two separate internal distribution systems. One system is a closed-loop, pumped hot water system mainly serving perimeter radiation, reheat coils serving zoned HVAC systems, and preheat coils in air handling units to temper incoming fresh air. The second is an open loop steam system, piped separately to serve applications such as ventilation air distribution systems, direct contact steam humidifiers, sterilizers, domestic water heaters, kitchen serving tables, and laundry equipment. Since the latter are open loop systems, the condensate is discharged into the city sewer system.

Table 3.3 Summary of internal building systems and annual usage

	NUMBER OF BUILDINGS	ANNUAL USAGE (MMBtu/yr)
Internal Steam	84	81,439
Internal Hot Water	52	180,139
Internal Steam and Hot Water	47	243,205
Total	183	504,783

NOTES DECC energy efficiency improvements included

Mixed use buildings, which utilize both steam and hot water, are likely to have steam coils in the air handling units and a hot water radiation loop. However, there are a mix of buildings in this category that have both hot water and steam coils in different areas of the building. Some buildings used steam coils in the air handlers and have hot water reheats, others have a heat pump loop with the entryways heated with steam column radiators.

The specifics of these steam and hot water buildings' mechanicals vary widely, and are not evaluated in detail for this plan.

3.1.1.3.3 *Hot Water*

Hot water customers' utilize exclusively hot water heating systems in their buildings. The building interfaces with the steam service typically thru shell and tube heat exchangers that transfer thermal energy from the steam service to an internal building hot water loop. The building loop pumps hot water to serve heating system equipment, such as perimeter radiation and central air handling units.

Hot water serves all the heating needs of the this category of building. The buildings have hot water coils in their air handlers and hot water radiation throughout. The condensate from the steam to water heat exchanger is often used to preheat or to serve the domestic hot water load of these buildings. The condensate is then sent to the city sewer.

3.1.1.3.4 *Canal Park Hot Water Service*

Canal Park has a hot water distribution network that serves several hotels, a brewery, a convention center, and an arena. The buildings are all indirectly connected, using a heat exchanger to separate the distribution network from each building's internal heating loop. The hotels use the system's hot water service for domestic water heating, pool and spa heating, snowmelt, and laundry purposes. The brewery uses the hot water for in-floor heat and to preheat brewing water. The convention center (DECC) and arena use hot water for space heat and domestic hot water. The annual usage for DECC (current and proposed) are detailed in Section 3.3.1. Peak load for the existing hot water network is shown in Table 3.4.

Table 3.4 Canal Park hot water usage and peak load

Annual Usage	86,584 MMBtu/yr
Annual Usage (With DECC Improvements)	62,584 MMBtu/yr
Peak Load (With DECC Improvements)	29.8 MMBtu/hr

DECC annual usage and peak load are estimated to be reduced to 62,584 MMBtu/yr through improvements. Building loads, with the exception of the brewery, are based on metered data. The brewery load is based on design specifications provided to Duluth Steam because this building is new to the system and annual meter data is not yet available.

3.1.1.3.5 *Chilled Water*

The chilled water loop exclusively serves buildings within the western portion of the CBD. The majority of the chilled water customers on the network are federal, city, or county buildings. The current chilled water system serves five properties with a total metered annual usage as shown in Table 3.5.

The absorption chiller displays peak load for tracking purposes. The chiller records annual peak output, which is typically reset each year before the cooling season begins. Duluth Steam operations staff has

Table 3.5 Annual chilled water consumption on cooling network

YEAR	ANNUAL USAGE (TON-HRS)
2010	417,147
2011	406,753
2012	456,192

NOTES Annual usage from metered data

observed the peak load readings at approximately 500 tons each year for the past few years. Assuming the peak output supplied by the chiller averages 500 tons, this would be the equivalent of approximately 850 full load hours.

3.1.1.3.6 *Existing Customer Summary*

Duluth Steam's customer base receives energy through one of two distribution networks, steam or hot water.Table 3.6 provides a summary of buildings and usage.

The existing Duluth Steam network is a very diverse system with many different types of customer interfaces and uses for the steam and hot water service. In general the customer buildings are split up into the three heating system design categories as described above. The annual energy consumption of each category is listed in Table 3.6 below.

Table 3.6 Summary of building and usage

	NUMBER OF BUILDINGS	ANNUAL USAGE (MMBtu/yr)
Existing Steam Customers	177	442,199
Existing Hot Water Customers	6	62,584
Total	183	504,783
NOTES DECC energy efficiency improvements included		

3.2 Non-System Customers

3.2.1 EXISTING BUILDINGS within Existing Distribution Area

Duluth Steam currently serves a large share of the buildings in the CBD and Canal Park area. However, there are still many buildings located near the distribution service network that are not yet served by the steam or hot water systems. Through increased marketing and customer development, it is assumed a portion of these buildings could become steam or hot water customers. Service from district energy systems is economically better suited for larger buildings due to the initial capital investment; however smaller buildings can also connect depending on their internal building design, proximity to the system, and individual economic conditions. For the purpose of this report and strategic plan, it is assumed that

Table 3.7 Non-customer estimated usage and peak load

Downtown Non-Customer Estimated Annual Usage (MMBtu/yr)	71,445
Downtown Non-Customer Estimated Peak Load (MMBtu/hr)	34.0
NOTES Assumes 30% of buildings under 10,000 ft^2 hook up to the district network. Values based on building parcel data and 80% 2003 CBECS build usage data. Equivalent full load hours of 2,100	

50% of the potential buildings could be connected to Duluth Steam within five years and 75% will be connected within 20 years.

To estimate the loads for buildings which are not yet customers of Duluth Steam, city parcel data was used with 2003 Commercial Buildings Energy Consumption Survey (CBECS) usage values. The CBECS values are based on building type. Table 3.7 shows the possibilities for additional load. Figure 3.4 identifies the location of the potential additional load within the current network

Downtown Duluth ▶▶ POTENTIAL ADDITIONAL LOAD

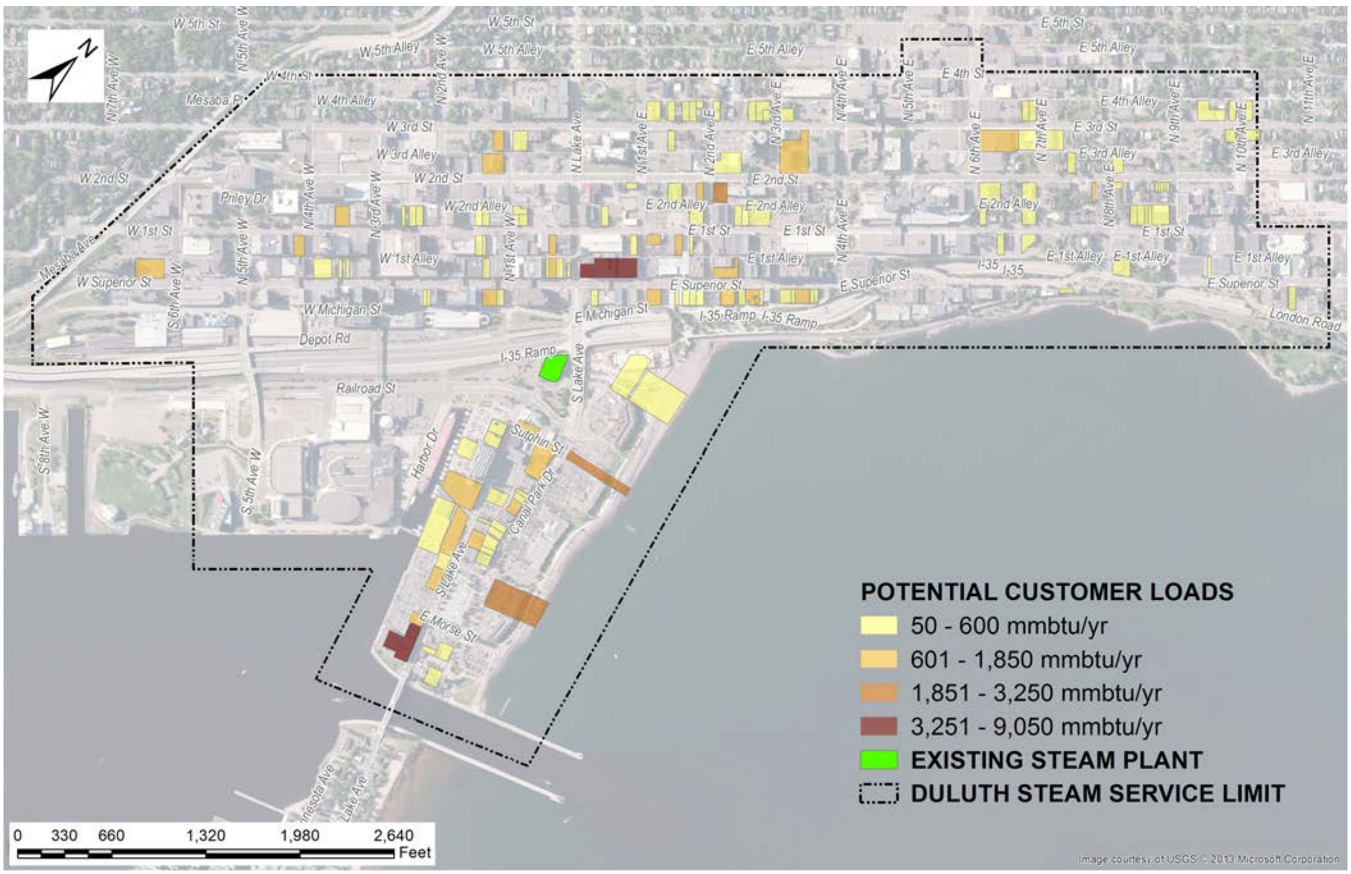


Figure 3.4 Potential additional load within existing distribution area

3.2.2 NEW DEVELOPMENT Within Existing Distribution Area

The following are building development projects occurring within the geographic area currently served by Duluth Steam and represent opportunities for expanding the customer base. These opportunities are also shown in Figure 3.4.

Corporate Towers The Duluth Corporate Towers is a 15-story business tower offering 300,000 square feet of office space with parking structure and skywalk. This project will be the largest downtown private development of its kind for this area. If the building installs an internal hot water distribution HVAC system, the building load is estimated to be 11,520 MMBtu per year.

DTA Multi-Modal Facility This transportation center will replace the existing Wells Fargo parking ramp below Michigan Street. This facility will include an 8-bay bus boarding platform, DTA-staffed information desk, indoor terminal and passenger-waiting area, a police substation, and public restrooms. The project will include the construction of a new Northwest Passage skywalk to the DECC. Although this building is still in the design stages, the estimated total heated space is assumed to be 20,000 square feet equating to an estimated load of 750 MMBtu per year.

This potential added load is summarized in Table 3.8.

Table 3.8 New Development Estimated Usage and Peak Load

New Development Annual Usage (MMBtu/yr)	**12,269**
New Development Peak Load (MMBtu/hr)	**5.84**

3.2.3 **EXISTING NON-CUSTOMER BUILDINGS** outside Existing Distribution Area

There are several buildings of considerable size to the east of the current system that have customer potential. A steam-to-hot water transfer station could be installed on the east end of the system and a hot water loop could be installed down London Road to serve buildings along the Lakewalk and neighboring areas. The estimated load on the east end is shown in the Table 3.9. The Master Plan assumes 50% of this load would be connected to the system within the next five years.

Table 3.9 Possible East Hot Water Loop Customers

East Non-Customer Estimated Annual Usage (MMBtu/yr)	**21,270**
East Non-Customer Estimate Peak Load (MMBtu/hr)	**10.1**

NOTES Assumes 30% of buildings under 10,000 Sq. Ft. hook up to the district network.
Values based on building parcel data and 80% 2003 CBECS build usage data.
Buildings have not been surveyed to quantify ease of connecting to a hot water system.
Equivalent full load hours of 2,100

3.2.4 **NEW DEVELOPMENT** outside Existing Distribution Area

In addition to the development within the existing distribution network, Duluth continues to grow in other areas of the city. Pier B is a high profile project under consideration for the development of a resort hotel and condominiums. Although final details of the development have not yet been released, assumptions were made for the size of this load based upon conversations with the developers of the property. It is assumed that the hotel will be approximately 80,000 square feet, with an additional 10,000 square feet of restaurant and banquet center and a 10,000 square foot multi-purpose facility.

Construction start dates have not yet been finalized, but system integration has been discussed with the developer. Integration with the Canal Park hot water system would allow for reduced capital costs for the property developer and would increase the load on the western leg of the network.

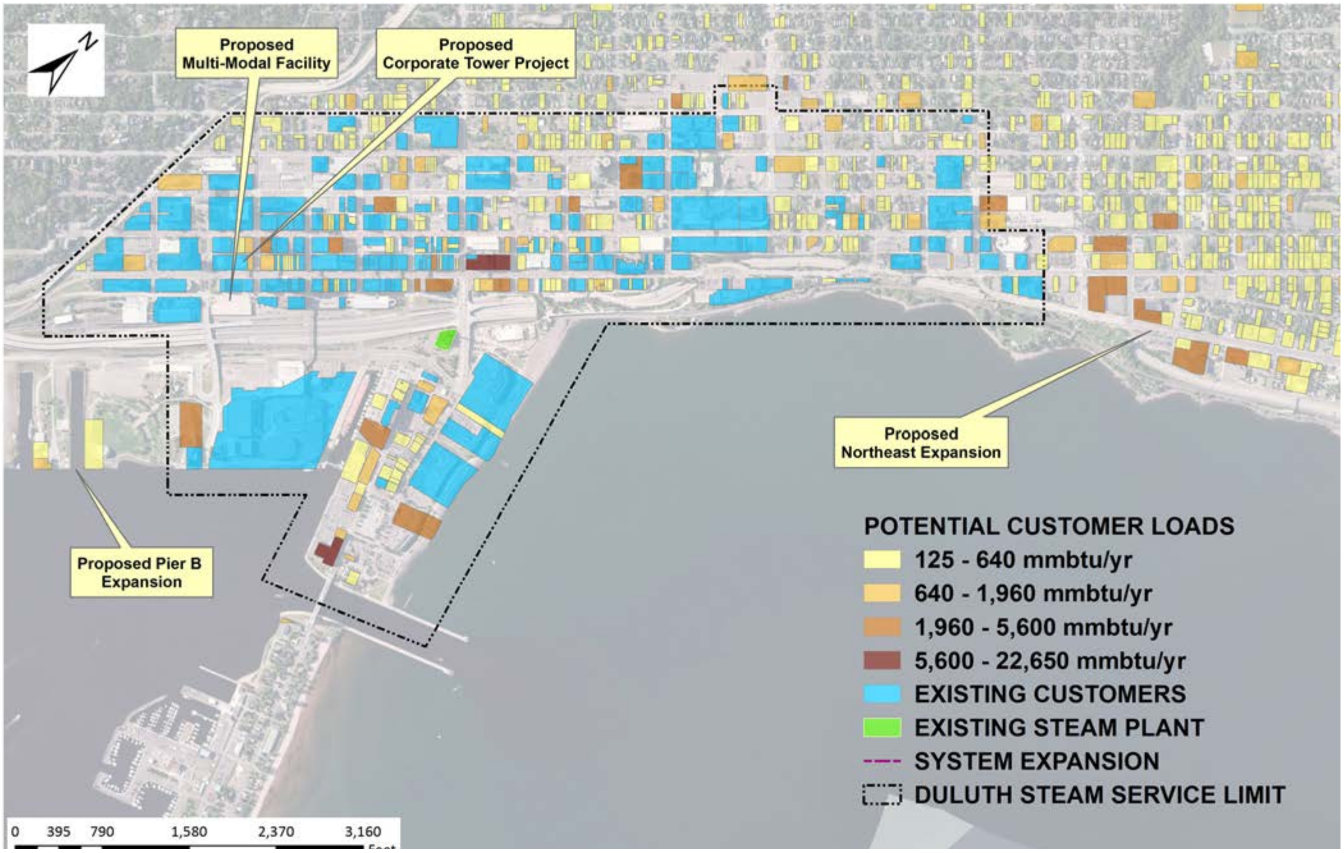


Figure 3.5 New development in downtown Duluth

3.3 Energy Conservation

Energy conservation is an important function for the plant, distribution system, and the end users. For building conservation, many key principles are applicable independent of their use of steam or hot water service. Connection to a district energy service delivers ease of operation and range of control, making it possible for the end user to achieve a high degree of energy conservation.

The controllable factors in determining the energy consumption of a building are as follows:

- Design and construction of the building
- Design of the heating system
- Operation and maintenance

The first two factors, construction of a building and its heating system, are of great importance because they affect the energy consumption throughout the life cycle of a particular building. Building codes are often the predominant factor for the design construction of the building and heating system. Operations and maintenance is the factor most likely to be under the control of the building engineer. Best practices for operation and maintenance can produce immediate results in reducing energy consumption and cost savings. Potential building envelope improvements include weather stripping, window replacements, and increased thermal insulation. There are also a number of improvements which can be made to building steam heating systems which will improve efficiency and occupants' comfort. The following best practices are recommended: :

- Valves for terminal equipment such as radiators should be operational and capable of responding to controlling thermostats.
- Steam traps should be checked on an annual basis for proper operation to reduce steam bypass thru the traps.
- Radiators should not be obstructed in order to allow air circulation.
- Heat should be extracted from steam condensate for heating domestic hot water or for other useful purpose before it is discharged to the sewer.
- Operating hours of HVAC systems should be reduced by utilizing perimeter radiation and fan scheduling.
- Reduce the operating temperature of the building heating loop during unoccupied hours and during the summer.
- Replace leaky fresh intake air dampers with low leakage dampers. Insulate piping in the equipment rooms to reduce waste heat.
- Domestic hot water temperature controls should be set at reasonable temperatures.
- Replace leaky control valves on heat exchangers.
- Radiation and convertor outside air temperature reset controllers should be operational and properly adjusted.
- Properly balance HVAC systems to reduce excess ventilation air and to maintain proper building pressurization.

In addition to the reduction in the cost of heating, the customer benefits through increased tenant comfort and building air quality.

3.3.1 ENERGY CONSERVATION AT THE DECC

The DECC is the largest energy consumer on the Canal Park hot water network, accounting for approximately 58% of the total hot water energy consumption and 11% of the overall system consumption. The DECC operates with a very low temperature differential (delta T) between the supply and return hot water lines, with a current delta T between 5 and 10°F, rather than 45°F to 55°F, which is the expectation for most hot water customer buildings. This means DECC is not efficiently extracting heat from the hot water system for use in the building, therefore requiring the consumption of more hot water and the associated hot water pumping energy in order to meet its heating load. The building's operation at this set point is necessary to avoid leaks from Victaulic gaskets in the convention center's building's secondary and building service piping loop. As a result, the DECC circulates hot water through the building during summer months and at other times when heat is not otherwise needed; consuming excess electricity and thermal energy. By replacing the Victaulic gaskets in the DECC's piping system, the delta T at the DECC could be increased, energy consumption could be reduced and the overall energy efficiency of the District could be improved. If DECC replaces their Victaulic gaskets, Duluth Steam could also establish a temperature reset program which

PHOTO COURTESY WWW.DECC.ORG.

Figure 3.5 Duluth Entertainment and Convention Center (DECC)

would decrease the temperature of the hot water loop as the outside air temperature increases. This would minimize distribution system heat losses and plant production requirements when heat is not in high demand.

The DECC also has three gas-fired back up boilers used to circulate district energy hot water for lay-up, resulting in radiant heat loss from the boiler walls as well as convective heat loss through the stack. During several site visits, these idle boilers were found to be hot to the touch. Bypassing these boilers with the hot water loop would result in additional reductions in energy consumption at the DECC, improving the overall efficiency of the system.

Figure 3.6 and Figure 3.7 on the following page provide a comparison of energy consumption per month for DECC and AMSOIL arena, along with the average heating degree days for the Duluth area over that time period. Typically a building's energy consumption will closely follow the heating degree day plot. As can be seen in these charts, the DECC's usage skews from the normal patterns of degree days, at approximately 3,000 MMBtu per month. AMSOIL's usage follows the heating degree days much more closely.

In comparison, the similar entertainment facilities in Saint Paul (served by a district hot water system) consume one-third to one-half the usage measured at the DECC on a per square foot basis. Based on the above observations, the potential for reduction of energy consumption could be achieved with minimal modifications.

Additional efficiency improvements: :

- Install variable frequency drives (VFD) on the internal hot water loop pumps which would reduce electric and hot water consumption. Remove hot water 3-way bypass valves at air handling units and reheat coils.
- Implement those improvements to in-building systems (at DECC) to allow Duluth Steam to implement a hot water temperature reset schedule.

The above suggestions are based only upon the observations during limited visits to the facility and are not intended to be a comprehensive list of all energy conservation measures. It is recommended that the DECC engage an energy auditor or re-commissioning consultant to perform a full evaluation of the facility so that all reasonable energy conservation measures may be identified.

All options presented in this Master Plan are based upon the assumption that the energy conservation improvements will be identified and implemented at the DECC. The primary sources of energy that could be captured to meet this additional heating load are from

Figure 3.6 DECC energy consumption per month (2011-2012) compared to average heating degree days per month for the Duluth area.

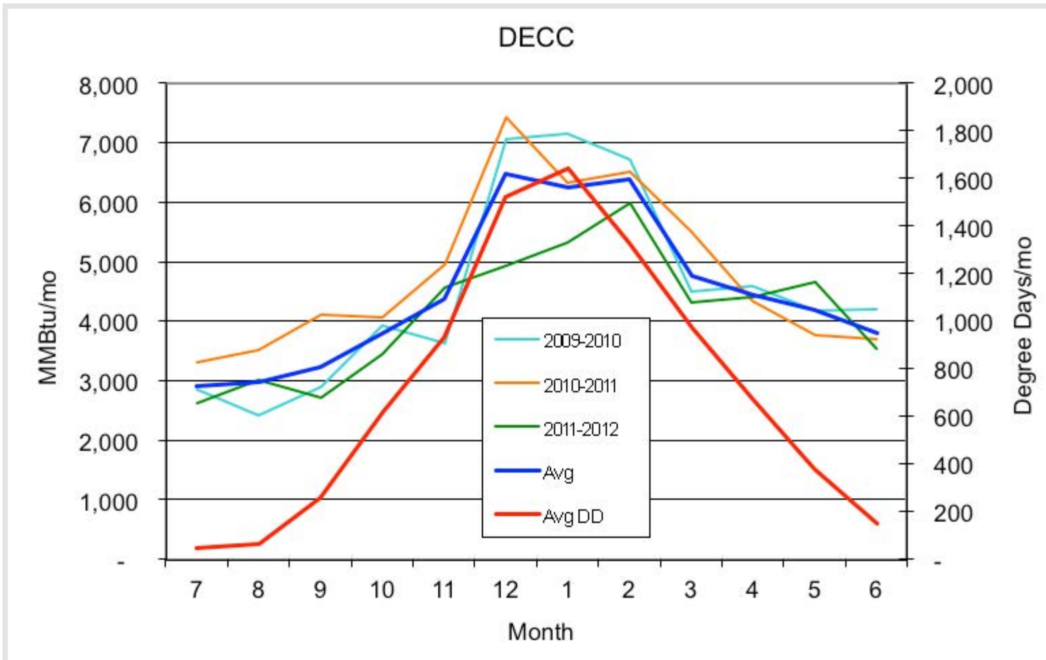


Figure 3.7 AMSOIL Arena energy consumption per month (2011–2012), compared to the average heating degree days per month for the Duluth area.

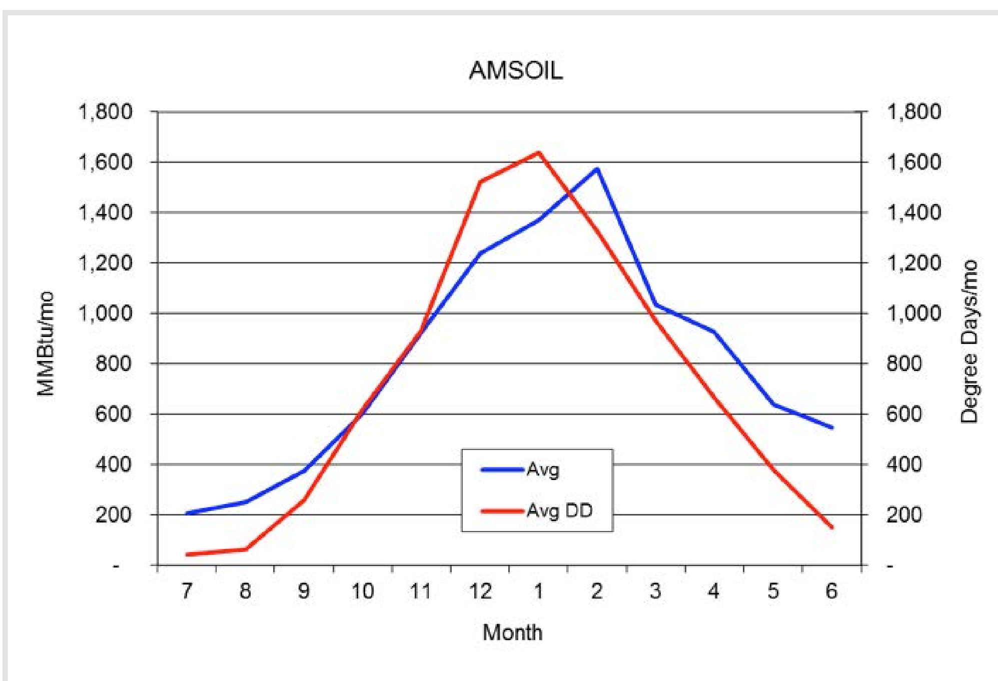
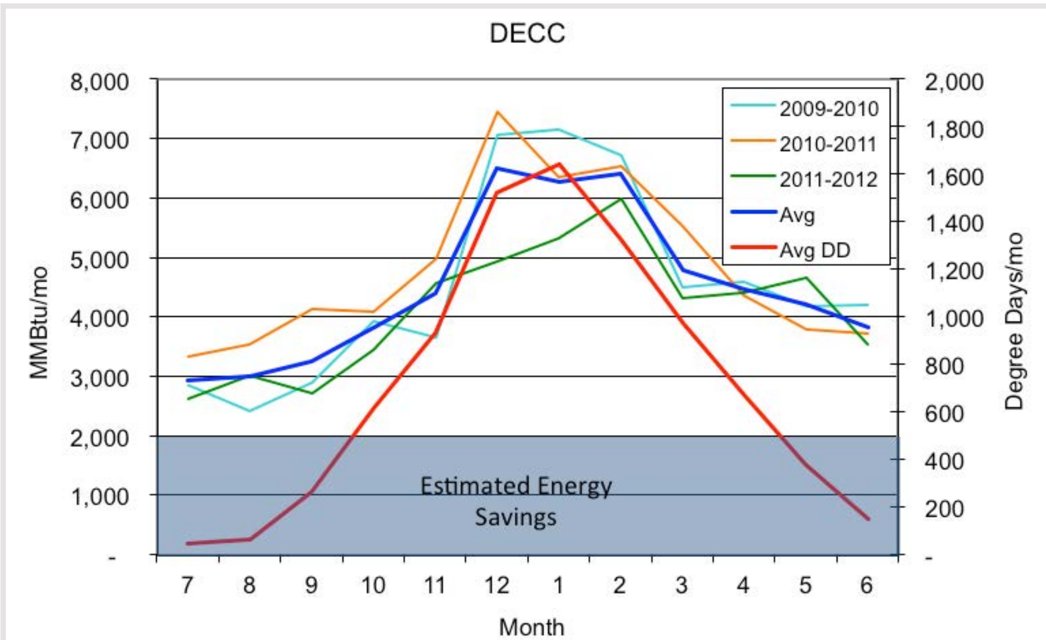


Figure 3.8 Possible energy to be saved by implementing energy conservation measures at the DECC.



converting the Canal Park district to hot water in lieu of steam and from improving the energy efficiency of the DECC. Figure 3.8 provides the basis for calculating the assumed energy savings by implementing energy conservation measures at the DECC. The area shaded in blue reflects the assumed savings.

3.4 Steam to Hot Water Conversion

As part of data collection, site visits were completed and a survey was distributed to existing steam customers. Throughout this data collection, it was common for steam customers to express frustration with their existing internal steam systems, primarily due to the age of these systems. Some of the heating systems have been in the buildings since the buildings were initially constructed. Converting the heating equipment throughout these buildings from steam to hot water can improve the efficiency of the system in those buildings along with the comfort level experienced by the tenants. Hot water heating systems can operate at lower temperatures while consuming less energy. Hot water systems eliminate losses due to condensate trap operations, as well. With the addition of controls on fans and radiators, the heating systems would be allowed to better respond to the building needs and provide comfort for occupants.

Conversion of internal mechanical systems will be different for each building depending upon the manner in which those mechanical systems are configured. For purposes of this Master Plan, buildings have been classified in one of three different categories:

3.4.1 HOT WATER BUILDINGS

Buildings with hot water loops that transition hot water or steam to their internal HVAC have proven to have more efficient heating systems than those with internal steam loops.

The hot water systems can be operated easily and are able to quickly respond to the needs of tenants and users.

Buildings with internal hot water mechanical systems are the easiest buildings to convert to hot water delivery service, wether its replacing on-site production or district steam service. In most cases the conversion will require the shell and tube steam to hot water heat exchangers to be removed and replaced with a water to water exchanger, typically a plate and frame or brazed plate exchanger. These buildings will likely also require upgrades to their controls and piping. Any domestic hot water steam-to-hot water heat exchangers will need to be analyzed to see if they can be used as water-to-water heat exchangers and still meet the heating demands of the building. If not, they could be replaced or additional heat exchangers could be added. Most of the existing buildings 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.

3.4.2 HW/STEAM BUILDINGS

Buildings with a mix of hot water and steam loops throughout their building are considered hybrid systems. They have both a hot water heating closed loop and a steam heating loop. From site surveys and building visits, it was common to see these buildings with a hot water perimeter radiation loop and steam coils in their air handling units, although these systems can vary slightly or drastically from building to building. To convert these buildings to hot water will require a water-to-water heat exchanger, supply piping for steam equipment and addition of controls upgrades. If the condensate return is in good condition and of adequate size it can be used as the return for a new hot water system. If the condensate piping does not pass a hydraulic pressure test, then new return piping will need to be run with the supply piping. Any steam coils in the air ventilation system should be evaluated to see if they are capable of using hot water to meet the heating demand. If existing steam coils cannot be used as a hot water coil, a new hot water coil will need to be added in place of the old steam coil. The new coil may change the pressure drop in the air handling unit, requiring verification that the fan has capacity to overcome the additional pressure drop.

3.4.3 STEAM BUILDINGS

Buildings using steam service throughout their building apply 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 if of adequate capacity. In this case the major modification work will be confined to the basement or mechanical room to install heat exchangers and circulating pumps. The main heat exchangers between the system hot water loop and the buildings' internal hot water loops can be fitted with control valves and outdoor/indoor controllers that respond to outdoor temperature. The closed loop water system will provide better comfort and reduce energy costs. The major saving is reducing consumption and controlling the wasted discarding of the condensate into the sewer. More complicated building systems (ex., utilization of air handling units for ventilation) will need to evaluate coil replacement to handle the heating loads and to provide better system controls. These types of buildings will see a major improvement in the building comfort, operation improvement and energy consumption reduction. Based on the team's experience with building heating system conversions from steam to hot water, the reduction of energy usage can vary from 20% to 40%. Buildings with steam heating equipment may also be converted to a hot water heating system by reusing radiators and most of the existing piping, but the cost of conversion will likely be more extensive than that of the hot water buildings.

3.4.4 CONVERSION COST

In a hot water heated building, as described in section 3.4.1, the majority of the conversion costs consist of work in the mechanical room with the installation of new heat exchanger equipment and controls. The estimated cost to convert this type of installation is minimal and is shown in the Table 3.10. Buildings described in section 3.4.2 typically require the heating coils in the existing air handling equipment to be replaced, including modifications to the existing steam piping. If condensate piping is too small for the flow then new hot water return piping will need to be installed. Hot water pumps, heat exchangers, hydronic accessories and controls are also required. Buildings described in section 3.4.3 present additional challenges and need to be investigated thoroughly. In many instances the terminal equipment and most of the distribution piping may be reused with modifications required to eliminate the steam traps and to add control equipment. These buildings often require the replacement of heating coils in the air handlers with added control; and the installation of heat exchangers and hydronic accessories.

Table 3.10 Summary of estimated cost to convert each category of building

CATEGORY	BUILDING SIZE	ESTIMATED COST PER SQ. FT.
Hot Water	Up to 60,000 Sq. Ft. 90,000 - 250,000 Sq. Ft.	$1.15 .80
Hot Water and Steam	Up to 150,000 Sq. Ft. 155,000 - 250,000 Sq. Ft.	1.90 1.65
Steam	Up to 100,000 Sq. Ft. 110,000 - 250,000 Sq. Ft.	4.50 2.75

NOTES The above cost estimates account for the mechanical conversion costs only, no general construction costs are included. Cost estimates are plus or minus 30%.

3.5 Chilled Water Expansion

The chilled water system currently serves a cluster of three buildings in close proximity to each other and from a central cooling plant located in a customer building. The chiller is a steam absorption unit which is fed by the steam distribution system. The cooling plant operates from mid-May thru mid-October, weather dependent. The short-term potential of expanding the chilled water system is limited to a few adjoining buildings, such as Duluth City Hall and the Public Library. Most of the buildings on the system have very limited needs for year-round cooling service due to the local climate and a lack of winter cooling load. The cooling system does however, have the capability to serve additional cooling needs of the community if this need were to develop.

Through site visits, our team determined that a number of buildings were relying on small chillers, utilizing city water service for condenser water heat rejection. Some office buildings have deactivated their old chillers and are relying on direct city water service in the cooling loop to provide some cooling in on extremely warm days. A number of steam customers have installed unitary heat pumps with a core water loop for heat rejection and a cooling tower to provide air conditioning in office spaces. In those instances, since it is a cooling loop, the perimeter steam radiators provide the space heating. Other buildings have made major rehabilitations to their HVAC systems by incorporating the water-to-air unitary heat pumps which provide heating and cooling for spaces in their building.

Two hospitals have been major institutional customer anchors on the east end of downtown, each using old electric driven chillers with substantial capacity. The two hospital campuses have a number of buildings with individual chillers and cooling towers and some with air cooled chillers. There is a possibility of aggregating the load of the hospital campuses and serving that load from a centralized chilled water production facility. This may provide some efficiency to the hospitals and free up some building space. The central system could then benefit from the diversity of the hospitals' loads and establish a platform for growing a chilled water loop on the east end of the downtown area.

3.6 Existing and New Customer Potential

The following sections summarize heating usage for existing customers and potential new customers in close proximity to the existing steam and hot water systems. The sections also outline a Five-Year Master Plan and a longer-term System Vision for how the system could be expanded.

The potential new customers are primarily:

- Existing buildings within the downtown area, not yet connected to the steam system.
- Planned new development within the downtown area, primarily on the west side.
- Existing buildings in close proximity to the steam system, primarily on the east side.
- Existing buildings in the Canal Park area.

Future new developments can also be anticipated in the Canal Park area west of the Great Lakes Aquarium for industrial usage and lakeside growth for tourism.

3.6.1 GROSS HEATING LOAD POTENTIAL

The gross heating usage in the area as described above is about 665,000 MMBtu/year. About 80%, or approximately 530,000 MMBtu/year, is presently connected to the steam and hot water systems, Table 3.11.

In Table 3.12 the gross heating usage has been adjusted to account only for potential heating load feasible to connect to the steam and hot water systems as well as potential energy conservation at DECC.

3.6.2 FIVE-YEAR MASTER PLAN

In the Five-Year Master Plan, 50% of the downtown buildings not yet connected to the system are projected to be connected to the existing steam system.

The expanded customer base includes potential customers located just east of the current downtown service area. These buildings could be connected to a small hot water network that is fed off the existing steam network. This extension assumes these buildings can accept service from a hot water network with limited conversion challenges. A new hot water network is also recommended for the west end of the existing steam network. New development in the area is also assumed to connect to this hot water loop.

In the Canal Park area, the existing hot water system is assumed to be expanded to include existing steam customers as well as new customers, with a focus on buildings exceeding 10,000 square feet.

Table 3.11 Summary of existing customers and potential customers

BUILDING GROUP	NUMBER OF BUILDINGS	ANNUAL USAGE (MMBtu/yr)
Existing Steam Customers	177	442,199
Existing Hot Water Customers	6	86,584
Total Existing	183	528,783
Potential Downtown Customers	118	79,652
Potential Canal Park Customers	29	29,046
Potential Customers in NE Downtown	95	27,033
Total Potential	242	135,731
Grand Total Existing and Potential	425	664,514

Table 3.12 Summary of existing customers and adjusted potential customers

BUILDING GROUP	NUMBER OF BUILDINGS	ANNUAL USAGE (MMBtu/yr)
Existing Steam Customers	157	392,337
Existing Hot Water Customers	6	62,584
Existing Steam Customer Converted to HW—Canal Park	5	6,871
Existing Steam Customer Converted to HW—NW Downtown	15	42,991
Total Existing	183	504,783[1]
Potential Downtown Customers	74	71,445
Potential Canal Park Customers	23	27,884
Potential Customers in NE Downtown	38	21,270
Total Potential	135	120,599
Grand Total Existing and Potential	318	625,382

NOTES [1]Revised consumption based upon improvements made at DECC (see section 3.3.1)
Potential customers adjusted to include all buildings over 10,000 Sq. Ft. and only 30% of buildings under 10,000 Sq. Ft.

Under these assumptions, the Master Plan would increase the percentage of connected buildings to the steam and hot water systems to about 90% of total energy usage in the community, or 579,000 MMBtu/year out of the gross heating usage, adjusted for energy conservation at DECC, of 640,000 MMBtu/year, Table 3.13.

3.6.3 SYSTEM VISION—CUSTOMER OUTLOOK

The Five-Year Master Plan projects 262 buildings connected to the system. The (20 year) System Vision prescribes the conversion of the majority of the steam system to hot water, connection of 75% of the potential customers in or adjacent to the existing network, resulting in 291 buildings connected to the system.

The overall amount of connected customer buildings increases, however, the total energy supplied to the connected buildings will decrease compared to the present due to avoided condensate losses and building efficiency improvements. For reasons described in section 3.4, buildings utilizing hot water in lieu of steam typically consume approximately 20% less energy. Table 3.14 provides a reduced system load based upon these assumptions.

Table 3.13 Summary of Five-Year Master Plan customers

BUILDING GROUP	NUMBER OF BUILDINGS	ANNUAL USAGE (MMBtu/yr)
Existing Steam Customers	157	392,337
Existing Hot Water Customers	6	62,584
Existing Steam Customer Converted to HW - Canal Park	5	6,871
Existing Steam Customer Converted to HW - NW Downtown	15	42,991
Total Existing	183	504,783
Potential Downtown Customers	37	35,722
Potential Canal Park Customers	23	27,884
Potential Customers in NE Downtown	19	10,635
Total Potential	79	74,242
Grand Total Existing and Potential	262	579,024

3.7 Conclusion

Duluth Steam's service network is currently distributed throughout the majority of the CBD and the Canal Park area. The focus of this Master Plan is to improve the current district heating service, improve building efficiency, reduce energy usage, and expand the customer base. Under the Master Plan, it is assumed that the customer base could be expanded from 183 buildings to an estimated 262 buildings, while converting 50,000 MMBtu of energy consumption per year from steam to hot water service. The System Vision includes connecting an additional 29 buildings and converting a majority of the customers to hot water, all while reducing the overall system energy consumption.

Table 3.14 Summary of System Vision customers

BUILDING GROUP	NUMBER OF BUILDINGS	ANNUAL USAGE (MMBtu/yr)
Existing Steam Customers[1]	157	313,869
Existing Hot Water Customers	6	62,584
Existing steam Customer Converted to HW - Canal Park	5	6,871
Existing Steam Customer Converted to HW—NW Downtown[1]	15	42,991
Total Existing	183	426,315
Potential Downtown Customers	56	53,584
Potential Canal Park Customers	23	27,884
Potential Customers in NE Downtown	29	15,953
Total Potential	108	97,420
Grand Total Existing and Potential	291	523,736

NOTES [1]Consumption reduced by 20% due to avoided internal "overuse."
75% of potential buildings over 10,000 Sq. Ft. and 30% smaller than 10,000 Sq. Ft. included in potential downtown and NE customers. Canal Park potential includes all buildings over 10,000 Sq. Ft. and 30% of buildings fewer than 10,000 Sq. Ft.

4. Distribution

Duluth Steam has several distribution networks which include steam, hot water and chilled water. The steam network is the most expansive out of the three, extending throughout the CBD and Canal Park area. The hot water and chilled water networks are more localized. The hot water network serves a good portion of the Canal Park area and the chilled water network serves several county and federal buildings on the west end of the CBD. These distribution networks provide the means to connect buildings to the system throughout the CBD.

4.1 Steam

The steam distribution system was originally constructed in the early 1930s. The distribution system's original design consisted of steel piping wrapped in up to 3" of asbestos

Downtown Duluth **EXISTING STEAM SERVICE**

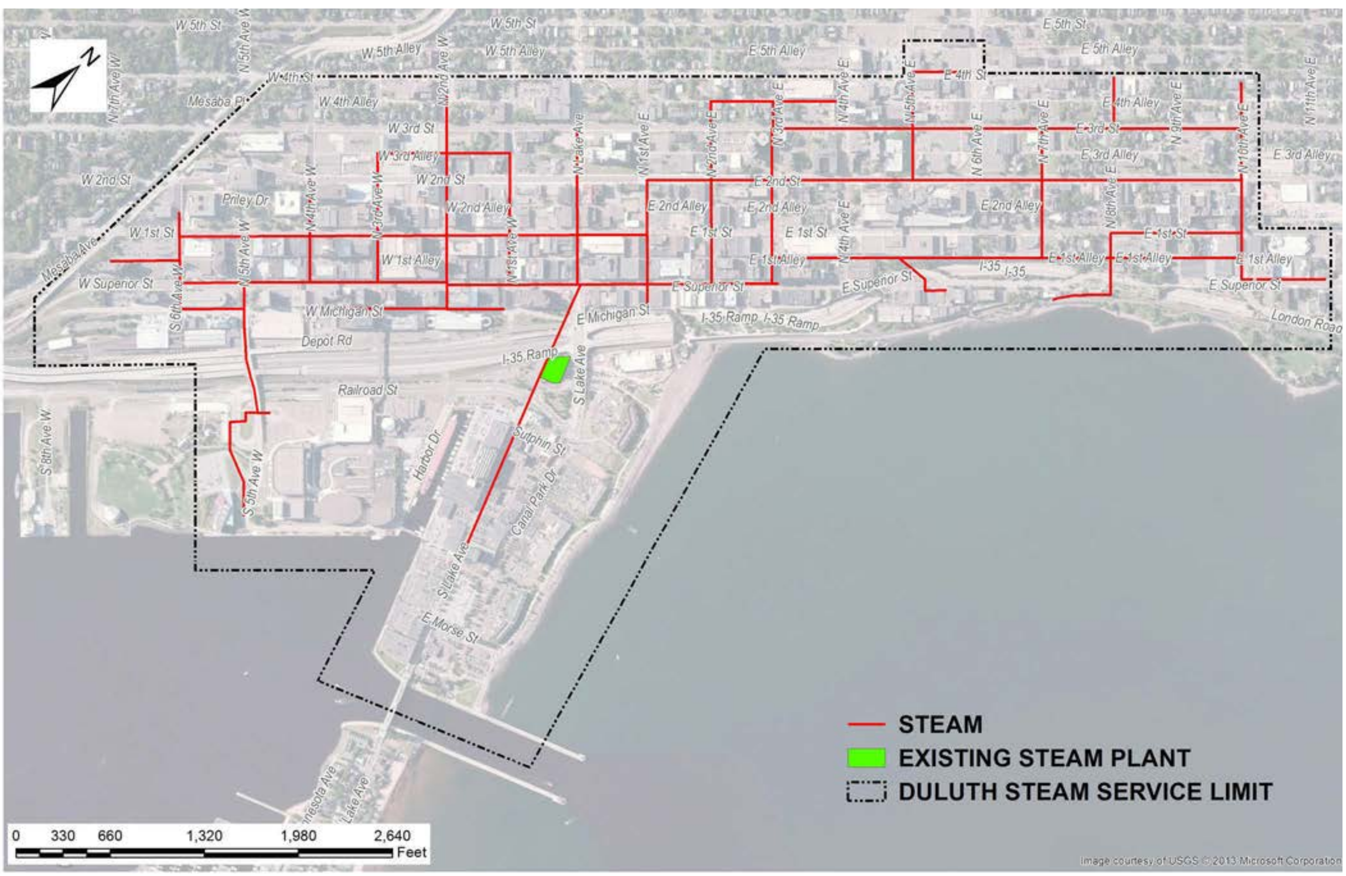


Figure 4.1 General routing of the current distribution network for Duluth Steam

insulation running in a square or rectangle conduit buried below the streets and sidewalks, approximately 3 feet below the surface. Throughout the years the steam system has expanded, with a majority of the distribution network as pre-insulated steam piping wrapped in asbestos or mineral wool. Services and repairs completed within the last 10 to 15 years have used a schedule 40 steel carrier pipe wrapped with 2" of mineral wool insulation, with a 1" air gap between the mineral wool and a galvanized casing. The casing is then covered with 1" of foam insulation and wrapped with HDPE. The general routing of the current distribution network is shown in Figure 4.1 (previous page).

4.1.1 STEAM DISTRIBUTION DYNAMICS

The steam network consists of over 10 miles of schedule 40 steel piping ranging in size from ½" to 20" in diameter. Table 4.1 shows the different pipe sizes and accompanying lengths that are found in the steam distribution network. The table includes both exterior and interior distribution piping. The interior piping includes laterals running through basements or buildings serving multiple customers and service extensions to mechanical rooms.

Table 4.1 Steam network pipe sizes and lengths

PIPE DIAMETER (INCHES)	TRENCH LENGTH (FEET)
0.5	900
0.75	1,100
1	3,700
1.25	2,400
1.5	2,900
2	6,300
2.5	20
3	3,400
4	11,500
6	9,700
8	10,800
10	1,500
12	5,400
14	100
18	1,900
20	700
Total	62,320

When the steam system was constructed it was thought the west end would make up a majority of the load, thus the steam mains west of Lake Avenue are sized much larger than the main pipes to the east. The eastern mains have a smaller diameter but are still sufficient to serve the hospital loads and current customer base, which happen to make up the majority of the system load. The steam network as a whole has sufficient capacity to serve the current customer demand and customer winter peaks. During peak periods the plant is able to deliver at least 100 psi steam to all of the customers on the system. During certain times of the year, several customers on the east end require high pressure steam. When their steam supply pressure needs approach 100 psi, the Plant operators will increase the supply pressure to 155 psi (compared to the normal 150 psi supply pressure).

The team prepared and analyzed a hydraulic model for the distribution system and found that the model shows less pressure drop than what has been observed in the network. The age and complexity of the system provides many unknowns that can cause an increase in the pressure losses, which may not be accounted for in a theoretical model. Some of these differences could be derived from the condition of the inner wall of the pipe, higher than estimated pressure drop across traps and fittings, and partially closed valves.

One area recognized for its substantial pressure drop is located on the east end, just west of one of the hospitals where the main line reduces from 12" to 6" and then reduces further to 4" before increasing back up to 6". This bottle neck is scheduled to be replaced with a new 6" pipe when repairs are completed on city infrastructure that incurred flood damage in 2012.

4.1.2 HEAT LOSSES

The distribution network has many high pressure steam traps that collect condensate and discard it into the storm sewer. From above ground, the condensate can be seen as vapor exiting from vents and storm sewers near the steam line. This condensate is unaccounted for and is not metered. The amount actually being discarded is unknown but can be assumed as the difference between metered customer usage and the metered supply steam line leaving the plant.

After a customer building uses the steam, the condensate from the building loop is discarded to the drain, which can account for up to 10% of the building's consumption. Customers could reduce their energy consumption by reclaiming the thermal energy in the condensate before dumping it to the sewer. Another option would be to collect the condensate and send it back to the plant through a separate distribution system.

The higher the steam pressure, the higher the distribution temperature. At higher distribution temperatures there is a larger temperature difference between the steam running through the pipes and the ambient or surrounding temperature. This larger temperature differential leads to a higher heat loss in the distribution network. If it were possible to lower the steam pressure, thermal losses would also be reduced.

Most of the steam system distribution piping was installed with 2" to 3" of asbestos wrapping. As noted in a 2006 Johnson Controls report, the insulation over the years has degraded and in most places is now 1.5" thick or completely washed out. Between the plant distribution output and the measured consumption at each customer building, there are unaccounted losses of 27% in the system. This has been attributed to distribution thermal and condensate losses.

Johnson Controls completed insulation repairs in 2006 by injecting closed cell foam insulation into steam conduits on Superior Street, 1st Street and 3rd Avenue East. The foam surrounds the pipe and fills the conduit, sealing out ground water and improving the insulation value. The general locations and lengths are listed in Table 4.2.

Table 4.2 Distribution pipes with upgraded insulation

LOCATION	PIPE SIZE (INCHES)	CONDUIT SIZE (INxIN)	LENGTH (LF)
Superior Street	12	33.5x27	1,300
Superior Street	14	28x25	470
Superior Street	18	33x35	1,790
Superior Street	12	33.527	460
1st Street	12	33.5x27	1,790
3rd Avenue East	8	24x30	140
Total			5,950

The insulation effort covered a small section of the steam system but did improve overall system efficiency. Duluth Steam distribution staff clarified that the addition of spray foam to the conduits prevented snow from melting above the steam line, which it did prior to the insulation upgrade.

Along with filling sections of the steam conduit with closed cell foam insulation, Johnson Controls provided removable insulation covers for 128 pipe fittings (including gate, ball, globe, triple offset valves, and guides). These were installed on previously non-insulated fittings located in manholes. The specific fittings are listed in Table 4.3.

Table 4.3 Insulated Fittings

FITTING	SIZE (INCHES)	QUANTITY
Gate Valve	1.25	2
Gate Valve	1.5	3
Ball Valve	2	3
Globe Valve	2	1
Gate Valve	2	5
Gate Valve	3	10
Ball Valve	4	3
Guide	4	1
Gate Valve	4	16
Gate Valve	6	27
Gate Valve	8	28
Triple Offset Valve	10	1
Gate Valve	12	24
Triple Offset Valve	18	4
Total		128

The total cost for the conduit spray foam insulation and removable fitting insulation covers was over $1.2 million and covered approximately 10% of the steam network. If the steam system is expected to be utilized for a long period of time, more extensive insulation should be investigated and investment should be contemplated to further reduce thermal heat losses in more of the existing steam network.

4.1.3 SHORT-TERM IMPROVEMENTS

A recent flood damaged close to 500 feet of the 6"and 4" steam line located in the 1st Street alleyway that extends from 3rd Ave East to 8th Ave East. The damaged piping will be replaced and 6" steam piping will be installed in place of the 4" bottle neck located at the intersection of the alley way and 7th Ave East.

Damaged or missing insulation within a manhole or a building is repaired or installed when identified. In locations where the insulation is prone to abuse, it should be covered with aluminum jacketing for additional protection.

Expansion joints are an area prone to leak as the joints age, and repairs should continue to be completed as necessary. An 8" expansion joint was recently repaired at 8th Avenue East and 2nd Street.

Duluth Steam is typically required to repair two to three manholes and vaults per year. The majority of the work in the vaults is repairing or replacing the roof and repairing of cracks. The vaults, which date back to when the system was originally installed in the 1930s, are typically found to be in acceptable condition while the later vaults that present issues. This could be from differences in concrete used and the degradation of the steel rebar from salts. The new vault roof repairs are now using stainless steel rebar and concrete cured outside of the manhole to avoid the concrete curing too fast from the live steam in the vault. One manhole scheduled for a rebuild is located at 4th Avenue West and 1st Street. Another manhole will be repaired before this Master Plan is completed, located at 2nd Avenue West and the alley. This manhole is in a location where the street has been undermined by rain and flooding.

4.1.4 LONG-TERM IMPROVEMENTS

Duluth Steam will need to evaluate how much investment should be made into the steam distribution system, based upon the timing and direction of system improvements that are planned. Insulation upgrades to the existing steam lines should be done when access is available. The existing steam piping and insulation has served its useful life and over the years has apparently reached a point where the insulation is insufficient and thermal losses are high. During the winter this can be seen by the lack of snow over the steam pipes which run under the sidewalks or streets.

Over time, the concrete conduit has also degraded, allowing varying amounts of moisture to come in contact with the insulation. Much of the insulation had been damaged by moisture or in some cases completely washed away by major leaks. As a result, the insulating value of the remaining insulation is significantly reduced, leading to excessive heat loss from the steam piping and contribution to unaccounted losses. Condensate return, where possible, would also greatly enhance system efficiency (see 4.5.2).

4.2 Hot Water

Duluth Steam added a hot water network in 2000 that currently serves the Canal Park area. The network is split into two separate branches, one feeding the DECC and AMSOIL Arena through 12" and 10" pre-insulated Schedule 40 pipes and the other branch extending down Canal Park

Drive to serve three hotels and a microbrewery. The hot water pipes extending down Canal Park Drive are 8" mains with 6" service laterals to the customer buildings. Both branches supply hot water at 215°F. Figure 4.2 provides the general routing of the hot water pipe.

4.2.1 CAPACITY

The network is split into two branches. The convention center branch has sufficient capacity to serve additional load once the DECC improves its energy efficiency and the hotel lateral has more than enough capacity to serve the current load with potential to serve more load. The approximate trench-feet of installed pipe for the entire hot water network are shown in Table 4.4.

4.2.2 HEAT LOSSES

A hot water network has significantly lower thermal losses than a high pressure steam system, primarily due to a lower operating temperature and does not have any losses associated with condensate traps. A new hot water network will have the latest improvements in insulation technology and jacketing, protecting and insulating the pipe for at least 50 years. Thermal losses on an annual basis are typically between 5 and 10% based on building load concentration. On top of lower thermal losses, hot water systems have supply and return piping, allowing for the thermal energy not consumed to be returned back to the plant for

Canal Park ▶▶ EXISTING HOT WATER SERVICE

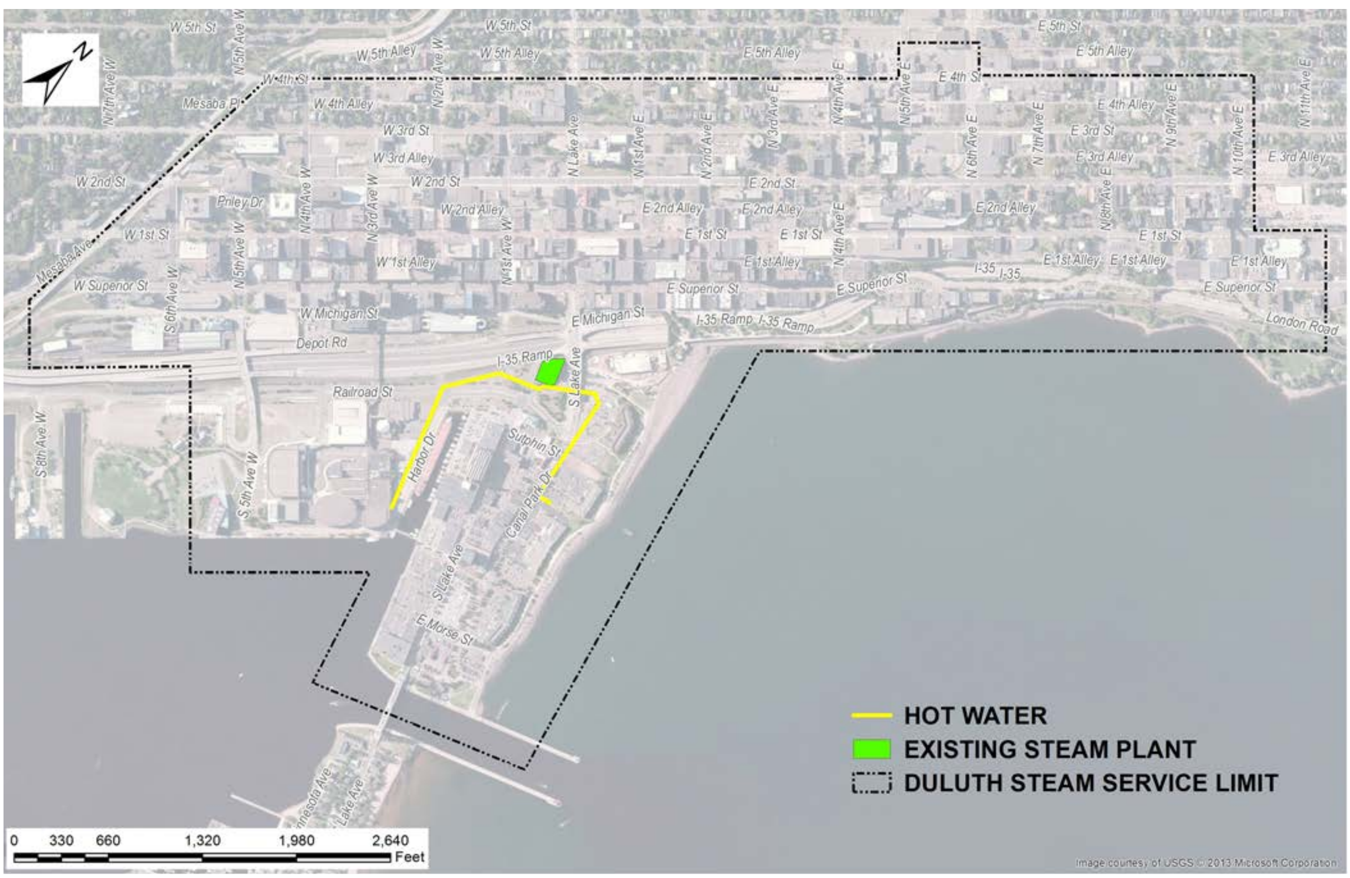


Figure 4.2 Hot water system map

Table 4.4 Hot water network pipe sizes and installed lengths

PIPE DIAMETER	TRENCH FEET
12	1,600
8	1,500
6	470
4	40
Total	3,610

reuse, thus preventing thermal energy from being lost to the drain as seen in the current one-pipe steam system.

4.2.3 SHORT-TERM IMPROVEMENTS

The current hot water system appears to be in good condition and does not require any significant improvements

4.2.4 LONG-TERM IMPROVEMENTS

Hot water systems are designed to last over 50 years. Maintaining proper protection of the pipe insulating from the elements, and keeping up with water treatment will have the system operating efficiently for many years. The current hot water distribution system doesn't incorporate a leak detection system. Going forward, a leak detection should be installed with any new hot water network, which will allow the distribution staff to quickly locate any leaks in the pipe or a break in the pipe jacketing. Quickly identifying leaks prevents corrosion on the outside of the pipe and degradation of the insulation.

4.3 Heat Loss Comparison

If the entire steam network were to be converted to hot water, the thermal losses of the distribution system would be reduced. The reduction in heat loss would enable water usage, fuel consumption, and greenhouse gas emissions to also be reduced. Table 4.5 compares actual system steam pipe thermal losses with a calculated thermal loss if the entire steam network were converted to hot water. The calculations use a thermal loss factor 7.5% for hot water, which is based on the team's experience with similar hot water district energy networks. The steam heat loss is measured from real data of the system and consists of the difference between the measured plant supply and the metered consumer data. The difference is assumed to be distribution and heat losses.

4.4 Chilled Water

Duluth Steam has a chilled water distribution system that serves five buildings on the west end of the CBD. The distribution system is made up of high density polyethylene (HDPE) pipes ranging in size from 4"to 10", with a majority of the main lines as 10". The HDPE pipe conforms to ASTM D3035 and is rated for 130 psi per the design specification.

Although not an active network, there are 10" HDPE supply and return distribution lines in the Canal Park district fed off of a 12" main in place to serve the DECC from the Duluth Steam Plant.

4.4.1 CAPACITY

The supply and return pipes leaving the chilled water plant are 10" high density polyethylene ("HDPE"). Depending upon the temperature differential (delta T) between the supply and return of the individual customers, the capacity of this pipe varies. The higher

Table 4.5 Heat loss comparison: steam versus hot water

	PIPE HEAT LOSS (MMBtu/yr)	WATER (GALLONS)	TONS OF COAL
Steam	133,189	16,648,620	11,933
Hot Water	39,280	0	3,519
Conversion Savings	93,909	16,648,620	8,414

NOTES Steam heat loss from measured data.
1,180 Btu/lb steam.
Hot water heat loss assumed to be 7.5%.
Western Coal 9,089 Btu/lb.
Water savings include metered condensate sent to sewer and condensate associated with the steam main line heat loss

Downtown Duluth CHILLED WATER DISTRIBUTION SYSTEM

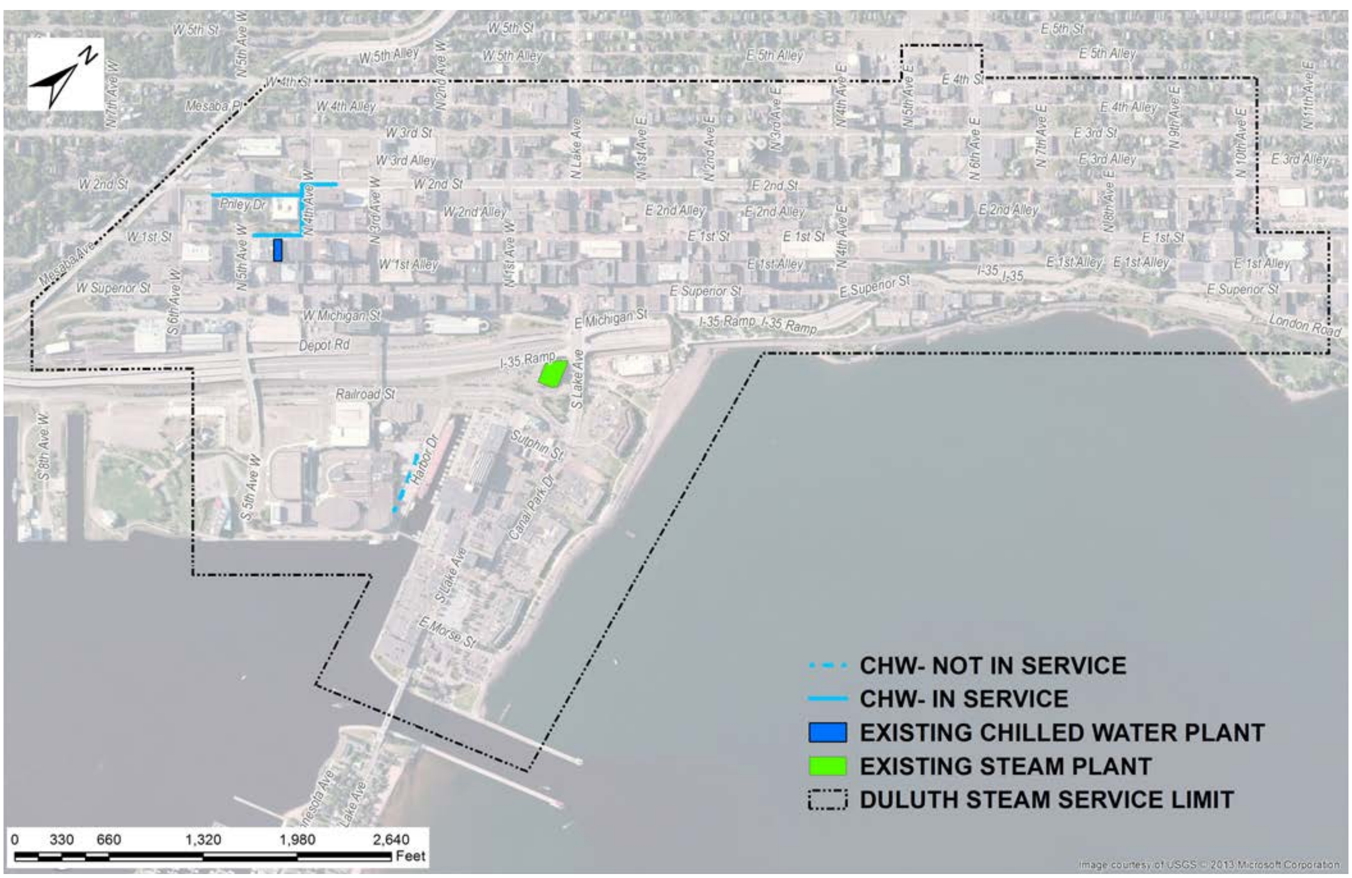


Figure 4.3 West end central business district chilled water system

Table 4.6 HDPE DR11 pipe capacity

PIPE DIAMETER (IN)	FLOWRATE (GPM)	COOLING CAPACITY AT TEMPERATURE DIFFERENTIAL (TONS)	
		12 Degrees F	16 Degrees F
6	290	150	190
8	575	290	380
10	1,000	500	670
12	1,600	800	1,010

NOTES Design flow rate to maintain a velocity below 10 ft/s and a pressure drop of ~1 ft water column per 100 feet, whichever is approached first.

the delta T at the customer site the more tons of cooling that can be delivered through the distribution network. Table 4.6 provides estimated tonnage based on pipe size and differential temperatures for HDPE pipe.

With a current customer peak demand of around 500 tons and assuming a delta T of 12°F, the existing 10" supply and return pipes have reached their design capacity. Improvement to the capacity of the existing system can be done through increasing the temperature differential at the customer buildings. If the temperature differential is increased from 12°F to 16°F, the capacity of the current piping exiting the plant can be increased by 25%.

4.4.2 SHORT-TERM IMPROVEMENTS

No significant improvements are necessary for the current chilled water network.

4.4.3 LONG-TERM IMPROVEMENTS

There are no foreseen improvements required for the chilled water network; it is in good operating condition.

4.5 Distribution System Advancements

4.5.1 HOT WATER DISTRIBUTION TO EXISTING CUSTOMERS

Extending the Canal Park current hot water network to serve existing and new customers in Canal Park and across Interstate 35 could be done by one of several methods. As excavating across the Interstate and railway is not feasible, the hot water pipes can be extended to the downtown by hanging under bridges or skywalks or by directionally drilling underneath the Interstate and railway. The following options were considered for purposes of this Master Plan.

4.5.1.1 Expanded Canal Park Hot Water Loop

The two existing hot water networks in Canal Park could be connected into one system and expanded to provide service to the entire Canal Park area. The looped system will allow most buildings in the Canal Park area the option to connect to the hot water network should they choose to do so.

The estimated cost to extend and connect the existing hot water network in Canal Park is shown Table 4.7.

Table 4.7 Distribution estimate for hot water Canal Park expansion

	TRENCH FEET	ESTIMATED COST
Main Lines	6,860	$4,609,000
Service Lines	2,335	1,759,000
Grand Total	9,195	$6,368,000

Canal Park ▶▶ PROPOSED HOT WATER SERVICE EXTENSION

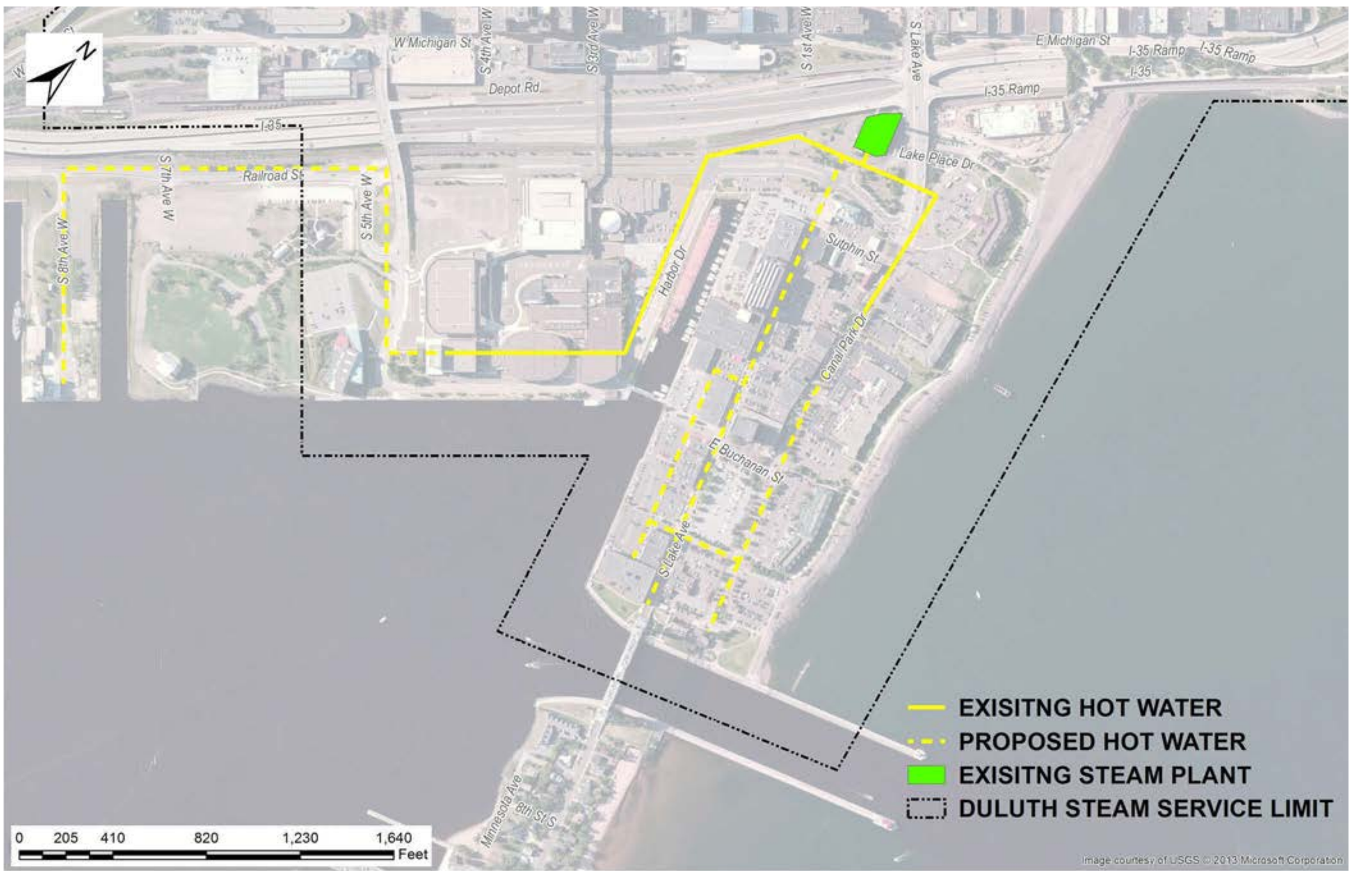


Figure 4.4 Proposed hot water system expansion loop to serve entire Canal Park area

4.5.1.2 Extension of Canal Park Distribution

To initially serve the west end of the CBD with hot water and provide capacity for further growth as well as a future loop for redundancy, a pair of 10" hot water pipes can be added. The new pipes could be extended from the main 12" hot water pipes heading west to serve the DECC. This main already has tees installed after the DECC takeoff, allowing for a future connection and extension. The new pipes could extend along W Railroad Street and cross

Interstate 35 under the 5th Avenue W Bridge. Another possible crossing point is the pedestrian skywalk that extends from the DECC and the CBD. This skywalk is being rebuilt and is in the design stage. A request to have the skywalk designed to be capable of supporting two hot water pipes should be made as soon as possible. Both bridges will need to be verified for the capability of supporting hot water pipes. The 5th Avenue Bridge is currently supporting an existing active steam line that supplies the Great Lakes Aquarium.

Downtown Duluth ▶▶ PROPOSED HOT WATER SYSTEM EXPANSION PLAN

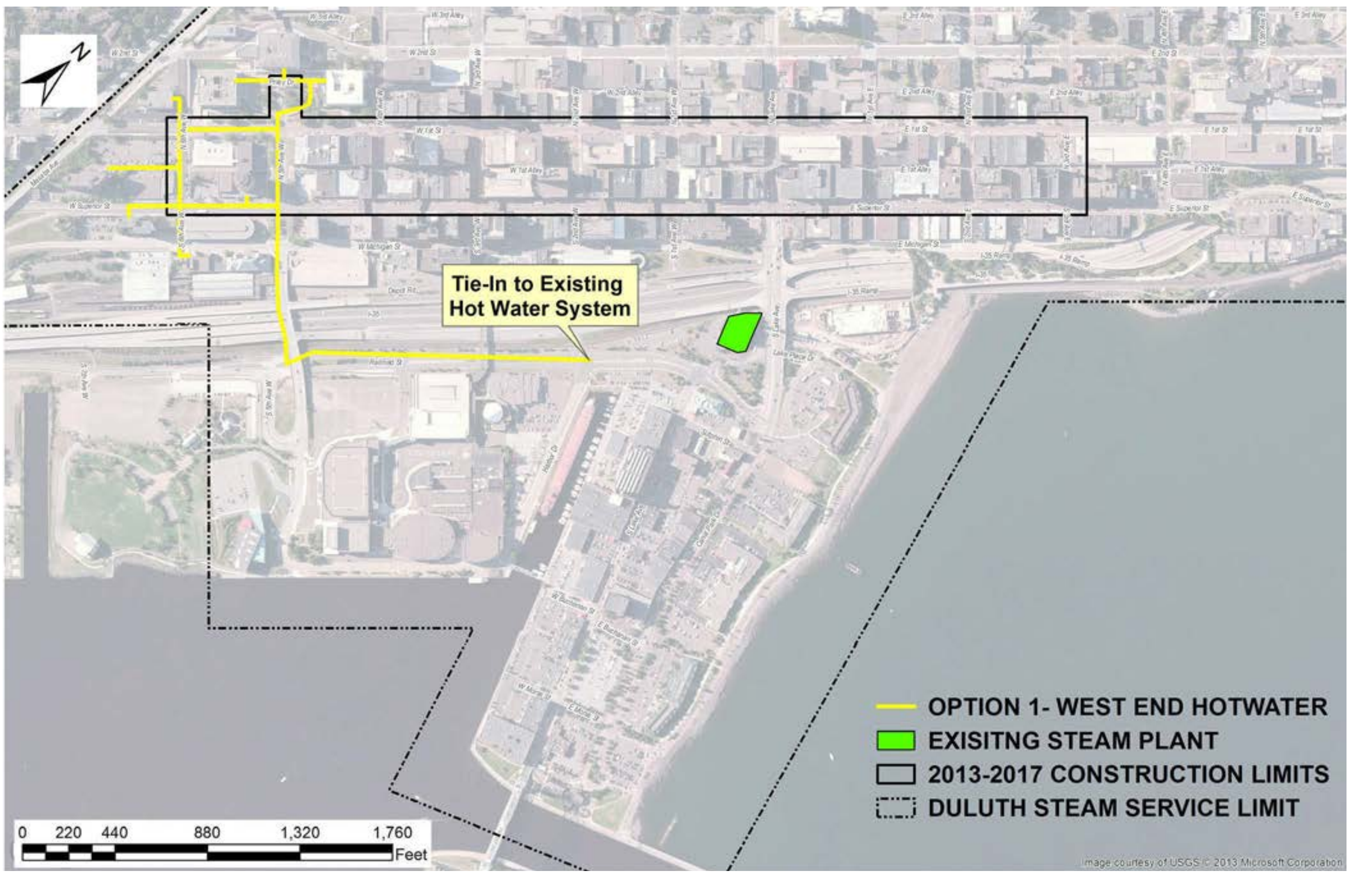


Figure 4.5 Hot water expansion to downtown via 5th Avenue W bridge

The estimated cost to install an extension off of the existing hot water western main to the downtown district is shown in Table 4.8. This budget assumes that either the 5th Avenue W Bridge or the pedestrian bridge is capable of supporting the new hot water pipes.

Table 4.8 Distribution estimate for hot water expansion via 5th Avenue W Bridge

	TRENCH FEET	ESTIMATED COST
Main Lines	4,670	$4,704,000
Service Lines	1,770	2,304,000
Grand Total	6,440	$7,008,000

4.5.1.3 S Lake Avenue Hot Water System

Another option for extending Duluth Steam's existing hot water network to the downtown area is to extend a pair of pipes through the existing steam tunnels or across the South Lake Avenue Bridge, and is shown in Figure 4.6. The extension is sized to account for the entire Duluth Steam network on the north side of Interstate 35, which requires the pipe to be 20" in diameter. The distribution piping would cross Interstate 35 and head down W. Superior Street to serve the west end of the system. The buildings west of N. 4th Avenue West are currently the easiest to connect to a hot water network, but the distribution pipes installed on W Superior Street are sized to account for future extensions to existing customers if they decide to receive hot water service.

Table 4.9 shows the estimated cost to install a pipe across the South Lake Avenue Bridge, assuming the bridge can hold a pair of 20" diameter hot water pipes. This also includes the cost to install the mains and services lines to feed the west end.

The estimated distribution system heat loss savings achieved by converting the west end to hot water are shown in Table 4.1.0. Both scenarios described in Sections 4.5.1.1 and 4.5.1.2 have similar heat losses with a little variation due to different lengths. This difference is

Downtown Duluth PROPOSED HOT WATER SERVICE EXTENSION PLAN, ALTERNATE

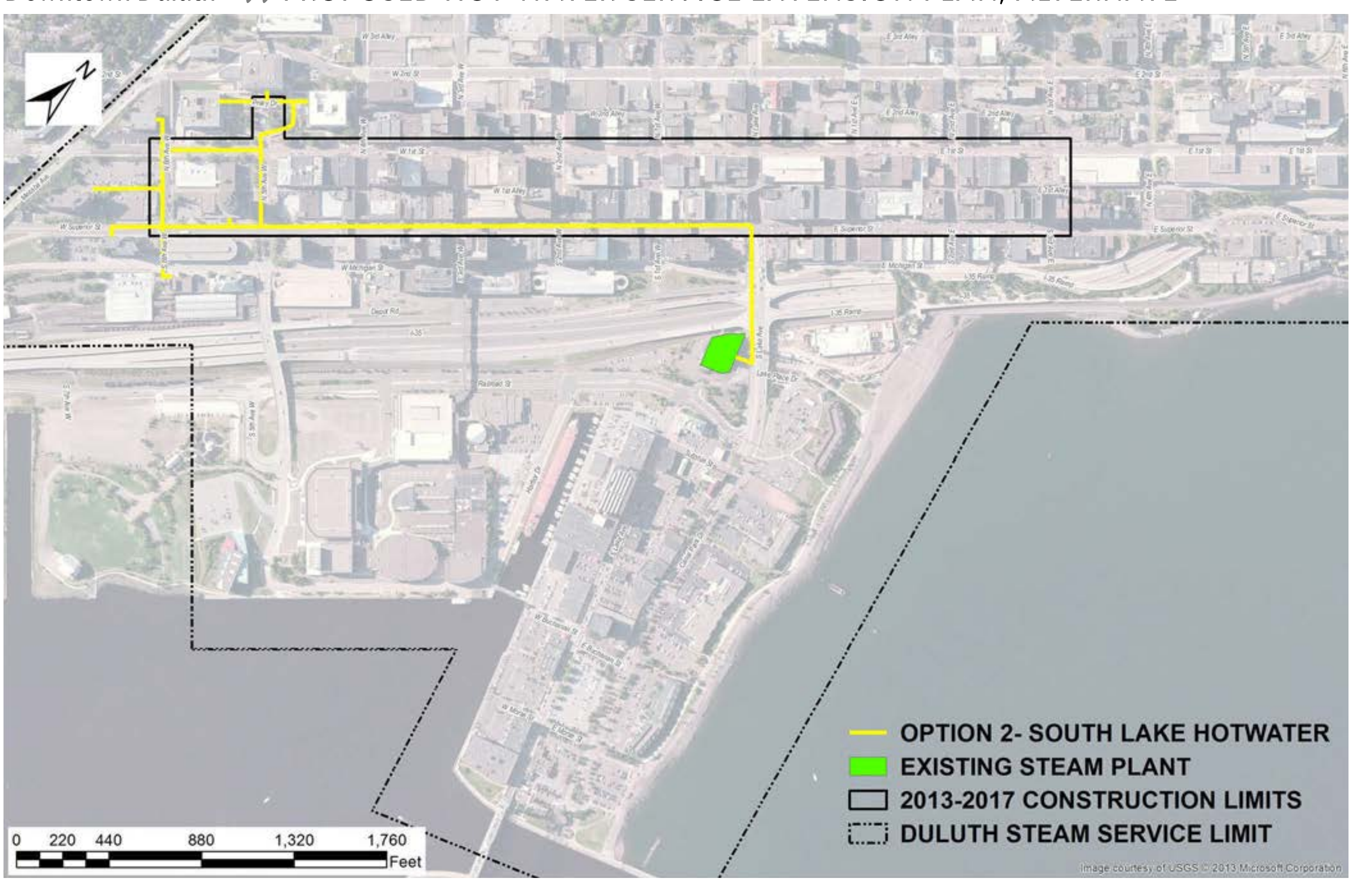


Figure 4.6 Hot water expansion to downtown via the S Lake Avenue bridge

Table 4.9 Distribution estimate for hot water expansion via S Lake Ave Bridge

	TRENCH FEET	ESTIMATED COST
Main Lines	5,610	$6,506,000
Service Lines	1,770	2,304,000
Grand Total	7,380	$8,810,000

Table 4.10 Estimated savings derived from converting Downtown West to hot water

	PIPE HEAT LOSS (MMBtu/yr)	WATER (GALLONS)	TONS OF COAL
Steam	5,886	735,732	527
Hot Water	4,084	0	366
Conversion Savings	1,802	735,732	161

NOTES Steam assumed overall heat loss of 13.7% for west end network. Hot water assumed overall heat loss of 9.5% for west end hot water network. Hot water consumption reduced by 10% for elimination of condensate losses

minimal and assumed to be the same for the purpose of this report. shows the estimated heat loss, water usage attributed to the distribution networks thermal loss, and fuel savings as a result of those losses.

4.5.1.4 Possible Full Loop

To serve the entire steam network customer base with hot water will require a significant capital investment. Although it is technically possible to install the entire hot water distribution network within the 5 year Master Plan, it is more likely that this implementation would occur over a longer period of time and the steam network would be kept in service to meet the needs of steam buildings. Figure 4.7 displays what a potential full loop covering the existing steam network, hot water network and an eastern extension.

To replace the entire steam network and serve the current steam customers with a new hot water network, the hot water distribution system will likely not follow the same routing of the steam system directly; rather it should be routed in a manner that allows for future growth of the system, and adequate redundancy and capacity while locating areas of cost savings. As a result, the distribution system will entail approximately 50,000 trench feet of pipe. At an average installed cost of $1,000 per trench foot, an estimate of probable cost is approximately $50 million. The hot water pipe sizes range from 1½" to 20" diameter and are sized assuming a delta T of 55°F and an 85% building load diversity. The above estimate does not route hot water in some of the areas where the steam system is abandoned or where hot water loops will be unnecessary. It also does not account for potential savings that can be realized if installation was coordinated with upcoming street repairs or distribution lines were routed through building basements.

4.5.2 CONDENSATE RETURN OPPORTUNITIES

The steam distribution system currently does not have a condensate return. All condensate generated in the distribution system as well as the customer buildings is discharged into the sewer as a system loss, thereby reducing the overall efficiency of the system.

There are two types of condensate losses in the system, one in the distribution lines and one at the customer buildings. In the 150 psig distribution system, condensate will form at a temperature of 360° F. This condensate is removed through steam traps and flashes to steam when released to the sewer. This loss amounts to approximately 27% of the overall distribution loss.

If the distribution system condensate is collected in a system pressurized to 15 psig, some amount of condensate will still flash until the temperature is down to 250° F. Collecting this condensate would recover approximately two-thirds of the overall condensate losses, while approximately one-third would still be lost.

Steam delivered to the customer buildings is generally cooled down to approximately 160° F in heat exchangers before it is released into the sewer as condensate. This discharged condensate amounts to approximately 10% of the energy delivered to the customers.

The potential impact of a condensate return system is detailed in Table 4.11. With a 15 psig condensate return system the overall system efficiency (fuel to end usage —see also section 5)

Downtown Duluth SYSTEM VISION, FULL HOT WATER SERVICE SYSTEM REPLACEMENT

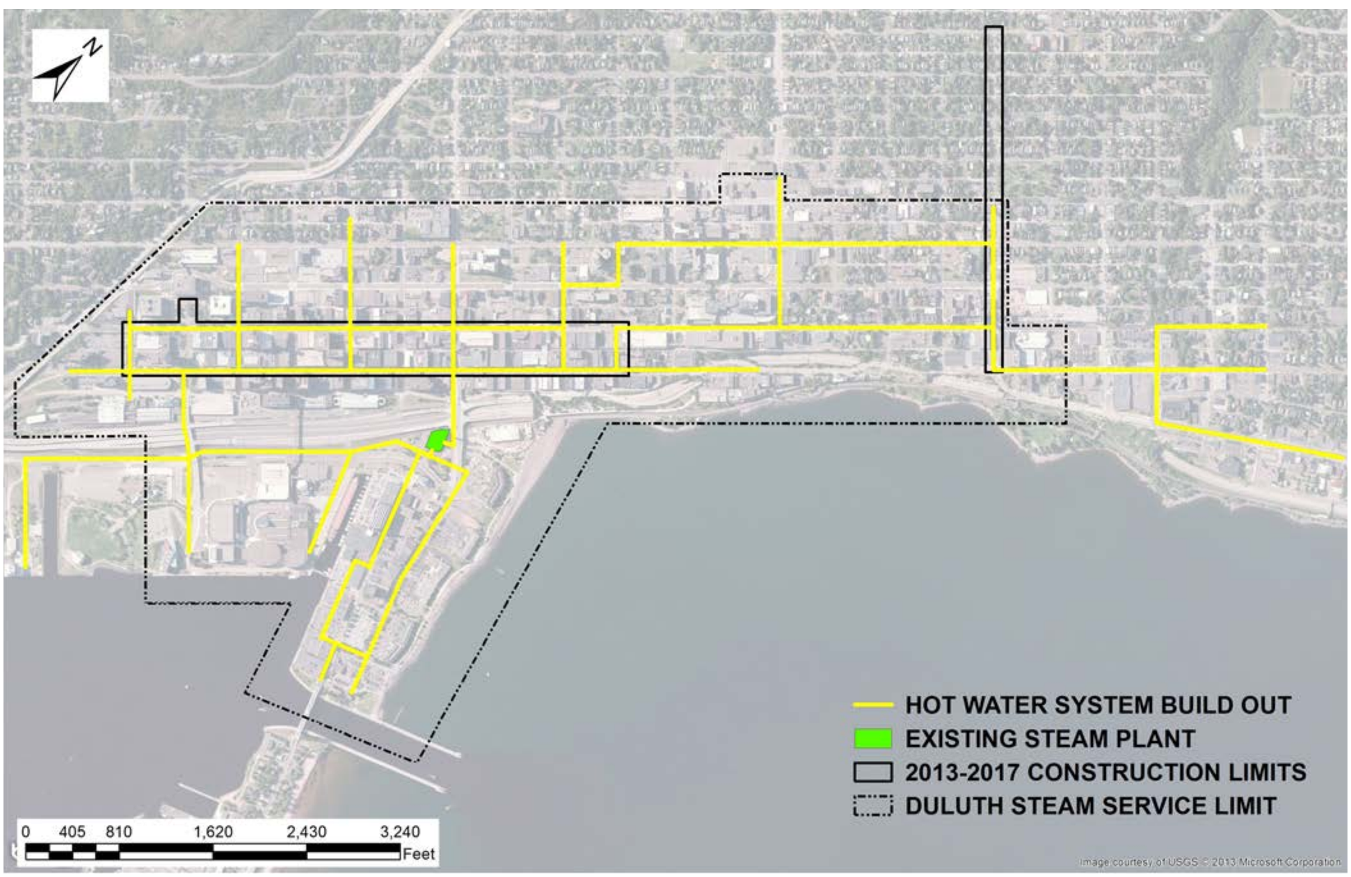


Figure 4.7 Potential future system includes existing steam and hot water network, plus eastern extension

would increase approximately 11% from 43.5% to 48.1%. Condensate return from the steam traps in the distribution system is relatively difficult and costly. With only the condensate from customers returned, the system efficiency would be increased to 46.5% rather than 48.1%.

Table 4.11 Condensate losses and potential impact of a condensate return system

Distribution Condensate Losses	
150 psig saturated steam	1,195 btu/lb
Water at 150 psig/360°F	335 btu/lb
Water at 15 psig/250°F	220 btu/lb
Water at 212°F	180 btu/lb
45°F makeup water	15 btu/lb
Condensate loss of total distribution energy loss	27%
Recoverable in a 15 psig condensate return system	17%
Recoverable in non-pressurized condensate return system	14%
Customer Condensate Losses	
150 psig saturated steam	1,195 btu/lb
160°F water	128 btu/lb
45°F makeup water	15 btu/lb
Condensate loss of total energy to customer	10%
System Efficiency (Fuel to End Usage)	
Without condensate return	43.5%
With distribution and customer condensate return (15 psig condensate system)	48.1%
With only customer condensate return	46.5%

A condensate return system also has some disadvantages:

- To install condensate piping for a 100% condensate return is cost prohibitive, with an estimated cost of approximately $30 million.
- Condensate pipes are highly susceptible to corrosion from carbonic acid and the availability of oxygen in partly filled condensate pipes, and the maintenance and repair costs are typically quite high.
- Without an extended hot water system to utilize additional exhaust steam energy available, the recovered energy in the condensate would merely increase the amount of energy lost in the exhaust steam from the steam turbines (see Section 5).

An alternative would be to install a condensate recovery system for selected customers and utilizing an expanded hot water system's return pipes as a means of sending the condensate return back to the plant. The condensate could be collected at selected locations in the downtown area based upon the quantity of condensate being generated and their proximity to the expanded hot water loop. The collected condensate would then be pumped through a limited condensate piping system, preferably to a holding tank for several customers with water treatment. The condensate would subsequently be pumped to the nearest hot water return main and sent back to the plant. At the plant the condensate would be pumped out of the hot water system and reused in the steam process. As noted above, this concept would be best implemented after an expansion of the current hot water system. A schematic of this suggested configuration is shown in Figure 4.8.

4.5.3 HYBRID STEAM AND HOT WATER DISTRIBUTION

A hybrid steam and hot water distribution system on the west end of downtown could consist of remote energy transfer stations and both steam and hot water networks. It provides a means to serve buildings that are hot water-ready with hot water while having the network in place for steam buildings as they update their internal HVAC systems for hot water use. This hybrid system, with a steam to hot water transfer station will take the energy from steam and transfer it to a localized closed loop hot water system. The transfer takes place through a heat exchanger and the hot water is pumped throughout a closed loop network. The hot water loop will reduce overall water usage by alleviating losses to condensate traps and building controls and heat loss through better insulation. Table 4.12 provides an estimated cost for this hybrid distribution system.

Figure 4.8 Potential condensate recovery system utilizing the hot water distribution system

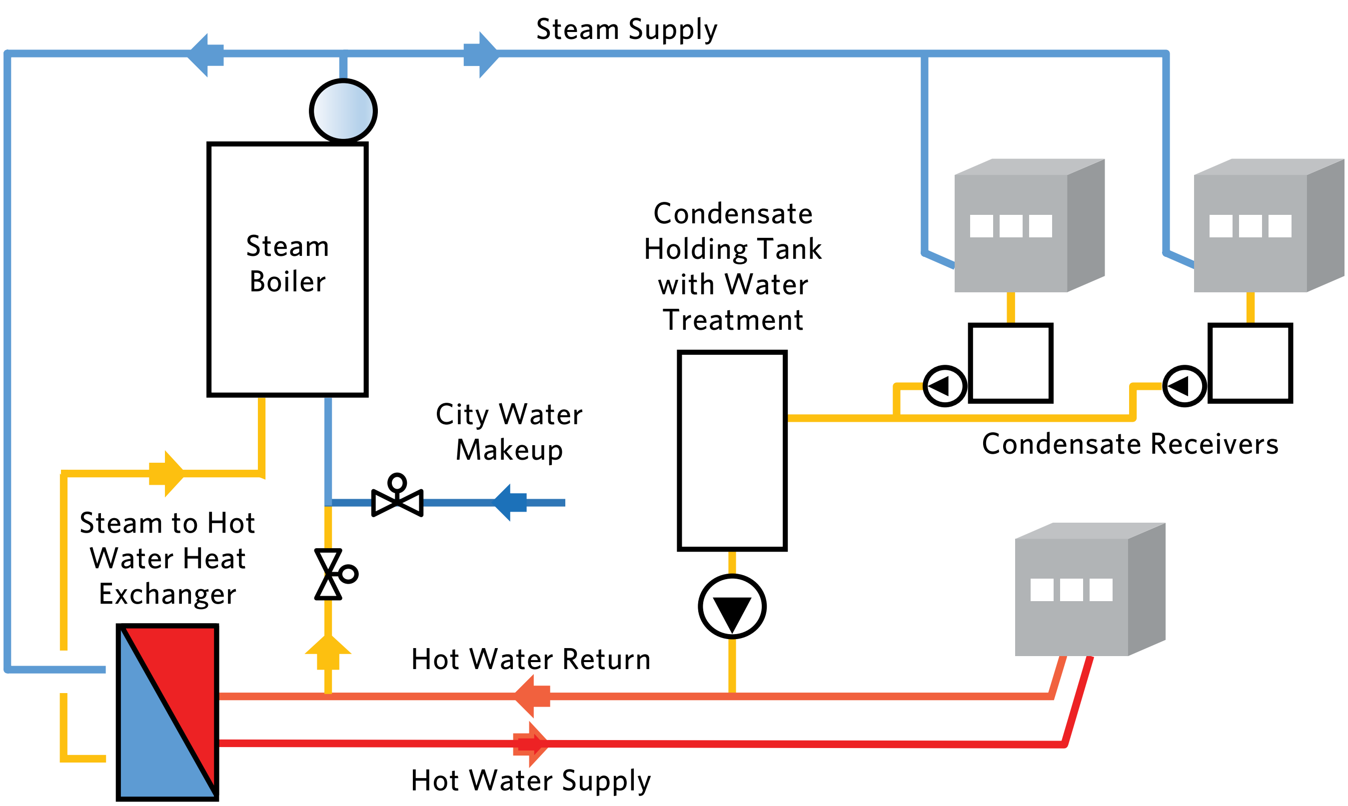


Table 4.12 Estimate for west end distribution piping and transfer station

	Estimated Cost
Distribution Piping—Mains	$4,737,000
Energy Transfer Station	$330,000
Grand Total	$5,067,000

NOTES Structure/building for housing transfer station cost not included.
Applicable building hot water conversion costs not included.
Expanded loop based on assumed load of area buildings

When compared to the scenarios laid out in sections 4.5.1 and 4.5.2, this hybrid system has some initial cost savings. However the transfer station will utilize the existing steam infrastructure and will still have condensate loses. Even though the maximum amount of energy will be transferred from the steam, there will still be higher thermal energy and water losses as compared to an extension of the existing hot water network. As the hot water network grows in the downtown area, an extension from the Duluth Steam plant and the existing hot water network may be inevitable.

Some of the areas where the hot water pipe would be installed could be done jointly with the paver restoration on Superior and 1st Street. As described in Section 4.7, coordinating the installation of distribution pipes with the street restoration could result in savings of up to 35%.

Similar to installing a steam to hot water energy transfer station and hot water network on the west end of the Duluth Steam system, there is also the potential of adding a hot water loop on the east end of the CBD. In this case the energy transfer station will be used to expand the system beyond its current limits and provide heating service to a new customer base. Table 4.13 provides the estimated cost for the distribution piping and the cost of the energy transfer station on the east end of the CBD.

Table 4.13 Estimate for east end distribution piping and transfer station

	Estimated Cost
Distribution Piping—Mains	$6.040,000
Energy Transfer Station	$195,000
Grand Total	$6,235,000

NOTES Structure/building for housing transfer station cost not included.
Applicable building hot water conversion costs not included.
Expanded loop based on assumed load of area buildings

4.6 Chilled Water Distribution Expansion

The chilled water distribution network is currently sized to accommodate the current cooling load. The network could be expanded in western downtown to connect other buildings as appropriate, although new loads may need to be served by a different mainline leaving the chilled water plant from the southeast side due to system pressure requirements.

There are three buildings on the west end that could add an additional 400 tons of cooling to the district cooling network. Serving these customers would require an estimated 1,300 trench feet of pipe ranging in sizes from 6" to 10" in diameter, with an estimated cost to expand the network to these three buildings of approximately $1,500,000.

4.7 Duluth Infrastructure Coordination

It is important for Duluth Steam to work with the City of Duluth's Public Works department and other local utilities to determine the most economical and least obstructive piping route that will minimize utility conflicts and recognize opportunities for coordination with other utility work. A large portion of the cost to install district energy piping in city streets is civil construction and street restoration work. If the installation of district energy piping

Downtown Duluth ▶▶ POTENTIAL COORDINATION AREAS WITH OTHER WORK PLANS

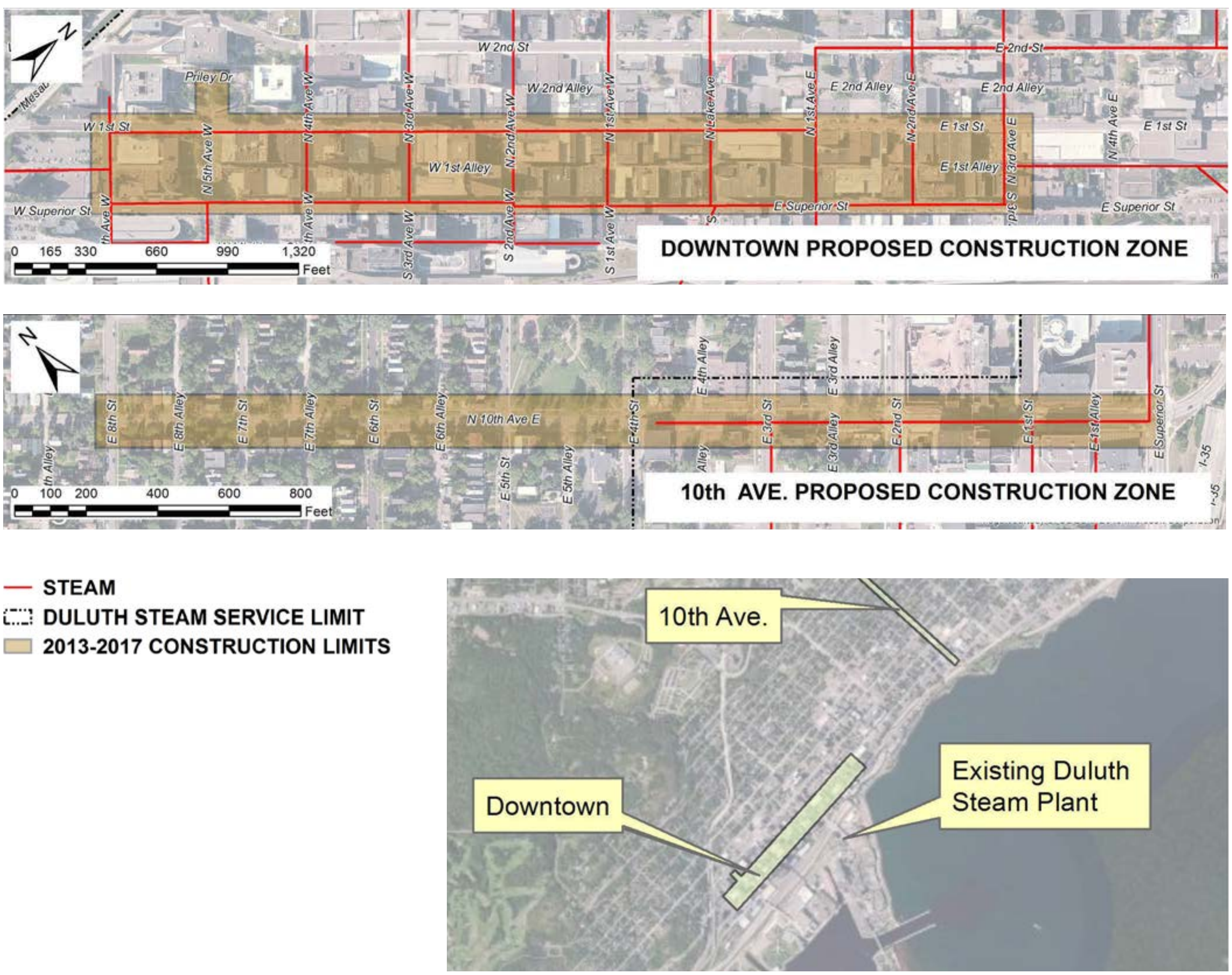


Figure 4.9 Upcoming work zones with opportunity for district energy distribution pipe installation

or maintenance is done in coordination with other utility work, cost savings of up to 35% could be realized due to the reduction in the amount of civil work.

One large opportunity in the very near future for installing hot water piping or making repairs to the existing steam system infrastructure is the reconstruction of the downtown area brick streets and avenues. This work will extend from N 3rd Avenue East to N 6th Avenue West and run down Superior Street and 1st Street, as well as the Avenues between Superior and 1st Street. This is the core of the downtown and covers a large part of the system's primary service area. From discussions with Public Works, other utility work is planned to be done during the brick street reconstruction. This work will take place between fiscal year 2013 and 2017, with the first year mainly as the planning phase. This provides Duluth Steam with an opportunity to coordinate with other utility work and avoid significant civil construction costs during the installation of the hot water distribution network.

Another area for notable street construction project is 10th Avenue East, which runs just East of St. Luke's Hospital. The construction will extend from Superior Street to E 9th Street and provides another opportunity to coordinate work and reduce the cost of installation for Duluth Steam.

The map in Figure 4.9 on the preceding page shows the work planned to occur in areas that may also include district energy distribution pipes in the future.

5. Production

HEATING PRODUCTION

5.1 Existing Heating Plant

5.1.1 INTRODUCTION

Steam is currently produced at the main plant in Canal Park primarily via pulverized coal fired boilers. The steam is distributed to customer buildings through a once-through steam distribution system and is also used in the plant for steam turbine drives of equipment such as pumps, coal pulverizers and fans.

The plant was built in 1932 and the four boilers have been maintained and repaired over the years but never completely exchanged. Other plant equipment such as pulverizers, forced draft fans, feed pumps and steam turbine drives have been upgraded over the years.

The boilers produce steam only for the purposes described above and no electricity is generated. However, the plant includes a standby generator and two emergency generators to operate equipment in the event of an electrical interruption.

The primary fuel for the steam boilers is pulverized sub-bituminous (western) coal, although bituminous (eastern) coal could also be used. Natural gas is used as backup fuel for two of the boilers and the plant is also permitted to burn No. 2 fuel oil.

Apart from fuel composition requirements, such as sulfur content, the main flue gas emission control measure is a flue gas baghouses for particulate emission control.

Hot water is produced by capturing steam from the exhaust of the steam turbine drives at the plant and then is distributed to Canal Park customers (see Appendix D).

5.1.2 CAPACITY

The four coal boilers have a total nameplate capacity of 400,000 lb/hr steam and 460 MMBtu/hr heat input. The current air permit limits the boiler operation to a maximum total load of 300,000 lb/hr and 345 MMbtu/hr heat input. The air permit limit would thereby allow operating all four boilers at 75,000 lb/hr each or three boilers at 100,000 lb/hr each with the fourth boiler as a backup.

Technical restrictions in the pulverizers also limit the capacity of each boiler to about 85,000 lb/hr each. The firm capacity, with one boiler as backup, is therefore 255,000 lb/hr.

In February of 2013 a plant peak load of 208,000 lb/hr was reached at an outdoor temperature of -17°F. The ASHRAE 99.6% dry bulb design temperature is -19.5°F for Duluth. If the peak plant load from February 2013 is extrapolated to the ASHRAE design temperature about 215,000 lb/hr steam would be needed at peak conditions (see Table 5.1). More extreme temperatures occur in Duluth and according to the ASHRAE Bin data an outdoor temperature of less than -30°F can be reached on an average of one hour per year. At -30°F a peak plant capacity of about 240,000 lb/hr would be needed.

Table 5.1 Estimated peak plant output requirement

February 2013	
Peak Plant Output	208,000 lb/hr
Outdoor Temperature	-17.0°F
Degree Hours (Base 65°F)	82.0°F
Output per Degree Hour	2,537 lb/F
ASHRAE Design	
99.6% Dry Bulb Design Temperature	-19.5°F
Peak Plant Output as ASHRAE Design	214,341 lb/hr
Min Outdoor Temperature	
Min Outdoor Temperature (ASHRAE Bin less than 1 hr/yr)	-30.0°F
Peak Plant Output	240,976 lb/hr

5.1.3 EFFICIENCY

The plant is generally operating in an efficient manner. The boilers are operated at 6% excess oxygen or above with a flue gas temperature of about 450°F. At those conditions the flue gas losses are about 18% (on Higher Heating Value). Of the 18% in flue gas losses, about 6% are due to water vapor in the flue gas from the moisture in the fuel. To recover any energy from condensation of the water vapor in the flue gas, the flue gas temperature would have to be lowered to below approximately 100°F.

Of the remaining 12% in flue gas losses, approximately 3% is due to the excess oxygen and 9% is due to the temperature. To control the CO emissions from the boilers within permitted levels, the excess oxygen cannot be reduced without substantial modifications of the combustion air supply to the boilers.

The flue gas losses could be reduced to approximately 15% if the flue gas temperature was lowered to 350°F in a flue gas economizer. With up to 1.4% sulfur by weight in the coal and thereby a relatively high sulfuric acid dew point, material selection in a flue gas economizer will be critical.

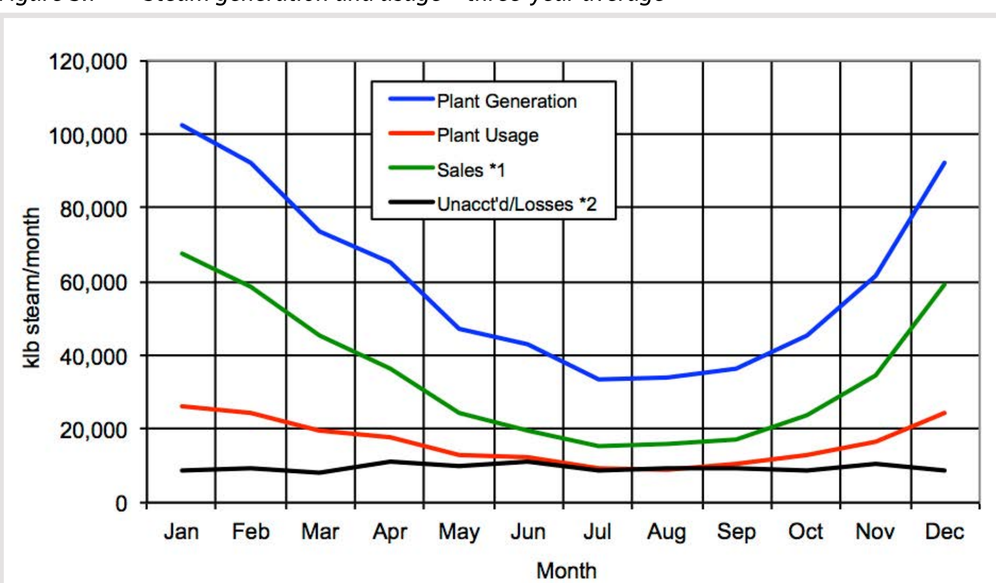
Table 5.1 and Figure 5.1 show the monthly steam generation, usage and losses for the present production and distribution system. As can be seen, the plant steam usage is about 25% of the total generated steam and the distribution losses are about 25% of the steam delivered to the customers, measured in pounds of steam.

Table 5.2 Steam generation and usage—three-year average

DULUTH STEAM GENERATION AND USAGE - 3 YEAR AVERAGE							
MONTH	STEAM (klb)				KEY NUMBERS		
	Plant Generation	Plant Usage	Sales[1]	Unacct'd/ Losses[2]	Plant Usage/ Gen.[3]	Losses/ Sales	Sales/Plant Gen
JAN	102,456	26,053	67,802	8,601	25.4%	12.7%	66.2%
FEB	91,939	24,142	58,686	9,111	26.3%	15.5%	63.8%
MAR	73,412	19,709	45,620	8,083	26.8%	17.7%	62.1%
APR	64,939	17,703	36,270	10,966	27.3%	30.2%	55.9%
MAY	47,166	12,849	24,223	10,094	27.2%	41.7%	51.4%
JUNE	42,720	12,311	19,585	10,824	28.8%	55.3%	45.8%
JUL	33,430	9,337	15,096	8,997	27.9%	59.6%	45.2%
AUG	33,948	8,929	15,653	9,366	26.3%	59.8%	46.1%
SEP	36,405	10,340	16,977	9,088	28.4%	53.5%	46.6%
OCT	45,223	12,841	23,904	8,478	28.4%	35.5%	52.9%
NOV	61,495	16,371	34,831	10,293	26.6%	29.6%	56.6%
DEC	92,490	24,102	59,417	8,971	26.1%	15.1%	64.2%
Total	725,623	194,687	418,064	112,872	26.8%	27.0%	57.6%

NOTES [1]Including steam to absorber.
[2]Distribution losses and metering inaccuracies.
[3]Energy % will be less due to HW production and condensate return

Figure 5.1 Steam generation and usage—three-year average



As noted, hot water is produced by capturing steam from the exhaust of the steam turbine drives which drives the fans, coal pulverizers, and pumps (see Appendix C). The thermal energy from the steam is transferred to the hot water via plate and frame heat exchang-ers. Hot water is pumped to system customers for energy extraction and return to the plant to be reheated. By utilizing a closed-loop hot water network the previously described distribution and condensate losses associated with steam distribution are eliminated for hot water customers.

Over the same three-year period as in Table 5.2, the fuel used in the plant is mainly coal plus a small amount of fuel oil as shown in Table 5.3. Based on an average fuel usage of 1,026,293 MMBtu per year the average boiler efficiency is 71.6% and the end usage ef-ficiency (net energy used by the customers not including energy in condensate, divided by fuel energy) is 43.5%.

The hot water system is currently served by capturing the heat from the steam turbine drive exhausts. There are approximately 190,000 MMBtu per year of heat available from

Table 5.3 Fuel and energy usage—three-year average.

DULUTH FUEL AND ENERGY USAGE—3 YEAR AVERAGE							
MONTH	Fuel Usage			Heat Output and Usage		Key Numbers	
	Coal[1] (Tons)	Oil[2] (Gal)	Total (MMBtu)	Boiler Heat Output (MMBtu)[3]	Customer Heat Usage (MMBtu)[4]	Boiler Efficiency[5]	End Usage Efficiency[6]
JAN	7,722	985	140,510	103,685	72,345	73.8%	51.5%
FEB	7,275	1,124	132,405	93,042	62,618	70.3%	47.3%
MAR	5,726	923	104,218	74,293	48,677	71.3%	46.7%
APR	4,994	1,259	90,960	65,718	38,700	72.2%	42.5%
MAY	3,689	861	67,181	47,732	25,846	71.0%	38.5%
JUNE	3,330	1,134	60,694	43,233	20,897	71.2%	34.4%
JUL	2,685	1,434	49,012	33,831	16,107	69.0%	32.9%
AUG	2,743	1,147	50,025	34,355	16,702	68.7%	33.4%
SEP	2,927	1,577	53,025	36,842	18,114	69.0%	33.9%
OCT	3,469	717	63,161	45,766	25,506	72.5%	40.4%
NOV	4,862	1,483	88,592	62,233	37,165	70.2%	42.0%
DEC	6,929	1,048	126,104	93,600	63,398	74.2%	50.3%
Total	56,351	13,692	1,026,293	734,330	446,074	71.6%	43.5%

NOTES [1]18.178 MMBtu/ton
[2]0.142 MMBtu/gal
[3]Saturated Steam 225 psig, 1,200 btu/lb; FW Water 220 °F, 188 btu/lb; Net 1,012 btu/lb
[4]Sat. Steam 150 psig, 1,195 btu/lb; Condensate 160 °F, 128 btu/lb; Net 1,067 btu/lb
[5]Boiler Heat Input/Fuel usage
[6]Customer Heat Usage/Fuel usage

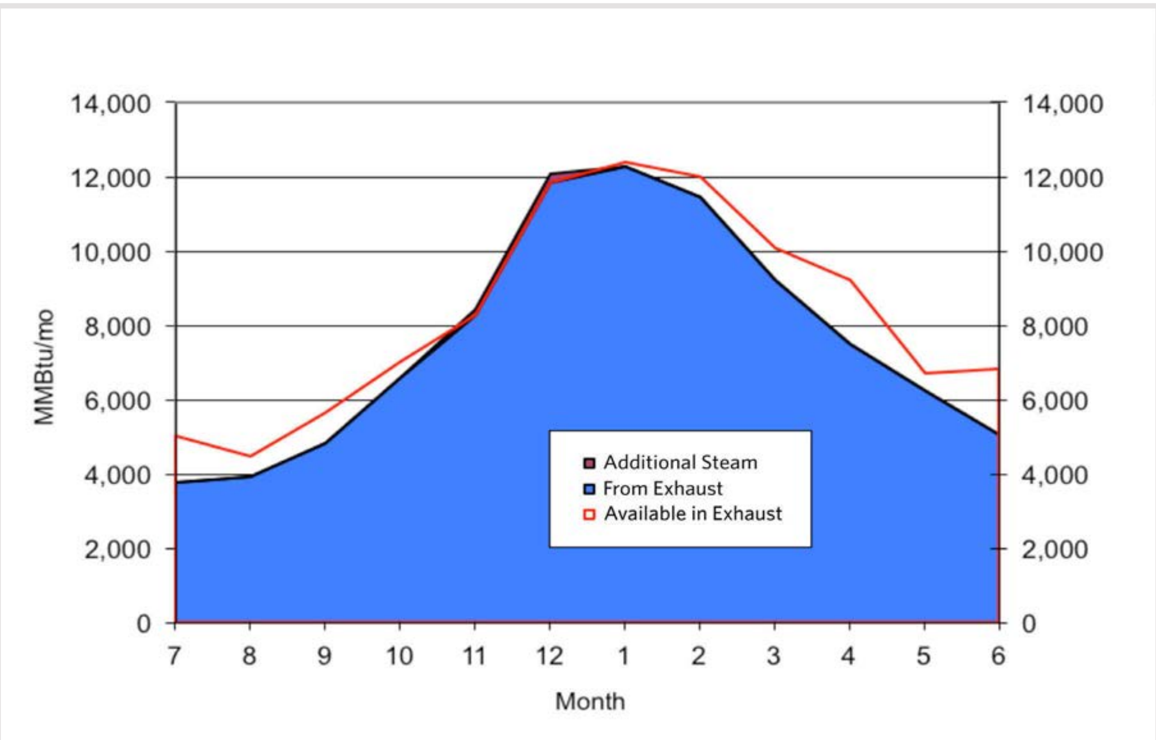
Table 5.4 *Makeup water heat balance for the existing steam system*

	ANNUAL			JANUARY		
	°F	btu/lb[1]	MMBtu	°F	btu/lb[1]	MMBtu
Makeup water	45	13	7,185	45	13	1,033
After blowdown preheater	59	27	14,782	59	26	2,106
After deaerator	220	188	103,908	220	188	14,942
Net exhaust steam used in deaerator	227	1,156	89,126	227	1,156	12,836
Available exhaust steam			188,457			25,219
Excess exhaust steam			99,331			12,384

NOTES [1] *Steam and water conditions*

	psig	°F	btu/lb
Boiler outlet steam	225	397	1,200
Boiler blowdown	225	397	372
Boiler blowdown after preheater		55	23
Plant usage	4	227	1,156
Deaerator		220	188
Makeup water		45	13

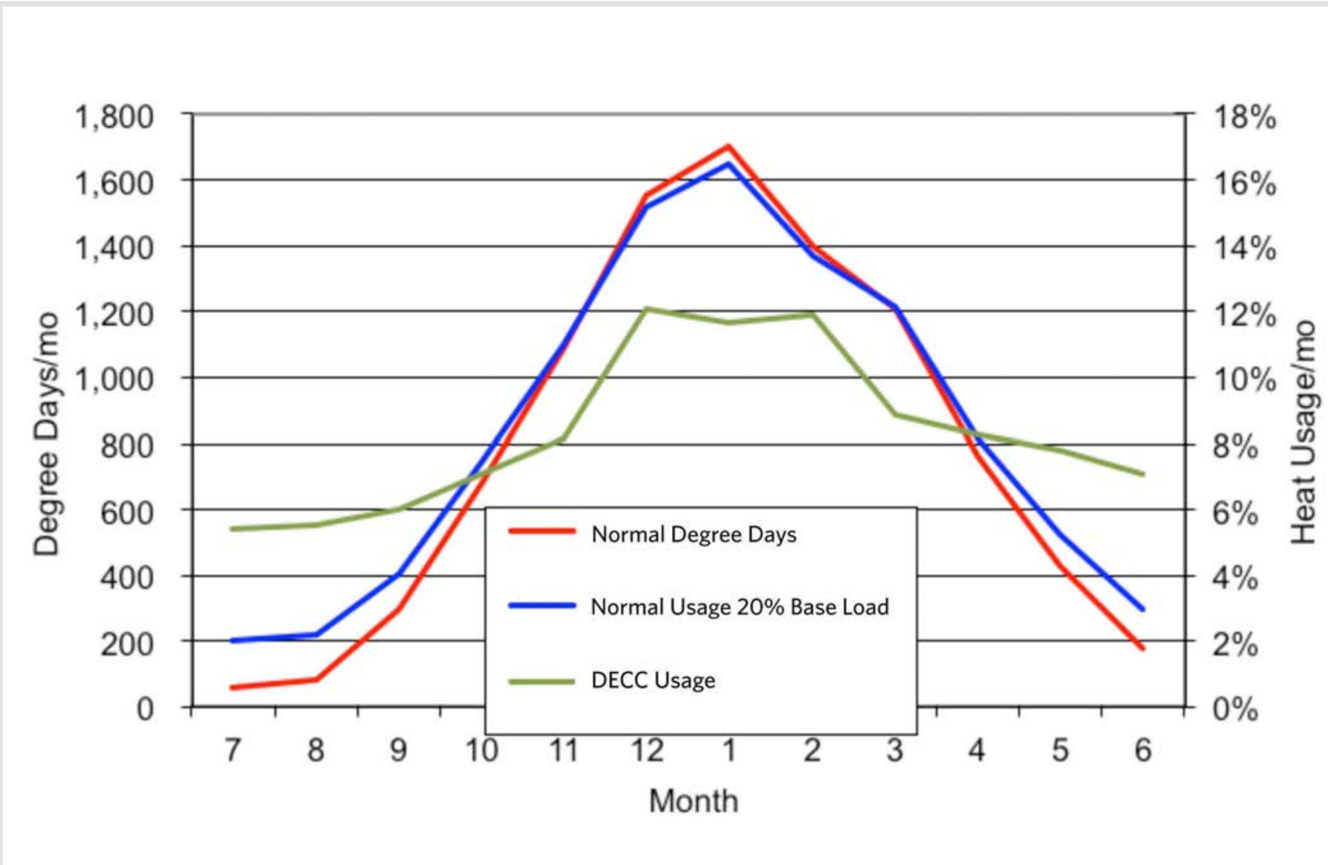
Figure 5.2 *Present excess exhaust steam energy balance*



the steam turbine exhausts, with almost 100,000 MMBtu per year available for the hot water system after about 90,000 MMBtu per year has been captured for feedwater preheating and deaeration based on the makeup water heat balance in Table 5.4.

Currently, there is a relatively good match between available exhaust steam heat and customer usage due to DECC's "over use" of heating during off-peak conditions (see Figure 5.2). However, the heat from the steam turbine drives does not fully align with the usage pattern for typical space and domestic hot water heating.

Figure 5.3 Typical hot water load profile



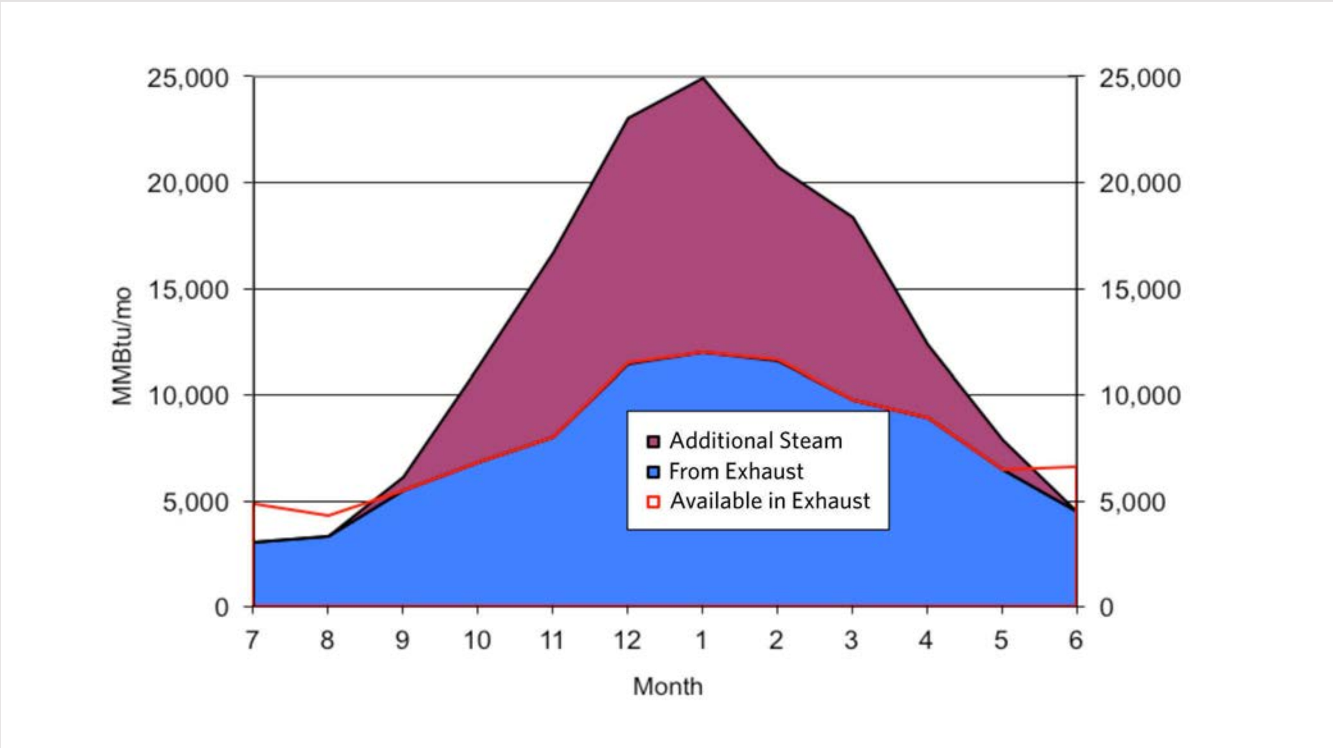
A typical hot water customer will have a base load of domestic hot water and consume energy for space heating closely following the degree days. In Figure 5.3 a typical hot water customer load profile has been generated based on the degree days for Duluth with an assumed base load of 20%.

Based on monthly heat balances for makeup water and exhaust steam as shown for January in Table 5.4 and a typical hot water load profile from Figure 5.3, an estimated 90,000 MMBtu per year can be captured from the available 95,000 MMBtu per year for the system advancement proposed in the Master Plan without condensate recovery (see Table 5.5 and Figure 5.4). The additional 60,000 MMBtu per year will have to be provided by additional steam production.

Table 5.5 Exhaust steam energy balance for Master Plan without condensate recovery

MONTH	AVAILABLE IN EXHAUST (MMBtu/mo)	FROM EXHAUST (MMBtu/mo)	ADD'L STEAM (MMBtu/mo)
7	4,820	2,991	0
8	4,285	3,299	0
9	5,439	5,439	629
10	6,752	6,752	4,473
11	7,979	7,979	8,652
12	11,427	11,427	11,553
1	11,946	11,946	12,949
2	11,562	11,562	9,109
3	9,708	9,708	8,640
4	8,884	8,884	3,396
5	6,443	6,443	1,408
6	6,578	4,475	0
Total	95,824	90,906	60,809

Figure 5.4 Exhaust steam energy balance for Five-Year Master Plan without condensate recovery



5.1.4 SHORT-TERM IMPROVEMENTS

The DECC loop heat exchanger in the plant is leaking and will require replacement. The estimated cost of this work is approximately $100,000. The Master Plan's requirement of additional heat exchanger capacity should be considered in this replacement.

EPA Boiler Maximum Achievable Controls Technology Standards (MACT) may put additional restrictions on the plant that will require measures in the short and long term. Short-term measures could include additional gas firing to replace coal usage and reduce mercury emissions.

Short-term test firing of alternative fuels such co-firing of sawdust could also be performed to evaluate the feasibility of integrating sawdust into the plant to reduce mercury emissions and greenhouse gas emissions.

5.1.5 LONG-TERM IMPROVEMENTS

Long-term improvements include expanding the hot water production equipment and introducing alternative fuels in the Plant fuel mix.

Currently, there are two separate systems with heat exchangers and distribution pumps for hot water distribution to the Canal Park area. In an effort to simplify the production system, the systems should be consolidated and expanded based on the advancements proposed in this Master Plan.

Equipment for biomass firing could also be installed based on test firing results and evaluation of the economics of new or used biomass equipment.

5.2 Alternative Heating Production

5.2.1 ALTERNATIVE FUEL SOURCES

5.2.1.1 Biomass

For purposes of the Duluth Steam System, the team evaluated two options for biomass integration, sawdust and woodchips. Biomass sawdust would primarily be wood residual material from a sawmill or other wood manufacturing processes such as furniture, cabinet, and pallet making. Biomass woodchips could be derived from wood residuals from logging operations or possibly trees removed due to storm damage, disease and urban development. The processing of the biomass woodchips could be done by a wood-chipper or grinder, resulting in approximately 1"-sized woodchips.

5.2.1.1.1 *Sawdust*

Without any changes to the existing coal boiler fuel preparation system, sawdust is the only possible fuel that could be co-fired with coal. Sawdust is also a possible design fuel for some used biomass boilers that are currently on the secondary market, such as the Georgia Pacific boiler.

This Five-Year Master Plan recommends that Duluth Steam should integrate both co-fired sawdust and a used 50 MMBtu biomass-fired boiler system to the production capabilities so that system coal consumption may be reduced. The team further recommends that the longer term System Vision would increase biomass-based production to 100 MMBtu as the hot water system is expanded.

5.2.1.1.2 *Sawdust Availability*

The closest sawmill is about 60 miles from Duluth. Based on the Master Plan need of 240,000 to 580,000 MMBtu/yr of sawdust, and assuming the fuel heat content is 10 MMBtu/ton, the sawdust required would be approximately 24,000 – 58,000 tons a year. 240,000 MMBtu/yr is based on only 25% sawdust co-firing in the existing boilers while 580,000 MMBtu/yr is the combined requirement from 25% co-firing and a 50 MMBtu/hr base load boiler. Based on current market conditions, the price delivered for the sawdust would be in the range of $25.00 - $30.00 per ton. Through market research, the team has found that a volume of between 19,000 – 37,000 tons should be obtainable. At these levels the system would be receiving between 8 – 16 truckloads a day on peak, assuming 20 ton loads and seven day a week delivery.

The larger volume may be a bit more challenging and should be further investigated as that decision approaches to verify that the sawdust biomass market could support this volume and the local infrastructure can accept that level of truck traffic.

5.2.1.1.3 *Woodchips*

Biomass in the form of woodchips can be used in a new biomass boiler. Woodchips can potentially also be used for co-firing in the existing boilers to broaden the fuel supply if a hammer mill is installed in series with the existing roller mills.

With a system vision of 100 MMBtu/hr biomass boiler capacity installed, the coal usage will be down to less than 10% of the total fuel usage. 25% sawdust co-firing in the existing coal boiler will then add very little to the overall biomass usage. With all 100 MMBtu/hr biomass boiler capacity designed for woodchips, up to 660,000 MMBtu/yr of woodchip biomass will be needed.

Assuming a fuel heat content of 9 MMBtu/ton, the woodchip tons required would be about 73,000 tons a year. Under the current market conditions, the price delivered for the woodchips would be in the range of $26.00 – $30.00 per ton. Competition for supply of this type of woody biomass would be strong due to the number of logging companies in the area and the limited processing needed for the material.

About 18 truckloads a day on peak would be needed assuming a seven day a week delivery.

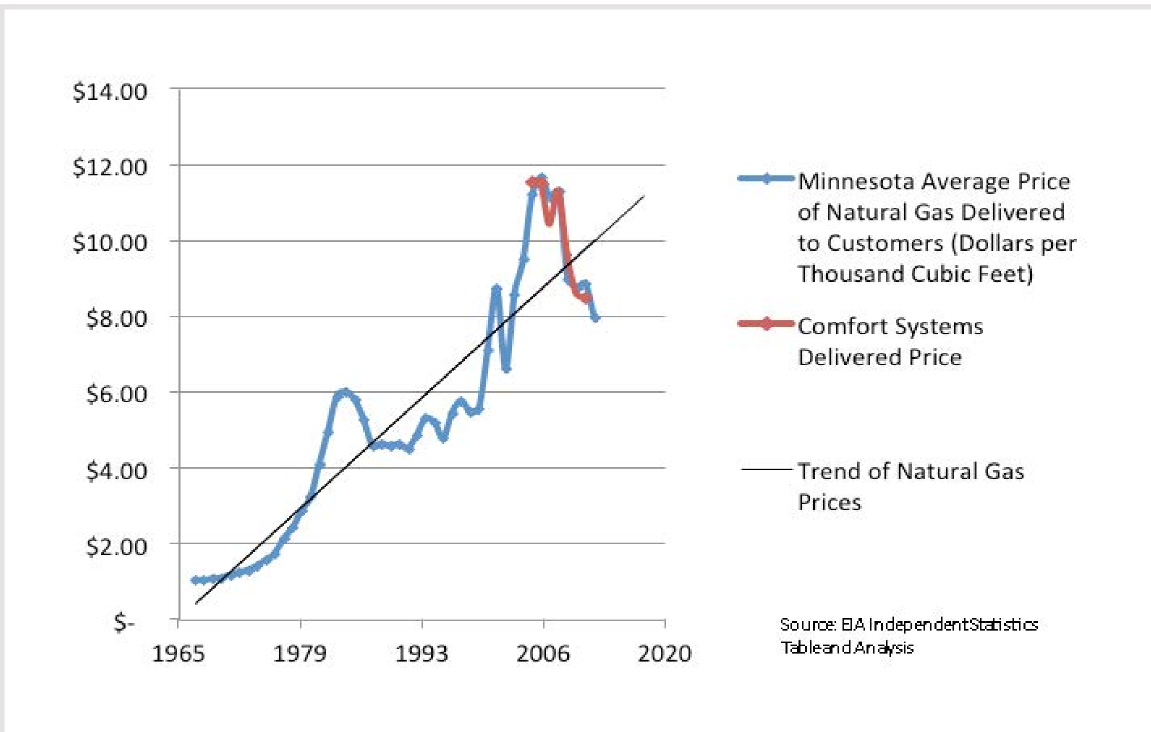
5.2.1.2 Natural Gas

The City of Duluth owns, operates, and maintains the municipal gas utility, Comfort Systems, to provide natural gas to approximately 26,300 customers. The approximately 5 billion cubic feet of natural gas consumed in Duluth each year originates primarily in Canada and is transported to Duluth in high pressure pipelines owned, maintained and operated by Northern Natural Gas, Great Lakes Gas Transmission, and Transcanada. The gas is transferred from the transmission companies' pipelines to Comfort Systems at city gate stations where the gas volume is measured, pressure is reduced from transmission line pressures to city line pressure, and the gas is odorized to provide the distinctive 'gas' smell. The gas is then delivered to the consumer through a network of steel and HDPE distribution pipelines.

The price of natural gas follows supply and demand trends. As the supply of natural gas increases, there is downward pressure on the commodity price. We are presently in a surplus position in the US due to a perceived impending shortage and the rising cost of natural gas during the 1998-2008 period. As prices escalated, gas exploration and traditional and non-traditional production increased creating a surplus in the market reserves. As prices escalated, natural gas developers increased exploration and production efforts through traditional drilling and a new extraction method known as hydraulic fracturing to increase supply. Hydraulic fracturing is used to exploit the extensive gas shale deposits in South Central and North East regions of the United States. The construction of new and expansion of existing coastal liquefied natural gas import terminals also increased the US natural gas supply. As a result, the predicted shortages that were anticipated in early 2000s have been delayed through the increase in currently available supply.

Natural gas is a commodity, purchased and sold on the worldwide futures markets and is subject to the volatility of market trading forces. In 1978, the Natural Gas Policy Act was passed and the natural gas market moved gradually from a federally regulated market to a traded commodity. Figure 5.5 shows a stable gradual increase in the price of delivered natural gas during the 1960s and 1970s. After deregulation, price fluctuations become larger and more pronounced due to market forces and the delay between developing reserves as prices rise. Currently, natural gas commodity prices are trending upwards, although the recent increase in supply has stifled that trend.

Figure 5.5 Natural gas costs and price trend in Minnesota



The 2012 Gas Cost of Service and Rate Study provides an analysis of rate needs through 2016. Recommendations include an increase in rates to cover costs associated with bonds, capital leases and other system inputs. The report does not identify system expansion plans or service territory details. The D-PUC unanimously passed resolution 13PUC-003 in late February 2013 approving a rate increase for gas.

Gas could be utilized as a primary or secondary fuel in the plant; however the cost of gas per MMBtu is much higher than that of either coal or biomass. If market conditions for these fuels change, however, gas could be considered as a more substantial fuel source in the future.

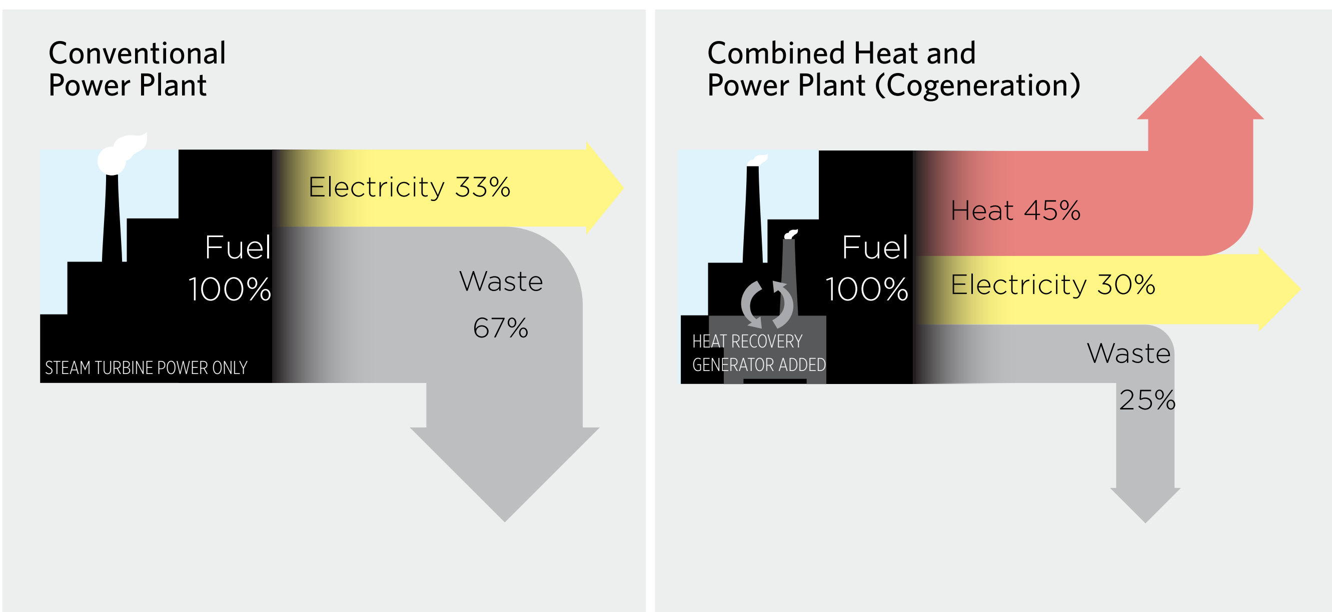
5.2.2 INTEGRATION WITH OTHER FACILITIES

The summer load for the system could be more effectively managed from a smaller, natural gas-fired boiler on or adjacent to the steam distribution network. One option could be the Saint Mary's boiler plant, which has three boilers with an output of 20,000 lb/hr output each. These boilers have the ability to operate up to 150 PSIG and could support the summer load of the system's customers with slight modifications. Other boilers could also be utilized to manage the summer load of the system and should be investigated to optimize the utilization of existing production assets within the community.

5.2.3 COMBINED HEAT AND POWER

Cogeneration, or combined heat and power, is recognized internationally as a mechanism for improving the energy profile for a community and maximizing the energy efficiency of electrical generation. Cogeneration captures the waste heat from the production of electricity to be used in a thermal system, such as a district energy system. Traditionally, cogeneration has been viewed as a means to nearly double the efficiency of electric generation facilities. Cogeneration also allows district energy businesses such as Duluth Steam to incorporate electrical production more effectively and create affordable, stable price structures for its customers.

Figure 5.6 Yield and waste comparison of conventional vs. cogenerational power plants



In August, 2012, President Barack Obama signed the Accelerating Investment in Industrial Energy Efficiency Executive Order, which encourages communities to "coordinate and strongly encourage efforts to achieve a national goal of deploying 40 gigawatts of new, cost effective industrial (cogeneration) in the United States by the end of 2020".

It could be beneficial for Duluth Steam to coordinate with an electric utility to place electric generation adjacent to the system so that waste heat could be captured and utilized within the district energy system.

5.2.4 WASTE HEAT

Across the United States, legislation is being introduced and passed which encourages the utilization of waste heat (or waste energy) for purposes of energy conservation improvement. In Minnesota, Governor Mark Dayton recently signed HF 729, which addresses the issue of waste heat in Minnesota's current energy system, into law. The law expands the definition of "energy conservation improvement" and adds "waste heat recovery used as thermal energy." Through the edition of this language, the Minnesota legislature opened the door for the recovery and reuse of waste heat from existing machinery, buildings or industrial processes, including combined heat and power, for heating and cooling. The expanded recovery and reuse of otherwise wasted heat to reduce demand side energy usage will now be eligible to participate in utilities' energy conservation improvement programs and the resulting energy savings will be eligible towards a utility's natural gas or electric energy savings goals. Expanding the hot water network will provide greater opportunities for the system to integrate waste heat into its energy profile.

As the adjacent industrial park to the east of Canal Park is redeveloped, Duluth Steam should look for opportunities of recovering waste heat from other facilities to improve the efficiency of the system and the community.

5.2.5 THERMAL STORAGE

Implementing hot water thermal energy storage at the Duluth Steam plant would allow more utilization hours of the turbine exhaust heat source. Currently if the Canal Park hot water network is not using the turbine exhaust steam source it is vented to the atmosphere. This vented steam could instead be captured through a steam to hot water heat exchanger and stored to keep up with the morning peaks realized in the Canal Park area and essentially increasing the capacity of the hot water network by storing thermal energy when it is not needed and dispatching it in times where the waste steam source cannot meet the demand load.

Further investigation will need to be performed to better understand the technical and economic feasibility of thermal storage, and also the capacity of the current site to locate thermal storage on the property.

5.2.6 SOLAR THERMAL

Solar thermal has been increasing in scale and efficiency in recent years, allowing utilities, colleges, and industrial applications to explore large-scale solar thermal integration. Solar thermal panels collect solar energy and convert it to heat, traditionally using a heat-transfer fluid, commonly a glycol-water mixture in Minnesota. The heated glycol-water mixture is pumped into a heat exchanger where the heat is released for utilization in the building. The heated glycol-water mixture returns to the panels to be reheated. Panels available on today's market can produce hot water temperatures above 200 °F. This heat can serve a singular building's hot water and space heating needs. When integrated with a hot water district heating system, excess heat can be exported into the hot water loop to be utilized by other customers. This integration serves as a thermal "smart grid" for energy sharing and allows highest-best use of the available solar energy.

Optimal logistics for integrating solar with the district energy system:

- Hot water distribution – Steam systems have integrated solar thermal installations. The steam distribution system requires the installation to utilize hot water storage tanks and does not maximize the benefit of system integration. Within steam systems, hot water loops could be utilized to connect solar thermal production to multiple buildings. Ideally, solar can be integrated with existing hot water loops, rather than adding loops for this purpose.

- Hot water internal system – Buildings with hydronic systems are ideal for solar thermal integration. This decreases any retrofitting to accommodate the heat load.
- Ground-standing – Ground-standing systems offer a unique scenario for solar thermal installations, reducing structural costs and offering easier installation and upkeep. (Note: upkeep is minimal for solar thermal installations.) Ground-standing systems would need to be within a feasible distance to extend piping from an existing customer building or the primary supply line. Each instance would be evaluated to determine technical and economic feasibility.
- Customer load – The heat produced by a solar installation has both an on-site (wholesale) and distributed (retail) value to the system. Ideally, the host building can consume a significant portion of the heat to improve economics and maximize use of the lower threshold of heat production. Buildings with higher process or domestic hot water loads can consume more of the available solar heat. Examples: aquariums, pools, breweries, food processors, restaurants, and hotels.

Items to investigate for a comprehensive analysis of solar feasibility

- Solar irradiance – Solar irradiance will be dependent on exposure to the southern horizon. The City can be mapped to identify which locations offer the most direct and uninterrupted exposure to the southern horizon.
- Structural – Solar thermal costs can be heavily dictated by the structural capacity of the host building. The City can provide best practices through codes and development training to help buildings become "solar-ready." Construction of solar-ready buildings will reduce overall structural costs to the building and the project.
- Engineering – Each customer on the system will have a comprehensive load analysis during system upgrades. This will allow loads and southern exposure to be analyzed for possible solar integration.
- Financing – Financing of solar installations will be dependent on ownership. Installations owned by Duluth Steam can be financed through investors looking to capitalize on investment tax credits. System or customer owned installations may have the opportunity to sell the renewable energy produced as a renewable energy credit (REC) within existing thermal REC markets. Property assessed clean energy (PACE) financing mechanisms have been utilized by local municipalities and may be available in Duluth to support solar development. Federal and state grants for solar thermal installations are cyclical and should be evaluated during planning stages.
- Demonstration projects – Many cities are developing demonstration projects as part of ongoing efforts to provide renewable energy education to the community. Installations on public buildings, educational institutions, or buildings with easily-accessed roofs should be considered for developing initial projects.

Solar thermal is an effective, renewable technology option for Minnesota applications. The City of Duluth and Duluth Steam should examine these opportunities with other partners during system upgrades and individual building analyses. A more comprehensive system hot water loop will be a key component of solar thermal integration.

5.2.7 PRODUCTION OPTIONS

The following sections outline production options for the Five-Year Master Plan as well as for the longer term System Vision.

The options focus on the introduction of biomass into the system and smaller amounts of natural gas for managing the summer load.

The focus mainly on biomass and gas should not be interpreted to mean that other measures such as solar thermal and flue gas heat recovery cannot be part of the future heat production. Solar thermal has particular efficiencies for the preheating of makeup water for the steam system. Co-firing of sawdust reduces the concentration of sulfuric acid in the flue gasses, thereby reducing the potential for corrosion when lowering the temperature in a flue gas heat recovery system. The following recommended steps expand the opportunities for adding these technologies. The base infrastructure of a hot water system would provide greater flexibility to receive energy from multiple sources if shown to be beneficial.

5.2.7.1 Five-year Master Plan

The Five-Year Master Plan production alternatives build on the introduction of biomass into the system through co-firing and replacement of some coal consumption. This scenario would likely require a smaller, used or new biomass boiler and utilization of natural gas-fired boilers for summer production in lieu of the primary coal plant.

As described in Section 7.2, up to 15% biomass can be co-fired in the existing boilers without triggering a reclassification from coal to biomass. Technically, the boilers could utilize 25% biomass, but the limit must be established through test firing.

While the combustion system is built for pulverized coal, sawdust is the only form of biomass fuel that can be incorporated without modifications to the fuel preparation system. The existing coal pulverizers are of the roller mill type and are not designed for fibrous materials such as biomass. To broaden the supply of biomass, a hammer mill can be installed in series with the existing pulverizers, thereby allowing for woodchips to be utilized.

With 25% sawdust co-firing and utilization of natural gas-fired boilers from June through August, the production mix would include 69% coal, 23% biomass, and 8% natural gas (see Figure 5.7).

The load duration curves in this section show the fuel utilization for the different production options and indicate the thermal production needs, including the distribution losses and customer usage. The curves are based on the ASHRAE Bin temperature data.

By adding a base loaded 50 MMBtu/hr biomass boiler, biomass utilization would increase to 55% as shown in Figure 5.8. The two biomass boilers at Georgia Pacific, for example, have a capacity of about 40 and 12 MMBtu/hr.

The low end production option cost with only sawdust co-firing and summer natural gas is estimated to about $1.5 million (see Table 5.7). The high end cost, with an added 50 MMBtu/hr base load biomass boiler, is $17.5 million (see Table 5.8).

5.2.7.2 System Vision

The vision for the system focuses on a primarily hot water distribution system, which could be served by utilizing primarily biomass-driven production. Natural gas-fired boilers would still be used during the summer months. Combined with the 50 MMBtu/hr biomass boiler

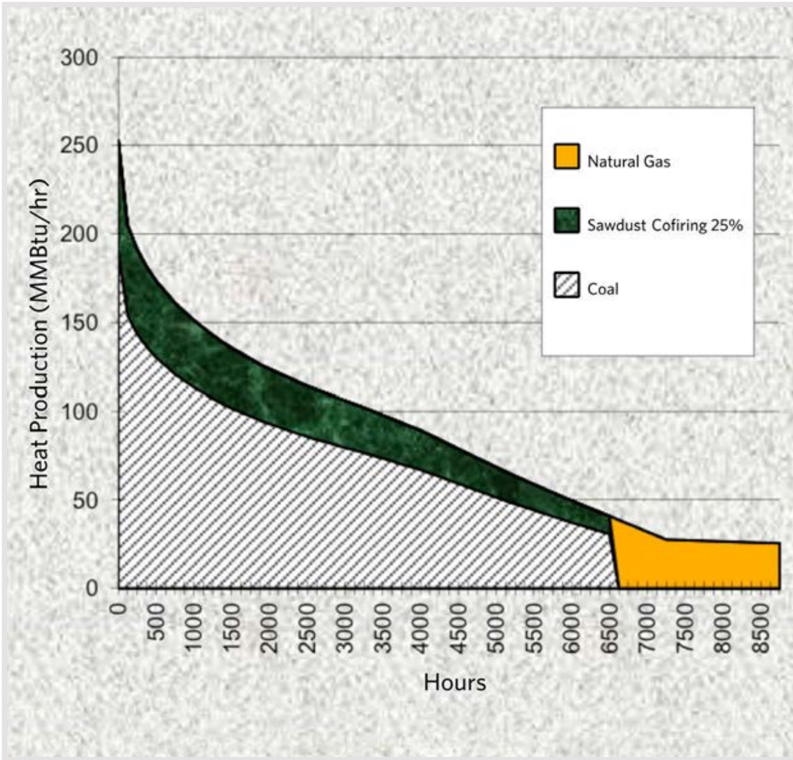


Figure 5.7 Energy production based on extended hot water distribution with condensate recovery, sawdust co-firing, and utilization of natural gas-fired boilers during the summer months

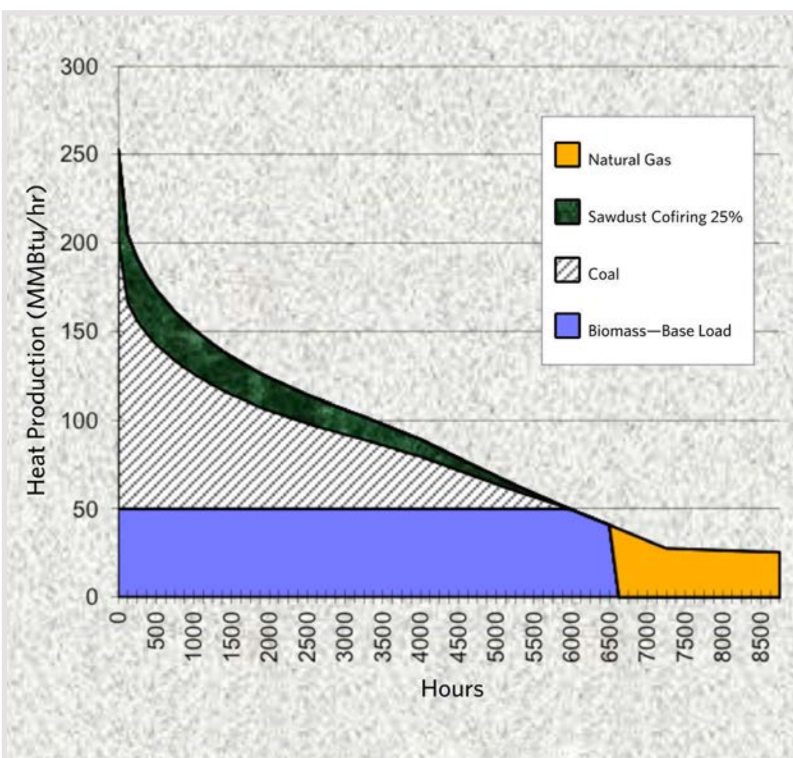


Figure 5.8 Energy production based on extended hot water distribution with condensate recovery, sawdust co-firing, base load biomass boiler and utilization of natural gas-fired boilers during the summer months

Table 5.7 Low end probable cost with energy production based on extended hot water distribution with condensate recovery, sawdust co-firing, and utilization of natural gas-fired boilers during the summer months

	SIZE	UNITS	UNIT PRICE	TOTAL
Biomass boiler/storage/ESP	50 MMBtu/hr	0	$6,480,000	$0
Steam heat exchanger	60 MMBtu/hr	2	250,000	500,000
Distribution pumps	2,500 gpm	2	30,000	60,000
Sawdust silo	16,000 cu.ft.	1	10	160,000
Hammer mill	100 kW	0	100,000	0
Natural gas related costs		1	150,000	150,000
BOP		1	50,000	50,000
Mechanical installation		1	10,000	10,000
Electrical installation		1	50,000	50,000
Controls installation		1	20,000	20,000
Building	9,000 SF	0	200	0
Subtotal				$1,000,000
Engineering	10%			100,000
General Conditions	15%			150,000
Contingency	25%			312,500
			Total	$1,562,500

Table 5.8 High end probable cost with energy production based on extended hot water distribution with condensate recovery, sawdust co-firing, base load, biomass boiler and utilization of natural gas-fired boilers during the summer months

	SIZE	UNITS	UNIT PRICE	TOTAL
Biomass boiler/storage/ESP	50 MMBtu/hr	1	$6,480,000	$6,480,000
Steam heat exchanger	60 MMBtu/hr	2	250,000	500,000
Distribution pumps	2,500 gpm	2	30,000	60,000
Sawdust silo	16,000 cu.ft.	1	10	160,000
Hammer mill	100 kW	1	100,000	100,000
Natural gas related costs		1	150,000	150,000
BOP		1	300,000	300,000
Mechanical installation		1	1,000,000	1,000,000
Electrical installation		1	500,000	500,000
Controls installation		1	100,000	100,000
Building	9,000 SF	1	200	1,800,000
Subtotal				$11,150,000
Engineering	10%			1,115,000
General Conditions	15%			1,672,500
Contingency	25%			3,484,375
			Total	$17,421,875

identified in the Master Plan, the production mix will be 64% biomass, 31% coal, and 5% gas. Increasing biomass production capacity to 100 MMBtu/hr will increase the biomass percentage to 85% with 10% coal and 5% gas as shown in Figure 5.9. With only 10% coal remaining under the 100 MMBtu/hr base load biomass case, co-firing is assumed to be discontinued.

The probable cost for adding an additional 50 MMBtu/hr biomass boiler and upgrading heat exchangers and distribution equipment for the System Vision is an additional $17.5 million (in addition to the cost of production improvements for the Five-Year Master Plan of $17.421 million).

Figure 5.9 Energy production based on hot water distribution, new 100 MMBtu/hr biomass boiler, and utilization of natural gas-fired boilers during the summer months

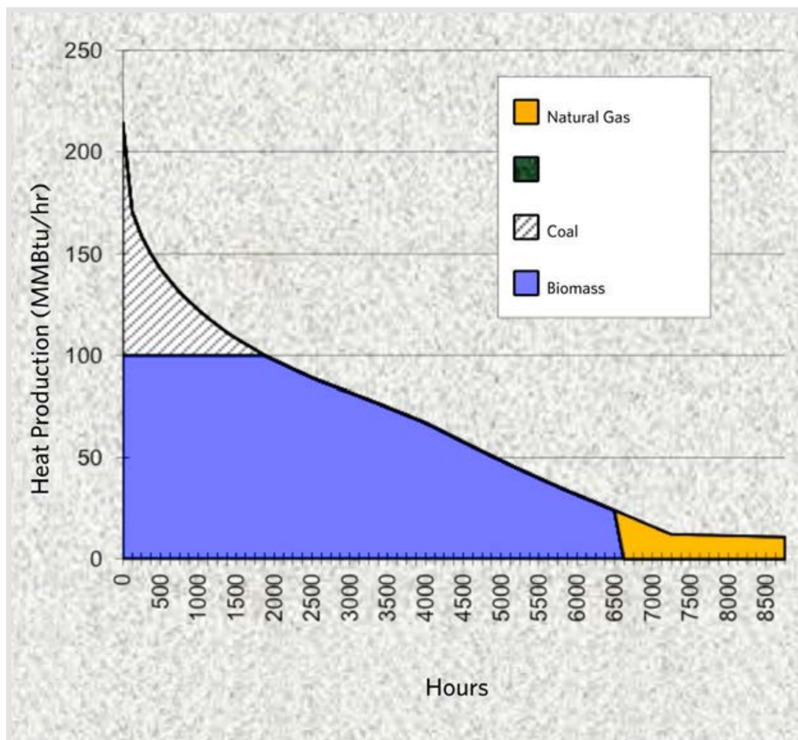


Table 5.9 Probable cost for an additional 50 MMBtu/hr biomass boiler and upgrade heat exchangers and distribution equipment

	SIZE	UNITS	UNIT PRICE	TOTAL
Biomass boiler/storage/ESP	50 MMBtu/hr	1	$6,480,000	$6,480,000
Steam heat exchanger	110 MMBtu/hr	2	410,000	820,000
Distribution pumps	8,000 gpm	1	76,000	76,000
Distribution pumps	2,500 gpm	1	30,000	30,000
Sawdust silo	16,000 cu.ft.	0	10	0
Hammer mill	100 kW	0	100,000	0
Natural gas related costs		0	150,000	0
BOP		1	300,000	300,000
Mechanical installation		1	1,000,000	1,000,000
Electrical installation		1	500,000	500,000
Controls installation		1	0	0
Building	9,000 SF	1	200	1,800,000
Subtotal				$11,106,000
Engineering	10%			1,110,600
General Conditions	15%			1,665,900
Contingency	25%			3,470,625
			Total	$17,353,125

5.3 Existing Cooling Plant

5.3.1 CAPACITY

The system's chilled water loop is served from a stand-alone production plant located at 414 W First Street, which is the old Water and Gas building located between the Duluth New Tribune storage building and the Duluth News Tribune administrative offices and presses. Within that plant, there is one (1), nine year old, 800 ton two-stage absorption chiller serving the cooling load of the system. In addition to the 800 ton absorption chiller there is a 400 ton centrifugal McQuay unit that is in declining condition and was not recommended for use by Duluth Steam staff. Adjacent to the 800 ton absorption chiller, there is piping in place to add another 800 ton unit, although a housekeeping pad may need to be added.

5.3.2 EFFICIENCY

The steam system efficiency from fuel to end use is approximately 43.5% as noted in Section 5.1.3. While the distribution losses are mainly dependent on the steam temperature and not the steam flow, the distribution losses will be constant even with additional summer steam usage to the absorption chiller. Excluding the distribution losses, the fuel to end user efficiency is about 55%. With a coal fuel price of about $3/MMBtu and a typical two-stage absorption chiller coefficient of performance ("COP") of 1.2, the cooling energy price, excluding electricity to auxiliaries such as condenser water pumps, etc., will be about 5.6 cent/ton-hour (see Table 5.10).

The comparable cooling energy price from an electric drive chiller, with a COP of 5.9 and an electricity price of 8.3 cent/kWh, is about 5.0 cent/ton-hour. Depending on how the electric demand ratchet will affect the electric service to the chiller however, the electric price could increase sharply.

Table 5.10 Cooling energy price from two-stage absorption and electric drive chiller

TWO-STAGE STEAM ABSORPTION CHILLER						
Fuel Price	DC Thermal Price			Efficiency	Cooling Price	
$/MMBtu	Steam η[1]	$/MMBtu	cent/kWh	COP[2]	cent/kWh	cent/ton-hr
3.10	55%	5.64	1.92	1.2	1.60	5.64
ELECTRIC DRIVE CHILLER						
			Electric Price	Efficiency	Cooling Price	
			cent/kWh	COP[3]	cent/kWh	cent/ton-hr
			8.30	5.9	1.41	4.95

NOTES [1]Fuel to steam efficiency excluding distribution losses
[2] kWcooling/kW thermal = 10,003 Btu/ton-hr "average"
[3] kWcooling / kW electricity = 0.60 kW/ton-hr "average"

If steam is provided directly from a natural gas fired boiler with an efficiency of 75% the cooling energy price from a two-stage absorption chiller would increase to an estimated 8 cent/ton-hour (see Table 5.11).

Table 5.11 Cooling energy price from two-stage absorption with steam from a natural gas fired boiler

TWO-STAGE STEAM ABSORPTION CHILLER						
Fuel Price	DC Thermal Price			Efficiency	Cooling Price	
$/MMBtu	Steam η[1]	$/MMBtu	cent/kWh	COP[2]	cent/kWh	cent/ton-hr
6.00	75%	8.00	2.73	1.2	2.27	8.00

NOTES [1]Natural gas boiler efficiency
[2] kWcooling/kW thermal = 10,003 Btu/ton-hr "average"

With a one-stage hot water absorption chiller connected to a hot water system the supply temperature will need to be maintained at 200 to 220° F during the summer. This would slightly increase distribution losses compared to the utilization of a hot water system for only domestic hot water and space heating. The transition to a hot water system as could improve the overall system efficiency to 67% (see also Section 6.5). With a typical COP of 0.67 for a one-stage absorption chiller the cooling energy price will be 8.3 cent/ton-hour with a coal price of about $3/MMBtu (see Table 5.12).

Table 5.12 Cooling energy price from one-stage absorption chiller

ONE-STAGE HW ABSORPTION CHILLER						
Fuel Price	DC Thermal Price			Efficiency	Cooling Price	
$/MMBtu	HW η[1]	$/MMBtu	cent/kWh	COP[2]	cent/kWh	cent/ton-hr
3.10	67%	4.63	1.58	.67	2.35	8.29

NOTES [1]Fuel to HW efficiency including distribution losses [2] kWcooling/kW thermal = 17,915 Btu/ton-hr "average"

5.3.3 SHORT-TERM IMPROVEMENTS

The system currently operates without sufficient backup production capabilities. If the 800 ton absorption unit were to experience a mechanical failure, customers may not receive reliable chilled water delivery. Duluth Steam should investigate the possibility of adding N+1 redundancy to the chilled water production system so that the system customers may continue to receive reliable service.

5.3.4 LONG-TERM IMPROVEMENTS

5.3.4.1 General

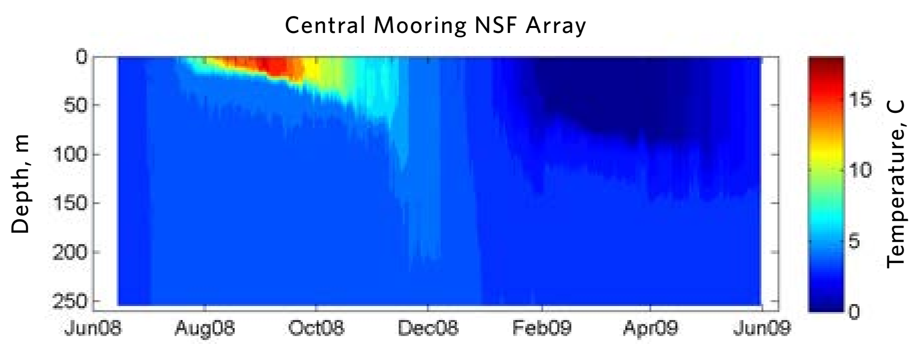
With a long-term expansion of a hot water distribution system, substituting the existing steam system, two-stage absorption chillers will only be used at the plant where steam can continue to be provided.

Expanded cooling service through cooling islands will likely be most cost-effective using electric drive chillers in lieu of one-stage hot water absorption chillers. However, at each installation, the effect of the electric demand increase should to be evaluated.

5.3.4.2 Renewable Energy Cooling from Lake Superior

Even though the average temperature in Lake Superior is about 40°F the surface water will reach 70°F in the summer. Twice each year the water column in Lake Superior is able to freely circulate from the surface to the floor (turnover). During the rest of the year, the water column separates into layers based on water density (stratification). Lake Superior exhibits a positive stratification in the summer, with a warm layer of water developing over a colder layer. In the winter, colder-over-warmer negative stratification develops (see Figure 5.10).

Figure 5.10 Temperature profile in Lake Superior 2008-2009



The summer water surface temperatures have risen about 2°F per decade since 1980 and 2010 was a year with one of the warmest water temperatures on record due to a very strong El Niño in 2009. The strong El Niño resulted in very little ice in Lake Superior during the winter of 2009-2010. 2012 With record high ambient temperatures in 2012, warm surface temperatures were expected but strong winds in the later part of the summer led to a mixing of the surface water with deeper colder water and the average surface temperature never surpassed that from 2010 (see Figure 5.11).

For district cooling purposes a water temperature below 45°F is preferable. The water temperature at different depths for 2010 is shown in Figure 5.12. The surface water starts to warm up in the spring and in July temperatures above 45°F could be found down to about 100 feet depth in 2010. At the autumn turnover in September, temperatures above 45°F could be found all the way down to almost 300 feet depth. A warmer supply temperature than 45°F in a district cooling system in Duluth may be acceptable in September while the cooling demand at that time has declined.

2010 may have been an exceptionally warm year for Lake Superior, however, a district cooling system utilizing lake water must be able to provide sufficient cooling during extreme conditions. For Duluth, the lake water intake would need to be at a depth below 100 feet or the district cooling system would also need to utilize chillers, preferably using lake water for condenser water cooling to supplement the direct lake water cooling.

Figure 5.11 Lake Superior average surface temperatures 2008 to 2013

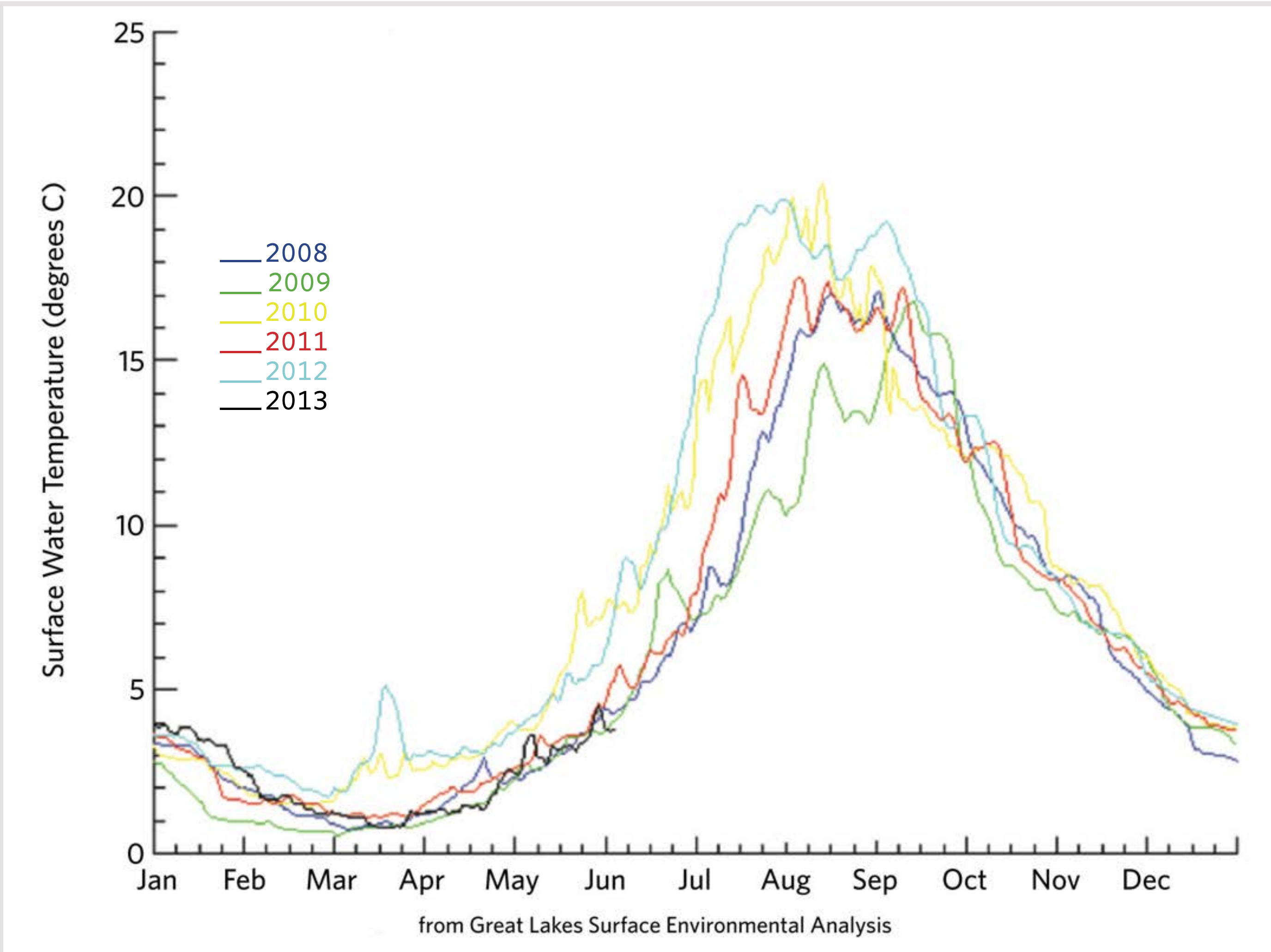


Figure 5.13 shows the bathymetry for Lake Superior in the vicinity of Duluth harbor and Canal Park. The red line closest to land indicates a distance of 10,000 feet from Canal Park and the second line a distance of 20,000 feet.

100 feet depth is reached about 30,000 feet from the shoreline. 10,000 feet from the shoreline the water depth is about 70 feet.

A district cooling system utilizing lake water would not likely be able to sustain a 30,000 feet long intake pipe. A potential system could therefore be devised around a hybrid system utilizing chillers with lake water condenser cooling to support the direct cooling from the lake at periods with elevated lake water temperatures.

Figure 5.12 Temperature profile in Lake Superior 2010

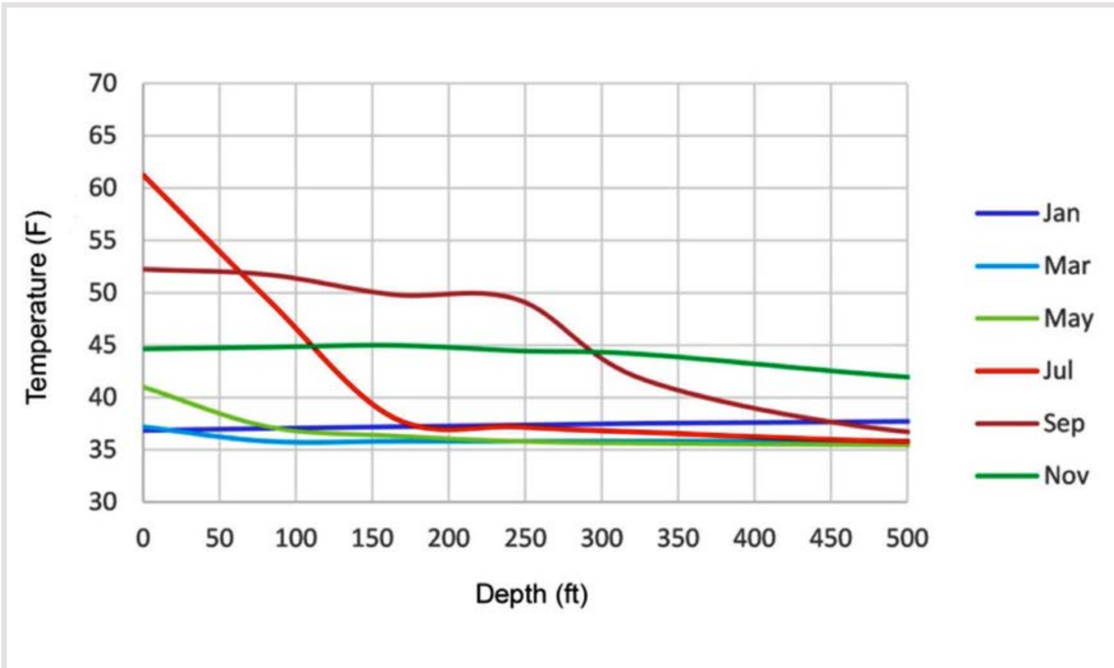
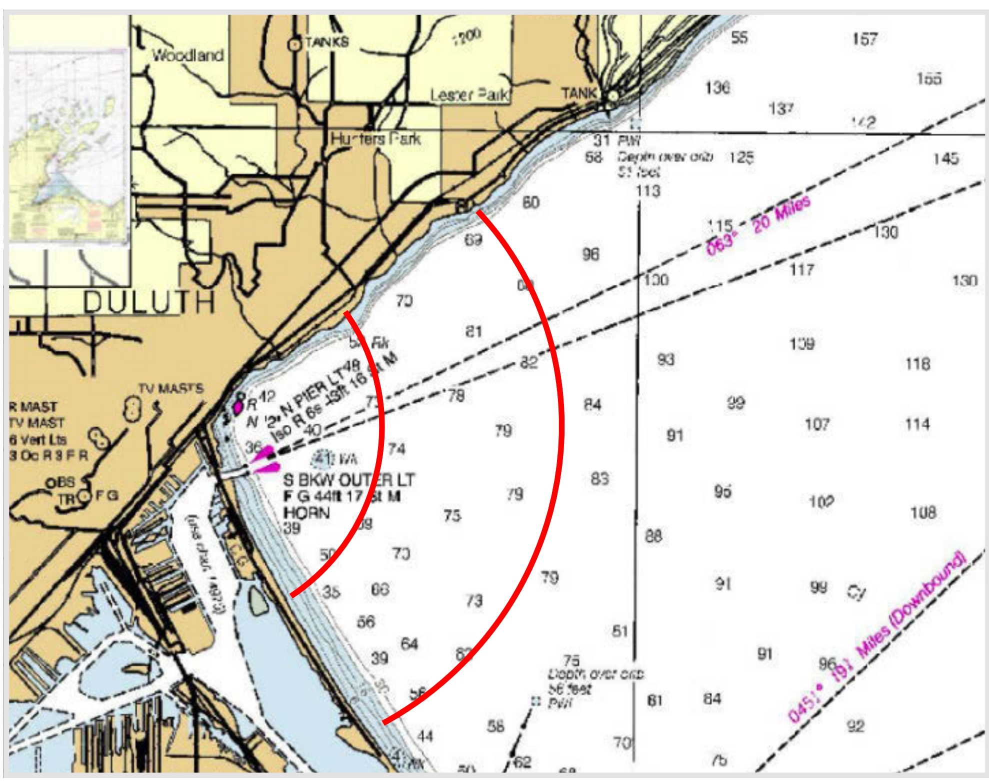


Figure 5.13 Lake Superior depth chart in feet. Red lines indicates 10,000 and 20,000 feet from Canal Park



The suggested next steps for a potential lake water based district cooling system for Duluth are to:

1. Assess the potential district cooling load over the next ten years.
2. Estimate the cost and performance for several intake depth options based on available lake temperature data.
3. Further investigate the local lake water temperatures in the area of interest, if the analysis indicates a positive cost/performance compared to alternative cooling options.

6. Energy Balance

6.1 On-Site Boiler Efficiency

Fuel-burning boilers can be defined in various ways including combustion type, thermal efficiency and seasonal efficiency. To be able to identify the performance characteristics for a boiler, efficiency evaluation should include part-load operation and availability of fuels. The above characteristics also need to account for the physical boiler selection with a burner and controls. These elements operate in collaboration with each other and they must be evaluated in the aggregate to be able to properly assess the final system performance characteristics on emissions, energy efficiency and indoor air quality.

The combustion and thermal efficiencies that are normally published for packaged boilers are measured under controlled laboratory test conditions, and generally range from 75% to 85% for most boilers. The tests do not take into consideration the varying load, the age of the boiler plant its affect on efficiency, and the effects of boiler maintenance and boiler water treatment on overall efficiency.

Seasonal efficiency is defined as the actual operating efficiency that the boiler will achieve during the heating season at various loads. Seasonal efficiency could be influenced by a number of different factors including:

Most heating boilers do operate at part load efficiency, accounting for heat losses when the boiler is off, which has a great effect on the seasonal efficiency.

When boilers cycle, the cool combustion air is passed through the boiler as a pre-purge cycle is completed, and the air does take heat from the boiler surfaces and discharges it through the chimney. Likewise, with a post-purge cycle, more heat is transferred from the boiler surface and vented to the atmosphere.

Boilers give up a portion of their heat to boiler rooms from insulation jacket losses.

Scale can affect boiler efficiency.

Too much excess air and less control adjustment can decrease boiler efficiency.

Boiler tests performed by Brookhaven National Laboratory indicate that boilers operating at 25% of the design load were producing at 25% seasonal efficiency.

Considering these losses, the potential range of seasonal efficiency for a boiler can vary from 75% down to 45%. For purposes of this section, however, we have assumed that non-customer buildings' boilers are operating at an efficiency level of 75%.

6.2 Duluth Community Energy Balance

The following energy balances include all present customers and potential customers as described in Section 3.6. The intent of the energy balance evaluation is to show the effect on the total energy usage for heating of individual and combined measures. To connect a new customer with a gas boiler efficiency of 75% to a system with an overall efficiency of 43.5% will, for example, increase the system fuel usage. However, in combination with other measures the overall system efficiency can still be increased while decreasing overall emissions.

The energy balances show the fuel used, system losses, heat recovery and end usage for different Master Plan and System Vision alternatives. No end usage energy conservation measures have been included in these energy balances. The total end usage is therefore the same in all alternatives.

Table 6.1 provides the estimated distribution losses utilized in the energy balances for each system configuration. The distribution losses are initial estimates and more detailed calculations will need to be performed during the next round of design development. The losses for the downtown steam distribution network are the measured losses of 27% while the losses for the hot water distribution are estimated in the range of 5 to 10%, depending on the heat load density. Figure 6.1 also provides a visual depiction of the current energy balance for the community.

6.3 Current Efficiency

The overall consumer market, including present steam and hot water customers and all potential customers as described in Section 3.6, uses about 1,180,000 MMBtu/yr of fuel to provide a net heating usage of 562,000 MMBtu/yr (see Table 6.2). The largest losses

Table 6.1 Estimated distribution losses used in energy balances

	DISTRIBUTION LOSS	
Present System	MMBtu/yr	%
Full Steam Network	133,189	27.4%
Canal Park HW	4,329	5.0%
Five-Year Master Plan	MMBtu/yr	%
West End HW	4,084	9.5%
East End HW	532	5.0%
Full Canal Park HW	7,300	7.5%
Downtown Steam add	4,891	13.7%
- West End Steam	-5,886	13.7%
- Canal Park Steam	-4,160	60.5%
20-Year System Vision	MMBtu/yr	%
Full HW Network	39,280	7.5

in the system are the boiler losses at 325,000 MMBtu/yr and the distribution losses at 140,000 MMBtu/yr.

The majority of the steam turbine excess exhaust heat is recovered to supply the existing hot water system (see also Figure 5.2). Only a miniscule amount of fresh steam has to be used for the hot water system.

6.4 Five-Year Master Plan

In the Five-Year Master Plan, the hot water system in the Canal Park area is expanded to the west end of the downtown area and additional customers are connected as described in Section 3.6.2.

The two scenarios described in this section are delineated by whether the extended hot water system is utilized for condensate recovery.

6.4.1 FIVE-YEAR MASTER PLAN without Condensate Recovery

Without condensate recovery the Master Plan provides a modest overall efficiency increase, from 47.6% for the current system to 48.7% (see Table 6.3).

With the net usage equivalent to the current system at 562,000 MMBtu/yr the increased overall system efficiency will reduce the fuel consumption from 1,180,000 to 1,150,000 MMBtu/yr. With the additional customers connected to the steam and hot water systems, the plant fuel usage will increase by about 70,000 MMBtu/yr.

The modest overall efficiency increase is primarily made up by reducing the overuse of heat at DECC. The estimated reduction at DECC of 24,000 MMBtu/yr would mean an increased overall system efficiency of 2%. Most of the additional excess exhaust steam available due to the reduced consumption at DECC will be used for the additional customers connected to the hot water system. However, some of the new customers are being connected to the steam system, exchanging 75% on-site boiler efficiency for a 43.5% efficiency, thereby reducing the overall community efficiency gain to 1%.

Some parts of the steam distribution system would be replaced with a hot water system, thereby reducing steam distribution losses. However, connecting additional customers to the steam network and expanding the hot water distribution network will outweigh those savings and the net result will be a small increase in the distribution losses.

6.4.2 FIVE-YEAR MASTER PLAN with Condensate Recovery

The Master Plan energy balance with condensate recovery is nearly identical to the previous without condensate recovery. Based upon the location of current and expected steam customers, it has been assumed that 50% of the condensate can be recovered and sent back to the plant mainly through the expanded hot water system.

A 50% condensate recovery will increase the overall system efficiency by about 1% to 49.8% (see Table 6.4). 50% condensate recovery is equal to about 21,000 MMBtu/yr or closer to a 2% efficiency increase. However, the excess steam turbine exhaust steam in the plant is used to heat up the makeup water. With less condensate losses and thereby less makeup water there will be more exhaust steam not utilized. Part of the additional exhaust steam available can be used for the expanded hot water system but the amount of exhaust steam not used will increase slightly due to seasonal imbalance between customer usage and steam availability.

Table 6.2 Energy balance for present customers and potential customers (MMBtu/yr)

STEAM CUSTOMERS									
Fuel[1]	Stack Losses	Steam Production	Exhaust Losses[3]	Distribution Losses[4]	To Customers incl. Cond. Losses	Cond. Losses[6]	To Customers	Control Losses[7]	Net Usage
998,257	279,512	718,745	99,137	133,189	486,419	44,220	442,199	78,467	363,732 36.4%
HW CUSTOMERS									
Fuel[1]	Stack Losses	HW Production	Heat Recovery	Distribution Losses[5]	To Customers incl. Cond. Losses	Cond. Losses	To Customers	Control Losses[8]	Net Usage
462	129	333	90,580	4,329	86,584	0	86,584	24,000	62,584 42.7%
POTENTIAL CUSTOMERS									
Fuel[2]	Stack Losses	HW Production	Heat Recovery	Distribution Losses	To Customers incl. Cond. Losses	Cond. Losses	To Customers	Control Losses	Net Usage
180,974	45,244				135,731		135,731		135,731 75.0%
TOTAL/NET									
1,179,694	324,885	719,078	8,557	137,518	708,734	44,220	664,514	102,468	562,046

NOTES [1]*Coal Boiler Efficiency HHV—72%*
[2]*Gas Boiler Efficiency HHV—75%*
[3]*Exhaust Loss of Steam to Distribution—16%*
[4]*Constant Losses Assumed at 1,180 btu/lb*
[5]*Assumed Distribution Losses—5%*
[6]*Condensate Losses at Customer—10%*
[7]*Steam Control Losses—20%*
[8]*DECC*

6.5 System Vision

The long term System Vision should be to convert the majority of the system over to hot water to lower the system temperatures and thereby reducing the losses in the system as well as facilitate utilization of low temperature renewable energy sources.

With the majority of the distribution system converted over to hot water, the comparable System efficiency will increase to 67.5% (see Table 6.5).

An alternative that may be discussed is the conversion of all customers to on-site gas boilers. Market efficiency may increase to 75%; however, this would require all customers to rely on a single fossil fuel source. This would create additional risk for customers based on fuel availability and market volatility. Utilization of a hot water network may deliver slightly lower system efficiency, but it can be diversified with alternative energy sources such as biomass, solar, and flue gas heat recovery.

The changes proposed in this Master Plan can provide incremental progress toward Duluth's energy efficiency goals and establish a framework for making more substantial efficiency improvements long-term.

Table 6.3 Energy balance for Five-Year Master Plan without condensate recovery (MMBtu/year)

STEAM CUSTOMERS									
Fuel[1]	Stack Losses	Steam Production	Exhaust Losses[3]	Distribution Losses[4]	To Customers incl. Cond. Losses	Cond. Losses[6]	To Customers	Control Losses[8]	Net Usage
964,892	270,170	694,722	95,824	128,034	470,865	42,806	428,059 44.4%	78,467	349,592 36.2%
HW CUSTOMERS									
Fuel[1]	Stack Losses	HW Production	Heat Recovery	Distribution Losses[5]	To Customers incl. Cond. Losses	Cond. Losses[7]	To Customers	Control Losses	Net Usage
106,405	29,793	76,612	90,096	11,916	155,601	4,636	150,965	0	150,965 46.7%
POTENTIAL CUSTOMERS									
Fuel[2]	Stack Losses	HW Production	Heat Recovery	Distribution Losses	To Customers incl. Cond. Losses	Cond. Losses	To Customers	Control Losses	Net Usage
81,986	20,496				61,489		61,489		61,489 75.0%
TOTAL/NET									
1,153,283	320,460	771,334	4,918	139,950	687,955	47,442	640,514	78,467	562,046 48.7%

NOTES [1]*Coal Boiler Efficiency HHV—72%*
[2]*Gas Boiler Efficiency HHV—75%*
[3]*Exhaust Loss of Steam to Distribution—16%*
[4]*See Separate Table*
[5]*See Separate Table*
[6]*Condensate Losses at Customer—10%*
[7]*Condensate Losses for East End HW—10%*
[8]*Steam Control Losses—20%*

Table 6.4 Energy balance for Five-Year Master Plan with condensate recovery (MMBtu/year)

STEAM CUSTOMERS									
Fuel[1]	Stack Losses	Steam Production	Exhaust Losses[3]	Distribution Losses[4]	To Customers incl. Cond. Losses	Cond. Losses[6]	To Customers	Control Losses[8]	Net Usage
960,136	268,838	691,298	113,802	128,034	449,462	21,403	428,059 44.6%	78,467	349,592 36.4%
HW CUSTOMERS									
Fuel[1]	Stack Losses	HW Production	Heat Recovery	Distribution Losses[5]	To Customers incl. Cond. Losses	Cond. Losses[7]	To Customers	Control Losses	Net Usage
86,065	24,098	61,967	105,551	11,916	155,601	4,636	150,965	0	150,965 47.8%
POTENTIAL CUSTOMERS									
Fuel[2]	Stack Losses	HW Production	Heat Recovery	Distribution Losses	To Customers incl. Cond. Losses	Cond. Losses	To Customers	Control Losses	Net Usage
81,986	20,496				61,489		61,489		61,489 75.0%
TOTAL/NET									
1,128,187	313,433	753,265	8,252	139,950	666,552	26,039	640,514	78,467	562,046 49.8%

NOTES [1]*Coal Boiler Efficiency HHV—72%*
[2]*Gas Boiler Efficiency HHV—75%*
[3]*Exhaust Loss of Steam to Distribution—16%*
[4]*See Separate Table*
[5]*See Separate Table*
[6]*Condensate Losses at Customer—10%; 50% Condensate Recovery*
[7]*Condensate Losses for East End HW—10%*
[8]*Steam Control Losses—20%*

Table 6.5 Energy balance for the System Vision (MMBtu/year)

STEAM CUSTOMERS									
Fuel[1]	Stack Losses	Steam Production	Exhaust Losses[3]	Distribution Losses	To Customers incl. Cond. Losses	Cond. Losses	To Customers	Control Losses	Net Usage
0	0	0							0
HW CUSTOMERS									
Fuel[1]	Stack Losses	HW Production	Heat Recovery[3]	Distribution Losses[4]	To Customers incl. Cond. Losses	Cond. Losses	To Customers	Control Losses	Net Usage
781,966	218,951	563,016	0	39,280	523,736	0	523,736	0	523,736 67.0%
POTENTIAL CUSTOMERS									
Fuel[2]	Stack Losses	HW Production	Heat Recovery	Distribution Losses	To Customers incl. Cond. Losses	Cond. Losses	To Customers	Control Losses	Net Usage
51,081	12,770				38,311		38,311		38,311 75.0%
TOTAL/NET									
833,047	231,721	563,016	0	39,280	562,046	0	562,046	0	562,046 67.5%

NOTES [1]Coal Boiler Efficiency HHV—72%
[2]Gas Boiler Efficiency HHV—75%
[3]All Exhaust Losses are Recovered
[4]Assumed Distibution Losses—7.5%

7. Environmental

The Ever-Green Energy team has investigated the environmental activity that relates to the Duluth Steam site. The following summarizes what was learned as part of the team's analysis of the system and possible modification of its dynamics, capacity and input fuels. Refer to Appendix A for more detailed environmental activity applicable to the site.

7.1 Clean Air Act

7.1.1 AIR PERMIT

In order to shift the Duluth Steam plant to biomass fuel sources, the Title V air permit which is issued by the Minnesota Pollution Control Agency, will need to be amended. As this change is classified as a major amendment, it should also be noted that the air permit is up for renewal within the next year. To save time and expense, it has been decided to perform the major amendment and permit renewal at the same time.

7.1.2 GACT

Barr Engineering evaluated compliance with the National Emission Standards for Hazardous Air Pollutants ("NESHAPs") as they apply to the four large industrial boilers located at the Duluth Steam plant.

Since the boilers at the Duluth Steam Plant are considered "minor" source, the facility falls under 40 CFR Part 63, Subpart JJJJJJ, which regulates boilers located at facilities that are minor (or "area") HAP sources. This regulation is referred to as the area source "Boiler GACT" (generally available control technology).

Listed below are activities that are required to meet the new GACT rules:

- Initial notification
- Compliance date
- Performance testing
- Continuous compliance
- Work-practice standards
- Semi-annual reporting

Attached in Appendix B is the complete Barr Engineering report identifying the Duluth Steam Plant's requirements pertaining to 40 CFR Part 63, Subpart JJJJJJ requirements.

7.2 Water

7.2.1 PERMIT STATUS

The Duluth Steam Plant discharges water to the Western Lake Superior Sanitary District (WLSSD) pursuant to authority contained in Minnesota Statutes, Chapter 458D, which complies with permit requirements under the National Pollution Discharge Elimination System and the provisions of applicable state and federal laws required by the Clean Water Act of 1977, as amended, and the General Pretreatment Regulations (40 CFR Part 403).

By type of operation (Article III, Section 1(a)), the Duluth Steam Plant is not regulated according to Federal Categorical Pretreatment Standards.

Article III, Section 2(b) of the WLSSD Industrial Pretreatment Ordinance specifies that all remaining Industrial Users affected by Article III, Section 1(a) will be reviewed by the WLSSD to determine whether a wastewater discharge permit is required after review of a completed initial compliance status report.

To date, this report has not been completed and submitted for determination of the site requiring a permit. Ever-Green will be submitting a report to WLSSD for determination on behalf of Duluth Steam.

7.2.2 WATER USAGE

Over the past three years, the average annual water consumption of the system has been approximately 90 million gallons. Transitioning to a closed-loop, hot water district energy system will greatly reduce this water consumption and subsequently the need for chemical water treatment. Over 90% of the water consumption could be expected to be eliminated if a closed-loop hot water system was installed per the System Vision.

7.3 Emissions

Based on the distribution and production alternatives according to Sections 3.6 and 5.3.6, CO_2 (carbon dioxide) and SO_2 (sulfur dioxide) emissions have been estimated to show the impact of the different proposed scenarios. Other emissions, such as CO (carbon monoxide), NO_x (nitrogen oxide) and PM (particulate matter), will in principal follow the same pattern. The reduction will however be slightly less as the CO, NO_x and PM emissions are combustion related while the CO_2 and SO_2 emissions are directly fuel related.

It should also be noted that for the alternatives listed below, the total emissions are for current customers and potential customers, not strictly the plant.

7.3.1 FIVE-YEAR MASTER PLAN.

The Five-Year Master Plan emissions are based only on the distribution scenario with condensate recovery to reduce the number of emission alternatives presented. Without condensate recovery the emissions will increase slightly.

With sawdust co-firing and utilizing natural gas-fired boilers, as shown in Figure 5.7, the CO_2 and SO_2 emissions will be reduced by about 25% according to Table 7.1. More specifically the CO_2 emissions will be reduced by 26% and the SO_2 emissions by 28%.

With an added 50 MMBtu/hr base load boiler as shown in Figure 5.8, the CO_2 will be reduced by 57% and SO_2 emissions by 61% according to Table 7.2.

Table 7.1 Emission comparisons between present system and Five-Year Master Plan utilizing natural gas-fired boilers during the summer plus sawdust co-firing (see also figure 5.7)

	EXISTING SYSTEM			FIVE-YEAR MASTER PLAN		
	Fuel Usage MMBtu/yr	CO_2 [1] tons/yr	SO_2 [2] tons/yr	Fuel Usage MMBtu/yr	CO_2 [1] tons/yr	SO_2 [2] tons/yr
Coal Usage	998,719	106,364	299.6	719,638	76,641	215.9
Gas Usage	180,974	10,497	_	168,910	9,797	_
Biomass Usage	_	_	_	239,639	_	1.2
Total	1,179,693	116,860	299.6	1,128,187	86,438	217.1

NOTES [1]lb/MMBtu: Coal, 213 Gas, 116 Biomass, 0
[2]lb/MMBtu: Coal, 0.6 Gas, 0 Biomass, 0.01

Table 7.2 Emission comparisons between present system and Five-Year Master Plan utilizing natural gas-fired boilers during the summer, and used biomass boilers plus sawdust co-firing (see also figure 5.8)

	EXISTING SYSTEM			FIVE-YEAR MASTER PLAN		
	Fuel Usage MMBtu/yr	CO_2 [1] tons/yr	SO_2 [2] tons/yr	Fuel Usage MMBtu/yr	CO_2 [1] tons/yr	SO_2 [2] tons/yr
Coal Usage	998,719	106,364	299.6	380,938	40,570	114.3
Gas Usage	180,974	10,497	_	168,910	9,797	_
Biomass Usage	_	_	_	578,339	_	2.9
Total	1,179,693	116,860	299.6	1,128,187	50,367	117.2

NOTES [1]lb/MMBtu: Coal, 213 Gas, 116 Biomass, 0
[2]lb/MMBtu: Coal, 0.6 Gas, 0 Biomass, 0.01

7.3.2 SYSTEM VISION

As with the Master Plan it should be noted that for the System Vision, the total emissions are presented for current customers as well as all potential customers.

With the base load biomass capacity increased to 100 MMBtu/hr (about the same size as one of the existing coal boilers) according to figure 5.9, the system CO_2 and SO_2 emissions with be reduced by about 90% according to Table 7.3.

Table 7.3 Emission comparisons between present system and the System Vision utilizing natural gas-fired boilers during the summer and 100 MMBtu/hr biomass boilers (see also figure 5.9)

	EXISTING SYSTEM			FIVE-YEAR MASTER PLAN		
	Fuel Usage MMBtu/yr	CO_2[1] tons/yr	SO_2[2] tons/yr	Fuel Usage MMBtu/yr	CO_2[1] tons/yr	SO_2[2] tons/yr
Coal Usage	998,719	106,364	299.6	79,229	8,438	23.8
Gas Usage	180,974	10,497	_	91,514	5,308	_
Biomass Usage	_	_	_	662,305	_	3.3
Total	1,179,693	116,860	299.6	833,047	13,746	27.1

NOTES [1]lb/MMBtu: Coal, 213 Gas, 116 Biomass, 0
[2]lb/MMBtu: Coal, 0.6 Gas, 0 Biomass, 0.01

Introducing biomass into the fuel mix as part of the Master Plan will help to reduce greenhouse gas emissions in the community. By adding biomass boilers to the system, emissions can be significantly reduced as biomass by displacing coal as the primary system fuel source.

Additionally, converting the distribution system from steam to hot water will allow for a significant reduction in water consumption in the community.

8. Architectural

As part of the system evaluation, the team contracted with an Architecture Field Office (AFO) out of Minneapolis, a firm that specializes in integrating industrial process facilities into the local community. Through collaboration with Ever-Green, the following design concepts have been developed by AFO:

The concept ideas for improvements to the Duluth Steam Plant are based on a few observations about the building's orientation and its relationship to Canal Park and the Duluth Lift Bridge. As the City of Duluth has evolved in the past 80 years, so has the building and its relationship to its context. What is evident is that the building's original front sides (north, east and west) were facing Duluth's downtown district while the south side was used primarily for service. Now, elevated highways have obscured part of the north and east plant elevations, and with the addition of equipment and a plant support structure, the original architectural facades are generally hidden. The remaining east façade is mostly intact and preserved in all of the design concepts presented.

To respond to this reorientation toward Canal Park, the three developed concepts have been developed with similar characteristics in their approach to improving the plant's south façade and are presented in Appendix E:

> To create a more interesting face to the Canal Park district***, Concept A*** employs an artistic approach with a graphic screen panel system applied to the existing façade. These panels could contain words and images that describe the functional characteristics of the plant, providing an engaging and educational 'front door' on axis with the Lift Bridge.
>
> ***Concept B*** applies a system of horizontal louvers, with banding painted in a color palette that is in character with the existing east façade of the plant.
>
> ***Concept C*** proposes the addition of a vertical metal panel screen executed in a variety of bright and lively colors, creating a focal point on the axis with the Lift Bridge. This concept attempts to be in concert with the district's entertainment atmosphere.

Landscaping in all three of the above concepts varies, depending on the amount of screening used at the base of the building. Landscape screen walls and metal panel are used to both obscure the condition at the base of the building while at the same time creating specific branding opportunities and clarity between service areas and the main entrance. Additional landscaping, using plants indigenous to northern Minnesota, along West Railroad Street will form a softer edge and more pedestrian-friendly experience along the property's edge.

Design ***Concept D*** addresses the view from the elevated road at the intersection of South Lake Avenue and the on- and off-ramps of Interstate 35. Because this side of the building faces downtown Duluth, the scheme takes a more unifying approach to the industrial nature of the equipment, pipes and outbuildings that comprise a vital part of the plant. A single screen, broken at the corner to reveal the existing building façade, unifies that face of the building and creates opportunities for formal signage for the Duluth Steam Plant.

The following preliminary opinions of possible cost have been developed for each of the design concepts:

Concept A:	$1.9 million to $2.2 million
Concept B:	$1.85 million to $2.1 million
Concept C:	$1.5 million to $1.65 million
Concept D:	$1.55 million to $1.7 million

Each of the concepts at this stage of the design has interchangeable components. As the design unfolds in more detail, these can be adjusted in form and color to create the final conceptual direction that will provide a unified architectural expression for the Duluth Steam Plant and provide an engaging visual experience for the community.

9. Community Relations

Duluth is the fourth largest city in Minnesota, which has drawn millions of people to visit, develop business, pursue education, explore recreational opportunities, and just under 90,000 have made the city their home. The city's diversity of experiences and resources requires the City of Duluth and Duluth Steam to carefully consider a community outreach strategy that is flexible to these interests.

City Initiatives

As part of the commitment to the City of Duluth, staff of Ever-Green Energy Duluth began participation with City initiatives in 2012. The primary activity was the Local Energy Action Planning process (LEAP). The recommendations from this process will influence the expectations for building owners and managers and will create opportunities for the system to support additional development of renewable energy. The recommendations included evaluating baseline energy data, setting conservation goals, and measuring progress against these goals in multiple sectors. Duluth Steam would participate in these efforts in support of their customers, which includes public buildings that are already tracking some of this information. Furthermore, there were recommendations for additional analysis and integration for alternative energy, including biomass and solar. As discussed in Section 5, Duluth Steam will continue evaluating these alternatives and be an active supporter of alternative energy development for Duluth.

Community Outreach

Duluth Steam is already an important part of the business community, as a service provider to the majority of the central downtown business district. Historically, staff has participated with the Duluth Chamber and other local civic organizations. As part of the development of the utility's services, there will be growing opportunities for participation and support of local organizations, to be determined by areas of interest and available resources. In keeping with the industry standard for community outreach, primary activities would include the following:

- Participation in efforts to support economic development, including the Duluth Chamber, APEX, and the Downtown Council.
- Participation in local and regional sustainability efforts, including the City's sustainability initiatives, climate adaptation and mitigation planning, and support of local organization's developing education and projects to support the environment.
- Development of an active partnership with local academic institutions.
- Develop partnerships with local utilities to adopt best practices for utility operations

and integration of alternative energy solutions for the region.

Participate in local and regional government efforts to develop and implement policies that support the balance of economic development and sustainability.

Education will be a common theme through all of these efforts. Ever-Green will connect the Duluth community to ongoing efforts across Minnesota and nationally to support energy curriculum development. There will also be opportunities to connect students directly to energy system education through first-hand tour experiences, classroom education, and potential internships.

10. Financial Analysis

10.1 Expanded Load

10.1.1 FIVE-YEAR MASTER PLAN

The Five-Year Master Plan envisions two new hot water networks, one expanding the system east of the system's current limits and another on the west end of the system, connecting buildings with hot water internal heating systems. The plan also includes the expansion of the existing hot water network to cover all of Canal Park and the addition of 50% of the downtown buildings not yet connected to the existing steam system. The Master Plan is estimated to increase the percentage of connected buildings to about 90% of total energy usage in the community. A summary of the amount of buildings and annual usage is shown in Table 10.1.

Table 10.1 Summary of Five-Year Master Plan customers

	NUMBER OF BUILDINGS	ANNUAL USAGE (MMBtu/yr)
Existing Customers	183	504,783
Potential Customers	79	74,242
Total	262	579,024

10.1.2 SYSTEM VISION

The System Vision projects the conversion of the majority of the steam system to hot water, connection of approximately 75% of the potential customers in the customer market, and a decrease in the overall energy profile through reduction of distribution losses and an increase in building efficiency. Table 10.2 shows an overall system load reduction of over 50,000 MMBTU after adding an additional 29 buildings to the system when compared to the Five-Year Master Plan.

Table 10.2 Summary of System Vision customers

	NUMBER OF BUILDINGS	ANNUAL USAGE (MMBtu/yr)
Existing Customers	183	426,315
Potential Customers	108	97,420
Total	291	523,736

10.2 Costs of the proposed work

The following summarizes a conservative estimate of the projected capital costs for the improvements proposed in the Five-Year Master Plan:

10.2.1 LOW-END ESTIMATE

Table 10.3 Estimated construction cost for the five- year Master Plan, plant upgrades allowing for 25% co-firing of sawdust.

		ESTIMATED COST
Distribution		$19,610,000
Customer Conversions		$8,140,000
Plant Upgrades		$1,000,000
	Total	$28,750,00
Engineering	10%	$2,850,000
General Conditions	15%	$4,312,500
Contingency—Distribution	10%	$1,961,000
Contingency—Plant and Customer Building Conversions	25%	$2,285,000
	Total	$40,183,500

10.2.2 HIGH-END ESTIMATE

Table 10.4 Estimated construction cost for the Five-Year Master Plan, plant upgrades include both 25% sawdust co-firing and a 50 MMBtu/hr base load biomass boiler.

		ESTIMATED COST
Distribution		$19,610,000
Customer Conversions		$8,140,000
Plant Upgrades		$11,150,000
	Total	$38,900,000
Engineering	10%	$2,875,000
General Conditions	15%	$4,312,500
Contingency—Distribution	10%	$1,961,000
Contingency—Plant and Customer Building Conversions	25%	$4,822,000
	Total	$52,871,000

NOTES Distribution estimate includes west end and Canal Park conversion to hot water as well as an extension of the network on the east end.
Customer conversion estimate includes west end, Canal Park, Downtown, and East End conversions for hot water or steam use.
Customer conversion costs are based on existing buildings and known building usage type.
Energy Transfer Station for east end hot water network included in distribution costs

10.3 Funding Estimates

The current average customer steam system cost is approximately $17/MMBtu. Based on the system growth outlined the Five-Year Master Plan, improved system efficiency and overall customer charges averaging $17/MMBtu, the system can support approximately $30 million of additional revenue bond financing (additional funding options are provided in Section 10.4). Security of the financing would be through customers signing long-term customer agreements. Table 10.5 provides a summary of the annual incremental funding sources and revenue bond funding based upon a 20-year revenue bond with an interest rate of 5%.

Table 10.5 Summary of incremental funding sources and revenue bond funding

ADDITIONAL INCREMENTAL REVENUES	ANNUAL USAGE (MMBtu/yr)	TOTAL FUNDING
Potential Customers	74,241	$1,262,097
Efficiency Savings	51,506	$164,106
Additional Customer Revenues	62,584	$524,483
Available for Debt Service Returns		$449,030
Additional Incremental Funding		$2,399,717
Revenue Bond Debt		$29,905,774
Annual Revenue Bond Debt Service (20yrs, 5%)		$2,399,717

10.4 Funding Options

Funding of the Five-Year Master Plan would be developed from a variety of sources. A majority of the funding of the Five-Year Master Plan will be from the issuance of revenue bonds with additional funding options provided in this section. Funding is anticipated to be supported by customer revenues under long-term contracts.

10.4.1 REVENUE BOND FUNDING

Revenue bond funding can be from a mixture of taxable and tax-exempt bonds. District energy projects are eligible for tax-exempt bond financing per IRS Code § 142. The following provides a list of qualified projects under per IRS Code § 142:

IRS Code § 142. Exempt facility bond (a) General rule For purposes of this part, the term "exempt facility bond" means any bond issued as part of an issue 95 % or more of the net proceeds of which are to be used to provide—

- Airports
- Docks and wharves
- Mass commuting facilities
- Facilities for the furnishing of water
- Sewage facilities
- Solid waste disposal facilities

- Qualified residential rental projects
- Facilities for the local furnishing of electric energy or gas
- Local district heating or cooling facilities
- Qualified hazardous waste facilities
- High-speed intercity rail facilities
- Environmental enhancements of hydroelectric generating facilities
- Qualified public educational facilities
- Qualified green building and sustainable design projects
- Qualified highway or surface freight transfer facilities

These tax-exempt exempt facility bonds are also classified as "Private Activity Bonds" and the bond issuance volume is subject to an annual State bond allocation cap (Minnesota volume cap is $511.018M in 2013). In Minnesota, each year bonding is available for certain district energy projects under the Public Facilities Pool until August 1st when additional funding is available through the Unified Pool. Proceeds from the tax-exempt bonds can only be used for distribution related system costs and associated financing costs. Additional funding is then provided by taxable revenue bond.

10.4.2 ADDITIONAL FUNDING SOURCES

Additional low cost funding sources for the Five-Year Master Plan will be required above the revenue bond funding. Identifying specific uses for the funds will improve the likelihood of receiving project funding. For example, separating funding for the biomass plant capital costs from the distribution funding will help frame the funding request. Some potential funding sources include the following:

New Market Tax Credits. The federal New Market Tax Credit (NMTC) program provides funding to qualified projects in economically distressed areas as defined in the NMTC program. NMTC can be used to fund approximately 20% of the total project cost with low cost funding. The program requests interest only payments for a period of seven years with a significant portion of the principal forgiven after the initial seven year period associated with the tax credits. A number of projects in Duluth have received NMTC funding.

Department of Energy. The Department of Energy provides grant and loan opportunities for various energy related projects. Among the eligible projects include renewable energy, combined heat and power, energy efficiency and heat recovery.

State of Minnesota Bonding. A request can be made by the City of Duluth to include Master Plan costs in the State of Minnesota bonding bill for capital improvements.

Minnesota Department of Commerce. The Minnesota Department of Commerce, Division of Energy Resources funds Conservation Applied Research and Development (CARD) grants on an annual basis. The CARD Grant Program is focused on identification of new technologies or strategies to maximize energy savings, improve effectiveness of energy conservation programs, or document the carbon dioxide reductions from energy conservation projects. Funding totals for this grant opportunity vary year-to-year.

Foundation Grants. Certain foundations provide grant funding for the project. Potential funds could include funding for of conversion costs for non-profit entities, funding of the energy efficiency improvements and funding of the renewable energy costs.

Conservation Improvement Program. The State of Minnesota Conservation Improvement Program (CIP) is a potential funding source. Minnesota Power has efficiency grants/rebates for electric customers to improve the efficiency of their buildings and equipment.

A number of options are available to fund the improvements suggested in this Master Plan. Depending upon the alternatives preferred by Duluth Steam, each of the above options should be further researched to determine their applicability and availability.

11. Conclusions

The City of Duluth is interested in improving the overall efficiency of the Duluth Steam system and advancing its integrated energy program to serve the energy needs of the Duluth Community today and in the future. In analyzing the current level of efficiency of the overall Duluth Steam system, analysis is targeted in three different areas: plant and production, distribution, and customer buildings.

11.1 Plant and Production Conclusions

Within the plant, the greatest improvements that could be made are attributable to a migration away from coal as an input fuel source. Although natural gas is readily available, biomass appears to be more cost competitive and also offers significant environmental gains. Through incorporation of the System Vision, biomass could replace coal as the primary fuel source. Coal and natural gas would still be utilized as part of a fuel portfolio. Waste heat recovery should be continued or expanded. Summer loads should be managed under a more effective model, moving away from the operation of the coal boilers at a reduced capacity. Increasing hot water production would also increase opportunities for the plant and system to integrate alternative energy sources.

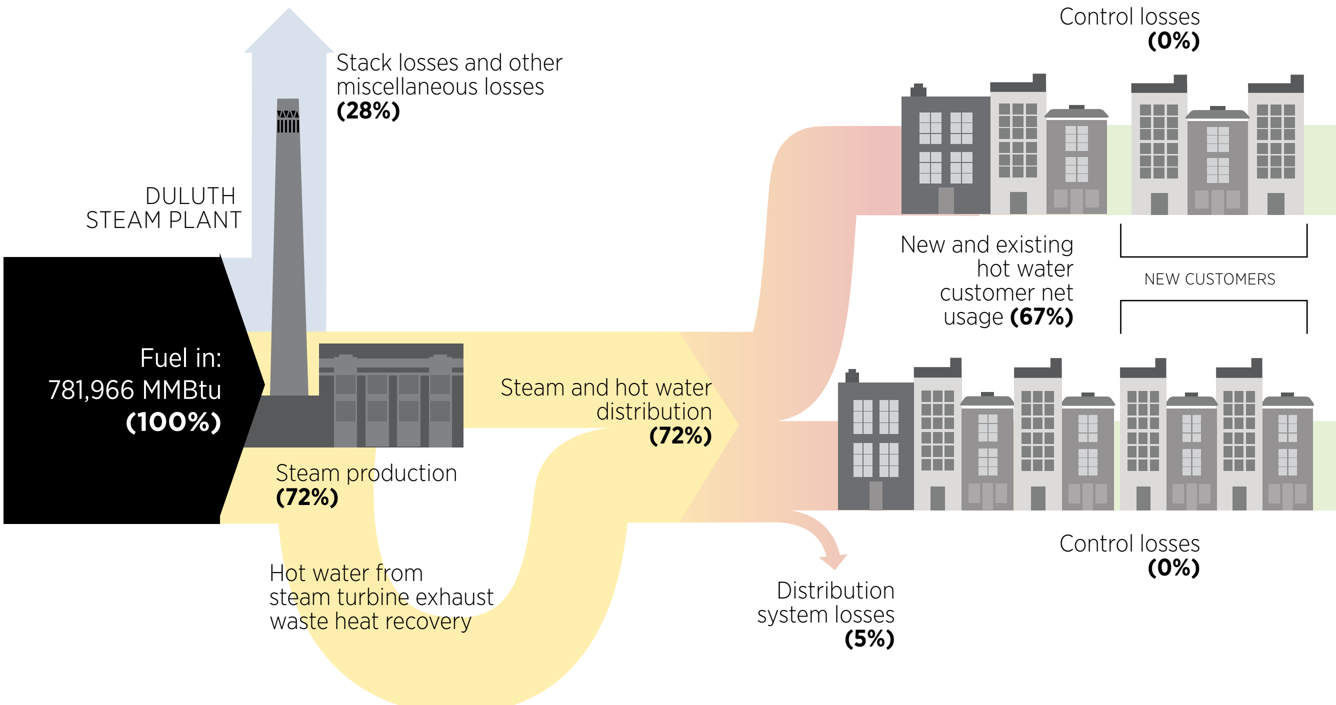
11.2 Customer Buildings

Improvements for customer buildings are also centered on the potential conversions from steam to hot water. Additional efficiency improvements could be made at customer buildings which are not directly related to the district energy system itself. These energy conservation measures have not been budgeted for within the findings of this Master Plan. These customer improvements will have other opportunities for funding, including performance contracting models or energy rebates. By connecting to a hot water system and utilizing hot water for building internal mechanical systems, customers can also expect to realize a decrease in their overall energy consumption by achieving better control over their HVAC systems.

11.3 Distribution

To maximize the potential of a system vision, the distribution system would require the most significant changes, including the replacement of the majority of the steam distribution network with a closed-loop hot water network. Replacing over 60,000 trench feet of steam piping with a more efficient hot water distribution loop will be a key contributor to the improvements in system efficiencies. Another benefit of such a change will be the reduction of nearly 90 million gallons of water usage annually, as the hot water loop will be a closed-loop system with minimal losses.

Figure 11.1 Duluth Steam System Vision energy balance



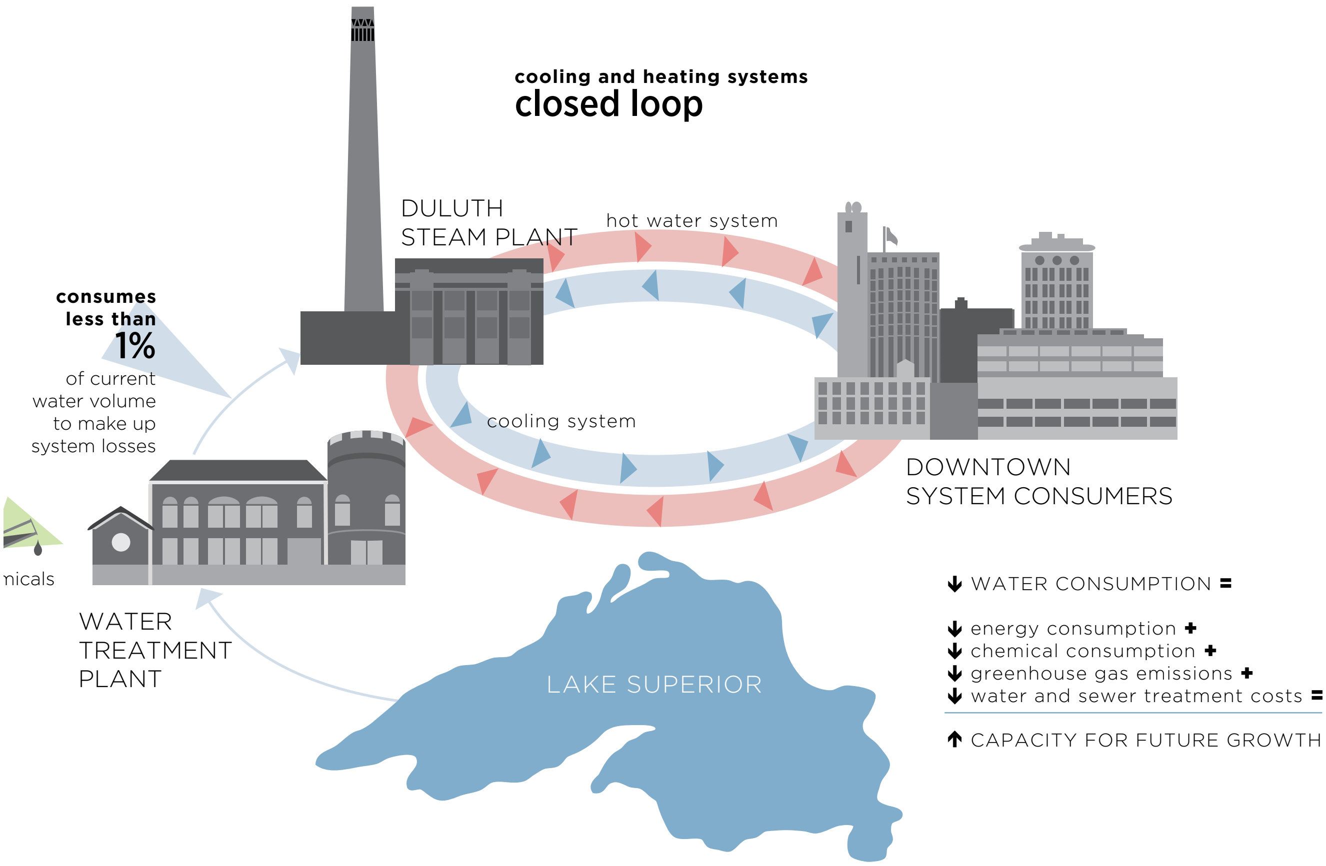
The distribution system offers the majority of opportunities for improvement, with the transition from a steam--based district energy network to hot water. Hot water will provide efficiency improvements in a number of areas, including a reduction in distribution losses, better control, and fewer losses at the customer buildings. Figure 11.1 provides a visual depiction of the vision for the Duluth Steam System.

The current steam system for Duluth Steam is a once-through steam network. Steam is sent from the plant to customer buildings through a series of distribution pipes. Condensate generated in the distribution network and at the customer buildings is not returned to the plant; rather it is discharged into the sanitary and storm sewers. The plant then receives over 90 million gallons of fresh make-up water annually from the city for purposes of heating and distribution. Under the System Vision, water would be reused so that the efficiency of the plant may be improved and also to greatly reduce the usage of water by the plant. Figure 11.2 provides a visual depiction of water consumption by the system under the long-term vision.

11.4 Overall Improvements

Achieving the System Vision will be a capital intensive endeavor and may require a number of years for full implementation. Although the model under the System Vision provides the greatest level of energy efficiency to the Duluth community while reducing greenhouse gas emissions, the process of implementing the transition will likely take time in order to secure the appropriate customer load, project financing,

Figure 11.2 Water and sewage treatment capacity for future growth



and other necessary requirements. In the short-term, incremental improvements could be made to the System that will move Duluth Steam forward in a less capital intensive manner. In particular, this Five-Year Master Plan has suggested the following incremental improvements which could be made with less significant capital outlay:

Improving the efficiency of the DECC and several other customers on the System

Co-firing of sawdust in the existing boilers up to a level of 25% of the boiler capacity

Converting the Canal Park District to hot water

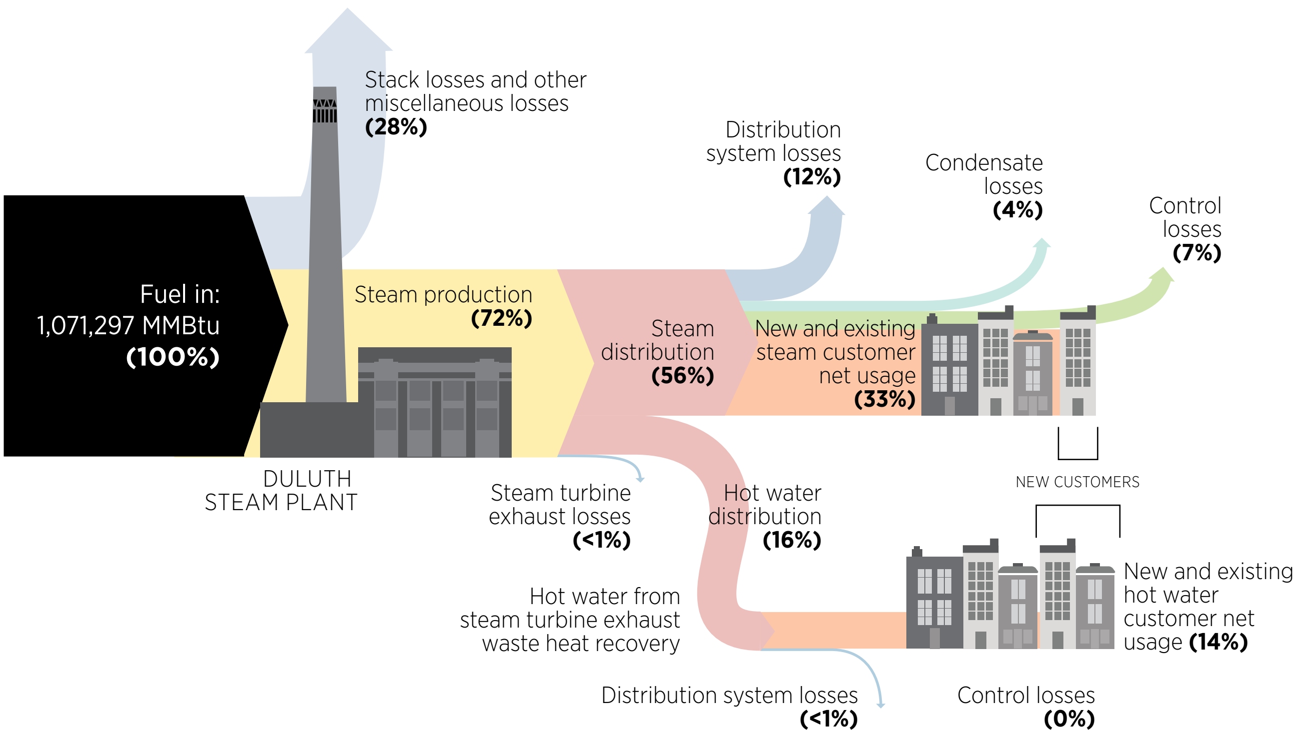
Serving the summer steam and hot water load from a natural gas-fired boiler somewhere on the network.

Establish hot water loops on the west and east end of town to serve those buildings that can easily receive hot water in lieu of steam.

Begin collecting condensate in those areas adjacent to hot water distribution systems so that the captured condensate may be connected with the hot water return loop. This option should only be implemented if the hot water loops connect back to the plant.

Each of the above options may be implemented exclusively, or they can be implemented as part of an integrated Master Plan approach. When fully implemented, the energy flow diagram for the system under the Master Plan is shown in Figure 11.3

Figure 11.3 Five-Year Master Plan: System Energy Flow Diagram



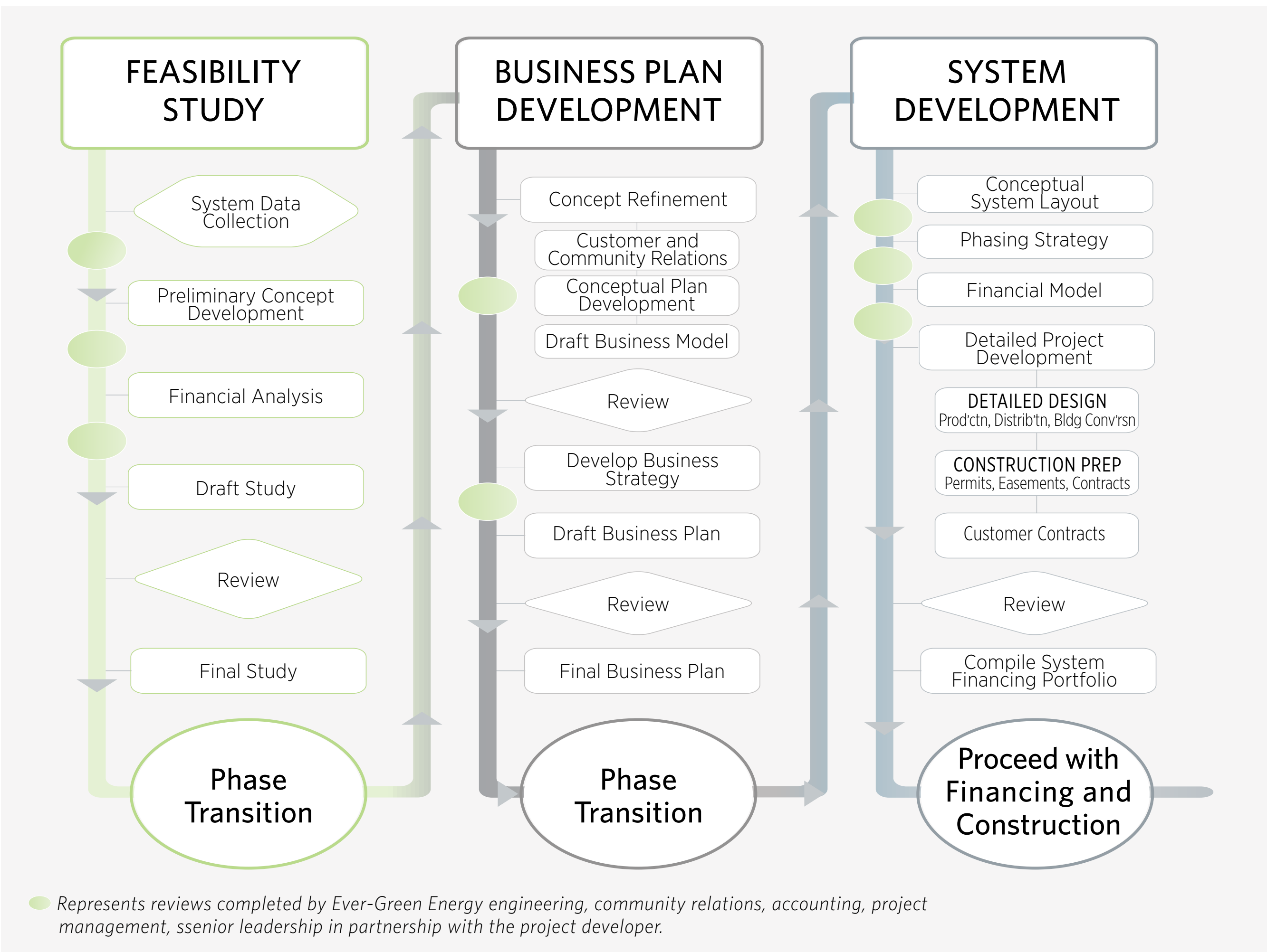
Each of the measures included in the Master Plan are conceptual in nature and require further vetting. Although each measure appears to have some merit and should contribute to the goals of the system, they each should be further developed in order to verify the technical feasibility of implementation, their full value and cost ramifications before implementation.

12.
Proposed Next Steps

12.1 A Model for Integrated Energy

The development or advancement of district energy systems requires significant evaluation and planning in order to account for all variables. Ever-Green Energy has developed an Integrated Energy Model (IEM) that it utilizes when working with its customers in helping them develop or advance their integrated energy systems. This model is summarized in Figure 12.1.

Figure 12.1 Integrated Energy Model for developmental evaluation and planning



This Master Plan has provided an initial analysis of how the Duluth Steam System could be advanced to serve its customers, the community and the environment in a sustainable manner. The analysis has evaluated the possibilities from a holistic approach and has identified a number of possibilities for next steps of advancement. In relating to the IEM above, the Master Plan is now at the Concept Refinement stage of development.

12.2 Detailed Next Steps

Review of Master Plan and System Vision—The technical and operational improvements recommended should now be further developed to verify their ease of implementation and also any considerations that may impact the success of these possibilities. Further development should entail a review of the Master Plan by management in order to identify those concepts that appear to have the greatest merit. Once those concepts have been identified, the possible future load should be evaluated so that a realistic customer load can be established for the first phase of advancement of the system.

***Customer Outreach and Cost Estimation*—**If the hot water system transitions are viewed favorably, this would entail meeting with existing and potential customers to gain a better understanding of their willingness to convert from steam to hot water, and also establish more detailed cost estimates for conversion of those buildings. Duluth Steam should also meet with existing customers either currently on hot water or proposed to convert to hot water to establish connection standards and identify any energy conservation measures that will support the efficient operation of the hot water district energy system.

***Conceptual Design for Production and Distribution*—**Once the revised load is established for the enhanced system, a conceptual design should then be performed for both the system production as well as the new distribution network. With the production system, fuel sources should be researched as well as existing permit allowances for alternative fuel integration. An integration plan should also be established for any new equipment in the existing facility, along with necessary alterations that will need to be made at any satellite production facilities that may serve the load.

For the distribution network, collaboration with Duluth Public Works will be important so that the installation of the new hot water supply and return pipes may be coordinated with other infrastructure projects in the area. The work should be planned to occur in conjunction with other street work to minimize the cost of the installation and to continue a strong working relationship with City staff.

***Draft Business Model*—**Upon verification of the Phase I implementation strategy by Duluth Steam's management, a draft business model should be established to verify the financial feasibility of the refined plan. The model should include a financing plan for the project with possible funding sources, along with possible rate structures that provide customers with competitive energy rates while still managing the debt service requirements for Duluth Steam.

***Business Plan Development*—**With the approval of the refined concept for system advancement, the team should then focus on completing the business plan for the system advancement. Some of the focus in business plan development should include detailed plans for design development, permits, financing, customer contracts and construction contracts. The business plan should also lay out the schedule and budget for completion of the development plan for system advancement along with a development budget. Lastly, the business plan should address significant risks of the development plan along with the proposed mitigations.

Implementation of Detailed Development—Upon approval of the business plan, detailed development should commence to prepare the project for full financing and implementation.

13. Assumptions

The information presented in this Master Plan document was based upon a set of assumptions. These assumptions should be validated as part of the next phase of development:

- Cost per square foot for building conversions are based on estimates generated after customer building site visits. The buildings ranged in size and were completed for each type of internal heating system.
- Non-customer buildings were not analyzed by the team for ease of integration with a steam or hot water district energy system. This should be researched.
- Distribution construction costs are based on experience with similar networks. For Duluth, in both the downtown area and Canal Park, it was assumed the installations will have a higher level of complexity accounting for traffic impacts, surface restoration, existing utilities, etc.
- Production plant retrofit costs were established based upon general rules of thumb.
- For buildings where metered data was not available, such as buildings not on one of Duluth Steam's networks, the energy consumption was based on square footage provided by parcel data and 80% of the 2003 CBECS building usage factors.
- DECC energy efficiency improvements were assumed based upon site visits and a review of the metered usage. Actual improvements may provide a different result.
- The City of Duluth is planning on retrofitting many streets in downtown Duluth. Coordinating distribution pipe installation with this work can allow for a reduced cost of pipe installation.
- Location of existing underground utilities can have a significant impact on the cost of installing a distribution system in downtown Duluth.
- It has been assumed that the proposed hot water pipes can be installed under one or more of the bridges crossing Interstate 35. This needs to be validated.
- A detailed analysis should be performed to determine the ease of integrating biomass as a part of the system's fuel mix.

Appendix A
Environmental Permits

NESHAP COMPLIANCE

Barr Engineering Co. has evaluated compliance with the National Emission Standards for Hazardous Air Pollutants ("NESHAPs") as they apply to the four large industrial boilers located at the steam plant. HAP emissions from boilers are regulated by one of two NESHAPs.

HAP emission limits were placed in the Duluth facility's Title V permit (permit 13700022-003, issued 8/4/09) to secure the facility's classification as an area source. As a result, the Duluth facility must comply with the area source Boiler GACT regulation.

The Boiler GACT (78 FR 7488, issued February 1, 2013) imposes different requirements depending on whether a boiler is existing, new or reconstructed, and which subcategory a boiler qualifies under. Since each of the four boilers at the Duluth steam plant commenced construction before June 4, 2010 and burns solid fossil fuel, all four boilers qualify as an existing affected source under the "coal" subcategory.

The emission units affected by this rule must be in compliance with the applicable emission limits and work practices listed below by March 21, 2014:

> Performance Testing: Performance testing must be completed by September 17, 2014.
>
> > Mercury: An emission unit can comply with mercury emission limits through fuel testing alone. (The limit for Mercury is 0.000022 lb/MMBtu)
> > CO: An emission unit can comply with its applicable emission limits through stack testing. (The limit for CO is 420 ppm (@3% O2) (ppm—test or 10 day average)
>
> Continuous Compliance: Operating parameter information must be collected during stack tests, with control equipment and other operating parameters recorded and used to develop operating parameter limits.
>
> Work-practice Standards: An energy assessment must be completed before March 21, 2014, and is described in Table 2 of the subpart. In addition, the boilers must adopt a biennial tune-up schedule.
>
> Semi-annual reporting must be completed: Semi-annual reporting is required as described in 40 CFR Part 63.11225(b), and must be completed by January 31 for July through December of the previous year and July 31 for January through June.

It should be noted that a boiler may burn up to 15 % biomass on an annual heat input basis while still qualifying for the coal subcategory. Burning more than this will change the boiler's subcategory from "coal" to "biomass" and trigger different requirements.

Making any changes to the system will require a review of each facility's existing air permit to determine if changes are allowed or if additional permitting is needed. This is a complicated situation in the context of the federal New Source Review—Prevention of Significant Deterioration (NSR-PSD) program, codified at 40 CFR 52.21.

AIR EMISSION PERMIT (MPCA Permit No. 13700022-003)

The Duluth Steam Plant maintains a Federal: Part 70 Reissuance/Major for NSR Permit. The current issue date is August 4, 2009 and the listed expiration date is August 4, 2014. Renewal for this permit must be submitted 180 days prior to expiration of the existing permit. A major amendment is in the planning to permit the facility to burn biomass as one of its fuel sources.

EPA, REGION 5—REQUEST FOR INFORMATION

In January of 2013, the EPA issued an information request under section 114(a) of the Clean Air Act (the Act), 42 U.S.C. § 7414(a). This request is requiring the Duluth Steam Cooperative to submit certain information about its steam generation facility. EPA is requesting this information to determine whether these emission sources are complying with the Clean Air Act.

Information was submitted going back approximately 10 years in time, of which almost all of this time not being under the management of Ever-Green Energy, LLC.

Although this information was submitted in March, 2013, it may take the EPA some time to reply with a request for more information or clarification of data submitted.

MANDATORY GREENHOUSE GAS REPORTING 40CFR Part 98 Subpart A

Because the facility did not meet listed requires as state in Tables 3 or 4 of the standard, but did meet the following requirements, the Duluth plant is required to report greenhouse gases under the federal standard.

Duluth plant classification was not listed as required in specified tables 3 & 4 of standard.

The aggregate maximum rated heat input capacity of the stationary fuel combustion units at the facility is 30 MMBtu or greater.

Facility emits 25,000 metric tons of CO2e or more per year in combined emissions from all stationary fuel combustion sources.

The facility has reported CO2e emissions for years 2010, 2011 and 2012. The reported quantity of CO2e emissions for 2012 was 59,683 metric Tons.

Annual reporting is required by March 1 for the previous year.

POLLUTION INSURANCE

Environmental pollution insurance was obtained to cover the following activities:

On-Site Cleanup of New Conditions

Third Party Claims for Off site cleanup from new conditions

Third party claims for bodily injury and property damage

Emergency response Costs

Third party claims for non-owned locations

Third Party claims for transported cargo

Insured Locations:

One Lake Place, Duluth, MN

Piping associated with operations per the layout of Steam Main, and service connection distribution map dated 6/18/96

Named Insured's are Ever-Green Energy, LLC and Ever-Green Energy Duluth, LLC. Policy is in effect from 9/24/12 – 9/24/2015.

REQUIREMENTS FOR ENGINE GENERATORS
40CFR Part 63

Duluth Steam Plant owns and operates two engine generators that are 248 and 512 HP in size and are subject to the NESHAP, Subpart 4Z.

In general, the standard's requirements mainly address operation and maintenance procedures; along with record keeping, and installing an hour meter so that the engines' use can be verified to be emergency use only.

HAZARDOUS WASTE
Very Small Quantity (VSQ) Generator(MPCA Permit MN0981530637)

Duluth Steam Plant maintains an annual VSQ generators license. Wastes generated are oils, minerals spirits and recyclable wastes. Presently, waste oils and mineral spirits are used as fuel for the boilers on site.

NPDES / STORMWATER PERMIT

Location has a National Pollutant Discharge Elimination System / State Disposal System (permit MN0055719), issued October 14, 2011 and expires September 30, 2016.

This permit requires the Duluth Steam plant to reduce pollutant levels to specified requirements at identified point source discharges. This permit also contains a Storm Water Management Plan for which the Duluth Steam Plant must comply with at its plant location.

SPILL PREVENTION, CONTROL, AND COUNTERMEASURE PLAN (40 CFR § 112.5)

Because of the amount of oil stored at the Duluth Steam plant and the close proximity to navigable waters, the site must have a Spill Prevention, Control, and Countermeasure Plan.

This plan is required to be reviewed every five years (last reviewed and amended March 2012). As a result of this review and evaluation, the owner or operator shall amend the SPCC plan within six months of the review to include more effective prevention and control technology if:

Such technology will significantly reduce the likelihood of a spill event from the facility.

If such technology has been field-proven at the time of the review.

The owner or operator must also amend the plan when there is a change in the facility design, construction, operation, or maintenance that materially affects its potential for a discharge.

This plan is intended to minimize the potential for Duluth Steam Cooperative Association to adversely impact its environment and for the facility to attain and maintain compliance with EPA standards for oil pollution prevention and response.

ABOVE GROUND STORAGE TANK

The Duluth Steam Plant has two above ground storage tanks (1,000 gallons each) at the facility storing Diesel Fuel #2 used as an alternate fuel for the boilers and to run the 2 small generators at the site. These tanks are registered with the MPCA as required.

As part of the site Air Emission Permit, there is a permitted emergency stand-by generator listed as an emissions unit. This generator is non-functional at this time, and includes a two hundred gallon belly tank, which is empty.

Appendix B
Barr Engineering Report

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BARR

Technical Memorandum

To: Michael Burns, Ever-Green Energy-Duluth, LLC

From: Paul Taylor, Barr Engineering (Minneapolis)
Lillian Woolley, Barr Engineering (Ann Arbor)

Subject: Applicability of the National Emission Standards for Hazardous Air Pollutants for Industrial, Commercial, and Institutional Boilers Area Sources (40 CFR Part 63, Subpart JJJJJJ)

Date: April 16, 2013

Project: 22691388.00

Barr has evaluated compliance with the National Emission Standards for Hazardous Air Pollutants ("NESHAPs") as they apply to the four large industrial boilers located at Ever-Green Energy-Duluth's steam plant. HAP emissions from boilers are regulated by one of two NESHAPs. 40 CFR Part 63, Subpart DDDDD regulates boilers located at facilities that are major HAP sources. The regulation is referred to as the major source "Boiler MACT" (maximum achievable control technology). 40 CFR Part 63, Subpart JJJJJJ regulates boilers located at facilities that are minor (or "area") HAP sources. This regulation is referred to as the area source "Boiler GACT" (generally available control technology).

Facilities are categorized as major or area sources depending upon their HAP emissions. Major sources have potential emissions of 10 tons per year or more of any individual HAP or 25 tons per year or more of any combination of HAP. Area sources have annual emissions below these thresholds. If practical for their operations, facilities may accept permit limits to maintain an area source designation and minimize NESHAP compliance by using the Boiler GACT regulation. These limits may be achieved by using emissions control equipment, fuel changes or by altering operations.

HAP emission limits were placed in the Duluth facility's Title V permit (permit 13700022-003, issued 8/4/09) to ensure the facility's classification as an area source. As a result, the Duluth facility must comply with the area source Boiler GACT regulation.

The Boiler GACT (78 FR 7488, issued February 1, 2013) imposes different requirements depending on whether a boiler is "existing" or "new" (or "reconstructed") and which "subcategory" a boiler qualifies under. Since each of the four boilers at the Duluth steam plant commenced construction before June 4, 2010 and burns solid fossil fuel, all four boilers qualify as an "existing" affected source under the "coal subcategory". A summary of limits applicable to the Duluth facility units under the area source Boiler GACT is attached as Table 1. Several activities are needed to comply with the emission limits in these rules, and are summarized below:

Initial Notification: An initial notification for the facility was likely completed, as the final rule was first issued on March 21, 2011 (76 FR 15554) and required an initial notification to be submitted by September 7, 2011. However, the notification deadline has since been extended to January 20, 2014. If a notification has already been completed, no additional notification is required. If a notification must still be completed, a form like the one attached can be used (though a form is not required). The form summarizes the information required in the initial notification, but that information can also be found in 40 CFR Part §63.9(b).

Compliance Date: The emission units affected by this rule must be in compliance with the applicable emission limits and work practices by March 21, 2014.

Performance Testing: Performance testing must be completed by September 17, 2014. Site-specific test plans must be submitted 60 days before testing, and test results must be submitted within 60 days of testing. Performance testing is described in Table 4 of the rule, while operating parameters that must be recorded during testing is described in Table 3.

<u>Mercury</u>: An emission unit can comply with mercury emission limits through fuel testing alone. A site specific monitoring plan must be developed before sampling and analysis of the fuel. Emissions are calculated using the equations included in 40 CFR Part 63.11211(c). Fuel tested must be a "worst case" for the applicable pollutant. If initial fuel sampling shows Hg concentrations in the fuel $\leq$ 50 % of concentrations at the emission limit, no additional fuel monitoring is required. If they are above 50 %, quarterly sampling is required. If compliance with the emission limits is to be shown through stack testing (fuel sampling and analysis is required during testing along with operating parameter monitoring), and stack testing shows emissions $\leq$ 50 % of the emission limit, no additional stack testing is required. If not, testing must be completed every three years (with no more than 37 months between tests).

<u>CO</u>: An emission unit can comply with its applicable emission limits through stack testing. A site-specific test plan must be developed according the requirements of 40 CFR Part 63.7. Stack testing is required every three years, with no more than 37 months after a prior test. Testing must be performed at a maximum load, as load will be restricted after the testing to 110 % of the average load. No emission units located at this facility are required to use CEMS, but CEMS <u>can</u> be used to show compliance with emission limits.

Boilers that belong to the same subcategory but vent to a common stack through common control equipment may be treated as a single emission unit, or they can be treated individually. If the Duluth facility would like to petition to have the four boilers treated as a single source and complete only one stack test instead of four, such a request should be included in the site-specific monitoring plan.

Continuous Compliance: Operating parameter information must be collected during stack tests, with control equipment and other operating parameters recorded and used to develop operating parameter limits. These operating parameters are described in Table 7 of Subpart JJJJJJ. For units with CO limits that are not using a CO CEMS to show compliance, an oxygen monitor must be installed and oxygen levels must be maintained above the lowest hourly average measured during the stack test, on a 30-day average. If the fabric filter is needed to show compliance with the emission limits included in Table 1, either opacity must be maintained at or below 10 % on a daily block average (measured using a continuous opacity monitoring system (COMS)) or a bag leak detection system must be used (and alarms must total less than 5 % of operating time during every six month reporting period.)

Work-practice Standards: Note that no limited-use or boilers with oxygen trim systems are located at this facility. An energy assessment must be completed before March 21, 2014, and is described in Table 2 of the subpart. In addition, the boilers must adopt a biennial tune-up schedule, as described in 40 CFR Part 63.11223, and the first tune-up must be completed before March 21, 2014. Emissions must be minimized during start-up and shutdown, following manufacturer's recommendations.

Semi-annual reporting must be completed: Semi-annual reporting is required as described in 40 CFR Part 63.11225(b), and must be completed by January 31 for July through December of the previous year and July 31 for January through June. Reporting on all compliance activities is done in this report, and is further described in 40 CFR Part 63.11225.

Additional Considerations:

Burning alternative fuels in the four boilers: This could involve either of the following two possibilities:

(i) Burning fuels for which the boilers are already permitted.
The primary fuel for each of the four boilers is pulverized coal (either bituminous or sub-bituminous) and natural gas is the principal backup fuel for two of the boilers (Boilers 2 and 3). However, the current Title V permit also authorizes each boiler to burn No. 2 fuel oil, small quantities of waste oil, and waste mineral spirits generated at the facility. Being permitted to burn these liquid fuels does not qualify the boilers for the "oil subcategory" in the Boiler GACT because they otherwise qualify for the "coal subcategory". If the waste oil is an off-specification used oil, additional review of the material is required to ensure that the material is not a waste, triggering the need for the boiler to comply with the Emission Guidelines (40 CFR 60, subpart DDDD) or New Source Performance Standards (40 CFR 60, subpart CCCC) for Commercial and Industrial Solid Waste Incineration (CISWI) Constructed before or after 11/30/99, respectively. Continued burning of the waste mineral spirits requires review and could require a non-waste determination. Non-waste determinations are described in 40 CFR 241.4.

(ii) Burning fuels for which the boilers are not already permitted.
The burning of such fuels will require a separate air permitting evaluation to determine what, if any, air permitting requirements may be triggered. It should be noted that a boiler may burn up to 15 percent biomass on an annual heat input basis while still qualifying for the coal subcategory. Burning more than this will change the boiler's subcategory from "coal" to "biomass" and trigger different requirements. Additional alternative fuels will also need to be reviewed separately with respect to this rule, specifically to determine if an alternative fuel could be labeled as a solid waste as defined in 40 CFR 258.2.

<u>Adding capacity to the steam distribution system through the use of existing boilers that are owned, operated and permitted by other entities at other locations</u>:

Making any changes to the system will require a review of each facility's existing air permit to determine if changes are allowed or if additional permitting is needed. This is a complicated situation in the context of the federal New Source Review – Prevention of Significant Deterioration (NSR-PSD) program, codified at 40 CFR 52.21. The complexity relates to the definition of "stationary source". Currently, the Duluth steam plant and each of the other nearby facilities with boiler capacity have their own (most likely, Part 70, or "Title V") air emission permits. Each facility is therefore considered as a separate stationary source for both Title V and PSD purposes. One question is whether the combination of boilers (that could potentially be used to supply steam to Duluth's steam distribution system) should be considered a single stationary source. Under PSD, three factors are considered when determining whether the collection of emission sources comprise a single stationary source:

(i) the industrial grouping (i.e., the first two digits in the Standard Industrial Classification (SIC) code);
(ii) whether the sources are located on one or more contiguous or adjacent properties;
(iii) whether the sources are under common ownership or control.

It seems unlikely, based on a preliminary review of these factors, especially factors (i) and (ii), that the collection of boilers would be considered a single stationary source. However, a full evaluation would require a thorough review of historical USEPA memoranda related to previous determinations, which is beyond the scope of the current project.

Table 1 - 40 CFR PART 63, Subpart JJJJJJ Limits that Apply to Ever-Green Energy-Duluth's Boilers

Emission Unit	Permit Designation	Rating (MMBtu/hr)	Fuels	Category and subcategory	PM (lb/MMBtu)	Mercury	CO (ppm - test or 10 day average)	Comments
EU 001	Boiler No. 1	Boilers total 460 MMBtu/hr design, but are limited to 345 MMBtu/hr total	Coal	Existing coal-fired > 30 MMBtu/hr	NA	0.000022 lb/MMBtu	420 ppm (@3% O_2)	All four units share a common stack. It may be possible to test only once for the total.
EU 002	Boiler No. 2				NA	0.000022 lb/MMBtu	420 ppm (@3% O_2)	
EU 003	Boiler No. 3				NA	0.000022 lb/MMBtu	420 ppm (@3% O_2)	
EU 004	Boiler No. 4				NA	0.000022 lb/MMBtu	420 ppm (@3% O_2)	

Emission rates do not apply during start-up and shutdown, but an emissions minimization plan is required and there are some other limitations on start-up and shutdown.

Example Initial Notification Report

National Emission Standards for Hazardous Air Pollutants for
Industrial, Commercial, and Institutional Boilers Area Sources

SECTION I : GENERAL INFORMATION

Operating Permit Number (IF AVAILABLE)[a] Facility ID Number (IF AVAILABLE)[b]

____

Responsible Official's Name Title

____

Street Address

____

City State ZIP Code

____

[a] (e.g., Title V permit number)
[b] (e.g., Air Facility System (AFS) facility ID)

Facility Name

____

Facility Street Address (if different than Responsible Official's Street Address listed above)

____

Street Address

____

City State ZIP Code

____

Facility Local Contact Name Title

____

Anticipated Compliance Date(s) (mm/dd/yy) (§63.9(b)(2)(iii))[c]:____

[c] See instructions on pg. 3 of this form to determine the compliance dates applicable to you.

SECTION II: SOURCE DESCRIPTION

1. Please complete the table below for each affected boiler per §63.9(b)(2)(iv).

Emission Unit ID[d]	Emission Unit Name (design and manufacturer name)	Size: Rated Heat Input Capacity (mmBtu/hr)[e]	Fuels Used[f]

[Add rows to the table for additional boilers, as necessary.]

[d] If the source has an operating permit, use the IDs that are consistent with those reported in the permit.

[e] mmBtu/hr refers to million British thermal units per hour. Boilers often have a nameplate listing the rated heat input capacity on the unit. This rated capacity may have also been reported to the entity insuring the boiler or the state labor and safety inspector.

[f] Report all fuels used in each of the units subject to the standard (e.g., bituminous coal, #6 fuel oil, #2 fuel oil, natural gas, bark, lumber, etc.).

3. Optional: Additional notes

4. My facility is a (please choose one): ☐ Major source ☐ Area source

If your facility is a major source of hazardous air pollutants (HAP), please refer to the National Emission Standards for Hazardous Air Pollutants for Major Sources: Industrial, Commercial, and Institutional Boilers and Process Heaters, 40 CFR Part 63 Subpart DDDDD at http://www.epa.gov/ttn/atw/boiler/boilerpg.html.

SECTION III: CERTIFICATION

I hereby certify that the information presented herein is correct to the best of my knowledge.

______________________________	______________________________
Signature	Date
______________________________	(________)______________________
Name/title	Telephone Number

To whom do I submit the initial notification?

a. Submit the notification to the appropriate EPA Regional Office using the list below.

b. In addition, if your State has been delegated the authority for this regulation under section 112(l) of the Clean Air Act, submit the notification to your State agency found at the following link: www.epa.gov/ttn/atw/area/table_state_contacts.doc

If your state/local contact is not listed at the above link, go to: www.4cleanair.org/contactUsaLevel.asp

EPA Region I (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont)
US Environmental Protection Agency
5 Post Office Square, Suite 100, Mail code: OES04-2,
Boston MA 02109-3912 Attention: Air Clerk

EPA Region II (New Jersey, New York, Puerto Rico, Virgin Islands)
Director, Division of Enforcement and Compliance Assistance
290 Broadway, New York, NY 10007-1866

EPA Region III (Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, West Virginia)
Director, Air Protection Division, 1650 Arch Street, Philadelphia, PA 19103

EPA Region IV (Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee)
Director, Air, Pesticides and Toxics Management Division
Atlanta Federal Center, 61 Forsyth Street, Atlanta, GA 30303–3104

EPA Region V (Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin)
Director, Air and Radiation Division, 77 West Jackson Blvd., Chicago, IL 60604–3507

EPA Region VI (Arkansas, Louisiana, New Mexico, Oklahoma, Texas)
Director, Air, Pesticides and Toxics, 1445 Ross Avenue, Dallas, TX 75202–2733

EPA Region VII (Iowa, Kansas, Missouri, Nebraska)
Director, Air and Waste Management Division, U.S. Environmental Protection Agency
901 N. 5th Street, Kansas City, KS 66101

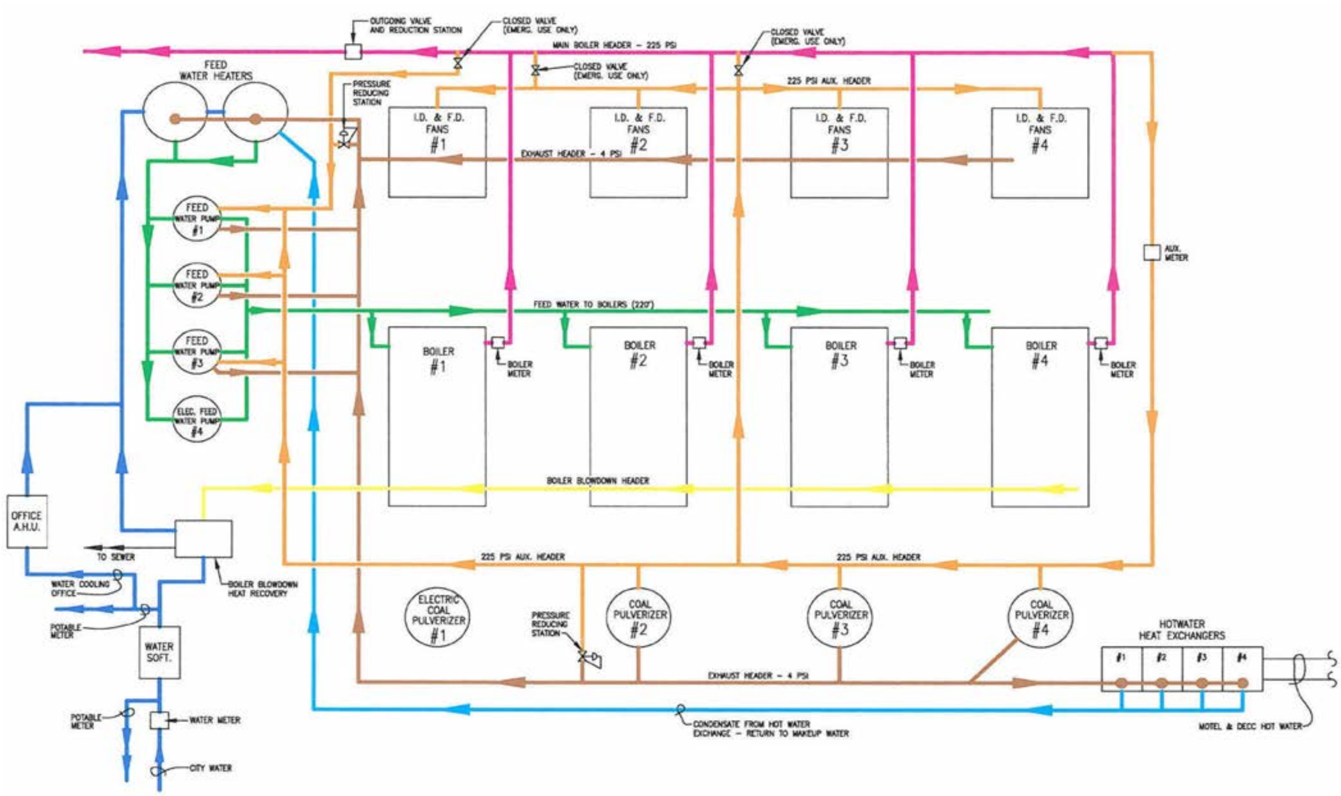
EPA Region VIII (Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming)
Director, Air and Toxics Technical Enforcement Program, Office of Enforcement, Compliance and Environmental Justice, 1595 Wynkoop Street, Denver, CO 80202-1129

EPA Region IX (Arizona, California, Hawaii, Nevada, American Samoa, Guam)
Director, Air and Toxics Division, 75 Hawthorne Street, San Francisco, CA 94105

EPA Region X (Alaska, Idaho, Oregon, Washington)
Director, Office of Air, Waste and Toxics, 1200 6th Ave., Suite 900, AWT-107, Seattle, WA 98101

[g] To determine whether your State has been delegated the authority for this regulation under section 112(l) of the Clean Air Act, contact your EPA Regional Office.

Appendix C
Steam Plant P&ID



Appendix D
Canal Park Study

CITY OF DULUTH

CANAL PARK ENERGY EFFICIENCY STUDY

JANUARY 31, 2013

THE CITY OF DULUTH MINNESOTA

Prepared By:

EVER-GREEN ENERGY™

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345 St. Peter Street
Saint Paul, MN 55102
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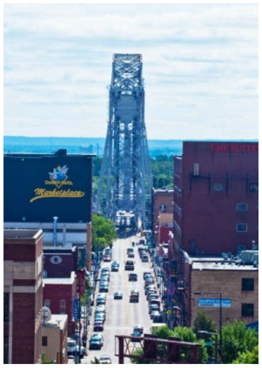
Fax: 651.292.9709
www.ever-greenenergy.com

Table of Contents

1 EXECUTIVE SUMMARY

1.1 Background



The City of Duluth is a unique community, serving as a harbor to Lake Superior and a gateway to the industry and natural resources of the North Shore. The city-owned Duluth Steam System (System), managed by Ever-Green Energy Duluth, provides district heating service to more than 225 buildings in Duluth's central business district and the Canal Park district (District). All of the buildings receiving district heating service in the central business district have heating provided via a once-through, high-pressure steam distribution system. The District is provided district heating by both a steam distribution system as well as a newer hot water distribution system.

Canal Park is a tourist and recreation-oriented district in Duluth. The District was formerly a warehouse district that was converted into hotels, restaurants, and shops. This conversion began in the 1980s as an attempt to use the city's rich industrial past as an asset for a prospective tourist industry. The District also includes the Duluth Entertainment Convention Center (DECC), and the new AMSOIL Arena, the area's prominent entertainment venue. See Appendix 1 for a full list of buildings and District map.

Since the 1960s, several buildings within Canal Park have been served by a once-through, high-pressure steam distribution piping system. As Canal Park was redeveloped, the System began serving the area with a closed-loop, hot water distribution piping system, which offers more efficiency than the steam distribution piping system and can utilize excess low-pressure, underutilized steam. While many of the buildings within the District now receive heating service from the Duluth Steam central plant via hot water or steam, a portion of the District continues to generate its own heating on-site through natural gas-fired heat generation.

The Duluth Steam central plant (Plant) burns western coal to create high pressure steam. The hot water distribution system serving Canal Park utilizes waste heat from the Plant as its primary source of energy. The City of Duluth, with support from the U.S. Department of Energy and the Minnesota Department of Commerce, Division of Energy Resources, chose to study the feasibility of eliminating the lower efficiency steam distribution system serving Canal Park and converting the entire district to hot water district heating service.

Completion of this study is complementing a 5-year strategic planning effort for the System. The purpose of the strategic planning effort is to identify opportunities to improve the efficiency of the System and evaluate transitioning the System from using 100 percent coal to cleaner and more sustainable sources of energy. Duluth Steam has identified the District as a potential opportunity to improve energy efficiency. The purpose of this study is to provide a detailed analysis of the technical feasibility of converting Canal Park entirely to hot water district heating service and to quantify the potential energy savings and environmental benefits that could be achieved by that conversion.

1.2 Conclusions

The buildings within the District currently have their heating needs met by one of three sources. Some buildings receive hot water from the System; others receive steam from the System; and the remaining buildings generate heating on-site with their own natural gas-fired generation. The energy consumption of the District is summarized in Table 1.2.1 below.

Building Category According to Energy Usage	Annual Usage MMBtu/yr	Peak Load MMBtu/hr
Existing Hot Water Customers	62,584	29.8
Existing Steam Customers	6,871	3.3
Non Duluth Steam Customers (Natural Gas)	27,884	13.3
TOTAL	97,339	46.4

Table 1.2.1: Anticipated future energy consumption load

The fundamental findings of this study show that the Canal Park District could be served via a hot water district energy system, primarily with the excess waste steam energy that is currently being produced at the Plant. By improving the efficiency of some buildings in Canal Park (particularly DECC), and transitioning the current steam customers to hot water, the District's hot water network could be expanded to serve the majority of the buildings in District with the excessive waste steam energy currently generated at the Plant. Connecting additional buildings to the System's hot water network would reduce greenhouse gas emissions in the District and could reduce or eliminate burning of natural gas at the individual buildings in Canal Park.

During the coldest days of winter, it is possible that the System load may exceed the current production capacity of the Plant. That peak load could be managed by dispatching a smaller natural gas-fired boiler connected to the System, by adding a biomass-fired boiler possibly located near the Pier B Development and connected to the System, by adding thermal storage capacity to the System or by increasing steam production at the Plant during those peak scenarios. In the event that a hot water transformation was to occur in the District, this solution would need further investigation.

1.3 DECC Facility Upgrades

DECC is the largest consumer of energy in the District, and is currently operating under less than ideal conditions based upon a number of findings:

1. The hot water supply from the System is circulated through the back-up boilers in the DECC mechanical room. This causes energy from the hot water loop to be lost through the boiler stack prior to it being utilized in the facility. The boilers should be bypassed to eliminate those losses so that the energy may be utilized for heating purposes.
2. A portion of the internal heating piping system has been installed using pipes jointed by Victaulic gasketed couplings instead of welded joints. At some time, the Victaulic gaskets on the internal piping system of the DECC were overheated, causing them to deteriorate. In order to prevent these gaskets from leaking water, the DECC operators have been keeping the temperature high in both the supply and return pipes keeping a temperature difference between the supply and return water of only 5-10°F. In doing so, DECC is pumping significantly more water through the building, so much that at times the AMSOIL Arena appears to be starved of hot water to meet its design demand. By replacing the Victaulic gaskets, at least on the return side of the building loop, the temperature difference (delta T) in the DECC system could be increased to a more appropriate level (~40°F), which would allow for more efficient utilization of the underutilized heat from the System and also would reduce the amount of electrical consumption for pumping the System and the facility system.
3. Ever-Green Energy's experience with similar types of buildings tells us that DECC's energy consumption per square foot is significantly greater than it should be. In walking through the building, a number of energy conservation opportunities were identified by the Team and should be further investigated for implementation.

By implementing these and other energy conservation measures, it is expected that DECC could significantly reduce its energy consumption. For purposes of this study, it is estimated a decrease of 24,000 MMBtu/year could be achieved, as detailed in section 3.2.2. The primary energy source for the hot water system feeding DECC is excess exhaust steam being recovered at the Plant. By implementing these improvements, the energy could be made available for other buildings in the District, which will result in a reduction of natural gas combustion and greenhouse gas emissions.

1.4 Environmental Benefits

Environmentally, the largest benefits can be gained by converting the current System steam users in the District to hot water and by implementing energy conservation measures at DECC. The conversion of the Great Lakes Aquarium and S Lake Avenue steam services would result in a reduction of approximately 1,000 tons of coal burned annually at the Plant. In addition, by connecting the majority of the buildings in the District to one hot water network and increasing the delta T of that network, the System can utilize more of the waste heat from the Plant in an efficient manner, thereby decreasing fossil fuel consumption for the entire district. The environmental benefits of this reduction are as follows:

	Annual Usage MMBtu/yr	Hot Water Conversion Savings			
		Fuel Saved MMBtu/yr	CO_2 tons/year	SO_2 tons/year	Water Gallons
Excess Steam Peaking with Coal	97,339	30,710	1,493	(2)	1,462,000
Excess Steam Peaking with Natural Gas	97,339	30,710	2,484	5	1,462,000

Table 1.4.1: Overall fuel and emission savings for the District by fuel source used to meet peak Demand

The data in Table 1.4.1 suggests that implementation of a hot water system could save as much as 2,500 tons of CO_2 emissions, 5 tons of SO_2 emissions and 1.5 million gallons of water per year. Conversion to hot water combined with the operational improvements at DECC should capture sufficient energy to serve the majority of the District's heating load with underutilized heat. System improvements should free up enough energy to convert Canal Park to hot water, displacing most if not all natural gas combustion in the District. Long-term, having all buildings connected to one central hot water system should also allow for a much easier transition of the District to renewable sources of energy.

1.5 Technical Feasibility

A high percentage of the mechanical systems inside the buildings within the District have hydronic-based heating systems, however most heating systems within the buildings will require some type of modification to connect to a hot water district system. Those buildings that are currently utilizing steam heat will also need some level of modification so that they may receive and utilize hot water. Table 1.5.1 summarizes the approximate thermal energy load of the various buildings within the District:

Building Category According to Energy Usage	**Annual Usage MMBtu/yr**	**Peak Load MMBtu/hr**
Existing Hot Water Customers	86,584	41.2
Existing Steam Customers	6,871	3.3
Non Duluth Steam Customers	29,046	13.8
TOTAL	122,501	58.3

Table 1.5.1: Annual heating load in the canal park district

The underground hot water distribution network would also need to be expanded in order to accommodate the expanded hot water service territory. Working with the Duluth Public Works staff, the feasibility of installing the hot water loop along the route identified in Figure 1.5.2 was evaluated.

Figure 1.5.2: Full build-out map

Although implementation of this loop does appear to be technically feasible, a number of factors would need to be investigated once an actual service area has been defined. Those factors include other city infrastructure projects, soil conditions, possible conflicts with other utilities and right-of-way easements.

To deliver hot water to the entire Canal Park District, some modifications will need to be made within the Plant. Those modifications primarily are related to the heat exchangers and pumps, and have been accounted for within this study.

1.6 Implementation

While converting the entire Canal Park District to hot water concurrently would have the greatest positive impact for the District and the City, district energy systems are often implemented in a phased approach. Primary factors that contribute to determining the magnitude and structure of the first phase of implementation include:

- Current and projected cost of energy.
- Individual building owners' interest in connecting to the System, possibly via a long-term contract.
- The cost of connecting the individual buildings to the System, along with the cost to convert the internal mechanical systems of the buildings to allow for a hot water district energy connection.
- The proximity of the building to the district energy distribution network.
- The size of the energy load for the individual building.
- The age and condition of the on-site energy production assets for each individual building.

As these factors are evaluated, a recommended course of action for the next phase of development, if appropriate, should become apparent.

2 INTRODUCTION

2.1 Canal Park Definition

Duluth Steam currently has two separate hot water networks within the District, one serving three hotels and the Canal Park Brewery and the other serving the DECC and AMSOIL Arena. The Ever-Green Energy study team (Team) decided to include the DECC, AMSOIL Arena, the Great Lakes Aquarium and the future Pier B Development in this study due to their proximity to Canal Park and the possible benefits that could be gained by operating one combined Canal Park hot water network. For example, by combining the two existing networks, the System could realize additional pumping and heat exchanger capacity and redundancy. For the purpose of this Study the DECC, AMSOIL Arena, the Great Lakes Aquarium and Pier B area will be called Canal Park West and Canal Park proper will be considered Canal Park East (See Figure 2.1.1).

Figure 2.1.1: Canal Park (District) definition

2.2 Methodology

The Team initially distributed a survey to all building owners in the District in an effort to better understand the consumption profile of each building, as well as any future development plans for the buildings. The Team then performed an on-site evaluation of the majority of the buildings to better understand the heating load of those buildings, as well as the probable cost of converting the buildings to receive service from a hot water district energy system.

Once the aggregate load of all buildings within the District was understood, the Team then focused on a production strategy for meeting that load, as well as a distribution strategy for delivering it to the individual buildings. Within this planning effort, attention was also given toward a potential phasing plan for implementation, based upon the assumption that the conversion may not all happen at once.

The benefits that this study determined are collective benefits for the community. This study does not determine or provide opinion on where connection and conversion costs should be borne, nor does it establish how energy rates should be structured. Rather, the study evaluated the environmental and technical benefits that the community as a whole could realize by converting to one centralized hot water district energy system.

2.3 Definitions

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

British Thermal Unit (Btu) – The amount of heat required to raise the temperature of one pound of water 1 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.

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

Condensate – Water produced by the condensation of steam

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

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

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

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

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

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

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

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.

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

Hot water supply and return lines – The district heating system piping that distributes hot water for heating purposes to customers (supply) and returns the cooler water to the Plant for reheating (return).

Medium temperature hot water – Thermal heat transferred via hot water at a temperature between 190 °F and 250 °F.

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

Normalized – Adjusted annual data of monthly building usage values measured on different monthly heating degree scales to a common scale prior to averaging.

Service line/service piping/customer connection – 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.

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

Thermal energy – Energy that is generated and measured in the form of heat.

Variable frequency drive – an electronic controller that controls the speed of an electric motor by modulating input frequency and voltage to match motor speed to the specific demands of the work being performed.

3 Energy Consumption

3.1 General

Hot water distribution systems are the most efficient community thermal energy systems employed globally. Hot water is used as the transfer media for delivering thermal energy from the location where the heat is produced to the location of the end user of the thermal energy. Compared to steam, hot water can be more effectively controlled at the customer buildings, is delivered at lower temperatures equating to less heat loss in the distribution system, has reduced loss of thermal media during distribution, and eliminates losses of condensate at the point of delivery of heat to the customer. The lower temperatures of hot water, when compared to steam, also provides a greater opportunity for utilizing a variety of technologies for producing hot water, such as solar thermal, thermal storage and waste heat recovery.

Due to the comparatively high system efficiencies of a hot water distribution network, as well as a long service life of the piping and related infrastructure, expanding the current hot water district heating system is recommended for the District. Specifically, a medium-temperature hot water distribution network is well suited for a community energy system such as the one that could serve the District. Such a district system could operate at a maximum supply temperature up to 250°F during peak usage conditions (with a reset schedule that limits supply temperature to 190°F in summer) and a return temperature of not higher than 160°F. This type of hot water system is extremely effective for utilizing low grade thermal sources, combined heat and power, and renewable energy sources.

Design temperatures for end use at individual buildings ranges from 120°F to 180°F. Space heating systems for human comfort are typically designed to operate at hot water heating temperatures from 130°F to 180°F. While domestic water heating systems typically operate at a temperature of 120°F to 140°F and commercial properties with food service and cleaning systems typically use domestic hot water heating at a maximum of 160°F. All of these systems are well-suited to utilize medium temperature hot water as the source of thermal energy. During a data-gathering visit by Ever-Green Energy staff, many of the buildings visited were found to have hydronic heating systems as described above and are well suited to use the hot water district heating services. Compatibility with existing building systems provides the potential for low-cost conversion of those buildings to utilize the district energy service, although conversion costs may vary widely from building to building depending upon the building compatibility, building load, mechanical room location and other routing and logistical issues.

While not all buildings within the District were found to be easily compatible with a hot water district heating system, there are good options for providing heat from a hot water system to a wide variety of buildings. Many smaller buildings, such as those in the District, utilize a heating system that distributes warm air throughout the building via natural gas-fired rooftop units. Contrary to general understanding buildings such as these are readily compatible with a hot water district heating system. In addition, the heating system in the building is simplified when served by hot water from a district system rather than direct gas combustion in the furnace. In the case of a warm air distribution system through a building, the conversion interface to utilize the district heating system is as shown in Figure 3.1.1 below. A hot water heating coil is mounted in the discharge air plenum of the furnace to replace the natural gas burner as the heat source. The hot water heating coils are a common type of construction that consists of multiple-rows of finned tubes or coils. These types of coils are very commonly used in the terminal units in apartment buildings, condominiums, and hotels. Often, the same coils are used to provide air conditioning to the building during the warmer months of the year by introducing chilled water to the same coils as are used with the hot water for heating during the colder portion of the year.

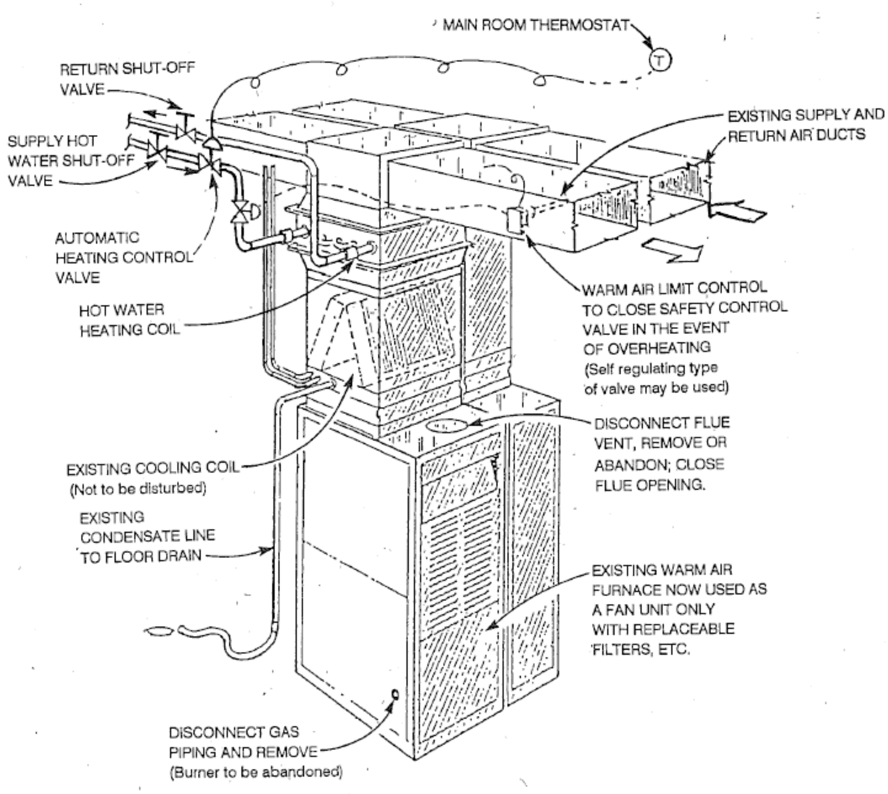


Figure 3.1.1: Typical conversion of warm-air furnace to hot water heating

3.2 Canal Park Buildings

3.2.1 Canal Park East

The Canal Park East District has a mixture of tourist attractions and recreation areas that have been converted from an industrial zone into retail shops, restaurants and hotels. The East District also has a small segment of the original steam system serving five buildings, primarily along the northern half of South Lake Avenue. All of the customers served by steam convert the steam to hot water within their buildings (with a few small exceptions). This existing once-through steam heating service has served the area since 1968, but is limited in its service zone area. The steam line has relatively poor insulation properties and thermal energy losses are significant throughout the year as can be seen from the ambient heating in Figure 3.2.1.1.

Figure 3.2.1.1: Picture on left shows a dry, clear sidewalk from the steam pipe running under the sidewalk while the picture on the right is directly across the street. Notice the snow banks along the curb area. Pictures were taken at the same time.

The District has been partially served by a hot water heating loop since 2000. The two-pipe hot water loop uses a well-insulated piping system that serves three buildings that are in close proximity to the existing Plant. These building enjoy the benefit of being served by an efficiently operating hot water system, with relatively easy operating parameters. This hot water heating loop serves the complete diversified needs of the individual buildings, including space heating, air tempering for space ventilation, domestic hot water for hotel guests, laundry services, indoor swimming pools and process operation service for a micro-brewery and restaurant. The water temperature of 215°F from the Plant has reliably accommodated the needs of the hot water district energy customers since it has been in place.

Hot Water Customers

The hot water network customers in Canal Park East have hot water distribution in their buildings for comfort and process loads (See Table 3.2.1.1). The three hotels use hot water for common space heating, laundry, domestic hot water, pool heat, hot tub heat, and snow melt for the lobby entry ways. The brewery uses hot water for in slab floor heat for the restaurant area, domestic hot water, and to bring water up to temperature for the brewing process.

Existing Hot Water Customers' Annual Usage	15,729	MMBtu/yr
Existing Hot Water Customers' Peak Load	7.5	MMBtu/hr

Table 3.2.1.1: Hot water customer annual and peak loads in Canal Park East

Steam Customers

Table 3.2.1.2 summarizes the existing steam customers' annual usage and peak load in Canal Park East. The customer buildings utilizing steam service use hot water for their internal building heating system. The energy is transferred from steam thru heat exchange equipment that heats the hot water loop in the building. As the function of the heat transfer process is satisfied, the treated and heated steam becomes low grade heated water and is discharged into the sewer systems. None of the energy remaining in the condensate is recaptured by the System; rather it currently is lost into the city sewer. To account for the lost condensate, the Plant then produces new steam from make-up water to the boilers, which comes from city water.

Some of the existing steam customers have remote areas of their buildings, such as stairwells, storage areas, etc., that were not included when the buildings were converted to distribute hot water. This isolated equipment needs to be converted to hot water and incorporated into the heating loop to eliminate all needs for steam service. In most instances the process of conversion will be outside of the finished and occupied spaces in the buildings and will require little to no modification to the existing distribution. The conversion may requiremodifications or replacement of the terminal equipment, such as steam heating coils in ventilation units or radiators in stairwells.

Existing Steam Customers' Annual Usage	4,792	MMBtu/yr
Existing Steam Customers' Peak Load	2.3	MMBtu/hr

Table 3.2.1.2: Steam customers in Canal Park East with annual & peak loads

Buildings Currently Not Receiving Community Steam or Hot Water Service

Many of the buildings in Canal Park East currently are not meeting their heating needs through a community based district system, but rather are producing heat on-site (See Table 3.2.1.3). Many of these buildings could be added to the existing or an extended hot water network without a significant cost. Most of these buildings either have their own hot water or steam boilers, or have natural gas rooftop units. There are a few exceptions where some buildings have some electric radiant heat or natural gas fired horizontal unit heaters. The size of these typically small building spaces and their minimal thermal demand requirement make them much less feasible to connect to a district energy system. All usage and peak load values in Table 3.2.1.3 were estimated based on the buildings square footage and 80% of 2003 CBECS Btu/ft² values by building type.

Non Duluth Steam Customers' (Natural Gas) Annual Usage	24,606	MMBtu/yr
Non Duluth Steam Customers' (Natural Gas) Peak Load	11.7	MMBtu/hr

Table 3.2.1.3: Non-district energy customers in Canal Park East with estimated annual & peak loads

Some of these existing buildings with internal hot water distribution service could be added to a hot water district energy system with relative ease. The simple conversion could occur in the mechanical room of the buildings. Buildings with steam heating equipment may also be converted to a hot water heating system by reusing radiators and most of the existing piping, but the cost of conversion will likely be more extensive than that of the hot water buildings. Commercial buildings with existing rooftop heating ventilation equipment could be converted by retrofitting the equipment with hot water heating coils (as shown in Section 3.1) in order to connect to a district energy system.

The cost of conversion for these different buildings will vary with the size of the system, equipment added and the complexity of the heat distribution in the buildings.

3.2.2 Canal Park West

Canal Park West includes the DECC and AMSOIL Arena, which are currently served with hot water and the Great Lakes Aquarium, which is served by steam from the System. To the west of the Great Lakes Aquarium there are plans to develop Pier B with a resort, condos, restaurant, and bar.

During site visits to the DECC, AMSOIL Arena and the Great Lakes Aquarium several opportunities were identified to save energy and reduce distribution heat losses in the District.

DECC

Photo courtesy of www.DECC.org.

DECC is largest energy consumer in the District, accounting for approximately 58% of the District's energy consumption. DECC has a very low temperature differential between the supply and return hot water lines, with a current delta T between 5 and 10°F. This means they are not efficiently utilizing the energy from the hot water system, which then requires more pumping capacity to meet its heating load. The current operation is necessary to avoid having leaks from Victaulic gaskets in the secondary or building service piping loop. As a result, DECC is circulating hot water through the building during summer months and times when heat is not otherwise needed, which results in excess use of electricity and thermal energy. By replacing the Victaulic gaskets in DECC's piping system, the delta T at the DECC could be increased, energy consumption could be reduced and the overall energy efficiency of the District could be improved. If DECC replaces their Victaulic gaskets, Duluth Steam could also establish a temperature reset program, decreasing the temperature of the hot water loop as the outside air temperature increases. This will then minimize distribution heat losses and plant production requirements during months when heat is not in high demand.

DECC also has three back up boilers through which the district energy hot water currently circulates, allowing for a large radiant heat loss through the stack. During several site visits, these idle boilers were found to be hot to the touch. Bypassing these boilers with the hot water loop would result in additional reductions in energy consumption at the DECC, improving the overall efficiency of the System.

Figures 3.2.2.1 and 3.2.2.2 provide a comparison of energy consumption per month for DECC and AMSOIL arena, along with the average heating degree days for the Duluth area over that time period. Typically a building's energy consumption will closely follow the heating degree day plot. As can be seen in these charts, DECC's usage bottoms out at approximately 3,000 MMBtu per month even when there are very few heating degree days, whereas AMSOIL's usage follows the heating degree days much more closely.

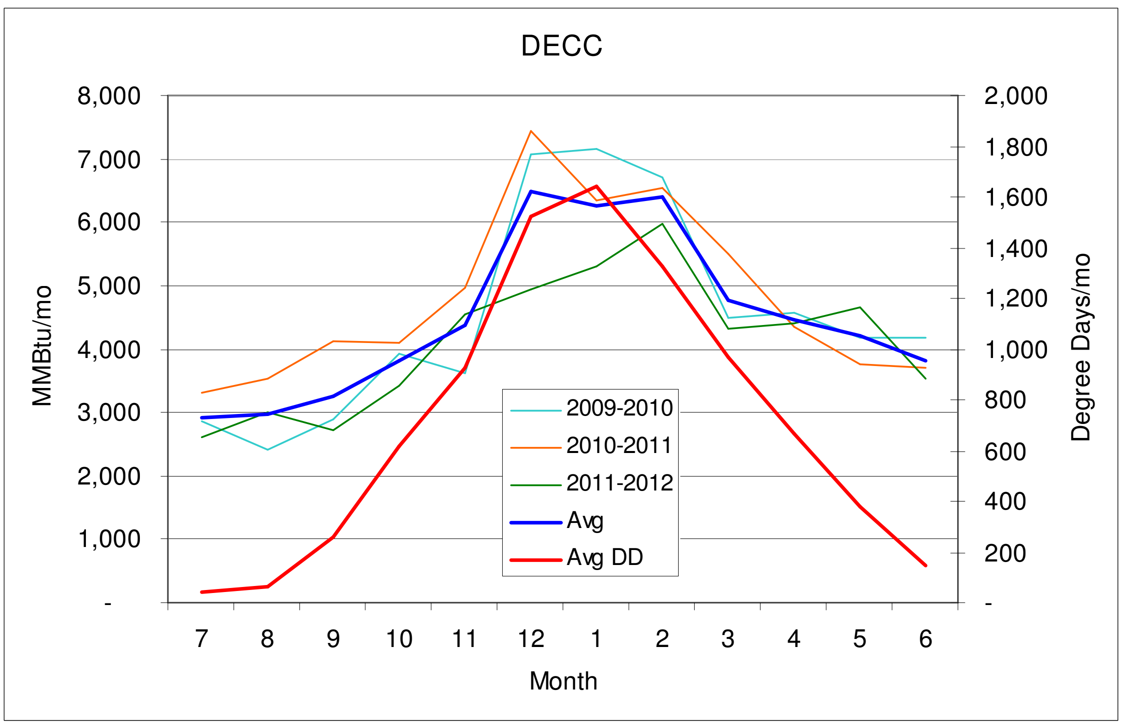


Figure 3.2.2.1: DECC energy consumption per month (2011-2012) compared to the average heating degree days per month for the Duluth area.

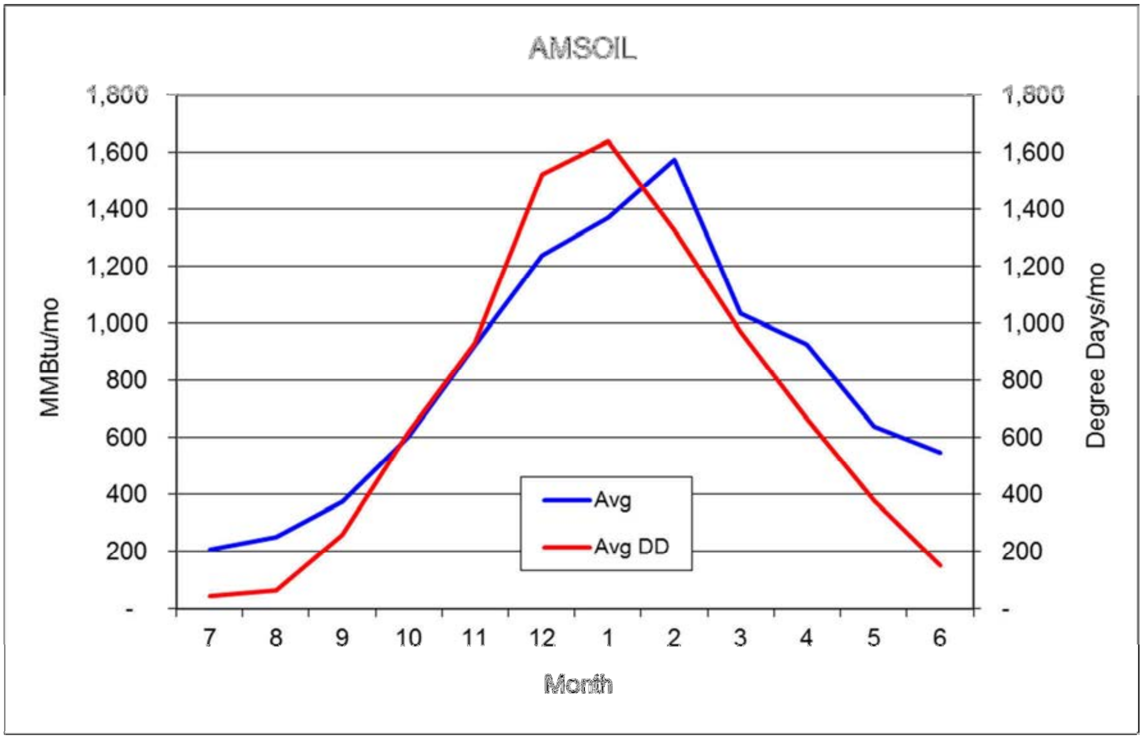


Figure 3.2.2.2: AMSOIL Arena energy consumption per month over2011-2012, compared to the average heating degree days per month for the Duluth area.

In comparison, the City of Saint Paul, Minnesota has similar entertainment facilities served by a thermal district system that are comparable in size to DECC and AMSOIL Arena. The thermal energy usage per square foot of these Saint Paul facilities is one-third to one-half the usage measured at DECC and AMSOIL Arena. Based on the above observations, the potential for reduction of energy consumption could be achieved with minimal modifications as stated below.

Some improvements that could be made include:

- Installing variable frequency drives (VFD) on the pumps, saving electricity and possibly obtaining electrical rebates through the local electricity provider
- Removing 3-way valve bypasses at air handling units, reheat coils, etc.
- Implementing a reset schedule with a minimum building loop temperature of 180° F.

The above suggestions are only based upon the Team's observations during their several visits to the facility. These are not intended as a comprehensive list of all energy conservation measures. The Team suggests that DECC engages an energy auditor to perform a full evaluation of the facility so that all reasonable energy conservation measures may be identified.

AMSOIL Arena

Photo source: http://www.bizjournals.com/twincities/blog/real_estate/2012/02/tkda-buying-duluth-design-firm.html?s=image_gallery&img_no=0

AMSOIL Arena (AMSOIL) is a multi-purpose arena built as an expansion of the DECC in 2010. AMSOIL utilizes hot water district energy service, but operates with a delta T lower than expected for a facility of this nature. Based upon the Team's experience with similar arenas and the Districts supply water temperature, the delta T at

AMSOIL should be closer to 40°F. A site visit by the Team identified a control valve that serves AMSOIL's main glycol loop air handling unit heat exchanger fully open. Based upon conversations with the related parties, it is assumed that increased flows at the DECC are preventing AMSOIL from operating more efficiently, as the AMSOIL hot water supply line branches off of DECC hot water supply line. The Team believes that solving the delta T challenges at DECC may also resolve the delta T challenges at AMSOIL.

Great Lakes Aquarium

Photo Source:
http://upload.wikimedia.org/wikipedia/commons/thumb/b/b4/Great_Lakes_Aquarium.jpg/800px-Great_Lakes_Aquarium.jpg

The Great Lakes Aquarium (Aquarium) is a relatively new building that uses hot water throughout the building, both for space heating and domestic hot water. The Aquarium currently receives steam from the System and converts it to hot water inside the building. The building was built before Duluth Steam constructed their hot water network extending to DECC so the Aquarium is served from a recommissioned steam line coming over the Interstate Highway 35E from downtown Duluth. A large section of this steam pipe is routed below the S 5th Avenue W Bridge with insulation that does not meet the current standard. After the steam pipe crosses the bridge it reenters the ground as a relatively new steam pipe (installed in 1999). The length of steam pipe to reach this single customer is close to 2,000 feet. With the old recommissioned steam pipe and the inefficient hanging pipe, there is significant heat loss in this service lateral. By decommissioning the steam line and extending a hot water pipe from AMSOIL Arena to the Aquarium, the System could experience energy efficiency improvements and a reduction in coal usage at the Plant.

Connecting the Aquarium to the hot water network will require the replacement of its steam to hot water space heating heat exchangers and the domestic hot water heaters. All of the equipment is located near the steam service entry so the estimated conversion cost is relatively low and is limited to the equipment room services.

Pier B Development

To the West of the Great Lakes Aquarium, a vacant cement terminal is targeted to house a resort and condominiums. Although final details of the development have not yet been determined, the Team has made some assumptions on the size of this load based upon conversations with the developers of the property. It is assumed that the hotel will be

Photo source:
http://cdinduluth.wordpress.com/2012/08/22/lafargepier-b-redevelopment-moving-forward/

approximately 80,000 square feet, with an additional 10,000 square feet of restaurant and banquet center along with a 10,000 square foot multi-purpose facility.

The property is currently targeted for construction commencement in 2013 with a projected opening in late 2014. Integration with the Canal Park hot water system would allow for reduced capital costs for the property developer, and would increase the load on the western leg of the network.

There also is an opportunity to integrate a summer load energy production source on this end of the hot water network, possibly within or adjacent to the Pier B development. A small biomass-fired boiler could be installed for purposes of offsetting fossil fuel use at the Plant and also meeting summer base-load hot water needs.

3.3 Canal Park Buildings Summary

Table 3.3.1 provides a summary analysis of all of the buildings within the Canal Park District, along with the size of the load and the estimated costs for each building to be converted to hot water district heating.

Building Category According to Energy Usage	Annual Usage (MMBtu)	Peak Load (MMBtu/hr)	Estimated Conversion Cost
Existing Hot Water Customers	86,584	41.2	$ -
Existing Steam Customers	9,259	4.4	$ 256,000
Non Duluth Steam Customers (Natural Gas)	26,659	12.7	$ 1,526,000
TOTAL	122,501	58.3	$ 1,782,000

Table 3.3.1: Canal Park buildings with consumption and estimated conversion costs

Notes

(1.) Non-System customer building energy consumption based on 2003 CBECS consumption per ft²

(2.) Existing System customers system energy consumption based on normalized historical usage.

4 Alternative Implementation Scenarios

In evaluating the energy efficiency improvement opportunities in the District, the Team identified three possible approaches for implementation. Although each alternative will have its own complexities and risks, the way in which they are presented could allow for a phased approach that could integrate all three alternatives upon full build-out of a hot water system.

All options presented are based upon the assumption that the energy conservation improvements will be identified and implemented at DECC. The primary sources of energy that could be captured to meet this additional heating load are from converting the District to hot water in lieu of steam and from improving the energy efficiency of DECC. Figure 4.1 provides the basis for calculating the assumed energy savings by implementing energy conservation measures at DECC. The area shaded in blue reflects the assumed savings.

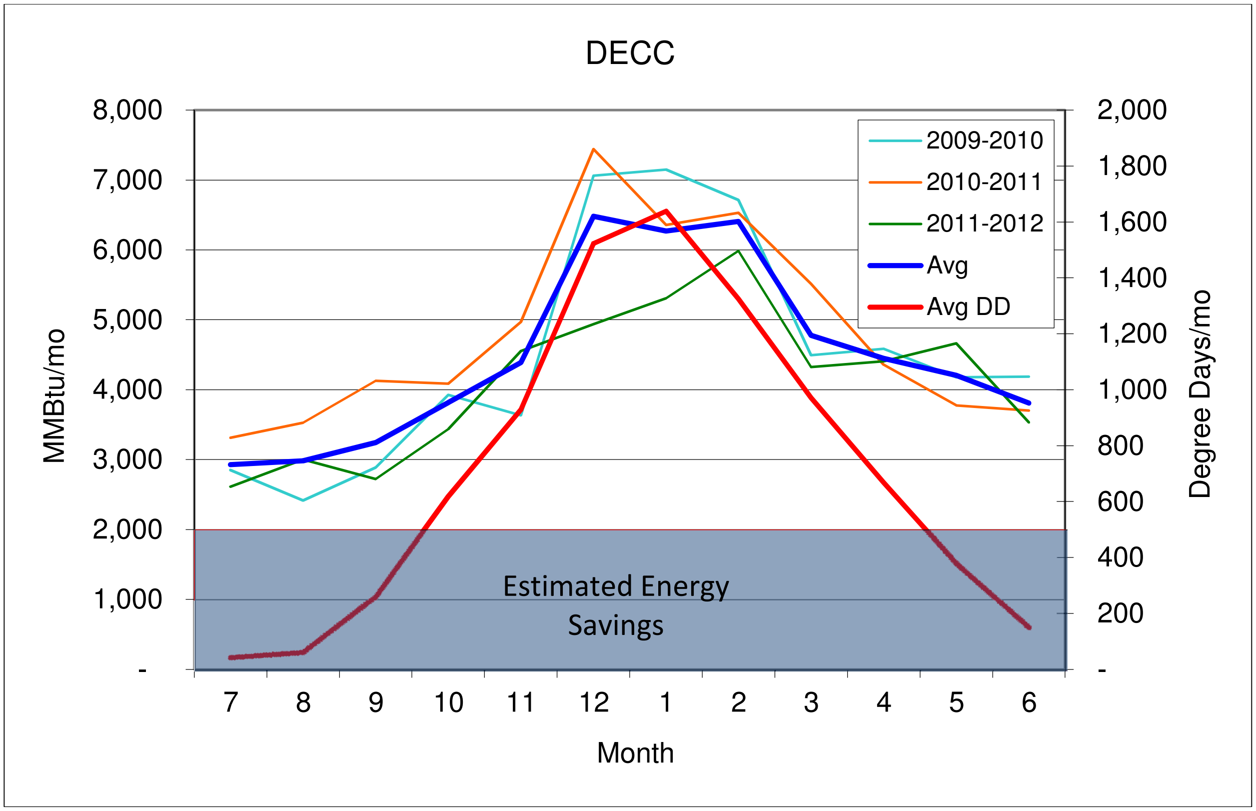


Figure 4.1: Possible energy to be saved by implementing energy conservation measures at DECC.

In the following maps the yellow lines resemble the existing hot water network, the dark red lines are the existing steam, and the blue lines are potential expansions to the System's network. The existing steam line is a once-through system so condensate from steam traps and individual buildings after the steam is used is currently being dumped into the sewer at temperatures as high as 180°F. All scenarios are based on the replacement of the existing steam line with a hot water supply and return line.

The proposed hot water distribution network was sized using a delta T of 55°F and 85% diversified load. All service lines were sized at 55°F delta T and 100% estimated peak load.

4.1 Alternative 1: Conversion of Existing Steam Line

Alternative 1 consists of replacing the existing steam line serving the North half of S Lake Avenue in Canal Park East with hot water distribution pipes. It also includes extending the Canal Park West network to Great Lakes Aquarium, as well as the future Pier B development as shown in Figure 4.1.1. This alternative will provide the base for further expansion of the hot water network, which will be shown later on in Alternatives 2 and 3.

Figure 4.1.1: Alternative 1 hot water distribution network.

4.1.1 Energy Consumption

Decommissioning the steam line on S Lake Avenue and replacing it with a pair of supply and return hot water lines will eliminate the loss from unreturned condensate which still has unused thermal energy. Instead, all hot water is circulated back to the Plant for reheating and reuse. The existing steam customer buildings will require replacement of their heat exchange equipment to receive hot water. By converting to a hot water district heating service along S Lake Street, the System could also serve the other buildings that are adjacent to the hot water line along that route. Most of these buildings are hot water compatible, and connecting to a hot water district energy system would be expected to be straightforward and require few, if any, modifications outside of the mechanical room.

Table 4.1.1.1 shows the estimated usage, peak load and the conversion costs for the buildings along the steam line replacement.

Building Category According to Energy Usage	Annual Usage (MMBtu)	Peak Load (MMBtu/hr)	Estimated Conversion Cost
Existing Hot Water Customers (1)	62,584	29.8	$ -
Existing Steam Customers	6,871	3.3	$ 256,000
Non Duluth Steam Customers (Natural Gas)	13,250	6.3	$ 497,000
TOTAL	82,705	39.4	$ 753,000

Table 4.1.1.1: Building usage, peak load and conversion cost for alternative 1

Notes: *(1.) DECC annual usage reduced by 2,000 MMBtu per month*

4.1.2 Distribution

The S Lake Avenue steam line, shown as the red line in Figure 4.1.2.1, has a large amount of heat loss. The heat loss can be felt on the manhole covers and seen visually in the winter after a snow fall as the sidewalk where the steam line runs under will be clear of snow. The high heat loss can be attributed to the corrosion of the canister protecting the steam carrier pipe and insulation, causing the insulation to become saturated with moisture reducing its insulating properties.

Figure 4.1.2.1: Existing steam (red) and hot water networks (yellow)

The replacement of this steam line with hot water supply and return pipes will reduce heat loss, coal consumption at the Plant, and condensate water being sent to the sewer. The savings from converting the S Lake Avenue steam line to hot water supply and return pipe are estimated as follows:

	Pipe Length (ft)	Annual Heat Loss (MMBtu)	Annual Usage (MMBtu) (1)	Annual Coal Consumption (tons) (2)	Annual CO2 Emissions (lbs) (3)	Annual SO2 Emissions (lbs) (4)	Annual Water Consumption (gal) (5)
Steam	1,370	2,050	5,258	650	2,440,000	7,100	913,000
Hot Water (6)	1,370	420	4,792	-	-	-	-
Savings	-	1,630	466	650	2,440,000	7,100	913,000

Notes:
(1.) Steam consumption includes addition of 9.7% for no condensate return
(2.) Western Coal 9,089 Btu/lb. Plant Efficiency of 61.4%
(3.) 205 lbs CO2 per MMBtu
(4.) 0.6 lbs SO2 per MMBtu
(5.) Water savings include metered condensate sent to sewer and condensate associated with the steam main line heat loss
(6.) Hot water production from excess exhaust steam and assumed serving existing steam customers only

Table 4.1.2.1: Estimated annual heat loss, coal consumption, emission, and water savings from conversion of steam to hot water for South Lake Ave steam line.

The Great Lakes Aquarium steam service currently extends from downtown Duluth across Interstate Highway 35E and includes a large section of hanging steam pipe under the S 5th Avenue W Bridge. The age, condition, insulation value, and length of steam pipe to serve this single customer provide good incentive to connect the Aquarium to the hot water network. The best way to accomplish this was determined to be to connect to the DECC and AMSOIL Arena hot water network. Figure 4.1.2.2 shows a probable route for extending district heating supply and return pipes from the AMSOIL garage to the Aquarium service entry.

Figure 4.1.2.2: Great Lakes Aquarium hot water extension served through AMSOIL Arena. The pipe routing through DECC and AMSOIL Arena is not actual and has been simplified.

The reduction in coal consumption, emissions and water consumption from replacing the Great Lakes Aquarium steam service pipe with hot water supply and return pipes are as follows:

	Pipe Length (ft)	Annual Heat Loss (MMBtu)	Annual Usage (MMBtu) (1)	Annual Coal Consumption (tons) (2)	Annual CO2 Emissions (lbs) (3)	Annual SO2 Emissions (lbs) (4)	Annual Water Consumption (gal) (5)
Steam	2,000	2,110	2,281	390	1,466,000	4,300	549,000
Hot Water (6)	800	220	2,079	-	-	-	-
Savings	1,200	1,890	202	390	1,466,000	4,300	549,000

Notes:
(1.) Steam consumption includes addition of 9.7% for no condensate return.
(2.) Western Coal 9,089 Btu/lb. Plant Efficiency of 61.4%.
(3.) 205 lbs CO2 per MMBtu
(4.) 0.6 lbs SO2 per MMBtu
(5.) Water savings include metered condensate sent to sewer and condensate associated with the steam main line heat loss
(6.) Hot water production from excess exhaust steam and assumed serving only Great Lakes Aquarium

Table 4.1.2.2: Estimated annual heat loss, coal consumption, emission, and water savings from conversion of steam to hot water for Great Lakes Aquarium steam service line.

4.1.3 Distribution Cost

The current steam customers, Great Lakes Aquarium, and the future Pier B Development can be connected to a hot water network with minimal internal building work and will provide a good base to expand the hot water system.

The expansion to the Aquarium and Pier B Development in Canal Park West is based upon the assumption that the DECC will implement energy conservation measures identified in this study. Should DECC choose not to implement these improvements, the System may not have sufficient capacity to meet the increased hot water load.

An estimate was put together to determine the cost of extending the hot water network to Pier B. When approaching the sizing of the piping extension, it was sized to allow for additional development beyond Pier B. The extension and service line to Pier B are sized to a diameter of 8 inches and 3 inches and have an estimated total length of 2,800 trench feet of piping, costing an estimated $1.8 million dollars. The total cost for the expansive build out for Alternative 1 of the District community hot water network can be seen in the Table 4.1.3.1 below.

	Trench Feet	Estimated Cost
S Lake Ave Main Lines	1,350	$ 948,000
S Lake Ave Service Lines	500	$ 456,000
Subtotal	1,850	$ 1,404,000
Aquarium Extension	610	$ 447,000
Pier B Extension	2,760	$ 1,836,000
Grand Total	5,220	$ 3,687,000

Table 4.1.3.1: Estimated distribution costs to replace steam line with hot water, includes connections to additional buildings.

4.2 Alternative 2: Conversion of Existing Steam Line with S Lake Ave Extension

Alternative 2 builds upon Alternative 1, from the replacement of the steam line an extension down S Lake Ave is added as shown in blue in Figure 4.2.1.

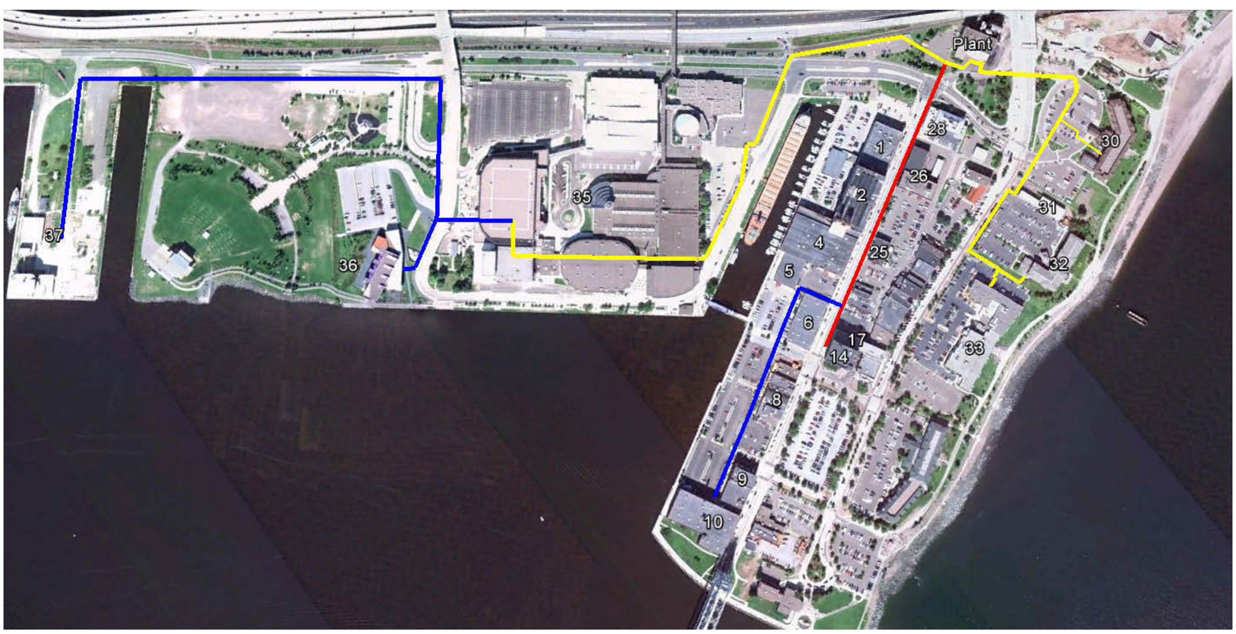


Figure 4.2.1: Replacement of steam line and extension down South Lake Avenue

4.2.1 Energy Consumption

This scenario includes all of the South Lake Avenue buildings with a few exceptions. Although it may be possible to connect these exceptions, they were not included in this scenario due to uncertanties of utilizing easments through other buildings. Table 4.2.1.1 shows the estimated usage, peak load and estimated conversion costs for the buildings that could hook up to the steam line replacement and extension down South Lake Avenue.

Building Category According to Energy Usage	Annual Usage (MMBtu)	Peak Load (MMBtu/hr)	Estimated Conversion Cost
Existing Hot Water Customers	62,584	29.8	$ -
Existing Steam Customers	9,259	4.4	$ 256,000
Non Duluth Steam Customers (Natural Gas)	18,404	8.8	$ 931,000
TOTAL	90,246	43.0	$ 1,187,000

Table 4.2.1.1: Building usage, peak load and estimated conversion cost for Alternative 2

4.2.2 Distribution

This scenario extends the hot water network to the south, allowing the System to pick up a majority of the buildings in the District, while minimizing the amount of piping being installed. This will provide the most market penetration per foot of installed pipe. The hot water pipes are shown crossing S Lake Avenue and runing behind the buildings in the parking lot. This routing was chosen to avoid utilities along S Lake Avenue such as a large power duct and shallow sewer. The hot water pipes will follow an abandoned steam pipe that runs from the the existing S Lake Avenue steam line (a section crossing S Lake Avenue has been removed) to the Southern end of Canal Park East. Based upon discussions with Duluth Public Works, it is believed that the System can obtain an easement to run hot water pipes along this route, however further investigation will be necessary in the event that this option is pursued.

The estimated costs for this scenario are shown in Table 4.2.2.1 below.

	Trench Feet	Estimated Cost
S Lake Ave & Extension Main Lines	2,320	$ 1,594,000
S Lake Ave & Extension Service Lines	700	$ 642,000
Subtotal	3,020	$ 2,236,000
Aquarium Extension	610	$ 447,000
Pier B Extension	2,760	$ 1,836,000
Grand Total	6,390	$ 4,519,000

Table 4.2.2.1: Estimated cost of replacement of Steam Line and Extend Down South Lake Avenue, including Canal Park West Extension to Great Lakes Aquarium and The Furture Pier B Development

4.3 Alternative 3: Full Build Out Scenario

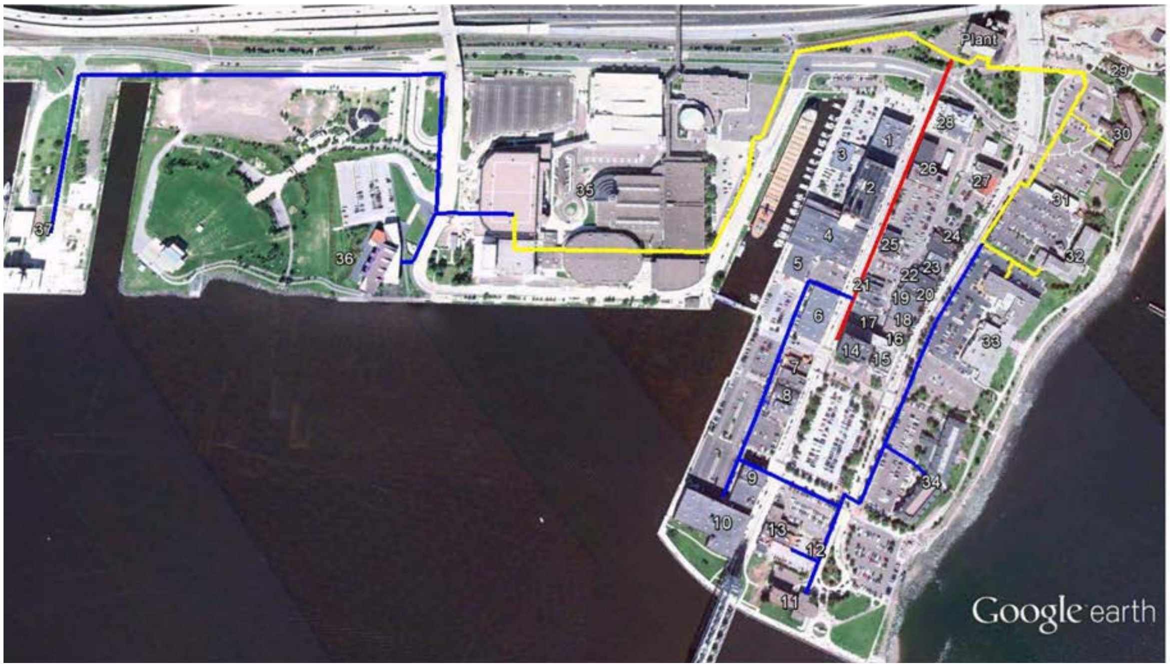


Figure 4.3.1: Full build out hot water distribution network

4.3.1 Energy Consumption

The full build out scenario, as shown in Figure 4.3.1, captures a majority of the load in Canal Park, including some of the small shops on Canal Park Drive. These small shops may be difficult to connect due to connection and conversion costs so it was assumed that 30% would connect. However, the main distribution pipes are large enough to supply all the small shops if they were to all eventually connect. Table 4.3.1.1 shows the estimated usage, peak load and estimated conversion costs for the buildings that could hook up to full build out alternative.

Building Category According to Energy Usage	Annual Usage (MMBtu)	Peak Load (MMBtu/hr)	Estimated Conversion Cost
Existing Hot Water Customers	62,584	29.8	$ -
Existing Steam Customers	9,259	4.4	$ 256,000
Non Duluth Steam Customers (Natural Gas)	25,497	12.1	$ 1,415,000
TOTAL	97,339	46.4	$ 1,671,000

Table 4.3.1.1: Full build-out building data

Notes:(1) Assumed 30% of retail shops under 10,000 ft² will hook up to district energy

4.3.2 Distribution

This is a full build out scenario of what a distribution network could look like if it were to serve the entire Canal Park District. The looped system will allow most buildings in the area the option to connect to the hot water network should they choose to do so. It also provides redundancy in the distribution network for maintenance shutdowns when they are required, allowing a section to be shutdown while maintaining service to customer buildings. This alternative requires more piping and capital which will require more buildings to hook up to the network to make it feasible. Once again, if this option is chosen, the System may need to obtain easements to allow for certain routing of the pipe to occur.

The Canal Park East distribution network expansion has pipe sizes ranging from 8 inches in diameter to 1.5 inches in diameter for service connections. The estimated costs to install the distribution network for this full build out scenario are shown in Table 4.3.2.1.

	Trench Feet	Estimated Cost
Full Build Out Main Lines	4,100	$ 2,773,000
Full Build Out Service Lines	1,725	$ 1,312,000
Subtotal	5,825	$ 4,085,000
Aquarium Extension	610	$ 447,000
Pier B Extension	2,760	$ 1,836,000
Grand Total	9,195	$ 6,368,000

Table 4.3.2.1: Full build-out including Great Lakes Aquarium and Pier B Development.

The full build out can be phased as buildings come onto the community hot water network and Table 4.3.2.2 provides a realistic phased approach as to how the system might grow.

Phase	Description	Mains (Trench Feet)	Estimated Mains Cost	Services (Trench Feet)	Estimated Services Cost	Total Estimated Cost
Phase 1	Steam Line Replacement	1,350	$ 948,000	500	$ 456,000	$ 1,404,000
Phase 2	South Lake Avenue Extension	970	$ 646,000	200	$ 186,000	$ 832,000
Phase 3	Canal Park Drive and Loop Connection	1,780	$ 1,179,000	1,025	$ 670,000	$ 1,849,000
GRAND TOTAL						$ 4,085,000

Table 4.3.2.2: Canal Park East phased approach

5 Energy Production

5.1 Introduction

Steam is currently produced at the Plant primarily via coal-fired boilers burning western coal. The steam is distributed to customer buildings through a once-through steam distribution system and also used in the Plant for steam turbine drives. The Plant is generally operating as efficient as can be achieved with the equipment and systems in place. Based on an average fuel usage of 1,026,293 MMBtu per year, the average Plant boiler efficiency is 71.6% and the end usage efficiency (net energy used by the customers not including energy in condensate divided by fuel energy) is 43.5%, as shown in Table 5.1.1.

Duluth Steam Generation and Usage - 3-Year Average				
	Heat Input and Usage		Key Numbers	
	Boiler Heat Input MMBtu *1	Customer Heat Usage MMBtu *2	Boiler Efficiency	End Usage Efficiency
Jan	103,685	72,345	73.8%	51.5%
Feb	93,042	62,618	70.3%	47.3%
Mar	74,293	48,677	71.3%	46.7%
Apr	65,718	38,700	72.2%	42.5%
May	47,732	25,846	71.0%	38.5%
Jun	43,233	20,897	71.2%	34.4%
Jul	33,831	16,107	69.0%	32.9%
Aug	34,355	16,702	68.7%	33.4%
Sep	36,842	18,114	69.0%	33.9%
Oct	45,766	25,506	72.5%	40.4%
Nov	62,233	37,165	70.2%	42.0%
Dec	93,600	63,398	74.2%	50.3%
TOTAL	734,330	446,074	71.6%	43.5%

*1	*Sat. Steam*	*225 psig*	*1,200*	*btu/lb*
	FW Water	*220 F*	*188*	*btu/lb*
	Net		*1,012*	*btu/lb*
*2	*Sat. Steam*	*150 psig*	*1195*	*btu/lb*
	Condensate	*160 F*	*128*	*btu/lb*
	Net		*1,067*	*btu/lb*

Table 5.1.1: Plant and system efficiency – three-year average.

Hot water is produced by capturing the excess steam from the exhaust of the steam turbine drives which drive the fans, coal pulverizers, and pumps (see Appendix 2). The thermal energy from the steam is transferred to the hot water via plate and frame heat exchangers. From there, hot water is then pumped to individual customers and returned to the Plant to be reheated. By utilizing a closed-loop hot water network the distribution and condensate losses associated with steam distribution referred to above are eliminated for hot water customers.

5.2 Energy Usage and production for Alternative 3 - Full Build-out

As described in section 4.3.1 the customers for the full build-out alternative are estimated to have a total energy usage of 97,339 MMBtu per year. The largest part of the energy consumption, or about 63,000 MMBtu/year, would be from customers already connected to the existing hot water system. Another 7,000 MMBtu per year would be from existing steam customers converted to hot water and about 28,000 MMBtu per year are new customers at present using natural gas (see Table 5.2.1).

Building Category According to Energy Usage	Annual Usage MMBtu/yr	Peak Load MMBtu/hr
Existing Hot Water Customers	62,584	29.8
Existing Steam Customers	6,871	3.3
Non Duluth Steam Customers (Natural Gas)	27,884	13.3
TOTAL	97,339	46.4

Table 5.2.1: Energy usage for Alternative 3.

The primary energy source for an expanded hot water system will come from capturing the excess heat from the steam turbine drive exhausts. Based on the annual make-up water heat balance for the Plant, almost 100,000 MMBtu per year in excess heat is available for a hot water system. This is after approximately 90,000 MMBtu per year has been captured for feedwater preheating and deaeration. On an annual basis, the available excess heat is sufficient to cover the energy usage for the District. However, the excess heat from the steam turbine drives does not fully align with the usage pattern for typical space and domestic hot water heating.

A typical hot water customer will have a base load of domestic hot water and process load; and will consume energy for space heating in a manner that closely follows the degree days. In Figure 5.2.1 a typical hot water customer load profile has been generated based on the degree days for Duluth with a base load (domestic water and process water) of 20%. The base load includes 5% for distribution heat losses which is a standard value for modern hot water distribution systems with similar extension and heat density.

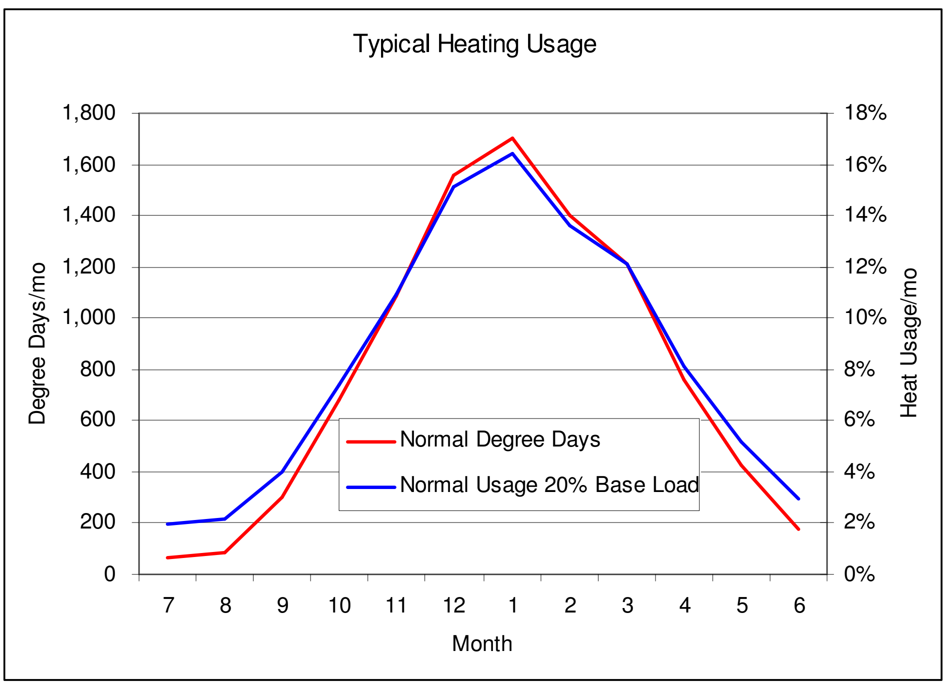


Figure 5.2.1: Typical hot water load profile

Based on monthly heat balances for makeup water and exhaust steam and a typical hot water load profile, including distribution losses, an estimated 86,000 MMBtu per year can be captured of the available 99,000 MMBtu per year. The annual building usage, including hot water distribution thermal losses, is estimated to be 102,000 MMBtu per year. The additional 16,000 MMBtu per year will have to be provided by additional production.

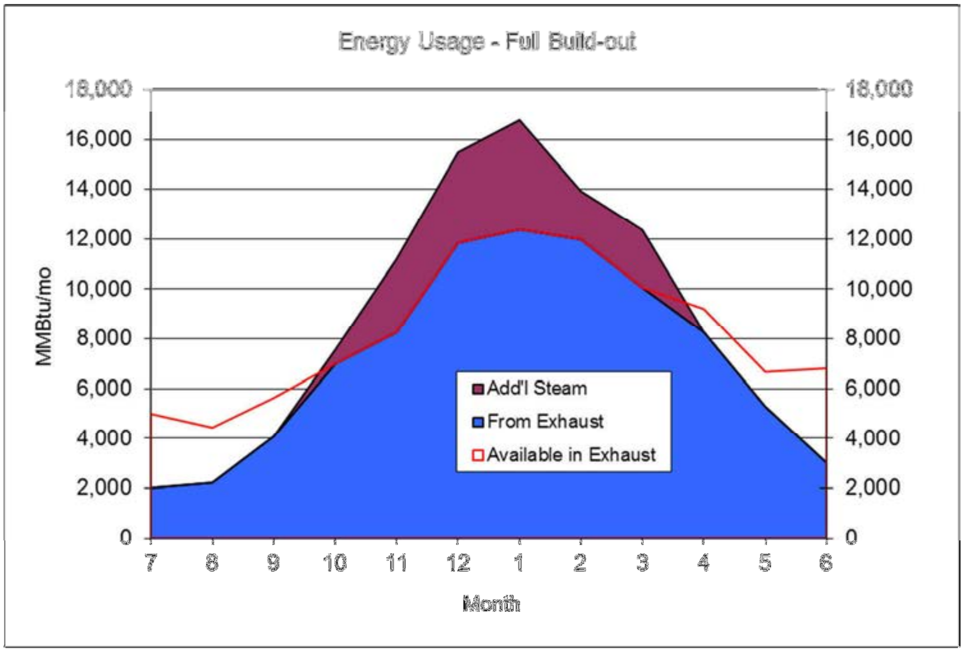


Figure 5.2.2: Estimated energy usage for Alternative 3

As shown in Figure 5.2.2, during the winter, the System load could exceed available excess steam at the Plant. That peak load could be managed by dispatching a smaller natural gas-fired boiler connected to the System, a biomass-fired boiler possibly located near the Pier B Development and connected to the System, by adding thermal storage capacity to the System or increasing steam production at the Plant during those peak scenarios.

5.3 Emissions

The District currently has a net fuel usage of 53,000 MMBtu per year, based on the assumption that all current hot water is generated from excess exhaust steam (with no additional fuel consumption). This emission accounts for all of the customer and non-customer buildings in the District. About 3,800 tons of CO_2 emissions and approximately 5 tons of SO_2 emissions will be emitted from the existing System to provide the 97,000 MMBtu per year of heating (see Table 5.3.1).

	End Usage	Existing System		
		Fuel Usage	CO_2 (4)	SO_2 (5)
	MMBtu/yr	MMBtu/yr	tons/year	tons/year
Existing HW Customers (1)	62,584	0	0	0
Existing Steam Customers (2)	6,871	15,795	1,619	4.7
Existing Gas Usage (3)	27,884	37,179	2,156	0
TOTAL	97,339	52,974	3,775	4.7
(1) Not utilized exhaust steam therefore no net contribution to emissions				
(2) End usage efficiency	*43.5%*			
(3) Gas boiler efficency	*75.0%*			
(4) lb/MMBtu	*205*	*Coal*	*116*	*Gas*
(5) lb/MMBtu	*0.6*	*Coal*	*0*	*Gas*

Table 5.3.1: Emissions for existing system

If coal is combusted to supplement the energy needs of a comprehensive hot water district (Alternative 3), the System will need to supplement the excess exhaust steam with about 22,000 MMBtu per year, 6,000 MMBtu per year more than for the existing System. The net result for the District is a decrease in CO_2 emissions of about 1,500 tons per year and an increase in SO_2 emissions of approximately 2 tons per year (see Table 5.3.2).

	Annual	Hot Water Conversion Savings			
	Usage	Fuel Saved	CO_2	SO_2	Water
	MMBtu/yr	MMBtu/yr	tons/year	tons/year	Gallons
Steam Line Replacement	82,705	26,593	1,940	2.7	1,462,000
Steam Line Replacement and Extension	90,246	29,213	1,761	0.4	1,462,000
Full Buildout	97,339	30,710	1,493	(1.9)	1,462,000

Table 5.3.2: Fuel and emission savings utilizing excess steam and coal for peak management

Similar to coal if natural gas is combusted to supplement the energy needs of a comprehensive hot water district (Alternative 3), the System will need to supplement the excess exhaust steam with about 22,000 MMBtu per year, 6,000 MMBtu per year more than for the existing System. The net result is a decrease in CO_2 emissions of about 2,500 tons per year and a decrease in SO_2 emissions of approximately 5 tons per year (see Table 5.3.3).

	Annual	Hot Water Conversion Savings			
	Usage	Fuel Saved	CO_2	SO_2	Water
	MMBtu/yr	MMBtu/yr	tons/year	tons/year	Gallons
Steam Line Replacement	82,705	26,593	2,245	4.7	1,462,000
Steam Line Replacement and Extension	90,246	29,213	2,397	4.7	1,462,000
Full Buildout	97,339	30,710	2,484	4.7	1,462,000

Table 5.3.3: Fuel and emission savings utilizing excess steam and natural gas for peak management.

5.4 Plant Modifications

To meet the needs of an expanded hot water network serving the District, modifications will be required at the Plant. The existing smaller steam to hot water heat exchangers would need to be replaced with two heat exchangers, sized for about 75% of peak capacity each. Existing smaller distribution pumps would also be removed and replaced by two 100% variable frequency drive pumps. The existing equipment for water treatment, motor control centers, etc. have been assumed to be sufficient for the expanded hot water system.

An estimate for the full build-out alternative is shown in Table 5.4.1 below.

	Size		Units	Unit price	Total
Package hot water boiler			N/A		$0
Steam heat exchanger	35	MMBtu/hr	2	160,000	320,000
Distribution pumps	2,000	gpm	2	30,000	60,000
Piping & insulation			1	100,000	100,000
Valves, strainers, etc			1	50,000	50,000
Water softener incl installation			N/A		0
Chemical feed equipment incl installation			N/A		0
Motor control centers			N/A		0
Electrical			1	40,000	40,000
Controls			1	40,000	40,000
Building			N/A		0
SUBTOTAL					610,000

Table 5.4.1: Probable cost of modifying the Duluth Steam Plant for an Alternative 3 full build-out scenario.

6 District Cooling

The majority of the buildings in the Canal Park District utilize city water to meet their chilled water production needs. Some buildings use the city water directly for cooling within their buildings while others use it as condenser water for their chillers. Most buildings within the district appear to be fulfilling their cooling needs in a relatively efficient manner. As a result, and due to the relatively small annual cooling load for the area, this study did not investigate the feasibility of an integrated district cooling system for the District.

7 Probable Costs of Implementation

The implementation of a comprehensive hot water district energy system will provide significant benefits and opportunities for the long-term sustainability of the District. It will also establish a basis for improved energy integration and options for incorporating renewable sources of energy made possible by hot water distribution. The estimated costs for implementation of this program are based upon the Team's past experience in constructing similar types of systems. It is also based upon conversations with local construction companies. The following estimated costs shown in Table 7.1, include allowances for work within the Plant, construction of a hot water distribution piping system and conversion of the customer buildings to receive the hot water. The following estimate has not accounted for the costs that the DECC will incur to improve its energy consumption profile.

		Probable Cost
Distribution		$ 6,368,000
Customer Conversions		$ 1,671,000
Plant Modifications		$ 610,000
SUBTOTAL		$ 8,649,000
Engineering	10%	$ 864,900
General Conditions	15%	$ 1,297,350
Contingency	25%	$ 2,162,250
Grand Total		$ 12,973,500

Table 7.1: Estimated costs for a full build-out of a Hot Water District Energy System for the Canal Park District.

8 Recommendations and Next Steps

Serving the Canal Park District with a hot water district energy system served by the Plant has been found to be technically feasible and environmentally beneficial. By improving the efficiency of some buildings in Canal Park (particularly DECC), and transitioning the current steam customers to hot water, the District's hot water network could be expanded to serve the majority of the buildings in Canal Park with the energy currently generated at the Plant. Connecting additional buildings to the System's hot water network could reduce or eliminate distributed burning of natural gas at those individual buildings, reducing greenhouse gas emissions in the District. If all buildings within the District were to connect to the System, there will be occurrences when the energy produced in the Plant would not be able to meet the peak demand of the customers. This will be managed through a number of options ranging from biomass combustion to dispatching of increased steam production within the Plant.

A key step in the successful development of a hot water district heating system is to communicate the benefits and opportunities created by the development of the hot water district heating to the larger community and to potential customers. An effective community outreach plan is an important component of gaining key stakeholder support of a community energy system.

In parallel with this community outreach plan, a series of steps should be pursued that will guide how such a project can proceed. Primary among these steps are:

- Perform a comprehensive energy audit of DECC to identify all reasonable energy conservation measures and implement those measures as appropriate.
- Complete a detailed plan for the conversion of the existing System steam users in Canal Park so that they may receive hot water.
- Develop the detailed design of the hot water distribution system that could feed the entire Canal Park district, allowing for a phased-in approach of implementation in the event that not all buildings choose to connect to the system immediately. Also collaborate with Duluth Public Works officials to coordinate pipe installation with other infrastructure projects, and avoid any possible utility conflicts that could arise.
- Work with the Pier B developer to better understand their initial energy needs and allow for connection to the hot water system upon substantial completion of construction. Also investigate the potential for the integration of a biomass-fired boiler in this area for purposes of peak management as well as summer load management.
- Determine the best environmental and economic option for managing peak load during the coldest months of the year.
- Build the business model for implementation of the study findings as deemed to be economically feasible.

Once these steps are taken, the System could have a clearer definition of a possible next phase of implementation, if appropriate.

9 Acknowledgements

The Ever-Green Energy Team would like to express our gratitude to the City of Duluth, the U.S. Department of Energy, the Minnesota Department of Commerce, Division of Energy Resources, the Customers of Duluth Steam in the Canal Park District and the Canal Park building owners not currently connected to the Duluth Steam system.

We appreciate the contributions of these and other stakeholders as we worked toward the completion of this study. We recognize the value of each of these contributions and understand that the success of this endeavor will be predicated upon the ongoing support of these parties.

Appendix 1 – Building List and Map

Map Building #	Building Name
1	Red Lobster, Timber Lodge Steakhouse, Condos
2	Waterfront Plaza, Suites, Condos
3	Garage/Warehouse (BUILDING DEMOLISHED)
4	Building D, Adventure Zone, Harley Davidson, Famous Daves
5	Office/Retail for lease
6	R. M. Chocolate Factory, First Time Antiques, Waters of Superior
7	Bellisio's
8	Grandma's Sports Garden
9	Red Rock Radio, Labor and Industry Department
10	Paulucci Building
11	US Corps of Engineers
12	Small Shop
13	Grandmas Saloon & Grill
14	DeWitt-Seitz Building
15	Little Angies
16	Duluth Pack, Eagle Environmental, Great Northern Service
17	Lake Avenue Café
18	Duluth Pack
19	Siivus
20	Northwood Collections, Antique Boutique, Grandmas Marathon
21	Subway
22	Cold Stone, Deco Bay, FJJ, JPG
23	Club Saratoga, Never too Many, Toys for Keeps
24	Spirit Bay
25	Green Mill
26	Canal Park Liquor/General Store/The Antique Center/Grizzlies
27	ICO/Toys for Keeps
28	KBJR TV
29	Small Shop
30	The Canal Park Lodge
31	Canal Park Brewery
32	Hampton Inn
33	Inn on Lake Superior
34	Comfort Suites
35	DECC/Omnimax/Amsoil
36	Great Lakes Aquarium
37	Pier B Development


Plant
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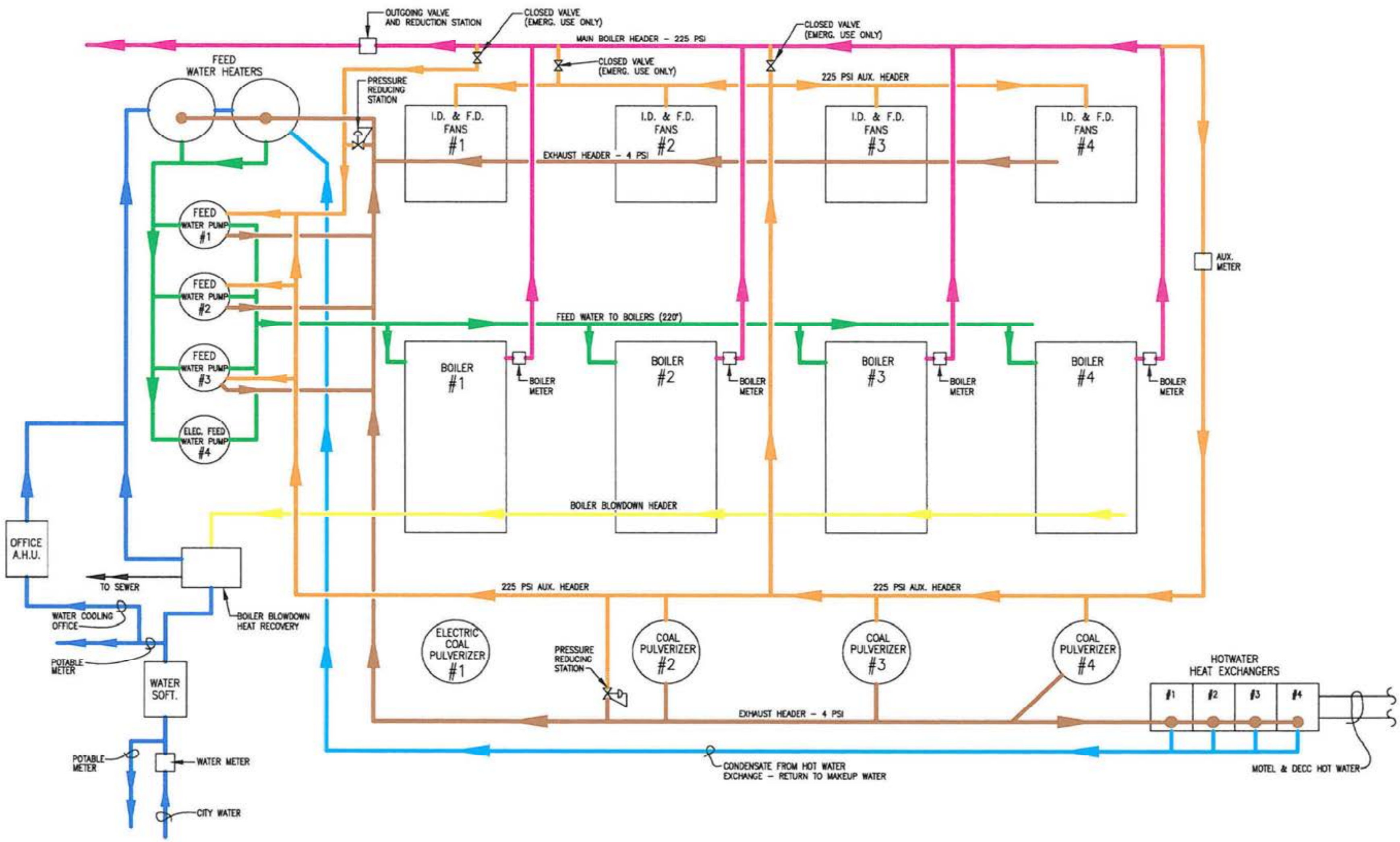
Appendix 2 – Steam Plant P&ID



Appendix E
Duluth Steam Design Strategy and Concepts

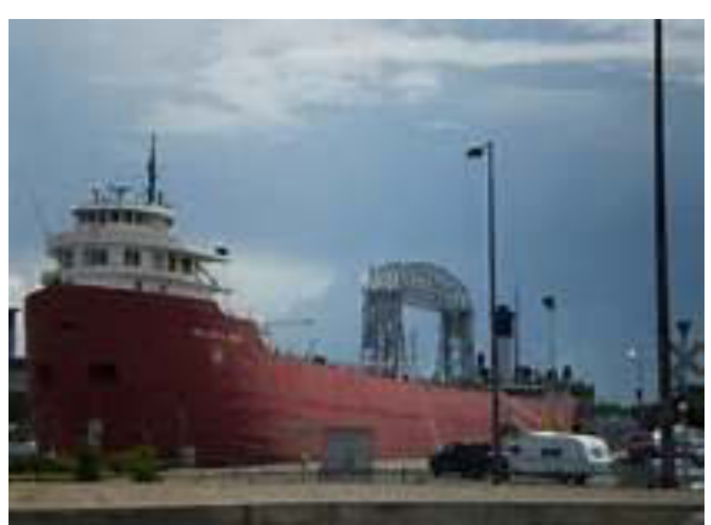
Duluth Steam

Design Strategy and Concepts

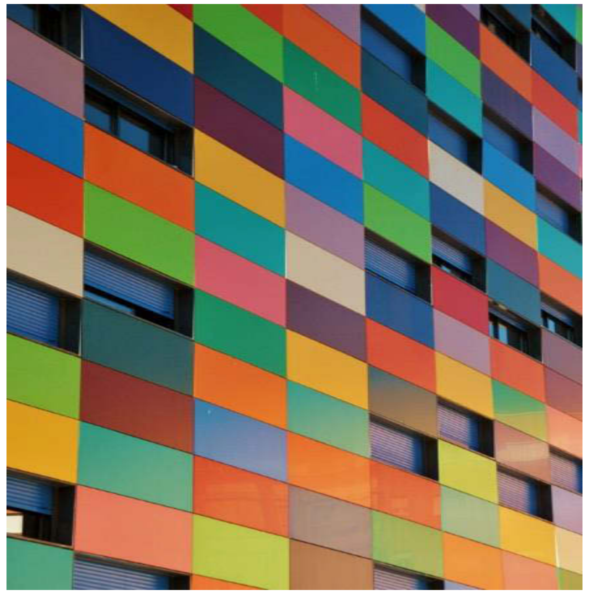
April 26 2013

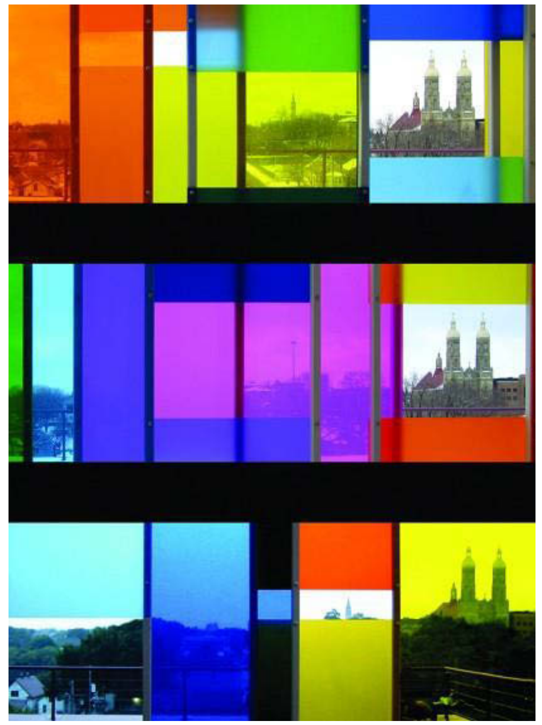
ARCHITECTURE FIELD OFFICE

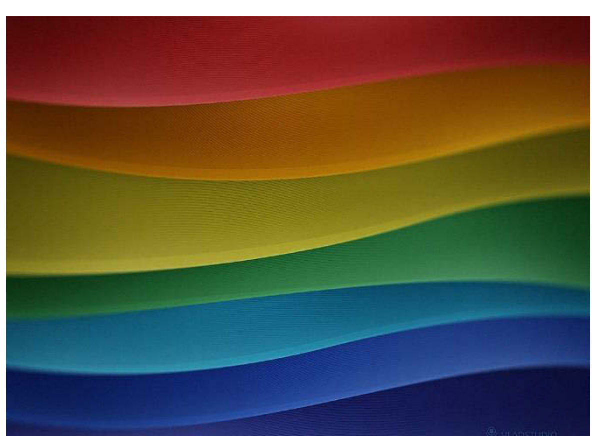
Canal Park History and Context

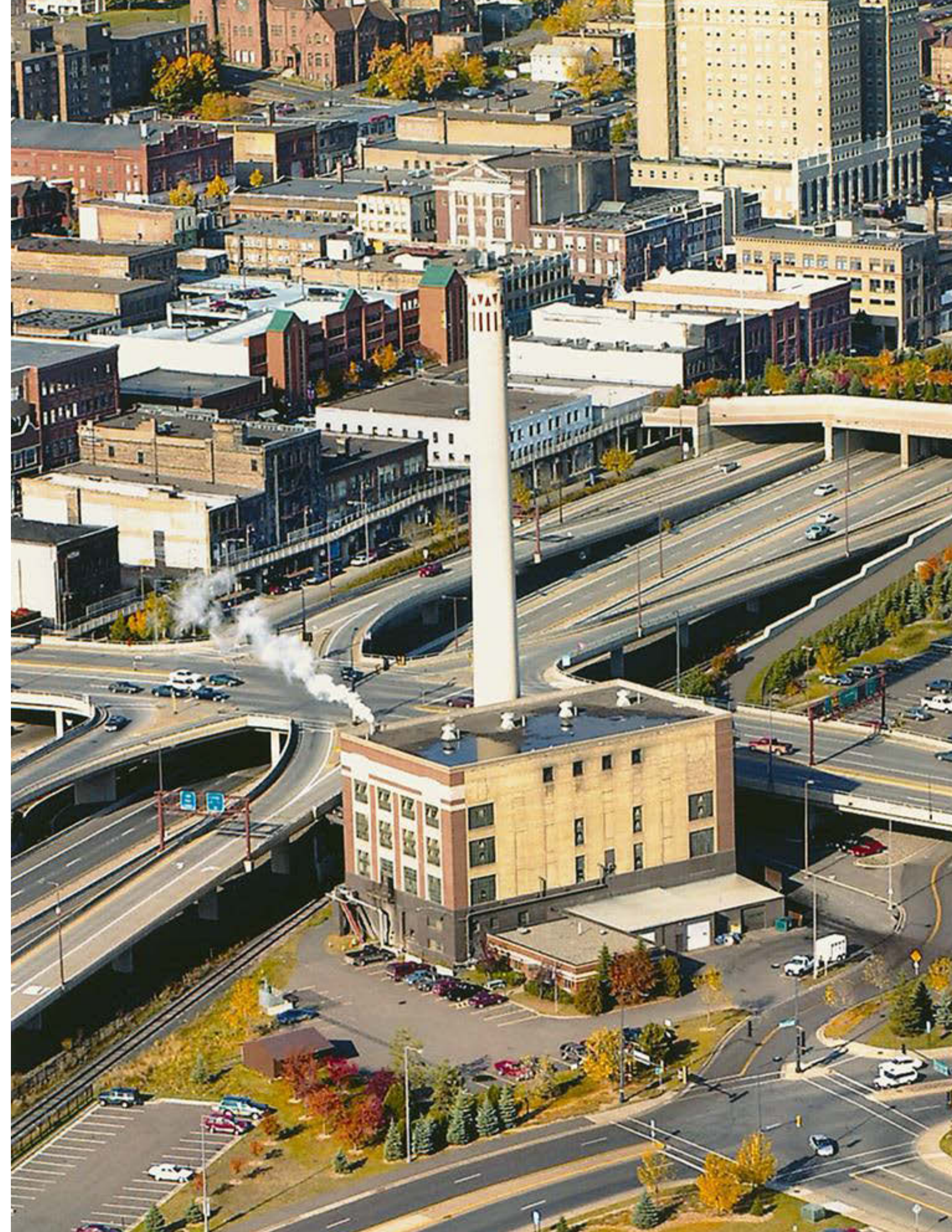


Ideas for Color and Revitalization



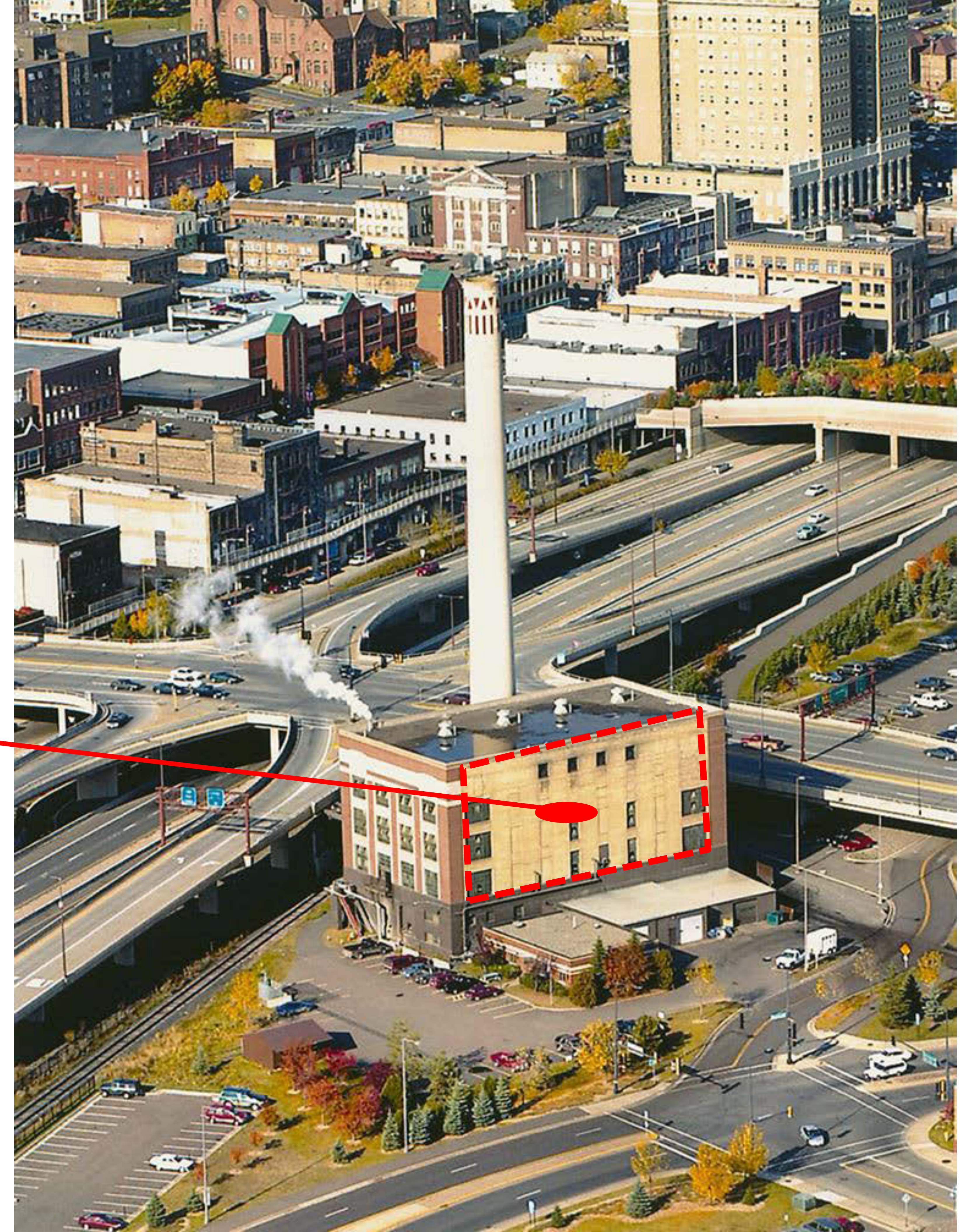






Design Concept 1 Precedent

Graphic Screen Options



Design Concept Option 1

Graphic Screen Option

Metal Graphic Screen

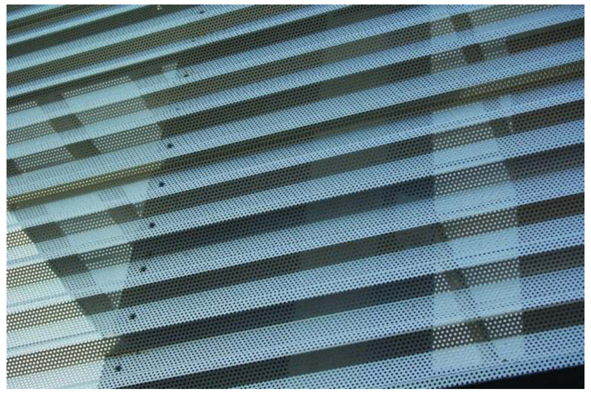
Metal Panel

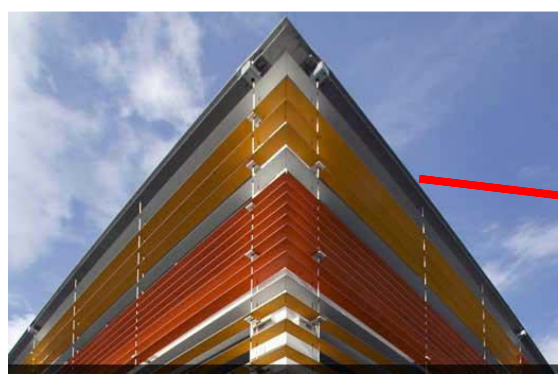
New Landscaping Berm and Wall

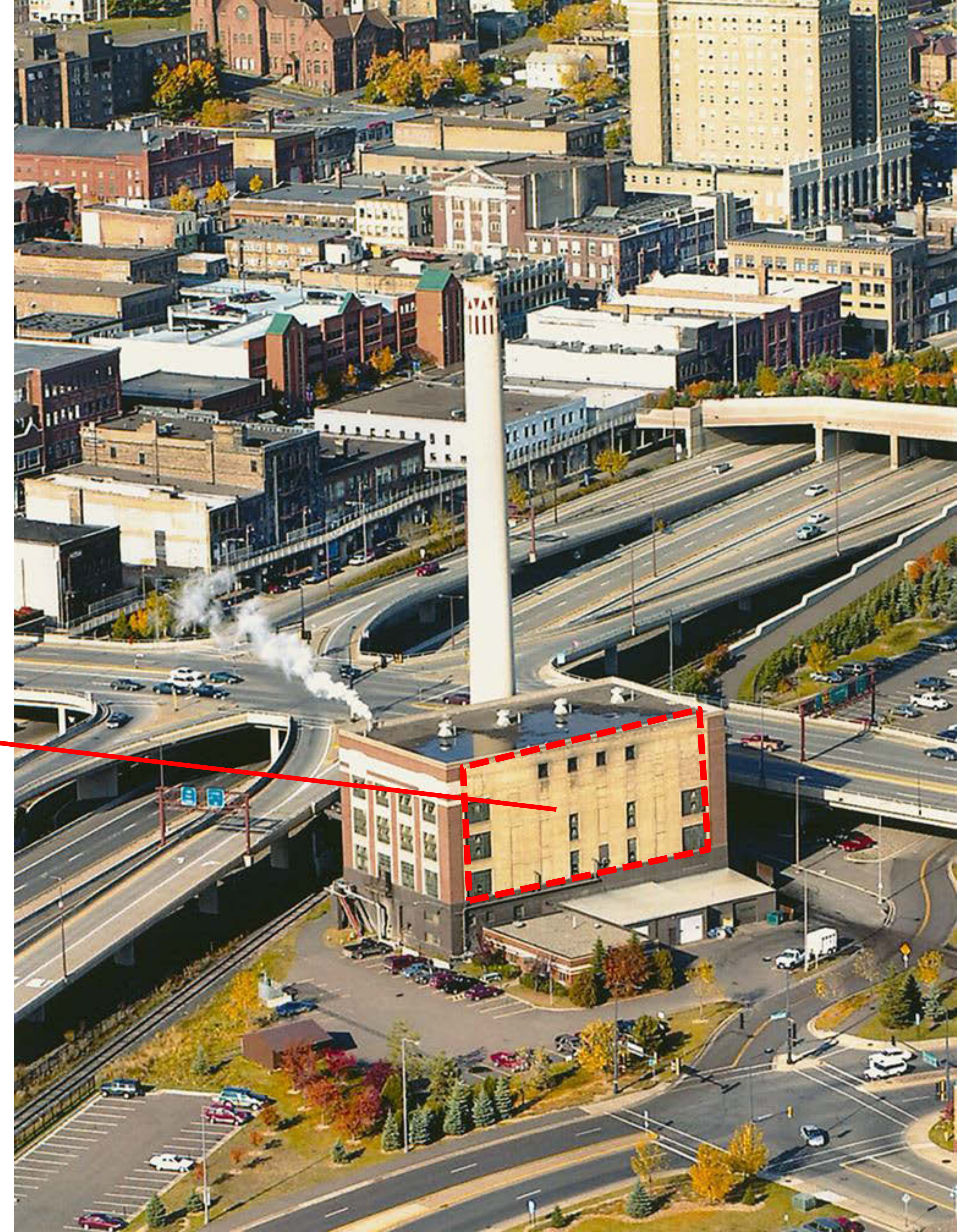
New Landscaping Berm and Trees

Design Concept 2 Precedent

Metal Louver Screen





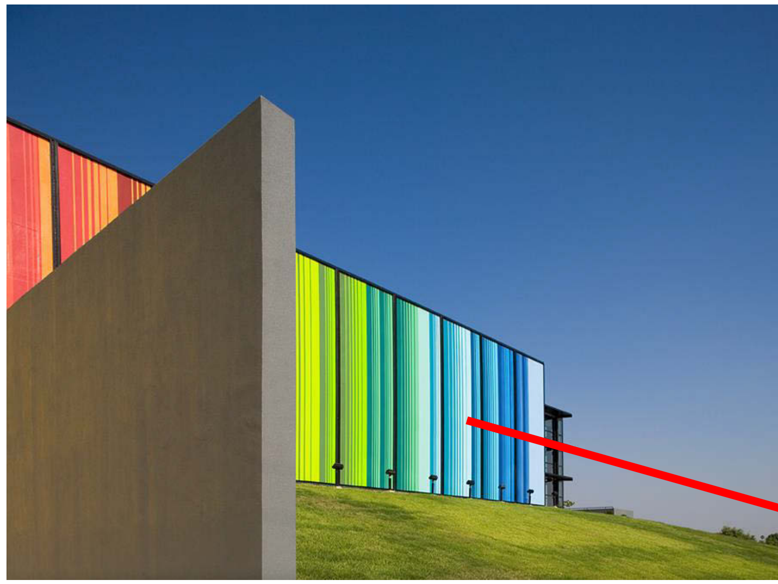


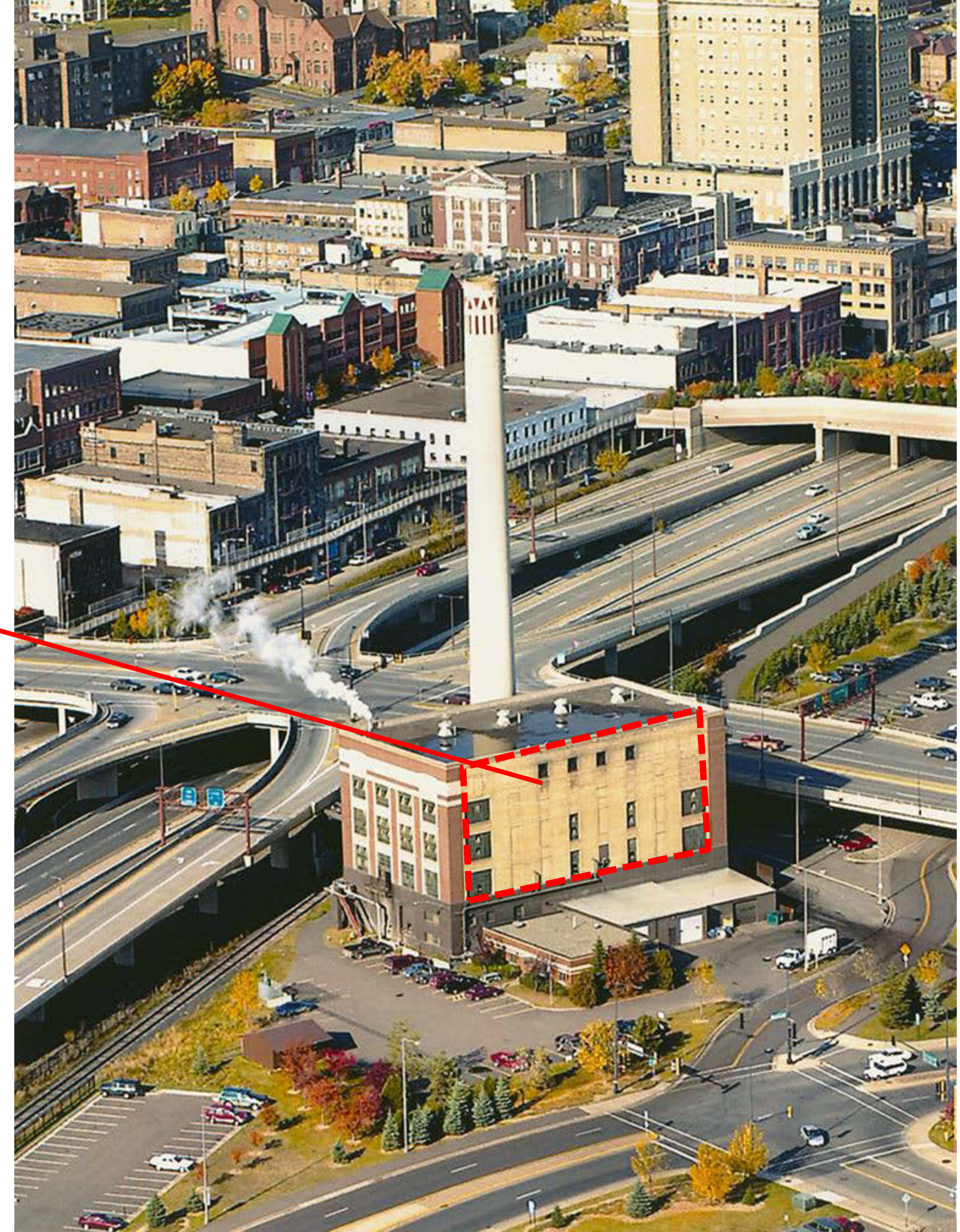
Design Concept Option 2

Metal Louver Screen

Design Concept 3 Precedent

Metal Panel Screen





Design Concept Option 3

Metal Panel Screen

Metal Panel Screen

Metal Panel

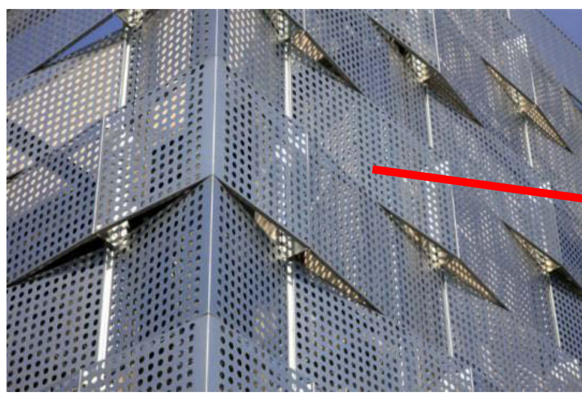
Green Screen

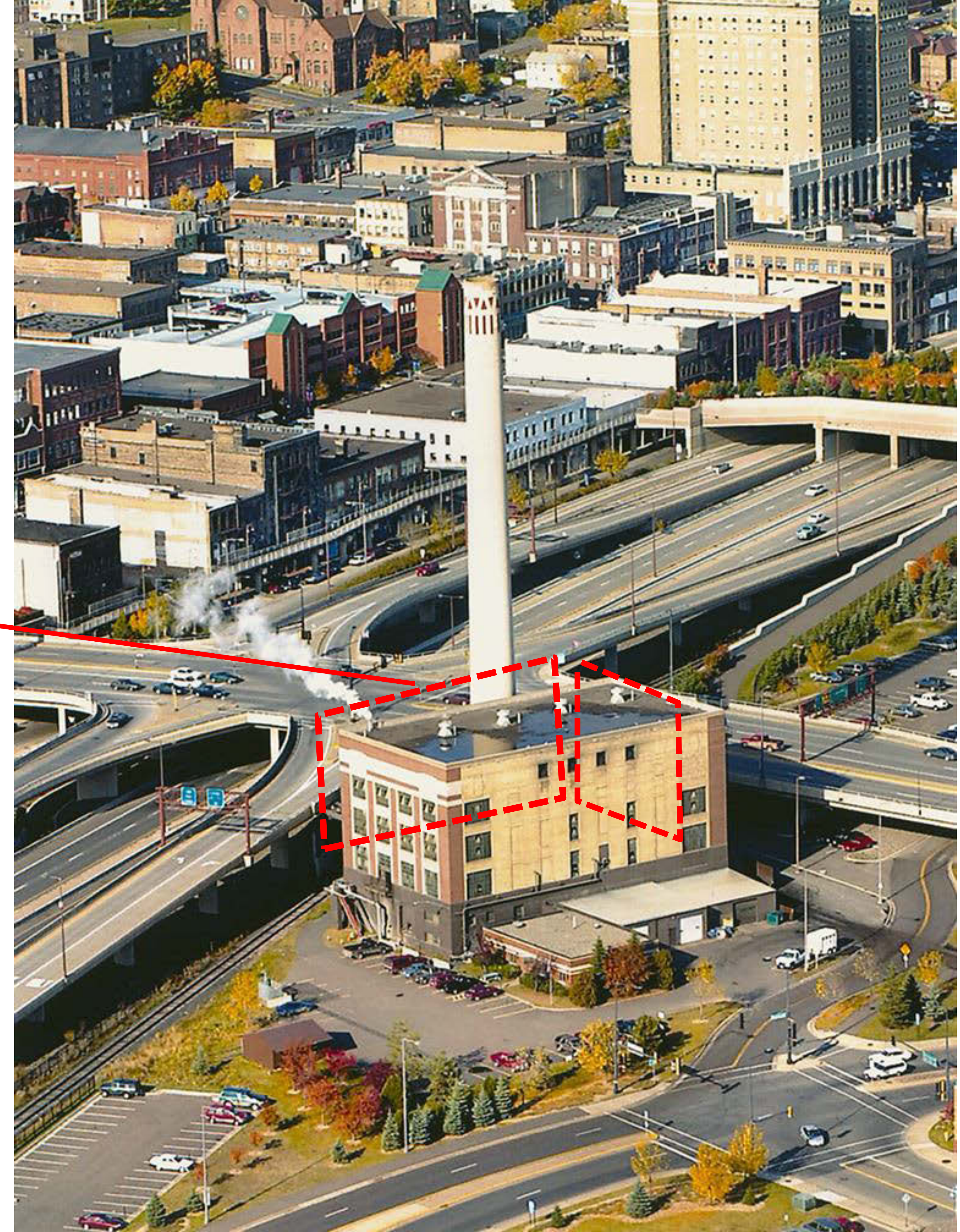
New Landscaping Berm, Wall & Trees

New Landscaping Berm and Trees

Design Concept 4 Precedent

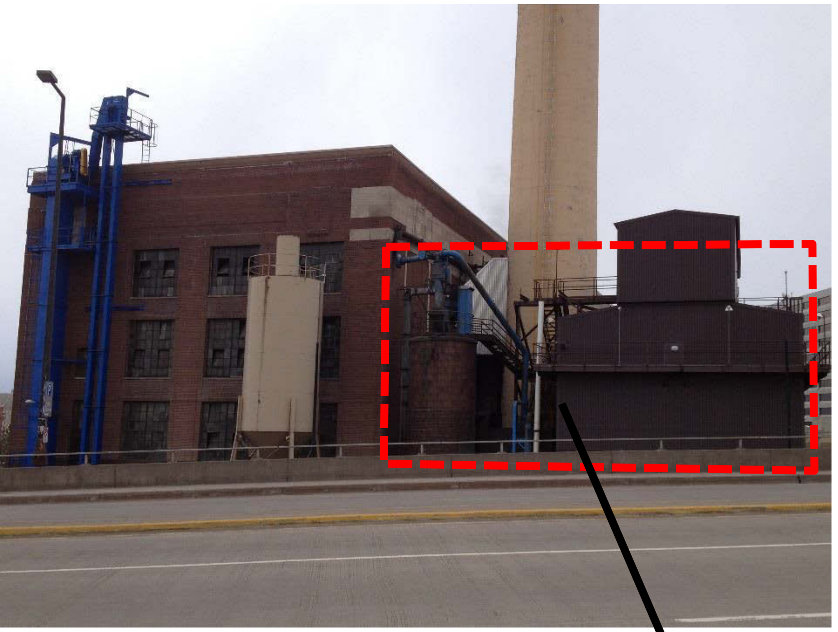
Metal Wire Screen On Back Side



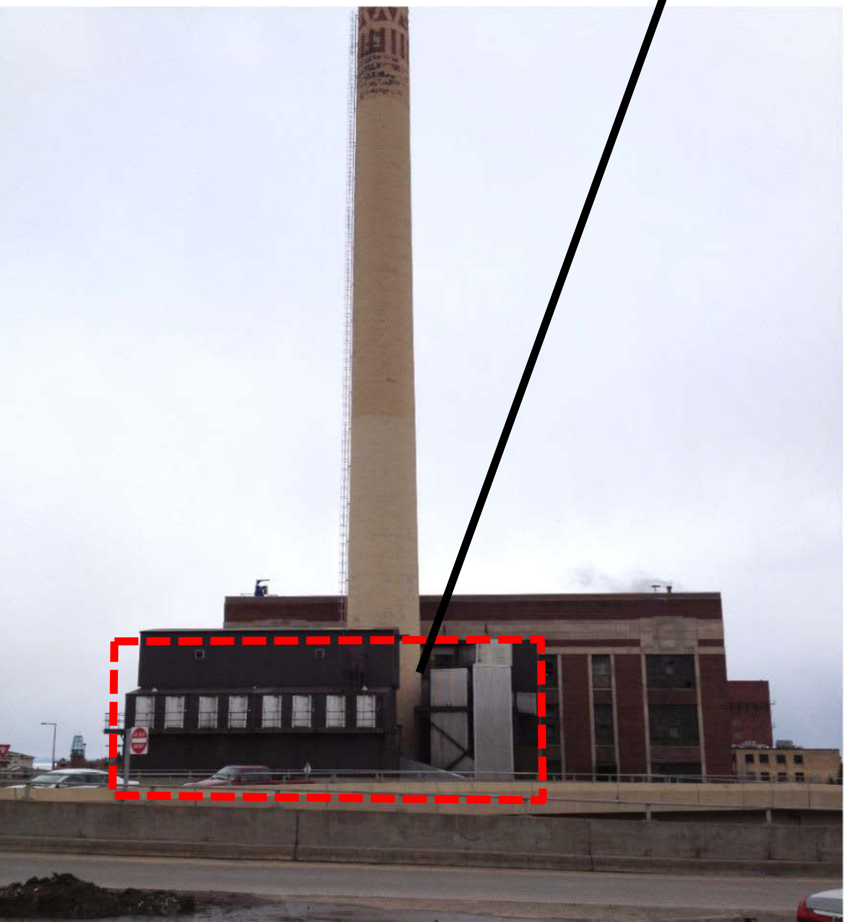


Design Concept Option 4

Metal Wire Screen

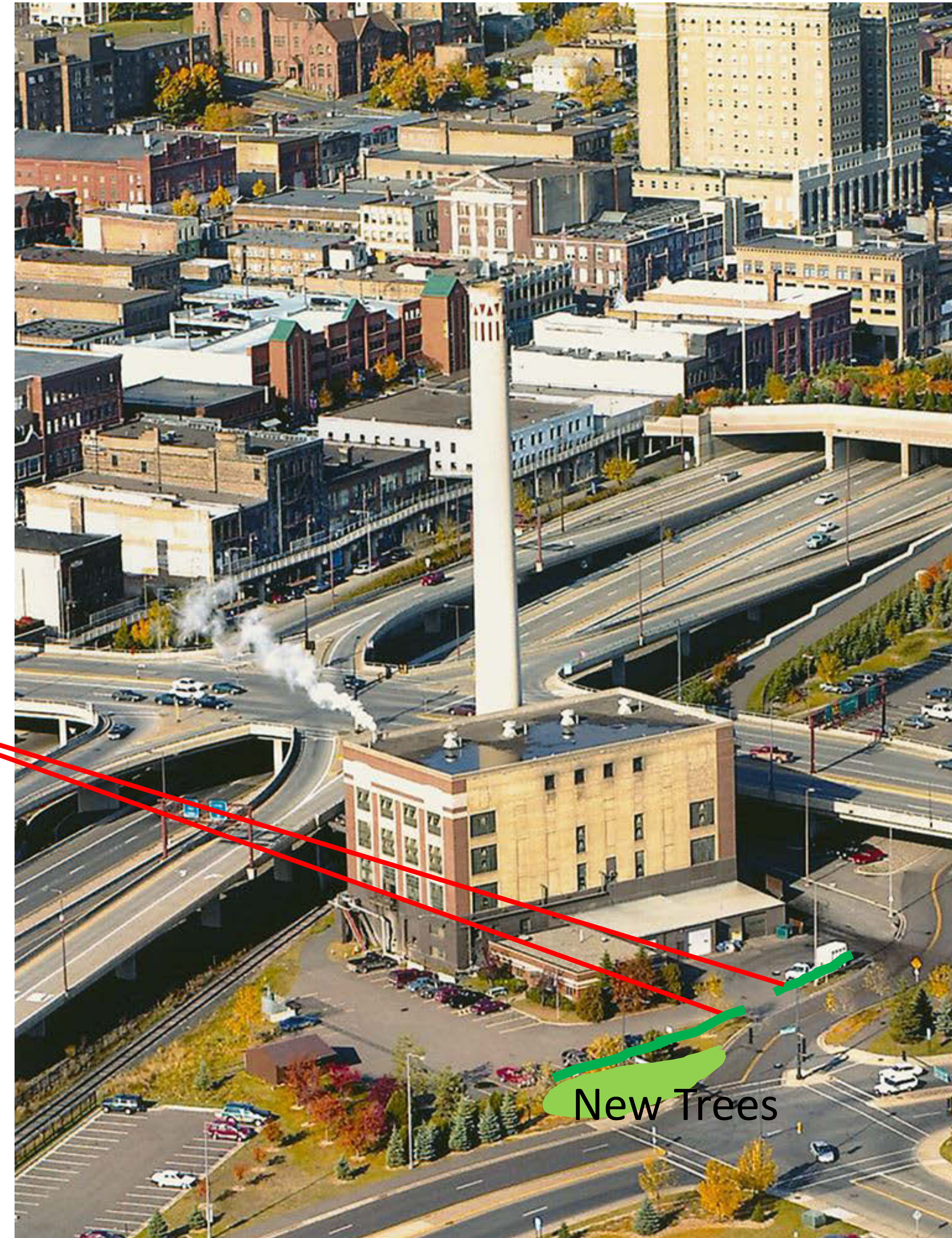


Metal Wire Screen

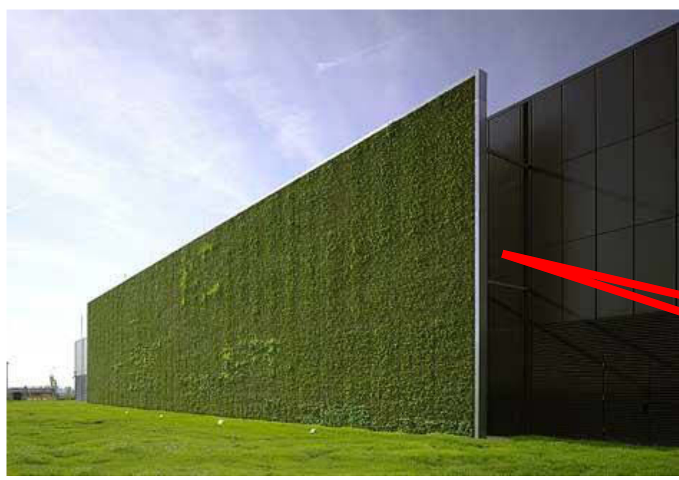


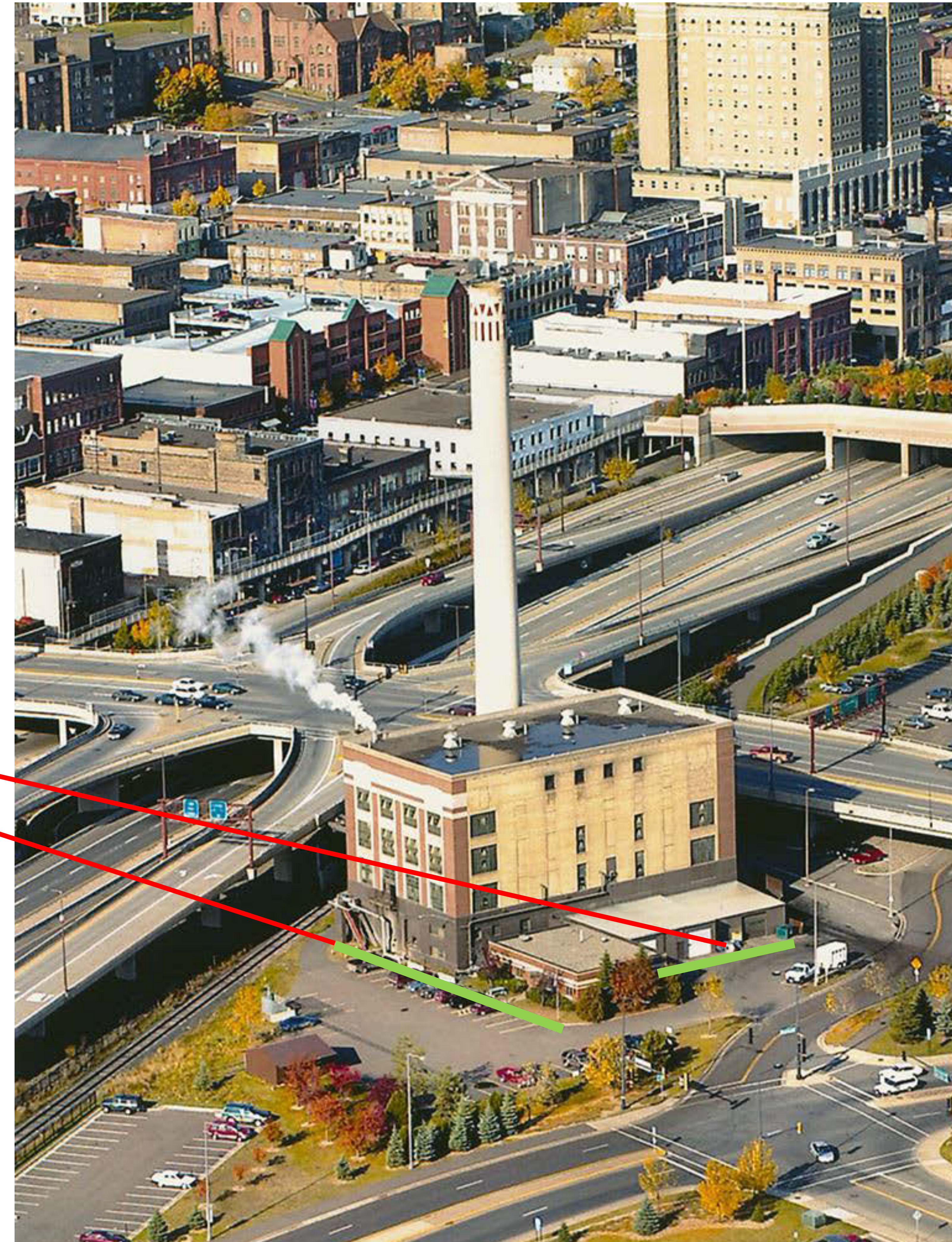
Landscaping Precedent

Landscape Walls & Trees



Green Wall Precedent





Design Concept Pricing

DULUTH STEAM
Design Strategy & Concepts
April 26, 20

	Budget Range
Design Concept #1 Graphic Screen and Landscaping	$1,911,255 – $2,177,877
Design Concept #2 Metal Louver Screen and Landscaping	$1,854,500 - $2,054,985
Design Concept #3 Metal Panel Screen and Landscaping	$1,479,015 - $1,638,910
Design Concept #4 Metal Wire Screen and Landscaping	$1,542,755 - $1,709,540

*All design concepts include a budget allowance of $184,000 for mandatory tuck pointing.

BAUER DESIGN BUILD, LLC

ARCHITECTURE FIELD OFFICE