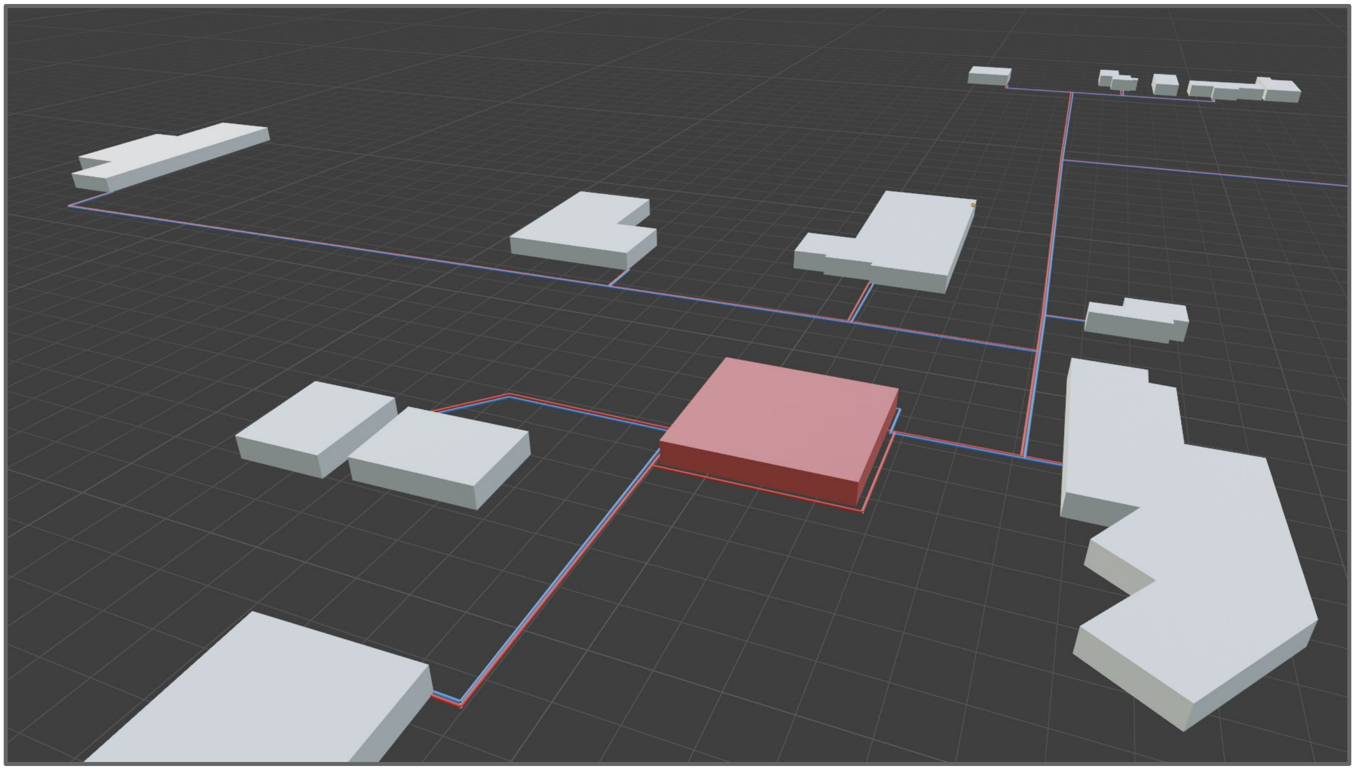
STRATEGIC COMMUNITY CONSULTING



Energy Efficiency Option Analysis for Municipal Buildings

Municipality of Emerson-Franklin

June 12, 2020

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Attestation of Completeness

I/we the undersigned attest that this Feasibility Study was undertaken using recognized assessment tools and practices, specifically including:

- *Natural Resources Canada's RETScreen Clean Energy Management Software*
- *Canada's National Inventory Report submitted to the United Nations Framework Convention on Climate Change*
- *The Standard for Sustainable and Resilient Infrastructure (SuRe)*

The assessment complies with criterion G1.6 Infrastructure Interconnectivity and Integration (MC), G1.8 Financial Sustainability (MC) and E1.1 Climate Change Mitigation (PC). The assessment applies the considerations of a climate resilience planning pathway; specifically, the pathway from analyzing energy and emissions assets to energy reduction measures, waste heat opportunities and renewable heat and energy systems. This assessment examines energy efficiencies and district energy options based on financial feasibility, climate impact mitigation and climate resilience.

This Feasibility Study uses the best-available utility projection data, geospatial and climate data and system costing information, including that available from:

- *Manitoba Hydro and the Public Utilities Board (PUB) of Manitoba*
- *Henry Hub prices set for the North American natural gas market*
- *Environment and Natural Resources Climate Data Repository*
- *RETScreen system component pricing based on Canadian system installations and international distributors*
- *Quotes from Triple Green Products, a Manitoba based company and leader in biomass energy systems*
- *British Columbia's Community Energy Association biomass heating research and system implementations*
- *OpenStreetMap and Microsoft Open Database Commons Canadian Building Footprints*

The Assessment complies with the general guidance of Canada's NIR and RETScreen Clean Energy Management Documentation and relevant sector-specific technical guidance published in international peer reviewed journals. This report should not be used for construction or environmental approvals but can inform strategy and prioritization. We do not accept any liability if this report is used for an alternative purpose from which it is intended, nor to any third party in respect of this report.

Attestation:* H.D.V________________________________ __June 12, 2020__

Henry David (Hank) Venema, PhD, P.Eng. – Chief Technology Officer *[Date]*

With contributions from Matthew Sebesteny and Kara Henrie.

STRATEGIC COMMUNITY CONSULTING

Executive Summary

Overview

Canada's 2030 Agenda National Strategy (2019) acknowledges that "*swift action is needed to reduce greenhouse gases, improve climate resilience and protect our natural environment*" and Manitoba is striving to be "*Canada's cleanest, greenest and most climate resilient province*" (Sustainable Development 2017). Sustainable Development reported in the Made-In-Manitoba Climate and Green Plan (2017) that building and water heat accounts for one third of energy use and "*the majority of emissions attributed to the operations of buildings*." In order to mitigate this component of emissions, improve resilience and reach these goals, communities, governments, businesses and individuals must begin to follow climate resilient planning pathways.

A climate resilience planning pathway is a multi-step process used to conduct an options analysis for, in this case, energy system alternatives. The pathway involves analysis of the current operational state, assessment of measures to drive down total energy demand (energy efficiency upgrades) and evaluation of renewable and community-based energy options. Based on the determined least cost portfolio of proven energy efficiency options and feasible district configurations, implementation is the final step in the pathway.

Energy efficiency upgrades can be simple to install and manage and generally inexpensive. The recommended upgrades can reduce Municipal utility costs associated with operations and GHG emissions. The trajectory of utilities, however, are still projected to rise with rising public utility rates, despite the reduction in total demanded energy. In order to change the trajectory of Municipal utility costs, a transition in energy source and distribution is recommended.

District community-based renewable heat and renewable heat and energy systems capitalize on local resources and provide opportunities for rural social and economic development. Utilizing local resources increases vertical integration of the energy supply chain stabilizing the trajectory of future utility costs. With rising concern of climate-related risks threatening aging Manitoba Hydro infrastructure, instability in foreign fossil-fuel markets and rising public utility rates, district energy systems are the key to economic, social and community sustainability. Manitoba's current policy context disallows the sale of generated electricity, therefore district heating systems are the primary district system recommendation with infrastructure to support future development to district combined heat and power. While energy efficiencies are good for reducing demanded energy, moving towards a biomass fueled community-based heating system will create significant change in annual utility costs and GHG emissions.

Recommended Efficiency Improvements

The recommended efficiency upgrades include the following. They are recommended for implementation in specific municipal buildings in each urban area. The resulting cumulative efficiency improvement (the percent reduction in total grid energy consumption) in Dominion City and Emerson, considering all recommended upgrades, is 22% and 13%, respectively. This equates to 576 GJ of grid energy reduced in Dominion City and 437 GJ in Emerson.

The Net Present Value (NPV) of the sum of savings from all recommended efficiency upgrades over the ten years after implementation is $70,527 in Dominion City. When compared to the net capital costs of all of the upgrades, $26,694, the net ten year return on investment (ROI) and net benefit-cost ratio (nBCR) for all upgrades is 167% and 2.6, respectively. Similarly, for Emerson, the ten year ROI is 509% and the ten year nBCR is 6.1 based on an NPV of savings of $39,527 and net capital costs of only $6,525.

- Boiler Temperature Control Sequencing
- LED (Interior, Exterior and Signage)
- Occupancy Sensors
- Programmable Thermostats (with Sequencing)
- Pool Boiler Control Sequencing
- Solar Pool Covers
- Air Side Heat Recovery Ventilator (HRV)
- Solar Hybrid Pool Heating
- Solar Thermal Hydronic Pre-Heating

Recommended District Energy Options

Many options for district heat and district CHP in Dominion City and Emerson resulted as feasible from the investment analysis, however, based on all of the collective analysis criteria - including investment figures, capital costs, GHG mitigation, climate resilience - only specific networks are recommended. While natural gas fueled systems have the potential for good ROI, they either result in no reduction of GHG emissions or they increase the GHG emissions emitted by the Municipality. Therefore, the recommended configurations are narrowed to biomass fueled systems only.

Dominion City

Biomass District Heating in Dominion City is feasible and recommended as soon as 2024. District heating is less cost prohibitive - the “low hanging fruit” - it does not have policy obstacles and it has relatively low institutional complexity. The addition of infrastructure for CHP, cabling and connecting the network’s buildings, is a ‘no regrets’ addition to the system - adding a component of resilience and future proofing with minimal additional capital. The addition of cabling capitalizes on the investment in excavation that is part of the district heating installation. Future phases can later connect to the installed cabling lines to expand the system from district heat to district CHP without needing to again invest in excavation. The system is recommended for two network layouts, the Central Municipal layout, which includes three Municipal operated buildings, and the Central Municipal and Other layout, which includes the same three Municipal operated buildings and five local, non-municipal buildings. The analysis criteria used to assess the network configurations are indicated below.

Central Municipal Network - Biomass District Heating with Cabling

- Year nBCR ≥ 1.5: 2024
- 20 Year ROI: 58%
- 20 Year nBCR: 1.58
- Simple Payback Period: 16 Years
- Capital Costs: $156,281
- System GHG Reduction (tCO2e/Year): 14.1
- Resilience Score: 4

Central Municipal and Other Network - Biomass District Heating with Cabling

- Year nBCR ≥ 1.5: 2030
- 20 Year ROI: 56%
- 20 Year nBCR: 1.56
- Simple Payback Period: 15 Years
- Capital Costs: $233,016
- System GHG Reduction (tCO2e/Year): 42.8
- Resilience Score: 4

Emerson

The lower energy density, or more distributed spatial proximity of buildings, in Emerson results in successful investment analysis only when both heat and power are supplemented on the network. The configurations recommended in Emerson are for Biomass District CHP for the Extended Municipal and the Extended Municipal and Other network layouts. Although these system configurations result in feasible investment analysis and good GHG reduction and climate resilience, they are both cost prohibitive, they involve management complexities and, because of Manitoba's energy policy context, the sale of electricity is currently not allowed. While these systems may not be immediately feasible due to the policy context in Manitoba or their prohibitive capital costs, they still have overall positive analysis criteria that warrants recommendation for future consideration should policy or technology changes occur. The two recommended network configurations include the four Municipal buildings in Emerson considered in district system analysis. The Extended Municipal and Other network also includes an additional four local, non-municipal buildings. The analysis criteria used to assess the network configurations for each layout are indicated below.

Extended Municipal Network - Biomass District Combined Heat and Power

- Year nBCR ≥ 1.5: 2025
- 20 Year ROI: 163%
- 20 Year nBCR: 2.63
- Simple Payback Period: 12 Years
- Capital Costs: $509,922
- System GHG Reduction (tCO2e/Year): 96.8
- Resilience Score: 8

Extended Municipal and Other Network - Biomass District Combined Heat and Power

- Year nBCR ≥ 1.5: 2020
- 20 Year ROI: 105%
- 20 Year nBCR: 2.05
- Simple Payback Period: 14 Years
- Capital Costs: $1,055,539
- System GHG Reduction (tCO2e/Year): 198.8
- Resilience Score: 8

Next Steps: Pilot Project and Port of Entry

Based on the results of this study, energy efficiency upgrades are no-regrets in both Dominion City and Emerson and could be implemented immediately. Biomass-based district energy in Dominion City is feasible and recommended next steps include detailed planning and testing. Next steps towards District Energy in Emerson await greater certainty that municipalities will be allowed by the Province of Manitoba to operate micro-utilities that produce and sell electricity in addition to heat. Provincially-owned buildings in the municipalities are good candidate customers for heat and potentially electricity. SCC believes the strong business case for energy efficiency and district energy along with the project's showcase potential, make a bundled project a strong candidate for FCM's Signature Initiative and Energy Recovery or District Energy funding streams. This study comprises the necessary feasibility analysis for further FCM funding eligibility.

Both FCM streams cover 50% of project costs up to $500,000. The Signature Initiative funding stream highlights projects that are "*transformative, best-in-class municipal projects*." SCC envisions that the multi-faceted, climate mitigation *and* climate adaptation components of district energy fit well within FCM's mandate. The revenue generation potential of the project also fits FCM's mandate to promote innovative municipal financing mechanisms that promote positive economic, social and environmental outcomes. The Energy Recovery or District Energy stream is intended to fund projects that examine financial performance of new or proven initiatives. In this case, biomass, a proven technology, is being applied in a new, innovative way as a revenue generating mechanism for the Municipality. Community-based district energy fits also within FCM's mandate of promoting biomass to displace fossil fuels.

An FCM project, as recommended, could be expanded with federal funding as a showcase innovation linked to economic development opportunities associated with Emerson-Franklin's strategic Port of Entry location along the mid-Continent Trade Corridor ("*Canada's most significant surface-based trade asset west of Windsor*"). As a component of the proposed sustainable pilot model for the Port of Entry, district energy would showcase municipal leadership and the potential for sustainable development at other Ports of Entry and in other rural Manitoba communities. Climate resilience and energy cost stability will attract industry and further the region's economic development.

Expanding district energy as a regional economic development project linked to the Port of Entry concept should consider three district energy networks: one in each of the urban areas of Emerson and Dominion City and one at the Port of Entry serving the proposed industrial development area. The three networks should operate within an integrated biomass fuel supply chain. The potential to refuel transport trucks with renewable energy at the border is a major regional sustainable development opportunity given anticipated shifts in trucking to increased use of biofuels and electricity. Clean and sustainable electric charging could be made available from biomass-fueled power generation. Biodiesel or biogas (wherever the market trends in the future) could also be made available for vehicle refueling at the Port of Entry.

We anticipate that FCM and the Provincial and Federal government will be impressed by the innovation and showcasing features of the recommended energy efficiency and district energy project. SCC recommends a next phase proposal with the following components:

- Recommended efficiency upgrades identified in this study for both Dominion City and Emerson.
- Building-level daily consumption monitoring for accurate energy demand profiles for all municipal and non-municipal buildings considered for district energy.
- A full engineering design study to size a biomass-based district energy system in Dominion City, Emerson and optionally at the Port of Entry based on existing or predicted daily consumption profiles.
- Engineering combustion tests of the oat hulls from Emerson Milling in a TGF Biomass Boiler System.
- A single building biomass heating pilot installation using a small commercial TGF Biomass Boiler (<5M BTU) to develop Municipal and Federal confidence in the technology and its economics.
- A regional biomass inventory to assess the cross-border vehicle fueling demand that could be supported with locally available renewable biomass resources.

SCC will be pleased to support Emerson-Franklin in planning and executing this and related projects.

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1 Project Background

1.1 Acknowledgements

SCC acknowledges the cooperation of Council and Public Works from the Municipality of Emerson-Franklin and the efforts of Nativus Energy in gathering and configuring building data and preliminary building analysis for this study.

1.2 Background

Canada's 2030 Agenda National Strategy (2019) acknowledges that "*swift action is needed to reduce greenhouse gases, improve climate resilience and protect our natural environment*" and Manitoba is striving to be "*Canada's cleanest, greenest and most climate resilient province*" (Sustainable Development 2017). In order for Manitoba to reach such a goal, communities, governments, businesses and individuals must follow a climate resilient pathway beginning with the mitigation of emissions to reduce the rate of climate change progression (COP23 2018; Wilbanks et al. 2014). Sustainable Development reported in the Made-In-Manitoba Climate and Green Plan (2017) that building and water heat accounts for one third of energy use and "*the majority of emissions attributed to the operations of buildings*." Of the primary energy systems in place in Manitoba, natural gas is the significant contributor of greenhouse gas (GHG) emissions in the building operations sector. Mitigation efforts in a climate resilient pathway begin with energy and emission analysis and, based on the data, lead to energy reduction and waste heat reuse measures.

Figure 1, provided in a report from Nativus Energy, shows the climate resilient planning pathway with analysis, energy reduction and reuse of waste heat at the base of the pyramid (Paul Amsler, Nativus Energy, report document, 2019). The goal of these measures is to drive down the total energy required by a building. Energy efficiencies can play a significant role in reducing the costs of operating a building and mitigating GHG emissions associated with its operation. There is, however, a point when reducing the energy required by a building becomes too costly and switching to alternative forms of energy is required for further cost savings and GHG emission reductions.

Figure 1: Climate Resilient Planning Pathway.

Renewable heat and renewable energy, on the top half of the pyramid in **Figure 1**, are recommended after financially feasible energy reduction measures are considered. Distributed community based renewable heat and renewable heat and energy systems capitalize on local resources and provide opportunities for rural economic development. A transition in energy source and distribution can make energy more dependable, while stimulating a new market, generating jobs and reducing GHG emissions (Sustainable Development 2017). With rising concern of climate-related risks threatening aging infrastructure, instability in foreign fossil-fuel markets, unknown escalation in carbon taxes and rising public utility rates, community energy planning will be key to economic, social and community sustainability and proper management of natural resources.

1.3 The Community

The Municipality of Emerson-Franklin is located south of Winnipeg along the Canada-USA border. It was incorporated as the Municipality of Emerson-Franklin in 2015 as a union between the RM of Franklin and the Town of Emerson. There are two clusters of municipal operated buildings in the region in the urban areas of Dominion City and Emerson. The Municipality demonstrated a desire to take on a leadership role in exploring a climate resilient pathway to save money and reduce energy use and GHG emissions from on-going operations of municipal buildings.

Climate resilience pathways involve both impact mitigation and climate resilient adaptations. In the energy space, this involves consideration of overall energy demand reduction through energy efficiencies and through a shift to low emission fuel sources. Climate resilient pathways, as indicated in

Climate Change 2014: Impacts, Adaptation, and Vulnerability (2014), can contribute to improving community social and economic well-being. In 2016, QUEST (Quality Urban Energy Systems of Tomorrow) published a report on Community Energy Planning (2016), which outlined the value proposition of energy system planning for Canadian communities:

> *"Canadian communities have untapped opportunities to strengthen local economies, reduce current and future energy costs and greenhouse gas (GHG) emissions, and create jobs by investing in smarter and more integrated approaches to energy use at the local level."*

Investment in community operated energy systems can also mitigate risk from, and vulnerability to, rising energy prices, unknown future climate policies and disruptions in energy supply (QUEST 2016).

1.4 The Proposed Project

This study continues the municipality's path set with the Climate Change Local Action Plan. It examines current operational functions of municipal run buildings and assesses technical and financial feasibility of proven energy-efficiency measures and community energy systems within the climate resilient pathway. SCC uses a systems-based approach in analyzing energy efficiencies and district system design based on an understanding of Emerson-Franklin's council and community economic development priorities. The study focuses on identifying the least cost portfolio of proven energy efficiency and waste-to-energy renewable technologies for municipal applications, including the system's potential co-benefits.

The marginal cost of energy efficiency upgrades and district networks are used to determine which upgrades are recommended and at what point district energy should be considered. Individual product or system assessment is based on its return on investment (ROI), net benefit-cost ratio (nBCR), capital cost, and potential to mitigate GHGs and climate vulnerability. Climate vulnerability assessment is based qualitatively on 'future-proofing' from foregin fossil fuel market, uncertain carbon pricing and aging public utility infrastructure dependencies. The enhancement, protection and growth of Manitoba's rural economy from the development of locally managed, community-based energy is also considered in the option assessments. District Energy options are considered municipally owned and operated which could act as an innovative revenue generator for the community.

The methods used in this study may serve as a model for assessing energy efficiency measures and the point at which to consider community-based energy options in the urban areas of Emerson-Franklin. They can be used to assess the feasibility of energy efficiency and conservation projects and community energy systems in other Manitoban communities. The methods can help other communities lower their energy costs, reduce their GHG footprints and improve their climate resilience.

2 Data Gathering and Analysis

The municipality provided Manitoba Hydro utility bills for the municipal run buildings in the urban areas of Dominion City and Emerson. Five buildings were included for the Emerson area and eight for Dominion City. **Table 1** lists the municipal buildings analyzed in each urban area. **Figures 2** (does not include the Public Works Yard due to proximity) and **3** show the location of the municipal operated buildings in proximity to one another.

Table 1: Municipal buildings considered in analysis.

Dominion City	Emerson
• Arena • Curling Rink • Abbeyfield Senior Home • RM Office • Fire Hall • Community Pool • Community Hall • Public Works Yard	• Recreation Complex • Fire Hall • Town Hall • Emerson Rink • Community Pool

Figure 2: Dominion City municipal operated buildings. The Public Works Yard is not shown in this figure.

Figure 3: Emerson municipal operated buildings.

The bills provided were for monthly natural gas and electricity consumption. The data was provided to a sub-consultant, Nativus Energy, who initiated an energy efficiency investigation phase. Nativus Energy conducted a high-level asset review of the buildings listed in **Table 1** - *note: Emerson's Recreation Complex was not assessed in this phase due to missing data*. The asset review included multiple components in two phases. The first was an investigation phase that involved a facility site walk through and survey, review of facility documentation, data assembly and preliminary energy use analysis. The second phase was the collection of the data into a report specifying facility inefficiencies, building utility breakdown, GHG equivalencies and potential low and high cost efficiency recommissioning measures. **Figure 4** is an example of the energy use analysis presented in Nativus Energy's final report. The figure shows the percent split of different utilities of the RM Office's total energy use. This analysis was conducted and presented for each municipal building.

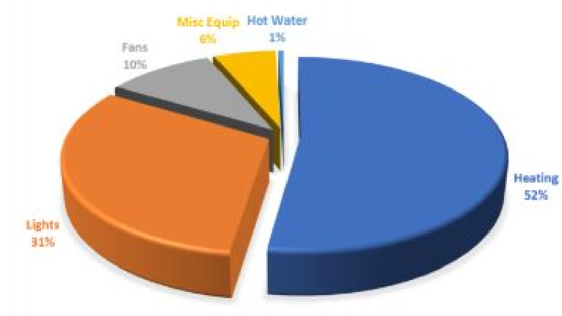


Figure 4: Example (of the RM Office) of the weighted energy use breakdowns provided in the Nativus Energy final report.

Table 2 and **3** list the low and high cost energy efficiency measures recommended for each of the analyzed municipal buildings in the report. The full Nativus Energy report is included in **Appendix 9.4.** A preliminary cost estimate is included for each of these improvements in the following sections of this report. Identifying the least expensive retrofit option and all of the options that are financially feasible.

Table 2: High and low cost energy efficiency measures for Dominion City Municipal buildings indicated in Nativus Energy's final report.

<table>
<tr><th>Dominion City</th><th>Low Cost Measures</th><th>High Cost Measures</th></tr>
<tr><td rowspan="4">RM Office</td><td>LED Interior, Exterior and Signage</td><td>Solar Air Preheating</td></tr>
<tr><td>Occupancy Sensors</td><td></td></tr>
<tr><td>Air Side Heat Recovery Ventilation (HRV)</td><td></td></tr>
<tr><td>Programmable Thermostat
- Occupied and Unoccupied Set Points
- Temperature Limiting Set Points
- Fan Limiting Set Points</td><td></td></tr>
<tr><td rowspan="2">Fire Hall</td><td>LED Interior, Exterior and Signage</td><td>Solar Thermal Hydronics</td></tr>
<tr><td>Boiler Temperature Control Sequence</td><td></td></tr>
<tr><td rowspan="2">Community Pool</td><td>LED Interior, Exterior and Signage</td><td>Solar Thermal for Hybrid Pool Heating</td></tr>
<tr><td>Night Set Back Boiler Water Temperature 2°F</td><td></td></tr>
<tr><td rowspan="2">Public Works Yard</td><td>LED Interior, Exterior and Signage</td><td>Solar Air Preheating</td></tr>
<tr><td>Programmable Thermostat
- Occupied and Unoccupied Set Points</td><td></td></tr>
<tr><td rowspan="2">Curling Club</td><td>LED Interior, Exterior and Signage</td><td>Solar Air Preheating</td></tr>
<tr><td>Programmable Thermostat
- Occupied and Unoccupied Set Points</td><td>Plant Side Heat Recovery</td></tr>
<tr><td rowspan="2">Community Hall</td><td>LED Interior, Exterior and Signage</td><td></td></tr>
<tr><td>Programmable Thermostat
- Occupied and Unoccupied Set Points</td><td></td></tr>
<tr><td>Abbeyfield Senior Home</td><td>LED Interior, Exterior and Signage</td><td></td></tr>
<tr><td>Arena</td><td></td><td>Plant Side Heat Recovery</td></tr>
</table>

Table 3: High and low cost energy efficiency measures for Emerson Municipal buildings indicated in Nativus Energy's final report.

Emerson	Low Cost Measures	High Cost Measures
Town Hall	LED Interior, Exterior and Signage	Solar Air Preheating
	Occupancy Sensors - Closed Spaces (Offices and Washrooms)	
	Air Side Heat Recovery Ventilation (HRV)	
	Programmable Thermostat - Occupied and Unoccupied Set Points - Temperature Limiting Set Points - Fan Limiting Set Points	
Community Pool	LED Interior, Exterior and Signage	Solar Thermal for Hybrid Pool Heating
	Night Set Back Boiler Water Temperature 2°F	
Fire Hall	LED Interior, Exterior and Signage	
Emerson Rink	LED Interior, Exterior and Signage	
	Occupancy Sensors - Closed Spaces (Offices and Washrooms)	
	Programmable Thermostat - Occupied and Unoccupied Set Points - Temperature Limiting Set Points - Fan Limiting Set Points	

Data for the monthly billing periods beginning Dec 22, 2017 and finishing Dec 21, 2018 were used to represent monthly consumption for January 2018 to December 2018. **Figure 5** and **6** show the monthly natural gas and electricity use, the total energy use, for the municipal operated buildings in Dominion City and Emerson, respectively, for the 2018 calendar year. The total energy use is displayed in gigajoules (GJ), a common unit of measure to compare electricity and natural gas consumption. One GJ is approximately equivalent to 277.78 kWh and 26.32 m^3 of natural gas.

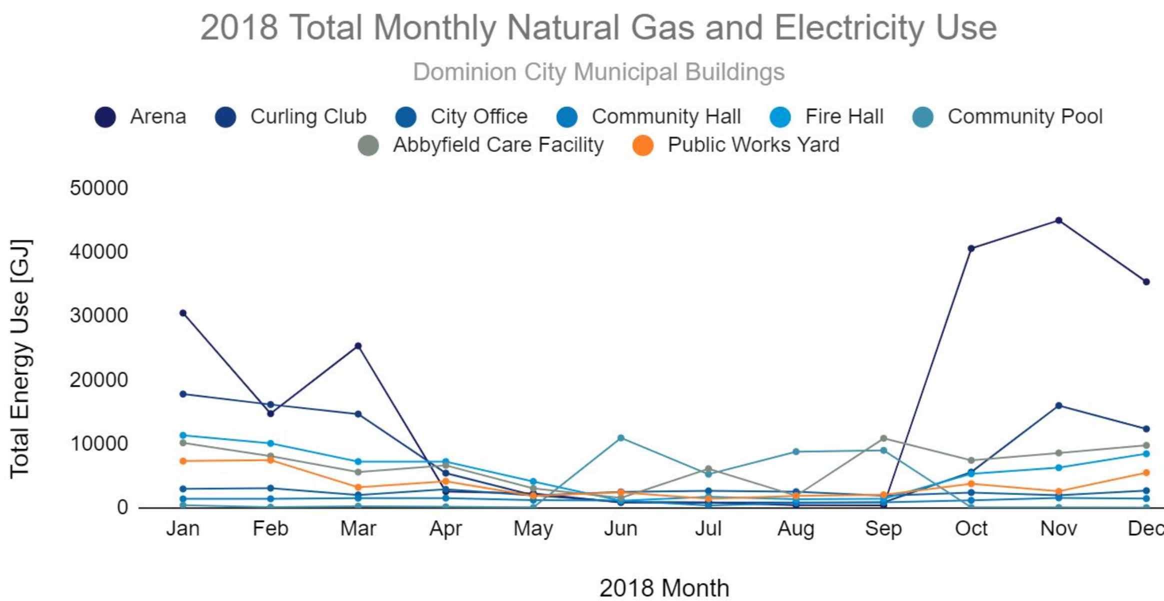


Figure 5: Total monthly natural gas and electricity use for Dominion City Municipal buildings represented as a total energy use in GJ.

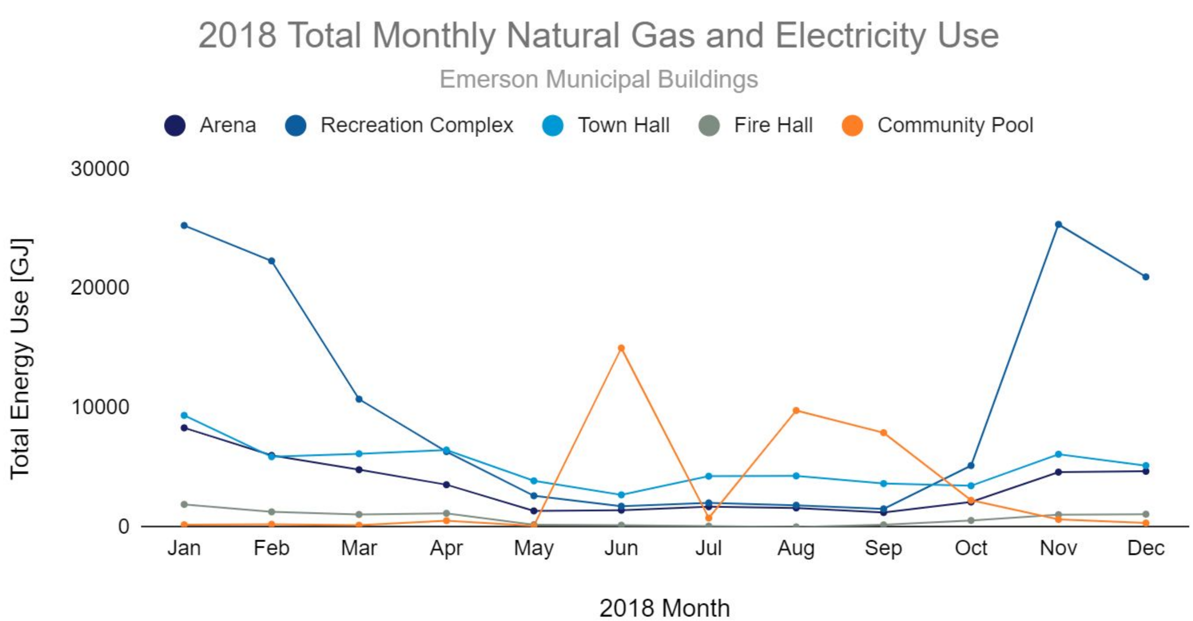


Figure 6: Total monthly natural gas and electricity use for Emerson Municipal buildings represented as a total energy use in GJ.

For buildings with incomplete data for this billing cycle, bills for the same period in 2017 or 2019 were used and adjusted linearly based on the month's heating degree days (HDD) recorded for the applicable year. **Figure 7** visualizes the data for monthly average temperature and monthly HDD from the Emerson weather station. The data was obtained from the Government of Canada's Environment and Natural Resources climate data repository (Environment and Natural Resources 2019).

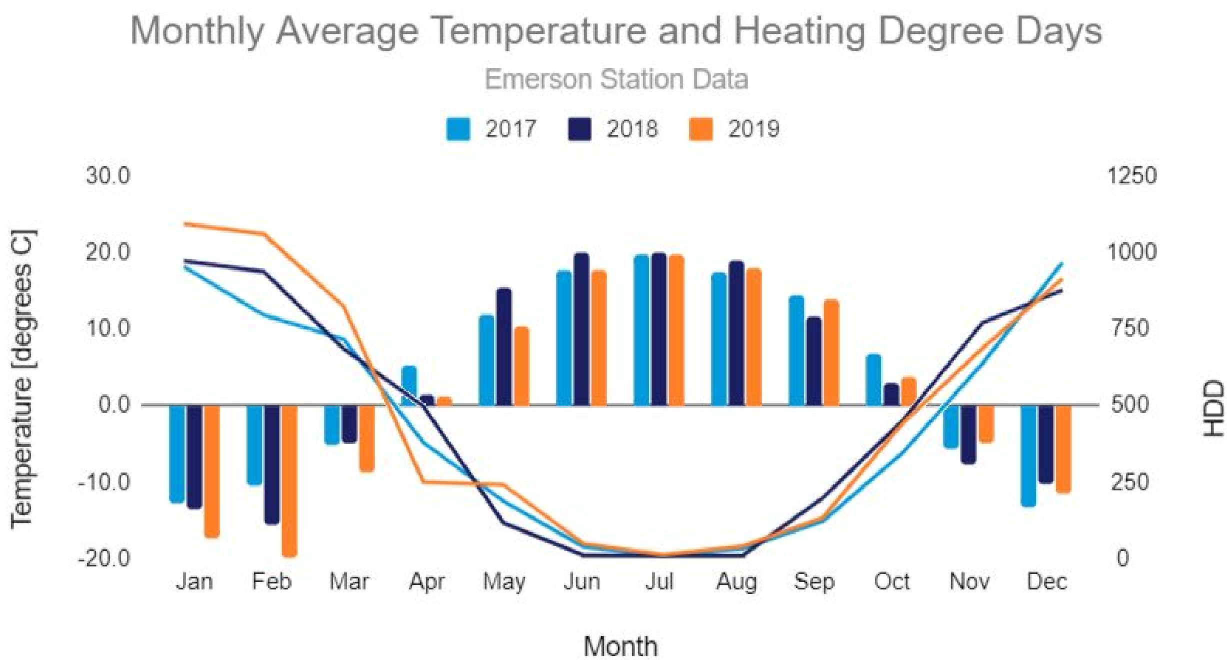


Figure 7: Monthly mean temperature and HDD at the Emerson station in 2017, 2018 and 2019.

3 Energy Price Forecast

Investment analysis is conducted with base electricity and natural gas prices at 2018 rates, \$0.11/kWh and \$0.29/m^3. Electricity rate increases are based on a 5.63% increase per year. This is an average between the 3.36% approved by the Public Utilities Board (PUB) of Manitoba in June 2017 and the 7.9% per year increase Manitoba Hydro requested from PUB Manitoba (Manitoba Hydro 2019). Natural gas rates are based on the Provincial flat rate carbon tax at \$25/t and predicted Henry Hub natural gas rate increases (AER 2019; Canada Energy Regulator 2018; Sustainable Development 2017). The two projections are shown in **Figure 8** as a time series over the 30 year analysis period.

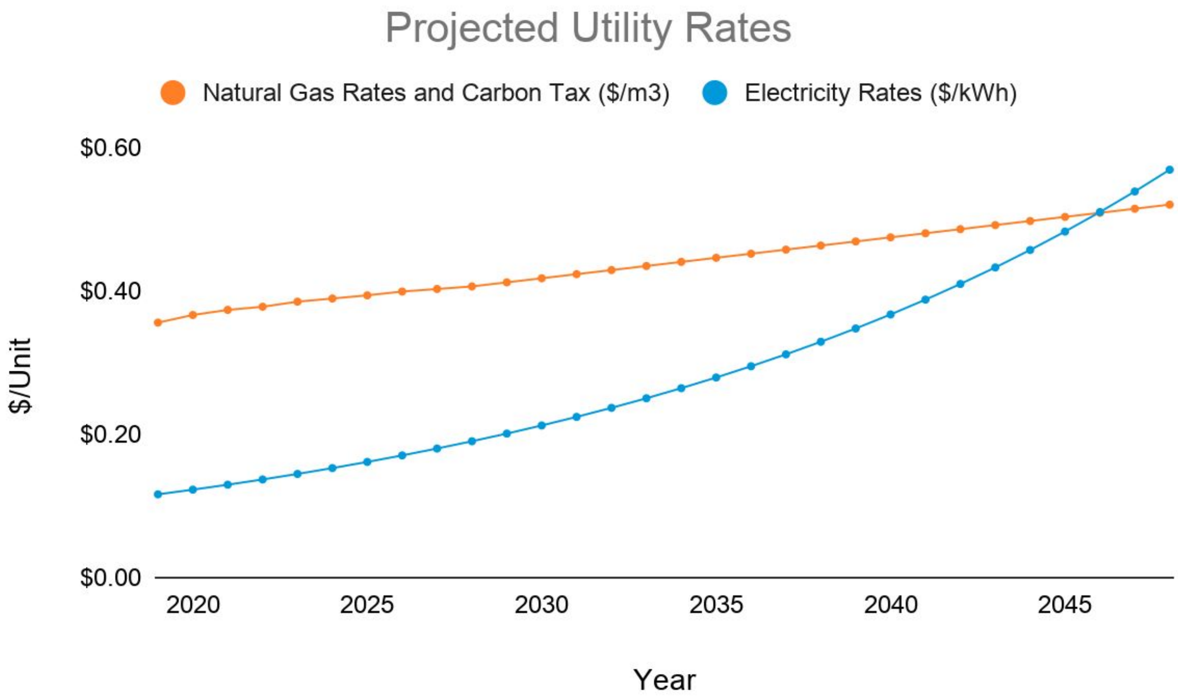


Figure 8: Projected natural gas and electricity rates from 2018 base rates over the 30 year study period.

4 Energy Efficiency Options Analysis

4.1 Efficiency Options

A preliminary cost estimate is included for incremental energy efficiency improvements for the portfolio of municipal buildings in Emerson-Franklin. Analysis utilizes the efficiency measures and energy end-use breakdown analysis included in Nativus Energy's report. The effectiveness of an option is assessed based on a balance of cost, lifespan, energy reduction potential and GHG mitigation potential in order to identify the lowest cost upgrade option, the option that most significantly reduces GHG emissions and all of the feasible options per community, based on investment analysis. The key figures associated with assessment of each efficiency upgrade are summarized in **Table 4**.

Table 4: Summary of cost and efficiency improvement of each assessed upgrade option.

Upgrade	Unit Cost	Useful Life (yrs)	Estimated Efficiency Benefit in Affected Sector(s) (%)	Additional Electricity Required for Upgrade Operation (kWh/yr)	Affected Energy Sectors
LED Interior, Exterior and Signage Occupancy Sensors	$29 / m2	10	50%	0	Lighting
Programmable Thermostat	$415 / unit	30	10%	0	Heating Cooling
Rink Heat Recovery	$56000 / system	20	70%	4800	Heating DHW
Air Side Heat Recovery Ventilator (HRV)	$2250 / unit	20	30%	2628	Heating Cooling
Solar Air Preheating	$30 / wallSF	40	20%	9	Heating
Boiler Temperature Control Sequence	$250 / unit	30	5%	0	Heating
Solar Thermal Hydronics	$1400 / panel	10	4%	0	Heating
Pool Boiler Control Sequence	$450 / unit	10	5%	0	Heating
Solar Pool Cover	$1000 / 2600SF	10	35%	0	Heating
Solar Pool Hybrid Heating	$6565 / 400SF	20	15%	0	Heating

The efficiency improvements from Light Emitting Diode (LED) lights and lighting occupancy sensors are grouped together. Their effect on energy consumption is based on a full transition of all lights to LED and occupancy sensors installed in closed spaces. The reduction rate is estimated at 50% of BAU electricity demand from lighting (Wei et al. 2015; EPA 2016; DOE). The capital costs are estimated on a per square meter basis for a 10 year approximate lifetime with full reinstallation after 10 years (Wei et al. 2015; Chesney 2016).

Programmable thermostats, pool boiler control sequencing and building boiler control sequencing are estimated to reduce 5% of BAU energy used for heating, and cooling where applicable (Peffera et al. 2013; DOE; NRCan 2016). Thermostat equipment, installation and professional optimal sequencing is estimated at a per building rate and it is assumed that the sequencing would remain untampered (Global Industrial 2019). Boiler control sequencing is based on the cost of professional optimal sequencing only per pool or building and is also assumed to remain untampered. All temperature control measures are estimated to have a 30 year useful lifespan (Chesney 2016).

Air Side Heat Recovery Ventilators (HRV) can provide energy efficiency benefits, however they also provide significant indoor air quality (IAQ) benefits. IAQ restrictions exist to ensure employee health and safety. Fresh air intake also reduces employee fatigue and can improve overall well-being at work. A 20% reduction of BAU energy from heating and cooling is estimated for the introduction of HRVs into building ventilation (Manitoba Hydro HVAC Program 2019). The costs are based on the units required to achieve the IAQ standards based on square meters of building space and approximate occupancy (ASHRAE 2003; Global Industrial 2020). Additional operating electricity costs are also associated with the installation of HRVs. The useful life of an HRV is estimated as 20 years (Chesney 2016). Where HRVs may not be recommended based on efficiency benefits they are still recommended for IAQ benefits.

Solar air pre-heating and solar thermal hydronics are first assessed based on building sun exposure and available wall space. Solar air pre-heating involves moving air through evacuated tubes that are exposed to direct sunlight. The air can either be further heated or blown directly into a space. Similarly, solar thermal hydronics involves running water through pipes exposed to sunlight and then into a boiler for further heating or directly into an in floor heating system. For the potentially viable buildings, costs are estimated based on the square footage of available south exposed wall space for collector installation. Solar air units are estimated to have a useful life of 40 years while solar thermal hydronic units, due to potential corrosion from flowing water, are estimated to have a 10 year useful life (Chesney 2016). The potential energy an air or hydronic unit can provide is based on the average high and low local ambient temperatures, local average wind speeds, sunrise and sunset times and sun strength (ISE 2007; NLSS 2015; NRCan 2000; SolarWall 2019; DOE 2016).

The most basic method to supplement pool heating costs is a thermal pool cover. This option was not included in Nativus Energy's report but is added to analysis. The cost of a pool cover is based on a per square meter estimation. The covers are expected to last for 10 years and provide up to 35% reduction of energy use for pool heating. They also provide additional benefit by reducing the volume of chemicals required in the pool by preventing evaporation (Francey et al 1980; ABGAL; Pool Supplies Canada 2020; Blue shield). Pool heating can also be supplemented by solar heat. Northern Lights Solar Solutions (2020) sells hybrid, flat panel solar pool heating kits that connect to existing pool heaters. The units used in analysis can provide heating for up to 400 square feet (sf). Efficiency is based on the percent, based on square footage of the pool surface, the collector would be able to supplement (NLSS 2020).

Ice plant heat recovery is a large, capital intensive system upgrade, however it can provide significant energy savings. The compressor in an ice plant produces significant amounts of heat that are typically pumped outside and wasted. This heat can be transferred through a heat exchanger to a ventilation system to supplement space heat or to water lines to supplement domestic hot water. The costs associated with the system are based on the capital expenditures of example projects (Broniszewski et al. 2018; Sask Power). The energy reduction potential is based on the energy expended by the ice plant, transmission and application efficiencies of 95% and the monthly energy demanded for space heating (Broniszewski et al. 2018; BOGE 2012).

4.2 Marginal Costs

The first step in analyzing the efficiency upgrades (listed in **Tables 2** and **3**) is determining the marginal costs. The marginal cost is the ratio of the annual amortized cost of the upgrade option for its anticipated useful life over the expected annual utility savings - it is summarized as the "$ Invested / $ Saved". The marginal costs utilize 2018 utility rates for the value of expected savings. The marginal cost ratios are plotted against the percent efficiency improvements (or percent reduction in total energy use) in **Figures 9** and **10**. The smaller the marginal cost implies less investment is required to achieve greater annual savings. **Tables 5** and **6** list, in the order plotted on the marginal cost curve, the efficiency upgrade option and the building it is considered in. Example calculations of the marginal costs are included in **Appendix 9.1**.

The values furthest to the left on the curves (with the flattest slopes) have the lowest relative cost of savings and the highest resulting efficiency improvement. These are considered the "low hanging fruit" and are recommended for implementation first. The improvements are added along the curve cumulatively.

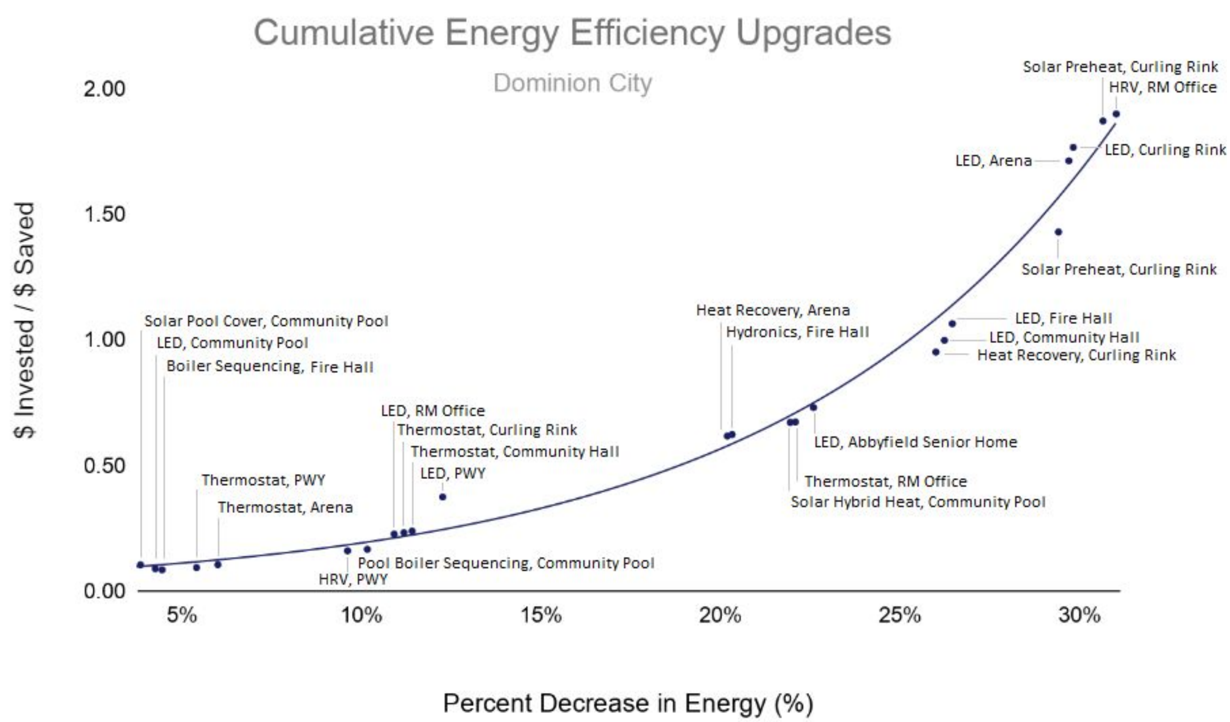


Figure 9: Marginal cost curve of incremental energy efficiency benefits in Dominion City.

Table 5: Upgrades in the order shown on the marginal cost curve for Dominion City in Figure 10.

Upgrade	Building
Solar Pool Cover	Community Pool
LED Interior, Exterior and Signage, Occupancy Sensors	Community Pool
Boiler Temperature Control Sequence	Fire Hall
Programmable Thermostat	Public Works Yard
Programmable Thermostat	Arena
Air Side Heat Recovery Ventilator (HRV)	Public Works Yard
Pool Boiler Control Sequence	Community Pool
LED Interior, Exterior and Signage, Occupancy Sensors	RM Office
Programmable Thermostat	Curling Rink
Programmable Thermostat	Community Hall
LED Interior, Exterior and Signage, Occupancy Sensors	Public Works Yard
Rink Heat Recovery	Arena
Solar Thermal Hydronics	Fire Hall
Solar Pool Hybrid Heating	Community Pool
Programmable Thermostat	RM Office
LED Interior, Exterior and Signage, Occupancy Sensors	Abbeyfield Senior Home
Rink Heat Recovery	Curling Rink
LED Interior, Exterior and Signage, Occupancy Sensors	Community Hall
LED Interior, Exterior and Signage, Occupancy Sensor	Fire Hall
Solar Air Preheating	Public Works Yard
LED Interior, Exterior and Signage, Occupancy Sensors	Arena
LED Interior, Exterior and Signage, Occupancy Sensors	Curling Rink
Solar Air Preheating	Curling Rink
Air Side Heat Recovery Ventilator (HRV)	RM Office

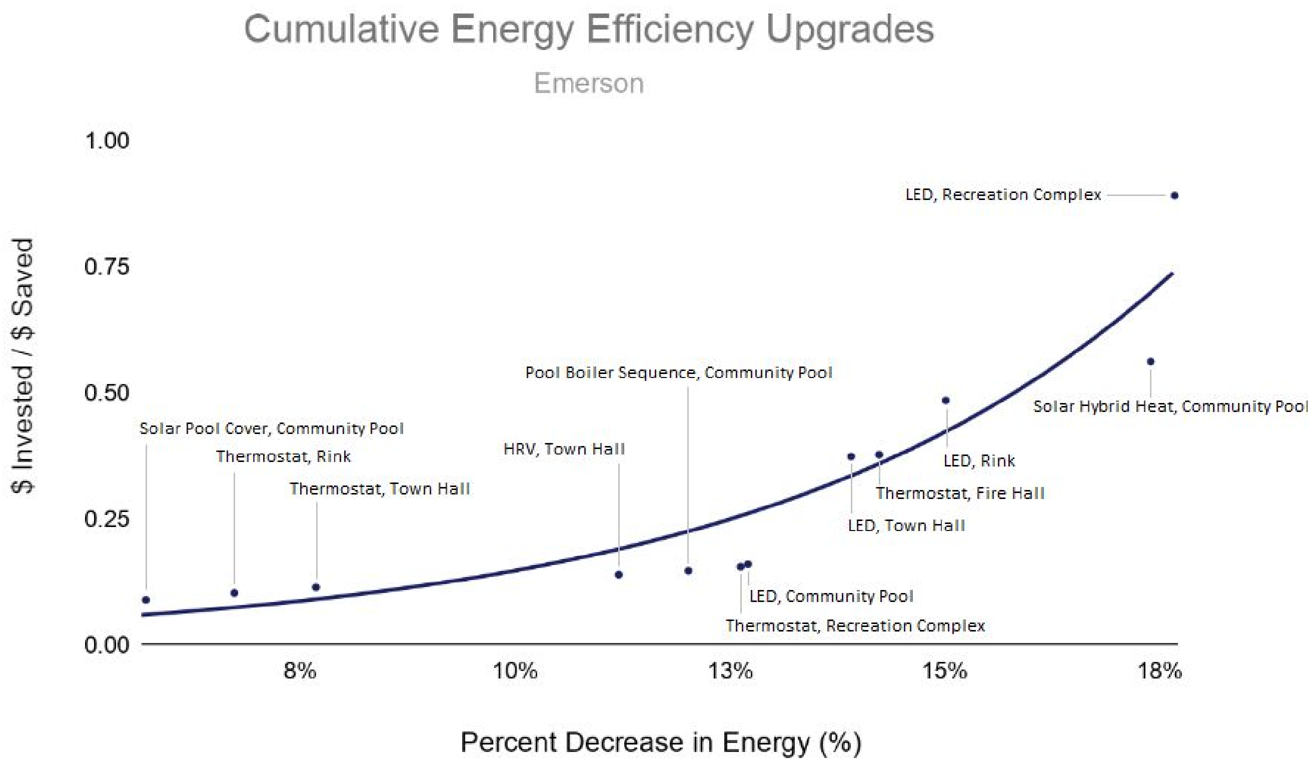


Figure 10: Marginal cost curve of incremental energy efficiency benefits in Emerson.

Table 6: Upgrades in the order shown on the marginal cost curve for Emerson in Figure 11.

Upgrade	Building
Solar Pool Cover	Community Pool
Programmable Thermostat	Emerson Rink
Programmable Thermostat	Town Hall
Air Side Heat Recovery Ventilator (HRV)	Town Hall
Pool Boiler Control Sequence	Community Pool
Programmable Thermostat	Recreation Complex
LED Interior, Exterior and Signage, Occupancy Sensors	Community Pool
LED Interior, Exterior and Signage, Occupancy Sensors	Town Hall
Programmable Thermostat	Fire Hall
LED Interior, Exterior and Signage, Occupancy Sensors	Emerson Rink
Solar Pool Hybrid Heating	Community Pool
LED Interior, Exterior and Signage, Occupancy Sensors	Recreation Complex

4.3 Investment Analysis

The efficiencies on the marginal cost curves in **Figures 9** and **10**, focusing on those on the left side of the curve, are further assessed for their ROI and nBCR over their anticipated useful life. Example calculations of ROI and nBCR are included in **Appendix 9.1**. Upgrade options with a negative ROI or an nBCR less than one are removed from further analysis. **Table 7** compares the ten year, post-2018 installation ROI and nBCR of the resulting feasible energy efficiency options in Dominion City and Emerson. The values are shown as the net ROI and nBCR for the installation of one or many of each upgrade in the municipal buildings. **Table 8** and **9** summarize the net ROI and nBCR for each building considering all feasible energy efficiency options.

Table 7: Ten year net ROI and nBCR for all recommended installations of each efficiency upgrade.

Upgrade		Dominion City Net	Emerson Net
Programmable Thermostat	10 Year ROI, 2018 Install	338%	582%
	10 Year nBCR	4.3	679%
LED Interior, Exterior and Signage Occupancy Sensors	10 Year ROI, 2018 Install	107%	92%
	10 Year nBCR	2.0	189%
Rink Heat Recovery		- ROI	*NA*
Air Side Heat Recovery Ventilator (HRV)	10 Year ROI, 2018 Install	172%	292%
	10 Year nBCR	2.7	389%
Solar Air Preheating		- ROI	*NA*
Boiler Temperature Control Sequence	10 Year ROI, 2018 Install	1163%	*NA*
	10 Year nBCR	12.6	*NA*
Solar Thermal Hydronics	10 Year ROI, 2018 Install	64%	*NA*
	10 Year nBCR	1.6	*NA*
Pool Boiler Control Sequence	10 Year ROI, 2018 Install	907%	492%
	10 Year nBCR	10.0	590%
Solar Pool Cover	10 Year ROI, 2018 Install	693%	831%
	10 Year nBCR	7.9	929%
Solar Pool Hybrid Heating	10 Year ROI, 2018 Install	4%	*NA*
	10 Year nBCR	1.0	*NA*

Table 8: Ten year net ROI and nBCR for all recommended efficiency upgrades per building in Dominion City.

	Dominion City							
	Arena	Curling Rink	RM Office	Community Hall	Fire Hall	Community Pool	Abbeyfield Senior Home	Public Works Yard
10 Year ROI, 2018 Install	491%	172%	43%	128%	230%	232%		229%
10 Year nBCR	5.9	2.7	1.4	2.2	3.3	3.3		3.3

Table 9: Ten year net ROI and nBCR for all recommended efficiency upgrades per building in Emerson.

	Emerson				
	Emerson Rink	Recreation Complex	Town Hall	Fire Hall	Community Pool
10 Year ROI, 2018 Install	716%	381%	348%		640%
10 Year nBCR	8.1	4.8	4.4		7.4

4.4 Efficiency Recommendations

The recommended efficiency upgrades in each urban area are listed in **Tables 10** and **11**. The options are sorted from lowest to highest annual amortized cost over the useful life of the upgrade. The potential reduction in annual utilities (at 2018 rates) and overall percent efficiency improvement are also indicated for each recommended upgrade. The resulting cumulative efficiency improvement (the percent reduction in total grid energy consumption) in Dominion City and Emerson, considering all recommended upgrades, is 22% and 13%, respectively. This equates to 576 GJ of grid energy reduced in Dominion City and 437 GJ in Emerson.

Table 10: Recommended efficiency upgrades in Dominion City.

Upgrade	Building	Amortized Cost ($/Year)	∆ 2018 Utilities ($/Year)	% Municipal Efficiency Improvement
Boiler Temperature Control Sequence	Fire Hall	$13	$250	0.2%
LED Interior, Exterior and Signage Occupancy Sensors	Community Pool	$30	$548	0.4%
Programmable Thermostat	Community Hall	$49	$76	0.2%
Programmable Thermostat	RM Office	$49	$49	0.1%
Programmable Thermostat	Public Works Yard	$49	$320	1.0%
Programmable Thermostat	Arena	$49	$199	0.6%
Programmable Thermostat	Curling Rink	$49	$91	0.3%
Pool Boiler Control Sequence	Community Pool	$53	$184	0.6%
Solar Pool Cover	Community Pool	$134	$1,285	3.9%
Solar Thermal Hydronics	Fire Hall	$164	$179	0.1%
Air Side Heat Recovery Ventilator (HRV)	Public Works Yard	$302	$989	3.6%
LED Interior, Exterior and Signage Occupancy Sensors	RM Office	$453	$988	0.7%
Solar Pool Hybrid Heating	Community Pool	$770	$539	1.6%

Table 11: Recommended efficiency upgrades in Emerson.

Upgrade	Building	Amortized Cost ($/Year)	∆ 2018 Utilities ($/Year)	% Municipal Efficiency Improvement
LED Interior, Exterior and Signage Occupancy Sensors	Community Pool	$30	$87	0.1%
Programmable Thermostat	Emerson Rink	$49	$274	1.0%
Programmable Thermostat	Town Hall	$49	$252	0.9%
Programmable Thermostat	Recreation Complex	$49	$161	0.6%
Pool Boiler Control Sequence	Community Pool	$53	$216	0.8%
Solar Pool Cover	Community Pool	$134	$1,510	5.7%
Air Side Heat Recovery Ventilator (HRV)	Town Hall	$151	$718	3.5%

5. District Energy Analysis

5.1 Background of District Energy

District energy systems provide heating, cooling or electricity, or a combination of utilities, to a network of buildings from one or few central power plants. Energy can be supplied to the system by various conventional or renewable input sources including coal, oil, natural gas, biomass, solar, wind, etc. Electricity can also be generated by converting heat to power using turbines.

5.1.1 District Heating

In district heating networks, heat energy is supplied through a network of buried distribution pipes. **Figure 11** shows a hot water pipe carrying water from a central power plant to various buildings on a network. A cooled water pipe returns the water back to the central power plant for reheating. Closed loop networks that return water for reheating, minimize water use and improve system efficiency.

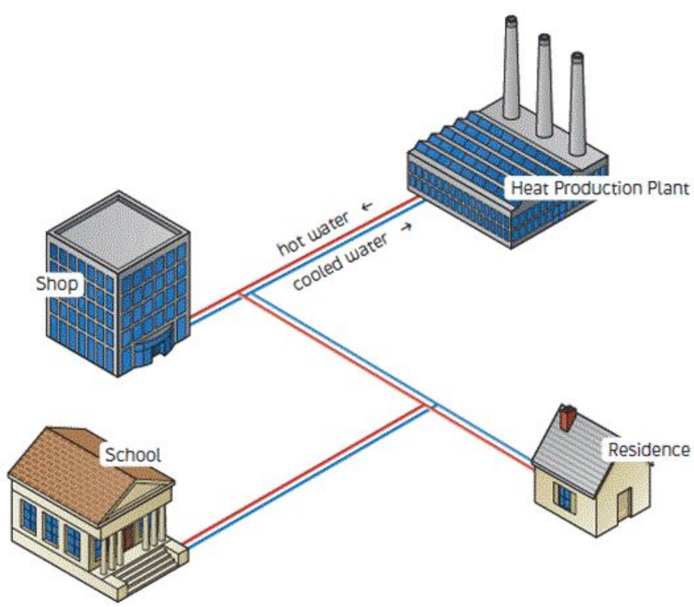


Figure 11: Simple district heating network diagram depicting the closed loop flow of water from a central power plant as hot water, to various buildings and returning to the power plant as cooled water (Statkraft).

District heating has existed for hundreds of years in small communities and urban centers all over the world. It is considered, by the Standard for Sustainable and Resilient Infrastructure (SuRe), an integrated type of energy infrastructure that can improve energy performance and support cost savings (2018). **Figure 12** iconifies the development of district heating systems from the year 1880 to 2020 and beyond. Modern systems, third generation or greater, utilize pre-insulated pipes and operate with supply temperatures below 100℃ (Lund et al. 2018). This modern development to a long standing technology eliminates the requirement of a steam certified operator and improves the cost efficiency of the overall system. Development has also led to the inclusion of flue gas filtration systems for fuels such as coal and various biomass feeds that produce ash. A newer technology to mitigate the release of ash and particulate matter (a common air pollutant) is a multi-cyclone filter collection system. These systems meet or exceed Manitoba's evolving environmental emission standards for air pollutants (Lyall Wiebe, Triple Green Products, personal communication, 11 March 2020). District heating systems are continuing to evolve to include more diverse energy inputs, heat recovery systems for data centres or industrial facilities and computer optimized energy production, storage and distribution methods.

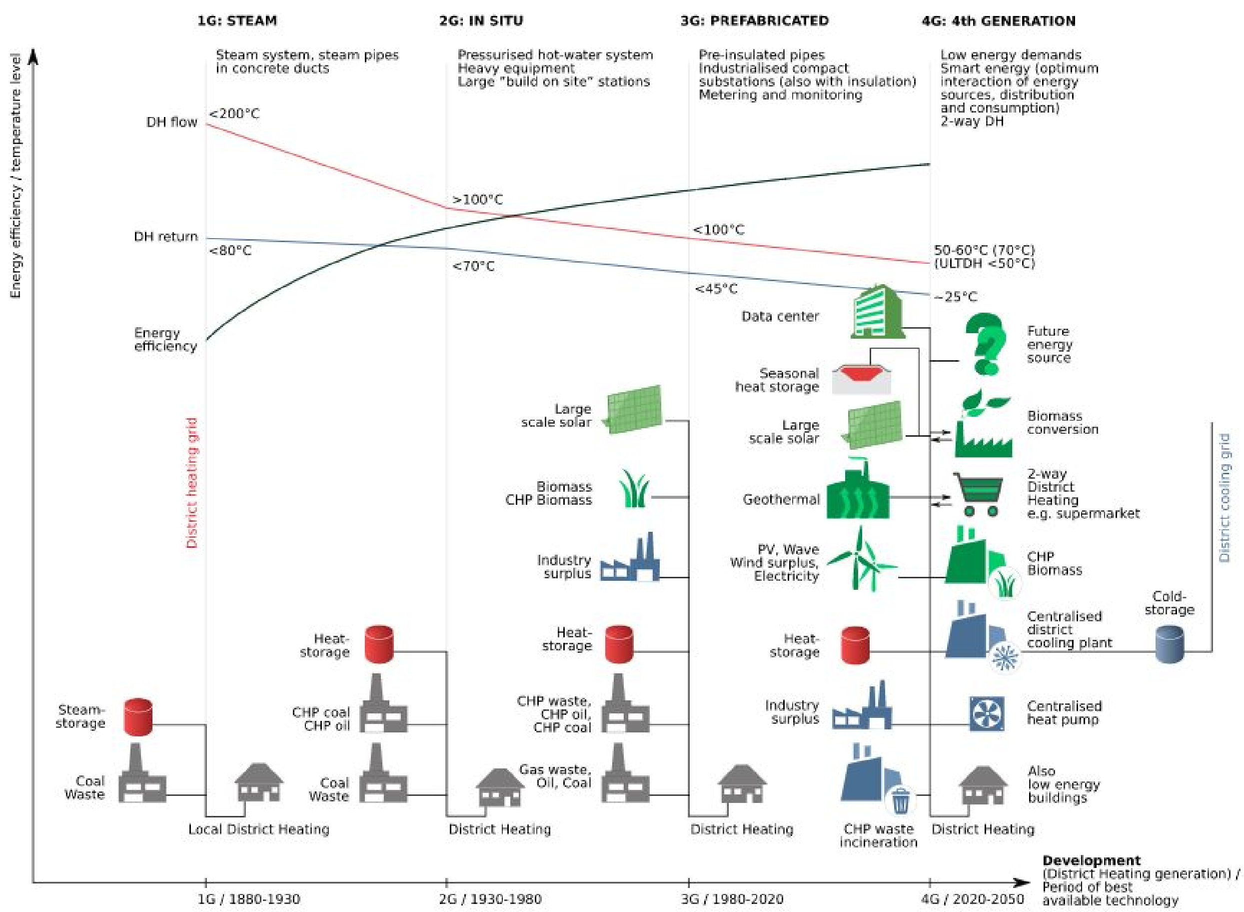


Figure 12: Progression of district heating technology (Lund et al. 2018).

5.1.2 District CHP

District energy networks, also referred to as Combined Heat and Power (CHP) systems, are slightly more complex than district heating systems. They do, however, offer greater GHG mitigation and climate vulnerability reduction by diversifying electric power supply. A CHP system supplies heat energy through buried water distribution pipes and electricity through transmission lines (above ground or buried). District CHP networks can also supply cooling in climates or building clusters where the cooling load is a significant component of the building energy footprints.

Organic Rankine Cycle (ORC) is a specific CHP technology that utilizes heat at relatively low temperature and pressure for electricity generation and therefore is successful with small systems. Heat from a natural gas or biomass powered boiler heats a fluid with a low boiling point in the ORC. Evaporation of the fluid drives a turbine to generate electricity. A portion of the heat can also be recovered from the ORC process when the fluid is condensed back into its liquid form. This heat can be contributed back to the heat distribution network.

5.2 Canadian Examples

Examples of communities taking action towards climate resilience can be found all across the country from British Columbia to Prince Edward Island and from Toronto to Yellowknife. The City of Yellowknife is a northern community located above the 60 degree North parallel. The community implemented a biomass district energy system powered by wood pellets to heat five municipal buildings: the Multiplex, the Fieldhouse, the City Garage, the Firehall and the Parks Garage. The system was designed to reduce GHG emissions by 829 tCO_2e per year and annual costs by $140,000 to $160,000 (Auge 2018). In Yukon, a First Nation community of less than 150 people, Teslin, has implemented a similar system. Their system burns low-grade wood waste to heat eighteen buildings with plans to add eight more (Chung 2019). Small communities of 1300 to 7500 people throughout British Columbia have also installed district energy systems. Telwa installed a wood fired biomass system in a vacant building to heat the city office and surrounding buildings (NRCan 2016). Enderby and Lillooet’s biomass systems were installed in 2013 and 2012, respectively and operate using pelletized wood waste. Ownership models, however, differ for the two communities. The district of Lillooet operates their own biomass energy system where Enderby’s system was privately-funded for operation by Fink Machine (BC Rural Centre 2016; Fink Machine 2014; SIBAC 2010). The Revelstoke Community Energy Corporation was developed by local volunteers as a wholly owned subsidiary of the city. The system services a range of municipal buildings and replaces propane that previously was trucked into the community (FVB 2003; Biomass Energy Resource Centre 2009). A Cree Nation of fewer than 1000 people in Ouje-Bougoumou, Quebec, operates a biomass plant with two boilers supplying 75% of the district heat to the entire community of 135 homes and 16 public buildings (FVB 2020).

District energy systems can also be powered by energy sources besides biomass, such as solar or geothermal. Okotoks, Alberta participated in a federal pilot project in 2007 to investigate solar thermal heating. The system provides more than 90% of the space heating requirements for 52 homes on the district network. In Manitoba, Ritchot, a community of less than 7000 people, installed a district geothermal system. The system supplies heat to the community arena, fire hall, community centre and banquet hall (Chang 2019).

5.3 Regional Biomass Availability

Biomass is a viable resource in Manitoba for supplementing or replacing public utilities for heat and electricity. The International Institute for Sustainable Development (IISD) (2018) estimates that there are five million tonnes of biomass available per year in Manitoba in the form of wood waste, crop residue or marginal land plant growth. The best option for a community is a biomass feed that is readily available and one with an optimal minimum distance to source and price of fuel and maximum calorific value. This study considers the use of waste oat hull from Emerson Milling located between the urban areas of Emerson and Dominion City. **Figure 13** shows the location of the mill relative to both urban areas.

Waste oat hull at this facility is being produced at a rate of approximately 100 t/day 365 days per year (Jarrod Firlotte, Emerson Milling, personal communication, 14 August 2019). The calorific value is estimated as 14.855 GJ/t in this study. This is a conservative estimate compared to other suggested values of 17 GJ/t by Zhang and Boris (2011) and 19.5 GJ/t estimated by Ontario's Ministry of Agriculture and Rural Affairs Burn Characteristics for Oat Hull (2019). The density of the oat hull being transported is assumed to be 128 kg/m^3 (Anval 2010). The price of the oat hull in this study is set to $40/t not including transportation. Utilizing the oat hull from Emerson Milling is considered a waste diversion method for the biomass.

Figure 13: Location of Emerson Milling relative to the urban areas of Emerson and Dominion City and the Dominion City Public Works Yard.

Figure 14 shows a handful of oat hulls produced at the General Mills cheerios factory in Minnesota (Hunt 2017). General Mills uses ten percent of their waste oat hulls from oat flour production to heat their factory. The remaining waste is sold to other companies, including Koda Energy, who uses the hulls to power their plant and 8000 nearby homes (Hunt 2017).

Figure 14: Waste Oat Hulls used in a biomass heating system at General Mills (Hunt 2017).

Biomass fuels have varying characteristics that affect their ability to burn (Lewis 2015). Oat hull burn characteristics are included in **Table 12** (OMAFRA 2011). The University of Iowa (2015) found oat hulls burnt efficiently, reduced their particulate matter and other atmospheric pollutants (as compared to coal) and were readily available from the nearby Quaker Oats facility, meeting all of their biomass fuel requirements (Power 2006). The ash content of oat hull, however, does require the inclusion of a complete ash removal system. At General Mills, they collect the ash from their system and make it available to local farmers for field application. **Figure 15** shows a truck at General Mills being loaded with ash from the oat hull combustion process (Hunt 2017).

Table 12: Burn characteristics of oat hull (OMAFRA 2011).

	Ash %	Carbon %	Hydrogen %	Nitrogen %	Sulphur %	Oxygen %	Total Chlorine (μg/g)[3]
Oat Hull	5.1%	46.7%	6.1%	0.9%	0.1%	41.1%	1065

Figure 15: Collected ash from a biomass heating system at General Mills being loaded into a truck bed for transport to local farm fields (Hunt 2017).

Other biomass feedstocks not evaluated in this study are also available in the region and may be good alternatives or options for use in combination with oat hulls. Other feedstocks include cattails from local ditches and retention ponds and local wood waste. Development of a local program to harvest cattails and/or collect wood waste could supplement the cost of input biomass to a district heat or CHP system. The biomass collection program could be coordinated with the Seine Rat Roseau Watershed District (SRRWD), which does periodically harvest cattails from water retention areas - a program the SRRWD could expand if demand increased.

5.4 District Energy Implementation Year

The implementation date of a district heat or district CHP system is the first assessment criteria in determining feasibility of a system. Systems that do not make financial sense with implementation before 2030 are removed from further analysis. Determination of the implementation year is based on the long term investment case over the 20-year useful life of the system. The earliest recommended implementation year is considered the earliest year the system has a nBCR of 1.5 or greater. **Figure 16** shows the new annual utility costs of a Biomass District CHP system versus the amortized capital costs for 2022 implementation resulting in an nBCR of 1.52. If the same system is installed in 2027 instead of 2022, the nBCR increases from 1.52 to 2.11.

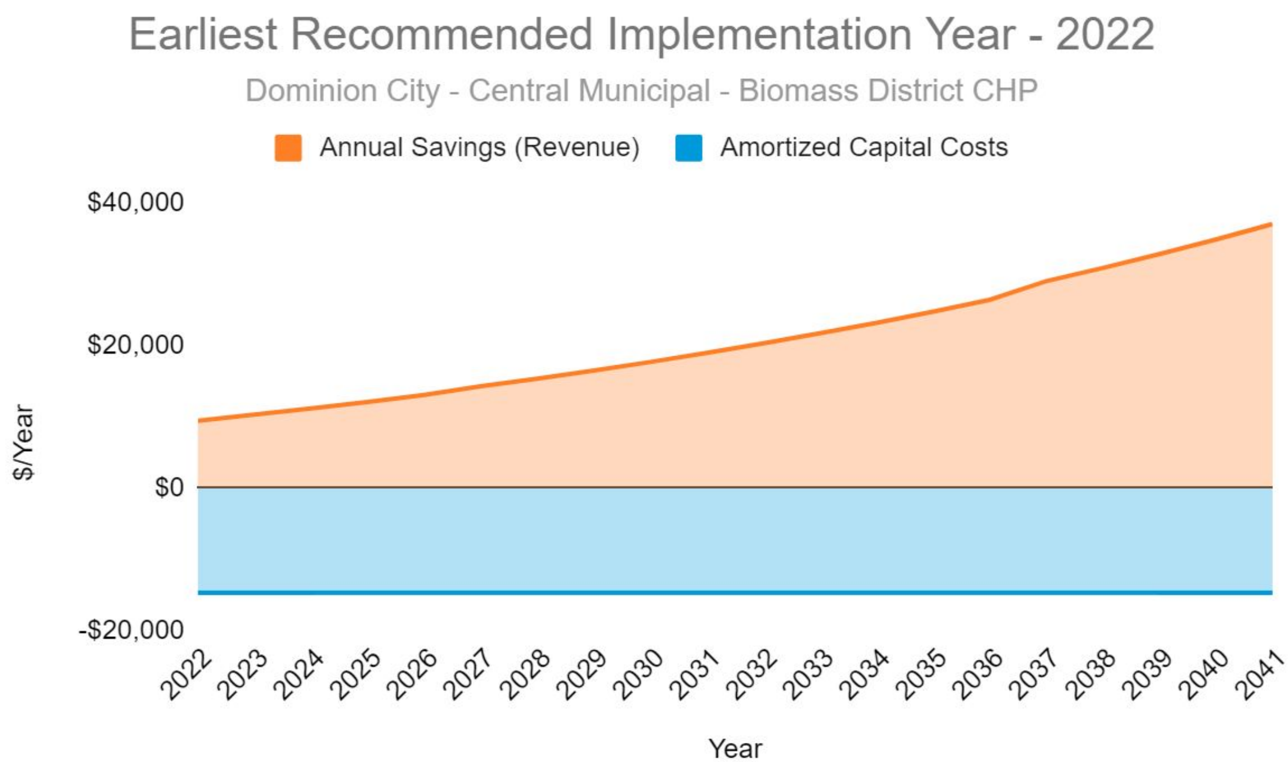


Figure 16: Example of a system installed at its earliest recommended implementation year based on a long term payback horizon resulting in an nBCR of 1.52.

5.5 When to Consider District Energy

After the recommended efficiency upgrades are implemented, the cost of savings (the marginal cost - $ Invested / $ Saved) from further energy efficiency upgrades exceeds the cost of savings from community-based energy systems. Using the marginal cost curves for Dominion City and Emerson in **Figures 9** and **10**, horizontal lines representing the marginal cost of biomass district systems can be added as "cut-offs" (**Figures 17** and **18**). The recommended efficiency upgrades are those on the marginal cost curves that fall below the district system lines and that also have individually successful ROI and nBCR values. The not recommended efficiency improvements are those with marginal costs above the district system lines. **Figures 17** and **18** show the marginal cost curve of efficiency upgrades with the horizontal lines for Biomass District CHP. **Figure 17** for Dominion City shows the Biomass District CHP system used in the above example showing its earliest recommendation year, 2022, and 2027 implementation. Similarly, **Figure 18** shows the comparison of energy efficiency upgrade marginal costs to that of a Biomass District CHP configuration. The configuration is shown for installation in 2020, with an nBCR of 2.63, and 2025 with an nBCR of 2.63.

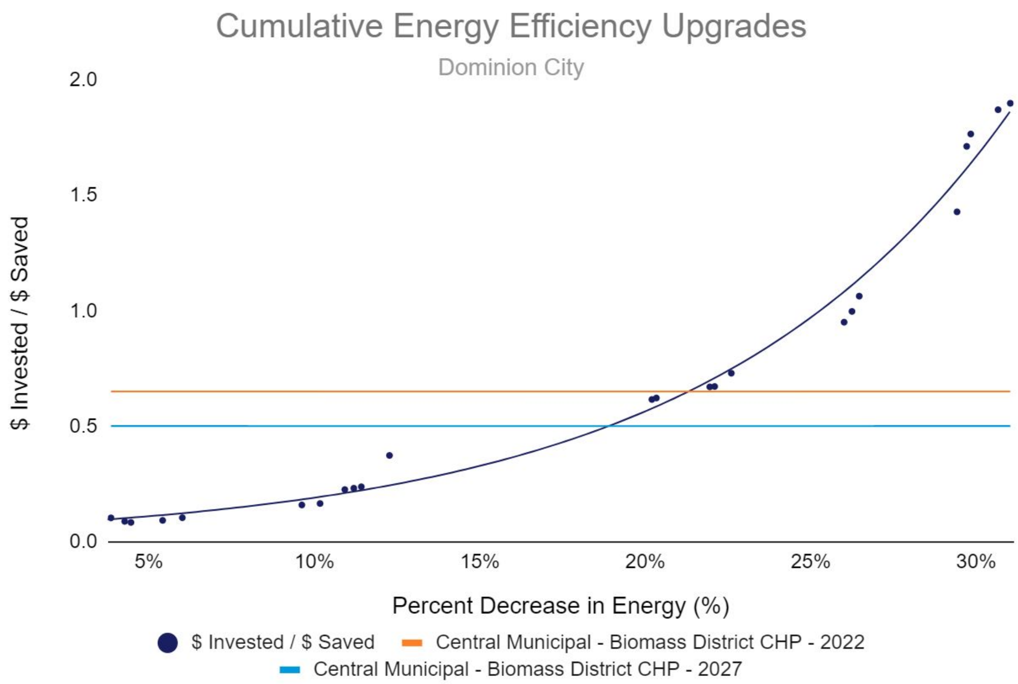


Figure 17: Marginal costs of efficiency upgrades in Dominion City compared to the marginal cost of a Biomass District CHP system with two example implementation years.

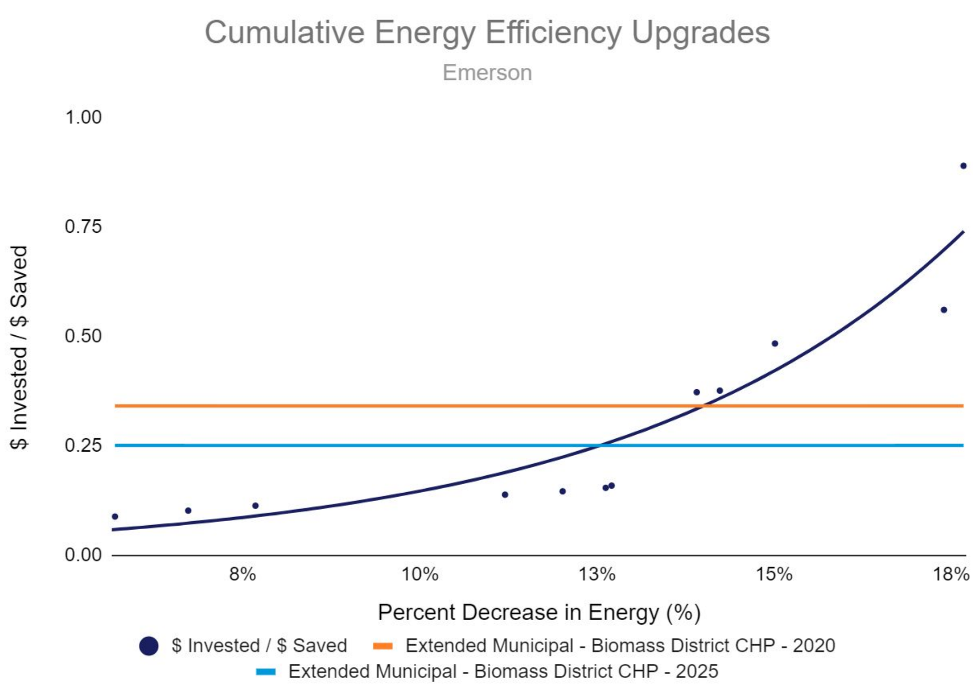


Figure 18: Marginal costs of efficiency upgrades in Emerson compared to the marginal cost of a Biomass District CHP system with two example implementation years.

Building efficiency improvements are an effective method in mitigating annual utility costs. They reduce the total energy demanded and therefore the resulting cost. The trajectory of annual costs, however, is still affected by rising utility rates. **Figure 19** shows the BAU annual utility costs for a cluster of municipal buildings in Dominion City and the cumulative effect of the recommended efficiency upgrades in the buildings. The figure visualizes the reduction potential of the efficiency upgrades but also the upward trajectory of utilities with increasing public utility rates. Conversely, the biomass district CHP option that changes the fuel source and fuel management, changes the trajectory of utility costs.

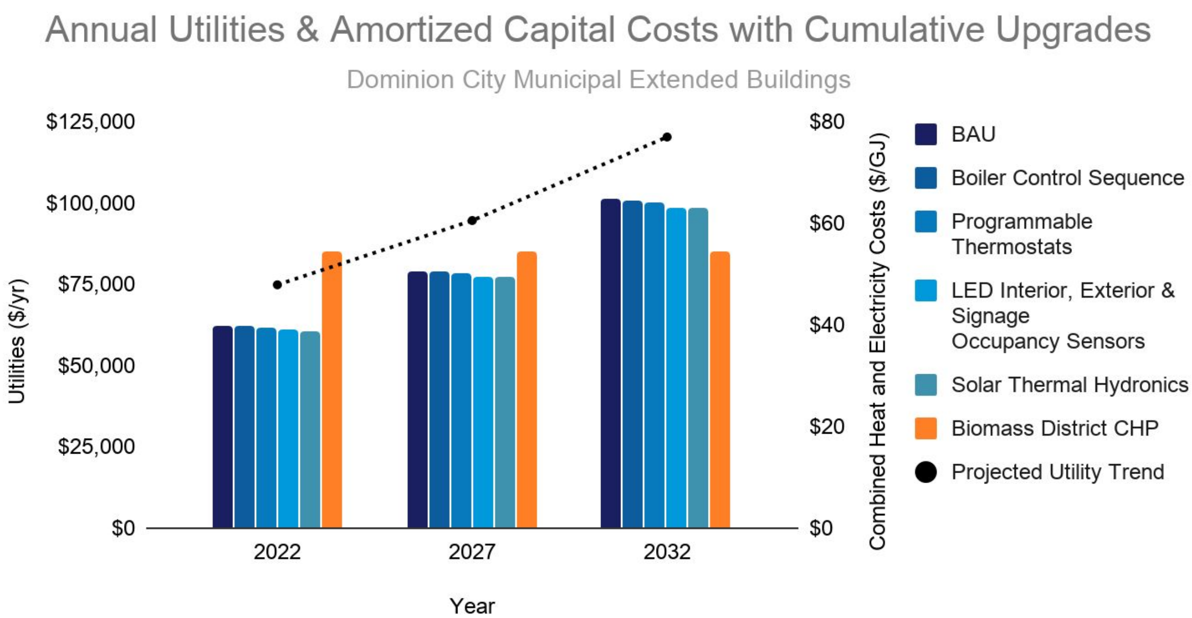


Figure 19: Dominion City annual utilities with cumulative savings and amortized capital costs from the feasible energy efficiency upgrades in Central Municipal buildings and implementation of Biomass District CHP for the same cluster of Municipal buildings.

The Made-in-Manitoba Climate and Green Plan acknowledges that transitioning to district, community-based energy systems can make energy more dependable, while reducing utility costs, generating jobs and reducing GHG emissions (Sustainable Development 2017). Additionally, they can capitalize on local resources and provide opportunities for further rural economic development. A district energy system mitigates community GHG emissions and reduces community climate vulnerability. Supplementing natural gas consumption reduces the most significant component of GHG emissions associated with heat and DHW and minimizes dependencies on out-of-province fossil fuel markets. Community-run electricity generation reduces vulnerability to outages from storms affecting Manitoba Hydro infrastructure, as downed power lines outside the community will not affect supply reliability from a district energy system.

5.6 Building Load Analysis

Energy consumption for municipal operated buildings was obtained from Manitoba Hydro bills provided by the municipality. Data for the monthly billing periods beginning Dec 22, 2017 and finishing Dec 21, 2018 are used to represent monthly consumption for January 2018 to December 2018. For buildings with incomplete data for this billing cycle, bills for the same period in 2017 or 2019 are used and adjusted linearly based on the month's heating degree days (HDD) recorded for the applicable year. The data is obtained from the Government of Canada's Environment and Natural Resources climate data repository (Environment and Natural Resources 2019). The efficiency of natural gas boilers operated by the municipality is assumed to be 70% and electric boilers are assumed to be 100% efficient.

Approximate annual consumption patterns for buildings not operated by the municipality but considered in this study are obtained from NRCan's *Canadian Energy Use Intensity by Property Type* Technical Reference (NRCan 2013). It is assumed these buildings are heated with natural gas at a rate of 70% efficiency. The percent of total building energy use attributed to heating and domestic hot water (DHW) is averaged for the municipal buildings. The average is used to estimate the component of NRCan's building footprint that results from heating and DHW. The remaining percent not attributed to heating or DHW is considered to be electricity use from varying applications. **Figure 20** shows the energy use breakdown for the RM Office developed by Nativus Energy. In order to estimate the monthly energy use for the non-municipal buildings, the monthly weighted percent of annual utilities attributed to heat and DHW in municipal buildings is averaged and applied to the approximate annual consumption of each non-municipal building. **Figure 21** visualizes the averaged weighted percent used to break down the approximate annual consumption of the non-municipal buildings into monthly figures.

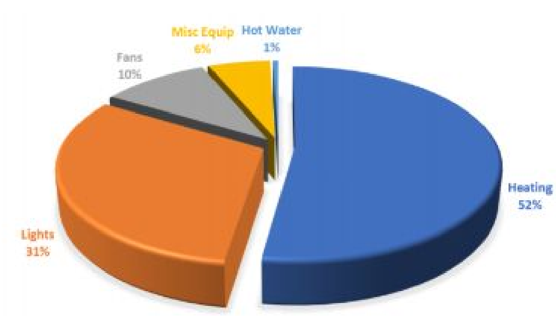


Figure 20: Example (using the Dominion City City Office) of the weighted energy use breakdowns provided in the Nativus Energy final report.

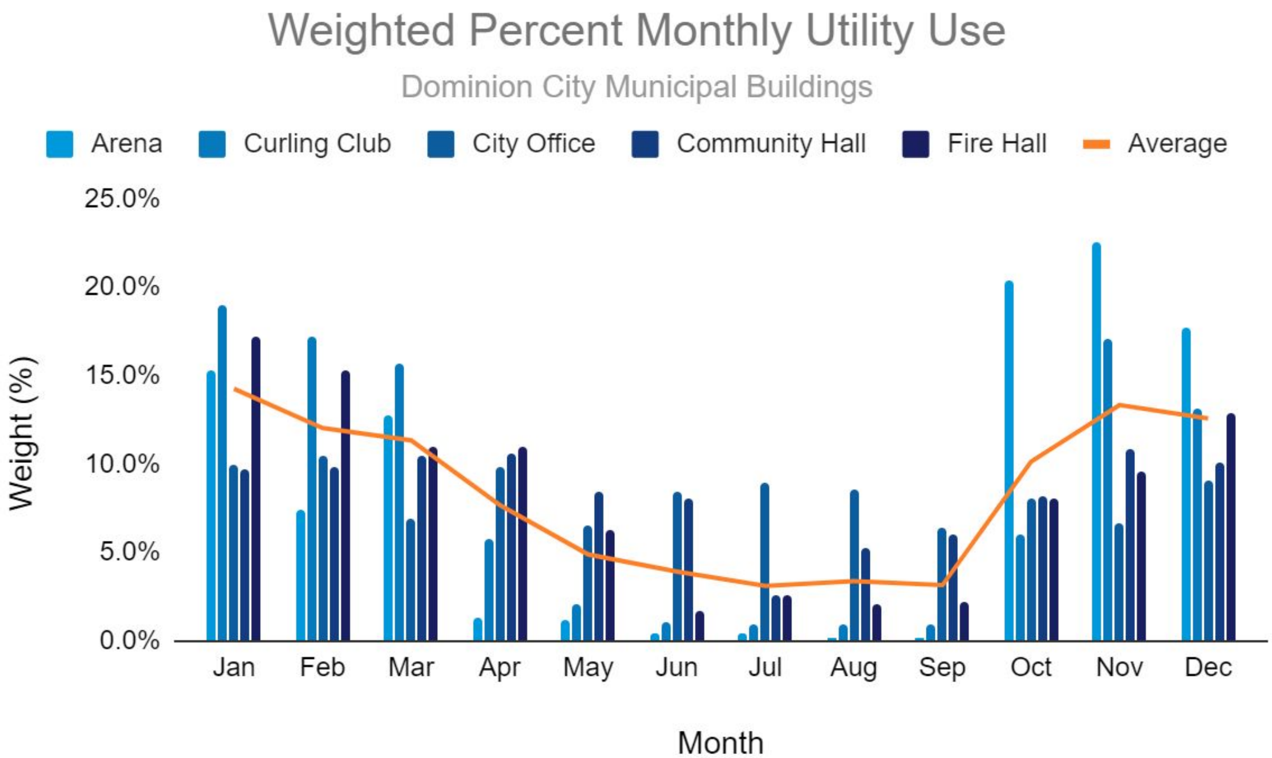


Figure 21: Average monthly heating use as weighted percent of total annual building energy consumption.

5.7 District Energy Design Process

The design of a district heat or heat and energy network layout involves a complex combination of decision variables that aim to minimize investment and operational costs while meeting the demand of the connected buildings (Vesterlund et al. 2017). The variables considered include network segment lengths, diameters and orientation in the community. Reducing the diameter and length of the pipe directly reduces the capital cost of the system (Martin-Du Pan et al. 2018; Chaurette 2003; Dalla Rosa et al. 2011; Boer 2018). The reduction also minimizes heat loss along the pipes reducing the fuel input requirements. The reduction of diameter, however, results in increased pumping requirements and therefore increased pump capital costs and electrical operational costs (Tommerup 2007).

The orientation of the network determines the length of the pipes required, the number of ninety and forty five degree turns in the layout and the extent of excavation. An increased number of turns, ninety degrees more significantly than forty five degrees, also contributes to increased pumping requirements (Wilson 2014). The layout is significantly dependent on existing infrastructure in the community. In order to minimize excavation costs, the networks avoid buildings, take the shortest path across roads and sidewalks and avoid crossing railways. The costs of excavation and infrastructure replacement increases drastically when excavating through sidewalks, roads and, most significantly, under railways.

There is also a significant non-monetary benefit to minimizing community activity disruption such as running lines across recreational fields and parks.

The Intelligent Energy Europe Programme (IEEP) (2013) quantified the cost efficiency of biomass energy based on the energy density of a community. The more energy that can be supplied by the district system per unit length of piping installed the better the investment case becomes for district energy. Because of the need for higher energy density, closely located, non-municipal buildings are included in the analysis of some district heat and district heat and energy configurations. **Figures 22** and **23** show the municipal and non-municipal buildings used in analysis. Buildings shown in navy are municipally operated. Those shown in light blue are non-municipal buildings considered in analysis. Orange buildings are other nearby buildings not considered in this analysis.

Figure 22: Municipal and non-municipal buildings in Dominion City considered in district heat and district CHP analysis.

Figure 23: Municipal and non-municipal buildings in Emerson considered in district heat and district CHP analysis.

Figure 24 shows an example configuration with some municipal and non-municipal buildings. The buildings are labelled with their energy footprint (W/m^2) - their energy demand relative to their size - and the load center of the network, indicated with a pink star. The gradient across the network visualizes the heat loss in transmission of the water from the power plant throughout the network of pipes (Vesterlund et al. 2013). Therefore, because of this heat loss effect in network transmission, the goal in designing a network is to locate the central power plant as close to this load center as possible. This ensures energy from the most demanding buildings is supplied as soon as possible to avoid significant energy loss in distribution.

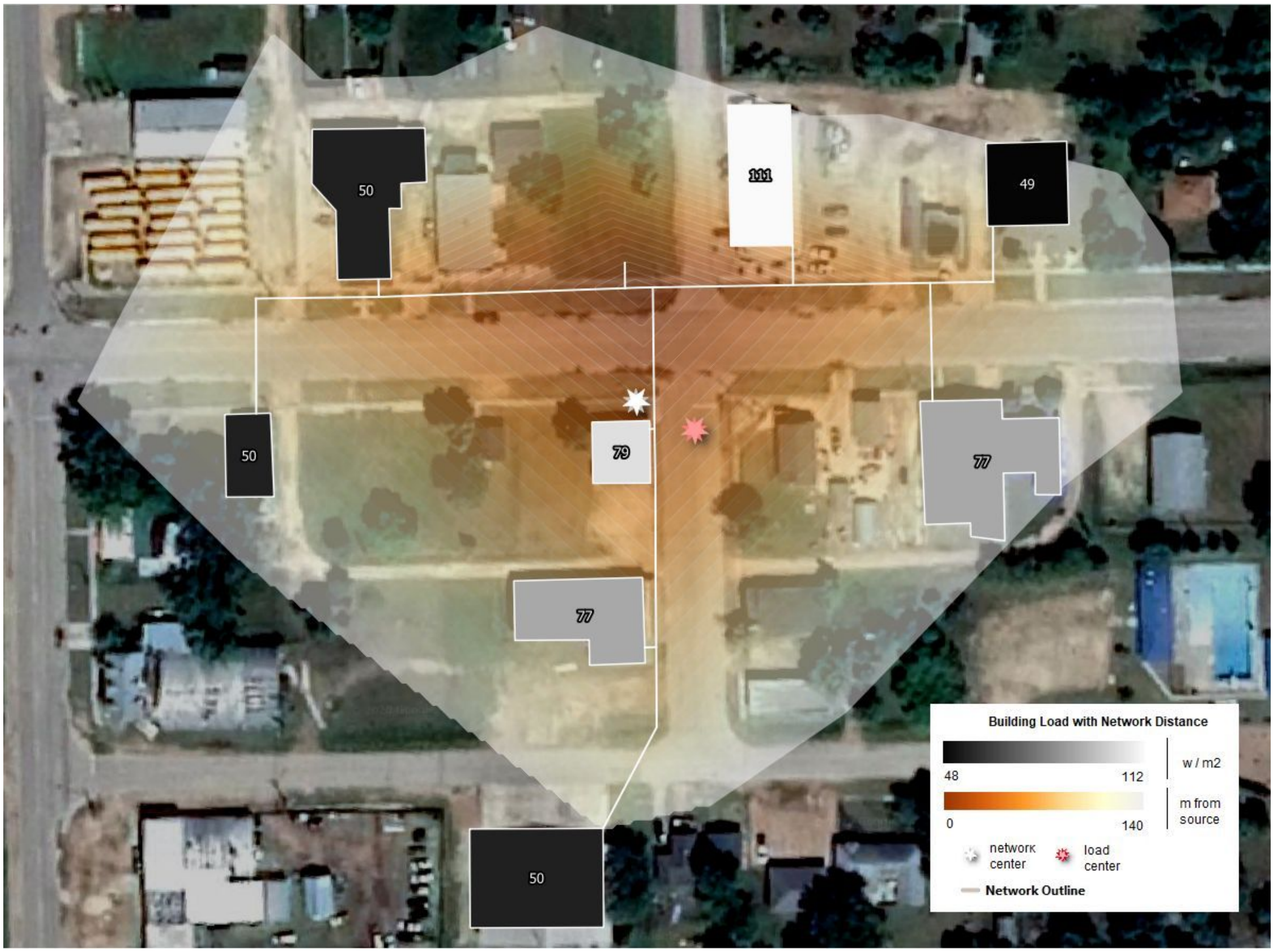


Figure 24: Dominion City network example with approximate energy footprint per building (W/m²) and the network load center.

5.8 Network Topology

Utilizing the design constraints outlined in the District Energy Design Process section, modern geospatial analysis is leveraged to define the network topology. This process is referred to as Integrated Community Energy Mapping (ICEM). ICEM provides a consistent methodology to assess energy use and emissions across different communities or building clusters. In 2016, Natural Resources Canada released a document titled *"Data Issues and Promising Practices for Integrated Community Energy Mapping"* which states the following about ICEM:

> *"Integrated community energy mapping (ICEM) is an emerging mapping and modelling approach that leverages existing and new datasets and available building and technology energy modelling software in combination with geographic information systems (GIS) to*

provide scalable spatial decision support to energy and emissions planning, policy, and program development, and their implementation and verification."

Network specific data is both stored in and determined using QGIS. The distribution network segment lengths are determined for each configuration option by the distance between the building polygons following the indicated constraints. OpenStreetMaps (OSM) and the Microsoft Open Database Commons *Canadian Building Footprints* are used as input geospatial data sources for the building polygons. QGIS also calculates the floor area of the buildings using the polygons. The number of storeys in each building is verified using Google Maps and Google Street View and adjusted in QGIS as necessary. **Figures 25** and **26** are examples of configurations in Emerson and Dominion City, respectively, with municipal and non-municipal buildings. The pipe segment lengths (m) and building footprints (m^2) are indicated on the figure. The network specific information from QGIS is used as input matrices in the energy modelling programs.

Figure 25: Example network configuration with building polygons in Emerson. Pipe lengths (shown in m) and building polygon area (shown in m^2) indicated for the configuration.

Figure 26: Example network configuration with building polygons in Dominion City. Pipe lengths (shown in m) and building polygon area (shown in m^2) indicated for the configuration.

5.9 Network Modelling

5.9.1 RETScreen

Two models are used for analyzing the feasibility of district energy networks in Dominion City and Emerson. The first model, RETScreen, is a "Clean Energy Management Software" developed by the Government of Canada to assess the feasibility of energy efficiency, renewable energy, or cogeneration projects (NRCan 2019). The model's Virtual Energy Analyzer considers the calorific value of a user defined biomass fuel or natural gas (GJ/t), building heated floor areas (m^2) and energy footprints (W/m^2), system efficiencies (%), a network configuration (m) and network design supply and return temperatures (℃). A calorific value of 14.855 GJ/t and supply and return temperatures of 90℃ and 60℃, respectively, are used consistently. The building sizes and energy footprints included in the asset review are used where available and others are determined using openly available data and QGIS. The lengths of the main and secondary network distribution lines output by QGIS are input for the specific network configuration options indicating the facilities they supply. Once entered, RETScreen immediately calculates the necessary pipe diameters to satisfy the building's requirements.

The diameters are calculated based on the flow rate of water that is necessary to provide the building with the heat energy it requires. **Equation 1** is used to determine the flowrate, *V,* in a pipe segment. It considers E_{pipe}, the required heating load carried by the pipe, ρ, the density of water, C_p, the specific heat of water, and ΔT, the difference between the supply and return water temperatures. **Table 13** lists the diameters associated with different resulting flow rates in millimeters (mm).

$$E_{pipe} = \rho V C_p \Delta T_{s-r} \quad (1)$$

Table 13: Maximum allowable flow rates for a selection of pipe sizes. Pipe Sizes are shown in millimeters (mm) - eg DN32 implies a diameter of 32 mm.

Pipe Size	Maximum Flow (m^3/h)
DN32	1.8
DN40	2.7
DN50	5.8
DN65	12.0
DN80	21.0
DN100	36.0
DN125	65.0
DN150	110.0

5.9.2 GNU Octave

The second model used in analysis is developed in GNU Octave - a free open source general programming language used for scientific and engineering applications. The model requires the input of network specific parameters and matrices. The matrices describe the network configuration, building heating fuel (natural gas or electricity), building operator (municipal or other customer), building energy footprints and square footage, heat and district hot water requirements and electricity requirements specific for each configuration. Further detail on the model is provided in the Technical Memo in **Appendix 9.3**. The pipe type for each network segment output by RETScreen are included in the network configuration matrix. Configurations could have one, some or all of the pipe types. **Table 14** lists the diameter for each classification of pipe type.

Table 14: Pipe diameter for each classification of pipe type.

Pipe Type	Diameter (mm)
Connection	32
Small Branch	40
Medium Branch	50
Mainline	65

Useful life of all systems are estimated as 20 years and an anticipated capital funding rate of 50% (to a maximum of $500,000) is set based on FCM funding opportunities (FCM 2020). Variable parameters are also required for each network configuration. Indication is required to specify if the network is powered by biomass fuel or natural gas, if the system is to supply heat or heat and energy and if income generated by the system is from only heat or heat and energy supplied to non-municipal customers.

System costs are considered either a one time cost grouped into Capital or an ongoing cost grouped into Operating. **Table 15** lists the categories of both Capital and Operating costs considered in the model. Income, indicated under operating costs, applies only to buildings on the network not operated by the municipality. Income is factored in for the amount of heat or heat and electricity demanded from these buildings at the rate of publicly available utilities.

Table 15: Capital and Operating cost categories in Octave.

Capital Costs	Operating Costs
Power Plant Building	Fuel Costs
Boiler	Trucking Costs (applies only to biomass systems)
Network Piping	System Electrical Requirements
Energy Transfer Stations	Operation and Maintenance Labour
Network Cabling	Income
Electricity Transfer Stations	
ORC or Solar	

The Octave model concludes by outputting the following figures for 2018 to 2048 based on projected public utility rates:

1. Annual Business as Usual (BAU) utility costs for Municipal buildings on the network
2. Annual costs associated with operating a network specific to the variable parameters and capital costs amortized over 20 years

3. Cash flows of system implementation - capital costs in year one, with annual revenues in the years following up until 2048

BAU costs consider the approximate replacement of existing hot water heaters, with an anticipated useful life of ten years, and in building boilers, with a useful life of 20 years (Lowes 2020; Furnaces Prices 2019). The systems are assumed to be brand new as of 2018 and therefore would not require replacement in the first ten years. The model also provides estimated BAU and new annual GHG emissions associated with heat or heat and electricity in tonnes of carbon dioxide equivalent (tCO_2e). The output data is exported to excel for investment analysis and to verify the optimal, climate resilient options.

5.10 Network Costing

5.10.1 Capital Costs

Capital costs are presented in analysis as pre-tax values. Equipment is assumed to have a project life of 20 years without any incremental investment required (Chesney 2016). The capital costs are categorized into Buildings, Boilers, Piping and Energy Transfer Stations for district heating systems with additional categories of ORC or Solar, Cabling and Electricity Transfer Stations for CHP systems.

Building prices are determined based on the size of building required to house the necessary systems. Natural gas powered systems are estimated to require a 16’ x 22’ building with 12’ ceiling height. Biomass powered heating systems are sized to 16’ x 22’ with 12’ ceilings for systems below 176 kW. Larger heating systems are sized at 20’ x 92’ with 18’ ceilings to accomodate a 50’ two wing walking floor (Lyall Wiebe, Triple Green Products, personal communication, 11 March 2020). Biomass CHP systems are minimally upsized by 25 square feet to accommodate additional equipment. Per square foot prices are based on the Atlus Group’s Canadian Cost Guide (2018) and, where applicable, an additional $15/square foot for a specialized concrete floor (Lyall Wiebe, Triple Green Products, personal communication, 11 March 2020).

Boiler costing includes equipment and installation, controls, piping connections, pumps and, for biomass boilers only, a chimney, fuel storage and automated walking floor (CEA 2014; Lyall Wiebe, Triple Green Products, personal communication, 11 March 2020). **Figures 27** and **28** show an example of a biomass boiler and a walking floor feeding biomass into a boiler, both produced by Triple Green Products. Natural gas and biomass boilers are sized to 110% of peak capacity. Backup for the district system is provided by the building level heating systems that are currently in place. Prices are estimated based on Triple Green Product quote estimates, community installations in British Columbia and RETScreen’s per kW price approximation from various biomass and natural gas system providers (CEA 2013; CEA 2014; BC Rural Centre; NRCan 2005).

Figure 27: Walking floor moving biomass feed into augers feeding a biomass heating system (TGF 2020).

Figure 28: Installed biomass boiler available from Triple Green Products (TGF 2020).

Network piping costs include the materials for supply and return lines, excavation and restoration of the pathway, pipe connections, inspection and testing and initial flushing prior to operation. The costing method is a per linear meter approximation for installation in an urban area (CEA 2014; NRCan 2005; REHAU 2016). **Figure 29** shows an installation of flexible, insulated district heating lines.

Figure 29: Flexible PEX district heating pipe being installed below ground (REHAU 2018).

Energy transfer stations include pre-fabricated heat exchangers for space heat and DHW, a control system, internal piping and necessary valves (CEA 2014). Energy transfer stations are required at every building and are priced based on the kW demand load of the individual building with a minimum cost of $5000 for buildings with 10000 kW demand or less. Energy transfer stations are intended to connect the district energy system to the building's existing space distribution system and DHW system. Slight variations are required between connections to existing forced air, steam or water systems. The energy transfer stations bypass the existing units in place in each building with the control ability to switch back to the existing system if needed. This allows for full redundancy in the heat supply mechanisms.

For district CHP systems, ORC pricing includes the ORC equipment and installation, piping connections to the unit and heat recovery components off the ORC (ElectraTherm 2020). Because the unit does require very minimal electrical power, a 3-day backup diesel generator for emergency use is considered in the price. Pricing is based on per kW demand requirement of the network sized to meet 100% of peak demand. Solar Photovoltaics (PV) panels are priced at the high estimate for panels, transport and installation in Manitoba (energyhub 2019). The number of panels implemented in a system is based on the available south facing roof space of the power plant building specific to the network at a 35 degree pitch (Matasci 2018). Cabling prices for ORC or solar includes the materials and installation and are based on per meter installation along the same path as the water distribution pipes (Blackstone 2019). Therefore, excavation and restoration is not included in the cabling costs. Electricity transfer stations are required at each building on the district CHP network and include the cost for labour to connect each building (Home Guide 2020). The estimate is based on a per kW rate.

Not included in the capital cost estimations are the costs associated with the following:

- Land acquisition, easements or rezoning required for the proposed power plant location
- Geotechnical analysis of the power plant building site
- Connections to public utilities (natural gas and/or electricity) at the power plant site
- Initial water volume for the thermal fluid in the network
- Crane rental for unloading systems at the power plant site
- Environmental permitting application costs
- Locating, relocating or removing any below grade features interfering with the piping network

5.10.2 Operating Costs

Operating costs for district heat and district CHP are calculated based on the fuel input. Natural gas fuel is assumed to have no additional operating and maintenance costs. The BAU operations and maintenance (O&M) costs for heating and hot water operations in the municipal buildings is estimated at $25/hour for one hour every week. Biomass heating systems are considered to require two hours every week and biomass CHP systems require three hours per week at the same rate.

The second component of operating costs is fuel. Biomass fuel costs are based on the BAU demand loads of the buildings and heat losses in the system with an additional 10% contingency added (Martin-Du Pan et al. 2018). The price of biomass fuel is set at $40/t. The biomass fuel cost also includes the costs associated with transportation. Transportation is estimated based on the distance of travel to the urban area from Emerson Milling and dump truck rental, fuel costs and labour approximations from Manitoba Agriculture Machinery Rental Rates (EIA 2016; Manitoba Agriculture 2020). Natural gas is priced based on projected public utility rates.

The third component is the income generated per year from supplying utilities to other local customers. Income is either not included, included for heat supplied at natural gas rates or included for heat at natural gas rates and electricity at public electricity rates. Costs are calculated based on demanded heat or electricity from non-municipal buildings at the rate of public utilities.

5.10.3 Uncertainties

Capital and operating cost estimates are based on quotations from local companies, similar community-based system installations and RETScreen, Natural Resources Canada's Clean Energy Management Software, pricing database. More accurate estimations can only be generated during engineering design and final product sourcing.

5.11 GHG Emissions

Greenhouse gas emissions (GHG) for the BAU cases include the emissions associated with Manitoba Hydro Electricity and Natural Gas consumed per year. Usage is determined based on the monthly Manitoba Hydro bills provided by the municipality. Conversion factors for Manitoba from the National Inventory Report Parts Two and Three (2015) are used with Canada's 4th assessment Global Warming Potential (GWP) figures to calculate a value for the tonnes of carbon dioxide equivalent (tCO_2e). The figures used are summarized in **Table 16**.

Table 16: Emission and GWP factors used to calculate GHG emissions in tCO_2e.

	CO_2		CH_4		N2O	
	Factor (g CO_2/unit)	GWP	Factor (g CH_4/unit)	GWP	Factor (g N_2O/unit)	GWP
Electricity (kWh)	3.3	1	0.0003	25	0.0001	298
Natural Gas (m^3)	1886		0.037		0.035	
Diesel (L)	2681		0.14		0.082	

District heat or CHP emissions powered by natural gas use the same emission factors to determine the new approximate GHG emissions associated with district operations. Biomass fuel is considered to have no emissions associated with combustion, however, emissions associated with transport of fuel via a diesel operated vehicle are considered. The emission factors for diesel are also included in the above table.

5.12 Investment Analysis

Investment analysis is conducted using the same base and projected utility rates as were used for assessing the energy efficiency upgrade options. Base electricity and natural gas prices are at 2018 rates, \$0.11/kWh and \$0.29/m3. Electricity rate increases are based on a 5.63% increase per year (Manitoba Hydro 2019). Natural gas rates are based on the Provincial flat rate carbon tax at \$25/t and predicted Henry Hub natural gas rate increases (AER 2019; and Sustainable Development 2017). The two projections are shown in **Figure 30** as a time series over the 30 year analysis period.

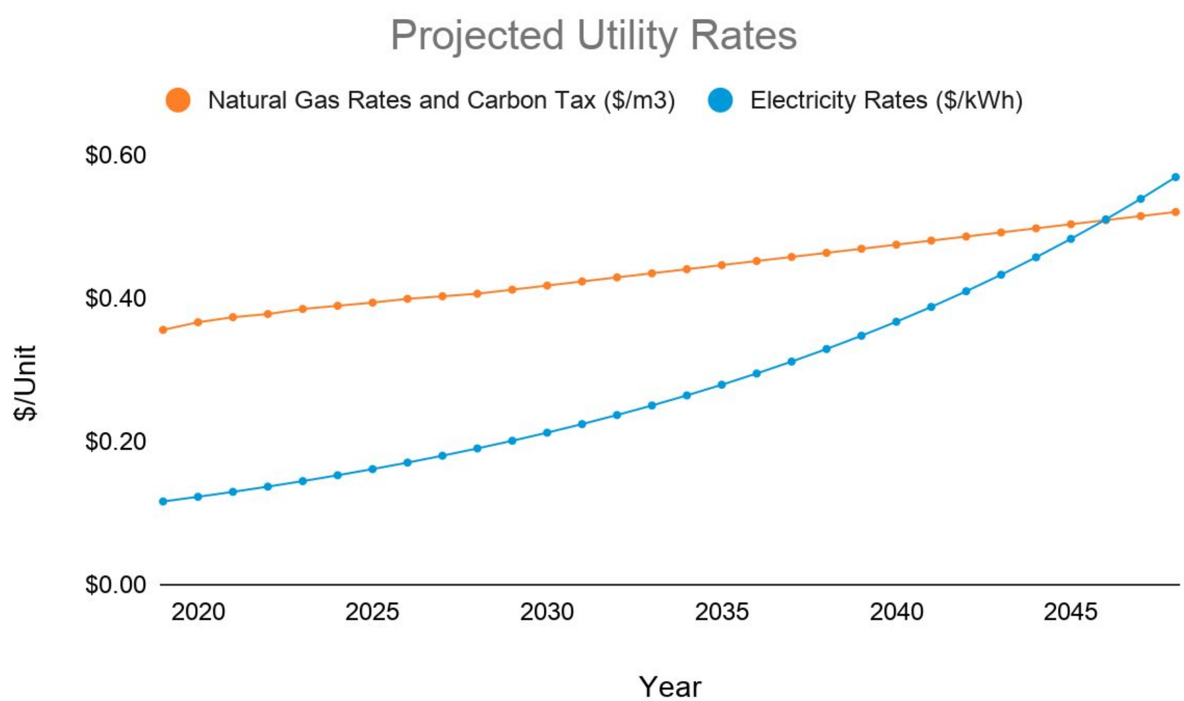


Figure 30: Projected natural gas and electricity rates from 2018 base rates over the 30 year study period.

There are many key indicators used in the final investment analysis to determine the recommended system configurations. Once a system is deemed feasible based on its earliest recommended implementation year, calculations become based on the 20 year period following the earliest recommended implementation year. This is referred to as the 'post-installation' period. Revenue during this period is calculated as the difference between the BAU costs per year and the new projected operating costs per year. **Figure 31** shows an example of the three cost schedules and the difference of annual costs, referred to as the revenue, for a biomass district CHP system. The BAU annual costs and new annual costs are shown both as negative stepped areas. The capital cost investment in year one is shown as a negative, single cash flow and, the difference between the BAU and new annual costs, is shown as the positive revenue. This revenue over the 20 year useful life period is compared to the capital costs of the system installation as the net present value (NPV) to determine the net ROI and the net benefit-cost ratio (nBCR).

Figure 32 shows a comparison of the same system's NPV of revenues during the 20 year post-installation period versus the initial capital costs of the system. This example, when considered at the earliest possible implementation year, has an ROI of 52% and nBCR of 1.52. An ROI greater than 0% and a nBCR value greater than one is considered to be a smart investment because the benefits of the investment outweigh the costs.

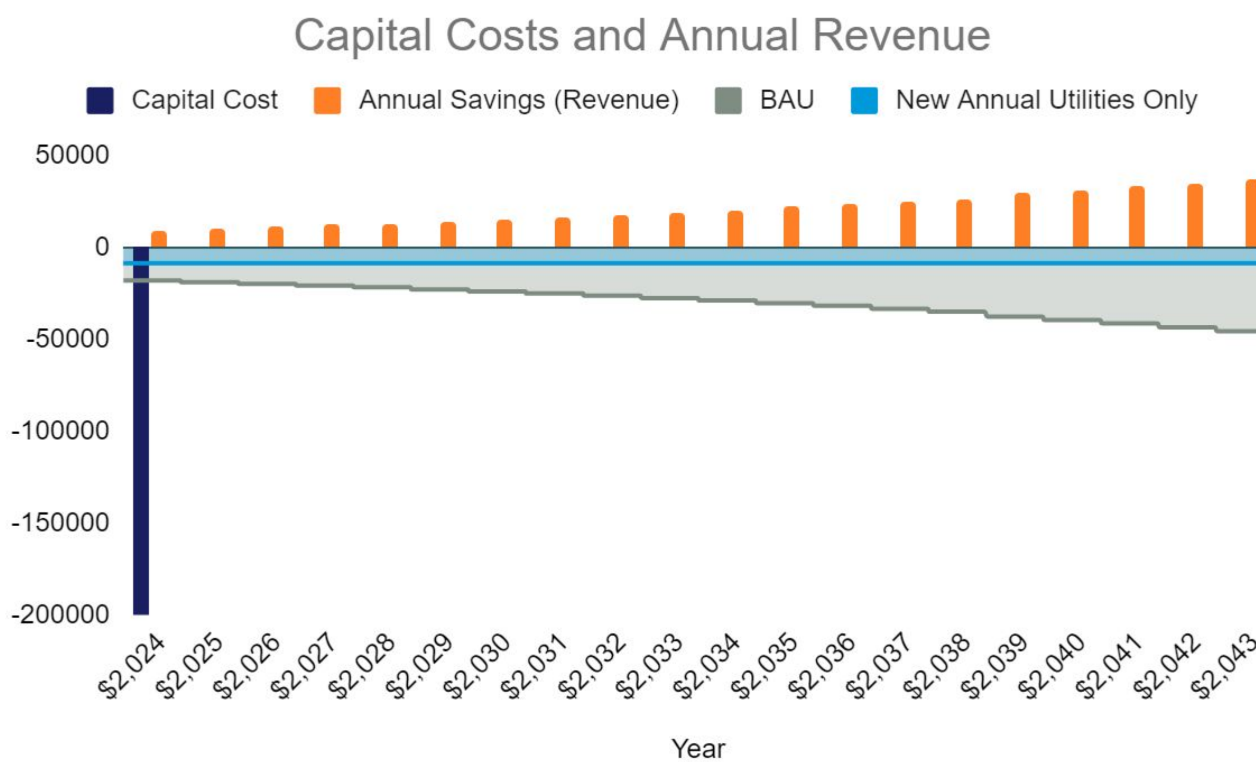


Figure 31: Capital cost (dark blue) is shown in year one. Revenue or Annual Savings (orange) is shown over the 20 year useful life. Revenue or Annual Savings (orange) is calculated as the difference between BAU (grey) and new Annual Utilities (light blue).

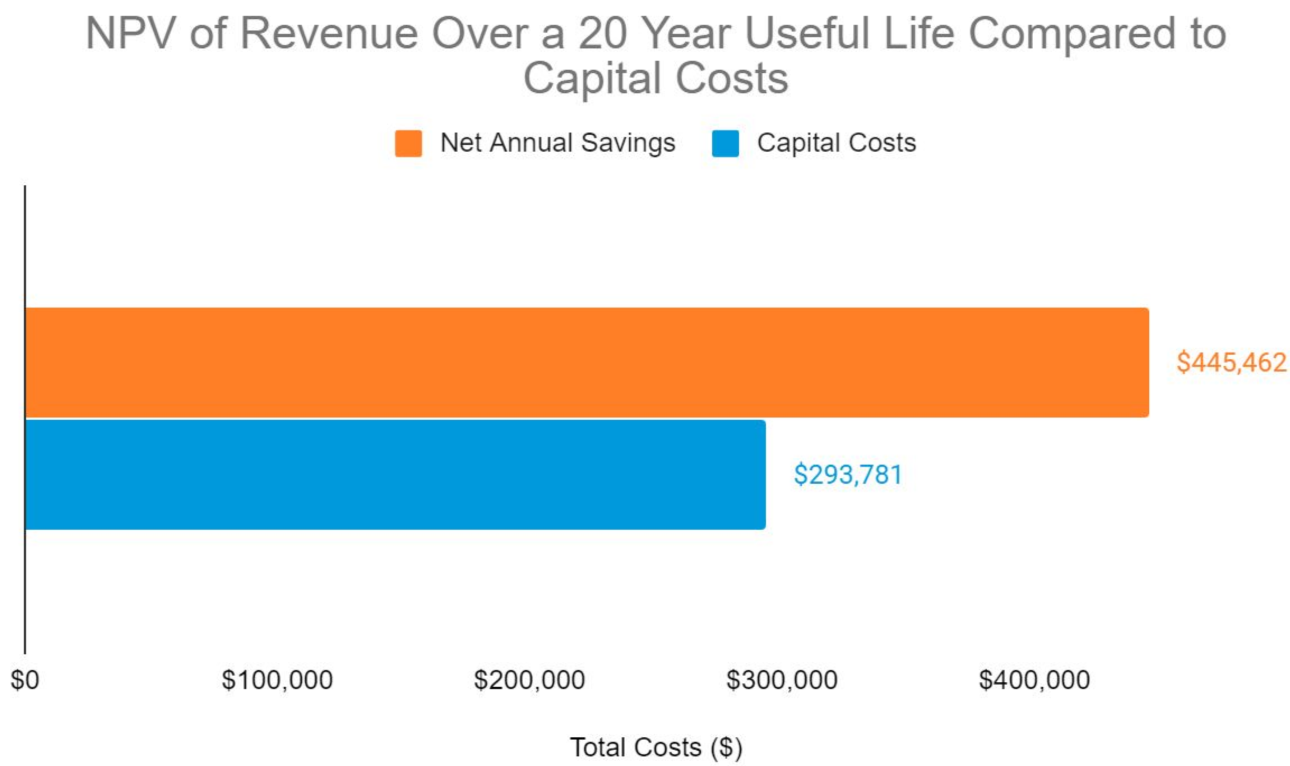


Figure 32: The NPV of the Revenue or Annual Savings over the 20 year useful life of a system compared to the initial capital costs in year one.

6 District Energy Options Analysis

6.1 Network Layouts

Nine network configurations, four for Dominion City, four for Emerson and one for the Public Works Yard, are evaluated in this study. Central power plant locations are assumed for each urban area and kept consistent for the different configurations. The size of the power plant however, is varied in capital cost calculations based on the required system size. Half of the configurations included only municipal operated buildings. The other half included additional non-municipal buildings in the community. These additional buildings were included to investigate the potential of increased energy density of the systems. The community pools in both urban areas are not included in the configurations because of their low energy requirements and proximity to other buildings. Additionally, the Dominion City Public Works Yard is excluded from the Dominion City configurations due to its proximity to the other buildings. Because there are multiple buildings as part of the Public Works Yard, a configuration is also evaluated for a separate, small-scale district system.

The configurations for Dominion City are shown in **Figure 33.** The first configuration, labelled "A", is referred to as the Central Municipal network. This network includes a subset of Municipal operated buildings. Configuration "B" is the Extended Municipal network and it includes all of the Municipal buildings investigated in the district systems. Configurations "C" and "D" include both Municipal and other buildings and are referred to as the Central Municipal and Other network and the Extended Municipal and Other network, respectively.

In Emerson (**Figure 34**), configurations "A" and "B", consistent with Dominion City, are referred to as the Central Municipal and Extended Municipal networks, respectively. Configuration "C" for Emerson is referred to as the Extended Municipal and Other network. Lastly, configuration "D" is the Extended Municipal and Extended Other network. The one configuration for the Public Works Yard in **Figure 35** includes the four large buildings on the property and is not referred to by any specific name.

Figure 33: Dominion City Network Configurations (OSM; MICROSOFT).

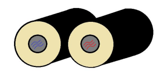
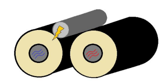
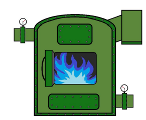
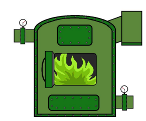
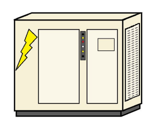
Figure 34: Emerson Network Configurations (OSM; MICROSOFT).

Figure 35: Dominion City Public Works Yard Configuration (OSM; MICROSOFT).

6.2 Key System Features

Each configuration is assessed for feasibility in a total of 40 configurations per urban area, eight for the Public Works Yard. **Table 17** summarizes the key system features varied in each network configuration. District heat and district heat and energy systems are assessed for four network configurations in each urban area plus one configuration for the Public Works Yard. Fuel inputs for heat are varied between natural gas and biomass fuel. District heat and energy, also commonly referred to as Combined Heat and Power (CHP), is also assessed for these configurations with the same heating fuel variants and additional variants for electricity supply. Electricity is from either an Organic Rankine Cycle (ORC) or a solar photovoltaic (PV) array. In configurations with ORC, the system is sized to supplement all Manitoba Hydro electricity for the buildings on the network. Solar PV however, is assessed to supplement only a portion of electricity based on the available space on the power plant rooftop. District heating configurations with electricity infrastructure but no electricity generation system are also considered with the intent of planning for further future development. In configurations with other buildings not operated by the municipality, income generation is modelled from the fuel demanded by these buildings. The income structure is based on either the amount of heat or the amount of heat and electricity provided to these other buildings at the rate of public utilities.

Table 17: Variable model input parameters.

Parameter	Variant	Description	Iconification
Network Type	District Heat	Piping carrying water as the heating medium to municipal buildings or municipal and other buildings.	
	District Heat with Electricity Infrastructure	Piping carrying water as the heating medium to municipal buildings or municipal and other buildings. Conduit with wiring for district power to municipal buildings or municipal and other buildings.	
Space Heat and District Hot Water (DHW)	Natural Gas	Central natural gas fueled boiler sized to 110% of network capacity. Natural gas supplied by public utilities.	
	Biomass	Central biomass fueled boiler sized to 110% of network capacity. Biomass fed via a walking floor system.	
Electricity	Organic Rankine Cycle (ORC)	ORC powered by the heating system sized to supply 100% of demanded electricity. Very minimal operating power to ORC supplied by public utilities.	
	Solar Photovoltaics (PV)	Solar PV panels supplement power to the extent space on the south face of the proposed power plant roof is available.	
Income	Income from heat demanded	In configurations with non-municipal operated buildings, income is considered for the amount of heat demanded by these customers.	
	Income from heat and electricity*** demanded	In configurations with non-municipal operated buildings, income is considered for the amount of heat and electricity demanded by these customers.	

**** In Manitoba, the currency policy context indicates electricity cannot be sold, however, we predict this is likely to come under some scrutiny with increased interest in renewable and micro-grid technologies. In the interim an alternative billing structure could be investigated.*

Considering the four network configurations per urban area, one for the Public Works Yard and the key system features indicated in **Table 17**, 88 total scenarios are modelled and analyzed.

6.3 Summary Assessment of Network Configurations

The 88 total modelled network configuration scenarios are first screened for implementation years sooner than 2030 based on a long term payback horizon. The resulting configurations are all assessed based on the following investment decision criteria:

1. ROI > 0%
2. nBCR > 1.0
3. Simple Payback Period < 20 Years

Investment decision analysis has historically focused only on these criteria. With the rise of sustainability as a decision-making principle, however, project criteria is being expanded. For the purposes of this analysis, GHG mitigation potential, climate vulnerability and “future-proofing”, summarized as Climate Resilience, are included as criteria. GHG mitigation is indicated as the potential tonnes of CO_2e per year that could be avoided by the system. Climate Resilience is a qualitative assessment of ‘future-proofing’, planning for the future, and reduction of vulnerability from foregin fossil fuel market, uncertain carbon pricing and aging public utility infrastructure dependencies. It is converted to a quantitative figure on a scale from 1 to 10, where 1 is the least resilient and 10 is the most resilient. Additionally, because district energy is often considered cost prohibitive, the capital cost of a project is also included in analysis criteria.

The network layouts in each urban area that result with the ‘*best*’ criteria for the most combinations of system features are chosen for further detailed analysis. The following sections provide details on the resulting feasible configurations for the two *best* network layouts in each urban area. Detailing the variation in system parameters and layouts exemplifies their sensitivity on the analysis criteria. Other configurations that are considered feasible but are not detailed in the following sections are summarized in tables in **Appendix 9.2**.

6.3.1 Dominion City - Configuration Assessment

The two network configurations with the best resulting analysis criteria for the most combination of system features in Dominion City are the Central Municipal network (“A” in **Figure 33**) and the Central Municipal and Other Network (“C” in **Figure 33**). The networks include a proposed central power plant and three Municipal operated buildings. The Central Municipal and Other network additionally includes five central buildings currently operating independent of the Municipality.

Eight system combinations for the Central Municipal (shown in **Figure 36**) network are outlined for their respective earliest implementation year for nBCR ≥ 1.5 in **Table 18**. There are four district heating systems outlined: two are for complete natural gas and biomass district heating systems and the other two are natural gas and biomass district heating systems with preliminary infrastructure, referred to as cabling, for district energy. The infrastructure for district energy is the cabling, run in with the district heat pipes, and the in building, electricity transfer infrastructure. These systems capitalize on the investment in excavation that is part of the district heating installation but do not require such substantive capital investment. Future phases can later connect to the installed cabling lines to expand the system from district heat to district CHP without needing to again invest in excavation. They also consider power plant building requirements in order to suit a later phase of development to a district energy system. The other four scenarios are for district heat and energy systems with ORC or solar PV. Both ORC and solar PV are outlined for use in combination with a natural gas boiler and a biomass boiler. The size of the solar system and the amount of electricity it can supplement is restricted to the available space on the rooftop of the analyzed central power plant.

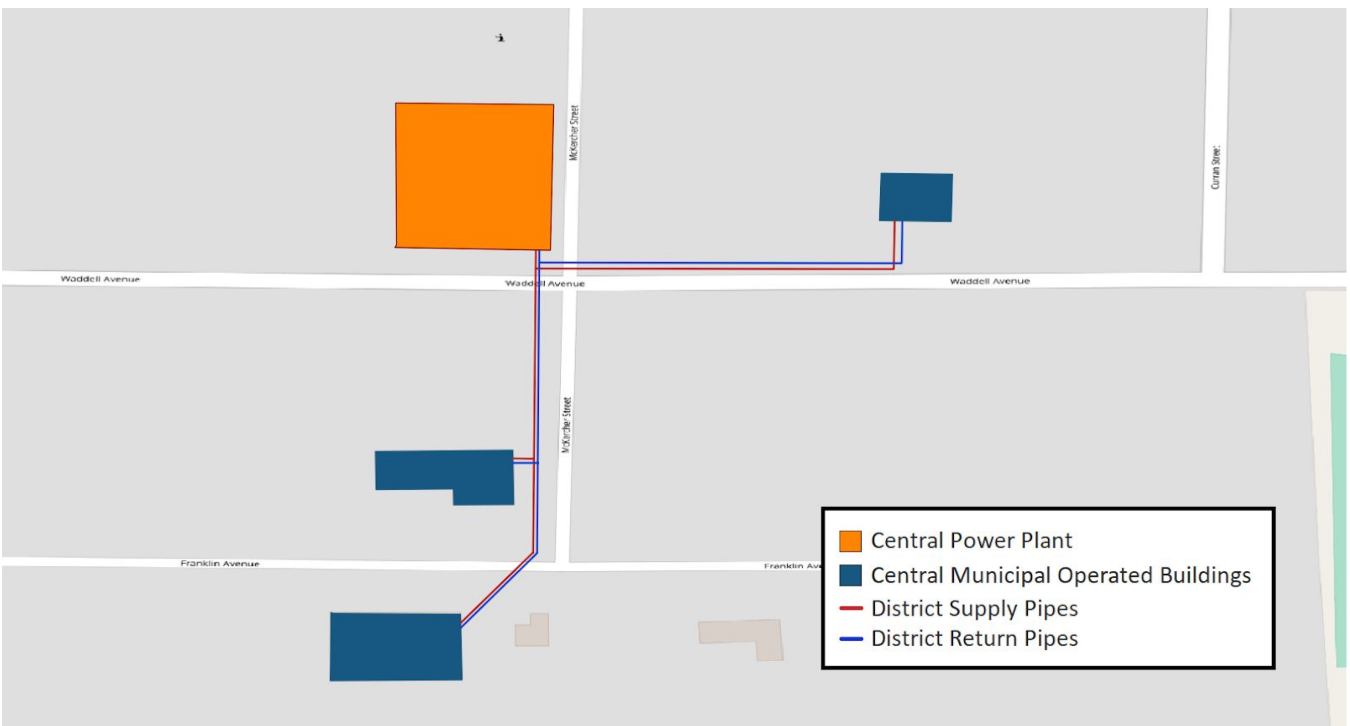


Figure 36: Dominion City Central Municipal network including the RM Office, the Community Hall and the Dominion City Fire Hall.

Table 18: Central Municipal network system configuration analysis criteria. Each of the system configurations are displayed with iconification of the technology the system includes - "Key Design Features".

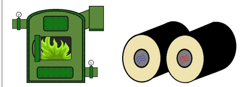
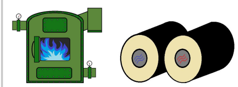
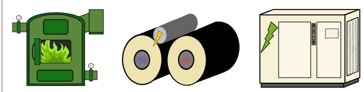
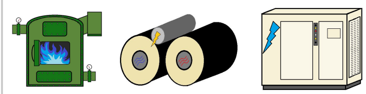
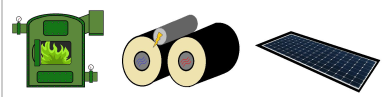
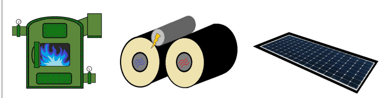
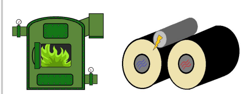
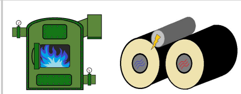
Central Municipal Network	Year nBCR >= 1.5	20 Year ROI	20 Year nBCR	Simple Payback	Capital Cost	System GHG (tCO2e/ year)	Resilience Score	Key Design Features
Natural Gas District Heat	2023	53%	1.53	16	$103,687	-20.5	1	
Biomass District Heat	2022	60%	1.60	16	$135,203	14.1	3	
Natural Gas District CHP with ORC	2023	53%	1.53	16	$255,160	-36.1	4	
Biomass District CHP with ORC	2022	52%	1.52	16	$293,781	14.2	8	
Natural Gas District CHP with Solar	2024	51%	1.51	16	$118,951	-24.3	3	
Biomass District CHP with Solar	2025	54%	1.54	16	$161,635	14.1	5	
Natural Gas District Heat with Cabling	2025	62%	1.62	16	$115,627	-20.5	2	
Biomass District Heat with Cabling	2024	58%	1.58	16	$156,281	14.1	4	

Table 19 outlines the five system combinations for the Central Municipal and Other (shown in **Figure 37**) network for their respective earliest implementation year for nBCR ≥ 1.5. There are two biomass district heating systems outlined: one for complete biomass district heating and the other a biomass district heating system with cabling for district energy. The other three scenarios are for biomass district heat and energy systems with ORC and solar PV and a natural gas district CHP system with ORC. The income structure from the non-municipal operated buildings is for heat only for the district heating configurations and for heat and electricity for the CHP configurations.

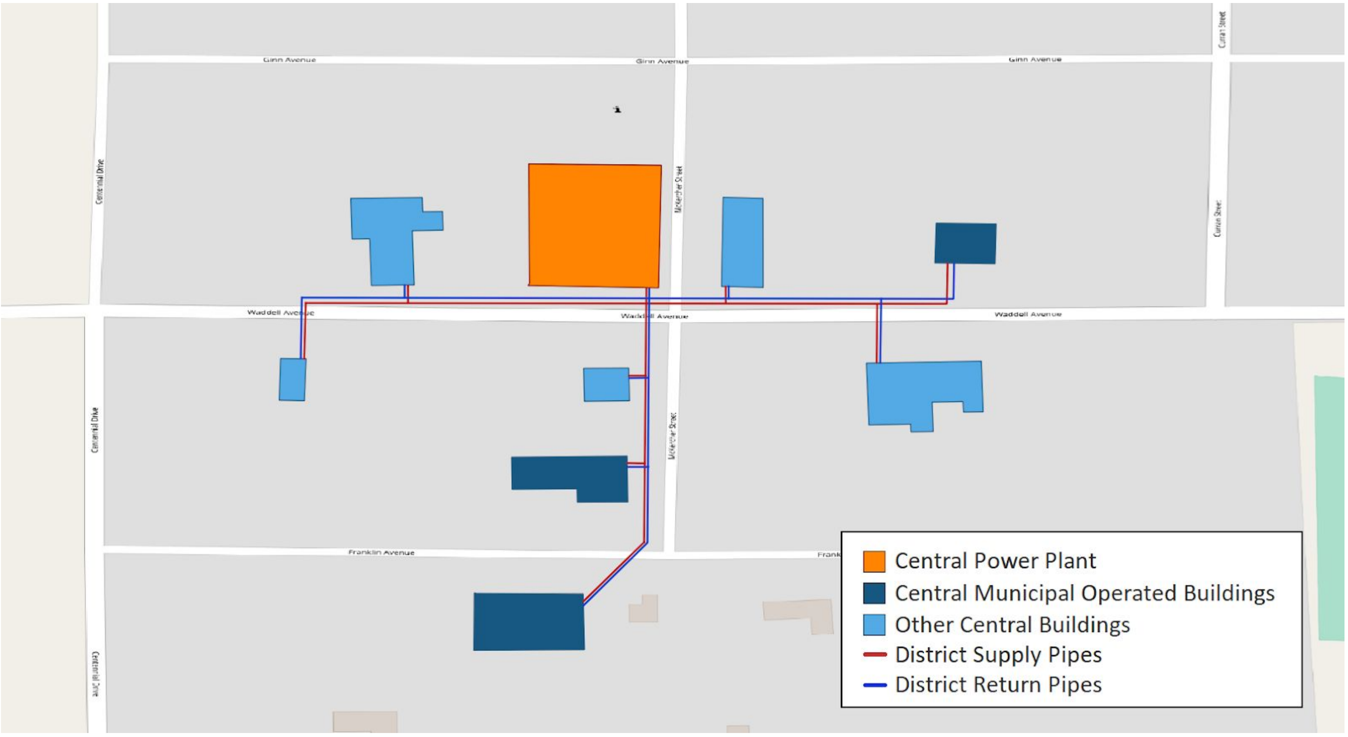
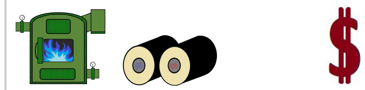
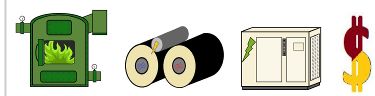
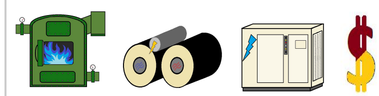
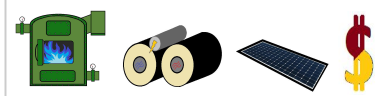
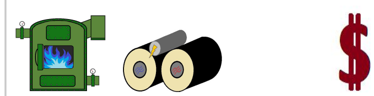


Figure 37: Central Municipal and Other network including the RM Office, the Community Hall, the Dominion City Fire Hall and five other centrally located buildings.

Table 19: Central Municipal and Other network system configuration analysis criteria. Each of the system configurations are displayed with iconification of the technology the system includes - "Key Design Features".

Central Municipal and Other Network	Year nBCR >= 1.5	20 Year ROI	20 Year nBCR	Simple Payback	Capital Cost	System GHG (tCO2e/ year)	Resilience Score	Key Design Features
Biomass District Heat - Income from Heat	2024	57%	1.57	16	$178,604	42.8	3	
Natural Gas District CHP with ORC - Income from Heat and Electricity	2020	86%	1.86	16	$347,263	-79.1	4	
Biomass District CHP with ORC - Income from Heat and Electricity	2020	50%	1.50	16	$608,961	43.2	8	
Biomass District CHP with Solar - Income from Heat and Electricity	2030	51%	1.51	15	$238,370	42.7	5	
Biomass District Heat with Cabling - Income from Heat	2030	56%	1.56	15	$233,016	42.8	4	

6.3.2 Public Works Yard - Configuration Assessment

The one network layout for the Dominion City Public Works Yard was assessed for eight varied network configurations. Considering a long term payback horizon, none of the eight configurations had a recommended implementation year before 2030. The best of the configuration options was Biomass District Heating which resulted in an nBCR of 1.1 for implementation in 2030, however, this is not recommended and not deemed feasible in this options analysis.

6.3.3 Emerson - Configuration Assessment

The Extended Municipal ("B" in **Figure 34**) and Extended Municipal and Other ("C" in **Figure 34**) networks in Emerson resulted in network configurations with the best analysis criteria. The networks include a proposed central power plant and four Municipal operated buildings. The Extended Municipal and Other network additionally includes four central buildings currently operating independent of the Municipality. The lower energy density, or more distributed spatial proximity of buildings, in Emerson results in successful investment analysis only when both heat and power are supplemented on the network.

The two system combinations for both networks (Extended Municipal shown in **Figure 38** and Extended Municipal and Other shown in **Figure 39**) are district CHP systems with ORC. One is fueled by natural gas and the other by biomass. They are outlined for their respective earliest implementation years for nBCR ≥ 1.5 in **Tables 20** and **21**. The Extended Municipal and Other network also includes income from heat and electricity to the non-municipal buildings on the network.

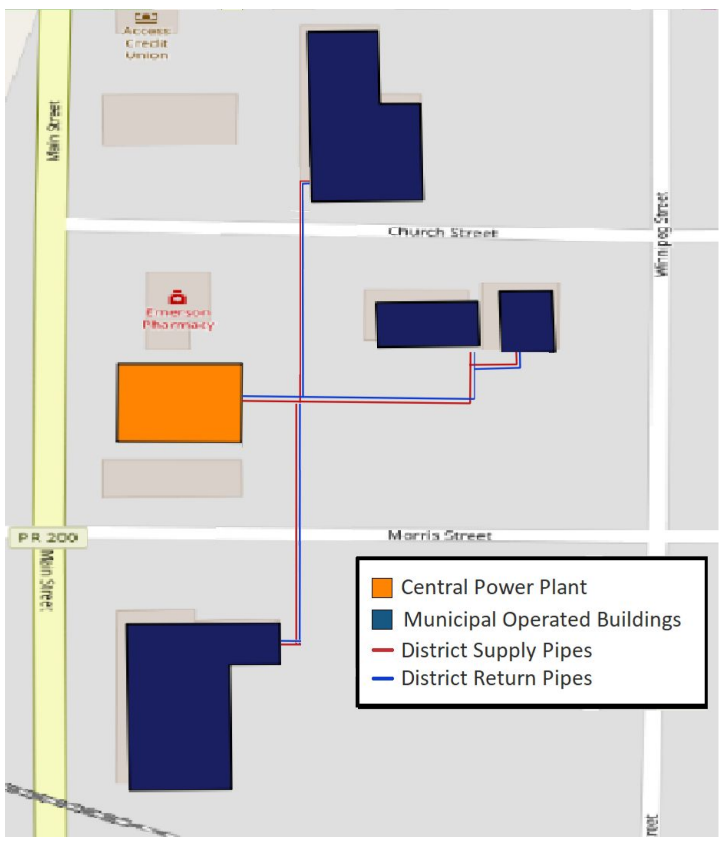
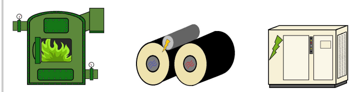
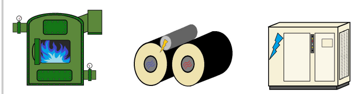


Figure 38: Emerson Extended Municipal network including the Arena (not rink area), the Recreation Complex, Emerson Fire Hall and the Town Hall.

Table 20: Extended Municipal network system configuration analysis criteria. Each of the system configurations are displayed with iconification of the technology the system includes - "Key Design Features".

Extended Municipal Network	Year nBCR >= 1.5	20 Year ROI	20 Year nBCR	Simple Payback	Capital Cost	System GHG (tCO2e/ year)	Resilience Score	Key Design Features
Natural Gas District CHP with ORC	2,020	103%	2.03	15	$300,341	-74.4	4	
Biomass District CHP with ORC	2,025	163%	2.63	12	$509,922	96.8	8	

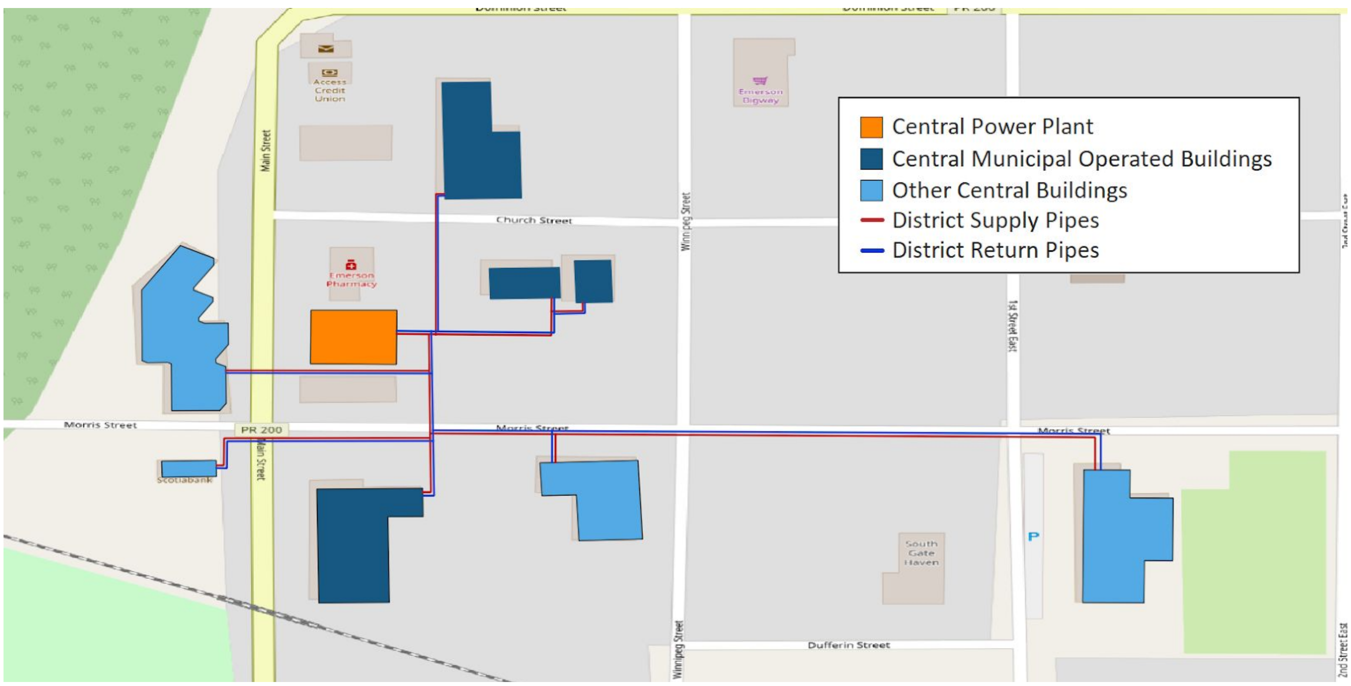
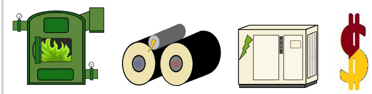
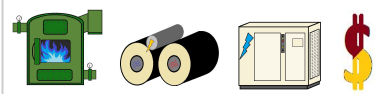


Figure 39: Emerson Extended Municipal and Other network including the Arena (not rink area), the Recreation Complex, Emerson Fire Hall, the Town Hall and four other centrally located buildings.

Table 21: Extended Municipal network system configuration analysis criteria. Each of the system configurations are displayed with iconification of the technology the system includes - "Key Design Features".

Extended Municipal and Other Network	Year nBCR >= 1.5	20 Year ROI	20 Year nBCR	Simple Payback	Capital Cost	System GHG (tCO2e/ year)	Resilience Score	Key Design Features
Natural Gas District CHP with ORC - Income from Heat and Electricity	2,020	82%	1.82	16	$675,375	-176.0	4	
Biomass District CHP with ORC - Income from Heat and Electricity	2,020	105%	2.05	14	$1,055,539	198.8	8	

7 Conclusions

Canada's 2030 Agenda National Strategy (2019) acknowledges that "*swift action is needed to reduce greenhouse gases, improve climate resilience and protect our natural environment*" and Manitoba is striving to be "*Canada's cleanest, greenest and most climate resilient province*" (Sustainable Development 2017). Sustainable Development reported in the Made-In-Manitoba Climate and Green Plan (2017) that building and water heat accounts for one third of energy use and "*the majority of emissions attributed to the operations of buildings*." In order to mitigate this component of emissions, improve resilience and reach these goals, communities, governments, businesses and individuals must begin to follow climate resilient planning pathways.

A climate resilience planning pathway is a multi-step process used to conduct an options analysis for, in this case, energy system alternatives. The pathway involves analysis of the current operational state, assessment of measures to drive down total energy demand (energy efficiency upgrades) and evaluation of renewable and community-based energy options. Based on the determined least cost portfolio of proven energy efficiency options and feasible district configurations, implementation is the final step in the pathway.

Energy efficiency upgrades can be simple to install and manage and generally inexpensive. The recommended upgrades can reduce Municipal utility costs associated with operations and GHG emissions. The trajectory of utilities, however, are still projected to rise with rising public utility rates, despite the reduction in total demanded energy. In order to change the trajectory of Municipal utility costs, a transition in energy source and distribution is recommended.

District community-based renewable heat and renewable heat and energy systems capitalize on local resources and provide opportunities for rural social and economic development. Utilizing local resources increases vertical integration of the energy supply chain stabilizing the trajectory of future utility costs. With rising concern of climate-related risks threatening aging Manitoba Hydro infrastructure, instability in foreign fossil-fuel markets and rising public utility rates, district energy systems are the key to economic, social and community sustainability. Manitoba's current policy context disallows the sale of generated electricity, therefore district heating systems are the primary district system recommendation with infrastructure to support future development to district combined heat and power. While energy efficiencies are good for reducing demanded energy, moving towards a biomass fueled community-based heating system will create significant change in annual utility costs and GHG emissions.

7.1 Recommended Efficiency Improvements

The recommended efficiency upgrades in each urban area are listed in **Tables 22** and **23**. The options are sorted from lowest to highest annual amortized cost over the useful life of the upgrade. The potential reduction in annual utilities (at 2018 rates) and overall percent efficiency improvement are also indicated for each recommended upgrade. The resulting cumulative efficiency improvement (the percent reduction in total grid energy consumption) in Dominion City and Emerson, considering all recommended upgrades, is 22% and 13%, respectively. This equates to 576 GJ of grid energy reduced in Dominion City and 437 GJ in Emerson.

The resulting ten year ROI and nBCR for each building in Dominion City and Emerson are listed in **Tables 24** and **25**. These figures assume all recommended upgrades are installed in each building. The Net Present Value (NPV) of the sum of savings over the ten years after implementation is $70,527 in Dominion City. When compared to the net capital costs of $26,694, the average ten year ROI and nBCR for all upgrades is 167% and 2.6, respectively. Similarly, for Emerson, the ten year ROI is 509% and the ten year nBCR is 6.1 based on an NPV of savings of $39,527 and net capital costs of only $6,525.

Table 22: Recommended efficiency upgrades in Dominion City.

Upgrade	Building	Amortized Cost ($/Year)	Δ 2018 Utilities ($/Year)	% Efficiency Improvement
Boiler Temperature Control Sequence	Fire Hall	$13	$250	0.2%
LED Interior, Exterior and Signage Occupancy Sensors	Community Pool	$30	$548	0.4%
Programmable Thermostat	Community Hall	$49	$76	0.2%
Programmable Thermostat	RM Office	$49	$49	0.1%
Programmable Thermostat	Public Works Yard	$49	$320	1.0%
Programmable Thermostat	Arena	$49	$199	0.6%
Programmable Thermostat	Curling Rink	$49	$91	0.3%
Pool Boiler Control Sequence	Community Pool	$53	$184	0.6%
Solar Pool Cover	Community Pool	$134	$1,285	3.9%
Solar Thermal Hydronics	Fire Hall	$164	$179	0.1%
Air Side Heat Recovery Ventilator (HRV)	Public Works Yard	$302	$989	3.6%
LED Interior, Exterior and Signage Occupancy Sensors	RM Office	$453	$988	0.7%
Solar Pool Hybrid Heating	Community Pool	$770	$539	1.6%

Table 23: Recommended efficiency upgrades in Emerson.

Upgrade	Building	Amortized Cost ($/Year)	Δ 2018 Utilities ($/Year)	% Efficiency Improvement
LED Interior, Exterior and Signage Occupancy Sensors	Community Pool	$30	$87	0.1%
Programmable Thermostat	Emerson Rink	$49	$274	1.0%
Programmable Thermostat	Town Hall	$49	$252	0.9%
Programmable Thermostat	Recreation Complex	$49	$161	0.6%
Pool Boiler Control Sequence	Community Pool	$53	$216	0.8%
Solar Pool Cover	Community Pool	$134	$1,510	5.7%
Air Side Heat Recovery Ventilator (HRV)	Town Hall	$151	$718	3.5%

Table 24: Ten year net ROI and nBCR for all recommended efficiency upgrades per building in Dominion City.

	Dominion City							
	Arena	Curling Rink	RM Office	Community Hall	Fire Hall	Community Pool	Abbeyfield Senior Home	Public Works Yard
10 Year ROI, 2018 Install	491%	172%	43%	128%	230%	232%		229%
10 Year nBCR	5.9	2.7	1.4	2.2	3.3	3.3		3.3

Table 25: Ten year net ROI and nBCR for all recommended efficiency upgrades per building in Emerson.

	Emerson				
	Emerson Rink	Recreation Complex	Town Hall	Fire Hall	Community Pool
10 Year ROI, 2018 Install	716%	381%	348%		640%
10 Year nBCR	8.1	4.8	4.4		7.4

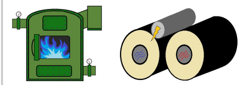
7.2 Recommended District Energy Options

Many options for district heat and district CHP in Dominion City and Emerson resulted as feasible from the investment analysis, however, based on all of the collective analysis criteria - including investment figures, capital costs, GHG mitigation and climate resilience - only specific networks are recommended. While natural gas fueled systems have the potential for good ROI, they either result in no reduction of GHG emissions or they increase the GHG emissions emitted by the Municipality. Therefore, the recommended configurations are narrowed to biomass fueled systems only.

7.2.1 Dominion City - Recommendations

Biomass District Heating in Dominion City is feasible and recommended as soon as 2024. District heating is less cost prohibitive - the "low hanging fruit" - it does not have policy obstacles and it has relatively low institutional complexity. The addition of infrastructure for CHP, cabling and connecting the network's buildings, is a 'no regrets' addition to the system - adding a component of resilience and future proofing with minimal additional capital. The addition of cabling capitalizes on the investment in excavation that is part of the district heating installation. Future phases can later connect to the installed cabling lines to expand the system from district heat to district CHP without needing to again invest in excavation. **Table 26** is pulled from the previous **Table 18**. It highlights the Biomass District Heating with Cabling analysis criteria for the Dominion City Central Municipal Network, shown in **Figure 40**.

Table 26: Central Municipal network system configuration analysis criteria. Each of the system configurations are displayed with iconification of the technology the system includes - "Key Design Features".

Central Municipal Network	Year nBCR >= 1.5	20 Year ROI	20 Year nBCR	Simple Payback	Capital Cost	System GHG (tCO2e/ year)	Resilience Score	Key Design Features
Biomass District Heat with Cabling	2024	58%	1.58	16	$156,281	14.1	4	

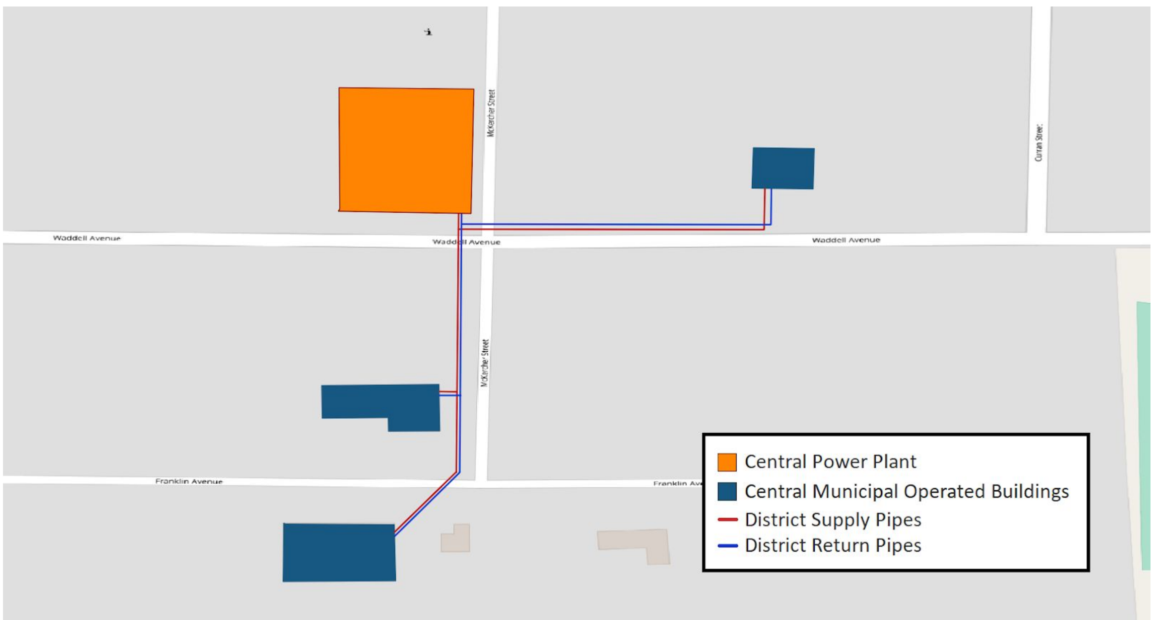


Figure 40: Dominion City Central Municipal network including the RM Office, the Community Hall and the Dominion City Fire Hall.

The earliest recommended implementation year, as indicated in the above **Table 26**, is 2024, however, the investment case further improves in the following years. **Figure 41** shows the nBCR and simple payback period for this system from 2024 to 2030. The 20 year nBCR reaches as high as 2.1 with implementation in 2030 with a simple payback period of 13 years.

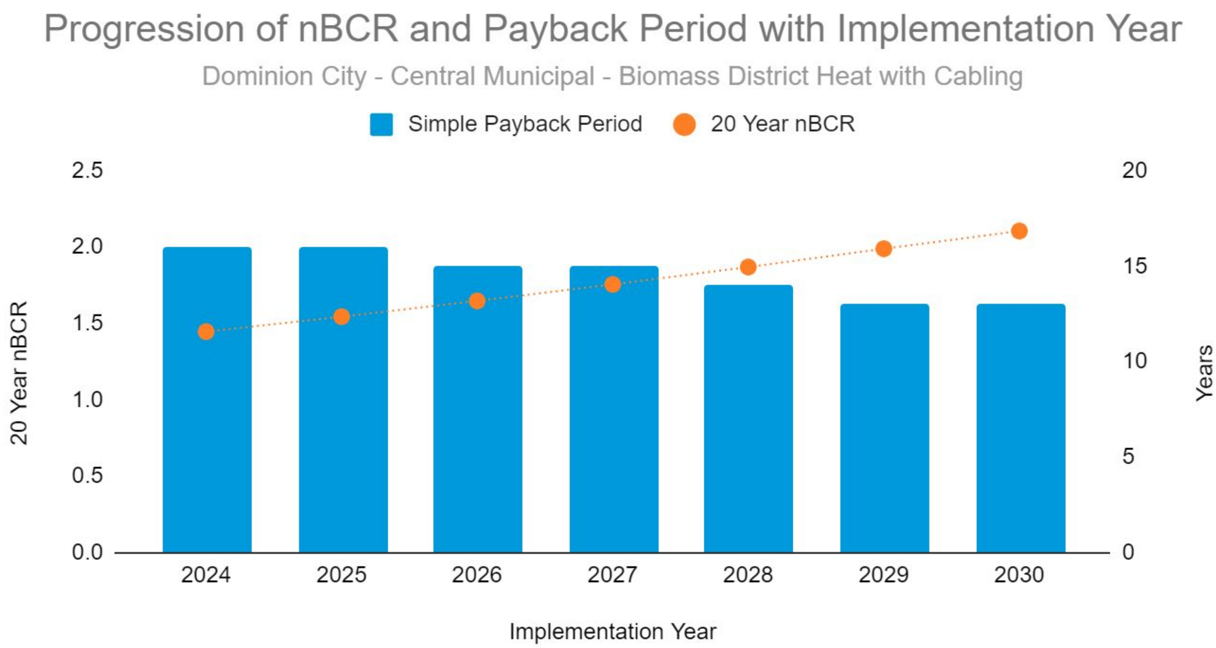


Figure 41: Increasing 20 year nBCR and decreasing simple payback period projected with delayed implementation.

The Biomass District Heating with Cabling configuration for the Dominion City Central Municipal layout has a capital cost, after the inclusion of 50% funding, of $156,281. The breakdown of the costs is provided in **Table 27**. The incremental cost of the addition of the cabling to the network includes the cable, $16,380, and the transfer stations at each building, $7,500, totalling $23,880 of additional capital. There are no additional operating costs related to the addition of the cabling until electricity generation units are implemented and tied to the installed cable.

Table 27: Capital and Operating Costs (2018 $CAD) for the Biomass District Heating with Cabling configuration for the Dominion City Central Municipal layout.

Capital Costs	
Building	$48,195
Boilers	$75,000
Piping	$145,620
ETS	$19,867
Solar/ORC	$0
Cable	$16,380
EITS	$7,500
Funding	-$156,281
Total CAPEX	**$156,281**

Operating Costs ($/Year)	
O & M	$2,600
Fuel	$1,757
Trans	$1,385
Pump	$57
Total OPEX	**$5,799**

Biomass District Heating with Cabling is also recommended for the Central Municipal and Other building network layout. This layout includes the centrally located municipal buildings included in the

Central Municipal network in **Figure 40** with the addition of local, non-municipal buildings. The Central Municipal and Other network is shown in **Figure 42**.

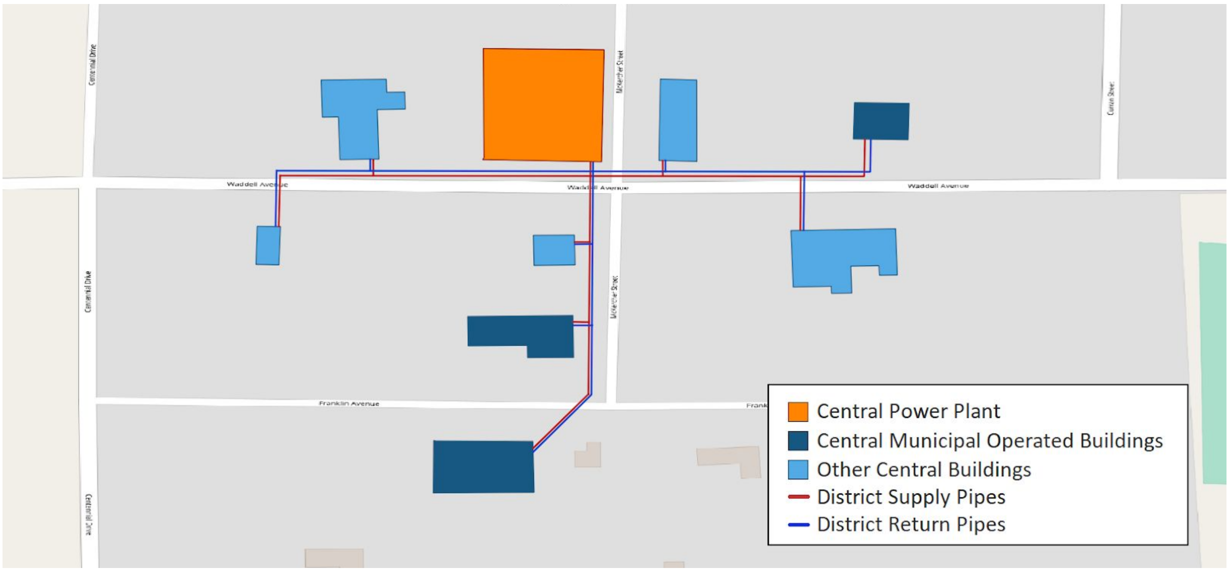
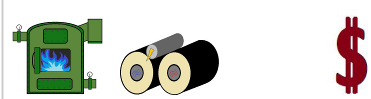


Figure 42: Central Municipal and Other network including the RM Office, the Community Hall, the Dominion City Fire Hall and five other centrally located buildings.

The addition of the non-municipal buildings displaces more locally consumed grid energy and further reduces local GHG emissions. The resulting investment case, however, is not significantly affected. The analysis criteria for the Biomass District Heating with Cabling for the Central Municipal and Other network layout is shown in **Table 28**. The configuration includes income generated from the distribution of heat to the non-municipal buildings.

Table 28: Central Municipal and Other network system configuration analysis criteria. Each of the system configurations are displayed with iconification of the technology the system includes - "Key Design Features".

Central Municipal and Other Network	Year nBCR >= 1.5	20 Year ROI	20 Year nBCR	Simple Payback	Capital Cost	System GHG (tCO2e/ year)	Resilience Score	Key Design Features
Biomass District Heat with Cabling - Income from Heat	2030	56%	1.56	15	$233,016	42.8	4	

The investment case for adding the non-municipal buildings improves when distributing and selling electricity to the non-municipal buildings in addition to heat. Currently, in the policy context in Manitoba, the sale of electricity is prohibited, therefore, the District CHP systems for Dominion City are not the recommended network configurations. With the cabling installed, however, the Municipality would capitalize on the excavation and restoration costs already being incurred and be ready for a future shift in policy enabling the distribution and sale of electricity. Renewable energy sources such as wind or solar or a generating system such as an ORC can be connected, with less capital investment, to the network in a future project phase.

The capital and operating costs of the Biomass District Heating with Cabling configuration for the two layouts, Central Municipal and the Central Municipal and Other, are directly compared in the below **Tables 29** and **30**. The capital cost of piping, cabling and the number of in building energy and electricity transfer stations increases with the increased number of buildings on the network. The operational costs of fuel, transport and pumping increase with the larger network, however, the increased operating costs are outweighed by the potential for income from the non-municipal buildings.

Table 29: Capital costs (2018 $CAD) for the Biomass District Heating with Cabling configuration for the Dominion City Central Municipal layout (left) and the Central Municipal and Other layout (right).

Capital Costs	
Building	$48,195
Boilers	$75,000
Piping	$145,620
ETS	$19,867
Solar/ORC	$0
Cable	$16,380
EITS	$7,500
Funding	-$156,281
Total CAPEX	**$156,281**

Capital Costs	
Building	$48,195
Boilers	$75,000
Piping	$248,202
ETS	$46,970
Solar/ORC	$0
Cable	$27,664
EITS	$20,000
Funding	-$233,016
Total CAPEX	**$233,016**

Table 30: Operating costs (2018 $CAD) for the Biomass District Heating with Cabling configuration for the Dominion City Central Municipal layout (left) and the Central Municipal and Other layout (right).

Operating Costs ($/Year)	
O & M	$2,600
Fuel	$1,757
Trans	$1,385
Pump	$57
Total OPEX	**$5,799**

Operating Costs ($/Year)	
O & M	$2,600
Fuel	$3,665
Trans	$2,771
Pump	$244
Income	-$4,482
Total OPEX	**$4,798**

7.2.2 Emerson - Recommendations

The lower energy density, or more distributed spatial proximity of buildings, in Emerson results in successful investment analysis only when both heat and power are supplemented on the network. The configurations recommended in Emerson are for Biomass District CHP for the Extended Municipal and the Extended Municipal and Other network layouts. Although these system configurations result in feasible investment analysis and good GHG reduction and climate resilience, they are both cost prohibitive, they involve management complexities and, because of Manitoba's energy policy context, the sale of electricity is currently not allowed.

While these systems may not be immediately feasible due to the policy context in Manitoba or their prohibitive capital costs, they still have overall positive analysis criteria that warrants recommendation for future consideration should policy or technology changes occur. The two recommended network configurations shown in **Figures 43** and **44** both include the four Municipal buildings in Emerson considered in district system analysis. The Extended Municipal and Other network also includes an additional four local, non-municipal buildings. The analysis criteria for the recommended system configuration for each network layout are outlined in **Tables 31** and **32** - excerpts from the previous **Tables 20** and **21**.

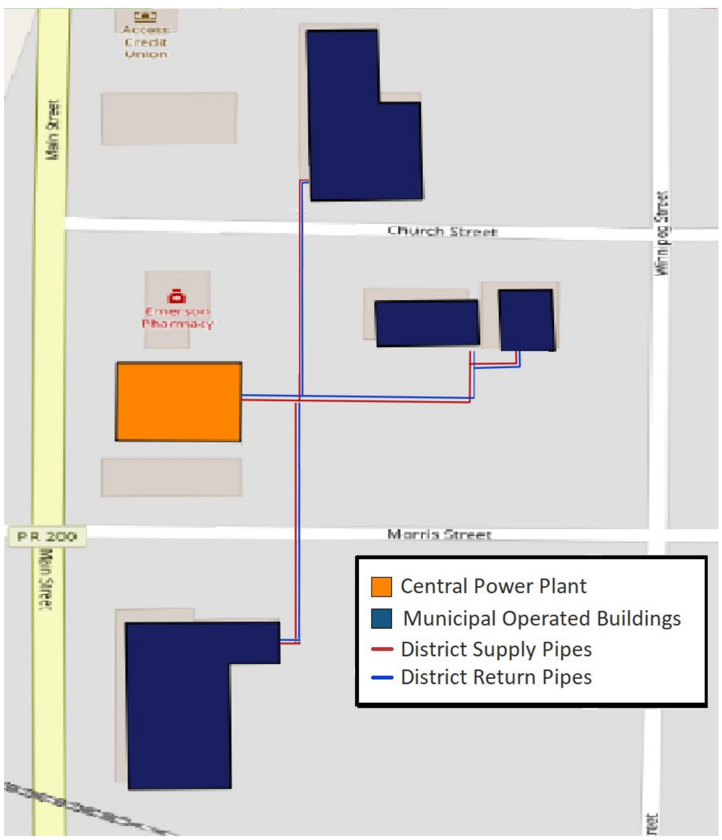
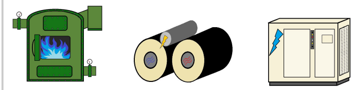


Figure 43: Emerson Extended Municipal network including the Arena (not rink area), the Recreation Complex, Emerson Fire Hall and the Town Hall.

Table 31: Extended Municipal network system configuration analysis criteria. Each of the system configurations are displayed with iconification of the technology the system includes - "Key Design Features".

Extended Municipal Network	Year nBCR >= 1.5	20 Year ROI	20 Year nBCR	Simple Payback	Capital Cost	System GHG (tCO2e/ year)	Resilience Score	Key Design Features
Biomass District CHP with ORC	2,025	163%	2.63	12	$509,922	96.8	8	

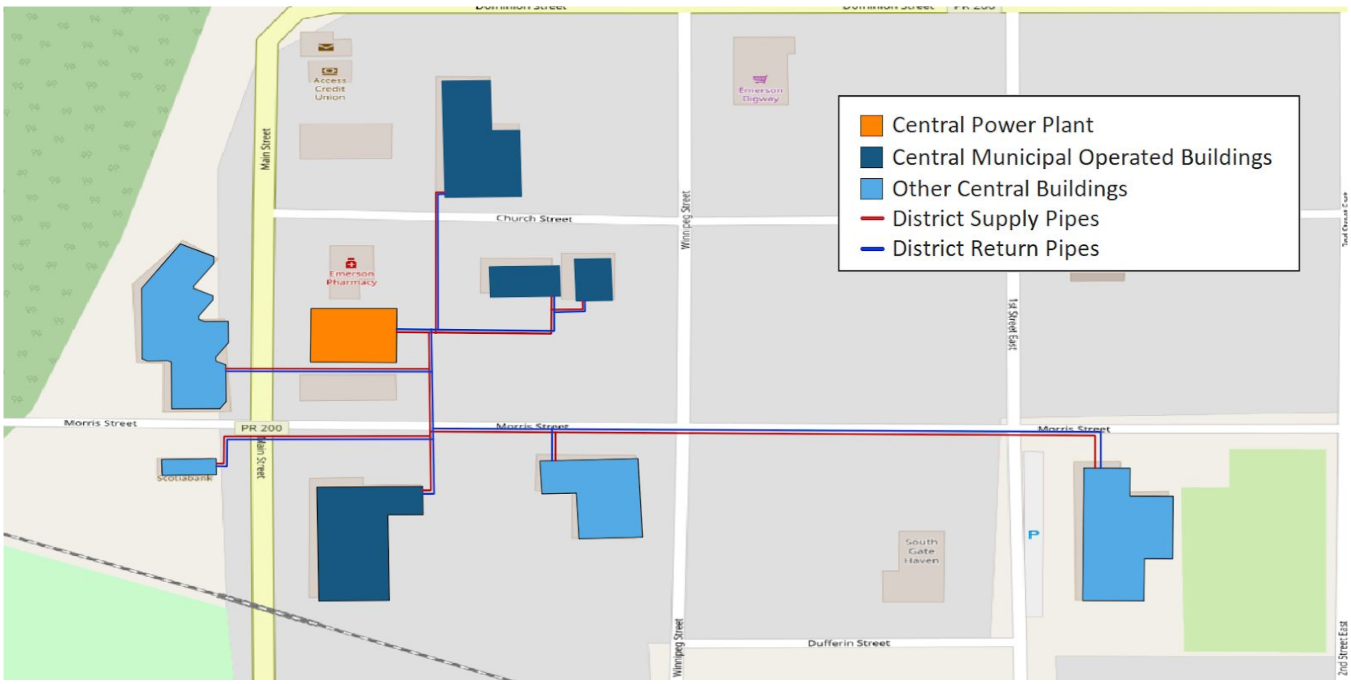
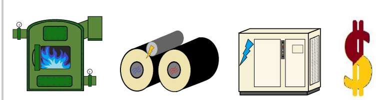


Figure 44: Emerson Extended Municipal and Other network including the Arena (not rink area), the Recreation Complex, Emerson Fire Hall, the Town Hall and four other centrally located buildings.

Table 32: Extended Municipal network system configuration analysis criteria. Each of the system configurations are displayed with iconification of the technology the system includes - "Key Design Features".

Extended Municipal and Other Network	Year nBCR >= 1.5	20 Year ROI	20 Year nBCR	Simple Payback	Capital Cost	System GHG (tCO2e/ year)	Resilience Score	Key Design Features
Biomass District CHP with ORC - Income from Heat and Electricity	2,020	105%	2.05	14	$1,055,539	198.8	8	

7.3 Next Steps: Pilot Project and Port of Entry

Based on the results of this study, energy efficiency upgrades are no-regrets in both Dominion City and Emerson and could be implemented immediately. Biomass-based District Energy in Dominion City is feasible and recommended next steps include detailed planning and testing. Next steps towards District Energy in Emerson await greater certainty that municipalities will be allowed by the Province of Manitoba to operate micro-utilities that produce and sell electricity in addition to heat. Provincially-owned buildings in the municipalities are good candidate customers for heat and potentially electricity. SCC believes the strong business case for energy efficiency and district energy along with the project's showcase potential, make a bundled project a strong candidate for FCM's Signature Initiative and Energy Recovery or District Energy funding streams. This study comprises the necessary feasibility analysis for further FCM funding eligibility.

Both FCM streams cover 50% of project costs up to $500,000. The Signature Initiative funding stream highlights projects that are "*transformative, best-in-class municipal projects*." SCC envisions that the multi-faceted, climate mitigation *and* climate adaptation components of district energy fit well within FCM's mandate. The revenue generation potential of the project also fits FCM's mandate to promote innovative municipal financing mechanisms that promote positive economic, social and environmental outcomes. The Energy Recovery or District Energy stream is intended to fund projects that examine financial performance of new or proven initiatives. In this case, biomass, a proven technology, is being applied in a new, innovative way as a revenue generating mechanism for the Municipality. Community-based district energy fits also within FCM's mandate of promoting biomass to displace fossil fuels.

An FCM project, as recommended, could be expanded with federal funding as a showcase innovation linked to economic development opportunities associated with Emerson-Franklin's strategic Port of Entry location along the mid-Continent Trade Corridor ("*Canada's most significant surface-based trade asset west of Windsor*"). As a component of the proposed sustainable pilot model for the Port of Entry, district energy would showcase municipal leadership and the potential for sustainable development at other Ports of Entry and in other rural Manitoba communities. Climate resilience and energy cost stability will attract industry and further the region's economic development.

Expanding district energy as a regional economic development project linked to the Port of Entry concept should consider three district energy networks: one in each of the urban areas of Emerson and Dominion City and one at the Port of Entry serving the proposed industrial development area. The three networks should operate within an integrated biomass fuel supply chain. The potential to refuel transport trucks with renewable energy at the border is a major regional sustainable development opportunity given anticipated shifts in trucking to increased use of biofuels and electricity. Clean and sustainable electric charging could be made available from biomass-fueled power generation.

Biodiesel or biogas (wherever the market trends in the future) could also be made available for vehicle refueling at the Port of Entry.

We anticipate that FCM and the Provincial and Federal government will be impressed by the innovation and showcasing features of the recommended energy efficiency and district energy project. SCC recommends a next phase proposal with the following components:

- Recommended efficiency upgrades identified in this study for both Dominion City and Emerson.
- Building-level daily consumption monitoring for accurate energy demand profiles for all municipal and non-municipal buildings considered for district energy.
- A full engineering design study to size a biomass-based district energy system in Dominion City, Emerson and optionally at the Port of Entry based on existing or predicted daily consumption profiles.
- Engineering combustion tests of the oat hulls from Emerson Milling in a TGF Biomass Boiler System.
- A single building biomass heating pilot installation using a small commercial TGF Biomass Boiler (<5M BTU) to develop Municipal, Provincial and Federal confidence in the technology and its economics.
- A regional biomass inventory to assess the cross-border vehicle fueling demand that could be supported with locally available renewable biomass resources.

SCC will be pleased to support Emerson-Franklin in planning and executing this and related projects.

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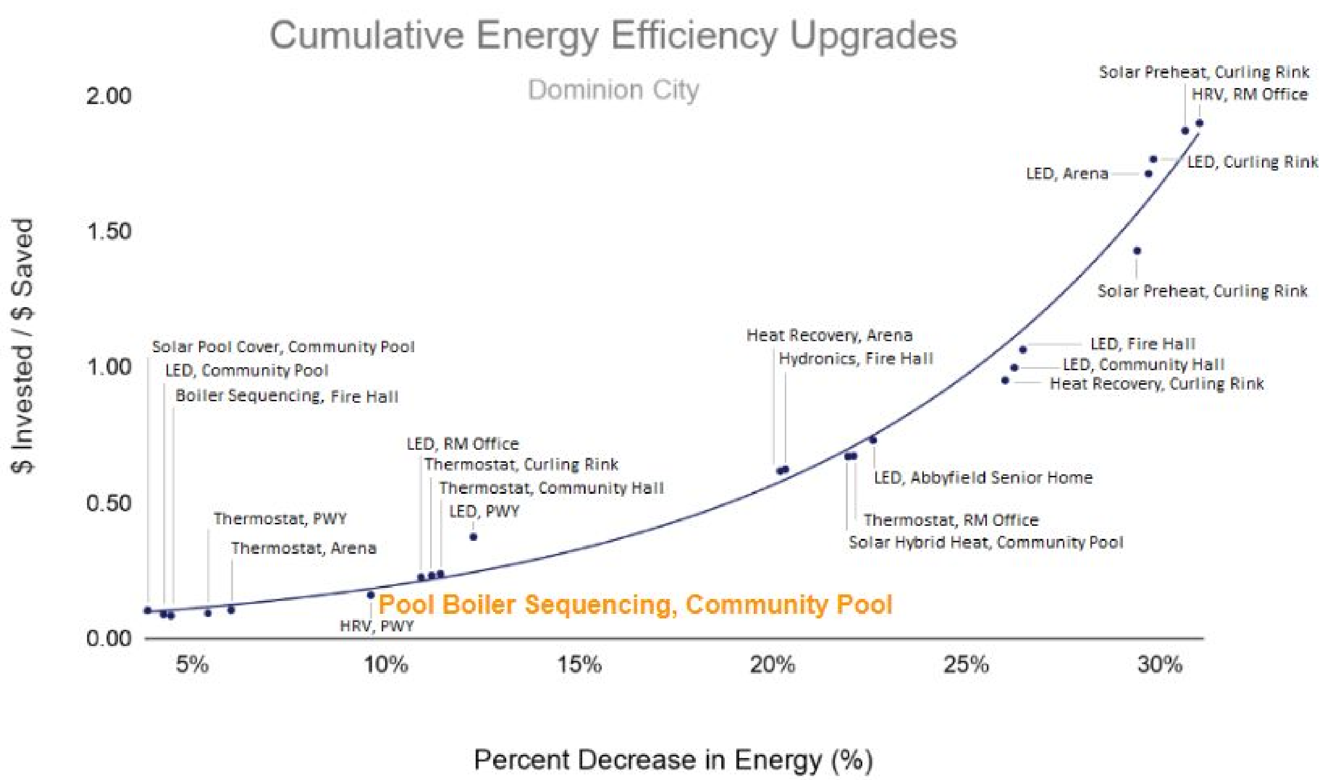
9 Appendices

9.1 Example Efficiency Calculations

The marginal cost ratio - referred to as "$ Invested / $ Saved" is calculated as the amortized cost of an efficiency upgrade divided by the annual cost of utility savings. Below is an example of how the figures are calculated highlighting Pool Boiler Controls and Sequencing for the Dominion City Community Pool. The Figure below highlights this efficiency on the Dominion City '*Cumulative Energy Efficiency Upgrades'* marginal cost curve.



Pool Boiler Control and Sequencing

<u>Upgrade Details</u>
Capital Cost: $450 / unit
- Unit Cost
- Installation
- Sequence Programming

Useful Life: 10 years
Related Energy Sector: Heating
Efficiency Improvement of Related Energy Sector: 5%

<u>$ Invested / $ Saved - Calculations</u>

Amortized Capital Cost ($/year) = pmt (3%, $450, 10 years)
= $52.75 / year

∆ Natural Gas (GJ) = Total Energy Use (GJ) x Heating End Use (%) x Efficiency (%)
= 23.81 (GJ)

Reduced Annual Utility Costs ($) = $/GJ x ∆ Natural Gas (GJ)
= $183.58 / year

Marginal Cost Ratio = Amortized Capital Cost ($/yr) / Reduced Annual Utility Costs ($/yr)
= 0.287

For the same energy efficiency upgrade, the Return on Investment (ROI) and net Benefit-Cost Ratio (nBCR) are outlined below. They are calculated for the approximate useful life of the upgrade based on utility projections.

ROI and nBCR - Calculations

∆ Natural Gas (GJ) = 23.81 (GJ)

Reduced Annual Utility Costs ($) =

Year	$/GJ	∆ Costs ($)
2018	$7.71	$183.62
2019	$9.30	$221.41
2020	$9.57	$228.01
2021	$9.76	$232.43
...	...	...
2027	$10.52	$250.65

Net Reduced Annual Costs ($) = sum(∆ Costs, 2018 - 2027) = $2326.55

Net Present Value (NPV) = NPV(3%, Net Reduced Cost)
= NPV(3%, $2326.55)
= $2258.79

Return on Investment (ROI) = (NPV - CAPEX) / CAPEX
= ($2258.79 - $450) / $450
= 405%

Net Benefit-Cost Ratio (nBCR) = NPV / CAPEX
= $2258.79 / $450
= 5.0

9.2 District System - Feasible Results Summary

The below tables list the financially feasible configurations in Emerson and Dominion City, respectively. The bolded configurations are those included in the final recommendations section in the report. The configurations not included did not pass the analysis criteria.

Emerson						
Network Configuration	Central Municipal	**Central Municipal**	Extended Municipal and Other	Extended Municipal and Other	Extended Municipal and Extended Other	**Extended Municipal and Extended Other**
System Type	District CHP	**District CHP**	District CHP	District CHP	District CHP	**District CHP**
Boiler Fuel	Biomass	**Biomass**	Natural Gas	Biomass	Natural Gas	**Biomass**
Electricity Generation	ORC	**ORC**	ORC	ORC	ORC	**ORC**
Income Source		**Distributed Heat**	Distributed Heat and Power	Distributed Heat and Power	Distributed Heat and Power	**Distributed Heat and Power**
Earliest Implementation Year	2025	**2030**	2020	2020	2021	**2020**
Capital Cost	$281,164	**$1,055,539**	$675,375	$1,055,539	$1,039,325	**$1,462,204**
Funding	-$281,164	**-$500,000**	-$500,000	-$500,000	-$500,000	**-$500,000**
Net ROI	51%	**53%**	82%	105%	60%	**85%**
nBCR	1.51	**1.53**	1.82	2.05	1.60	**1.85**
Simple Payback	16	**15**	16	14	16	**15**

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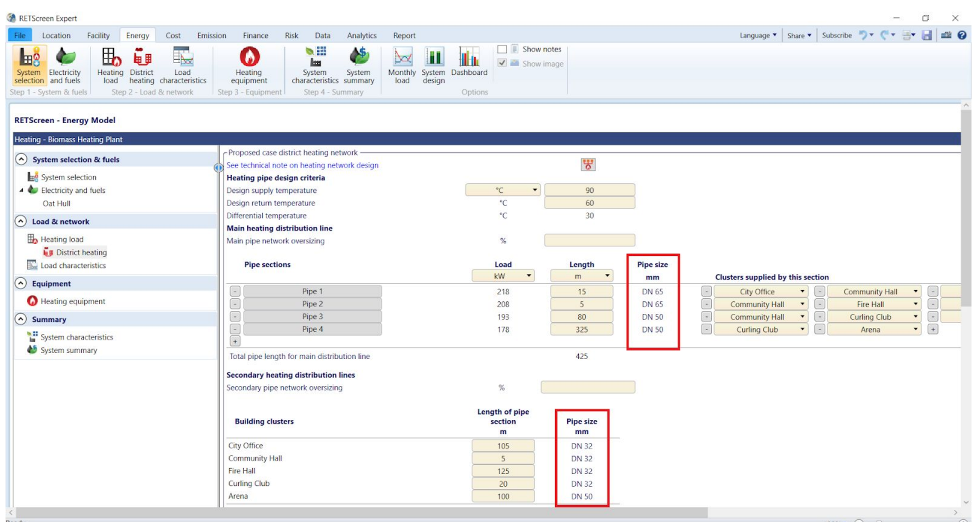
9.3 Technical Memo

Executive Summary	RETScreen, Natural Resources Canada's (NRCan) Clean Energy Management Software, was used in conjunction with a custom model developed in GNU Octave to assess the feasibility of district heating and district combined heat and power (CHP). The models determine a "best" solution from varying input network configurations, fuels (biomass and projected public utility), system options and income structures. They also determine the point when converting to district heat or CHP, considering projected increases in public utilities, makes financial sense and the reduction in annual utility costs, greenhouse gas (GHG emissions and climate vulnerability as compared to the business as usual (BAU) case. The output from these models is further analyzed to determine each system's return on investment (ROI) and net benefit cost ratio (nBCR). The GNU Octave model was developed for the feasibility assessment of district heating and district CHP in the Municipality of Emerson-Franklin. Building utility data, energy use split and heated floor areas were provided for municipal operated buildings in the urban areas of the Municipality. Additional data for buildings in the regions was obtained from the Microsoft Open Database Commons *Canadian Building Footprints* and NRCan's *Canadian Energy Use Intensity by Property Type*. The model output was validated using RETScreen. It was run for various network configurations, system designs, fuel types and income structures to develop an optimal solution. The models are recommended to be used for: 1. Analyzing the feasibility of district heat and district CHP for a building, cluster of buildings or an urban area 2. Assessing the feasibility of biomass utilization in rural Manitoba 3. Assessing the feasibility of community-based electricity generation in rural Manitoba 4. Determining when it is optimal to convert to district heat or district CHP
Context	To evaluate the feasibility of district heat and CHP in the urban regions of Emerson-Franklin and establish pre-engineering recommendations, two models were used to adequately size a system, assess fuel requirements and propose capital and operating costs. Utility data and building footprints for municipal operated buildings were provided by the municipality and additional buildings considered in analyses were approximated using NRCan's technical references. Utility data was input into RETScreen and calibrated to recorded temperature conditions at the Emerson Auto Weather Station. The model output network configuration specifications, including diameter satisfactory to flow requirements. To assess costs and fuel requirements for the potential project, a secondary model was developed in Octave. The RETScreen output was applied in Octave to generate BAU projected costs for the municipality, annual costs

	associated with district heat or CHP and when the project is best suited for implementation. This memo provides: ● A summary of the data used in the models ● RETScreen model setup and configuration ● An example of network diameter output from RETScreen ● Octave model structure ● An example of output from Octave ● Investment analysis structure using Octave model output
Data Availability and Processing	The municipality provided Manitoba Hydro utility bills for the municipal run buildings in the urban areas of Dominion City and Emerson. Five buildings were included for the Emerson area and eight for Dominion City. The bills provided were for monthly natural gas and electricity consumption. The data was provided to a sub-consultant, Nativus Energy, who initiated an energy efficiency investigation phase. Data for the monthly billing periods beginning Dec 22, 2017 and finishing Dec, 22, 2018 were used to represent monthly consumption for January 2018 to December 2018. For buildings with incomplete data for this billing cycle, bills for the same period in 2017 or 2019 were used and adjusted linearly based on the month's heating degree days recorded for the applicable year. Weather data for the Emerson Auto station was obtained from the Government of Canada's Environment and Natural Resources climate data repository (Environment and Natural Resources 2019). Approximate annual consumption patterns for buildings not operated by the municipality but considered in this study were obtained from NRCan's *Canadian Energy Use Intensity by Property Type* Technical Reference (NRCan 2013). The function and footprint of the buildings were estimated using Google Maps, Google Street View, Microsoft Open Database Commons *Canadian Building Footprints* and QGIS. The percent of total building energy use attributed to heating and domestic hot water (DHW) was averaged for the municipal buildings. The average was used to estimate the component of NRCan's building footprint that resulted from heating and DHW. The remaining percent not attributed to heating or DHW was considered to be electricity use from varying applications. In order to estimate the monthly energy use for these buildings, monthly consumption for municipal operated buildings was weighted and applied to the approximate annual consumption of the other buildings. The efficiency of natural gas boilers operated by the municipality was assumed to be 70% and electric boilers were assumed to be 100% efficient. It was assumed for other buildings considered in analysis that space heating and domestic hot water was provided by natural gas at a rate of 70% efficiency. Additional data was required to analyze the feasibility of district energy systems in the communities. The distribution network segment lengths were determined using QGIS between the building polygons from Microsoft Open Database

	Commons Canadian Building Footprints. The location, availability and calorific value of oat hull in the region was identified by Jarrod Firlotte at Emerson Milling. Emerson milling is located seven kilometres north of Emerson and approximately 14 km South of Dominion City. The plant is estimated to produce 100 tons of oat hull waste per day, 365 days per year (Jarrod Firlotte, Emerson Milling, personal communication, 14 August 2019). The calorific value was estimated to be 14.855 GJ/t which was verified as a very conservative estimate compared to other suggested values of 17 GJ/t by Zhang and Boris (2011) and 19.5 GJ/t estimated by Ontario's Ministry of Agriculture and Rural Affairs Burn Characteristics for Oat Hull (2019).
RETScreen	RETScreen is a "Clean Energy Management Software" developed by the Government of Canada to assess the feasibility of energy efficiency, renewable energy, or cogeneration projects (NRCan 2019). The model's Virtual Energy Analyzer is utilized to assess a biomass powered heating facility. A user defined fuel is entered with a calorific value of 14.855 GJ/t. In the Energy section, the multiple buildings and space heating options are selected and heating loads (W/m^2), building heated floor areas (m^2), and efficiencies (%) are entered for the specific network configuration. The design supply and return temperatures are set for a 90°C - 60°C system. The lengths of the main and secondary network distribution lines (m) are entered for the specific configuration indicating the facilities they supply. Once entered, RETScreen immediately calculates the necessary pipe diameters to satisfy a flow rate capable of supplying sufficient energy to meet the building's requirements. **Figure 1** has highlighted in red the diameters calculated by RETScreen for each piping segment in a network example.  *Figure 1: RETScreen District Heating Tab displaying calculated pipe segment diameters.*
Octave	GNU Octave is a language intended for linear and nonlinear numerical computations and experiments (GNU Octave 2020). The model was developed as a script with input matrices that describe the network configuration, the end user BAU heating fuel, the type of end user (municipal or other customer) and

	the end user monthly energy consumption. The diameters output by RETScreen are included as a column in the network configuration matrix. The script calls 31 functions to produce an output of four arrays for each network configuration. The first array is for annual BAU utility costs for 2018 to 2048 based on projected public utility rates. The second array has annual costs from 2018 to 2048 associated with operating a district energy network specific to the variable parameters inputted with capital costs amortized over 20 years. The third array has the capital costs in year one, 2018, with annual costs from 2019 to 2048 in the years following. The fourth array contains the BAU and new annual emissions associated with heat or heat and electricity in tonnes of carbon dioxide equivalent (tCO_2e). These arrays, for each analyzed configuration, were exported to excel for investment analysis and to verify the optimal, climate resilient options. The first step to filter sub-optimal results was a comparison of BAU annual costs in 2030 to district energy operating and amortized costs in 2030. Configurations with costs higher than BAU were discarded from potential options and further analysis. The remaining configurations were assessed for the 20 year annualized post-installation ROI from the recommended implementation year, the net ROI and the net benefit-cost ratio. The following is an example of output that could be produced by the model. >>Heat Only System Biomass Boiler Income from Natural Gas Boiler Size: [kW] 167.002 CAPITAL COSTS [$] Building: $29920.00 Boilers: $75000.00 Piping: $248202.00 ETS: $46970.10 Solar/ORC: $0.00 Cable: $0.00 ElTS:

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$0.00
Funding:
-$200046.05

$200046.05

OPERATING COSTS [$/yr]
O & M:
$2600.00
Fuel:
$3664.94
Trans:
$2770.56
Pump:
$244.00

$4798.31

Amortized Costs [$/yr]:	Utility Costs [$/yr]:	BAU Costs [$/yr]:
$18244.55	-$200046.05	$13060.92
$17336.24	$3890.01	$14721.83
$17189.64	$3743.41	$15262.09
$17097.10	$3650.86	$15741.56
$17046.45	$3600.22	$16178.37
$16955.90	$3509.66	$16699.42
$16907.03	$3460.79	$17173.18
$16859.27	$3413.03	$17670.04
$16798.94	$3352.71	$18210.36
$16765.55	$3319.32	$19298.00
$16734.79	$3288.55	$19843.75
$16671.94	$3225.70	$20467.04
$16610.42	$3164.18	$21118.04
$16550.45	$3104.21	$21801.38
$16491.81	$3045.58	$22512.42
$16434.95	$2988.71	$23260.42
$16379.42	$2933.18	$24036.13
$16325.88	$2879.65	$24853.41
$16274.12	$2827.89	$25707.64
$16224.36	$2778.12	$29518.69
$16175.29	$2729.06	$30462.94
$16129.74	$2683.51	$31446.50
$16086.41	$2640.18	$32476.24
$16045.74	$2599.51	$33561.41
$16007.51	$2561.28	$34697.38
$15972.17	$2525.93	$35893.41
$15939.48	$2493.24	$37144.85
$15910.12	$2463.89	$38465.58

	$15883.65	$2437.41	$39846.35
	$15860.73	$2414.49	$41863.73
	$15841.57	$2395.33	$43396.93

BAU GHG [tCO2e/year]: New GHG [tCO2e/year]:

43.12 0.36

Capital costs in the model for a district heating system are made up of four categories of costs: Building, Boilers, Piping and Energy Transfer Stations. Piping, and the associated components and installation, is priced using **Equation 1** affected by both inner pipe diameter, d (m), and length, L (m), of the pre-insulated pipe. Boiler costs and building costs are based on the size of the boiler required. Boiler size is calculated using **Equation 3**, where n is the number of buildings in the network, E is the energy footprint of each building (W/m^2), A is the heated floor area of each building (m^2), m is the number of pipes in the network, and Q, calculated by **Equation 2**, is the heat loss in the length and fittings of each pipe (kW), where T_{flow} and T_{env} are the water supply temperature and soil temperature (k), respectively, k is the thermal conductivity of the pipe material (W/mk), and d_{ins} is the full insulated diameter of the pipe (m) (Community Energy Association 2014, Martin-Du Pan et al 2018). The building costs for biomass systems for heat and CHP shown in **Equations 4a** and **4b** and **4c** and **4d**, respectively. Building costs for a natural gas heat or CHP system are shown in **Equation 4e**. The cost of a biomass boiler is based on the maximum capacity required, **Equations 5a** through **5c**. Systems requiring more than 530 kW were priced based on an approximate per kW price (**Equation 5d**). Natural gas boiler costs are based on **Equation 5e**. The cost for an energy transfer station (ETS) is set to a floor of $3000 for buildings with peak loads less than 10 kW. The cost for buildings with loads greater than 10 kW is calculated using **Equation 6** (CETC 2005, Community Energy Association 2014, Community Energy Association 2013).

$$\text{PipeCost (\$)} = L \cdot (d \cdot 5000 + 450) \quad (1)$$

$$Q\ (kW) = \frac{2 \pi L k (T_{flow} - T_{env})}{1000 \cdot ln(d / d_{ins})} \quad (2)$$

$$\text{BoilerSize (kW)} = \left(\sum_{i=0}^{n} (E_i \cdot A_i \cdot \frac{1}{1000}) + \sum_{j=0}^{m} Q_j \right) \cdot 1.1 \quad (3)$$

BoilerSize < 176 kW, heat: BuildingCost ($) = 16 · 22 · (70+15) (4a)
BoilerSize > 176 kW, heat: BuildingCost ($) = 20 · 92 · (70+15) (4b)
BoilerSize < 176 kW, CHP: BuildingCost ($) = 21 · 27 · (70+15) (4c)
BoilerSize > 176 kW, CHP: BuildingCost ($) = 25 · 97 · (70+15) (4d)
Natural Gas, heat or CHP: BuildingCost ($) = 16 · 22 · 70 (4e)

BoilerSize < 176 kW: BoilerCost ($) = 75000 (5a)
BoilerSize < 410 kW: BoilerCost ($) = 285000 (5b)

BoilerSize < 530 kW: BoilerCost ($) = 310000 (5c)

BoilerSize > 530 kW: BoilerCost ($) = $BoilerSize \cdot 585$ (5d)

Natural Gas Boiler: BoilerCost ($) = $BoilerSize \cdot 600 \cdot 0.37$ (5e)

$$ETSCost\ (\$) = \sum_{i=0}^{n} (E_i \cdot A_i \cdot \frac{1}{1000} \cdot 300) \quad (6)$$

Additional capital cost categories for district CHP are: ORC or Solar Photovoltaics (PV), Cabling and Electricity Transfer Stations. All capital cost can optionally be supplemented by an input percent of funding to a maximum of $500,000. The cost of including an ORC in the system is based on the required size calculated by **Equation 7** that utilizes the monthly electrical consumption (kWh/m) of all the buildings on the network in array, S. **Equation 8a** and **8b** are used to calculate the cost for systems less and greater than 75 kW, respectively. The cost of solar PV panels is based on the space available for their installation. Space for a biomass system is calculated based on **Equations 9a** and **9b** and natural gas is based on **9c**. The solar cost is then calculated (**Equation 10**) using the space available and the solar potential in the region and the capability of the panel, s (ft^2/kW). Electricity transfer stations are calculated as $2500 per building wiring as shown in **Equation 11**. Electrical cabling is calculated at a rate of $70/m (**Equation 12**) of wire and conduit for the same path as the district heat pipe.

$$ElecReq\ (kW) = max(S) \cdot \frac{1}{24} \cdot \frac{1}{30} \quad (7)$$

ElecReq < 75 kW: ORCCost ($) = 275000 (8a)

ElecReq > 75kW: ORCCost ($) = 405000 (8b)

BoilerSize < 176 kW, Biomass: Space (ft^2) = $\frac{10.5}{cos(35)} \cdot 27$ (9a)

BoilerSize > 176 kW, Biomass: Space (ft^2) = $\frac{12.5}{cos(35)} \cdot 97$ (9b)

Natural Gas Boiler: Space (ft^2) = $\frac{8}{cos(35)} \cdot 22$ (9c)

$$Solar\ Cost\ (\$) = \frac{Space}{s} \cdot 1000 \cdot 3.31 \quad (10)$$

$$ElecTSCost\ (\$) = n \cdot 2500 \quad (11)$$

$$CablingCost\ (\$) = L \cdot 70 \quad (12)$$

The costs associated with operating a system includes the cost of fuel necessary to fulfill end-user demand, the cost of trucking for systems utilizing biomass, the electrical requirements of operating a distribution pump and the labour costs associated with operation and maintenance. Additionally, in cases where end-users are customers on the distribution network, income from these customers can be factored into operating costs at the rate of available natural gas and electricity from public suppliers. Biomass fuel and trucking costs are calculated by **Equation 16** and **20**, respectively. Both equations require the calculation of the fuel required per year (**Equation 13** for heat only, **Equation 14** for heat and CHP with ORC), where q is the peak monthly load required from the network (GJ/month), C is the fuel's calorific value (GJ/t) and p is the unit cost of the biomass fuel ($/t). Calculating the trucking costs also includes the calculation of the volume of fuel, vol (m^3), the number of truck loads, l, and the drive time required per load, t (h) in **Equations 17, 18,** and **19**, where ρ is the fuel density (m^3/t), V_t is the truck volume (m^3), D is the distance to the biomass source to the power plant (km) and v_{av} is the average speed of the transport vehicle (km/h). Natural gas has no associated trucking costs. The cost of the fuel for systems utilizing natural gas for fuel also uses **Equations 14** and **15** however the cost is calculated by **Equation 21** instead, where p_{ng} is the projected cost of natural gas.

$$\text{Fuel (t/year)} = \left(\sum_{i=1}^{12} q + \frac{24 \cdot 365}{277.78}\sum_{j=0}^{m} Q_j\right) \cdot \frac{1.1}{C} \tag{14}$$

$$\text{Fuel (t/year)} = \left(\sum_{i=1}^{12} q + \frac{24 \cdot 365}{277.78}\sum_{j=0}^{m} Q_j + \frac{1}{277.78}\sum_{i=1}^{12} S\right) \cdot \frac{1.1 \cdot 1.1}{C} \tag{15}$$

$$\text{FuelCost (\$/year)} = Fuel \cdot p \tag{16}$$

$$\text{vol (m}^3) = \frac{Fuel}{\rho} \tag{17}$$

$$\text{l} = \frac{vol}{t_v} \tag{18}$$

$$\text{t (h)} = 2 \cdot \frac{D}{v_{av}} \tag{19}$$

$$\text{TruckCosts (\$/year)} = l \cdot (t + lt + ut) \cdot (c_{labour} + c_{truck}) \tag{20}$$

$$\text{FuelCost (\$/year)} = Fuel \cdot p_{ng} \tag{21}$$

The truck cost includes a set labour cost per hour, c_{labour}, and truck rental cost per hour, c_{truck}, and set approximates for loading and unloading time, lt and ut, respectively (h).

Pumping requirements are based on the flow requirements in the network that suffice to supply the necessary energy to each building, the pressure loss in the network and the efficiency of the pump, η, **Equation 22** (Tommerup et al 2007). The district system is a closed network and therefore the water in the pipes follows the conservation of mass. The flow rate required of the system, V_{sys} (m^3/s), is calculated as the sum of the required flow rates at each building, V_i (m^3/s), as shown in **Equation 23** (Lindgren 2015).

$$P_{pump}\ (kW) = \frac{P_{drop} \cdot V_{sys}}{\eta} \quad (22)$$

$$V_{sys}\ (m^3/s) = \sum_{i=0}^{n} V_i \quad (23)$$

The flow rate at each building is calculated by **Equation 24**, where c_p is the specific heat of water (kJ/kgC), ρ is the density of water (kg/m^3), ΔT is the change in water temperature across a building transfer station and Φ is the peak load at the building (kW) (Martin-Du Pan et al 2018, De Boer 2018).

$$V_i\ (m^3/s) = \frac{\Phi_i}{c_p\ \rho\ \Delta T} \quad (23)$$

Pressure loss, P_{drop} , in the network depends on the pipe contractions, the fittings and connections, the presence of heat exchangers and flow through tee throughs and open valves. **Equation 24** is used to calculate the pressure drop across heat exchangers, ΔP_{HE} (kPa), open valves, ΔP_{OV} (kPa), and the equivalent length of the pipe ΔPL_{eq} (m). The equivalent length is calculated by **Equation 25** where (L/D) is the unitless equivalency conversion of a pipe fitting. The pressure drop across the equivalent length, ΔPL_{eq}, is calculated by **Equation 26**, where v is the flow velocity (m/s) in the pipe. The friction factor, f, is calculated iteratively using the Colebrook-White equation, **Equation 27**, where ε is the roughness of the pipe (m) and R is the Reynolds number. The Reynolds number for turbulent pipe flow is calculated by **Equation 28**, where μ is the dynamic viscosity of water (Lindgren 2015, Neutrium 2012, Tommerup et al 2007, Wilson 2014).

$$\Delta P_{drop}\ (kPa) = \sum_{i=0}^{m} (\Delta P_{HE-i} + \Delta P_{OV-i} + \Delta PL_{eq-i}) \quad (24)$$

$$L_{eq}\ (kPa) = L + (L/D) \cdot d \quad (25)$$

$$\Delta PL_{eq}\ (kPa) = \frac{f\ \rho\ v^2 L_{eq}}{2\ d} \quad (26)$$

$$\frac{1}{\sqrt{f}} = -2log\left(\frac{\varepsilon/d}{3.7} + \frac{2.51}{R\sqrt{f}}\right) \quad (27)$$

$$R = \frac{\rho\ v\ d}{\mu} \quad (28)$$

The operations and maintenance costs are estimated based on other district heating projects in Canada and approximate time requirements estimated by producers of biomass boilers and distributors of ORC systems. The cost per year for natural gas boilers is assumed to be the same as BAU O & M costs. Biomass heat is calculated using **Equation 29a** and biomass CHP is calculated using **Equation 29b** (BC. District of Lillooet).

O&MCosts ($/year) = $25 \cdot 2 \cdot 52$ (29a)

O&MCosts ($/year) = $25 \cdot 3 \cdot 52$ (29b)

The final component of the operational costs is the optional inclusion of income from customers connected to the network. Income is calculated as the sum of heat supplied multiplied by the current natural gas rate and can optionally also include the sum of the electricity supplied multiplied by the current electricity rate.

Total annual costs can be calculated as the sum of amortized capital costs ($/year) and operational costs ($/year). These costs can be compared to BAU operating costs and modeled for future, projected public utility rate increases. For systems supplying only heat, BAU costs are calculated as the sum of all BAU heat in the buildings on the network. In a CHP system with ORC, BAU costs are the sum of heat and electricity costs. In a CHP system with solar PV, BAU costs are the sum of all heating costs and the portion of electricity costs that could be supplemented by the installation of solar as calculated above. BAU operating costs are calculated by **Equation 30,** where OM_{BAU} is the BAU operations and maintenance costs and c_{NG} ($/$m^3$) and C_E ($/kWh) are natural gas and electricity prices, respectively. Electricity can be excluded in part or full depending on the network configuration and system setup.

BAUCosts = (30)

$$OM_{BAU} + \sum_{i=1}^{12}(q_{i-natural\ gas}) \cdot c_{NG} + \sum_{i=1}^{12}(\Phi_{i-electricity}) \cdot c_E$$

The model also outputs BAU GHG emissions and new GHG emissions associated with the evaluated system. Similar to calculating costs, GHG emissions for heat only systems only consider the BAU emissions associated with heating the network's buildings. For CHP systems, emissions include those associated with heating and either some or all those associated with electricity, depending on whether some or all electricity is supplemented. Emission calculations are based on Manitoba emission factors from Canada's National Inventory Report (2015) and the 4th assessment of Global Warming Potentials (Canada 2020). GHG emissions associated with natural gas are calculated using **Equation 31** and those associated with Manitoba Hydro Electricity are calculated using **Equation 32**. Biomass was concerned as a net zero fuel with no associated emissions at the time of combustion. Therefore, emissions associated with biomass are only attributed to the transport of the fuel. **Equations 14** or **15**, **17**, and **18** are required to determine the number of truck loads. The total distance is determined by **Equation 33** and includes the truck loads, l, the distance, D (km) and an exaggeration factor of 3. The emissions associated with the transport assume a diesel powered vehicle with a fuel efficiency of 2.55, calculated in **Equation 34**.

$$GHG_{ng}\ (tCO_2e) = \frac{\sum_{i=1}^{12}(q_{i-natural\ gas})}{0.038} \cdot [1886 + 0.037 \cdot 25 + 0.035 \cdot 295] \cdot \frac{1}{1000 \cdot 1000} \quad (31)$$

$$GHG_{elec}\ (tCO_2e) = \sum_{i=1}^{12}(\Phi_{i-electricity}) \cdot [3.3 + 0.0003 \cdot 25 + 0.0001 \cdot 295] \cdot \frac{277.78}{1000 \cdot 1000} \quad (32)$$

$$totalDistance\ (km) = l \cdot D \cdot 3 \quad (33)$$

$$GHG_{diesel}\ (tCO_2e) = \frac{totalDistance}{2.55} \cdot [2681 + 0.14 \cdot 25 + 0.082 \cdot 295] \cdot \frac{1}{1000 \cdot 1000} \quad (34)$$

Input for the Octave model is set to the following for all configurations. Connection diameters are set to 32 mm, small and medium branch diameters are set to 40 and 50 mm, respectively and the mainline diameters are set to 65 mm. Configurations could have one, some or all of these diameters. The base electricity and natural gas prices are set to 2018 rates, \$0.11/kWh and \$0.295/m^3. Electricity rates were set to increase by 5.63% per year based on the average approved rate increase of 3.36% by PUB in 2017 and Manitoba Hydro's requested increase rate of 7.9% (Manitoba Hydro 2019). Natural gas rates were based on the Provincial flat rate carbon tax at \$25/t and predicted Henry Hub natural gas rate increases (AER 2019;Sustainable Development 2017). The biomass fuel calorific value is set to 14.855 [GJ/t] for oat hull with a density of 0.128 [t/m3]. An interest rate of 3% is used for investment calculations with an estimated useful life of 20 years and an anticipated capital funding rate of 50%.

Each network configuration modelled requires the input of six matrices. The first sized n x 12, with n number of buildings and energy use [GJ] per month from January to December. The second sized n x 12, with electricity (not associated with heating) use [kWh] per month from January to December. The third sized n x 2, with n number of buildings and the energy footprint [W/m^2] and the building footprint [m^2]. The fourth and fifth for heating types and building owners are sized n x 1, with a 1 indicating BAU heat supplied by natural gas and a 0 indicating electricity or a 1 indiciating municipal ownership and a 0 for other owners. The six matrix is sized m x 9, with m pipe segments in the configuration. The first column is for the length of the pipe [m], the second is for the diameter of the previous pipe in the network [m], the third is for the diameter of the pipe [m], the fourth indicates the presence of a contraction in the segment (1 indicates its presence, 0 is that it is not present), the fifth through ninth indicate the presence of ninety degree fittings, forty-five degree fittings, tee throughs, heat exchanger or an open valve, respectively. The distance between Emerson Milling, the biomass source, and the plant locations in each urban area were set

	as 7 [km] for Emerson network configurations and 14 [km] for Dominion City configurations. The biomass fuel costs was set to $40/t for all configurations. The model concludes by outputting four arrays. The first for annual BAU utility costs for 2018 to 2048, the second has annual costs from 2018 to 2048 associated with operating a district energy network specific to the variable parameters inputted with capital costs amortized over 20 years, the third has the capital costs in year one, 2018, with annual costs from 2019 to 2048 in the years following. The fourth array contains the BAU and new annual emissions associated with heat or heat and electricity in tonnes of carbon dioxide equivalent (tCO_2e). These arrays, for each analyzed configuration, were exported to excel for investment analysis and to verify the optimal, climate resilient options.
Validation	The primary output from RETScreen used for analysis are the diameter sizes for the network configuration, however RETScreen was also used to validate the capital cost output from the Octave model. Capital costs for Boilers, Piping and Energy Transfer Stations were compared. RETScreen's technical documentation indicates the boiler costs as being inclusive of major equipment and installation costs associated with a biomass boiler sized to 110% of the peak load (CETC 2005). The Octave model was created to cost a biomass boiler sized to 110% of the peak load, all piping, controls and pumps necessary for a full working system, fuel storage, walking floor, an electrostatic precipitator for PM10 control, engineering costs, construction and installation costs and contingencies (Community Energy Association, 2014). Piping costs for both models are inclusive of the costs associated with excavating and restoring a trench, pre-insulated piping for both supply and return lines and distribution pump(s). RETScreen additionally includes the costs of replacing existing sidewalks or other infrastructure disturbed (CETC 2005). The Octave model includes inspection, testing, cleaning and flushing as part of the installation (Community Energy Association, 2014). Energy Transfer Stations are priced in both models depending on the peak load of the building. Costs include indirect prefabricated heat exchangers for space heating and domestic hot water heating, control equipment and piping and valves (CETC 2005). The Octave model additionally includes meters, engineering and construction costs and contingencies. **Table 1** summarizes the percent differences between the capital costs for the RETScreen and Octave model outputs for one of the Dominion City network configurations. The Octave results are consistently larger than RETScreen suggesting a conservative analysis of ROI from the Octave results.

Octave	RetScreen	% Difference
Boiler Size (kW)		
169	155	8.7%
Capital Costs		
Biomass Boiler		
$104,920	$94,705	10.2%
District Network Piping		
$471,540	$441,141	6.7%
Enerrgy Transfer Stations		
$42,909	$41,397	3.6%

Table 1: Capital cost breakdown for an example network configuration comparing output from RETScreen and Octave.

Excel Visualization

The Octave model produces five output arrays which are exported to excel for further investment analysis. The annual costs for the BAU cases and the annual costs of the system with the amortized capital costs over a 20 year useful life are plotted for each network configuration. The plots determine the year that implementation of the system is recommended. Systems with implementation years in 2030 or sooner (the next ten years) are considered to be feasible. Further analysis of ROI and nBCR were calculated from this year onward for 20 years for the feasible configurations. **Figure 2** is an example of one of the plots for Dominion City that demonstrates the year implementation is recommended (when the orange line with new system annual costs goes below the blue, BAU line).

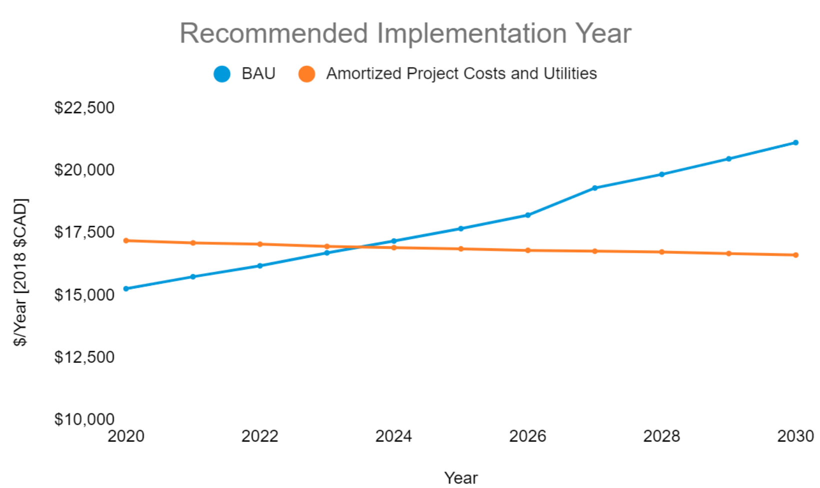

Figure 2: Utilities and amortized capital costs per year versus BAU costs with projected utility rates for a Dominion City network configuration

Analysis for feasible configurations and system combinations includes determination of the nBCR, simple payback period, annualized ROI and ROI. All figures are calculated for the 20 year useful life period after the recommended implementation year. The annual revenue for a system is calculated as the

	difference between the BAU annual costs and the new annual utility costs and amortized capital costs. The nBCR is calculated as the net present value (NPV) of the revenues over 20 years of operation divided by the capital costs of a system. An nBCR greater than one indicates a system that has greater benefit than it does cost over its useful life. The NPV is also used to calculate the simple payback period and ROI. The year when the cumulative NPV of revenues from time of installation exceeds that of the capital costs is the year when the system is considered to be paid back. The ROI is calculated as the NPV of the revenues over 20 years minus the capital costs divided by the capital costs. The ROI is presented as a percentage. Annualized ROI, also a percentage, is calculated using **Equation 35**, where R is the sum of revenues. Annualized ROI (%) = $(1 - NPV(R)^{(1/20)}) - 1$ (35)
References	Alberta Energy Regulator. 2019. Henry Hub Price. https://www.aer.ca/providing-information/data-and-reports/statistical-reports/st98/prices-and-capital-expenditure/natural-gas-prices/henry-hub-price British Columbia. District of Lillooet - Biomass Heating System. Green Energy as a Rural Economic Development Tool Project. http://www.finkmachine.com/pdf/district-of-lillooet-case-study-rural-green-bc.pdf CANMET Energy Technology Centre (CETC). 2005. Clean Energy Project Analysis: RETScreen® Engineering & Cases Textbook. Biomass Heating Project Analysis. Natural Resources Canada. Community Energy Association. 2013. Small-Scale Biomass District Heating Guide: A Guide for BC Communities. http://www.urecon.com/documents/pdfs/white_papers/BC_Biomass.pdf Community Energy Association. 2014. Small Scale Biomass District Heating Handbook - A Reference for Alberta and BC Local Governments. https://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/apa14836/$file/handbook.pdf Clarke, S. and Preto, F. 2011. Biomass Burn Characteristics. Ministry of Agriculture, Food and Rural Affairs. http://www.omafra.gov.on.ca/english/engineer/facts/11-033.htm De Boer, T.J .2018. Optimization of a District Heating Network with the Focus on Heat Loss. Delft University of Technology. GNU Octave. 2020. About. https://www.gnu.org/software/octave/about.html Lindgren, J. 2015. Numerical modelling of district heating networks. Umeå University, Faculty of Science and Technology, Department of Physics. Martin-Du Pan, O., Woods, P. and Hanson-Graville, R. 2018. Optimising pipe sizing and operating temperatures for district heating networks to minimise operational energy consumption. Building Services Engineering Research and Technology. Technical Note: 1-19. Natural Resources Canada (NRCan). 2019. RETScreen. https://www.nrcan.gc.ca/maps-tools-publications/tools/data-analysis-software-modelling/retscreen/7465

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STRATEGIC COMMUNITY CONSULTING

9.4 Nativus Energy: Facility Asset Energy and Emissions Review

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NATIVUS ENERGY

Facility Asset Energy and Emissions Review

Municipality of Emerson-Franklin

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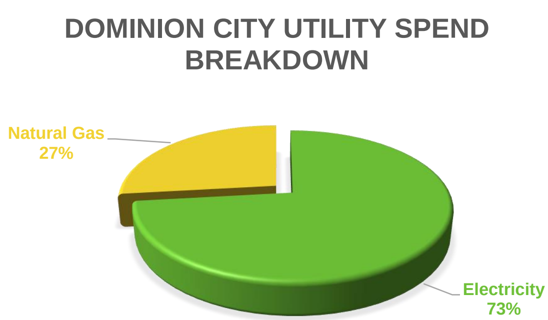
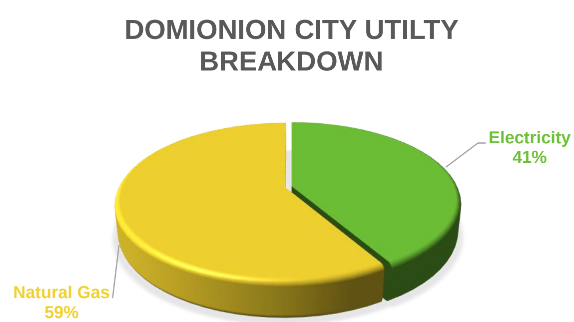
Summary

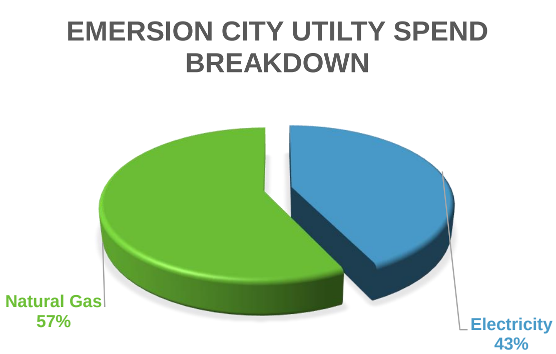
An analysis of select building stock within Dominion City and the Town of Emerson was evaluated to determine high level energy conservation measures and ascertain the energy profile and emissions impact they have on their respective community. Within table 1 below the summation of energy and emissions data is provided by community.

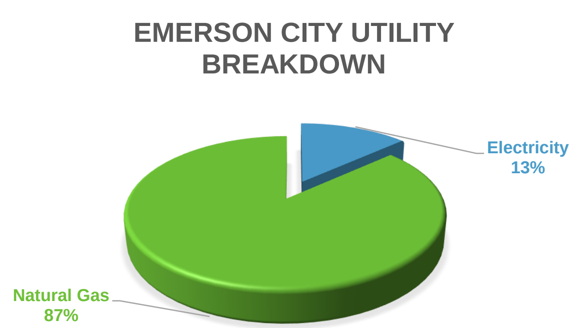
Community	Electrical Consumption (kWh)	Electrical Emissions (eMtC02)	Electrical Cost	Natural Gas Consumption (m3)	Natural Gas Emissions (eMtC02)	Natural Gas Cost
Dominion City	504,937	1.714	$52,883.13	67,488	128.15	$19,338.41
Town of Emerson	92,690*	.307*	$23,554.00	57,071*	108.43*	$13,472.00

*Excludes Firehall Electrical Data Along with Community Hall and Curling Club Data. Data Was Not Provided For These Facilities.









PATHWAY

The pathway for taking action on energy within the community and within community infrastructure is to take action by following the conservation pyramid.

Following this approach, the identification through implementation process provides a clear pathway for making intelligent decisions that creates a beneficial impact to the long-term sustainability of the community.

POTENTIAL OPPORTUNITIES

Through review of utility data provided via Dominion City opportunities can be identified from a high-level overview by looking at the facility its function and the role it plays within the community.

The following opportunity list is based solely on bulk utility data and a site walk-thru. No real-time data logging was utilized for this project based on project deliverables.

DOMINION CITY ASSETS

1. DOMINION CITY OFFICE

The City Office is approximately 306 m2. The facility is heated and ventilated through 3 gas fired furnaces. The furnaces have no outside air connections therefore there is no outside air energy load. With this in mind the building is only subject to the effects of the thermal resistance of the building from weather.

ENERGY INTENSITY AND EMISSIONS EQUIVALENCY

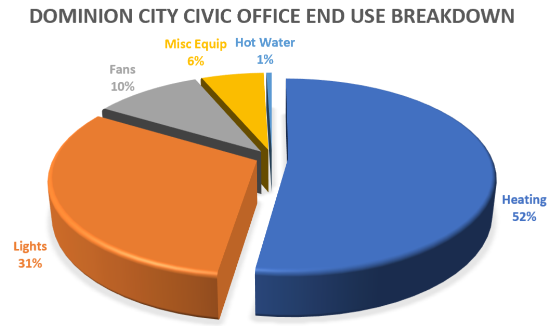
The buildings energy utilization index or energy footprint is 0.67 GJ/m2.

This value is very good for the facility. (GHG emissions are based on Manitoba Hydro conversation factors. Electricity factors are based on Manitoba Hydro's Climate Change Report as a global perspective. Natural gas factors are based on the National Inventory Report – Part 2 and proposed valuation for the Manitoba Carbon Tax program. Conversion factors the FCM uses displayed in brackets).

Baseline electrical consumption (average): 26,613 kWh or 95.8 GJ
Baseline natural gas consumption (average): 2825 m3 or 108 GJ

Emissions from electrical consumption: 18.62 etC02 (0.09 etC02)
Emissions from natural gas consumption: 5.37 etC02

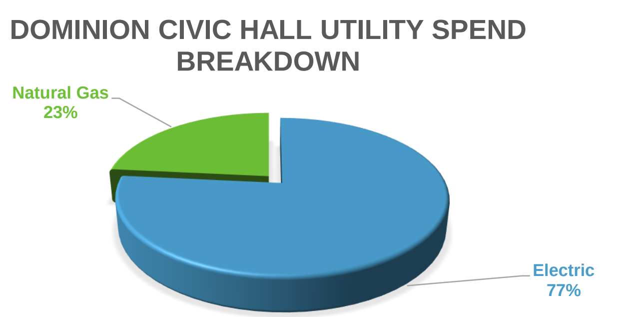
ENERGY END USE BREAKDOWN

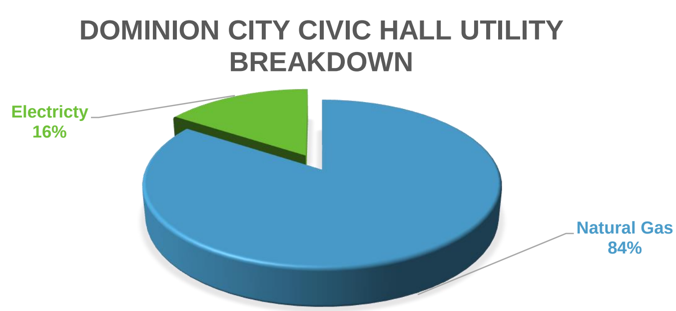


UTILITY DATA SUMMARY

Electrical Consumption Annual (2018): 27,010 kWh
Electrical Cost Annual (2018): $2,967.64
Cost Per kWh (Blended): $0.109/kWh

Natural Gas Consumption Annual (2018): 2761.4 m3
Natural Gas Cost Annual (2018): $909.49
Cost Per m3 (Blended): $0.329





It shall be noted that some data from utility bills is estimate.

ENERGY PROFILE

Image 1 and 2 provide building energy profiles for electricity and natural gas consumption. We can see that the profiles have a consistent trend with no anomalies in energy consumption.

Image 1

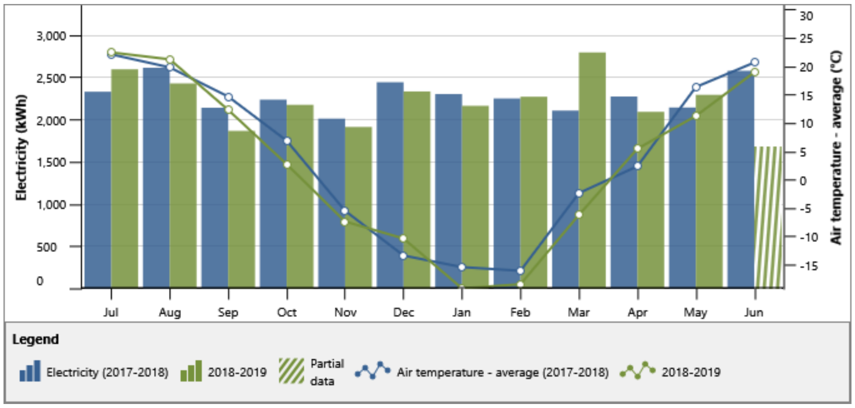
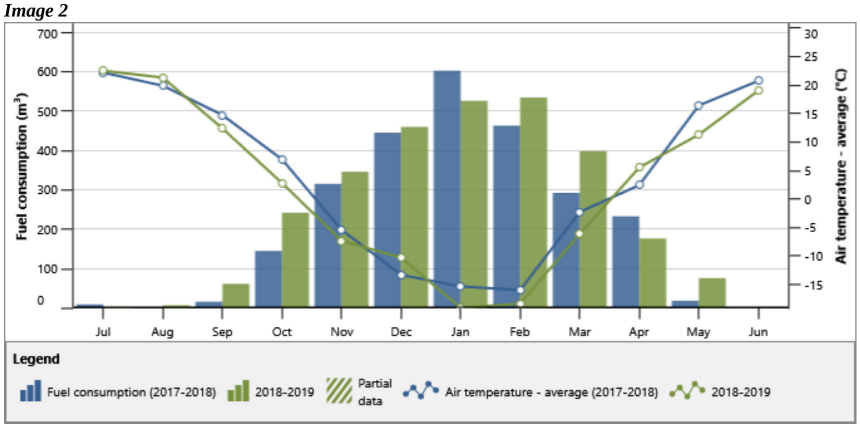


Image 2



We can also see control of the heating plant is quite good through image 3. This is a function of the lack of outside air being drawn into the facility which typically creates larger variations in how well the facility is controlled. Implementation of programmable thermostats would add to the controllability and enable some energy reductions in natural gas consumption and electricity.

Image 3

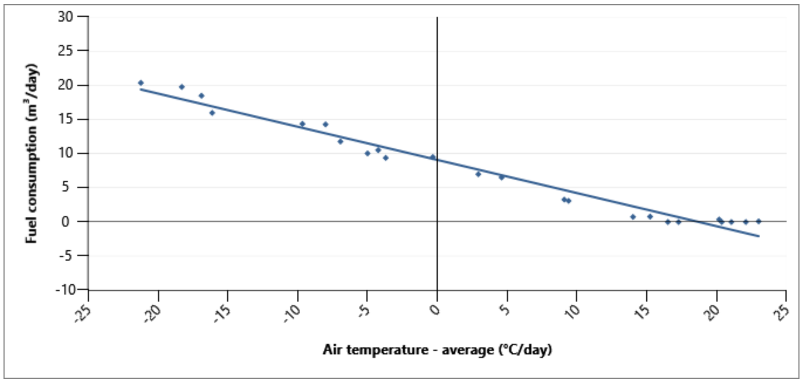
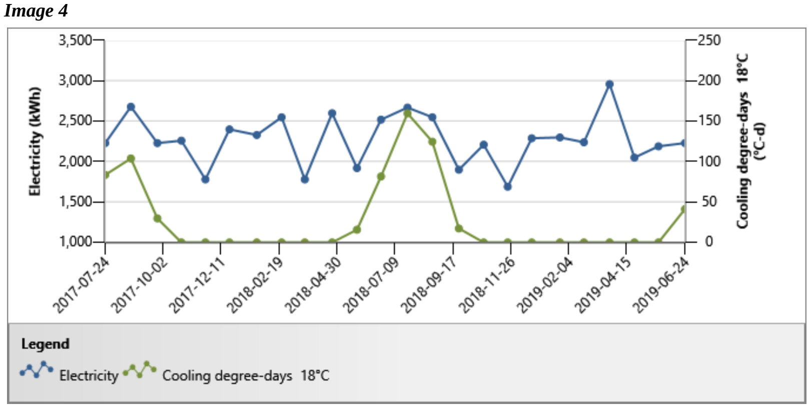


Image 4 details the electrical variability, which when evaluated against cooling degree days (cooling need) and heating degree days (heating need), weather plays a minor role in consumption. Utilization of end-use electrical components such as computers, printer/scanners, and lighting drive the consumption of electricity within the facility. Controlling the use of these end use devices will provide a more consistent and lower use pattern.

Image 4



LOW COST CONSERVATION MEASURES

i. LED Interior, Exterior, and Signage. (Offset Purchase of Electricity)
    a. Varying lights

ii. Occupancy Sensors
    - Washrooms and Closed Office Spaces

iii. Air Side Heat Recovery Ventilation
    i. It shall be noted that with the introduction of ventilation air to meet Indoor Air Quality Requirements (IAQ), additional heating and cooling loads/costs will be incurred.

iv. Programmable Thermostats (Offset Heating (Electricity and Natural Gas)
  i. Occupied and Unoccupied Set Points
  ii. Temperature Limiting
  iii. Fan Limiting

HIGHER COST CONSERVATION MEASURES

i. Solar Air Heating. (Offset Purchase of Heating Fuel (Electricity and Natural Gas)

2. DOMINION CITY FIRE HALL

The fire hall is approximately 690 m2. The facility is heated through 2 wall mount electric boilers feeding in floor heating pipes. Ventilation within the fire hall is through a heat recovery ventilator.
The kitchen/meeting area is provided with a wall mount air conditioner.

ENERGY INTENSITY AND EMISSIONS EQUIVALENCY

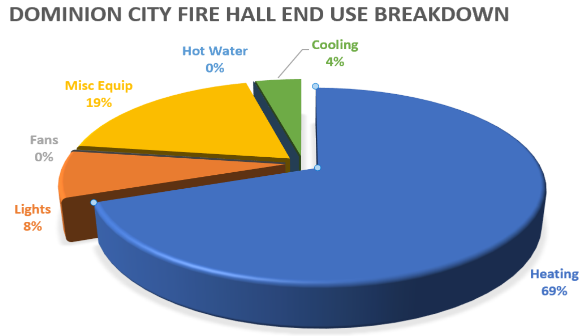
The buildings energy utilization index or energy footprint is 0.34 GJ/m2.

This value is very good for the facility. (GHG emissions are based on Manitoba Hydro conversation factors. Electricity factors are based on Manitoba Hydro's Climate Change Report as a global perspective. Natural gas factors are based on the National Inventory Report – Part 2 and proposed valuation for the Manitoba Carbon Tax program. Conversion factors the FCM uses displayed in brackets).

Baseline electrical consumption (average): 65,400 kWh or 235 GJ
Baseline natural gas consumption (average): No Natural Gas

Emissions from electrical consumption: 57.44 etC02 (0.23 etC02)
Emissions from natural gas consumption: No Natural Gas

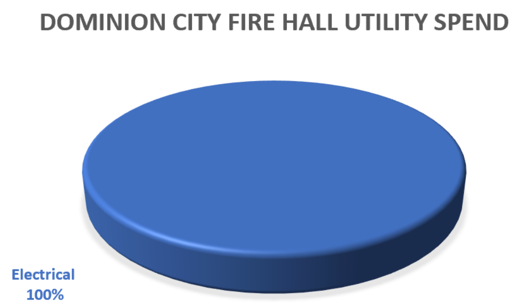
Energy End Use Breakdown



Utility Data Summary

Electrical Consumption Annual (2018): 65.983 kWh
Electrical Cost Annual (2018): $6,900.56
Cost Per kWh (Blended): $0.105/kWh

Natural Gas Consumption Annual (2018): No Natural Gas
Natural Gas Cost Annual (2018): No Natural Gas
Cost Per m3 (Blended): No Natural Gas

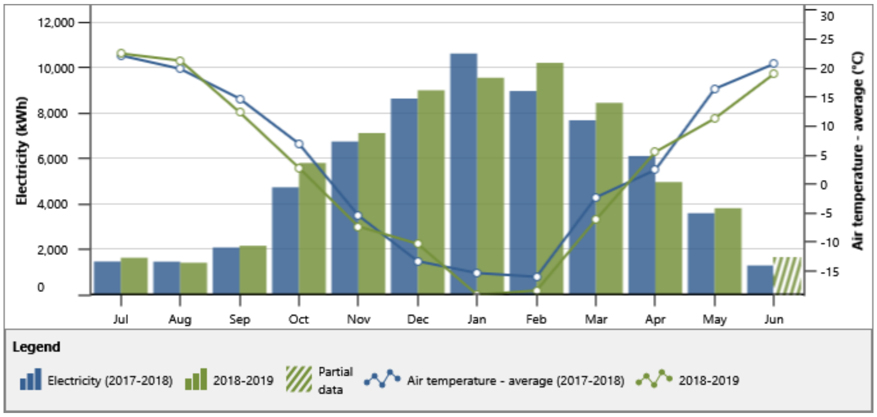


It shall be noted that some data from utility bills is estimate.

ENERGY PROFILE

Image 1 provides the building energy profile for electricity consumption. We can see that the profiles have a consistent trend with no anomalies in energy consumption.

Image 1



We can also see control of the heating plant is quite good through image 2. This is a function of the lack of outside air being drawn into the facility which typically creates larger variations in how well the facility is controlled. Variances in electrical demand are attributed to the misc. loads within the facility such as the air pak machine.

Image 2

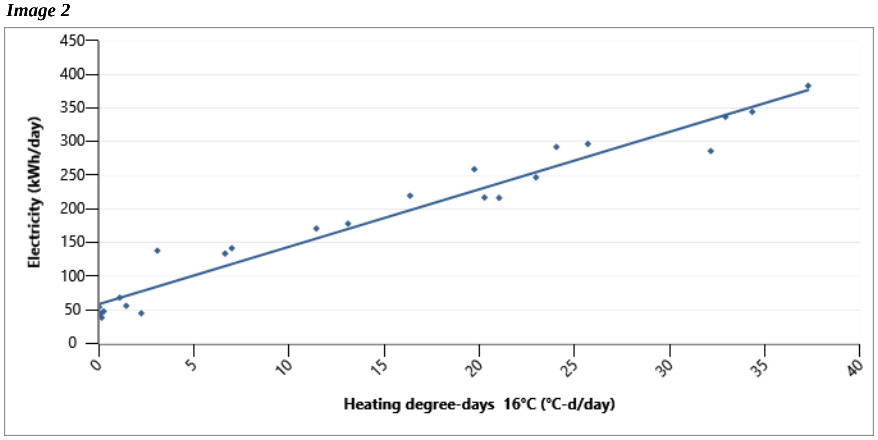
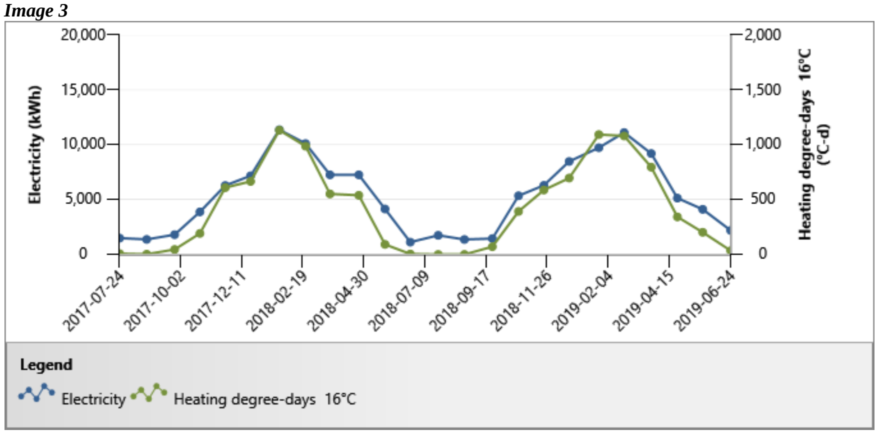


Image 3 outlines the close control of electrical energy vs outdoor air temperature.

Image 3



Low Cost Conservation Measures

i. LED Interior, Exterior, and Signage. (Offset Purchase of Electricity)
   b. Varying lights

ii. Review temperature control sequence for boilers.

Higher Cost Conservation Measures

i. Solar Thermal Hydronic. (Offset Purchase of Heating Fuel (Electricity and Natural Gas)

3. Dominion City Public Works Yard

The public works yard is a warehouse facility with some small work and storage spaces.

Energy Intensity and Emissions Equivalency

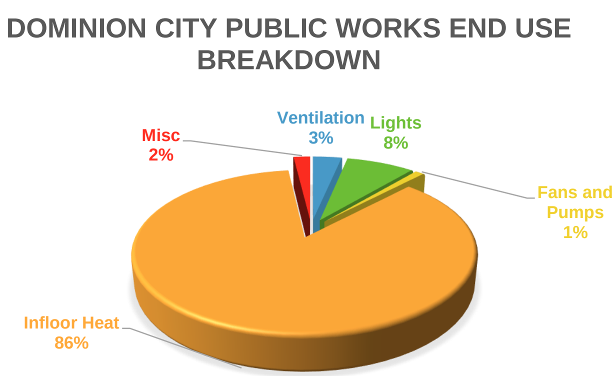
The buildings energy utilization index or energy footprint is 1.4 GJ/m2.

(GHG emissions are based on Manitoba Hydro conversation factors. Electricity factors are based on Manitoba Hydro's Climate Change Report as a global perspective. Natural gas factors are based on the National Inventory Report – Part 2 and proposed valuation for the Manitoba Carbon Tax program. Conversion factors the FCM uses displayed in brackets).

Baseline electrical consumption (average): 25,267 kWh or 91 GJ
Baseline natural gas consumption (average): 24582 m3 or 941 GJ

Emissions from electrical consumption: 18.95 etC02 (0.09 etC02)
Emissions from natural gas consumption: 46.7 etC02

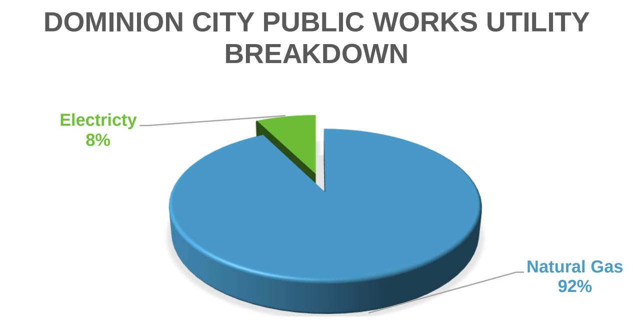
Energy End Use Breakdown

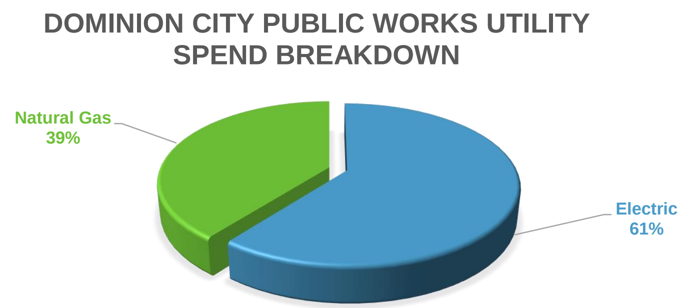


Utility Data Summary

Electrical Consumption Annual (2018): 21,720 kWh
Electrical Cost Annual (2018): $2,444.00
Cost Per kWh (Blended): $0.113/kWh

Natural Gas Consumption Annual (2018): 25,130.8 m3
Natural Gas Cost Annual (2018): $6,198.46
Cost Per m3 (Blended): $0.25/m3





It shall be noted that some data from utility bills are estimates.

ENERGY PROFILE

Image 1 and 2 provide building energy profiles for electricity and natural gas consumption.
The electrical profile (image 1) in March 2019 there was a large power consumption, which is not weather dependant as can be seen against other weather data. This increase in consumption could be from a welding process.

The natural gas profile (image 2) in December 2018 and March 2019 there were large changes in consumption. While weather plays a factor in natural gas consumption on this site, the consumption does not correlate to weather influences unless the facility doors were left open for extended periods of time or thermostat set points were changed.

Image 1

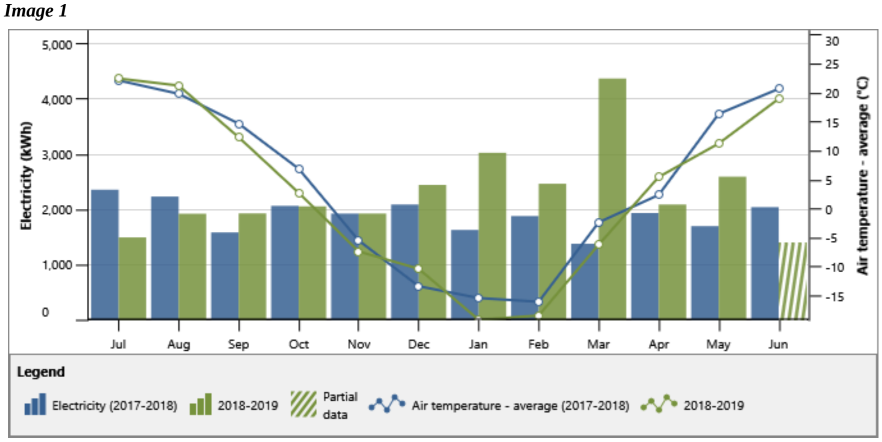
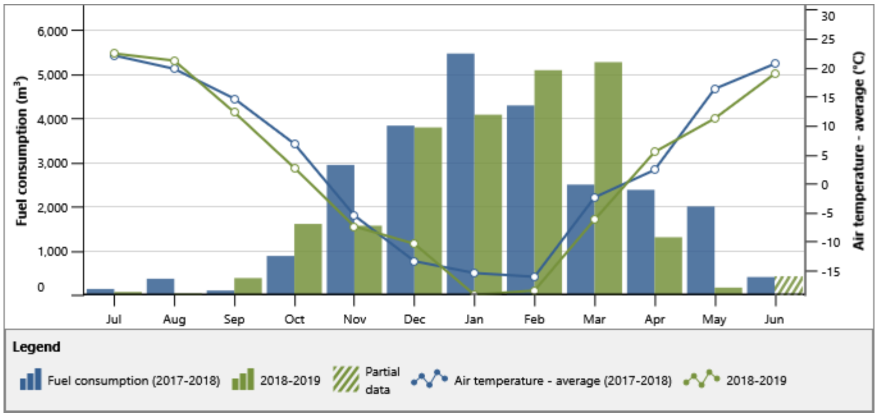
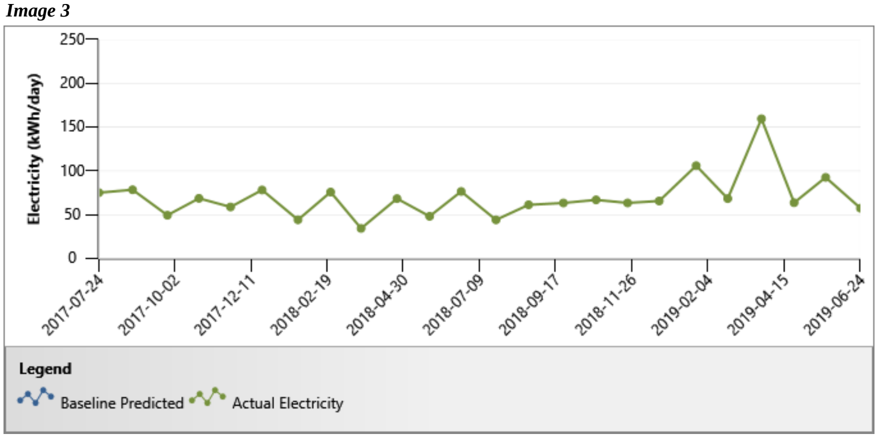


Image 2



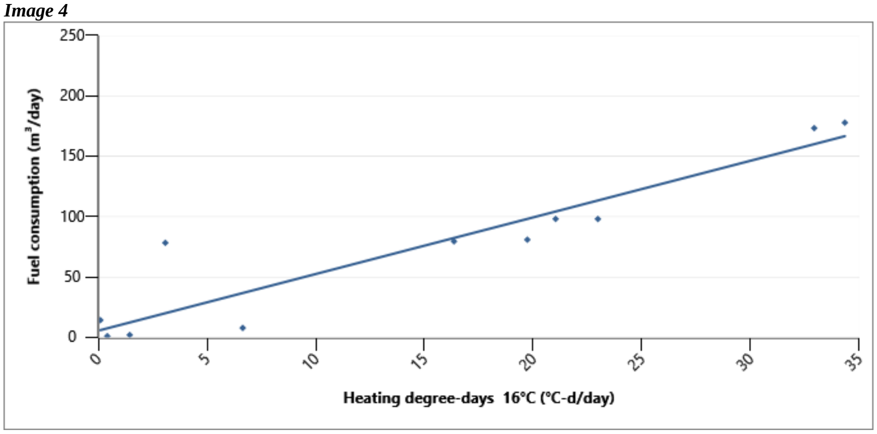
Within image 3 electrical consumption in kWh/day is consistent month over month.

Image 3



Heating within the facility is fairly stable and inline with heating requirements as they relate to weather. Closer control will bring down natural gas consumption.

Image 4



LOW COST CONSERVATION MEASURES

i. LED Interior, Exterior, and Signage. (Offset Purchase of Electricity)
    a. Varying lights

iii. Install Programmable Thermostats
    a. Implement Occupied/Unoccupied Set Points

HIGHER COST CONSERVATION MEASURES

i. Solar Air Heating. (Offset Purchase of Heating Fuel (Natural Gas)

4. DOMINION CITY CURLING CLUB

ENERGY INTENSITY AND EMISSIONS EQUIVALENCY

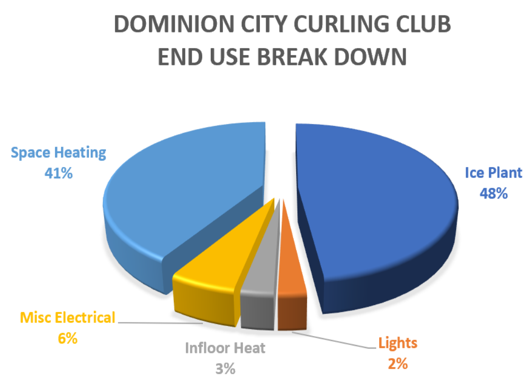
The buildings energy utilization index or energy footprint is 91 GJ/m2.

(GHG emissions are based on Manitoba Hydro conversation factors. Electricity factors are based on Manitoba Hydro's Climate Change Report as a global perspective. Natural gas factors are based on the National Inventory Report – Part 2 and proposed valuation for the Manitoba Carbon Tax program. Conversion factors the FCM uses displayed in brackets).

Baseline electrical consumption (average): 87,980 kWh or 317 GJ
Baseline natural gas consumption (average): 5,744 m3 or 220 GJ

Emissions from electrical consumption: 65.985 etC02 (0.318 etC02)
Emissions from natural gas consumption: 10.91 etC02

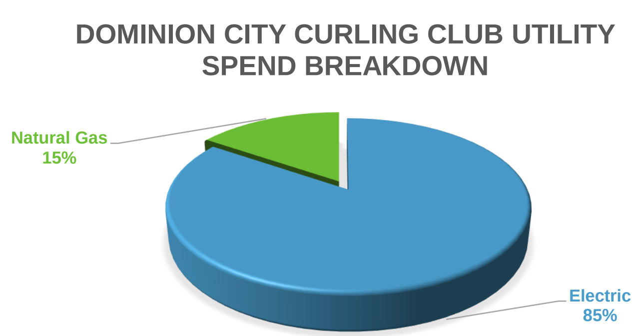
ENERGY END USE BREAKDOWN



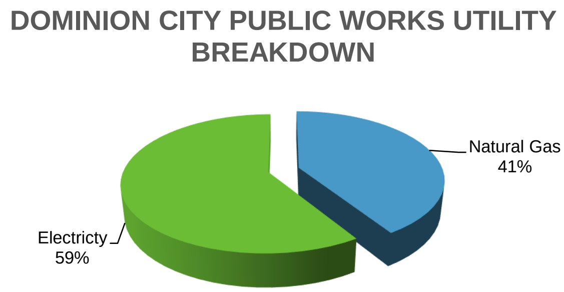
UTILITY DATA SUMMARY

Electrical Consumption Annual (2018): 87,980 kWh
Electrical Cost Annual (2018): $9,548.14
Cost Per kWh (Blended): $0.108/kWh

Natural Gas Consumption Annual (2018): 5,744.519 m3
Natural Gas Cost Annual (2018): $1,749.53
Cost Per m3 (Blended): $0.30/m3



It shall be noted that some data from utility bills are estimates.



Energy Profile

Image 1-3 provide building energy profiles for electricity and natural gas consumption.
The electrical profile (image 1) shows a consistent energy pattern with energy consumption being driven by the refrigeration plant. Image 2 shows the impact of the ice plant from a demand charge perspective, which is a separate charge to kWh energy.

The natural gas profile (image 3) in December 2018 and March 2019 there were.large changes in consumption. While weather plays a factor in natural gas consumption on this site, the consumption does not correlate to weather influences unless the facility doors were left open for extended periods of time or thermostat set points were changed.

Image 1

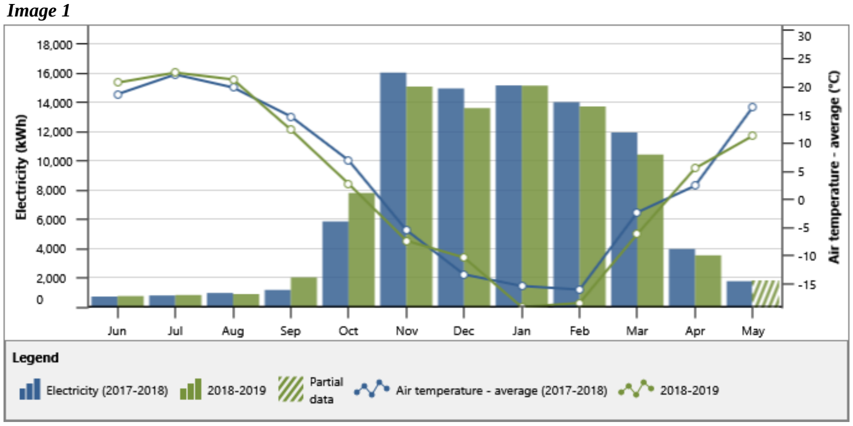


Image 2

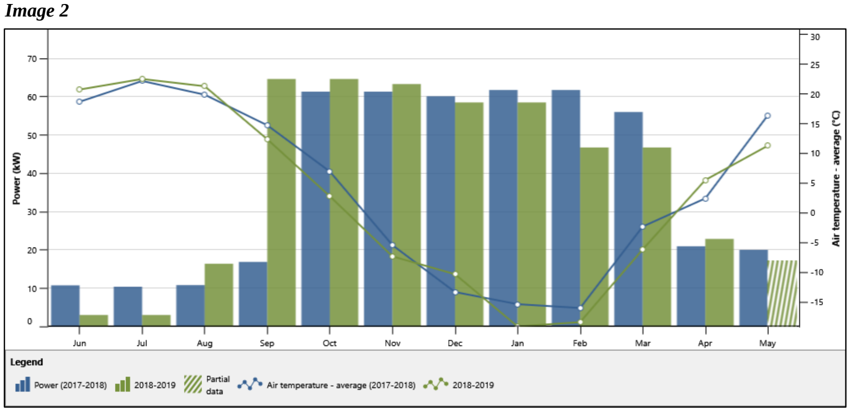
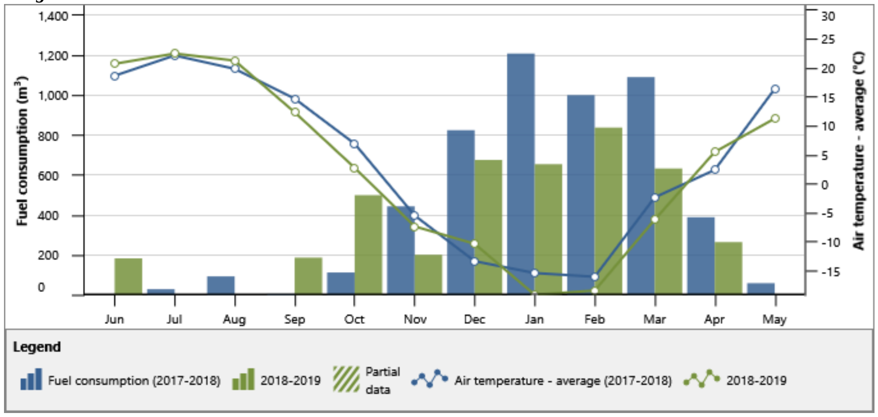
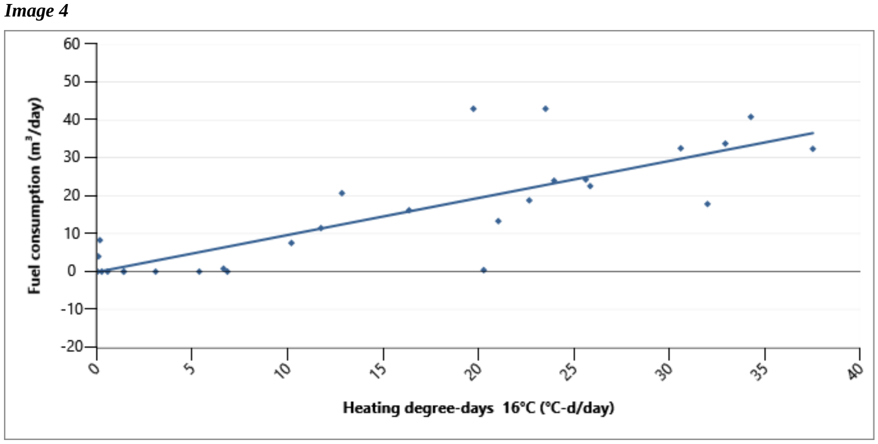


Image 3



The erratic natural gas consumption can be seen from image 4. Improving control will reduce the heating variability thus the consumption.

Image 4



Low Cost Conservation Measures

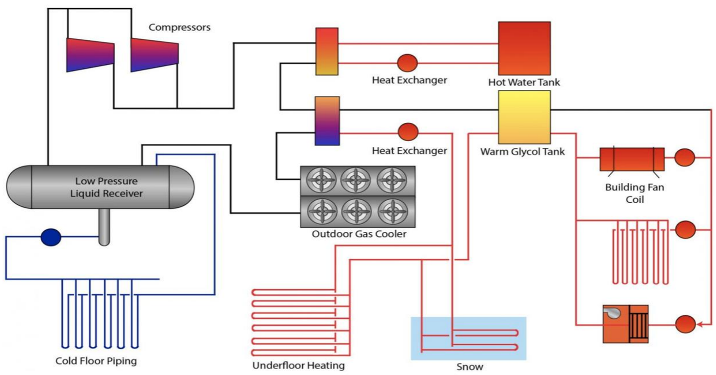
i. LED Interior, Exterior, and Signage. (Offset Purchase of Electricity)

ii. Install Programmable Thermostats
   a. Implement Occupied/Unoccupied Set Points

Higher Cost Conservation Measures

i. Solar Air Heating. (Offset Purchase of Heating Fuel (Natural Gas)

ii. Upgrade Ice Plant w/Heat Recovery and Controls – Arena Plant Side (Offset Purchase of Heating Fuel (Electricity and Natural Gas)



5. Dominion City Community Pool

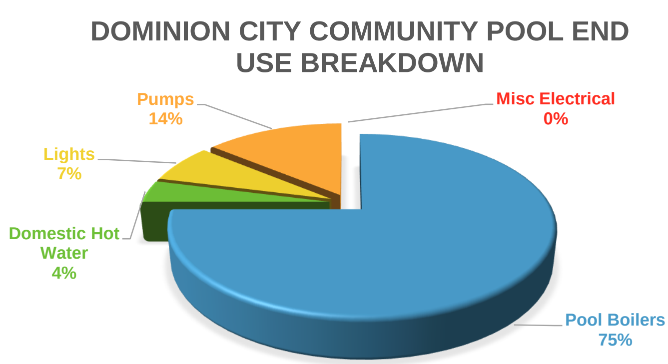
Energy Intensity and Emissions Equivalency

(GHG emissions are based on Manitoba Hydro conversation factors. Electricity factors are based on Manitoba Hydro's Climate Change Report as a global perspective. Natural gas factors are based on the National Inventory Report – Part 2 and proposed valuation for the Manitoba Carbon Tax program. Conversion factors the FCM uses displayed in brackets).

Baseline electrical consumption (average): 23,885 (86 GJ)
Baseline natural gas consumption (average): 10,208 (646.6 GJ)

Emissions from electrical consumption: 17.92 eMtc02 (0.1)
Emissions from natural gas consumption: 19.39 eMtc02

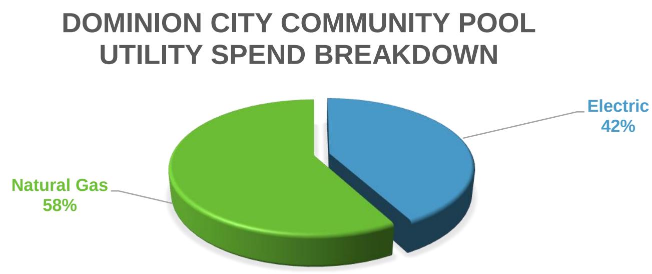
Energy End Use Breakdown



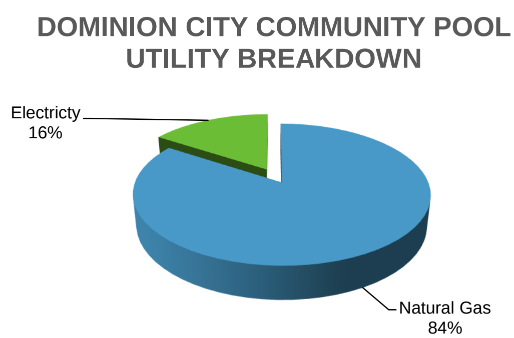
UTILITY DATA SUMMARY

Electrical Consumption Annual (2017): 23,440 kWh
Electrical Cost Annual (2017): $2,579.12
Cost Per kWh (Blended): $0.11/kWh

Natural Gas Consumption Annual (2017): 9,292.90 m3
Natural Gas Cost Annual (2017): $3,185.14
Cost Per m3 (Blended): $0.34/m3



It shall be noted that some data from utility bills are estimates.



Energy Profile

Image 1 and 2 provide building energy profiles for electricity and natural gas consumption.

Due to the seasonal nature only monthly analysis of the utility profiles has been undertaken. It was also observed that utility data had numerous estimated values by Manitoba Hydro which create caution in data review. Image 1 shows an outlier in electrical consumption for July. July 2017 has a value of 7,000 kWh vs July 2018 of 4,000 kWh. Utility data during the operating months is expected to be consistent. This variance could be due to a pump failure/repair undertaken offsetting electrical use.

Image 1

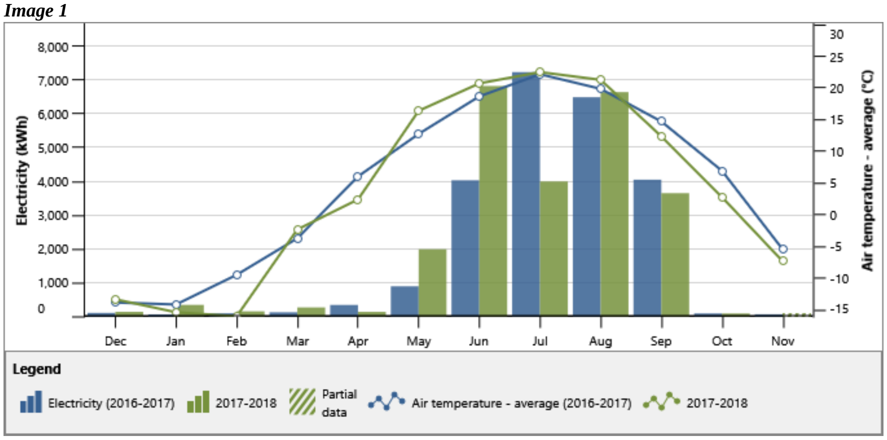
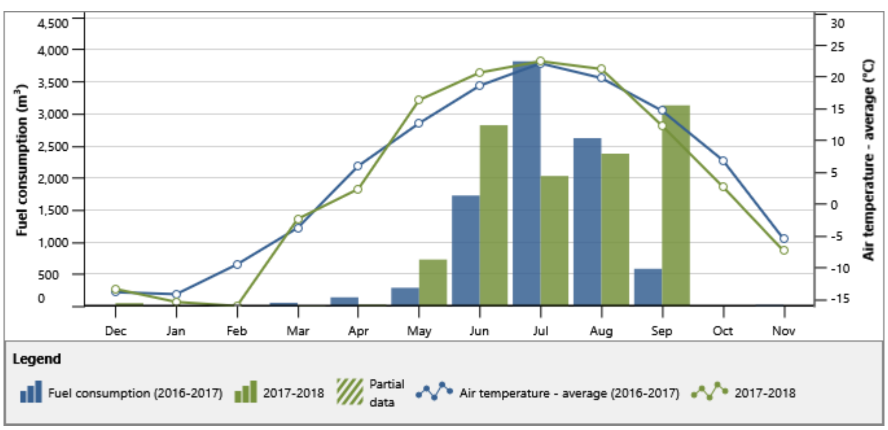


Image 2 provides insight to the natural gas use on site. We see a 45% decrease in natural gas use in 2018 compared to 2017. Due to the similarity in outdoor temperatures it is expected the 2017 values are due to improper boiler set point.

Image 2



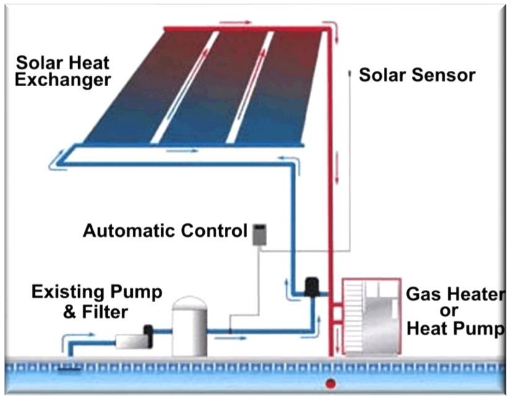
Low Cost Conservation Measures

i. LED Interior, Exterior, and Signage. (Offset Purchase of Electricity)

ii. Night Set Back Boiler Water Temperature 2 deg F

Higher Cost Conservation Measures

i. Utilize solar thermal for hybrid pool water heating



6. Dominion City Community Hall

Energy Intensity and Emissions Equivalency

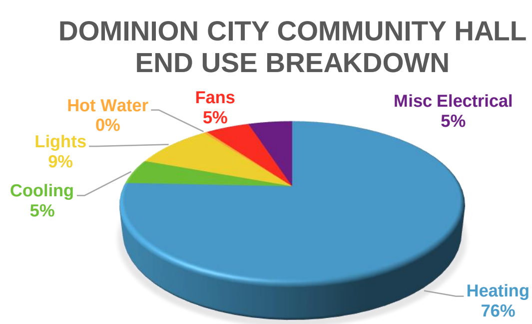
The buildings energy utilization index or energy footprint is 0.44 GJ/m2.

(GHG emissions are based on Manitoba Hydro conversation factors. Electricity factors are based on Manitoba Hydro's Climate Change Report as a global perspective. Natural gas factors are based on the National Inventory Report – Part 2 and proposed valuation for the Manitoba Carbon Tax program. Conversion factors the FCM uses displayed in brackets).

Baseline electrical consumption (average): 8017 kWh or 28.86 GJ
Baseline natural gas consumption (average): 5,562 m3 or 210 GJ

Emissions from electrical consumption: 5.612 etC02 (0.03 etC02)
Emissions from natural gas consumption: 11.124 etC02

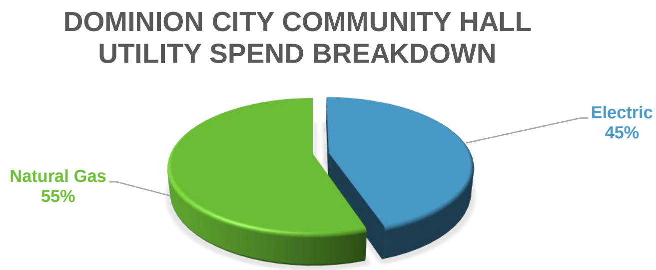
Energy End Use Breakdown



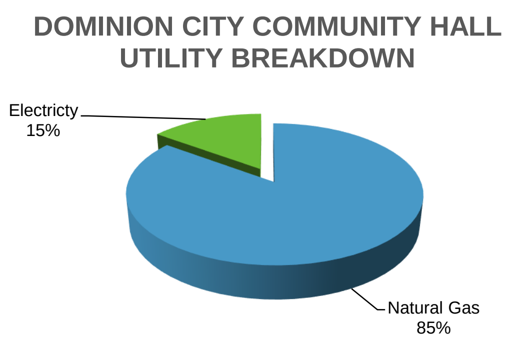
Utility Data Summary

Electrical Consumption Annual (2018): 9514 kWh
Electrical Cost Annual (2018): $1,233.77
Cost Per kWh (Blended): $0.13/kWh

Natural Gas Consumption Annual (2018): 5,117.95 m3
Natural Gas Cost Annual (2018): $1,513.84
Cost Per m3 (Blended): $0.30/m3



It shall be noted that some data from utility bills are estimates.



Energy Profile

Image 1-3 provide building energy profiles for electricity and natural gas consumption.
The electrical profile (image 1) shows a consistent energy pattern respective to air temperature. It shall be noted that the facility is heated through natural gas, thus the impact of air temperature has little influence on consumption. Consumption with the building is driven by lighting and misc kitchen equipment and 1 duct heater.

Image 2 shows the natural gas profile with an outlier occurring in January, February, March in 2018. Natural Gas consumption does not coincide with thermal impact from weather. This may be a result of thermostat manipulation beyond typical temperature set points. 2019 Has a consumption profile in line with expectations.

Image 1

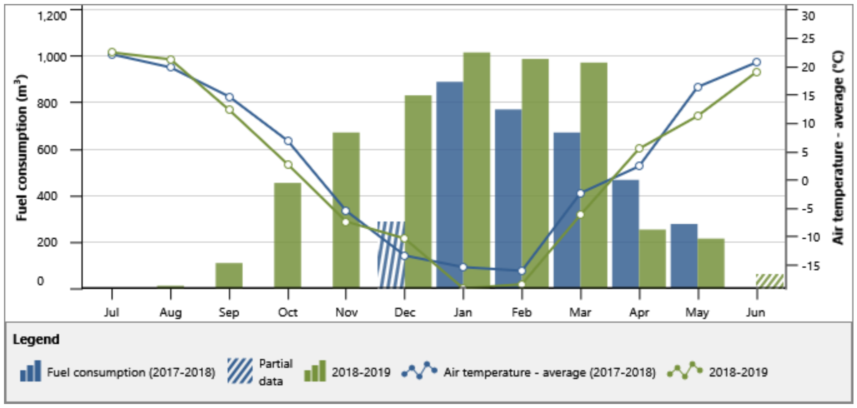
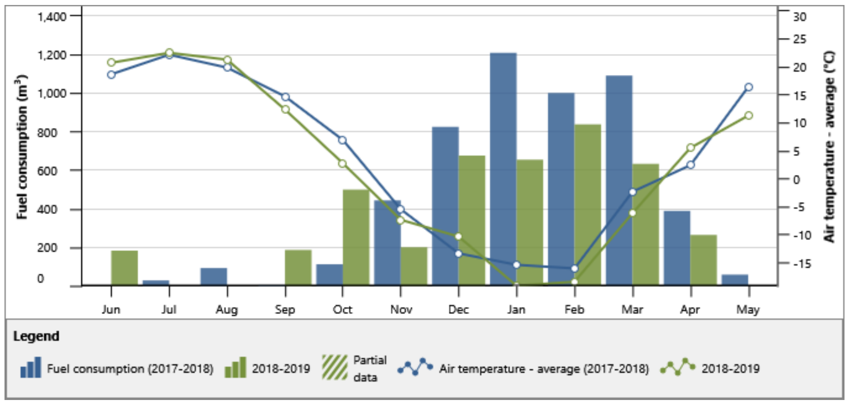
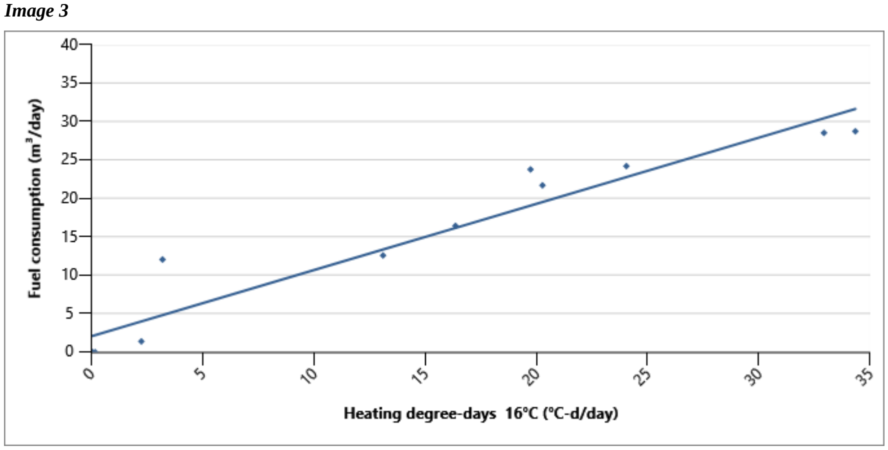


Image 2



The regression profile for natural gas in image 3 for 2019, shows good control of the HVAC equipment. Additional improvement can be achieved through set point enforcement and occupied and unoccupied temperature set points.

Image 3



Low Cost Conservation Measures

ii. LED Interior, Exterior, and Signage. (Offset Purchase of Electricity)

iii. Install Programmable Thermostats
   a. Implement Occupied/Unoccupied Set Points

7. Dominion City Abbyfield Care Facility

Energy Intensity and Emissions Equivalency

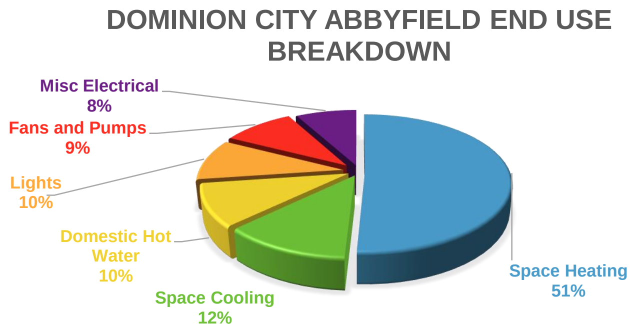
The buildings energy utilization index or energy footprint is 0.54 GJ/m2.

(GHG emissions are based on Manitoba Hydro conversation factors. Electricity factors are based on Manitoba Hydro's Climate Change Report as a global perspective. Natural gas factors are based on the National Inventory Report – Part 2 and proposed valuation for the Manitoba Carbon Tax program. Conversion factors the FCM uses displayed in brackets).

Baseline electrical consumption (average): 65,520 kWh or 236 GJ
Baseline natural gas consumption (average): 3,545 m3 or 132 GJ

Emissions from electrical consumption: 45.86 (0.22 etC02)
Emissions from natural gas consumption: 17.72 etC02

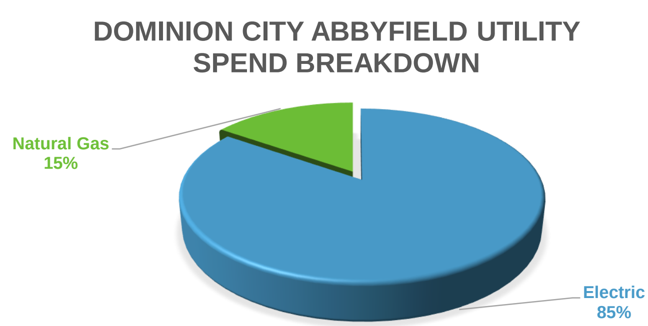
Energy End Use Breakdown



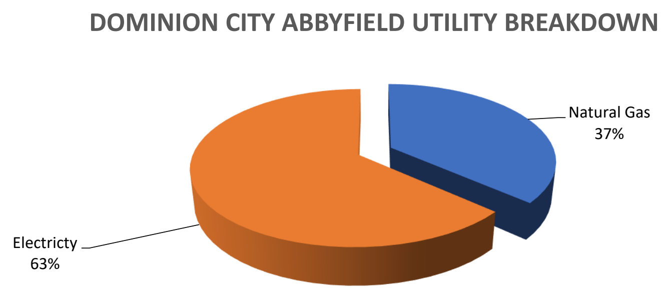
Utility Data Summary

Electrical Consumption Annual (2017): 65,520 kWh
Electrical Cost Annual (2017): $6,506.90
Cost Per kWh (Blended): $0.10/kWh

Natural Gas Consumption Annual (2017): 3,545 m3
Natural Gas Cost Annual (2017): $1,178.95
Cost Per m3 (Blended): $0.33/m3



It shall be noted that some data from utility bills are estimates.



Energy Profile

Image 1-3 provide building energy profiles for electricity and natural gas consumption.
The electrical profile (image 1) shows a levelized consumption pattern.   Limited utility data eliminates the ability to review year over year patterns or anomalies.
We can see increases in electrical energy due to cooling and zoned electric baseboard reheat.

Image 2 shows the natural gas profile. As the building is well controlled and constructed we see .

Image 1

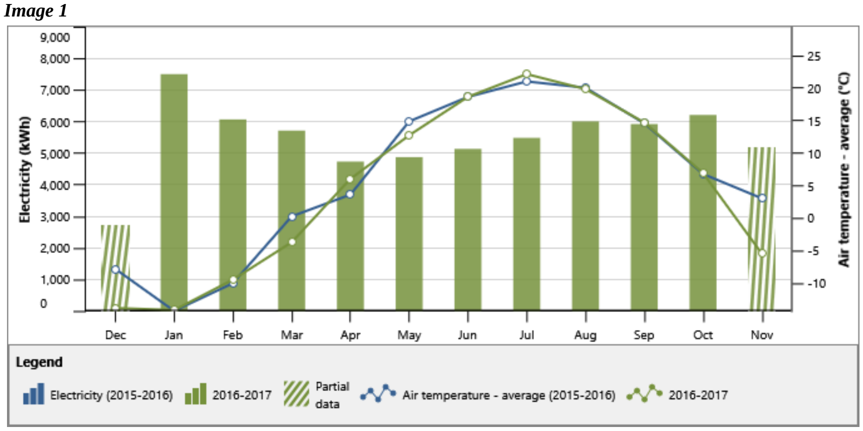
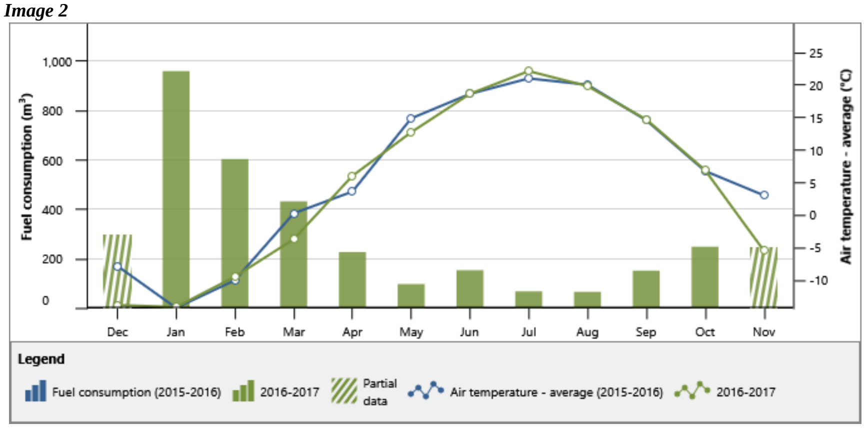


Image 2



Low Cost Conservation Measures

i. LED Interior, Exterior, and Signage. (Offset Purchase of Electricity)

ii. Set Net Set Back Schedules. (Reduce Natural Gas Consumption)

8. Dominion City Arena

Energy Intensity and Emissions Equivalency

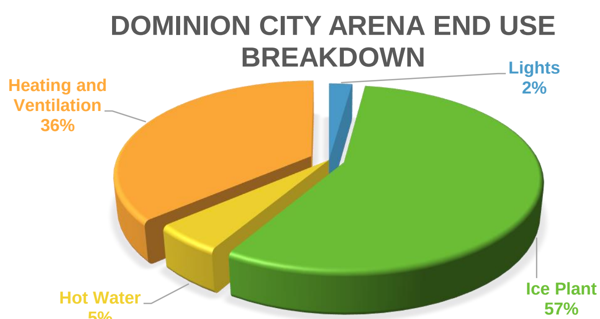
The buildings energy utilization index or energy footprint is 0.50 GJ/m2.

(GHG emissions are based on Manitoba Hydro conversation factors. Electricity factors are based on Manitoba Hydro's Climate Change Report as a global perspective. Natural gas factors are based on the National Inventory Report – Part 2 and proposed valuation for the Manitoba Carbon Tax program. Conversion factors the FCM uses displayed in brackets).

Baseline electrical consumption (average): 202,255 kWh or 728.12 GJ
Baseline natural gas consumption (average): 14,982 m3 or 567.67 GJ

Emissions from electrical consumption: 141.56 etC02 (0.672 etC02)
Emissions from natural gas consumption: 29.96 etC02

Energy End Use Breakdown

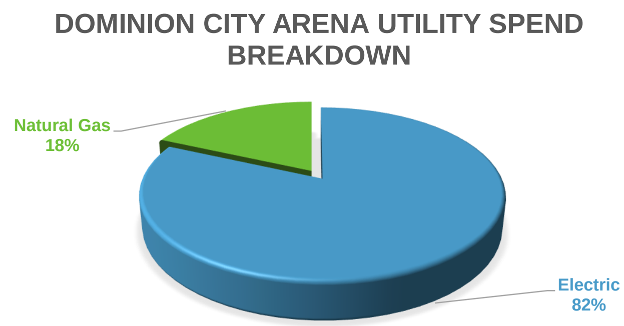


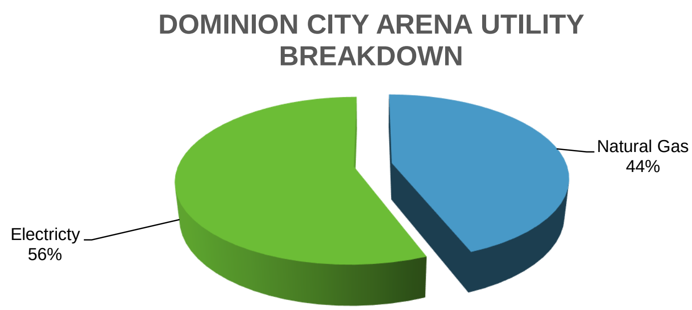
Utility Data

Summary

Electrical Consumption Annual (2018/2019): 202,255 kWh
Electrical Cost Annual (2018/2019): $20,703
Cost Per kWh (Blended): $0.102/kWh

Natural Gas Consumption Annual (2018/2019): 14,982 m3
Natural Gas Cost Annual (2018/2019): $4,630.00
Cost Per m3 (Blended): $0.31/m3





It shall be noted that some data from utility bills are estimates.

ENERGY PROFILE

Image 1-3 provide building energy profiles for electricity and natural gas consumption.
The electrical profile (image 1) shows a levelized consumption pattern.   Limited utility data eliminates the ability to review year over year patterns or anomalies.
We can see increases in electrical energy due to cooling and zoned electric baseboard reheat.

Image 2 shows the natural gas profile. As the building is well controlled and constructed we see .

Image 1

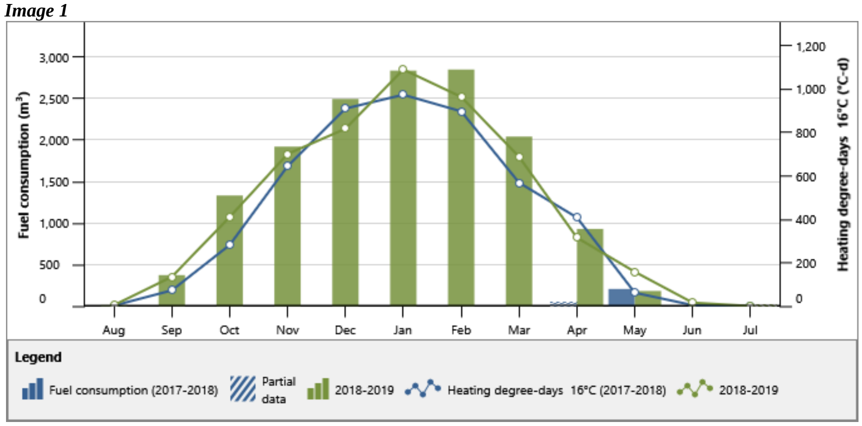
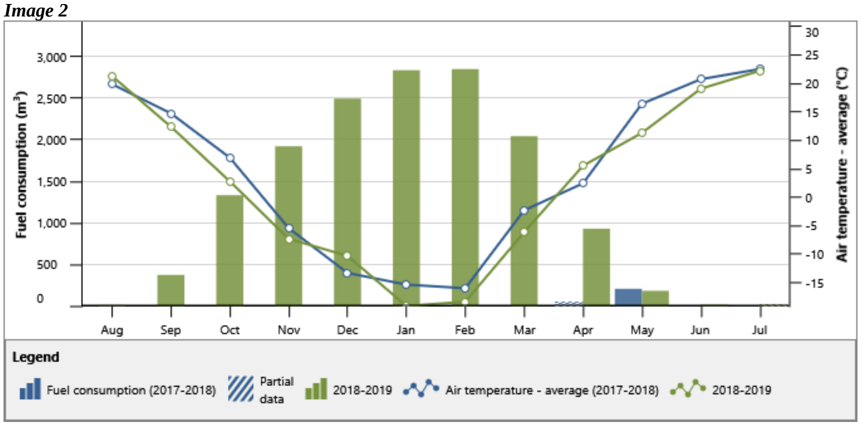
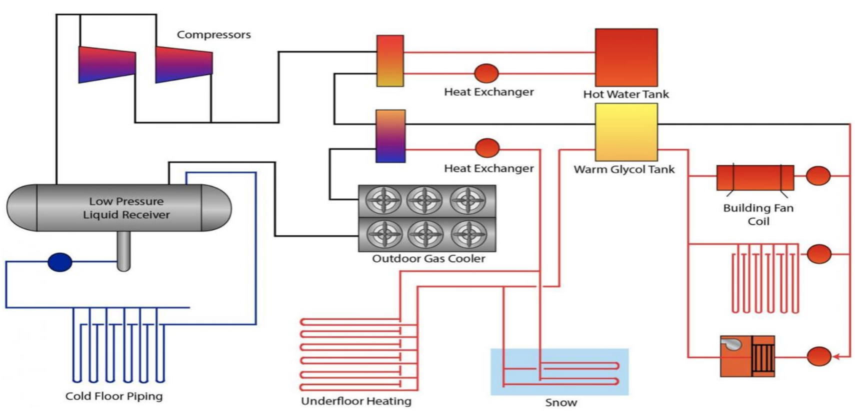


Image 2



HIGH COST CONSERVATION MEASURES

i. Heat Recovery – Arena Plant Side (Offset Purchase of Heating Fuel (Electricity and Natural Gas)



It shall be noted that at the time of inspection the existing ammonia plan was leaking ammonia and we evacuated the building. This is a legacy plant and needs attention.

EMERSON

1. EMERSION TOWN HALL

The City Office is approximately 783 m2. The facility is heated with a new natural gas fired boiler feeding cast iron radiators. The facility has no mechanical outside air connections therefore there is no outside air energy load. With this in mind the building is only subject to the effects of the thermal resistance of the building from weather.

ENERGY INTENSITY AND EMISSIONS EQUIVALENCY

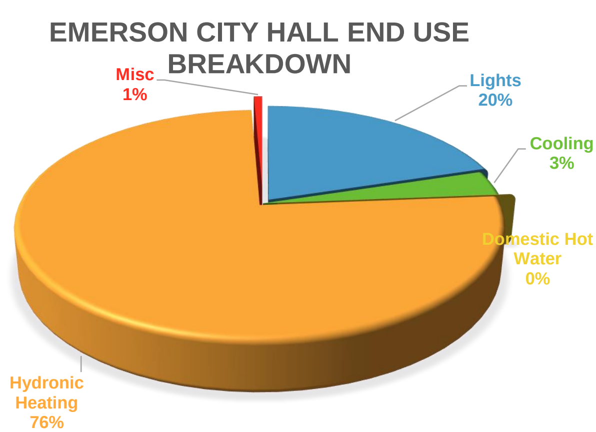
The buildings energy utilization index or energy footprint is 1.0 GJ/m2.

(GHG emissions are based on Manitoba Hydro conversation factors. Electricity factors are based on Manitoba Hydro's Climate Change Report as a global perspective. Natural gas factors are based on the National Inventory Report – Part 2 and proposed valuation for the Manitoba Carbon Tax program. Conversion factors the FCM uses displayed in brackets).

Baseline electrical consumption (average): 44,329 kWh or 159.58 GJ
Baseline natural gas consumption (average): 16,990 m3 or 643.75 GJ

Emissions from electrical consumption: 31.03 etC02 (0.147 etC02)
Emissions from natural gas consumption: 33.98 etC02

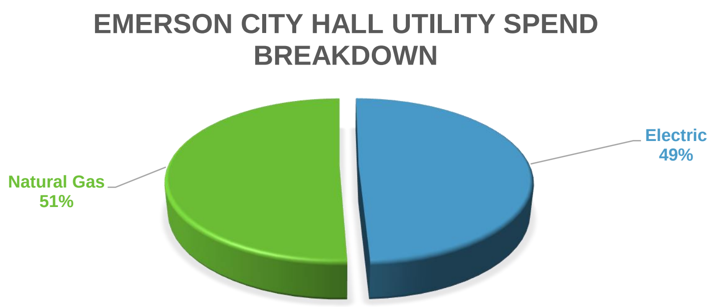
ENERGY END USE BREAKDOWN



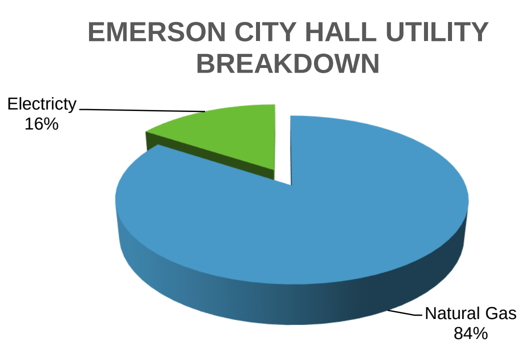
UTILITY DATA SUMMARY

Electrical Consumption Annual (2018): 43,640 kWh
Electrical Cost Annual (2018): $4,609.00
Cost Per kWh (Blended): $0.106/kWh

Natural Gas Consumption Annual (2018): 17,620 m3
Natural Gas Cost Annual (2018): $4,721.00
Cost Per m3 (Blended): $0.268



It shall be noted that some data from utility bills is estimate. Values from Manitoba hydro for 0 consumption of gas is due to meter readings not being read.



ENERGY PROFILE

Image 1 and 2 provide building energy profiles for electricity and natural gas consumption. We can see that the profiles have a consistent trend with no anomalies in energy consumption.

Image 1

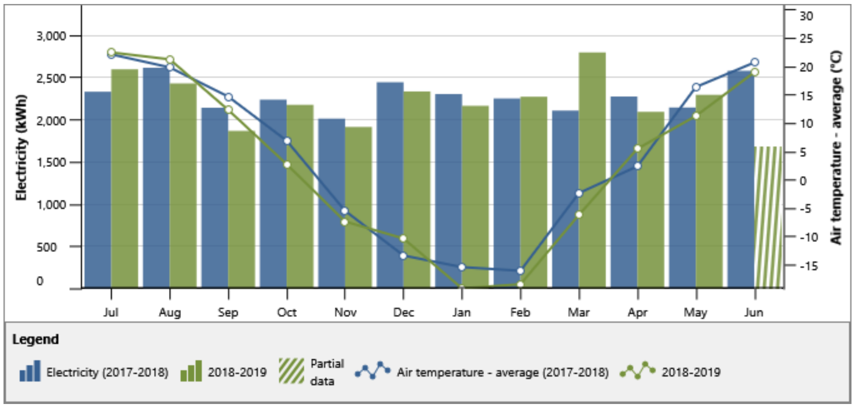
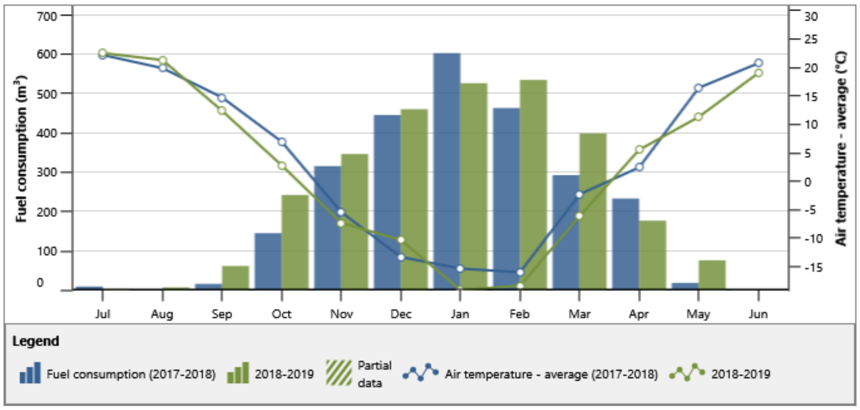
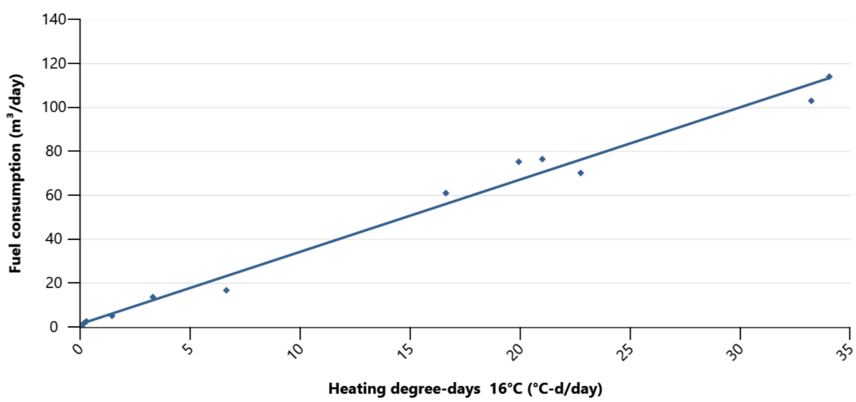


Image 2



We can also see control of the heating plant is quite good through image 3. With the lack of outside air being drawn into the facility there is very limited variability. Additionally, with the new boiler and temperature actuators this enhances the efficiency of the system.

Image 3



Low Cost Conservation Measures

i. LED Interior, Exterior, and Signage. (Offset Purchase of Electricity)
   a. Varying lights

ii. Occupancy Sensors
   - Washrooms and Closed Office Spaces

iii. Air Side Heat Recovery Ventilation
   i. It shall be noted that with the introduction of ventilation air to meet Indoor Air Quality Requirements (IAQ), additional heating and cooling loads/costs will be incurred.

iv. Programmable Thermostats (Offset Heating (Electricity and Natural Gas)
   i. Occupied and Unoccupied Set Points
   ii. Temperature Limiting
   iii. Fan Limiting

Higher Cost Conservation Measures

i. Insulate All Heating Lines
   i. All hydronic heating lines are bare without insulation. Insulating lines will reduce energy losses in the distribution piping though-out the facility.

ii. Solar Air Heating. (Offset Purchase of Heating Fuel (Electricity and Natural Gas)

9. Emerson City Community Pool

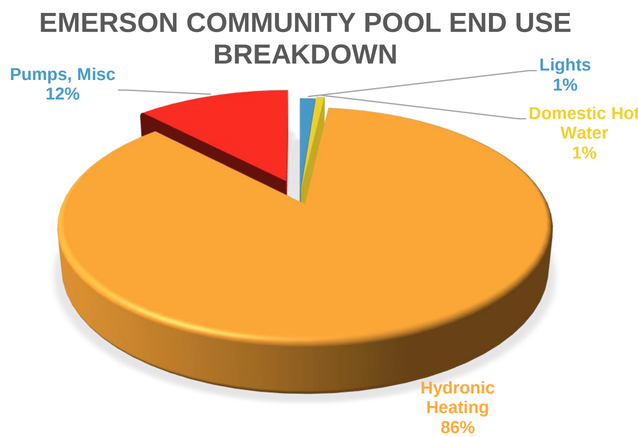
Energy Intensity and Emissions Equivalency

(GHG emissions are based on Manitoba Hydro conversation factors. Electricity factors are based on Manitoba Hydro's Climate Change Report as a global perspective. Natural gas factors are based on the National Inventory Report – Part 2 and proposed valuation for the Manitoba Carbon Tax program. Conversion factors the FCM uses displayed in brackets).

Baseline electrical consumption (average): 26,474 kWh (95.31 GJ)
Baseline natural gas consumption (average): 14,455 m3 (547.7 GJ)

Emissions from electrical consumption: 18.53 eMtc02 (0.09)
Emissions from natural gas consumption: 28.91 eMtc02

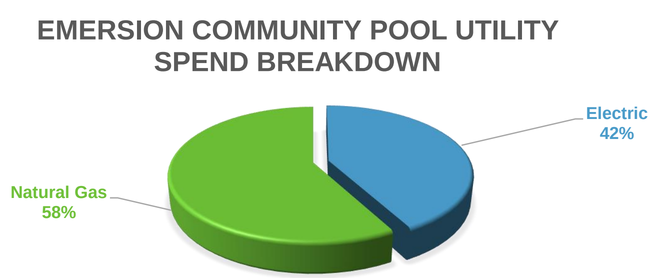
Energy End Use Breakdown



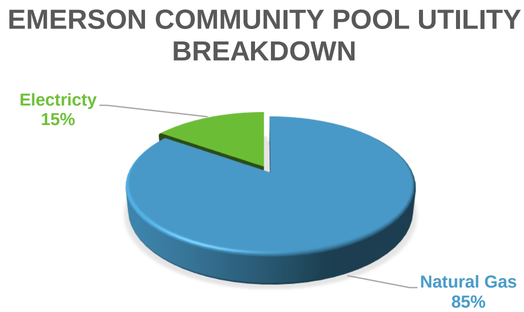
Utility Data Summary

Electrical Consumption Annual (2018): 25,143 kWh
Electrical Cost Annual (2017): $2,855.00
Cost Per kWh (Blended): $0.113/kWh

Natural Gas Consumption Annual (2017): 12,639 m3
Natural Gas Cost Annual (2017): $3,921.00
Cost Per m3 (Blended): $0.31/m3



It shall be noted that some data from utility bills are estimates.



ENERGY PROFILE

Image 1 and 2 provide building energy profiles for electricity and natural gas consumption.

Due to the seasonal nature only monthly analysis of the utility profiles has been undertaken. It was also observed that utility data had numerous estimated values by Manitoba Hydro which create caution in data review. Image 1 shows an outlier in electrical consumption for July. July 2017 has a value of 9800 kWh vs July 2018 of 2,200 kWh. Utility data during the operating months is expected to be consistent. This variance could be due to a pump failure/repair undertaken offsetting electrical use or unusual operating conditions. The dashed line in June 2018/2019 data is due to partial utility data available for that month.

Image 1

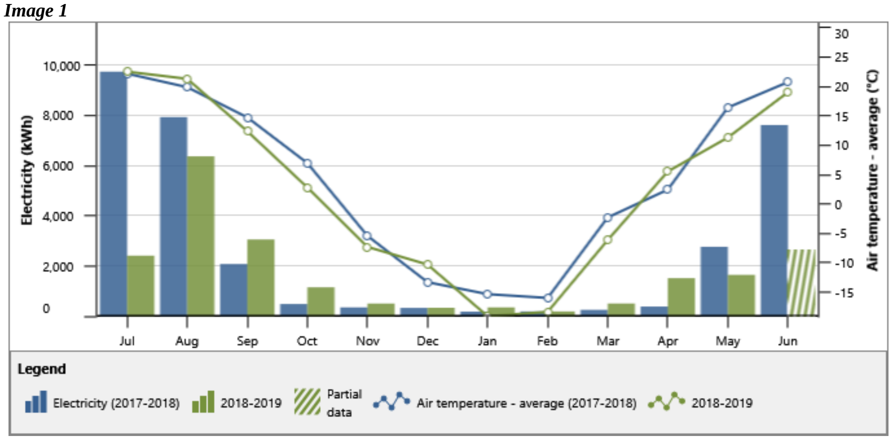
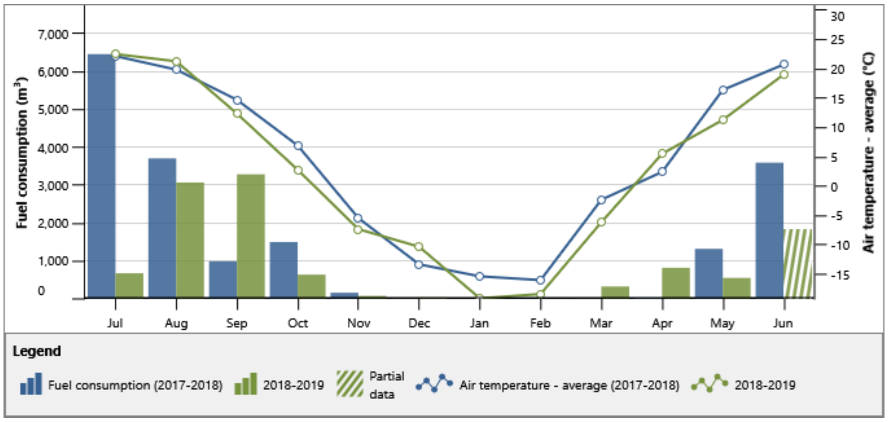


Image 2 provides insight to the natural gas use on site. We see an extreme natural gas use in 2018 compared to 2017 variation in July. Due to the similarity in outdoor temperatures it is expected the 2017 values are due to improper boiler set point. The utility bills are both actual and not estimated. We can also see an abnormal variation in September.

Image 2



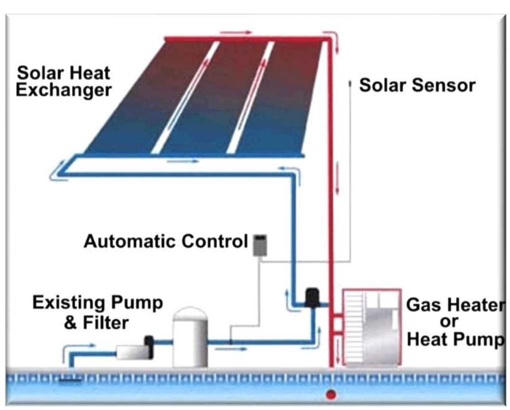
LOW COST CONSERVATION MEASURES

i. LED Interior, Exterior, and Signage. (Offset Purchase of Electricity)

ii. Night Set Back Boiler Water Temperature 2 deg F

HIGHER COST CONSERVATION MEASURES

i. Utilize solar thermal for hybrid pool water heating (Offset Purchase of Natural Gas)



10. Emerson City Arena

Energy Intensity and Emissions Equivalency

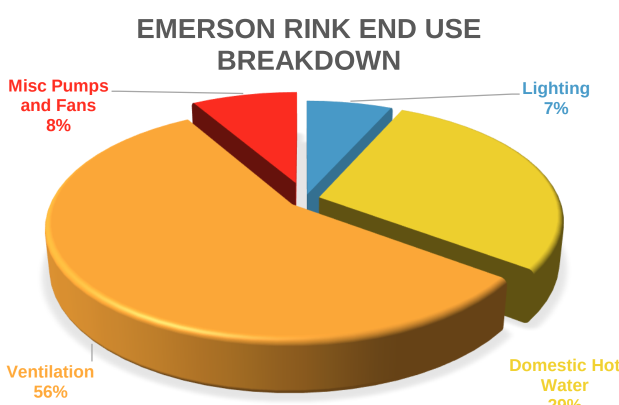
The buildings energy utilization index or energy footprint is 0.26 GJ/m2.

(GHG emissions are based on Manitoba Hydro conversation factors. Electricity factors are based on Manitoba Hydro's Climate Change Report as a global perspective. Natural gas factors are based on the National Inventory Report – Part 2 and proposed valuation for the Manitoba Carbon Tax program. Conversion factors the FCM uses displayed in brackets).

Baseline electrical consumption (average): 21,887.5 kWh or 78.8 GJ
Baseline natural gas consumption (average): 17,065 m3 or 646.6 GJ

Emissions from electrical consumption: 15.321 etC02 (0.07etC02)
Emissions from natural gas consumption: 34.13 etC02

Energy End Use Breakdown

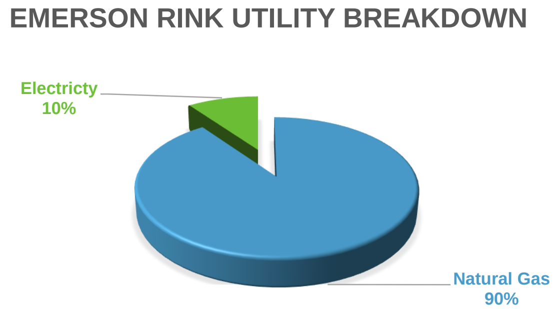


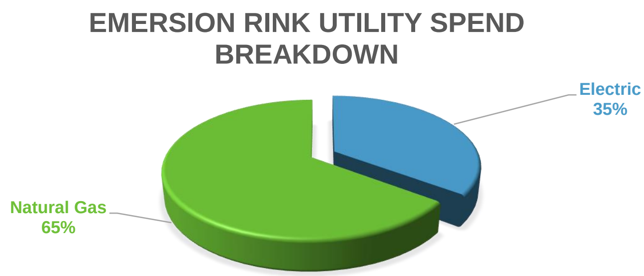
Utility Data Summary

Electrical Consumption Annual (2018): 20,820 kWh
Electrical Cost Annual (2018): $2,618.00
Cost Per kWh (Blended): $0.126/kWh

Natural Gas Consumption Annual (2018): 17,912 m3
Natural Gas Cost Annual (2018): $ 4,830.00
Cost Per m3 (Blended): $0.269/m3

It shall be noted that some data from utility bills are estimates.





ENERGY PROFILE

Image 1-2 provide building energy profiles for electricity and natural gas consumption.

The electrical profile (image 1) shows a levelized consumption pattern. As this facility does not operate a mechanical ice plant, the electrical load is minimal in comparison to facilities with mechanical ice plants.

Image 1

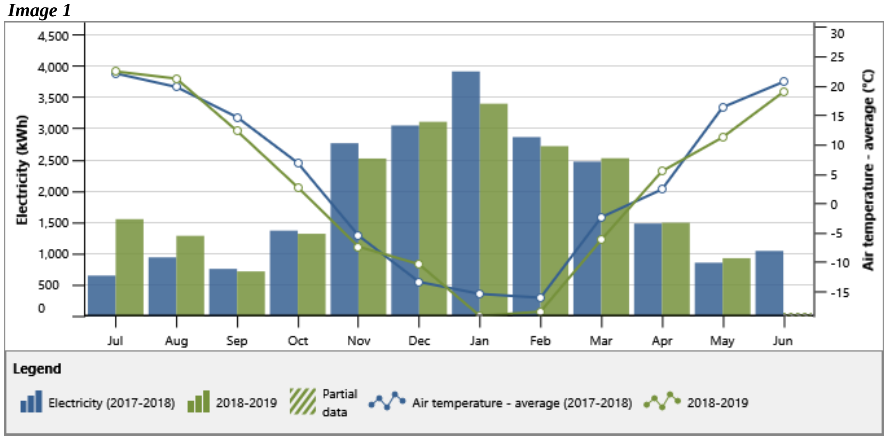


Image 2 shows the natural gas profile follows the expected weather dependency curve.

Image 2

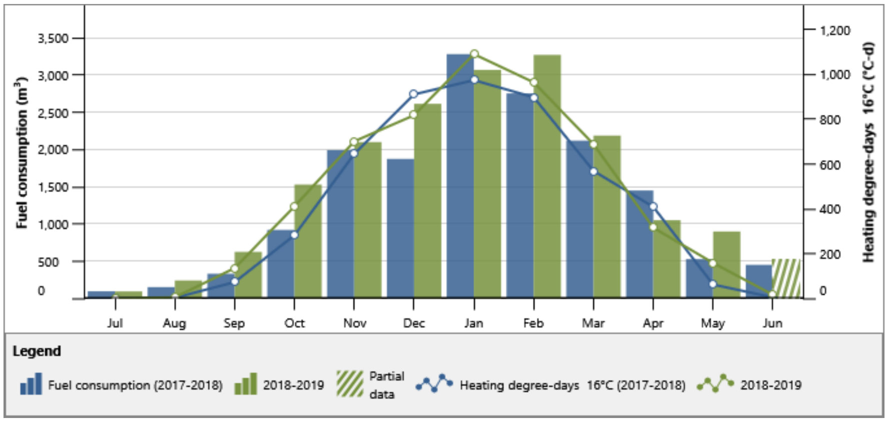
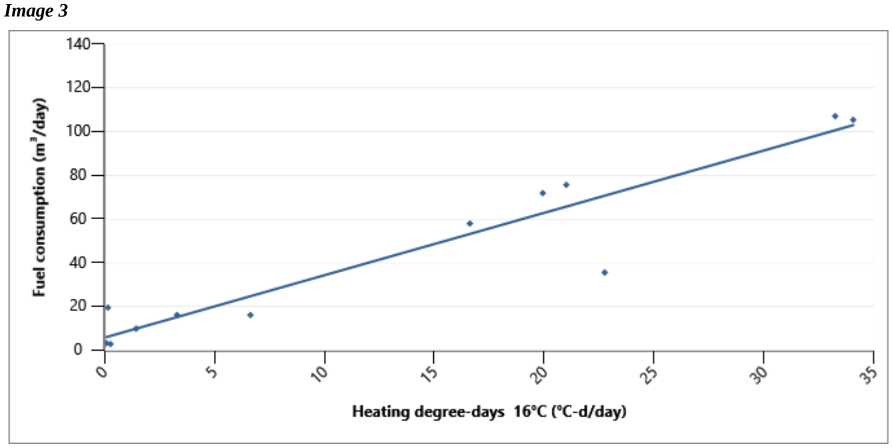


Image 3 is the regression analysis for the heating season. The facility is controlled quite well. Some improvements with programmable thermostats would help increase the controllability and reduce some of the energy spend.

Image 3



LOW COST CONSERVATION MEASURES

i. Occupancy Sensors
   - Washrooms and Closed Office Spaces

ii. Programmable Thermostats (Offset Heating (Electricity and Natural Gas)
   i. Occupied and Unoccupied Set Points
   ii. Temperature Limiting
   iii. Fan Limiting

iii. LED Interior, Exterior, and Signage. (Offset Purchase of Electricity)

11. EMERSON FIRE HALL

The fire hall is approximately 481 m2. The facility is heated through a gas fired boiler feeding in floor heating pipes.
Ventilation within the fire hall is through a heat recovery ventilator.
The kitchen/meeting area is provided with a DX fan coil.

ENERGY INTENSITY AND EMISSIONS EQUIVALENCY

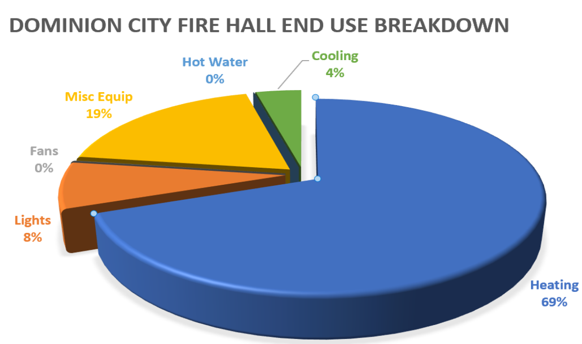
The buildings energy utilization index or energy footprint is GJ/m2.

This value is very good for the facility. (GHG emissions are based on Manitoba Hydro conversation factors. Electricity factors are based on Manitoba Hydro's Climate Change Report as a global perspective. Natural gas factors are based on the National Inventory Report – Part 2 and proposed valuation for the Manitoba Carbon Tax program. Conversion factors the FCM uses displayed in brackets).

Baseline electrical consumption (average): kWh or GJ
Baseline natural gas consumption (average): 8,561 m3 (324.4 GJ)

Emissions from electrical consumption: etC02 (etC02)
Emissions from natural gas consumption: 16.26 etC02

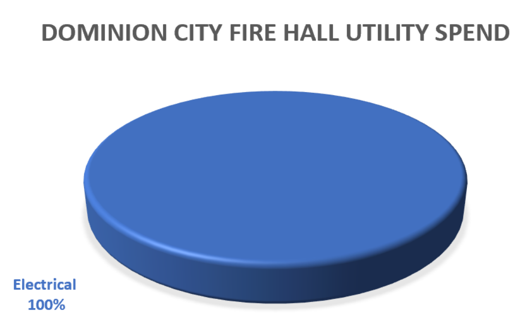
ENERGY END USE BREAKDOWN



UTILITY DATA SUMMARY

Electrical Consumption Annual (2018): 65.983 kWh
Electrical Cost Annual (2018): $6,900.56
Cost Per kWh (Blended): $0.105/kWh

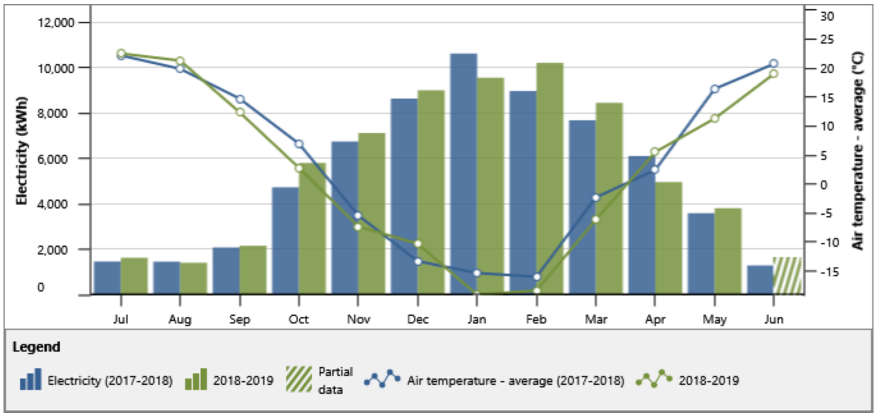
Natural Gas Consumption Annual (2018): No Natural Gas
Natural Gas Cost Annual (2018): No Natural Gas
Cost Per m3 (Blended): No Natural Gas



Energy Profile

Image 1 provides the building energy profile for electricity consumption. We can see that the profiles have a consistent trend with no anomalies in energy consumption.

Image 1



We can also see control of the heating plant is quite good through image 2. This is a function of the lack of outside air being drawn into the facility which typically creates larger variations in how well the facility is controlled.   Variances in electrical demand are attributed to the misc. loads within the facility such as the air pak machine.

Image 2

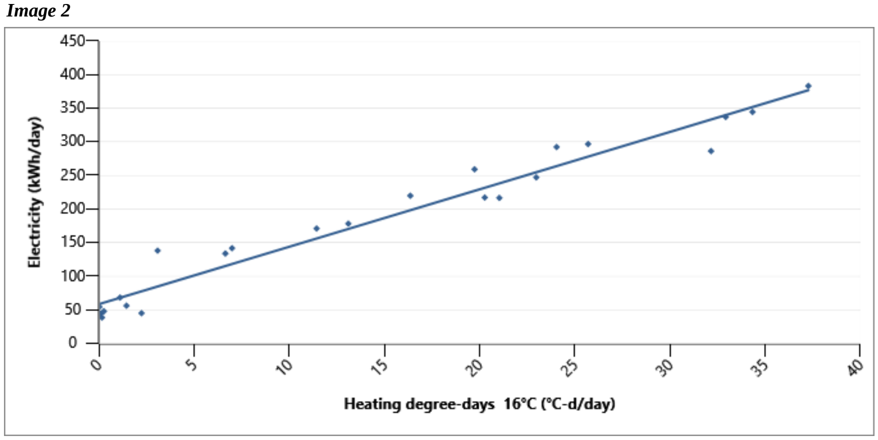
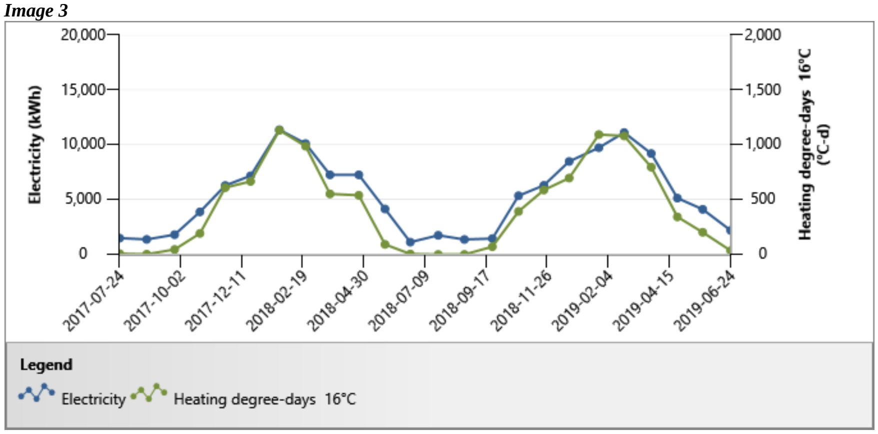


Image 3 outlines the close control of electrical energy vs outdoor air temperature.

Image 3



Low Cost Conservation Measures

ii. LED Interior, Exterior, and Signage. (Offset Purchase of Electricity)
   a. Varying lights

iv. Review temperature control sequence for boilers.

Higher Cost Conservation Measures

i. Solar Thermal Hydronic. (Offset Purchase of Heating Fuel - Natural Gas)