December 12th, 2024

Roadmap to Low Carbon
Final Report – Thessalon Curling Club

Building towards a sustainable future

Executive summary

Enerlife Consulting and CIMCO Refrigeration have worked closely with municipal staff to develop this Roadmap plan to cut carbon emissions, save energy and reduce operating costs for the Thessalon Curling Club.

The Roadmap presents the **strong business case** for implementing this comprehensive, integrated project. The Thessalon Curling Club is relatively energy inefficient, aging and in need of infrastructure renewal. Under business-as-usual (BAU), the Town of Thessalon can expect to spend close to $2.4M on initial equipment replacements, and almost $1.8M on utilities, over the next 30 years. The Roadmap plan will only require an additional $413k of upfront capital, will reduce utility costs by around 33% and yield **a positive incremental net present value (NPV) with funding of almost $170k** relative to the BAU path over the 30-year period.

Table 1 compares the business-as-usual (BAU) to the low carbon pathway in terms of initial capital costs, cumulative GHG reductions and utility costs and NPVs over the study period. Under BAU, the Town of Thessalon's total net spend (negative NPV) on plant and operations for this facility over the next 30 years will be a little over $767k. Without FCM funding, adopting the Roadmap will cost the municipality an estimated $131K. With FCM funding the savings are almost $170k.

Table 1: Business Case to move forward with a low carbon pathway relative to business-as-usual

Pathway	Total capital costs with Inflation[1] ($)	Cumulative GHG reduction (tCO_2e)	Cumulative Utility Costs ($)	NPV ($) without funding	NPV ($) with funding
Business-as-usual (BAU)	$ 814,232	-	$ 1,766,291	$ - 767,541	$ - 767,541
Low carbon plan	$ 1,227,710	519	$ 1,176,811	$ - 899,058	$ - 597,780
Difference	**$ - 413,478**	**519**	**$ 589,480**	**$ - 131,517**	**$ 169,761**

The **environmental case** is equally compelling. This roadmap will lower operational greenhouse gas emissions of this facility by 93%, risk-proofing the Town of Thessalon against carbon pricing and regulations which can be expected to come into effect between now and 2050.

The **community case for action** may be the strongest of all. A majority of Canadians are feeling climate anxiety and looking for practical, meaningful action from their government leaders. Sustainable renewal of the Thessalon Curling Club, with advanced lighting, heat recovery and rooftop solar generation, will be a highly visible demonstration of environmental leadership.

[1] Total capital costs include only initial replacement costs in the pathway for the 30-year period. Subsequent replacements are included in the NPVs.

The proposed solutions outlined below are the culmination of an integrated design process with municipal stakeholders that collectively determined the energy and GHG reduction goals, facility equipment and operational needs, and preferred measures. The solutions presented include analysis of emission savings, costs, and net present value (NPV) compared to an April 2023 – March 2024 baseline.

The key measures for achieving the Thessalon Curling Club GHG emission reduction goals are as follows:

- Air-source heat pump (ASHP) furnaces – An electrification measure, with additional efficiency improvements by upgrading to ASHP technologies. Replacing the existing fuel-fired furnaces serving the lounge with an appropriately sized ASHP unit may result in potential GHG reductions of 12.3 tCO_2e. [2]
- Space temperature setbacks – Implementing space temperature setbacks during unoccupied hours is an efficiency improvement that will save energy, costs, and emissions. The majority of the emissions reductions are from natural gas savings. Potential GHG reductions of 7.2 tCO_2e. [2]
- Electric curling sheet unit heaters – Electrifying the gas-fired unit heaters serving the curling sheets would eliminate the fossil fuel consumption, resulting in potential GHG reductions of 6.7 tCO_2e. [2]

Table 2 provides the full list of measures with proposed year of implementation, initial capital costs with energy savings and utility cost savings in today's dollars, together with GHG savings and net present value (NPV) including external funding. NPV is calculated using the cashflow due to savings and expenses from the measures, over a 30-year period. In order to adhere to industry guidelines such as the ASHRAE 2015 Handbook for equipment life expectancy, replacements are typically scheduled to be implemented at the end of life for each piece of equipment, based on its known installation date. Replacement intervals are based on the same guidelines, and the associated costs have been accounted for, if occurring within the 30-year study period.

Note, the residual value of equipment beyond the study period is accounted appropriately in the life cycle cost analyses in the impact of the NPVs presented. Further information on NPV and the methodology used can be found in Section 4, and measure life expectancy is found in Appendix E – Measure costing breakdown.

[2] GHG emissions reduction are with respect to current emission factors (2023) and without consideration to interactive effects from other measures.

Table 2: Summary of low carbon measures to be implemented in the typical pathway

Measure ID	Low Carbon Measure	Year	Initial Capital Costs ($)	Annual Energy Savings (ekWh)	Annual Cost Savings ($)	Annual GHG Savings (tCO_2e)	NPV ($) Without Funding	NPV ($) With Funding
MEC-07	Space temperature setbacks	2025	$ 15,000	43,174	$ 2,939	7.2	$ 80,435	$ 83,238
BAU-01	Electric unit heaters like-for-like replacement	2026	$ 2,300	-	-	-	$ - 2,349	$ - 2,349
BAU-08	Lighting fixtures LED like-for-like replacement	2026	$ 48,700	-	-	-	$ - 59,680	$ - 59,680
MEC-08	Electric instantaneous pebbling water heater	2026	$ 3,600	435	$ 92	-	$ - 2,009	$ - 900
MEC-11	Low flow water fixtures	2026	$ 800	498	$ 21	0.1	$ 76	$ 222
RFG-01	VFDs on brine pumps	2026	$ 47,900	12,490	$ 2,635	1.0	$ 10,288	$ 25,043
RFG-02	Refrigeration plant optimization - CO2	2026	$ 870,600	7,676	$ 1,620	0.6	$ - 846,799	$ - 588,565
ELE-01	Facility-wide LED upgrade	2026	$ 9,400	378	$ 283	- 0.1	$ - 4,550	$ - 1,655
ELE-02	Lighting Occupancy Controls	2026	$ 1,100	112	$ 62	-	$ 182	$ 521
ENV-04B	Improve airtightness - Excluding rink	2030	$ 20,700	4,464	$ 243	0.8	$ - 7,383	$ - 3,870
MEC-03	ASHP replacement of furnaces	2034	$ 55,000	42,447	$ - 5,863	12.3	$ - 136,549	$ - 123,784
BAU-05	Instantaneous DHW heaters like-for-like replacements	2037	$ 6,600	-	-	-	$ - 4,376	$ - 4,376
MEC-06	Electric curling sheets unit heaters	2042	$ 35,000	15,671	$ - 5,699	6.7	$ - 74,954	$ - 70,238
Total [3]			**$1,116,700**	**136,007**	**$ 6,802**	**31.1**	**$ - 899,058**	**$ - 597,780**

[3] The totals for the individual measures (except for initial capital costs, in today's dollars) cannot simply be summed as their interactive effects need to be considered. All remaining totals are for the entire implementation pathway, accounting for interactive effects. Emissions savings are representative of relevant emissions factors in the final targeted year of the pathway.

Table 3 below presents the NPVs of category bundles, where related low carbon and business-as-usual measures are grouped, to show impact of choosing one pathway over the other. The table shows the incremental NPV which is the difference between low carbon against BAU, where positive values indicate that the low carbon measures outperform the BAU, and negative values indicate that low carbon measures are more financially costly in the 30 years period investigated in the study. The totals presented show the incremental NPVs of the entire pathways, with consideration to the interactive effects between systems within the facility. Note that proper preventative maintenance can help extend the life expectancy of your major equipment, potentially allowing for deferred replacement years. By deferring the replacement years beyond the typical industry guidelines, the value of the equipment over its lifespan and the NPV values are enhanced. This improvement is proportional to the energy efficiency, emission reduction, and cost savings achieved through its operation. It's crucial to work with your trusted staff and contractors for proper maintenance, ensuring optimal equipment performance. This not only prolongs the equipment lifespan but also contributes to a sustainable future and improved financial outcomes. Measure IDs can be referenced in Table 2.

Table 3. Incremental NPV of measure categories, comparing typical low carbon against the business-as-usual pathway

	Low Carbon			Business As Usual		Incremental NPV	
Category:	**Measures**	**NPV No Funding ($)**	**NPV With Funding ($)**	**Measures**	**NPV No Funding ($)**	**No Funding ($)**	**With Funding ($)**
Heating	BAU-01, MEC-03, MEC-06, MEC-07	$ - 133,418	$ - 113,134	BAU-01, BAU-02, BAU-03	$ - 23,079	$ - 110,339	$ - 90,055
Domestic Hot Water	BAU-05, MEC-08, MEC-11	$ - 6,309	$ - 5,054	BAU-04, BAU-05	$ - 8,669	$ 2,360	$ 3,615
Refrigeration	RFG-01, RFG-02	$ - 836,512	$ - 563,522	BAU-06, BAU-07	$ - 665,452	$ - 171,060	$ 101,930
Lighting	BAU-08, ELE-01, ELE-02	$ - 64,049	$ - 60,814	BAU-08, BAU-09	$ - 70,342	$ 6,293	$ 9,528
Envelope	ENV-04B	$ - 7,383	$ - 3,870	-	-	$ - 7,383	$ - 3,870
Total						**$ - 131,517**	**$ 169,761**

Figure 1 compares cumulative cash flows for the three pathways over the 30-year study period. The net cash flow (distinct from NPV, which is current dollars) between the typical low carbon pathway and business-as-usual pathway is approximately negative $480k without funding and positive $178k with funding on the typical pathway, and positive $135k for the aggressive pathway. Unlike the life cycle cost analysis, which discounts the value of the equipment beyond the study period to more accurately present the NPV, the cashflow presented below does not include residual value and presents the full cost of any additional equipment replacements based on anticipated end of life. As the study period extends, overall trends will be more pronounced, such as low carbon pathways trending upwards.

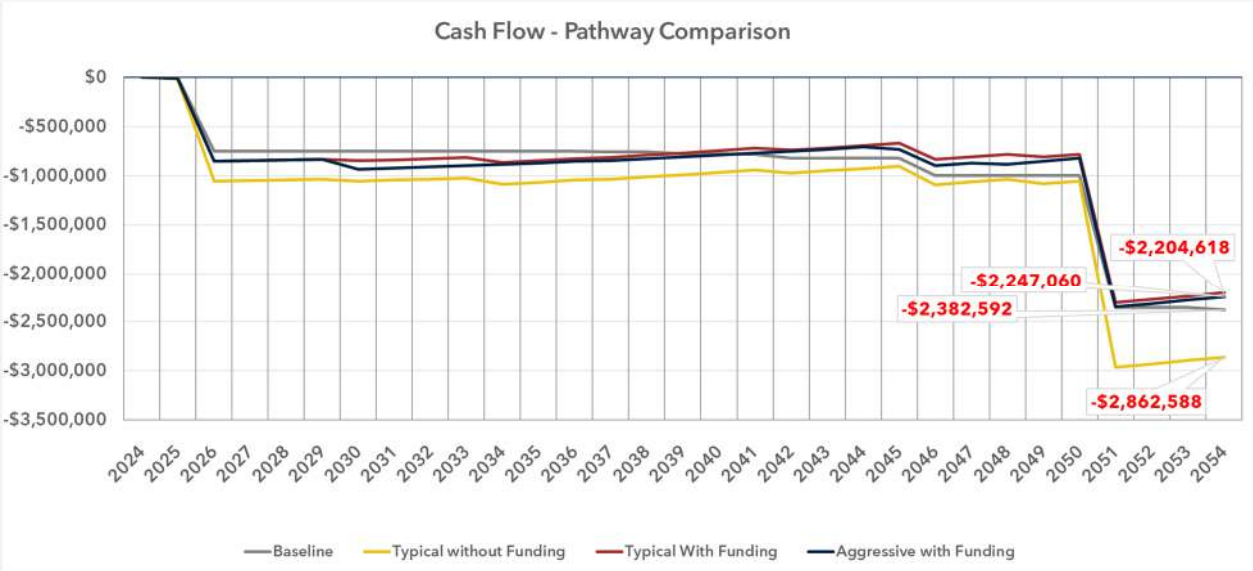

Figure 1: Typical pathway cash flow comparisons over the 30-year study period

The implementation roadmap in the table below provides the recommended phases, where measures are bundled, to provide a roadmap to ensure successful implementation. Table 2 provides the details on which measures are to be implemented immediately, or at end of equipment life, while Table 4 below provides a year when detailed design, procurement and installation planning begins, to provide the municipality with time needed to have the strategy, materials and staff available to implement the measures successfully. The table also shows the initial budgets required if the municipality chooses to apply the recommended measures through the funding programs available. For this study, the primary funding program was the FCM CBR Funding Program. An equivalent amount to the initial budget required (20% of initial capital cost) is provided as a grant through the program for low carbon measures only. Business-as-usual measures are not applicable. Measure IDs can be referenced in Table 2.

Table 4. Implementation phase breakdown summary with initial budgets required, and loans provided by funding program

Phase	Planning Year	Selected Measures	Cumulative GHG % Reduction	Initial Capital Costs with Inflation ($)	Total Low Carbon Grant Value ($)	Total Initial Budget Required ($)	Low-Interest Loan Provided by CBR ($)
Immediate	2025	MEC-07	25%	$ 15,450	$ 3,090	$ 3,090	$ 9,270
1	2026	BAU-01, BAU-08, MEC-08, MEC-11, RFG-01, RFG-02, ELE-01, ELE-02	38%	$ 1,044,350	$ 198,049	$ 252,155	$ 594,146
2	2032	ENV-04B, MEC-03, BAU-05	85%	$ 108,325	$ 19,726	$ 29,419	$ 59,179
3	2040	MEC-06	93%	$ 59,585	$ 11,917	$ 11,917	$ 35,751
Total			**93%**	**$ 1,227,710**	**$ 232,782**	**$ 296,581**	**$ 698,347**

This Roadmap plan for the Thessalon Curling Club exceeds the FCM minimum requirements of achieving 50% greenhouse gas (GHG) reduction in the first 10 years and 80% GHG reduction in 20 years as shown in Table 5 below. Baseline emissions listed below are calibrated model data, using grid emissions factors at the start of the study period (April 2023 - March 2024). The plan establishes the current energy and greenhouse gas (GHG) performance of the building and outlines the following three potential scenarios for reducing GHGs and energy use:

1. Business-as-usual (BAU), which assumes ongoing maintenance and energy use and like-for-like replacements of equipment when it reaches end of life.
2. Low carbon measures implemented on a typical timeline to meet 10-year and 20-year greenhouse gas (GHG) emission reduction goals both with and without external funding.
3. Low carbon measures implemented on an aggressive timeline which includes a 5-year deep retrofit implementation plan for the measures eligible for external funding.

Table 5: April 2023-March 2024 and forecasted carbon emissions for different pathways

Utility	Baseline	Typical timeline approach		Aggressive timeline approach
		10-year	20-year	5-year
Electricity Emissions (tCO_2e)	7.3	0.1	-	3.7
Natural Gas Emissions (tCO_2e)	26.1	5.0	2.4	2.4
Total (tCO_2e [% reduction])	**33.5**	**5.0 [84.9%]**	**2.4 [92.8%]**	**6.1 [81.8%]**

General Terms and Definitions

Energy and Emissions:

- **GHG (Greenhouse Gas):** Gases in Earth's atmosphere that trap heat, contributing to the greenhouse effect. The report focuses on reducing emissions of these gases to mitigate climate change.
- **tCO_2e (Tonnes of Carbon Dioxide Equivalent):** Quantifies the equivalent of one tonne of CO_2 emissions that contributes to climate change impacts.
- **ekWh/ft² (Equivalent kilowatt-hour per square feet):** An energy use intensity metric to provide a method of comparison for building energy use. Will vary depending on building type and purpose, and ideally compared to buildings with similar operations.

Project Context and Planning:

- **BAU (Business-As-Usual):** Standard operational practices, including equipment replacement without enhancements for efficiency.
- **EOL (End of Life):** Describes whether an equipment is at the end of its operating life cycle and requires replacement, due to condition or industry best practices for system replacement timeline.
- **LCP (Low Carbon Plan):** Framework aimed at reducing GHG emissions through sustainable practices.
- **GHGI (Greenhouse Gas Intensities):** Measures GHG emissions per unit of output, identifying high-emission areas for improvement.
- **FCM (Federation of Canadian Municipalities):** Represents Canadian municipalities, focusing on sustainable urban development.
- **CBR (Community Building Retrofit Fund):** Funding initiative aimed at supporting community building retrofits for energy efficiency.

Financial Metrics:

- **NPV (Net Present Value):** Evaluates the profitability of an investment, calculating the difference between the present value of cash inflows and outflows. Positive values meaning low carbon is more attractive, and negative values meaning the opposite.
- **ILCC (Incremental Life Cycle Cost):** The difference in NPV associated with implementing a low-carbon alternative compared to a conventional option, over the project's lifecycle.

Energy Efficiency and Systems:

- **EUI (Energy Use Intensity):** Measures a building's energy efficiency, based on annual energy consumed per square foot.
- **ASHP (Air Source Heat Pump):** Transfers heat between the outside and inside of a building, providing efficient heating and cooling.
- **LED (Light Emitting Diode):** A highly energy-efficient lighting technology.
- **PV (Photovoltaics):** Converts light into electricity using semiconducting materials.
- **VFD (Variable Frequency Drive):** Controls the speed of an electric motor to reduce energy use and match load requirements.

Building and Mechanical Systems:

- **MEP (Mechanical, Electrical, and Plumbing):** Covers the design and installation of these systems in buildings.
- **BAS (Building Automation System):** Automates and controls the building's mechanical and electrical equipment for optimal operation.

- **AHU (Air Handling Units):** Devices used to regulate and circulate air as part of HVAC systems.
- **RTU (Rooftop Units):** Air conditioning units installed on roofs, used for space heating and cooling.

Water and Heating:

- **DHW (Domestic Hot Water):** Hot water used for domestic purposes, like bathing and cooking.
- **DHX (Domestic Hot Water Exchange):** Transfers heat to domestic water, improving energy efficiency.

Standards and Measurements:

- **ASHRAE (The American Society of Heating, Refrigerating, and Air-Conditioning Engineers):** Sets industry standards and best practice guidelines for HVAC systems and operations.
- **BPS (Building Performance Standards):** Building Performance Standards as developed or required by respective jurisdictions. Typically applied to existing building performance and include the requirements of MVP (Measurement and Verification Protocols) and O&M (Operations and Maintenance) requirements.
- **MEPS (Minimum Equipment Performance Standards):** Regulated by Canada's Energy Efficiency Act and Energy Efficiency Regulations, defines the minimum equipment performance required to be used in any new installation, additions, or retrofits. These are defined by Natural Resources Canada (NRCan).
- **U-value:** Measures heat transfer through a structure, with lower values indicating better insulation.
- **R-value:** The inverse of U-Value indicates thermal resistance, with higher values representing better insulation properties.
- **AFUE (Annual Fuel Utilization Efficiency)**: Measurement of how efficiency a fuel-fired heating system converts fuel to heat. A standard measurement for furnaces, boilers, and other fuel-fired systems.
- **COP (Coefficient of Performance)**: Commonly used to define the efficiency of heat pumps, chillers, compressors, and air conditioning equipment. Is the ratio of useful heating or cooling provided by the system, given the work (or energy) that is put into to operate said system. Higher values equate more performance output for less energy consumption.

Additional Technologies and Interfaces:

- **HMI (Human-Machine Interface):** User interfaces that connect a person to a system, allowing for interaction and control.
- **PHE (Plate and Frame Heat Exchanger):** Transfers heat between two fluids, used in various heating and cooling applications.
- **LDC (Local Distribution Company):** Utility company responsible for distributing electricity or natural gas to customers.
- **ekWh (Kilowatt Hour Equivalent):** Unit of energy equivalent, used for comparing different forms of energy consumption.
- **RH (Relative Humidity):** The amount of moisture in the air compared to what the air can hold at that temperature.

Table of Contents

1 Background

Municipalities across Canada are accelerating action on climate change and reducing energy use and emissions in their facilities. Investing in energy reduction and climate change readiness is fiscally prudent, with funding opportunities and technological advancements making it increasingly accessible every year.

As indicated in the Executive Summary, this study identifies three scenarios, with two low carbon scenarios envisioning the implementation of the best possible retrofit and operational measures to reduce the emissions at the Thessalon Curling Club from its April 2023 – March 2024 baseline utility emissions of 33.5 tonnes of carbon equivalent (tCO_2e) by at least 80% at the end of each pathway. It provides budget requirements, life cycle costing, energy and carbon reductions and timelines for implementation of measures, aligned with asset management and capital plans, over time.

This plan is the culmination of three phases of work which incorporate reviewing building information, site visits, and two integrated design workshops. It maps out the retrofit and operational changes required to reduce emissions by 80% within 20 years and 5 years.

An initial review of building data and characteristics was conducted looking at key drawings, trend logs (as available), and capital plans. A site visit was conducted on March 21st, 2024, to confirm details, collect additional information, and interview the building operator and facility manager. This process ensures operational conditions and potential issues, and savings opportunities are adequately addressed (refer to the Site Visit Assessment Report – Appendix A).

Two integrated design workshops were conducted, which brought together building management, operators, and finance staff to collectively determine the best possible solutions and plans for the building. At the first workshop, the team reviewed current performance and potential carbon reductions, low/no carbon measures that best fit the management team's goals, and measure implementation timelines. Bringing together technical and operational expertise ensured operations and asset renewal were considered and everyone had early input at an early stage. This avoided costly omissions and helped get municipal stakeholder on board with the proposed changes. In the second integrated design workshop, measures and associated costs were reviewed with finance staff to get their input and feedback.

2 Building Characteristics

2.1 Building information

The Thessalon Curling Club is a recreational curling rink located in Thessalon, ON, with an approximate gross floor area (GFA) of 10,500 ft^2. The facility is used as a curling rink for curling programs, gathering space for events, and rentals. The lobby is two floors with a kitchen and lounge space on a lower level. The facility was rebuilt in the 1960s. It is primarily occupied on weekdays and only occupied on weekends during the bonspiels through the ice season from November to March. Throughout the year it is used every Wednesday for a local raffle. During the offseason it is used approximately once per month for events and/or rentals. Ice for the curling sheets is made in mid-September and is taken out by the first week of April.

This study was completed with information and data provided through the following sources:

- Utility billing data
- As-built architectural, mechanical, and electrical drawings
- Building condition assessments, reports, and audits
- Equipment specifications
- Site visit review and operator interviews

2.2 Heating, cooling, and ventilation

The facility is heated by a gas-fired furnace serving the lobby and basement, two gas-fired unit heaters serving the curling sheets, and an electric baseboard radiator serving the workshop. The furnace is rated at 120 MBH with 97.5% efficiency. It was installed 2019. The unit heaters serving the curling sheets were recently installed in November 2022 and are rated at 142 MBH with 81% efficiency. The baseboard heater for the workshop is rated at 7 MBH and is set at a minimum level to prevent freezing. There are no temperature setbacks in any of the spaces.

There is no space cooling within the facility, however, there is a beverage and food cooler room that runs and AC unit 24/7. There is interest in installing a dedicated cooling system for the lobby to regulate temperature in the summer months.

There is no dehumidification within the curling sheets space.

Three exhaust fans are present serving the washrooms. There is a range hood serving the kitchen. There are no ceiling fans or exhaust fans noted to be serving the curling sheets.

2.3 Domestic hot water

Domestic hot water (DHW) is served by one gas-fired instantaneous unit and one electric unit. The gas-fired instantaneous unit is rated for 180 MBH and set at 140°F. The unit was recently installed in 2022. The electric unit is rated at 10.24 MBH and set at 100°F and is used for heating water for pebbling the ice surface. It is noted that this unit has reached its end-of-life. Curling sheets are maintained with pebbling packs, which is used by the operators during the ice season at an estimated 5 USG per curling day.

2.4 Refrigeration

The facility has one ammonia ice plant rated at 26-tons to serve the approximately 150’ x 60’ ice pad. It is noted that the ice plant requires frequent refrigerant recharging and is approaching its end-of-life. The ice plant consists of one 30 HP compressor, which was rebuilt in 2023, one 10 HP brine pump, one 0.75 HP condenser pump, one shell-and-tube chiller, and one evaporative condenser. The ice plant is believed to have approached its end-of-life. Due to sand and variances in elevation, the ice thickness is kept around 3.5” – 4”. The ice plant is controlled by Honeywell slab sensors, with a setpoint 23°F.

2.5 Lighting

Interior lighting includes a combination of incandescent, fluorescent, and LED fixtures. The curling sheets were upgraded to LED T8 fixtures as part of an LED retrofit. The lobby has incandescent bulbs, while the basement has fluorescent T8 fixtures. Some small spaces are noted to be LED bulbs, and the exterior lighting is noted to be halogen There are no lighting plans, controls, or schedules. The lighting does not include occupancy sensors or daylight sensors.

2.6 Building envelope

The facility was rebuilt in the 1960s; there are two floors with the main lobby on the ground floor and kitchen on a lower floor. The overall effective insulation levels of walls and roofs are assumed based on the building vintage. It is noted that there is no insulation on curling sheet walls and likely not on roof. Exterior windows and doors are original, and no other significant retrofits of the building envelope have been reported. A low-emissivity ceiling in the arena prevents solar radiation from reaching the ice.

2.7 Process and plug loads

The facility has a variety of plug and process loads, mainly serving the kitchen and ice maintenance equipment. Kitchen equipment includes two commercial ovens, one griddle, two fryers, and two ranges. Natural gas loads are present from the commercial kitchen on-site, with a schedule that varies with the frequency of rentals and events. The kitchen is estimated to be used once per month in the summer and three times per month in the winter. Electric kitchen loads are found in the bar/serving area including the walk-in fridge. This fridge is serviced by a window AC unit that rejects heat into the washroom.

2.8 Building automation system

The facility has no building automation system (BAS). Controls are handled through local thermostats, manual switches, or control panels on a space or system basis. The refrigeration system is operated through local controls with a Honeywell T775 slab sensor.

3 Historical building performance

3.1 Data summary

Analysis of the potential reductions in GHG emissions uses the baseline year of April 2023 – March 2024. The facility is assumed to be operating at typical, full capacity during the baseline year, as per discussions with the facility operators and staff. Table 6 presents the annual energy consumption and costs as per the billing provided for the baseline year.

Table 6: Annual energy use and costs (April 2023 - March 2024)

Facility	Electricity use (kWh)	Electricity cost ($)	Natural gas use (m³)	Natural gas cost ($)
Thessalon Curling Club	84,553	$ 17,841	13,767	$ 5,969

A monthly breakdown of energy costs for each facility can be found in Appendix B. Utility rate structures and assumptions used for cost analysis, escalation rates, and carbon pricing are found in Appendix C.

3.2 Total energy benchmark April 2023 - March 2024

Benchmarking the facility's total energy consumption (including electricity and thermal) against other similar buildings helps identify areas where energy consumption can be reduced and improve overall energy efficiency. Energy use intensities (EUIs) for the facility and for the top decile are shown in Table 7 below.

To achieve 80% emissions reductions, the following targets, using proportional savings across all utilities and baseline GHG emission factors, can be seen in Table 7. In reality, there are multiple pathways to 80% GHG emissions reductions. These pathways are dependent upon many variables such as the equipment in the facility, load profile, and changes to grid emissions factors. Some pathways are more favorable when looking through a financial or social lens. Later sections of this report discuss the various measures and pathways analyzed to achieve the 80% emissions reductions target.

Table 7: Energy Intensity Comparison

	Electrical energy intensity (kWh/ft²/year)	Gas (thermal) energy intensity (ekWh/ft²/year)	Total energy intensity (ekWh/ft²/year)
Thessalon Curling Rink	5.8	9.8	15.6
80% Emissions Reduction	1.2	2.0	3.1

3.3 Total energy breakdown April 2023 – March 2024

In order to improve the efficiency of the facility and reduce its overall carbon emissions, it is important to know where energy is being consumed in the facility. Based on energy data collected

and the site visit information gathered regarding the operation of the buildings systems, an energy balance was developed to show how much of the energy is being used by which building systems. The graphs below show the energy (electricity and thermal) breakdown by end use for the facility.

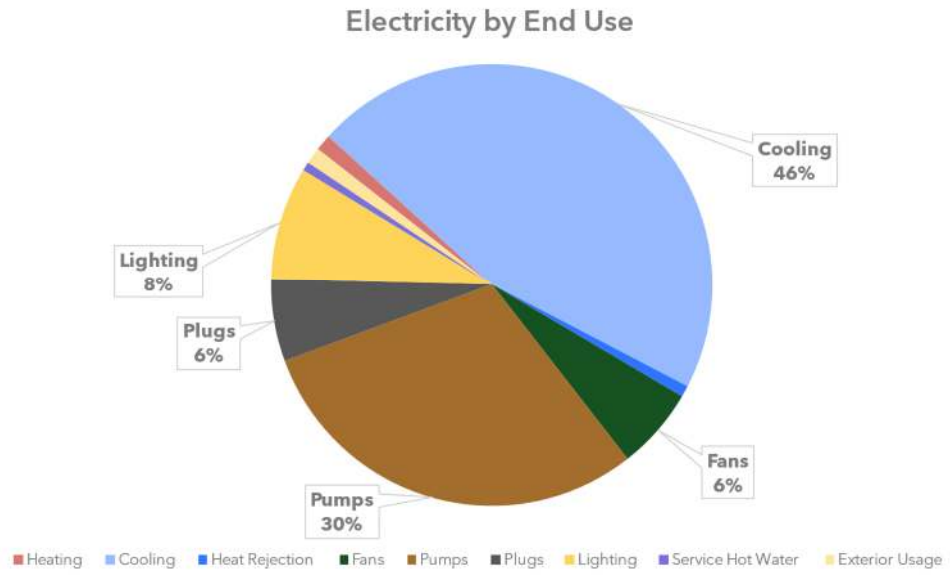

Figure 2: Electricity Consumption by End Use

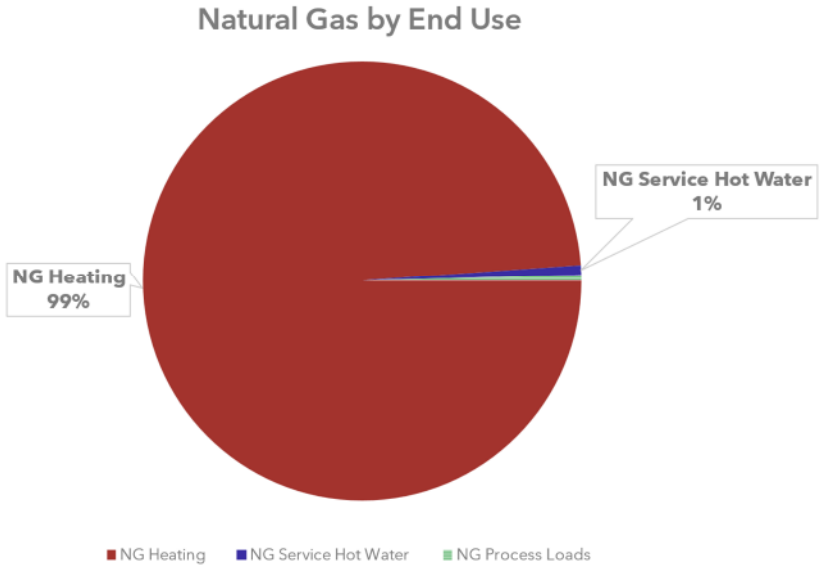

Figure 3 Thermal consumption by end use

As seen in Figure 2 above, the three primary electrical end-uses within the facility are refrigeration, pumps, and lighting, accounting for 46%, 30%, and 8% of the entire facility's electrical consumption, respectfully. The refrigeration end-use accounts for electricity used in the ice plant

required to transfer heat between the brine and condenser loops (condenser and pump power excluded). The pump end-use accounts for ice plant's brine pump used to circulate brine beneath the ice slab. The lighting end-use accounts for all interior and exterior lighting at the facility.

Similarly, Figure 3 above shows the primary end-uses for thermal energy consumption within the facility. Thermal energy is provided by natural gas which is used for space heating, water heating, and process loads. Space heating is the dominant end-use for natural gas, accounting for roughly 99% of the facility's entire thermal energy consumption. The water heating and process load end-use each account for roughly 1% of the load. Water heating accounts for all water heated for domestic and pebbling purposes. Water heating is serviced by an instantaneous water heater (IWH) which minimizes the associated energy consumption. The process load end-use accounts for natural gas use within the facility's kitchen, which has minimal use.

3.4 Energy, emissions, and cost comparison for April 2023 - March 2024

Figure 4 below shows the energy use intensity (EUI) in equivalent kilowatts per square feet (ekWh/ft^2), total greenhouse gas intensity in tonnes of CO_2 equivalent, and the operational costs as a result of energy use. This figure shows where the greatest opportunities lie, when looking to reduce cost or emissions, with respect to the energy source. As expected, fossil fuel costs are lowest currently with respect to electricity but have the highest emissions. Electricity emissions are also largely driven by the efforts of the province to clean up their respective electricity grids.

The goal of this study is to provide a low carbon pathway focused on emissions reductions, where the facility can achieve the minimum requirements of 50% reductions in 10 years, and 80% in 20 years. This goal is applied primarily to the emissions listed in the figure below, but the study will also aim to find the most cost-effective options where possible, to minimize capital requirement and improve implementation potential.

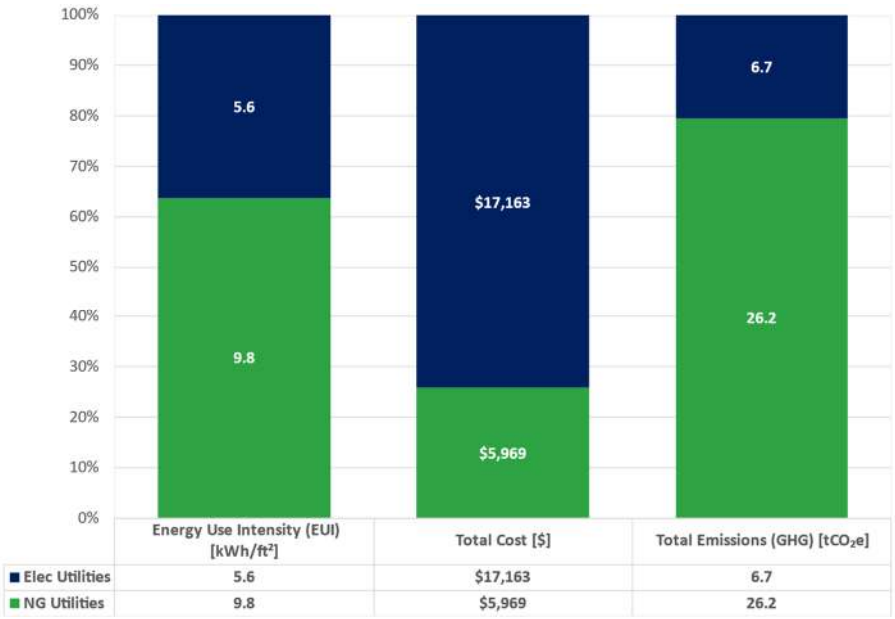

Figure 4: April 2023 - March 2024 annual energy use intensity, cost, and emissions by utility

3.5 Observations and opportunities

The site visit and interviews with the facility staff gave the team insight into building operations and opportunities for improvement. Some immediate opportunities for energy, cost, and greenhouse gas emission reduction are listed below.

Key observations for the Thessalon Curling Club are as follows:

- Gas kitchen equipment is estimated to be used once per month in the summer, and 3 times a month in the winter. The facility has an AC cooler room that runs 24/7.
- The operating staff is interested in installing a cooling system for the lobby space to improve thermal comfort during the summer months.
- Ice thickness is high at 3.5" to 4" due to notable variances in sand and ice sheet foundations. Noted that concrete floor would be needed to reduce this.
- Budget consideration should be given to expect the required replacement of the following equipment within 5 years:
    - Refrigeration ice plant
    - Pebbling water heater (DHW-2)

Opportunities for operational improvements are as follows:

- Approve requests of user groups by implementing space cooling in the lobby while capitalizing on available funding opportunities by incorporating an air-source heat pump (ASHP) to serve as the cooling system while offsetting fossil fuel use for heating.
- Given the proximity between the Thessalon Arena and Curling Club, an opportunity exists to replace the two individual ice plants with one larger, shared ice plant.
- The ice plant is nearing end-of-life, and the Town is looking into replacing the entire ice plant in the short-term. Given this opportunity, the Town should consider a holistic retrofit of the ice plant including premium options allowing for maximum energy savings via heat recovery and reclamation. A holistic heat recovery package comes at a higher capital cost, but with the added benefits of long-term savings found via energy efficiency, as well as greater emissions reductions and environmental stewardship.
- A heat recovery package should be considered given the overlap of required replacements for significant ice plant, and space heating equipment alike. This may address, in addition to ice refrigeration, future dehumidification and heating of general conditioned spaces.

4 Methodology

A four-phase measure prioritization approach was used to develop the roadmap to low/zero carbon:

i) Energy efficiency
    - Ensuring the existing systems are running efficiently and taking advantage of opportunities for operational energy saving reduces the energy load and provides early wins. Acting on energy efficiency opportunities first can reduce the future replacement equipment capacities.

ii) Building performance (heating, cooling, ventilation, and lighting)
- Heating, cooling, ventilation, and lighting make up the majority of the building's energy use baseline. These systems should be optimized as much as possible, taking into consideration when equipment is at end-of-life and needs to be replaced.
- Wherever feasible, heat recovery will be considered as it reduces heating requirements, maximizes energy use and offsets high-emissions gas consumption.

iii) On-site renewable energy generation
- A range of on-site renewable energy generation options have been reviewed as part of the study, taking into account technical and financial suitability. Solar photovoltaics (PV) are generally the most attractive on-site renewable for this type of facility.

iv) Carbon offsets
- Purchasing renewables credits to offset any remaining emissions can be considered after the prior phases have been exhausted.

4.1 Net present value, comparative costs and NPV by system

Net present value (NPV) is a key tool in evaluating which measures to implement. With longer planning periods, the total cost of the measure over its life cycle is important in evaluating investment. NPV calculates the end result of how much money will be gained or lost over the full time period in terms of today's dollars. It lays out the total cost savings over a 30-year period, as compared to current operations, using April 2023 – March 2024 year as the baseline.

The analysis includes both upfront costs (initial capital costs) and life cycle cost analysis. Budgets for each measure are based on costs from costing databases, suppliers, and previous experience.

Net present value considers initial costs, delayed or future costs (end-of life replacements), inflation, annual operation, maintenance costs and other considerations such as second and subsequent replacements if required within the 30-year study.

Replacements occur at regular intervals based on industry accepted guidelines on equipment life expectancy such as the ASHRAE 2015 Handbook. Since replacements will typically last beyond the study period, the life cycle cost analysis accounts for this residual value through the straight-line depreciation method and adds the remaining value back at the end of the study period based on remaining lifespan. This provides an NPV that represents the value of the measures strictly within the study period. As a consequence, measures implemented at the near the end of the study period may seem more positive as their full life cycle cost is not captured in the analysis. Study period would need to be extended to see the full impact. 30 years is the selected timeline for these studies, as most measures would see reasonable use within this period.

Measures with a positive NPV are recommended. Measures that result in a negative NPV will need to be evaluated in terms of trade-offs between emission savings and creation of financial value. Measures recommended in this report have either a positive NPV, positive emission

savings or both. If a measure has a negative NPV, increases emissions and is not needed to support other low carbon measures, then it was not recommended.

As outlined above, measures have been bundled by system or implementation phase and NPV calculated for each measure. Life cycle costing assumptions are provided in Appendix C and individual measure costing and replacement year estimates are provided in Appendix E.

4.2 Energy modelling approach

To model the performance of the building and calibrate a baseline, utility data from a recent standard year of operation was used.

Using April 2023 – March 2024 utility data and site information for this facility a baseline hourly energy model was developed to simulate energy consumption and demand, that is calibrated in adherence to ASHRAE 14 - Measurement of Energy, Demand, And Water Savings Guidelines. With the benchmarking, achievable weather-normalized high performance (top decile) energy and GHG targets were established for the Thessalon Curling Club.

The model calculates energy consumption of all significant systems based on current building systems and operation. Energy conservation measures (ECMs) are then modelled to modify current building systems and operations to reflect the impact on the facility and interactions with other adjacent systems. See Appendix D to review calibration results for the model, where ASHARE 14 requirements are met.

4.3 Carbon factor forecasting

Emissions reductions can only go so far at the site, whereas source emissions from electrical grids and generation plants are expected to bear the remaining weight through infrastructure improvements and clean energy resources. Environment and Climate Change Canada publishes the annual forecasts of electrical grid GHG emissions by province. This data set was used to calculate the expected annual emissions for the facility. Refer to Appendix C.

4.4 Electrical Infrastructure

The roadmap to low carbon would not be feasible without the electrification measures proposed as part of the pathways. Electric service upgrades or electrification of systems entails replacing fuel-fired equipment with the most efficient electric equivalent. Since this adds electric loads to a building, it will translate to an increase in electrical demand and capacity needs. This likely require upgrading existing switchgears, electric panels, feeders, and wiring capacities. The costs associated with electrification is highly site and measure specific. Municipalities are encouraged to hire a specialized electrical firm to provide a detailed cost assessment of the electrical upgrades aligned with the proposed pathways. The cost of electrical upgrades is not accounted in the initial outlays, or the net present values presented in this study.

In addition, the electrification of the building would not be possible without the required infrastructure upgrades on the delivery side, which needs to be coordinated with the local distribution companies (LDC). Municipalities and the LDCs should plan upgrades with regards to minimizing disruptions to services or supply. Futureproofing for 100% electric-readiness should

be included in the facility capital plan, to enable additional electrical measures to be included as equipment replacements are needed as per the low carbon pathways.

5 Details of identified measures

For each of the measures identified and under consideration, a description of the measure, upfront costs, carbon savings, energy savings, and net present value (NPV) are presented. Carbon and cost savings are calculated using the emission factors and utility rates of the current year. Where cost savings are negative and energy savings are positive in electrification measures, this is a result of higher electricity costs for the current year. Current year utility rates are used to calculate energy costs. When reviewing NPV values, it is recommended to compare the NPV values of low carbon pathways to business-as-usual. Higher NPV values in low carbon pathway represent better return on investment over the study period. Refer to Section 4.1 for NPV methodology. Note that this is an overview of all of the measures under consideration and not all of these measures are being recommended in the low carbon pathways.

5.1 Heating and cooling measures

The facility has a fairly simple heating system, with one gas-fired furnace serving both the lobby and basement spaces, and electric baseboards and radiators providing additional space heating. The curling sheets are heated with two gas-fired unit heaters, set to 42°F above the ice. Setbacks are not currently used.

The heating and cooling systems can be optimized and result in carbon reduction by implementing the following measures:

5.1.1 Air source heat pump (ASHP)

Air Source Heat Pumps (ASHP) are a viable option for reducing carbon emissions from fossil fuel combustion in heating and cooling systems such as rooftop units (RTUs), furnaces or air conditioning units. They offer better efficiency than fuel-fired or 100% electric heating equipment, with high coefficient of performance (COP) values for both heating and cooling. As the ASHPs run on a heat pump cycle, the performance is not significantly improved over cooling provided through direct expansion (DX). The primary benefit of the ASHP can be found in its heating performance when exploring electrification options. However, ASHPs tend to have poorer performance at the lowest outdoor temperatures, where unit capacity may not be able to meet the heating demand of the space. The coldest days will need auxiliary heating which is assumed to be through electric heating. Fuel-fired auxiliary heating can be implemented but the systems must be sized to minimize the operation of the auxiliary heating annually**.** The measures assume electric auxiliary to eliminate GHG emissions.

With this measure recommendation, existing furnaces can have their burners removed and fan system maintained or refurbished, to continue to use it as an air handler, and install new reversible ASHP units, to provide heating or cooling through new refrigerant coils within the AHU. This will allow less capital expenditure while electrifying the heating system. This will also allow facility to only replace units as needed and minimize maintenance. The burner can be left in place to be used as auxiliary backup heating for temperatures below the threshold of the ASHP operation.

For this study, electric heating is assumed to reduce GHG emissions. Controls should be appropriately programmed to avoid overlap of operation between the ASHP and auxiliary heating.

Currently ASHP technologies do come at a cost premium, and the facility electric infrastructure would need to be investigated to see whether the electric demand of the unit can be met. In addition, space constraints and structural limitations should be explored to ensure that ASHP systems of the appropriate size can be installed in the facility.

5.1.2 Electric furnaces and unit heaters

Electric furnace and unit heaters are a good option when hydronic heating is not available and there is not enough heating demand and limited space to justify a heat pump based system. A full electric equivalent of the existing fuel-fired furnaces and unit heaters are investigated due to ease of install and conversion. These electric units would operate at 100% efficiency. Prior to electrification it is important to confirm that there is sufficient electrical capacity in the facility to meet the peak loads of these units. With sophisticated controls and scheduling, energy use can be modulated to minimize the additional electricity demand the units would add to the facility.

5.1.3 Space temperature setback

If the capability exists, night setback can be scheduled through the building automation system (BAS) or through manual setbacks during facility closing hours. It is advisable to install a BAS that can automate intelligent scheduling based on facility operation, occupancy, and scheduled events in the spaces. This would allow for a more hands-off control strategy that would save significant heating and cooling energy use in the spaces being controlled. With reduced overnight space temperatures, higher heating and cooling demand would occur in the morning when system resume and to meet daytime setpoints however, this load can be reduced if the morning start-up is staged slowly to meet the setpoint before the facility is opened. Unoccupied space setback temperatures are recommended to be at least 4°F from the occupied setpoint.

Alternatively, one could achieve these setbacks via be programmable thermostats. While BAS are more comprehensive units capable of integrating an entire facility's HVAC network and controlling multiple zones, programmable thermostats are standalone devices used for individual units or smaller spaces. Programmable thermostats require less upfront capital investment but lack the complex control and integration capabilities of a BAS. Generally, one may consider programmable thermostats as the more ideal option for smaller installations, simple facilities, or when budget restrictions limit investments. Many modern programmable thermostats offer features allowing for ease of controls through smart devices. Installed devices are recommended to have trending capabilities.

Curling ice requires very precise temperature control, usually kept around -4°C (24°F), to ensure the ice remains hard and smooth while providing the right level of friction for curling stones to glide predictably. Temperature fluctuations can create inconsistent ice texture and softness, leading to irregular curling stone behavior and impacting game quality. It is noted by the facility operator that introducing nighttime temperature setbacks in the curling sheets may result in negative impacts such as frost build-up on the curling rocks. To implement temperature setbacks without compromising ice quality or causing frost buildup, curling facilities can use a gradual, controlled setback approach during periods with no play, such as overnight. Using a small setback

range, with programming in-place to ensure a gradual return to operating temperatures in advance of occupied hours would allow operators to achieve energy and cost savings without significantly impacting ice quality. Additionally, incorporating dehumidification would help prevent frost build-up.

5.1.4 Ice plant heat recovery – Hydronic conversions

Hydronic systems allow for centralized equipment to deliver energy throughout the facility, which in turn provides a more accessible point where efficiency improvements and heat recovery measures can be focused.

In a facility with an ice rink, the refrigeration plant operated throughout the heating season, resulting in a source of heat rejected that can be recovered for use for space heating requirements. Dedicated heat recovery chiller plants can achieve this, when sized correctly and can provide high grade heat. In some cases, where high grade heat is not required, the condenser loop may be used to meet the heating load, with assistance from auxiliary heating backup to meet remaining unmet load. The temperature of the condenser loop is typically capped of at 90-95°F and as such, the space heating needs should be lower, or the loop must be boosted with a supplemental heating system such a heat pump or other system to provide higher grade heat.

Existing fuel-fired furnaces that can be reconfigured to use heating coils that can operate off low-grade temperature loops as preheat, with remaining demand topped off with auxiliary heating, significant fuel savings, and emissions reductions can be found. If the burner is left in, the system can operate as a hybrid system, if complete electrification is not feasible with current infrastructure. For the purpose of decarbonization, equipping a hydronic loop that can provide preheat to the air, and topped with electric heating or heat pump system, can reduce energy demand and consumption. Additional heating is required if high-grade heat is not available for furnace operation to maintain existing design and space heating/ventilation requirements.

If this measure were implemented, the controls would need to be programmed to give precedence to the hydronic heating if refrigeration plant is in operation, prior to any backup or auxiliary heating systems or burners to meet heating demand. As a part of this measure, additional mechanical design would be required to minimize the additional piping and ductwork to be installed. Testing, balancing and commissioning is required to ensure optimal operation for the facility. The mechanical work required for this measure to be implemented will be disruptive to normal facility operation.

5.1.5 Heating and cooling measure summary

Table 8: Heating and cooling measure summary

Measures	Descriptions
Electric unit heaters like-for-like replacement	Like-for-like replacement of electric unit heaters.
Fuel fired furnace unit like-for-like replacement	Like-for-like replacement of fuel fired furnaces.
Curling sheet heaters (1-2) like-for-like replacement	Like-for-like replacement of fuel-fired unit heaters 1-2 serving the curling rink.

Measures	Descriptions
ASHP replacement of furnace	Replace the forced-air fuel-fired furnace with split air source heat pump (ASHP) to provide heating and cooling in space with appropriate backup heat source.
Hydronic AHU conversion	Using heat recovery from ice plant to provide space hydronic heating to the lobby spaces by incorporating FCUs into the existing ductwork and furnace AHU, via a new hydronic piping as required.
Hydronic UH conversion	Using heat recovery from ice plant to provide space hydronic heating to the curling sheets by incorporating a hydronic AHU and via new piping as required.
Electric furnace	Replace fuel-fired furnace with electric equivalent.
Electric curling sheets unit heaters	Replace the existing fuel fired unit heaters in the curling sheets with electric unit heaters. This is an electrification measure.
Space temperature setbacks	Maintain lower overnight setpoint temperature and optimize unit operation to operate with respect to other units in same or adjacent spaces (avoid operation conflicts in heating and cooling). This measure requires extensive BAS improvements.

Business-as-usual measures	**Initial capital costs ($)**	**Total energy savings (ekWh)**	**Total net annual savings ($)**	**Annual GHG reduction (tCO_2e)**	**NPV ($) without funding**
Electric unit heaters like-for-like replacement	$ 2,300	-	-	-	$ - 2,349
Fuel fired furnace unit like-for-like replacement	$ 11,900	-	-	-	$ - 8,615
Curling sheet heaters like-for-like replacement	$ 21,300	-	-	-	$ - 12,115
Low carbon measures	**Initial capital costs ($)**	**Total energy savings (ekWh)**	**Total net annual savings ($)**	**Annual GHG reduction (tCO_2e)**	**NPV ($) without funding**
ASHP replacement of furnaces	$ 55,000	42,447	$ - 5,863	12.3	$ - 136,549
Hydronic AHU conversion	$ 191,400	56,677	$ - 2,860	13.5	$ - 267,812
Hydronic UH conversion	$ 116,900	38,416	$ - 900	8.5	$ - 140,396
Electric furnace	$ 19,400	6,500	$ - 13,448	9.3	$ - 241,918
Electric curling sheets unit heaters	$ 35,000	15,671	$ - 5,699	6.7	$ - 74,954
Space temperature setbacks	$ 15,000	43,17	$ 2,939	7.2	$ 80,435

5.2 Domestic hot water measures

The facility has two hot water systems. One electric tanked, hot water system is dedicated for pebbling hot water, for ice surface maintenance. The second unit is a tankless, gas-fired system that serves all other hot water needs, such as washrooms, kitchen sinks, etc. Loop temperature of the gas-fired system was noted to be 140°F, and the pebbling hot water tank at 100°F which is adequate for the needs.

The domestic hot water system can be optimized by implementing the following measures:

5.2.1 Air source heat pump (ASHP) hot water heater

Indoor residential sized ASHP DHW heaters can use excess heat from high heat gain spaces (e.g. mechanical rooms) to provide hot water needs but will result in a localized cooling effect. It is important to note the locations of these smaller units that have this local cooling consequence, as they should not be near thermostats that control the operation of heating systems such as space unit heaters. The cooling effect may unintentionally trigger heating systems, to counteract the localized cooling. A primary benefit of indoor DHW systems is that they do not operate using outdoor air, and as such do not have a period where they cannot meet demand (from low outdoor air temperatures), as such, auxiliary heating is not needed or minimized depending on available space heat or through hybrid ASHP and electrical element operation.

Available electrical capacity must be investigated for electrification measures and any upgrades to electrical infrastructure examined before proceeding with this measure.

For this facility the switch from the existing tankless gas-fired floodwater heaters to suitably sized ASHP options was examined. ASHP systems are not generally available for tankless hot water heating; when examining ASHP floodwater heaters, a hot water storage tank was included. This re-adds standby losses associated with the storage tank, however the ASHP technology allows a low-carbon alternative that can minimize the electric demand increase associated with electrifying fuel-fired water heaters.

5.2.2 Electric hot water heater

To electrify fuel-fired domestic hot water heater systems, a 100% electric unit with equivalent heating capacity can be provided, typically using electric elements. Different sizes and equipment footprints are available based on domestic hot water demand. Electrical capacity upgrades are necessary for this measure. Compared to ASHP systems, full electrical heaters have higher consumption but lower initial costs and do not require ducting for outside air. Costs for electrical infrastructure upgrades are not accounted for in the analysis but are likely higher than an indoor ASHP system that uses electrical auxiliary top-up.

5.2.3 Tankless water heaters

Tankless water heaters, also referred to as Instantaneous Water Heaters (IWH), are units that can provide significant savings, depending on the specific hot water use cases needed by the facility and spaces. A domestic hot water heater with a tank generally requires additional piping to deliver hot water to various points in a facility, has a higher maintenance cost, lower life span than an IWH. When the DHW flow rates required are low, i.e., no high flow fixtures or hot water demand such as multiple showers, laundry, or dishwashers, an IWH can be a cost and space saving option.

A tankless water heater will have less heat losses due to reduced piping, and lack of storage tank. With a conventional system the domestic hot water tank if programmed to a hot water setpoint that it is filled to maintain. If the facility or spaces do not have consistent hot water demand, hot water stored will be impacted by standby heat loss. Tankless water heaters will have minimal to no standby heat loss, which will reduce energy consumption and GHG emissions as a result. With a longer life span, which lasts typically 20 years relative to the 10 years of a conventional tank hot water system, it is often a more optimal investment for low flow systems.

This measure would most benefit the pebbling hot water heater, as the unit can be more compact, low demand and temperature, and does not have frequent use. Extending the lifetime of the equipment with less use and maintenance requirements.

5.2.4 Low flow fixtures

Low flow fixtures are a low-cost method to reduce water heating use and demand, along with reduced water consumption costs. Typically, flow fixtures are not changed on a schedule, but when failure occurs and as needed. Fully replacing all flow fixtures, which includes, sink, lavatory, shower heads, in addition to flush fixtures such as toilets and urinals, would reduce hot water energy use from the flow fixtures and water use from flow and flush fixtures. Low flow fixtures can often be found to have 50%+ reductions relative to their standard counterparts. Occupants should be made aware to not use fixtures for more than necessary due to perceived water flow, which would reduce the savings realized.

Financial savings associated with this measure are inclusive of fuels required to heat hot water used by these fixtures but are exclusive of utility billing associated with water.

5.2.5 Domestic hot water measure summary

Table 9: Domestic hot water measure summary

Measures	Descriptions
Electric pebbling heater like-for-like replacement	Like-for-like replacement of electric DHW boiler.
Instantaneous DHW heaters like-for-like replacements	Like-for-like replacement of fuel fired instantaneous DHW for washrooms, showers, kitchen use at end of life.
Electric instantaneous pebbling water heater	Switching to tankless water heaters can save energy and costs by eliminating thermal losses from tanks and unused hot water, making it a better option for infrequent hot water use.
ASHP domestic hot water heater	Replace the existing fuel fired instantaneous DHW heaters with air-source heat pump (ASHP) tanked water heater, which will have higher heating efficiency. This involves transitioning from a tankless unit to a 40 USG tanked unit.
Electric tankless water heater	Replace the existing fuel fired tankless DHW heaters with electric tankless water heaters. This is an electrification measure.
Low flow water fixtures	Low flow fixtures to reduce hot water load and water consumption.

Business-as-usual measures	Initial capital costs ($)	Total energy savings (ekWh)	Total net annual savings ($)	Annual GHG reduction (tCO_2e)	NPV ($) without funding
Electric pebbling heater like-for-like replacement	$ 2,800	-	-	-	$ - 4,293
Instantaneous DHW heaters like-for-like replacements	$ 6,600	-	-	-	$ - 4,376
Low carbon measures	**Initial capital costs ($)**	**Total energy savings (ekWh)**	**Total net annual savings ($)**	**Annual GHG reduction (tCO_2e)**	**NPV ($) without funding**
Electric instantaneous pebbling water heater	$ 3,600	435	$ 92	-	$ - 2,009
ASHP domestic hot water heater	$ 11,400	- 49	$ - 277	0.1	$ - 13,300
Electric tankless water heater	$ 11,400	20	$ - 130	0.1	$ - 9,726
Low flow water fixtures	$ 800	49	$ 21	0.1	$ 76

5.3 Refrigeration plant measures

The ammonia-based refrigeration plant is nearing end of life. Using slab sensors and a Honeywell T775 controller to maintain ice temperatures at around 23°F - 24°F, and no setbacks currently in place. There is interest in having a combined, shared plant with the arena next door, which can help modulate load and reduce operation costs.

The refrigeration plant is the most significant single source of energy consumption in facilities with ice rinks. There are significant opportunities in energy and emissions reductions by implementing the following measures:

5.3.1 Ice temperature optimization

Using a night setback on ice temperature during unoccupied hours can save energy on the refrigeration plant. The recommended ice temperature setback is 2°F higher than current setpoints, with an early start-up to avoid high electrical demand during the day. Avoiding high electrical demand peaks is essential, as they could increase demand costs. A Building Automation System (BAS) can optimize setback schedules, and accurate temperature sensors, such as infrared sensors in addition to existing slab and or brine return temperature sensors, are necessary to monitor and control ice hardness for occupants. It is important that prior to implementing this measure, all applicable sensors are calibrated; the same is true for ice temperature sensors even without the implementation of a BAS.

The setback option has significant savings due to how often a setback would be implemented. The curling schedule is minimal per week, with setbacks applied for the entire weekends, and majority of the weekdays. It was noted that operations staff has had issues with setbacks in the past, with frost formation on the curling stones. It is recommended to have early startup to give the surface time to cool slowly, reduce load on the plant, and ideally minimize frost risk. Typically,

setback temperatures are encouraged to be about 4°F for rinks, but aiming for 2°F with gradual startup can give insight into the limits of when frost formation is most likely.

5.3.2 Variable frequency drives (VFDs) on brine pumps

Controlling brine pump flow rate offers finer temperature control and load modulation with the changing seasons. In conjunction with daily scheduling and setbacks, VFDs can further reduce load during off-peak hours and gradually increase load during morning start-up with BAS integration. It should be noted that a minimum flow must be maintained within the loop to ensure enough turbulence to maintain high heat transfer between the loop and ice sheets. BAS trending and archiving can help optimize the VFD operation for each specific ice rink brine loop configuration.

5.3.3 Refrigeration plant desuperheaters

Desuperheaters are a useful addition to ice plants, providing high-grade heat recovered from compressor operation to nearby sources. Desuperheaters provide temperatures from 100-140°F depending on the heat exchanger capacity and flow rates, which can be used to preheat DHW systems. The high-grade heat can also be used for hydronic heating, but lower flow rates and cyclical nature of compressor operation would not provide stable output. With thermal storage tanks, or used as preheat, this would offer notable savings on DHW use. However, opportunities for heat recovery will depend on proximity to the refrigeration plant as long piping distances can be cost-prohibitive and disruptive to install.

As this facility is noted to have low hot water demand through the ice season, as the pebbling hot water load is minimal, there isn't significant savings opportunities for the cost. The superheat that is recovered, would be better used in the neighbouring arena if a combined plant package is installed.

5.3.4 Transcritical CO_2 refrigeration plant

CO_2 refrigeration plants are a unique and sustainable option in the market, immune to refrigerant phaseouts mandated by international agreements like the Kigali Amendment. These systems excel in cold climates, making them particularly effective for facilities with seasonal ice rinks that primarily operate during winter and shoulder months. CO_2 plants are designed differently from typical ice plants due to the high-pressure characteristics of the CO_2 working fluid and its operation in different physical states to provide cooling.

These systems use multiple smaller compressors, with at least one equipped with a Variable Frequency Drive (VFD). The VFD ensures smoother load adjustments and compressor stability, a process known as trimming. This design enables precise load tuning compared to traditional ammonia or Freon systems, which rely on more cyclic control. CO_2 plants are available in two configurations: direct and indirect. Direct systems are ideal for new constructions, where CO_2 is used directly in subfloor cooling loops. In contrast, indirect systems, which employ secondary fluids like glycol or brine, are better suited for retrofitting existing plants as they reduce implementation costs and preserve infrastructure. However, indirect systems are less efficient due to higher pumping requirements and lower heat transfer performance. The choice of heat exchangers depends on the secondary fluid, with shell-and-tube flooded exchangers for brine and brazed plate-and-frame exchangers for glycol.

CO_2 plants can significantly improve efficiency for facilities operating seasonally in cold climates, particularly when running in subcritical modes. Additionally, during transcritical operation, CO_2 plants offer excellent potential for high-grade heat recovery, making them well-suited to meet facility heating demands with a consistent and stable load profile, but have decreased performance as a consequence. In contrast, ammonia ice plants often use cyclic control with fewer compressors, leading to inconsistent load profiles that may not align effectively with the heating requirements of the facility.

Although CO_2 plants require high operating pressures, leakage risks are rare occurrences with steel-welded piping installed by experienced professionals. Recharging loops are also low cost if necessary. Regular maintenance is crucial for stable operation. A notable drawback is the need for more frequent equipment replacements—typically every 10 years—due to the stress of high-pressure operation and flash gas compression. In contrast, ammonia systems may have 20- to 25-year replacement cycles. However, CO_2 equipment tends to be smaller and more affordable, partially offsetting this disadvantage. Overall, CO_2 plants offer an efficient, reliable, and environmentally friendly solution for facilities in cold climates.

Town operations staff had shown interest in a merged ice plant between the neighbouring arena facility. This CO_2 plant recommendation would be a packaged unit set to serve both systems and would be able to better modulate the capacities needed for both facilities while on different ice season schedules. This system will also enable hydronic conversions of existing furnaces with to maximize potential energy and demand reductions, to bring the facility to low carbon.

5.3.5 Refrigeration measure summary

Table 10: Refrigeration measure summary

Measures	Descriptions
Full refrigeration plant like-for-like replacement	Like-for-like replacements of all systems in refrigeration plant at end of life.
Brine pumps like-for-like	Like-for-like replacements of brine pumps
VFDs on brine pumps	Install new brine pumps with VFDs to modulate flow, this allows for tighter control of setback schedules.
Refrigeration plant optimization - CO2	Replace existing plant with low footprint, CO2 package. This will be optimized for heat recovery through new controls. This measure will include HX to enable condenser loop heat recovery for other measures.
Ice plant desuperheater	Optimize heat recovery with the addition of desuperheaters to capture waste heat from ice plant operation to be used for DHW pre-heat or space heating.
Ice temperature optimization	Adjust temperature of the ice to be 2°F higher during night-time where it is not in use. Early start-up needed to gradually increase temperature and reduce shock into system and ice surface.

Business-as-usual measures	Initial capital costs ($)	Total energy savings (ekWh)	Total net annual savings ($)	Annual GHG reduction (tCO_2e)	NPV ($) without funding
Full refrigeration plant like-for-like replacement	$ 607,500	-	-	-	$ - 620,477
Brine pumps like-for-like	$ 36,700	-	-	-	$ - 44,975
Low carbon measures	**Initial capital costs ($)**	**Total energy savings (ekWh)**	**Total net annual savings ($)**	**Annual GHG reduction (tCO_2e)**	**NPV ($) without funding**
VFDs on brine pumps	$ 47,900	12,490	$ 2,635	1.0	$ 10,288
Refrigeration plant optimization - CO2	$ 870,600	7,676	$ 1,620	0.6	$ - 846,799
Ice plant desuperheater	$ 90,000	1,02	$ 43	0.2	$ - 90,430
Ice temperature optimization	$ 31,000	12,696	$ 1,559	1.7	$ 18,551

5.4 Dehumidification measures

Currently the facility has no dehumidification system but would benefit from a more controlled environment. With operations staff mentioning issues with frost, reduced humidity may improve some of the issues on ice quality and space control. However, adding a new system will result in higher energy consumption overall, and thus negatively impact the energy and emissions of the facility. This measure would primarily improve operations, occupant experience, and extend building life.

Dehumidifier measures include scheduling controls of the units. Ice rinks typically maintain a relative humidity (RH) of 50-55%. However, during warm days, increasing RH to 60% can reduce energy consumption while preventing condensation. This requires a building automation system (BAS) to dynamically adjust humidity setpoints based on wall surface temperatures. At night, when the rink is unoccupied, dehumidification can be set back to 65% RH to save energy, though this may cause slight condensation and uneven ice surfaces. A low-e ceiling can help reduce condensation, and coordination with other systems is essential to minimize energy demand during morning start-up.

The dehumidification system can be optimized by implementing the following measures:

5.4.1 Install electric desiccant dehumidifier

Controlling humidity in an ice rink is vital to maintaining good ice quality. High humidity can lead to condensation on the ice sheet, increasing impurities and requiring more ice resurfacing events. Additionally, condensation on the roof and beams can drip and form bumps on the ice that are difficult to even out. Standard practice is to maintain humidity levels between 50-55% RH during occupied periods. However, ice rinks have high latent heat and humidity due to active occupants

and ice melt, which can lead to mold and mildew if not managed properly. While improving humidity control can enhance ice quality, adding a new system will increase energy use and could raise overall building energy consumption and emissions, depending on the unit's energy source. An electric desiccant unit is recommended to be able to provide humidity control at low air temperatures, and to minimize any on-site fossil fuel use.

5.4.2 Mechanical dehumidifier with ventilation

This form of mechanical dehumidification utilizes hydronic heating and cooling coils with heat recovered from the refrigeration plant, and cooling from the same plant when it is operating. As most ice rink dehumidification systems do not have dedicated fresh air provided to the space, which is required by current code and best practices (e.g., ASHRAE 62.1), this is an opportunity to do so. This system could also enable the space to be used for events during the summer season when the ice is not in, as it provides both space heating and cooling.

The following are scenarios when ice batteries are needed to force plant operation and make heat reclaim available to meet heating demand:

- Periods when there may be cooling (dehumidification) or heating demand in the space at a time when the refrigeration plant is not operational,
- During a night setback period when the plant is not operating, but spaces have heating demand.

Ice built through ice battery operation is stored and melted at a later time, where no heating demand exists but the plant is operational. It is likely that in the winter, the refrigeration plant load would be too low to provide enough heat recovery to the space, and auxiliary heat will be needed to make up the difference. These details will be worked out during design development (see Section 9).

Implementing this system would allow for a unit that provides space heating, cooling, ventilation, and dehumidification, likely utilizing ice batteries. It ties into the existing refrigeration plant, so the additional energy use comes from the unit's fan operation, pumping power for heating and cooling pipes, and ice battery pumping power. If the existing systems aren't hydronic, significant piping work is required for heating and cooling the ice plant to reach the mechanical dehumidifier. It's best to locate the unit close to the ice plant to minimize piping. Additional ducting and diffusers may be required to supply fresh air to the occupants.

The CIMCO EcoDry unit is a mechanical dehumidifier that is specifically designed to be used with BAS systems used in ice rinks, such as the 6000E or CIMCO IQ controller.

5.4.3 Dehumidification measure summary

Table 11: Dehumidification measure summary

Measures	Descriptions
Mechanical hydronic dehumidifier w/ setpoint scheduling	Add a CIMCO Eco Dry or equivalent mechanical dehumidification unit. This will enable the system to provide code ventilation with CO2 demand control, heating and cooling. This allows the spaces to be used in the summer where events can be held. Includes comprehensive dewpoint monitoring and setback controls.
Electric dehumidifier w/ setpoint scheduling	Replace existing fuel-fired desiccant dehumidifiers with an electric desiccant dehumidifier. Includes comprehensive dewpoint monitoring and setback controls.

Low carbon measures	Initial capital costs ($)	Total energy savings (ekWh)	Total net annual savings ($)	Annual GHG reduction (tCO_2e)	NPV ($) without funding
Mechanical hydronic dehumidifier w/ setpoint scheduling	$ 393,800	35,053	$ - 1,609	8.3	$ - 522,653
Electric dehumidifier w/ setpoint scheduling	$ 55,100	- 8,669	$ - 1,829	- 0.7	$ - 132,366

5.5 Lighting, Receptacle, and Power measures

It was noted on site that the curling sheet lights have been replaced with LED retrofit tubes. However, the rest of the building remains mostly on non-LED fixtures, and also includes no occupancy sensors.

The lighting systems can be optimized by implementing the following measures:

5.5.1 Facility wide LED upgrade

LED lighting is an affordable way to reduce electricity consumption and demand in a facility. To minimize costs when transitioning from fluorescent or incandescent lighting, it's best to minimize changes to ballasts and panels. Reevaluating lighting density during a retrofit can identify areas where fixtures can be removed to further improve lighting. Reducing lighting power can also reduce internal heat gains, which can increase heating demand but decrease cooling demand depending on the spaces they serve. Care should be taken to avoid over-lighting spaces by matching design illumination levels (lux), or reducing fixture counts to maintain the required illumination for occupant comfort and visibility. This is ideally carried out by an experienced lighting designer.

Pricing for LED retrofits is inclusive ballast and fixture replacements to ensure longevity of the overall lighting systems.

5.5.2 Lighting occupancy controls

Lighting sensors can improve electricity scheduling and operation in commonly used spaces that have inconsistent occupancy, such as washrooms, changerooms, and multipurpose spaces. Some spaces that are typically occupied, like office spaces would also benefit from sensors, due to different work schedules, breaks, etc. Lighting occupancy sensors are typically installed using motion sensors, connected to the lighting circuits of individual spaces. These sensors can also be scheduled to provide dimming capability for when the space is occupied during times where occupancy isn't anticipated, e.g., during nighttime in a multipurpose space where no occupancy is anticipated, but cleaning staff may be present. Wireless sensors are a lower cost, and less disruptive implementation option, as long as facility wide internet connections are available. Dimming capability is costly if implemented separately from a full fixture replacement.

5.5.3 Lighting measure summary

Table 12: Lighting measure summary

Measures	Descriptions
Lighting fixtures LED like-for-like replacement	Replacing all LED lighting fixtures at end of life with like-for-like equivalents.
Lighting fixtures non-LED like-for-like replacement	Replacing all non-LED lighting fixtures at end of life with like-for-like equivalents.
Facility-wide LED upgrade	Replace all remaining non-LED lighting fixtures with LED fixtures.
Lighting Occupancy Controls	Install occupancy sensors and dimming controls to minimize lighting usage when natural daylight is abundant, and spaces are unoccupied.

Business-as-usual measures	Initial capital costs ($)	Total energy savings (ekWh)	Total net annual savings ($)	Annual GHG reduction (tCO_2e)	NPV ($) without funding
Lighting fixtures LED like-for-like replacement	$ 48,700	-	-	-	$ - 59,680
Lighting fixtures non-LED like-for-like replacement	$ 8,700	-	-	-	$ - 10,662
Low carbon measures	**Initial capital costs ($)**	**Total energy savings (ekWh)**	**Total net annual savings ($)**	**Annual GHG reduction (tCO_2e)**	**NPV ($) without funding**
Facility-wide LED upgrade	$ 9,400	378	$ 283	- 0.1	$ - 4,550
Lighting Occupancy Controls	$ 1,100	112	$ 62	-	$ 182

5.6 Envelope measures

Envelope typically does not have any business-as-usual measures as it is expected that and replacements or retrofits will be done on an as-needed basis, such as situations where insulation or structural is compromised.

It should be noted that adding insulation on the ice rinks, when the months of operation are predominately winter months, would likely increase ice plant load. This is due to better heat retention of the space, and reduced benefit of the 'free cooling' from the winter months on the ice plant load.

The envelope can be optimized by implementing the following measures:

5.6.1 Exterior wall insulation upgrade

To improve thermal performance and reduce energy consumption in a building with thermal bridging issues, the proposal would be to increase wall insulation using spray foam to R-26. This upgrade could decrease heating and cooling demand, prevent thermal bridging, and can seal infiltration/exfiltration points. Envelope upgrades are typically disruptive measures that require significant construction work, and the engagement of an envelope design team. This would be a high-cost measure and would ideally be done during a deep retrofit of the facility.

5.6.2 Exterior roof insulation upgrade

The roof of the building has an estimated effective thermal performance based on its age and construction. Since the building is in a heating-dominant climate, most of the heat loss occurs during colder months. Adding more insulation to achieve an effective R-40 and reducing thermal bridging would be recommended, especially in amenity spaces where heat loss is most significant. However, these envelope upgrades require further study to assess weight and structural limitations and may be disruptive to normal building operation, especially with regards to adding elements such as a rooftop PV array. Ideally, they should be completed at the end of the building's life or during a deep retrofit project, where feasible.

5.6.3 Triple pane windows

Triple glazing with thermally broken framing can improve window performance by achieving an effective U-value of U-0.24, which reduces heating demand and insulates from heat gain. However, this improvement comes at a significant cost premium. While the solar heat gain coefficients (SHGC) remain the same, they may need to be revisited if the facility must meet lower energy use intensity targets to reach net zero goals. SHGC affects the facility's ability to utilize or avoid solar radiation. It is recommended to implement these measures at the end of the existing windows' life or during replacement.

5.6.4 Improve facility wide airtightness

Air tightness is crucial in managing envelope losses and gains, which impacts heating and cooling demand in a facility. Improvements are made by measuring hot or cold spots and evaluating air leakage through pressurization, thermography, and smoke tests. Weather sealing corners, gaps, and envelope interfaces, such as windows and door edges, significantly improve air tightness.

However, note that the ice rink operates at its lowest load during winter due to cold air infiltration, aiding the refrigeration plant. Insulating and sealing the ice rink space can trap more heat, increasing the load on the refrigeration plant. This measure must be evaluated with the design team to optimize weather sealing for heating-dominant spaces, especially since ice rinks often operate during colder seasons.

It should be noted that increasing air tightness will reduce the air transfer into the building, which is especially a concern for spaces that do not have adequate ventilation and depend on a leaky envelope to be ventilated. Considerations should be made to add a dedicated ventilation system for spaces that have none and rely on infiltration.

5.6.5 Exterior envelope upgrades for ice surfaces

For ice facilities operating or looking to extend the ice season into warmer months, increasing the insulation and air tightness levels of the exterior envelope of the ice rink space prevents thermal gains which would result in higher ice plant loads. During sufficiently cooler months however, upgrading the ice rink envelope may have the unintended consequences of trapping internal heat gains within the space, and reducing the potential free cooling effect from the cold ambient environment during the winter months. Both effects result in an increased demand on the ice plant, and thus increased energy consumption. That said, increasing insulation levels in these spaces provides several benefits to ice plant operators and user groups, such as humidity control, and thermal stability and controlled heat management. To counteract potential negative consequences of increased ice rink envelope, best practice would be to implement strategies to manage space conditions. The ratio of benefits to consequences of increasing the ice rink envelope is dependent on climate and length of the ice season.

5.6.6 Envelope measure summary

Table 13: Envelope measure summary

Measures	Descriptions
Exterior wall insulation - Entire facility	Upgrade the exterior wall insulation to R26 or similar to increase U value of the overall wall. This measure applies to the entire facility.
Exterior wall insulation - Excluding rink	Upgrade the exterior wall insulation to R26 or similar to increase U value of the overall wall. This measure applies to the entire facility, less the rink area.
Exterior roof insulation - Entire facility	Upgrade the roof insulation to R40 or similar to increase U value of the overall roof. This measure applies to the entire facility
Exterior roof insulation upgrade - Excluding Rink	Upgrade the roof insulation to R40 or similar to increase U value of the overall roof. This measure applies to the entire facility, less the rink space.
Triple pane windows	Replace double pane windows at end of life with triple pane thermally broken, (U-0.46 to U-0.24).
Improve airtightness - Entire facility	Improve infiltration (air tightness) with weather sealing. This measure applies to the entire facility.

Measures	Descriptions
Improve airtightness - Excluding rink	Improve infiltration (air tightness) with weather sealing. This measure applies to the entire facility, less the rink space.

Low carbon measures	Initial capital costs ($)	Total energy savings (ekWh)	Total net annual savings ($)	Annual GHG reduction (tCO_2e)	NPV ($) without funding
Exterior wall insulation - Entire facility	$ 83,100	7,536	$ 435	1.3	$ - 16,085
Exterior wall insulation - Excluding rink	$ 36,500	4,369	$ 243	0.8	$ - 6,524
Exterior roof insulation - Entire facility	$ 155,100	17,951	$ 1,646	2.8	$ - 23,063
Exterior roof insulation upgrade - Excluding Rink	$ 36,300	3,792	$ 205	0.7	$ - 6,842
Triple pane windows	$ 14,800	402	$ 20	0.1	$ - 3,432
Improve airtightness - Entire facility	$ 41,300	4,847	$ - 350	1.2	$ - 33,413
Improve airtightness - Excluding rink	$ 20,700	4,464	$ 243	0.8	$ - 7,383

5.7 Renewables

Renewables, such as solar photovoltaics (PV) enable the municipality to reduce its electrical costs and are key to meeting GHG emissions reductions targets for the 10-year and 20-year outlooks.

In Ontario, under Ontario Regulation 541/05: Net Metering, excess electricity generation can be credited for up to 11 months. When installing large capacity systems (>100 kW), the facility must coordinate with the local distribution company (LDC) to ensure the infrastructure is in place to allow for appropriate net metering. Typically, solar PV excess generation would occur in the summer, where solar radiation is at its peak, and lowest in the winter.

The municipality must coordinate with the LDC to ensure the infrastructure is in place for two-way transmission to allow for net metering. This can be initiated by facility owners to request a connection impact assessment (CIA) or equivalent through the applicable LDC to ensure that the infrastructure exists both at the facility, and electrical utility grid. Electrical single line diagrams and drawings of the facility's electrical infrastructure are needed to establish what conditions are optimal for this connection. If none exist, an electrical engineer is required to be retained to develop these drawing sets. Typically, solar PV excess generation would occur in the summer, where solar radiation is at its peak, and lowest in the winter.

As ice rink facilities have most of their electrical consumption during the winter season due to the ice rink operation, most electricity consumption may not be offset by solar PV monthly but will depend on net metering and credits that carry forward.

If measures are included that reduce electricity demand and consumption, the array capacity can be reduced, and vice versa if electrification measures are introduced and demand and consumption increase. The final array size will depend on the measures selected and limited by available area on site.

5.7.1 Solar PV (photovoltaics)

When implementing rooftop PV arrays, a structural analysis must be completed to identify if the existing structures can support the weight of PV panels and minimize any thermal bridging on the roof structures. Existing structures such as rooftop units, cooling tower, and elevated building envelope elements such as parapets and elevated roofs must be accounted for to avoid poor PV panel placements and incurring unnecessary shading losses. Space must also be planned to provide appropriate walkways and access for staff to perform regular maintenance. This should be accounted for by an experienced PV contractor. Prior to any major PV array implementation on rooftops, structural engineering studies are recommended to be carried out to ensure safety of the structures and that they can withstand the stresses induced. The stresses from the weight and wind loads from the additions of PV can be greatly reduced through good design practices with consideration to the climate and surroundings of the facility location.

Options exist to explore thin film solar panels, that are lightweight and flexible to be laid on different surface geometries. Procurement may come at a cost premium depending on location. If there is ample ground space, ground mounted units may also be an option, but keeping units safe and secure may incur additional costs but would avoid significant structural upgrade costs to the facility. The approach explored in this measure is for roof mounted units for partial area of the roof, which is typically the more economical option if local PV contracting, and procurement is available.

Figure 5 below shows the monthly electricity generation for the facility for the studied PV array capacity. This monthly profile was calculated using System Advisor Model (SAM) developed by the National Renewable Energy Laboratory (NREL). It can be seen that peak generation is during the summer season, with the lowest in the winter. Winter electricity generation is affected by snow coverage and reduced solar irradiance.

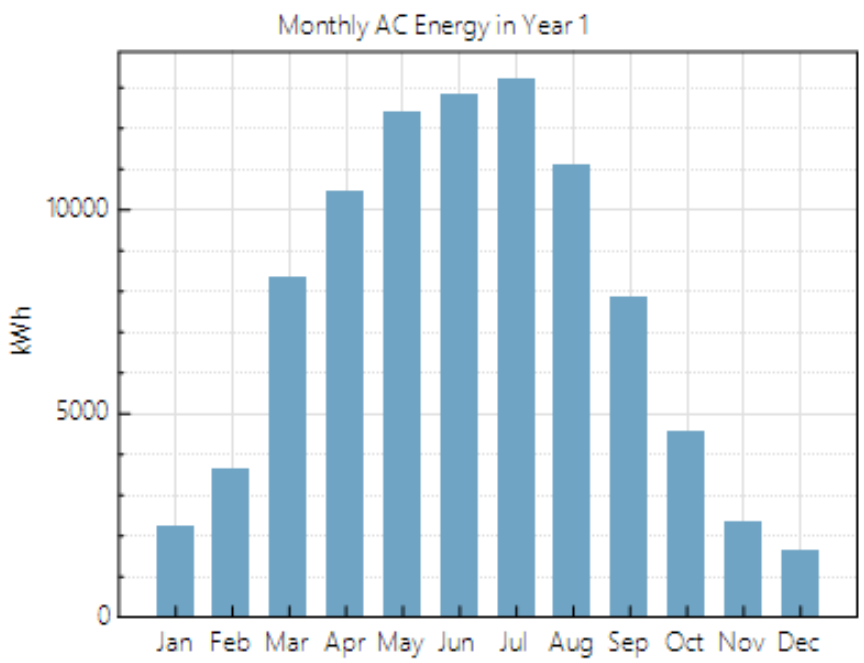

Figure 5. Monthly solar electricity generation from PV array ECM.

5.7.2 Renewable measure summary

Table 14: Renewable measure summary

Measures		Descriptions			
Solar PV - 86 kW array		Provide solar panels on the available roof area to optimize electricity generation and savings through utility net metering.			
Low carbon measures	**Initial capital costs ($)**	**Total energy savings (ekWh)**	**Total net annual savings ($)**	**Annual GHG reduction (tCO_2e)**	**NPV ($) without funding**
Solar PV - 86 kW array	$ 263,000	83,511	$ 17,621	6.9	$ 192,664

5.8 Measures considered but not recommended

The following list of measures were considered or investigated, but not recommended due to many factors identified in the description:

Table 15: Measures considered but not recommended.

Measure	Description
ASHP Curling Heaters	Not investigated due to limitations of incorporating a system in a similar configuration to existing unit heaters. Would require ducting, diffusers, and notable change to space heating strategy for the same capacity. Avoiding converting system into a ducted option.
Geothermal plant	Great energy savings opportunity but NPV is not attractive, and implementation will be disruptive.
Combined heat and power plant	Not preferable with current projections on grid emission factors, with expectations of aiming for low carbon grid.
Solar Thermal Pre-heat	Current prioritization of roof space is given to PV array for electricity generation. Space for solar thermal tubes and panels is not readily available. PV/T panels are not readily available in Canada.
Battery storage	Significant material and associated electrical infrastructure costs, not critical to measures.
Electric load shifting	Facility did not have significant opportunity for load shifting with current operations.
VFDs on condenser pumps	Capacity of pumps are low and cost of VFD for improvement would not be attractive.
Variable refrigerant flow (VRV) systems	Cost to implement new refrigerant piping throughout facility for the amount of savings potential was not attractive.
Waste-water heat pump	No consistent wastewater source, no pool areas where energy can be tapped. Not cost effective for small capacity systems.
Demand Control Ventilation	No centralized ventilation system, or variable volume ventilation system currently in place. Cost of CO_2 sensors, dampers in each space and additional ducting are prohibitive to measure implementation.
Energy Recovery Ventilators (ERVs)	No dedicated ventilation systems on-site. Adding such systems may improve indoor air-quality but would result in an increase in energy consumption.
Drain Water Heat Recovery	Drain water heat recovery works best when there are large flows of grey water (washroom sinks and showers) or condensate, and drainage infrastructure exists. Capital intensive and disruptive to facility operations.
Plug load replacements	Assumed that replacement of this equipment would be as needed by the facility staff, recommended to select energy star equipment as available. Not investigated in study.

6 Summary of measures

This section provides three different scenarios of recommended measures, timing, and actions for the facility with initial capital costs (in today's dollars), emission savings, total net annual savings, and net present value (NPV). Each of these scenarios considers a 30-year implementation timeline, taking the facility to the end date for most municipal greenhouse gas reduction goals. These scenarios are as follows:

i) Business-as-usual scenario. This outlines the replacement of equipment as needed with equivalent, standard replacements, no optimization of existing systems, no heat recovery, nor any consideration for renewables.

ii) Low carbon approach without funding. This scenario incorporates all reviewed low carbon measures based on maximizing energy efficiency, utilizing heat recovery and replacement of equipment at end of life. It includes implementing operational measures in 2025, along with measures that make technical and financial sense to be implemented immediately such as BAS reprogramming and optimization.

iii) Low carbon with funding. This envisions the implementation of low carbon measures using the FCM CBR GHG reduction pathway retrofit capital project funding.

For some measures, multiple capital replacements were included in the scenario, as the equipment would need to be replaced more than once based on recommended lifespan within the study period. For the low carbon pathways, if there is equipment that is reaching end of life, but a low carbon measure isn't recommended for the replacement due to various reasons, the business-as-usual equivalent measure is expected to remain, and will be accounted for in the pathway breakdowns found in sections 6.4 and 6.5.

As equipment is maintained well, and life expectancy is extended, replacement years can be pushed out further. If this equipment life expectancy is extended beyond typical values provided in industry guidelines and best practices, it will improve the value of the equipment over its life and NPV values would improve. This improvement would be proportional to the energy, emissions, and other cost savings achieved through its operation.

6.1 Business-as-usual measures

This scenario assumes that planned capital replacements go forward with standard like-for-like replacements. Refer to Section 4.1 for details on lifecycle costing and net present value calculations. Business-as-usual equipment replacement under this scenario results in negligible energy savings and GHG emissions reduction.

Table 16: Business-as-usual measures summary

Business-as-usual measure	Year	Initial capital costs ($)	Total energy savings (ekWh)	Total net annual savings ($)	Annual GHG reduction (tCO_2e)	NPV ($)
Electric unit heaters like-for-like replacement	2026	$ 2,300	-	-	-	$ - 2,349
Electric pebbling heater like-for-like replacement	2026	$ 2,800	-	-	-	$ - 4,293
Full refrigeration plant like-for-like replacement	2026	$ 607,500	-	-	-	$ - 620,477
Brine pumps like-for-like	2026	$ 36,700	-	-	-	$ - 44,975
Lighting fixtures LED like-for-like replacement	2026	$ 48,700	-	-	-	$ - 59,680
Lighting fixtures non-LED like-for-like replacement	2026	$ 8,700	-	-	-	$ - 10,662
Instantaneous DHW heaters like-for-like replacements	2037	$ 6,600	-	-	-	$ - 4,376
Fuel fired furnace unit like-for-like replacement	2039	$ 11,900	-	-	-	$ - 8,615
Curling sheet heaters like-for-like replacement	2042	$ 21,300	-	-	-	$ - 12,115
Total		**$ 746,500**	**-**	**-**	**-**	**$ - 767,541**

6.2 Low carbon measures on typical implementation pathway with and without funding

The following scenario incorporates low/zero carbon measures based on equipment end of life without funding from other sources. Implementing these measures will allow each facility to meet the FCM GHG reduction pathway goals for the 50% GHG reductions by year 10 and 80% GHG reductions by year 20.

Some business-as-usual (BAU) like-for-like replacement measures are recommended in the low-carbon pathway, as low-carbon alternatives are not necessary to meet the feasibility targets, economically viable, and/or the existing equipment is adequate.

Measures that are not recommended as they are not needed to achieve the GHG reductions targets, do not have an attractive NPV or implementation is not deemed feasible are listed below:

- **Envelope measures** – due to disruptive implementation, poor NPV relative to the GHG emissions reduced and energy saved.

    - The exception to this is that infiltration excluding the ice rink, as the measure is low cost, and fairly attractive NPV for envelope upgrades.
- **Hydronic AHU and unit heater conversion** – cost of implementation is significant for the replacement of a single furnace and two unit heaters. Addition of piping and distribution systems upgrades do not allow for an attractive NPV, relative to the savings achieved.
- **Electric furnaces** – not selected in favour of using an ASHP option, helping the facility reach lower carbon with less electrical demand increases and consumption.
- **ASHP domestic hot water heaters** – an electrification measure that would be adding additional electrical demand to the facility, and energy savings are not significant enough to have a more attractive NPV than existing tankless option.
- **Electric tankless domestic hot water heaters** – an electrification measure that would be adding additional electrical demand to the facility, and energy savings are not significant enough to have a more attractive NPV than existing tankless option.
- **Ice plant desuperheater** – not recommended as the savings are minimal for the cost of implementation. This measure has a poor NPV.
- **Ice temperature optimization** – facility staff had suggested that setbacks have been tried in the past but cause frost issues, so this measure is not included to meet the pathway. It is still recommended to attempt new strategies for ice temperature setbacks and make gradual changes to reduce frost build up on stones.
- **Mechanical hydronic dehumidifier** – this measure would replace spectator IR heaters in addition to the gas-fired desiccant dehumidifier. This was avoided as other measures were able to achieve the same goals with a more attractive NPV.
- **Electric desiccant dehumidifier** – this measure is not recommended due to the addition of energy consumption in the facility, resulting in poor incremental NPV as there is no business as usual case. It is however recommended for building longevity.
- **Solar PV Panels** – This measure has a positive NPV and would be recommended for implementation as it will reduce energy costs, and net metering rules in Ontario is very favourable. If funding can be secured, solar panels will provide good return on investment given the escalating costs of electricity in the future, and implemented sooner, would reap more rewards. This measure is not included in the pathway only to keep costs down, and as it is not needed to meet the FCM pathway GHG targets for the typical pathway.

Table 17: Low carbon measure with and without funding based on typical timeline

Low carbon measure	Year	Initial capital costs ($)	Total energy savings (ekWh)	Total net annual savings ($)	Annual GHG reduction (tCO_2e)	NPV ($) without funding	NPV ($) with funding
Space temperature setbacks	2025	$ 15,000	43,174	$ 2,939	7.2	$ 80,435	$ 83,238
Electric unit heaters like-for-like replacement	2026	$ 2,300	-	-	-	$ - 2,349	$ - 2,349
Lighting fixtures LED like-for-like replacement	2026	$ 48,700	-	-	-	$ - 59,680	$ - 59,680
Electric instantaneous pebbling water heater	2026	$ 3,600	435	$ 92	-	$ - 2,009	$ - 900
Low flow water fixtures	2026	$ 800	498	$ 21	0.1	$ 76	$ 222
VFDs on brine pumps	2026	$ 47,900	12,490	$ 2,635	1.0	$ 10,288	$ 25,043
Refrigeration plant optimization - CO_2	2026	$ 870,600	7,676	$ 1,620	0.6	$ - 846,799	$ - 588,565
Facility-wide LED upgrade	2026	$ 9,400	378	$ 283	- 0.1	$ - 4,550	$ - 1,655
Lighting Occupancy Controls	2026	$ 1,100	112	$ 62	-	$ 182	$ 521
Improve airtightness - Excluding rink	2030	$ 20,700	4,464	$ 243	0.8	$ - 7,383	$ - 3,870
ASHP replacement of furnaces	2034	$ 55,000	42,447	$ - 5,863	12.3	$ - 136,549	$ - 123,784
Instantaneous DHW heaters like-for-like replacements	2037	$ 6,600	-	-	-	$ - 4,376	$ - 4,376
Electric curling sheets unit heaters	2042	$ 35,000	15,671	$ - 5,699	6.7	$ - 74,954	$ - 70,238
Total [3]		**$1,116,700**	**136,007**	**$ 6,802**	**31.1**	**$ - 899,058**	**$ - 597,780**

6.3 Low carbon measures on aggressive implementation pathway with funding

Table 18 below presents the costs of implementing the necessary low carbon measures funding in an aggressive timeline (less than 5 years if eligible for funding) to meet the GHG targets. The low carbon measures with funding scenario have the highest NPV, delivering the highest cost savings over the current baseline for the 30-year period examined. Differences between tables

would be reflected in the NPVs of the measures that need to be completed earlier to meet the timeline and/or GHG targets of the aggressive pathway. In some cases, additional measures are needed to meet the targets.

Some business-as-usual (BAU) like-for-like replacement measures are recommended in the low-carbon pathway, as low-carbon alternatives are not necessary to meet the feasibility targets, economically viable, and/or the existing equipment is adequate.

Measures that are not recommended as they are not needed to achieve the GHG reductions targets, do not have an attractive NPV or implementation is not deemed feasible are listed under section 6.2 above.

Table 18: Low carbon measures with funding based on aggressive timeline

Low carbon measure	Year	Initial capital costs ($)	Total energy savings (ekWh)	Total net annual savings ($)	Annual GHG reduction (tCO_2e)	NPV ($) with funding
Space temperature setbacks	2025	$ 15,000	43,174	$ 2,939	7.2	$ 83,238
Electric unit heaters like-for-like replacement	2026	$ 2,300	-	-	-	$ - 2,349
Lighting fixtures LED like-for-like replacement	2026	$ 48,700	-	-	-	$ - 59,680
Electric instantaneous pebbling water heater	2026	$ 3,600	435	$ 92	-	$ - 900
Low flow water fixtures	2026	$ 800	498	$ 21	0.1	$ 222
VFDs on brine pumps	2026	$ 47,900	12,490	$ 2,635	1.0	$ 25,043
Refrigeration plant optimization - CO_2	2026	$ 870,600	7,676	$ 1,620	0.6	$ - 588,565
Facility-wide LED upgrade	2026	$ 9,400	378	$ 283	- 0.1	$ - 1,655
Lighting Occupancy Controls	2026	$ 1,100	112	$ 62	-	$ 521
ASHP replacement of furnaces	2030	$ 55,000	42,447	$ - 5,863	12.3	$ - 150,169
Electric curling sheets unit heaters	2030	$ 35,000	15,671	$ - 5,699	6.7	$ - 136,644
Improve airtightness - Excluding rink	2030	$ 20,700	4,464	$ 243	0.8	$ - 3,870
Instantaneous DHW heaters like-for-like replacements	2037	$ 6,600	-	-	-	$ - 4,376
Total[3]		**$1,116,700**	**136,007**	**$6,802**	**27.4**	**$ - 632,722**

6.4 Comparative costs and NPV by year

The following tables highlight capital requirements by year for the specified measures, inflation, annual energy emission savings, cost escalations, and maintenance costs have been factored into the NPV. The table presents justification for the recommendation of the given measures in the specified year. Only recommended measures are listed in the table below. These measures are selected to meet the low carbon pathways, provide the most optimal NPV, and meet the ambitions for the facility's operational future. Refer to Appendix E and F for measure ID tags.

Table 19: Financial summary year – Business-as-usual scenario

Business-as-Usual year of replacement	Initial outlay of costs with inflation ($)	NPV ($)	Measures (ID #)	Explanation
2026	$ 749,738	$ - 742,436	BAU-01, BAU-04, BAU-06, BAU-07, BAU-08, BAU-09	End of life replacement(s).
2037	$ 9,692	$ - 4,376	BAU-05	End of life replacement(s).
2039	$ 18,540	$ - 8,615	BAU-02	End of life replacement(s).
2042	$ 36,262	$ - 12,115	BAU-03	End of life replacement(s).
Total	**$ 814,232**	**$ - 767,541**		

Table 20: Financial summary by year – Low carbon on typical pathway

Typical pathway year of replacement	Initial capital costs with inflation ($)	NPV without Funding ($)	NPV with Funding ($)	Measures (ID #)	Explanation
2025	$ 15,450	$ 80,435	$ 83,238	MEC-07	MEC-07 – Control optimization measures and can be implemented immediately
2026	$ 1,044,350	$ - 904,843	$ - 627,362	BAU-01, BAU-08, MEC-08, MEC-11, RFG-01, RFG-02, ELE-01, ELE-02	BAU-01, 08 – Measure(s) to be implemented at end of life or expected replacement. Feasible low carbon equivalent(s) not available. MEC-11 – Low flow fixtures replacement after reviewing replacements needed. Most are original fixtures. RFG-01, 02 – Ice plant CO2 replacement package, including VFDs on brine pumps. To be installed as a combined plant serving both curling facility and arena facility. ELE-01, 02 – Replacement of lighting fixtures with occupancy sensors and dimmer controls included.
2030	$ 24,717	$ - 7,383	$ - 3,870	ENV-04B	ENV-04B – Upgrade building envelope infiltration, excluding the rink space to reduce energy use. Scheduled later in project timeline to investigate facility envelope needs.
2034	$ 73,915	$ - 136,549	$ - 123,784	MEC-03	MEC-03 – Replace existing gas-fired furnace with ASHP option, to electrify energy use at lower demand. May use fuel fired back-up if capacity limitations exist. Currently assumes electric backup.
2037	$ 9,692	$ - 4,376	$ - 4,376	BAU-05	BAU-05 – Measure(s) to be implemented at end of life or expected replacement. Feasible low carbon equivalent(s) not available.
2042	$ 59,585	$ - 74,954	$ - 70,238	MEC-06	MEC-06 – Replace gas-fired unit heaters serving curling sheets space, with electric equivalents.
Total	**$ 1,227,710**	**$ - 899,058**	**$ - 597,780**		

Table 21: Financial summary by year – Low carbon on aggressive pathway

Aggressive pathway year of replacement	Initial capital costs with inflation ($)	NPV with Funding ($)	Measures (ID #)	Explanation
2025	$ 15,450	$ 83,238	MEC-07	MEC-07 – Control optimization measures and can be implemented immediately
2026	$ 1,044,350	$ - 627,362	BAU-01, BAU-08, MEC-08, MEC-11, RFG-01, RFG-02, ELE-01, ELE-02	BAU-01, 08 – Measure(s) to be implemented at end of life or expected replacement. Feasible low carbon equivalent(s) not available. MEC-11 – Low flow fixtures replacement after reviewing replacements needed. Most are original fixtures. RFG-01, 02 – Ice plant CO2 replacement package, including VFDs on brine pumps. To be installed as a combined plant serving both curling facility and arena facility. ELE-01, 02 – Replacement of lighting fixtures with occupancy sensors and dimmer controls included.
2030	$ 132,182	$ - 290,684	MEC-03, MEC-06, ENV-04B	ENV-04B – Upgrade building envelope infiltration, excluding the rink space to reduce energy use. Scheduled later in project timeline to investigate facility envelope needs. MEC-03, 06 – Measure implemented during the 5-year mark for aggressive pathway, to approach FCM GHG reduction targets of 80%.
2037	$ 9,692	$ - 4,376	BAU-05	BAU-05 – Measure(s) to be implemented at end of life or expected replacement. Feasible low carbon equivalent(s) not available.
Total	**$ 1,201,674**	**$ - 632,722**		

6.5 Comparative NPV by end-use category

The following tables highlight the net present value (NPV) differences of low carbon measures against business-as-usual measures by primary end-use categories. The table presents justification for the recommendation of the given measures when compared to the business-as-usual measures, with respect to measures selected for the different pathways. On the occasion that no low carbon measures are recommended to replace the business-as-usual equivalent (due to poor NPV, not needed to meet target, high capital cost, etc.), the business-as-usual measure is included in the low carbon pathway to remain as is. Refer to Appendix E and F for measure ID tags.

Table 22. NPV summary of low carbon measures and business-as-usual measures with the savings differences between both cases for the typical implementation pathway

	Low Carbon			Business As Usual		Savings Difference	
Category:	**Measure (#)**	**NPV No Funding ($)**	**NPV With Funding ($)**	**Measure (#)**	**NPV No Funding ($)**	**NPV No Funding ($)**	**NPV With Funding ($)**
Heating	BAU-01, MEC-03, MEC-06, MEC-07	$ - 133,418	$ - 113,134	BAU-01, BAU-02, BAU-03	$ - 23,079	$ - 110,339	$ - 90,055
Domestic Hot Water	BAU-05, MEC-08, MEC-11	$ - 6,309	$ - 5,054	BAU-04, BAU-05	$ - 8,669	$ 2,360	$ 3,615
Refrigeration	RFG-01, RFG-02	$ - 836,512	$ - 563,522	BAU-06, BAU-07	$ - 665,452	$ - 171,060	$ 101,930
Lighting	BAU-08, ELE-01, ELE-02	$ - 64,049	$ - 60,814	BAU-08, BAU-09	$ - 70,342	$ 6,293	$ 9,528
Envelope	ENV-04B	$ - 7,383	$ - 3,870	-	-	$ - 7,383	$ - 3,870
Total						**$ - 131,517**	**$ 169,761**

Table 23. NPV summary of low carbon measures and business-as-usual measures with the savings differences between both cases for the aggressive implementation pathway

	Low Carbon			Business As Usual		Savings Difference	
Category:	**Measure (#)**	**NPV No Funding ($)**	**NPV With Funding ($)**	**Measure (#)**	**NPV No Funding ($)**	**NPV No Funding ($)**	**NPV With Funding ($)**
Heating	BAU-01, MEC-03, MEC-06, MEC-07	$ - 231,215	$ - 205,925	BAU-01, BAU-02, BAU-03	$ - 23,079	$ - 208,137	$ - 182,847
Domestic Hot Water	BAU-05, MEC-08, MEC-11	$ - 6,309	$ - 5,054	BAU-04, BAU-05	$ - 8,669	$ 2,360	$ 3,615
Refrigeration	RFG-01, RFG-02	$ - 836,512	$ - 563,522	BAU-06, BAU-07	$ - 665,452	$ - 171,060	$ 101,930
Lighting	BAU-08, ELE-01, ELE-02	$ - 64,049	$ - 60,814	BAU-08, BAU-09	$ - 70,342	$ 6,293	$ 9,528
Envelope	ENV-04B	$ - 7,383	$ - 3,870		-	$ - 7,383	$ - 3,870
Total						**$ - 171,465**	**$ 134,819**

7 Roadmap to net zero - pathways

Fundamental to each scenario, or pathway, is the idea of implementing measures over time to maximize savings, efficiency, and funding. The low carbon measures recommended for the net zero pathway are listed in Table 17 and Table 18.

Sections 7.1 presents the current and projected greenhouse gas intensity (GHGI). The 10- and 20-year marks are projected using GHG factors for 2035 and 2045 respectively. For the 5-year aggressive approach, the projected GHG factor for 2030 is used.

7.1 Thessalon Curling Club low carbon pathways

The tables below show the low carbon greenhouse gas emissions intensity (GHGI) and GHG savings for the typical (without funding), and aggressive (with funding) pathways. Included in the table is the incremental life cycle cost (ILCC) which is the difference in NPV between low carbon measures and business-as-usual measures per tonne of equivalent CO_2 emissions reduced within the same forecast period.

Table 24: Projected GHG emissions reductions to meet 50% GHG reductions in 10 years and 80% GHG reductions in 20 years (typical timeline)

GHG emissions savings	Current	10-year forecast	20-year forecast
Electricity emissions (tCO_2e)	7.3	0.1	-
Natural Gas emissions (tCO_2e)	26.1	5.0	2.4
Total emissions (tCO_2e)	33.5	5.0	2.4
GHGI ($kgCO_2e/ft^2$)	2.3	0.4	0.2
$ILCC/$tCO_2e$	-	$ 2,487	$ - 1,594
% Saving	-	84.9%	92.8%

Table 25: Projected GHG emissions reductions where most measures are implemented in first 5 years (aggressive timeline)

GHG emissions savings	Current	5-year forecast
Electricity emissions (tCO_2e)	7.3	3.7
Natural Gas emissions (tCO_2e)	26.1	2.4
Total emissions (tCO_2e)	33.5	6.1
GHGI ($kgCO_2e/ft^2$)	2.3	0.4
$ILCC/$tCO_2e$	-	$ 7,246
% Saving	-	81.8%

Through legislation, incentives, and policy changes, the electric grid is projected to become cleaner and have a lower GHG emissions factor. The current estimated GHG factors for the grid

are found in Appendix C, which was released by Environment and Climate Change Canada. As a result, the typical pathway will have lower emissions as the grid cleans up, but more measures may be needed to meet the same emissions targets in the aggressive pathway timeline.

8 Cash flows

The following graphs show the changes in cash flow over time for the three scenarios described. Inflation rates, escalation rates, operations and maintenance and cost savings are embedded in the NPV, and the year-by-year analysis is presented through the cashflow diagrams below. The cashflows presented below do not include residual value and include the full cost of second and further replacements of measures for all pathways. As the study period extends, overall trends will be more pronounced.

Under the business-as-usual case shown in Figure 6 below, the cash flow is steadily negative in a for the entire period. This is a result of various capital investments along the time period and no energy savings as equipment performance remains stagnant. With inflation, the total 30-year spend is close to $2.4M.

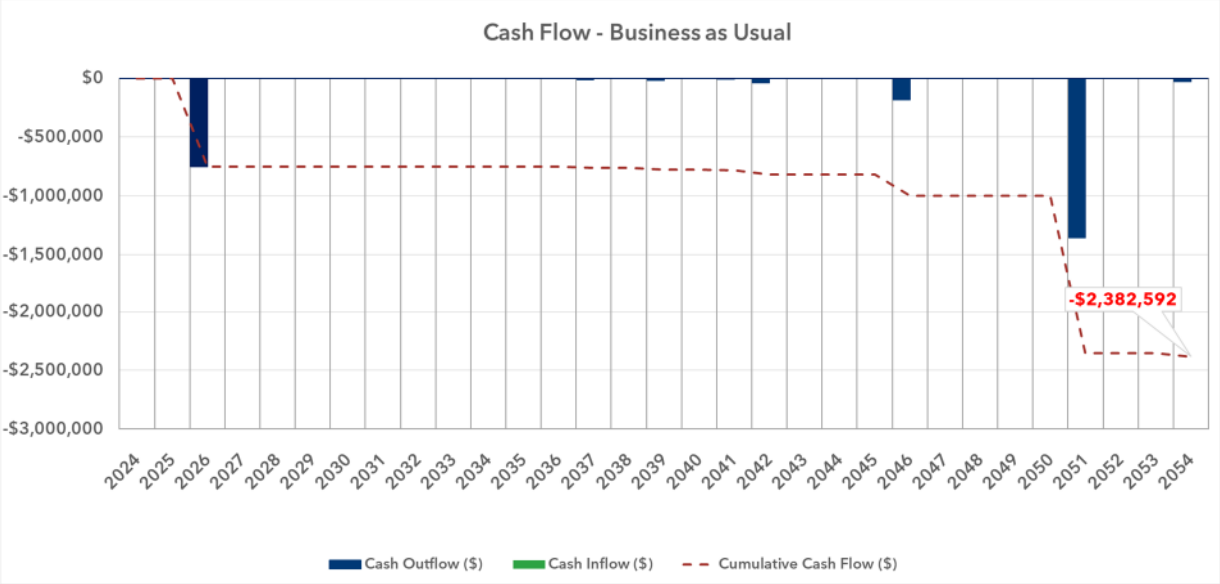

Figure 6: Cash Flow – Business-as-usual

The typical low carbon path without funding scenario shown below includes the additional investment in low carbon measures, as well as the savings from escalating utility costs and carbon taxes (green bars). Cash inflows from energy and carbon tax savings provides a return but are insufficient to breakeven during the study period. Within the study period the cumulative cash flow peaks around 2046 before equipment replacements must occur again, and the cycle repeats. A breakeven point is unlikely within the study period, and the total cumulative cash flow of this pathway is close to negative $2.9M. Cash inflows are projected to continue to increase

beyond the study period due to higher savings from escalated energy costs and estimated carbon tax increases.

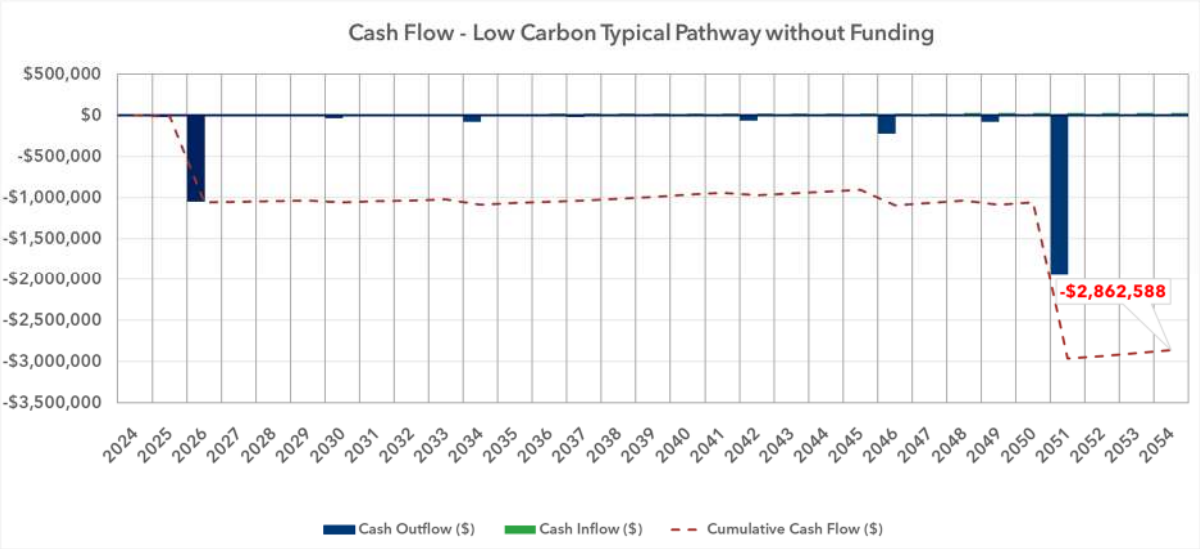

Figure 7: Cash Flow – Low Carbon Approach on Typical Pathway without Funding

The figures below present the equivalent forecast with FCM funding for both the typical and aggressive pathways. Similar to the above, neither pathway reaches a financial breakeven point within the study period. It can be seen that the aggressive pathway has more investments within the first five years of the study period to meet the emissions reductions requirements within that time. The total cumulative cash flows of the low carbon pathways with funding on the typical and aggressive timelines are negative $2.20M and negative $2.25M.

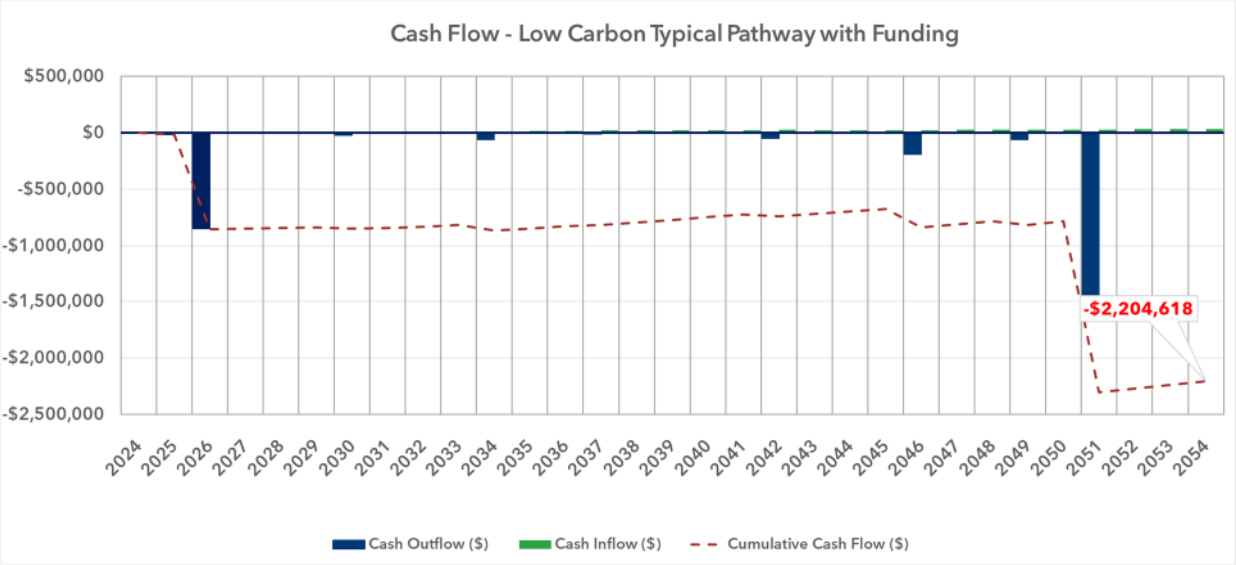

Figure 8. Cash Flow – Low Carbon Approach on Typical Pathway with Funding

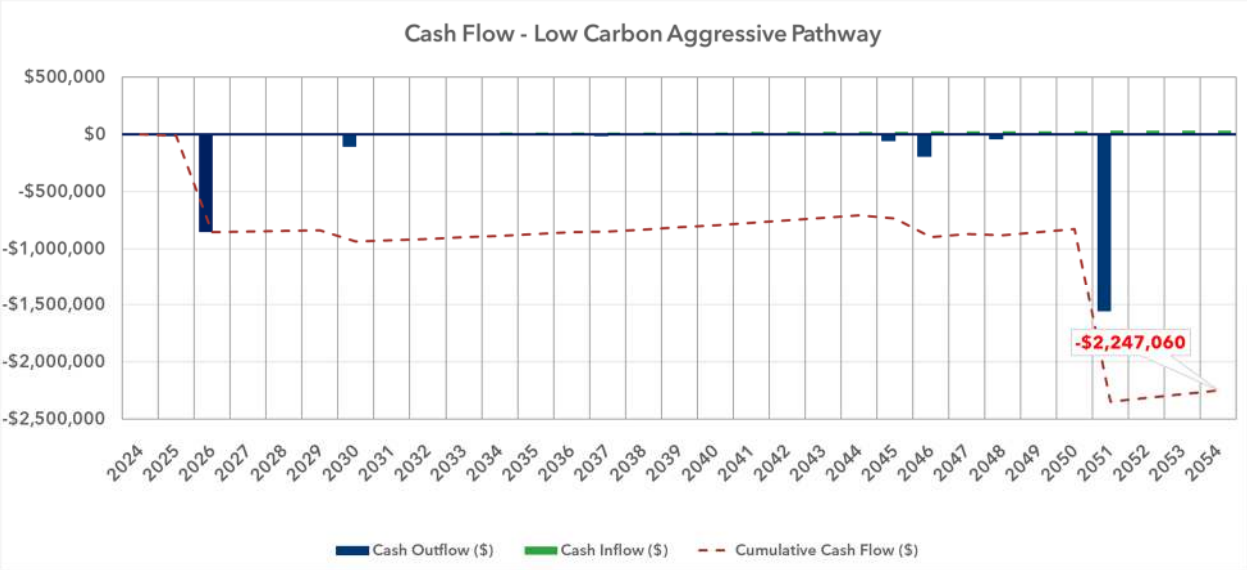

Figure 9: Cash Flow – Low Carbon Approach on Aggressive Pathway with Funding

Figure 10 compares cumulative cash flows for the three pathways over the 30-year study period. The net cash flow (distinct from NPV, which is current dollars) between the low carbon pathway and business-as-usual pathway is approximately negative $480k without funding and $178k with funding on the typical pathway, and $135k for the aggressive pathway. Breakeven does not occur in any 30-year pathway given the second replacements that happen within the study period.

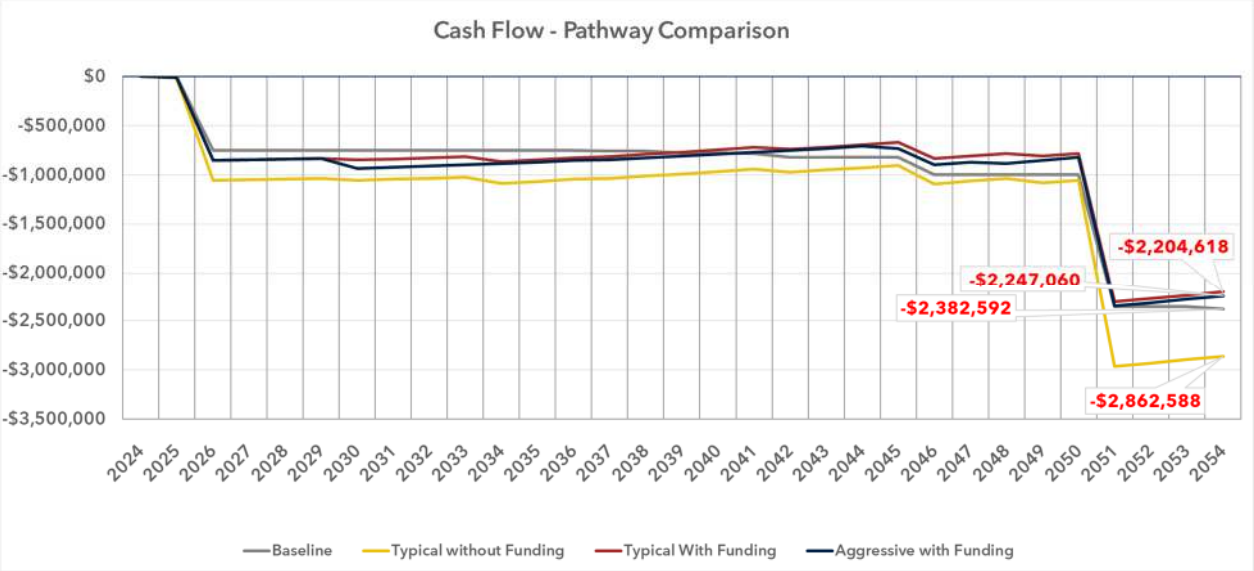

Figure 10. Cumulative cashflow comparison of the three pathways studied

8.1 Thessalon Curling Club annual utility cost per pathway

Figure 11 below presents 30-year annual utility costs, including energy and carbon, for business-as-usual (BAU), and typical and aggressive low carbon pathway (LCP) scenarios. Without action to improve energy efficiency and lower the facility's carbon footprint (remaining business-as-usual), the Town of Thessalon can expect to spend close to $1.8M over the next 30 years due to utility and carbon price escalations. The measures recommended in this Roadmap will reduce that spend by almost 33% over the 30-year study period in the typical low carbon pathway, with the savings invested in fully repaying the investment in upgraded building systems and a surplus accruing to the municipality. These values are accounted for in the NPV values presented in this report.

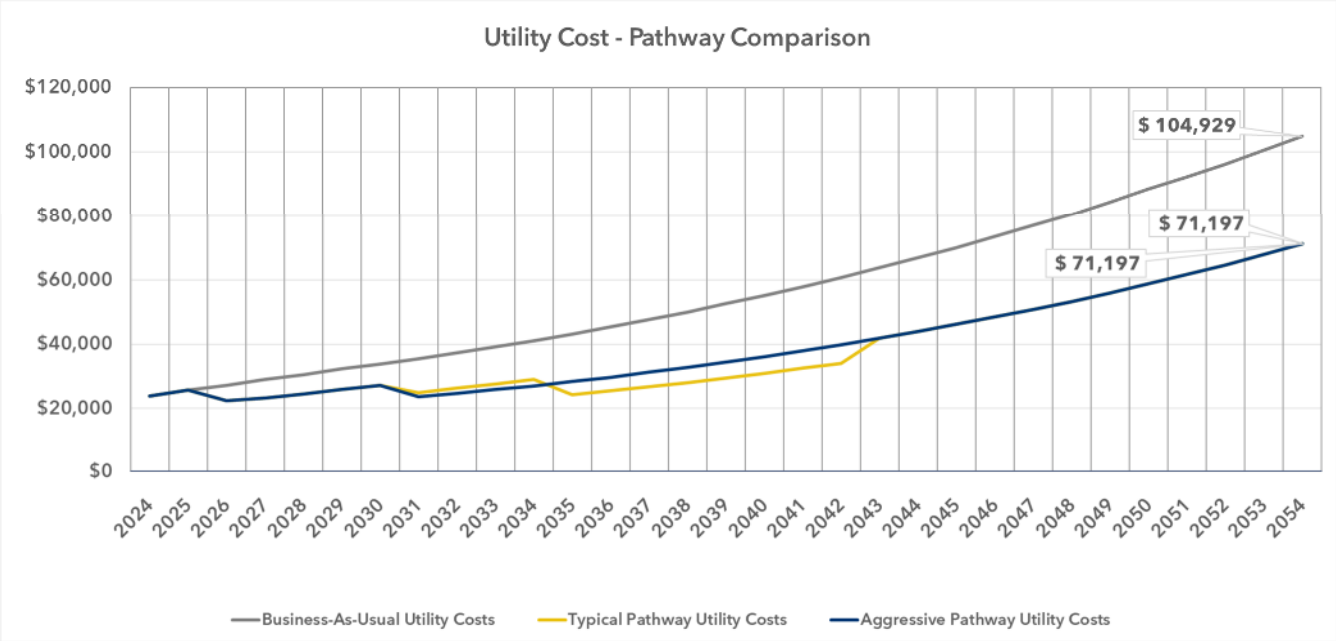

Figure 11. Annual utility cost comparison between pathways

9 Project implementation

This report lays out a strategic, phased approach for transforming the Thessalon Curling Club into a sustainable, low-carbon facility. By adopting this low carbon pathway, the Town of Thessalon not only addresses climate change, but also benefits from the economic potential of these low-carbon upgrades and sets an example for community-led environmental stewardship. Achieving this vision will require careful planning and attention to obtaining corporate commitment, financing, design development and performance verification. Our project delivery team is here to help with each step along the way, and an Implementation Workshop is recommended to discuss and decide the best approach to each of the elements described below.

9.1 Making the Business, Environmental and Community Case for Action

Meetings with the Town of Thessalon's senior leadership team and Council will make the case for taking this approach, address both risks and opportunities, as well as answer any questions:

- The report makes the **business case** for implementing these comprehensive, integrated projects. The facility is relatively energy inefficient, aging and in need of infrastructure renewal. This report outlines the case for a comprehensive, integrated approach to modernizing the Thessalon Curling Club by comparing the expenditures under business-as-usual ($1.8M utilities and nearly $2.4M on initial equipment replacements over the next 30 years) to the 30-year projection for the proposed alternative low-carbon upgrade projects. The proposed projects will require an additional $415k of upfront capital but will reduce utility costs by around 33% and yield a positive incremental net present value with funding of around $170k relative to the BAU pathway over the 30-year period. Taking this low carbon approach will actually make money for the Town of Thessalon.
- The **environmental case** is equally compelling. The environmental benefits of this project are profound, offering a dramatic reduction in greenhouse gas emissions by around 93%. This initiative not only positions the Town of Thessalon as a leader in combating climate change but also proactively shields the community from the future impacts of carbon pricing and environmental regulations, ensuring resilience and sustainability up to 2050 and beyond.
- Making the **community case for action** may be the strongest of all. A majority of Canadians are feeling climate anxiety and looking for practical, meaningful action from their government leaders. This forward-thinking and sustainable renewal of the Thessalon Curling Club with advanced lighting, heat recovery and rooftop solar generation, will position the community as a model for sustainable community development, deeply resonating with Canadians' desire for decisive climate action and showcasing the tangible steps being taken by their leaders to combat climate anxiety. Sustainable renewal of the Thessalon Curling Club will be a highly visible demonstration of environmental leadership.

9.2 Project Financing

Financial modeling of the project allows for staged implementation of the main elements of work over the next 30 years, beginning immediately with operational and no-cost improvements followed by low-cost measures that have lower turnaround time, or require end-of-life replacements. This is again followed up high capital cost equipment replacements, retrofits or system conversions that require detailed design and planning and have longer implementation timelines. These phases can be grouped to minimize disruption, operations, and costs with overlapping or interacting systems. These timelines can be adjusted based on preferred financing arrangements of available capital for the required infrastructure renewal or if building operational needs change.

In this study, costs for preliminary studies or upgrades are not included and would be required to ensure adequate implementation of related measures. This includes studies such as recommissioning of HVAC, air and water testing and balancing, smoke pencil or blower door testing, roof structural integrity for PV panel installations, electrical infrastructure upgrades to improve building capacity and allow for 2-way transmission for PV net metering, etc. These studies and tests should be done prior to any detailed design stage to allow design teams to account for current building conditions.

The municipality will need to work with the LDCs to develop the electrical infrastructure within the municipality in the case that larger limitations apply to the local grid that inhibit the ability to apply the recommended low carbon measures.

With the completion of this GHG Reduction Pathway Feasibility Study, the community of the Town of Thessalon can apply for the GHG Reduction Capital Pathway Retrofit Funding through the Community Buildings Retrofit (CBR). This stream is designed to support your community in implementing each phase of your GHG Reduction plan, through a combined grant (25%) and loan (75%), for up to 80% of the project costs, up to $5million per phase (each phase requires a new application to be submitted). Further details are available on the CBR webpage. (https://fcm.ca/en/programs/green-municipal-fund/community-buildings-retrofit-initiative). The utilization of this capital pathway grant has been included in the financial analysis of this report where "with funding" is identified. Under this program, the community of the Town of Thessalon is eligible for approximately $233k in grants. In Table 26 below, the total initial budget required is listed to engage the funding application and begin the implementation process. For the case of low carbon measures eligible for CBR funding, this total initial budget (20% of total) works out to be equivalent to the grants provided (also 20% of total), with low-interest loans provided for the remainder. Business-as-usual measures are included in initial budget required as 100% of the capital cost, as no funding is available with like-for-like. The required capital budget for the low carbon pathway can be compared to the business-as-usual annual capital requirements presented in Table 19 of this study. Measure IDs can be referenced from Appendix E and F.

Table 26. Implementation phase breakdown summary with initial budgets required, and loans provided by funding program

Phase	Planning Year	Selected Measures (ID #)	Cumulative GHG % Reduction	Initial Capital Costs with Inflation ($)	Total Low Carbon Grant Value ($)	Total Initial Budget Required ($)	Low-Interest Loan Provided by CBR ($)
Immediate	2025	MEC-07	25%	$ 15,450	$ 3,090	$ 3,090	$ 9,270
1	2026	BAU-01, BAU-08, MEC-08, MEC-11, RFG-01, RFG-02, ELE-01, ELE-02	38%	$ 1,044,350	$ 198,049	$ 252,155	$ 594,146
2	2032	ENV-04B, MEC-03, BAU-05	85%	$ 108,325	$ 19,726	$ 29,419	$ 59,179
3	2040	MEC-06	93%	$ 59,585	$ 11,917	$ 11,917	$ 35,751
Total			**93%**	**$ 1,227,710**	**$ 232,782**	**$ 296,581**	**$ 698,347**

This feasibility study may also be used to apply for other government and utility funding that becomes available, including Ontario's Save on Energy incentives.

Options for funding the Town of Thessalon's net capital requirements for implementing the roadmap plan may be explored in the Implementation Workshop.

9.3 Procurement

This integrated project involves discrete elements of work – refrigeration plant and dehumidifiers, lighting, rooftop solar PV, heating system, domestic hot water, BAS controls, etc. – implemented in stages over the next 30 years by different delivery partners. It is important to keep in mind the interactive effects of each measure, to avoid slipping back into a business-as-usual procurement process. Procurement aims to ensure the overall performance outcomes are achieved, including delivering the energy, emissions and utility cost savings, while meeting BPS guidelines. Coordination with the Town of Thessalon's procurement department and agencies such as Canoe Procurement Group will develop the most efficient and effective approach. More information on the benefits of utilizing Canoe Procurement Group can be found on their webpage: https://canoeprocurement.ca/.

9.4 Re-commissioning, Controls and Operations

A significant share of the savings in the refrigeration plant, HVAC systems and lighting can be achieved through low-cost improvements to operations, maintenance, and controls. Work can begin immediately with the Town of Thessalon's staff and service contractors on identifying and implementing these changes to provide early wins and positive cashflow. For any HVAC measures, it is recommended to do perform air and water testing and balancing to ensure that systems are providing as per design. Recommissioning efforts can also identify controls and operation improvements by verifying that equipment and systems are operating and installed according to specifications. This is a crucial step that is often missed, and results in significant improvements in operation, or identifies key weakness that can be addressed during replacements at equipment EOL. It is also encouraged to use BAS to trend and archive building system performance and operations, along with fault detection to identify opportunities and challenges which can be addressed by facility operators or inform better design through the low carbon roadmap.

9.5 Additional Building Assessments

When making major upgrades, having certain assessments completed will enable smoother implementation and verification of capital measures. For general facility operations and tracking, a building condition assessment should be completed to document current conditions of existing equipment and envelope. Blower door and/or smoke pencil testing will inform measures where infiltration of the facility is to be improved to achieve optimal savings. For PV implementation, it is recommended that studies are completed to evaluate roof structural integrity to support the load of a PV array, and electrical connection capacity of the facility. Additionally for PV arrays intended to capitalize on net-metering programs where available, coordination with the LDC must

occur to ensure the infrastructure is in place for two-way transmission to allow for net-metering. For envelope measures, it is recommended that an appropriate assessment is completed to understand the limitations and prioritize components for improvements or replacements.

9.6 Capital Works Design Development and Project Management

Capital projects that require detailed design carry a budget for design development, working drawings and specifications to produce the best solution given the facility's space, location, electrical, and structural constraints. Project management will coordinate this work, along with installation and commissioning, to ensure that the individual projects and the overall work achieves the energy targets set out in this report.

9.7 Standards, Staff Training, and Service Contracts

This project will establish equipment and performance standards to inform future retrofit design and facilitate ongoing operations and maintenance at the Thessalon Curling Club and other properties. Standards will include building automation system functionality and programming, HVAC scheduling and setpoints, and lighting products, levels, and controls. Staff training and service contractor standards will similarly need to be developed to provide a common level of understanding and knowledge and full engagement in facility performance across all properties.

9.8 Performance Measurement and Verification

As part of this study, the municipality has a one-year membership in the Mayors' Megawatt Challenge (MMC) [https://mayorsmegawattchallenge.com/], a program working with municipalities across Canada to reduce energy use and greenhouse gas emissions in their own municipal buildings. Continuing membership will provide quarterly reporting of actual, weather normalized savings achieved, along with access to webinars, applied research projects, the Annual Forum and a network of other municipalities working together on the challenges and opportunities of energy efficiency and decarbonization. Additional buildings can be added to MMC membership over time.

With the rising importance of energy and carbon, it is also recommended that municipalities invest in energy management information systems (EMIS) to record, monitor, and report on all energy use in their corporate facilities.

9.9 Communications and Community Outreach

Municipalities are leaders of their communities in responding to the climate crisis. Leadership by example can inspire and enable their residences and businesses to take positive climate action. Projects like decarbonization of the Thessalon Curling Club demonstrate what is possible and should be widely communicated to the community-at-large and beyond.

This project was carried out with assistance from the Green Municipal Fund, a Fund financed by the Government of Canada and administered by the Federation of Canadian Municipalities. Notwithstanding this support, views expressed are those of the authors, and the Federation of Canadian Municipalities and the Government of Canada accept no responsibility for them.

Appendix A – Site visit assessment report

Site Name	Thessalon Curling Center
Participants Performing Site Visit	Kajen Ethirveerasingham Sean Mitchinson
Date Performed	March 21st, 2024

Building Details

Gross Floor Area	10,500 ft^2
Number of stories	2 floor lobby (1 + 1) Curling is one large story
Area of other significant spaces	
Construction Date	Rebuilt in the 1960s
Use of Facility	Curling Center Gathering space Rentals

Systems to Consider

System	Present	Drawings available	Notes
Fan Systems (AHUs/RTU)	☒	☐	
Refrigeration Plant	☒	☐	
Heating (Boilers, DHW)	☒	☐	
Solar PV	☐	☐	
Water	☒	☐	
Lighting	☒	☐	
BAS	☐	☐	
Other:	☐	☐	

Drawings

Drawing	Drawings available	Notes
No drawings available		

Architectural

Photos	
Building Exterior (different faces show wall finish and windows)	☐
Interior (typical wall construction, window types, ceiling)	☐
Roof (if easily accessible)	☐
General notes on Architectural details related to the building envelope (doors, windows, insulation, etc. to determine its current condition)	
No insulation on curling sheet walls, likely not on roof. Lobby and basement walls will be assumed based on building vintage.	

Receptacles and Plug Loads

Kitchen Equipment and source?	Gas kitchen, commercial ovens x 2, griddle, 2 fryers, 2 ranges . Used once per month during summer. 3 times per month in winter. Window AC cooler runs 24/7.
High use plug loads (data servers, commercial electric kitchens, etc.)	No
Any variable loads in building? (Process loads, equipment, tools, transitional or seasonal)	No
Additional Notes:	

Heating

How many hot water systems are there in total?	2		
System Name	Purpose/Type: (space heating, DHW/ electric, gas)	Notes (loop temp, control, etc.)	Year Installed/ Condition
NG Tankless IWH	DHW	140 F	2022
Electric DHW	Pebbling 20 USG. Rev	95 F, 120 F	EOL
Is there an unoccupied temperature set back in place? If so, describe the set points during unoccupied periods.			
No			

How is Heating system controlled? *(BAS, Manually, or other)*	Digital, programmable
Do they have their own controllers?	
Are there any air curtains on the doors (typically with overhead doors)?	
No	
Are the doors interlocked with any heating (typically with overhead doors)? Also, what is approximate frequency and duration for doors opening?	
N/A	
Auxiliary Heaters (electric radiative, Gas Heaters, electric baseboard, etc.)	

How many Gas Fired Heaters are there in total?			3
Heater Type	Capacity/Control	Location Served	Year Installed
Furnace		Lobby	10 years old
UH x 2		Curling Sheets	November 2022
How many Electric Heaters are there in total?			2
Heater Type	Capacity/Control	Location Served	Year Installed
Electric UH	Not used	Basement	
Baseboard Radiator	0 C	Workshop	

Water Use

Space	Fixture Type/Qty/ Flow rate (low flow, etc.)	Controls (sensors)	Year Installed/ Condition
DHW	Sinks, toilets x 8	Manual, old	1960s
Pebbling	5 USG per curling day	Manual, old	EOL
3 Washrooms	Men's WR, Women's WR, Accessibility WR		
Is there any seasonal water use? (Landscaping, cooling tower make-up, etc.)		No	
Is water used for cooling tower make-up?		Yes	
Any replacements/upgrades of water fixtures planned?		No	

Ventilation and Air Conditioning & Plumbing Table

Equipment Name or Tag	Capacity and Specs (Airflow CFM. heating and cooling capacity, Fan/Pump HP, power input)	Control Method (BAS or Standalone)	Area/Zone Served and Location	Operation/ Setpoint Schedule	Age/ Condition
Range Hood		Manual			
EF-1,2,3		Timers			
	No DH, ceiling fans, or exhaust fans in curling sheets				

Schedules

Location/Tag HVAC zone or Space	Operation/Occupancy Schedule Weekday, weekend, seasonal operation/occupancy	Lighting (matches operation?)	HVAC (matches operation?)
Curling Season (Whole Building)	Weekdays 3.5 hours per night 35 people Weekends Not occupied Bonspiels Weekends are unoccupied unless there are bonspiels. 4 weekends per season 14 hours 100 occupants Ice being made mid-September. Publicly available start of November. Taken out first week of April.	☒	☐
Off season	1 event per month 8h 40 occupants	☒	☐
Pebbling	5 USG per weekday	☐	☐
Basements	1 hour per weekday before and after events	☒	☐
Raffle (Lobby)	Raffle every Wednesday. 40 people in the evening.	☒	☐
Temperature, RH, Loop Setpoints			

Location/Tag HVAC zone or Space	Daytime Setpoint Space Temperature, RH, etc. during Weekday, weekend, seasonal operation/occupancy	Nighttime Setpoint Space Temperature, RH, etc. during Weekday, weekend, seasonal	Activity Setpoint Space Temperature, RH, etc. during Weekday, weekend, seasonal
Lobby	70 F	Constant	Constant
Curling Sheets	42 F @ 6ft off ice	Cannot do setbacks	Cannot do setbacks
Is there a separate facility wide schedule for lighting or HVAC?			
No			
Are these controlled with a BAS or sensors? (Method of control)			
No			
Are there any significant deviations in operation of the facility, seasonally? *Different usage during summer and winter, spaces repurposed seasonally*			
Facility mainly used during curling season.			

Lighting

What are the primary fixture types?	LED in sheets Incandescent in lobby spaces Fluorescent in basement
Is there a lighting plan and schedule?	No
Do unique spaces have different lighting, and what fixtures?	No
Have LED retrofits been completed, and when? (only for certain spaces or facility wide and year of completion)	Curling Sheets
Occupancy or daylighting sensors? (what spaces and how many)	No
Lighting control and scheduling? (when is the lighting scheduled, is there seasonal changes, and is it on a BAS)	No
General notes on lighting operation, concerns, opportunities	
No	

Refrigeration System

Refrigerant Type	Ammonia

Type of Controls Ice IR sensors, ice slab sensor and/or brine water return temperature		Slab sensors, Honeywell T775	
Refrigeration Equipment *Compressors, Pumps, Evaporative Fans,*			
Equipment Name/Type/ Quantity	System Capacity	Year Installed/ Condition	Notes (Control methods, VFDs, etc.)
Compressor	30 HP	Rebuilt 2023	
Evaporative Condenser			No VFD
Brine Pump	10 HP		
Condenser Pump	0.75 HP		
Chiller			Shell and Tube
Is there any heat recovery? For ice melting, underfloor, heating system? Is there a desuperheater or heat recovery heat pump system?			
No			
What is the ice rink under slab setpoint temp (if this is used to control ice temperature)?			
General Notes and Comments (Facility space, existing equipment, measures requested)			
26 RT. 2-inch foam. Sand floor.			

Ice Rink

When is the Ice In and Out?	Ice being made mid-September. Publicly available start of November. Taken out first week of April
What kind of activity does the rink experience? *Ice hockey, figure skating, public skate etc.*	Curling
Is there a low-e Ceiling? When was it installed?	Suspended low-e ceiling
Number of Rinks	1
Dimensions of Rinks (ft)	4 sheets 150’ long x 60’ wide
Area of Rinks (ft²)	
Setpoints	

Temperature the ice is maintained at?	23 - 24 F
Nighttime Setback temperature for Ice?	Operator not interested in these setbacks
Space RH setpoint?	N/A
Space temperature of the rink?	42 F @ 6ft off ice
Space temperature setpoints based on activities?	Operator not interested in these setbacks
Nighttime setback for space temperature?	Operator not interested in these setbacks
Do the setpoints change during Winter and Summer season for temperature and RH?	N/A
Intended/Target Ice thickness? Any concerns with maintenance?	~ 3.5 – 4 “ (Due to sand and variances in elevations. To reduce ice thickness would require a concrete floor)
Spectator Occupancy	
Number of seats in spectator area and typical occupancy per game?	N/A
How are Spectator Areas heated?	N/A
How often and for how long is spectator heating used?	N/A
Take pictures of entire space, ceiling, lighting, walls, windows. ☐	
Brine Headers	
Accessible? *(under concrete or wood boarding)*	
Length (ft)	
Material *(steel/plastic)*	Plastic
Insulated? *(covered in ice, foam insulation, etc.)*	No

Ice Resurfacing Machine

Number of resurfacing machines and fuel source? When was it installed?	1 electric ice scraper
How many times a day is the ice resurfaced?	
On typical Weekday	5 USG per curling day
On typical Weekend	

How many times does the machine need to be refueling/recharged per week?	
On typical Weekday	
On typical Weekend	
Water Temp in Ice resurfacing machine	
Do they have REALice?	N/A
Is RO Water used for resurfacing?	Yes
What volume of water does Ice resurfacing machine hold?	
Approximately what % of total water is used during resurfacing	5 USG per curling day
Take a picture of the nameplate & model number	☐

BAS

Please take pictures or screenshots of all BAS pages	☐
Are there trend logs? If so, please describe how they are set up, and what they are recording	
N/A	
How do operators use the BAS?	
N/A	
Do they actively change setpoints or schedules?	
N/A	
Are schedules updated for activities* on an ongoing basis and are the equipment schedules edited accordingly, or are schedules and setpoints alone regardless of activities?	
General Notes and Comments	

Appendix B – Monthly billing data

The tables below list monthly energy use and cost as per monthly billing.

Prices below are exclusive of HST but include carbon pricing.

Table 27: Monthly energy use and costs for April 2023 – March 2024

Month	Electricity use (kWh)	Electricity cost ($)	Natural Gas use (m³)	Natural Gas cost ($)
Apr-2023	1,054	$ 222	1,542	$ 715
May-2023	1,068	$ 225	813	$ 371
Jun-2023	524	$ 111	45	$ 43
Jul-2023	650	$ 137	36	$ 40
Aug-2023	787	$ 166	9	$ 12
Sep-2023	6,746	$ 1,423	11	$ 29
Oct-2023	13,643	$ 2,879	529	$ 250
Nov-2023	10,786	$ 2,276	1,634	$ 713
Dec-2023	11,600	$ 2,448	2,233	$ 963
Jan-2024	12,246	$ 2,584	2,746	$ 1,129
Feb-2024	13,455	$ 2,839	2,245	$ 915
Mar-2024	11,995	$ 2,531	1,924	$ 789
Total	**84,553**	**$ 17,841**	**13,767**	**$ 5,969**

Appendix C – Life cycle cost assumptions

The assumptions incorporated in the life cycle costing are outlined below. The primary sources for the tables are the Community Buildings Retrofit Initiative Green Municipal Fund, Federation of Canadian Municipalities, the Pricing Carbon Pollution produced by Canada.ca, and the National Inventory Report for emission factors. Escalation rates may change in the future, however, varying the escalation rates does not change the overall impact.

Pricing Carbon Pollution, A Healthy Environment and A Healthy Economy. – www.canada.ca/content/dam/eccc/documents/pdf/climate-change/climate-plan/annex_pricing_carbon_pollution.pdf

Assumptions	
Inflation (current consumer price index)	3.00%
Escalation rate – Utilities – Electricity	5.00%
Escalation rate – Utilities – Natural Gas	5.00%
Escalation rate – Labor and maintenance	3.00%
Discount rate	5.00%
Loan interest rate	6.00%
Amortization period (yrs.)	30

Carbon pricing assumptions	
Year	$/tonne
2024	$80.00
2025	$95.00
2026	$110.00
2027	$125.00
2028	$140.00
2029	$155.00
2030	$170.00
2031 – 2039	+ $15.00/year up to 305$/tonne max
> 2040	$305.00

There are two electricity meters found at the facility. Utility rates of both electricity meters at the facility are based on Hydro One Commercial General Service, the rates effective January 1st, 2024, can be found in the table below.

Utility rate structure – Electricity, Commercial General Service	
Time-of-Use On-Peak	18.2 ¢/kWh
Time-of-Use Mid-Peak	12.2 ¢/kWh
Time-of-Use Off-Peak	8.7 ¢/kWh
Monthly Service Charge	32.78 $/month
Smart Metering Entity Charge	0.42 $/month
Distribution volume charge (metered use)	7.21 ¢/kWh
Transmission Connection Charge (adjusted use)	0.74 ¢/kWh
Transmission Network Charge (adjusted use)	0.93 ¢/kWh
Standard supply service administration charge	0.25 $/month
Rural or Remote Rate Protection Charge (adjusted usage)	0.14 ¢/kWh
Wholesale market service rate (adjusted usage)	0.45 ¢/kWh
HST	13%
Ontario Electricity Rebate	13.1%

Natural gas utility rates are based on Enbridge Residential Rate 01 Union North West – Effective January 1st, 2024, can be found in the table below.

Utility rate structure – Natural gas, Residential Rate 01	
Monthly Service Charge	$23.98
First 100 m³	13.0783 ¢/m³
Next 200 m³	12.8010 ¢/m³
Next 200 m³	12.3613 ¢/m³
Next 500 m³	11.9580 ¢/m³
All over 1,000 m³	11.6244 ¢/m³
Facility Carbon Charge	0.0143 ¢/m³
Transportation to Enbridge	3.3067 ¢/m³
Federal Carbon Charge	15.2500 ¢/m³
Gas Supply Charge	10.9959 ¢/m³
Cost Adjustment	-2.5676 ¢/m³
Components - Gas Supply	-2.9454 ¢/m³
Components - Transportation	0.3778 ¢/m³
GST/HST	13%

Energy use emissions factors are provided in the tables below for the Province of Ontario. Electricity GHG emissions forecasts were used using data provided through the Environment and Climate Change Canada (ECCC) 2023 report source below:

https://data-donnees.az.ec.gc.ca/data/substances/monitor/canada-s-greenhouse-gas-emissions-projections/Current-Projections-Actuelles/Energy-Energie/AM%20Scenario%20AMS/Grid-O&G-Intensities-Intensites-Reseau-Delectricite-P&G/?lang=en

Year	Electricity emissions factor (tCO_2e/kWh)	Year	Electricity emissions factor (tCO_2e/kWh)
2024	0.0000655	2040	0.0000002
2025	0.0000878	2041	0.0000002
2026	0.0000767	2042	0.0000002
2027	0.0000871	2043	0.0000002
2028	0.0000754	2044	0.0000002
2029	0.0000693	2045	0.0000002
2030	0.0000481	2046	0.0000002
2031	0.0000247	2047	0.0000002
2032	0.0000207	2048	0.0000002
2033	0.0000139	2049	0.0000002
2034	0.0000066	2050	0.0000003
2035	0.0000009	2051	0.0000003
2036	0.0000005	2052	0.0000003
2037	0.0000002	2053	0.0000003
2038	0.0000002	2054	0.0000003
2039	0.0000002		

Fuel fired emissions are provided in the table below:

Fuel emission factors		
Natural gas	tCO_2e/m^3	0.001915

Appendix D – Calibration results

Data used to calibrate is normalized for energy use per day of the month, and does not directly use monthly billing data, as billing periods do not align directly with each month, i.e., billing periods may overlap in multiple months.

The tables below provide the modelled and actual monthly utility energy use, and the Coefficient of Variation of the Root Mean Square Error (CV(RMSE)) and Normalized Mean Bias Error (NMBE).

Table 28: Electricity consumption (kWh) modelling error

Month	Model	Actual
1	9,966	12,610
2	11,660	11,787
3	12,580	12,622
4	3,423	4,191
5	940	1,056
6	710	703
7	682	595
8	779	736
9	4,325	4,362
10	10,653	11,060
11	12,272	12,215
12	13,669	11,710
Total	**81,659**	**83,648**
CV(RMSE)	14.7%	
NMBE	2.6%	

Table 29: Natural gas consumption (kWh) modelling error

Month	Model	Actual
1	27,465	25,698
2	23,691	21,384
3	21,457	21,344
4	13,889	13,218
5	7,790	6,758
6	85	481
7	44	310
8	100	97
9	1,248	973
10	8,823	7,620
11	15,971	19,691
12	22,807	25,720
Total	**143,370**	**143,295**
CV(RMSE)	14.7%	
NMBE	- 0.1%	

Figures below show the end use breakdown as per the model calibrated against monthly utility bills energy consumption. These bar graphs show the predominant loads in the facility in the baseline year.

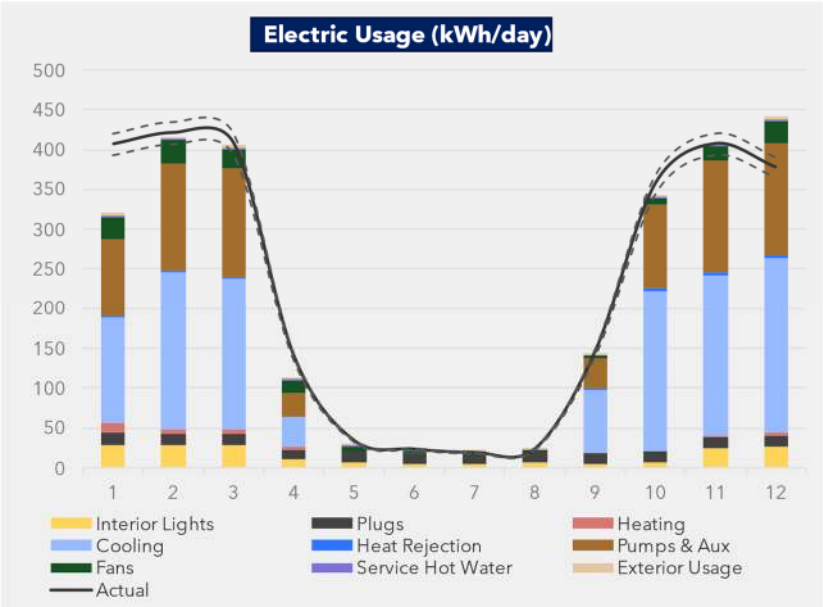

Figure 12: Calibrated Model Monthly End Uses vs Electricity Utility Billing Monthly Totals for April 2023 - March 2024

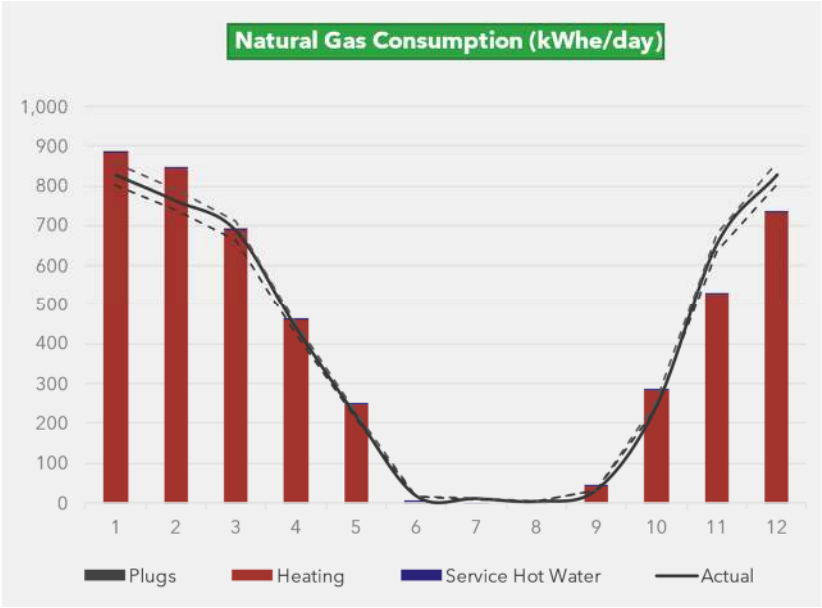

Figure 13: Calibrated Model Monthly End Uses vs Natural Gas Utility Billing Monthly Totals for April 2023 - March 2024

Appendix E – Measure costing breakdown

Subsequent replacements costs after the initial installation costs are dependent on the measure. In the case where the initial cost accounts for laying foundational systems, such as ducting, piping, electrical upgrades, etc., the replacement costs would only account the system that has the shorted life expectancy, such as AHUs, furnaces, and similar. For these measures, reduced replacement costs will improve the NPV as the study period is extended beyond 30 years.

ECM ID #	Measure	Initial cost ($)	Replacement and Maintenance Cost ($)	Breakdown
BAU-01	Electric unit heaters like-for-like replacement	$ 2,300	-	The life expectancy of this measure until the next replacement is 25 years. Includes 25% contingency. Material and Equipment cost = $1,500 Labor and Installation cost = $300 Soft cost (Engineering and/or other services) not included.
BAU-02	Fuel fired furnace unit like-for-like replacement	$ 11,900	-	The life expectancy of this measure until the next replacement is 15 years. Includes 25% contingency. Material and Equipment cost = $7,000 Labor and Installation cost = $2,500 Soft cost (Engineering and/or other services) not included.
BAU-03	Curling sheet heaters like-for-like replacement	$ 21,300	-	The life expectancy of this measure until the next replacement is 15 years. Includes 25% contingency. Material and Equipment cost = $14,000 Labor and Installation cost = $3,000 Soft cost (Engineering and/or other services) not included.
BAU-04	Electric pebbling heater like-for-like replacement	$ 2,800	-	The life expectancy of this measure until the next replacement is 15 years. Includes 20% contingency. Material and Equipment cost = $1,600 Labor and Installation cost = $750 Soft cost (Engineering and/or other services) not included.

ECM ID #	Measure	Initial cost ($)	Replacement and Maintenance Cost ($)	Breakdown
BAU-05	Instantaneous DHW heaters like-for-like replacements	$ 6,600	-	The life expectancy of this measure until the next replacement is 20 years. Includes 20% contingency. Material and Equipment cost = $4,000 Labor and Installation cost = $1,500 Soft cost (Engineering and/or other services) not included.
BAU-06	Full refrigeration plant like-for-like replacement	$ 607,500	-	The life expectancy of this measure until the next replacement is 25 years. Includes 20% contingency. Material and Equipment cost = $405,000 Labor and Installation cost = $101,250 Soft cost (Engineering and/or other services) not included. Additional Notes: Decommissioning of existing plant + Supply, Installation, Testing & Commissioning of new plant
BAU-07	Brine pumps like-for-like	$ 36,700	-	The life expectancy of this measure until the next replacement is 20 years. Includes 20% contingency. Material and Equipment cost = $23,500 Labor and Installation cost = $7,050 Soft cost (Engineering and/or other services) not included. Additional Notes: Decommissioning of existing unit + Supply, Installation, Testing & Commissioning of new pump
BAU-08	Lighting fixtures LED like-for-like replacement	$ 48,700	-	The life expectancy of this measure until the next replacement is 20 years. Includes 20% contingency. Material and Equipment cost = $4,516 Labor and Installation cost = $36,050 Soft cost (Engineering and/or other services) not included.
BAU-09	Lighting fixtures non-LED like-for-like replacement	$ 8,700	-	The life expectancy of this measure until the next replacement is 20 years. Includes 20% contingency. Material and Equipment cost = $1,130 Labor and Installation cost = $6,125 Soft cost (Engineering and/or other services) not included.

ECM ID #	Measure	Initial cost ($)	Replacement and Maintenance Cost ($)	Breakdown
ELE-01	Facility-wide LED upgrade	$ 9,400	-	The life expectancy of this measure until the next replacement is 20 years. Includes 20% contingency. Material and Equipment cost = $1,620 Labor and Installation cost = $6,175 Soft cost (Engineering and/or other services) not included.
ELE-02	Lighting Occupancy Controls	$ 1,100	-	The life expectancy of this measure until the next replacement is 20 years. Includes 20% contingency. Material and Equipment cost = $500 Labor and Installation cost = $400 Soft cost (Engineering and/or other services) not included.
ENV-01A	Exterior wall insulation - Entire facility	$ 83,100	-	This measure is only replaced as needed. Includes 20% contingency. Material and Equipment cost = $65,965 Labor and Installation cost is included in Material costs. Soft cost (Engineering and/or other services) = $3,298
ENV-01B	Exterior wall insulation - Excluding rink	$ 36,500	-	This measure is only replaced as needed. Includes 20% contingency. Material and Equipment cost = $28,965 Labor and Installation cost is included in Material costs. Soft cost (Engineering and/or other services) = $1,448
ENV-02A	Exterior roof insulation - Entire facility	$ 155,100	-	This measure is only replaced as needed. Includes 20% contingency. Material and Equipment cost = $123,105 Labor and Installation cost is included in Material costs. Soft cost (Engineering and/or other services) = $6,155
ENV-02B	Exterior roof insulation upgrade - Excluding Rink	$ 36,300	-	This measure is only replaced as needed. Includes 20% contingency. Material and Equipment cost = $28,806 Labor and Installation cost is included in Material costs. Soft cost (Engineering and/or other services) = $1,440

ECM ID #	Measure	Initial cost ($)	Replacement and Maintenance Cost ($)	Breakdown
ENV-03	Triple pane windows	$ 14,800	-	This measure is only replaced as needed. Includes 20% contingency. Material and Equipment cost = $11,760 Labor and Installation cost is included in Material costs. Soft cost (Engineering and/or other services) = $588
ENV-04A	Improve airtightness - Entire facility	$ 41,300	-	This measure is only replaced as needed. Includes 20% contingency. Material and Equipment cost = $32,783 Labor and Installation cost is included in Material costs. Soft cost (Engineering and/or other services) = $1,639
ENV-04B	Improve airtightness - Excluding rink	$ 20,700	-	This measure is only replaced as needed. Includes 20% contingency. Material and Equipment cost = $16,391 Labor and Installation cost is included in Material costs. Soft cost (Engineering and/or other services) = $820
MEC-01	Mechanical hydronic dehumidifier w/ setpoint scheduling	$ 393,800	$ 225,000	The life expectancy of this measure until the next replacement is 15 years. Includes 20% contingency. Material and Equipment cost = $250,000 Labor and Installation cost = $62,500 Soft cost (Engineering and/or other services) = $15,625 Additional Notes: Decommissioning of existing unit + Supply, Installation, Testing & Commissioning of new unit
MEC-02	Electric dehumidifier w/ setpoint scheduling	$ 55,100	-	The life expectancy of this measure until the next replacement is 15 years. Includes 20% contingency. Material and Equipment cost = $35,000 Labor and Installation cost = $8,750 Soft cost (Engineering and/or other services) = $2,188 Additional Notes: Decommissioning of existing unit + Supply, Installation, Testing & Commissioning of new unit

ECM ID #	Measure	Initial cost ($)	Replacement and Maintenance Cost ($)	Breakdown
MEC-03	ASHP replacement of furnaces	$ 55,000	$ 35,000	The life expectancy of this measure until the next replacement is 15 years. Includes 25% contingency. Material and Equipment cost = $33,000 Labor and Installation cost = $7,000 Soft cost (Engineering and/or other services) = $4,000 Additional Notes: Initial installation cost includes provisions for electrical, piping, coil and structural support works. Replacement costs only include the ASHP equipment and installation cost.
MEC-04A	Hydronic AHU conversion	$ 191,400	$ 115,000	The life expectancy of this measure until the next replacement is 15 years. Includes 20% contingency. Material and Equipment cost = $115,000 Labor and Installation cost = $30,000 Soft cost (Engineering and/or other services) = $14,500 Additional Notes: Initial installation cost includes provisions for electrical, piping, coil and structural support works. Replacement costs only include the equipment and installation cost.
MEC-04B	Hydronic UH conversion	$ 116,900	$ 65,000	The life expectancy of this measure until the next replacement is 15 years. Includes 25% contingency. Material and Equipment cost = $60,000 Labor and Installation cost = $25,000 Soft cost (Engineering and/or other services) = $8,500 Additional Notes: Initial installation cost includes provisions for electrical, piping, coil and structural support works. Replacement costs only include the equipment and installation cost.
MEC-05	Electric furnace	$ 19,400	$ 10,000	The life expectancy of this measure until the next replacement is 18 years. Includes 25% contingency. Material and Equipment cost = $9,500 Labor and Installation cost = $4,500 Soft cost (Engineering and/or other services) = $1,500 Additional Notes: Initial installation cost includes provisions for electrical works. Replacement costs only include the electric furnace equipment and installation cost.

ECM ID #	Measure	Initial cost ($)	Replacement and Maintenance Cost ($)	Breakdown
MEC-06	Electric curling sheets unit heaters	$ 35,000	$ 23,000	The life expectancy of this measure until the next replacement is 18 years. Includes 25% contingency. Material and Equipment cost = $19,000 Labor and Installation cost = $9,000 Soft cost (Engineering and/or other services) not included. Additional Notes: Initial installation cost includes provisions for electrical works. Replacement costs only include the electric furnace equipment and installation cost.
MEC-07	Space temperature setbacks	$ 15,000	-	This measure is only replaced as needed. Includes 20% contingency. Material and Equipment cost = $8,000 Labor and Installation cost = $4,500 Soft cost (Engineering and/or other services) not included. Additional Notes: Includes smart thermostat installation, and localization onto one device for ease of control.
MEC-08	Electric instantaneous pebbling water heater	$ 3,600	-	The life expectancy of this measure until the next replacement is 20 years. Includes 20% contingency. Material and Equipment cost = $1,000 Labor and Installation cost = $2,000 Soft cost (Engineering and/or other services) not included.
MEC-09	ASHP domestic hot water heater	$ 11,400	$ 7,000	The life expectancy of this measure until the next replacement is 15 years. Includes 20% contingency. Material and Equipment cost = $5,000 Labor and Installation cost = $4,500 Soft cost (Engineering and/or other services) not included. Additional Notes: Initial installation cost includes provisions for electrical, piping, coil and structural support works. Replacement costs only include the ASHP equipment and installation cost.

ECM ID #	Measure	Initial cost ($)	Replacement and Maintenance Cost ($)	Breakdown
MEC-10	Electric tankless water heater	$ 11,400	$ 7,000	The life expectancy of this measure until the next replacement is 20 years. Includes 20% contingency. Material and Equipment cost = $5,000 Labor and Installation cost = $4,500 Soft cost (Engineering and/or other services) not included. Additional Notes: Initial installation cost includes provisions for electrical works. Replacement costs only include the electric water heater equipment and installation cost.
MEC-11	Low flow water fixtures	$ 800	-	This measure is only replaced as needed. Includes 20% contingency. Material and Equipment cost = $360 Labor and Installation cost = $338 Soft cost (Engineering and/or other services) not included.
RFG-01	VFDs on brine pumps	$ 47,900	-	The life expectancy of this measure until the next replacement is 20 years. Includes 20% contingency. Material and Equipment cost = $30,000 Labor and Installation cost = $8,000 Soft cost (Engineering and/or other services) = $1,900 Additional Notes: Decommissioning of existing unit + Supply, Installation, Testing & Commissioning of new unit
RFG-02	Refrigeration plant optimization - CO2	$ 870,600	-	The life expectancy of this measure until the next replacement is 25 years. Includes 20% contingency. Material and Equipment cost = $575,800 Labor and Installation cost = $115,160 Soft cost (Engineering and/or other services) = $34,548 Additional Notes: Decommissioning of existing plant + Supply, Installation, Testing & Commissioning of new plant
RFG-03	Ice plant desuperheater	$ 90,000	-	The life expectancy of this measure until the next replacement is 25 years. Includes 20% contingency. Material and Equipment cost = $40,825 Labor and Installation cost = $30,600 Soft cost (Engineering and/or other services) = $3,571

ECM ID #	Measure	Initial cost ($)	Replacement and Maintenance Cost ($)	Breakdown
				Additional Notes: Supply, Installation, Testing & Commissioning + Connection to DHW and heating systems.
RFG-04	Ice temperature optimization	$ 31,000	-	This measure is only replaced as needed. Includes 20% contingency. Material and Equipment cost = $19,670 Labor and Installation cost = $4,917 Soft cost (Engineering and/or other services) = $1,229 Additional Notes: Decommissioning of existing plant + Supply, Installation, Testing & Commissioning of new plant
RNW-01	Solar PV - 86 kW array	$ 263,000	$ 17,200	This measure is only replaced as needed. Includes 20% contingency. Material and Equipment cost = $189,200 Labor and Installation cost = - Soft cost (Engineering and/or other services) = $30,000 Additional Notes: Supply, Installation, Testing & Commissioning

Appendix F – Energy Conservation Measure (ECM) savings breakdown

ECM ID #	Low carbon measure	Electricity savings (kWh)	Electricity cost savings ($)	Natural gas savings (m³)	Natural gas cost savings ($)
ELE-01	Facility-wide LED upgrade	1,578	333	- 116	$ - 50
ELE-02	Lighting Occupancy Controls	336	71	- 22	$ - 9
ENV-01A	Exterior wall insulation - Entire facility	709	150	659	$ 286
ENV-01B	Exterior wall insulation - Excluding rink	355	75	387	$ 168
ENV-02A	Exterior roof insulation - Entire facility	5,293	1,117	1,222	$ 530
ENV-02B	Exterior roof insulation upgrade - Excluding Rink	276	58	339	$ 147
ENV-03	Triple pane windows	21	4	37	$ 16
ENV-04A	Improve airtightness - Entire facility	- 3,269	- 690	783	$ 340
ENV-04B	Improve airtightness - Excluding rink	333	70	399	$ 173
MEC-01	Mechanical hydronic dehumidifier w/ setpoint scheduling	- 18,185	- 3,837	5,138	$ 2,228
MEC-02	Electric dehumidifier w/ setpoint scheduling	- 8,669	- 1,829	-	-
MEC-03	ASHP replacement of furnaces	- 45,160	- 9,529	8,455	$ 3,666
MEC-04A	Hydronic AHU conversion	- 30,930	- 6,526	8,455	$ 3,666
MEC-04B	Hydronic UH conversion	- 14,822	- 3,127	5,138	$ 2,228
MEC-05	Electric furnace	- 81,107	- 17,114	8,455	$ 3,666
MEC-06	Electric curling sheets unit heaters	- 37,567	- 7,927	5,138	$ 2,228
MEC-07	Space temperature setbacks	6,695	1,413	3,521	$ 1,526
MEC-08	Electric instantaneous pebbling water heater	435	92	-	-

ECM ID #	Low carbon measure	Electricity savings (kWh)	Electricity cost savings ($)	Natural gas savings (m^3)	Natural gas cost savings ($)
MEC-09	ASHP domestic hot water heater	- 1,516	- 320	99	$ 43
MEC-10	Electric tankless water heater	- 821	- 173	99	$ 43
MEC-11	Low flow water fixtures	-	-	48	$ 21
RFG-01	VFDs on brine pumps	12,490	2,635	-	-
RFG-02	Refrigeration plant optimization - CO_2	7,676	1,620	-	-
RFG-03	Ice plant desuperheater	-	-	99	$ 43
RFG-04	Ice temperature optimization	6,074	1,282	639	$ 277
RNW-01	Solar PV - 86 kW array	83,511	17,621	-	-