December 6th, 2024

Roadmap to Low Carbon Final Report – Thessalon Arena

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 Arena.

The Roadmap presents the **business case** for implementing this comprehensive, integrated project. The Thessalon Arena 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 $1.9M on initial equipment replacements, and over $3.5M on utilities, over the next 30 years. The Roadmap plan will require an additional $1.8M of upfront capital, will reduce utility costs by almost 16%, and yield **a negative incremental net present value (NPV) with funding of only $375k** 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 almost $2M. Without FCM funding, adopting the Roadmap will cost the municipality an additional $1.2M. With FCM funding the additional costs are only $375k.

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)	$ 1,853,240	-	$ 3,546,828	$ - 1,960,421	$ - 1,960,421
Low carbon plan	$ 3,633,693	1,028	$ 2,991,874	$ - 3,180,547	$ - 2,334,977
Difference	**$ - 1,780,453**	**1,028**	**$ 554,954**	**$ - 1,220,125**	**$ - 374,555**

Although the Roadmap for the entire pathway is an increased overall cost of ownership, the **financial case** still promotes energy efficiency for some end-uses. As will be discussed in Table 3, to achieve 80% GHG emissions reductions, some end-uses, such as heating and dehumidification result in significantly increased cost of ownership (negative NPVs), while others, such as refrigeration and domestic hot water result in a **reduced overall cost of ownership, along with environmental and social benefits.**

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[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 **environmental case** is equally compelling. This roadmap will lower operational greenhouse gas emissions of this facility by over 86%, 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 Arena, with heat pumps and heat recovery, will be a highly visible demonstration of environmental leadership.

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 Arena GHG emission reduction goals are as follows:

- Hydronic AHU conversions – This measure includes replacing the existing fuel fired furnaces with water-to-air water-source heat pumps using heat recovery from the ice plant to provide space heating. Potential GHG reductions of 22.4 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 5.8 tCO_2e[2]
- Ice plant desuperheaters – Incorporating desuperheaters recovers waste heat from the ice plant to preheat domestic hot water, reducing the need for gas-fired water heaters. This decreases energy consumption and associated GHG emissions, while improving overall building energy efficiency. Potential GHG reductions of 4.5 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.

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[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-12	Space temperature setbacks	2025	$ 16,700	35,023	$ 2,444	5.8	$ 65,864	$ 69,045
RFG-03	Ice temperature optimization	2025	$ 7,200	23,475	$ 4,325	2.3	$ 116,625	$ 117,996
BAU-05	Electric DHW heater like-for-like	2026	$ 2,900	-	-	-	$ - 4,638	$ - 4,638
MEC-08B	Hydronic AHU 4 - 6 conversion	2026	$ 408,900	36,903	$ - 1,133	8.3	$ - 468,536	$ - 369,882
MEC-15	Condensing tankless floodwater heater	2026	$ 8,600	4,978	$ 207	0.9	$ - 3,418	$ - 717
MEC-19	Condensing tankless domestic hot water heater	2026	$ 16,300	22,975	$ 955	4.2	$ 14,204	$ 19,322
RFG-02	Cold water ice resurfacing system	2026	$ 60,600	24,935	$ 1,521	4.3	$ - 1,070	$ 10,253
RFG-04	Refrigeration plant optimization - CO2	2026	$ 1,483,000	6,181	$ 1,304	0.5	$ - 1,553,148	$ - 1,104,724
RFG-05	Refrigeration plant desuperheaters	2026	$ 90,000	24,633	$ 1,024	4.5	$ - 77,718	$ - 49,455
RFG-06	VFDs on brine pumps	2026	$ 58,600	31,024	$ 6,546	2.6	$ 102,395	$ 120,797
MEC-01	Dehumidifier controls – daytime scheduling	2027	$ 4,800	1,127	$ 47	0.2	$ - 2,228	$ - 1,349
MEC-02	Dehumidifier controls – night setback scheduling	2027	$ 4,800	2,138	$ 89	0.4	$ - 732	$ 147
MEC-07	Bleacher hydronic heating	2027	$ 208,300	10,672	$ - 164	2.3	$ - 201,556	$ - 158,543

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-20	Low flow water fixtures	2027	$ 14,900	3,936	$ 431	0.6	$ 101	$ 2,832
MEC-21	Replace HRV units with ERV units	2027	$ 27,200	2,196	$ 92	0.4	$ - 32,953	$ - 24,441
RFG-01	Electric resurfacing machine	2027	$ 180,000	5,283	$ 696	1.7	$ - 310,818	$ - 253,102
BAU-02	Electric unit heaters like-for-like	2030	$ 3,100	-	-	-	$ - 2,713	$ - 2,713
MEC-05	Interlocking overhead doors	2030	$ 13,400	941	$ 44	0.2	$ - 8,233	$ - 5,915
MEC-04	Electric dehumidifier	2034	$ 55,100	5,779	$ - 3,676	3.4	$ - 122,709	$ - 107,267
ENV-06	Suspended low-e ceiling	2035	$ 82,700	- 41	$ 387	- 0.2	$ - 49,795	$ - 36,799
MEC-08A	Hydronic AHU 1 - 3 conversion	2037	$ 408,900	59,191	$ - 3,007	14.1	$ - 337,675	$ - 257,831
BAU-13	Lighting fixtures LED like-for-like	2039	$ 82,000	-	-	-	$ - 51,057	$ - 51,057
ELE-01	Lighting Occupancy Controls	2039	$ 5,400	84	$ 37	-	$ - 2,833	$ - 2,047
ENV-04B	Improve airtightness - Excluding rink	2040	$ 21,100	2,104	$ 95	0.4	$ - 6,988	$ - 3,976
Total [3]			**$ 3,264,500**	**191,193**	**$ 3,160**	**56.2**	**$ - 3,180,547**	**$ - 2,334,977**

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[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 the impact of choosing one pathway over the other. The table shows the incremental NPV which is the difference between low carbon compared to 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 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 ($)**
Dehumidification	MEC-01, MEC-02, MEC-04	$ - 125,670	$ - 108,468	BAU-12	$ - 42,373	$ - 83,297	$ - 66,095
Domestic Hot Water	BAU-05, MEC-15, MEC-19, MEC-20	$ 6,249	$ 16,799	BAU-05, BAU-06, BAU-07	$ - 52,445	$ 58,694	$ 69,244
Heating	BAU-02, MEC-05, MEC-07, MEC-08A, MEC-08B, MEC-12	$ - 952,850	$ - 725,839	BAU-01, BAU-02, BAU-03A, BAU-03B, BAU-04	$ - 109,235	$ - 843,614	$ - 616,603
Ventilation	MEC-21	$ - 32,953	$ - 24,441	BAU-08	$ - 31,299	$ - 1,654	$ 6,858
Lighting	BAU-13, ELE-01	$ - 53,890	$ - 53,104	BAU-13	$ - 51,057	$ - 2,833	$ - 2,047
Refrigeration	RFG-02, RFG-03, RFG-04, RFG-05, RFG-06	$ - 1,412,916	$ - 905,132	BAU-10, BAU-11	$ - 1,425,691	$ 12,775	$ 520,559
Ice Resurfacing	RFG-01	$ - 310,818	$ - 253,102	BAU-09	$ - 248,321	$ - 62,498	$ - 4,781
Envelope	ENV-04B, ENV-06	$ - 56,783	$ - 40,775		-	$ - 56,783	$ - 40,775
Total						**$ - 1,220,125**	**$ - 374,555**

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 low carbon pathway and BAU pathway is approximately negative $2.6 million without funding and negative $0.9M million with funding, and positive $0.6M for the aggressive pathway with funding. Cashflow breakeven does not occur for any of the pathways. 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.

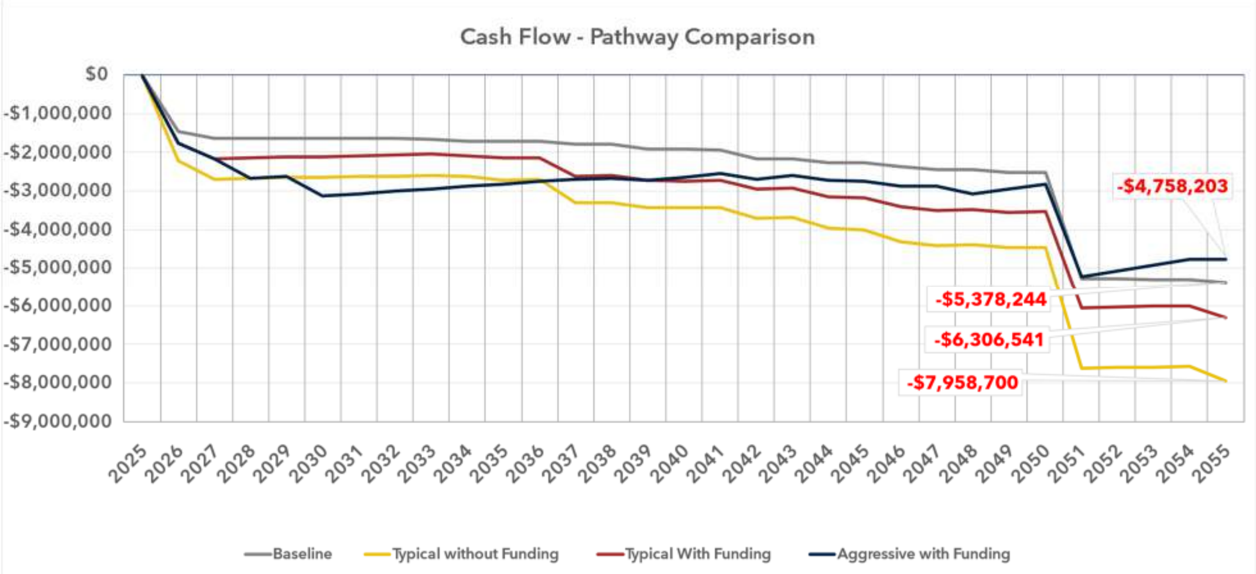

Figure 1: Typical pathway cash flow comparisons over the 30-year study period

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 Retrofit 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. BAU 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-12, RFG-03, MEC-01, MEC-02, ELE-01	12%	$ 42,253	$ 8,451	$ 8,451	$ 25,352
1	2026	BAU-05, MEC-08B, MEC-15, MEC-19, RFG-02, MEC-07, MEC-20, MEC-21, RFG-01, RFG-04, RFG-05, RFG-06	43%	$ 2,649,378	$ 529,278	$ 532,265	$ 1,587,835
2	2029	BAU-02, MEC-05	52%	$ 19,128	$ 3,107	$ 6,701	$ 9,321
3	2032	MEC-04, ENV-06	65%	$ 183,035	$ 36,607	$ 36,607	$ 109,821
Total			**86%**	**$ 3,633,693**	**$ 700,616**	**$ 831,229**	**$ 2,101,848**

This Roadmap plan for the Thessalon Arena 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)	14.6	0.1	-	1.6
Natural Gas Emissions (tCO_2e)	48.5	22.1	8.7	8.7
Gasoline Emissions (tCO_2e)	1.9	-	-	-
Total (tCO_2e [% reduction])	**65.0**	**22.3 [65.7%]**	**8.8 [86.5%]**	**10.3 [84.1%]**

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.
- **$ekWh/ft^2$ (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.

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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 Thessalon Arena from its April 2023 – March 2024 baseline utility emissions of 65.0 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 Memorial Arena is a recreational facility located in Thessalon, ON, with an approximate gross floor area (GFA) of 33,864 ft^2. The facility is comprised of a central arena space, a two-story lobby, a Zamboni room, and two dressing room blocks. The lobby is two stories, containing a kitchen, bar, and rental space on the second floor. The facility was originally constructed in the 1940's, with a dressing room addition in 1991, a Zamboni room addition in 1999, and the second floor of the lobby addition in 2007. The primary purpose is activities served on the ice surface such as hockey and figure skating. Ice is publicly available from the middle of October through the end of March. Occupancy is mainly weekday evenings, with one full day of weekend operation per month. Beginning summer 2023, the dry floor of the arena is used weekly for pickle ball. Additional occupancy is noted in the lobby from activities and meetings of the local senior population. The second floor is rented an estimated one time per month, year-round. The facility is located directly beside the Thessalon Curling Club. The ice plants share one room, located within the curling facility.

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

Heating is served by a decentralized system consisting of six gas-fired furnaces, two gas-fired unit heaters, and five gas-fired infrared radiant (IR) heaters. Four of the furnaces are manufactured by Keeprite, with installation dates ranging from 2009 to 2022. Two of these units independently serve the original changerooms and lobby. The remaining two units serve the changeroom addition. The final two furnaces are manufactured by Carrier, were installed in 2007, and serve the second floor of the lobby. The two gas-fired unit heaters are both manufactured by Reznor, and independently serve the Zamboni room and compressor room. The spectator bleachers are served by five gas-fired IR heaters, manufactured by Re-Verber-Ray. It is noted that these units operate infrequently, estimated at 6-7 uses per month based on the schedule of hockey games and requests for user groups. No temperature setbacks are in place at this facility. There is no space cooling within the facility.

Two Venmar heat recovery ventilators (HRVs) are paired with the two furnaces serving the second floor of the lobby. Exhaust fans are found throughout the facility in typical spaces such as washrooms, showers, and kitchens. Two arena exhaust fans serve the arena space, which are turned on when fuel-fired equipment is operated within the space.

Dehumidification is present in the arena, served by one gas-fired desiccant unit. This unit was manufactured by Munters and is noted to be from 2009. This unit is controlled via a relative humidity (RH) sensor with setpoints of around 50%. On-site measurements over a four-hour period at the time of the site visit measures average conditions of -2°C at 43.5% RH.

2.3 Domestic hot water

Domestic hot water (DHW is served by three gas-fired units and one electric. Two of the gas-fired units serve the dressing room addition and are rated for 125 MBH with 75 USG storage tanks. These units were set at 140°F and 155°F and dated 2010. The final gas-fired unit serves the original dressing rooms, which are noted to be used infrequently. This unit is rated for 34 MBH with a 40 USG storage tank and is dated 2008. The second floor of the lobby is served by the electric unit, rated for 4.5 kW with a 40 USG storage tank, and is dated 2007.

Floodwater is served by one gas-fired instantaneous water heater (IWH). This unit is rated for 199 MBH and is dated 1999. During the ice season there is an estimate of five floods per weeknight, as well as one weekend with nine floods per month. Each resurfacing event is estimated to dump 75% of the ice resurfacers 166 USG tank. Prior to the 2023-2024 ice season, untreated cold city water was used for ice resurfacing, however this was switched to warm water at 140°F to improve ice quality.

2.4 Refrigeration

The facility has one ice plant rated estimated at 61 tons of refrigeration to serve the approximately 85’ x 200’ ice pad. The ice plant uses ammonia (R717) as the refrigerant. The coefficient of performance (COP) is assumed based on the plant age and equipment vintage. The ice plant consists of one shell-and-tube chiller, one 50 HP compressor, one 30 HP compressor, one 15 HP brine pump, one 3 HP condenser pump, and one evaporative condenser. The brine pump, condenser pump, and evaporative condenser are all from approximately 2010-2015. The 50 HP compressor is from 2020, while the 30 HP unit is at end-of-life. It is noted that the electric motor of the 50 HP compressor has been replaced twice in the last seven years, likely due to power fluctuations and surges. The ice plant chiller is at end-of-life. It is a top priority for the Town to replace this ice plant as it is nearing end-of-life and facing reliability issues. This replacement will avoid increasing insurance premiums.

The ice plant is controlled by Honeywell slab sensors. In previous years, when the ice was resurfaced with cold water, the slab temperature setpoint was as high as 22°F. As of the 2023-2024 ice season, when the operations staff switched to warm floodwater, the slab temperature setpoint was lowered to 18°F. It was noted on site that the slab sensor appeared to be malfunctioning, oscillating between 19°F and 20°F. No temperature setbacks are in place for the ice surface. The ice thickness is kept around 2” in flat areas, likely up to 3” in the corners.

2.5 Lighting

Lighting is provided by LED fixtures, installed in 2019 as part of an LED retrofit. The arena is served by LED fixtures noted to be 109 W, while the remainder of the facility is served by LED T8s. Occupancy sensors are found in the lower floor washrooms, lobby, and office. Some small zones are served by LED pot lights. The original dressing rooms are still served by a total of 12 fluorescent T8s. These zones have minimal use, and it is recommended that these units be upgraded to LED equivalent options at end-of-life.

2.6 Building envelope

The original arena was constructed in the 1940's, with additions installed between 1991 and 2007; the overall effective insulation levels of walls and roofs are assumed based on the building vintage. Exterior windows and doors are believed to be original, and no other significant retrofits of the building envelope have been reported. A low-emissivity ceiling is found in the arena to prevent solar radiation from reaching the ice, increase luminance levels, and prevent moisture related issues. The facility envelope is generally believed to be in good condition.

2.7 Process and plug loads

The facility has a variety of process and plug loads, including typical office and kitchen use, and ice maintenance specific loads. Gasoline process loads are found via the ice resurfacer, which operates during the ice season at an estimated 5 floods per weekday, plus one weekend per month with 9 floods. Electric kitchen loads and refrigerators are present in the canteen and kitchen, following the hockey schedule and rental schedule, respectively. Typical electric plug loads such as office equipment and control equipment are also found on site in the staff offices.

2.8 Building automation system

The facility has no building automation system (BAS) or scheduled controls. Controls are handled through local thermostats, or control panels on a space or system basis. The refrigeration system is operated through local controls with a Honeywell 775 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 ($)	Natural gas use (m³)	Natural gas cost ($)	Gasoline (L)	Gasoline cost ($)
Thessalon Arena	167,730	$ 35,391	24,505	$ 10,550	833	$ 1,134

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 – Life cycle cost assumptions.

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 ($kWh/ft^2/year$)	Natural Gas (thermal) energy intensity ($ekWh/ft^2/year$)	Gasoline energy intensity ($ekWh/ft^2/year$)	Total energy intensity ($ekWh/ft^2/year$)
Thessalon Arena	4.95	7.50	0.20	12.65
80% Emissions Reduction	0.99	1.50	0.04	2.53

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.

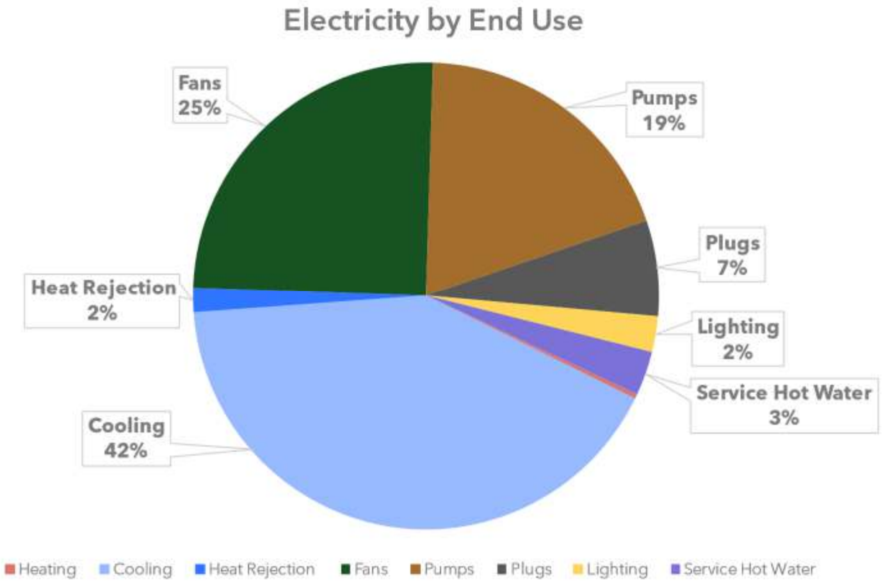

Figure 2: Electricity Consumption by End Use

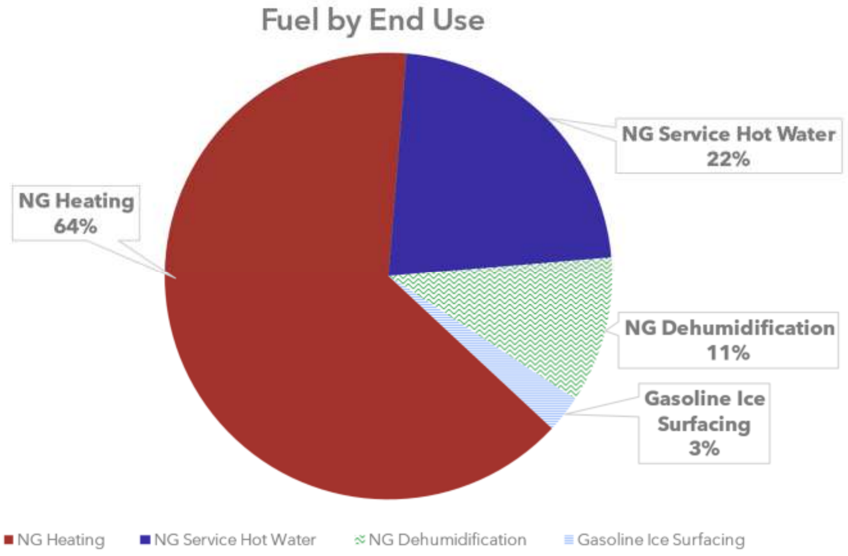

Figure 3 Thermal consumption by end use

As seen in Figure 2 above, the three primary electrical end-uses within the facility are refrigeration, fans, and pumps, accounting for 42%, 25%, and 19% 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 fan end-use accounts for accounts for all ventilation equipment including furnace fans and HRVs. The pump end-use accounts for ice plant's brine pump used to circulate brine beneath the ice slab.

Similarly, Figure 3 above shows the primary end-uses for thermal energy consumption within the facility. Thermal energy is provided by natural gas and gasoline. Natural gas is used for space heating, water heating, and dehumidification, while gasoline is used for ice resurfacing. These natural gas end-uses respectively account for 64%, 22%, and 11% of the entire thermal energy consumption, with the balance being consumed in the gasoline ice resurfacer. Space heating accounts for traditional space heating served by furnaces, unit heaters, etc. Water heating includes all water heated for domestic and floodwater water heating purposes.

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.

	Energy Use Intensity (EUI) [kWh/ft²]	Total Cost [$]	Total Emissions (GHG) [tCO₂e]
■ Gasoline Utilities	0.2	$1,134	1.9
■ Elec Utilities	5.0	$35,391	13.9
■ NG Utilities	7.5	$10,550	46.6

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 Arena are as follows:

- The Town is interested in replacing the Arena and nearby Curling ice plants with one shared plant. During this retrofit the Town would like to connect the Arena and Curling facilities with an internal space containing an elevator.
- Cold, untreated city water was used for resurfacing prior to the 2023-2024 ice season. The switch to heated (140°F) floodwater was made for the 2023-2024 ice season to improve ice quality.
- Ice thickness is maintained at 2” in flat areas, and closer to 3” in the corners.
- An increase in hot water consumption was stated during the month of April to wash plastic lines from the ice/slab.
- Budget consideration should be given to expect the required replacement of the following equipment within 5 years:
    - Refrigeration ice plant
    - Gas furnaces (F-4, 5, 6)
    - Heat recovery ventilators (HRV-1, 2)
    - Gas desiccant dehumidifier (DH-1)
    - Spectator seating radiant infrared heaters (IR-1, 2, 3, 4, 5)
    - Ice resurfacer
    - Gas domestic hot water heaters (DHW-1, 2, 4)
    - Electric domestic hot water heater (DHW-3)
    - Gas instantaneous floodwater heaters (DHW-5)

Opportunities for operational improvements are as follows:

- 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.
- It was noted that the electric motor for the 50 HP compressor has been replaced twice in the past 7 years. This is likely due to power fluctuations and surges. A phase monitor may help resolve these issues.
- It was noted that for some winters, additional electric heating is brought into the lobby space to prevent pipes from freezing. It is believed that this did not occur during the baseline period. Increased insulation levels and improved airtightness should be considered beyond energy impacts to mitigate risk and improve building quality.
- It was noted that insurance for the ice plant increased by $20,000 for the 2023-2024 ice season. Although insurance premiums are outside of the scope of this study, it is generally understood that this premium increase was dependent on the increasing age of the ice plant. Replacing the ice plant may result in a decrease in insurance premiums for the facility.

- 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, dehumidification, and space heating equipment alike. This may address, in addition to ice refrigeration, dehumidification and heating for flood water, spectators, or 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 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. 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 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 Arena.

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 will 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 Arena is heated primarily through the use of 6 gas-fired condensing furnaces, some of which are coupled with HRVs for fresh air. Gas-fired infrared heaters are used for bleacher seating in the rink space and are manually controlled. There are also some gas-fired and electric unit heaters maintaining temperatures in other smaller spaces. It is noted that of the 6 furnaces, 3 were replaced relatively recently, and the other 3 are at end of life. In this study, these systems were separated to more accurately account the total cost of ownership, based on when the systems would be replaced.

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, natural gas hybrid heating is assumed. 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 radiant heaters

Electric radiant heaters are a good option when hydronic heating is not available and there is not enough heating demand to justify a heat pump unit for the space. These electric units would operate at 100% efficiency and are to replace mounted radiant tube heaters. These units would be smaller in capacity and higher in quantity, which would enable a higher level of control. There must be 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. This measure would replace the bleacher, gas-fired IR radiant heaters.

5.1.3 Electric furnaces and unit heaters

Electric furnaces 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 is 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.

5.1.4 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 advised 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.

5.1.5 Interlocking overhead doors with unit heaters

An often overlooked and avoidable source of energy consumption is unit heater operation in spaces that have operational overhead doors leading into an unconditioned space. This is usually due to a constant temperature setpoint for unit heater operation, along with lack of communication with the unit and overhead doors to know when heating done in the space is lost to an unconditioned environment. This measure proposes installing sensors and relays to disable the unit heaters when overhead doors are open for more than several minutes, to reduce the heat lost from the space, and minimize excessive heating load as a result.

For example, ice resurfacer rooms that typically have overhead doors that open into the ice rinks, where the ice resurfacer machines are to be moved into. If the unit heaters in the room continue to operate while the doors are open, not only is heating lost to the ice rink space, but this heating will also increase the load on the ice rink, as it now must keep the ice sheets colder to counter the heated air moving in. If the unit heaters are fuel-fired, this results in significant additional GHG emissions, that can be avoided through controls and sensor additions.

5.1.6 Ice plant heat recovery – Hydronic conversions, Hydronic forced air bleacher heating, etc.

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 operates 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.

With low grade heat, it is possible to provide forced-air bleacher seating heating, through a new hydronic AHU, which would not need to deliver high temperature air, but only what would be comfortable to occupants in a generally cold space. The AHU would also be able to provide fresh air ventilation in a space that generally does not have any other dedicated ventilation. Using recovered heat will offset any fuel costs from existing units but will increase pumping and fan energy due to additional equipment.

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.

As some of these furnaces are grouped in different locations in the facilities, piping costs can be a notable factor on how feasible this option can be. As there are 2 different sets of furnace replacements due to the year of installations, it is recommended to install piping in advance to enable the option to future proof for hydronic conversion, when the ice plant is installed. This would result in higher initial costs on the first set of replacements and enable an easier switch over with the second set. Alternatively, only one set of furnaces can be replaced to make the most use of available heat recovery.

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.

5.1.7 Heating and cooling measure summary

Table 8: Heating and cooling measure summary

Measures	Descriptions
Fuel fired unit heaters like-for-like	Like-for-like replacement of fuel fired unit heaters.
Electric unit heaters like-for-like	Like-for-like replacement of electric unit heaters.
Fuel fired furnaces (1 - 3) unit like-for-like	Like-for-like replacement of fuel fired furnaces 1 - 3.
Fuel fired furnaces (4 - 6) unit like-for-like	Like-for-like replacement of fuel fired furnaces 4 - 6.
Fuel fired infrared bleachers heaters like-for-like	Like-for-like replacement of fuel fired infrared (IR) heaters.
Interlocking overhead doors	Turning off room radiant heaters when doors to ice rink is opened. Reduced heating usage and load introduced to ice rink.
Electric radiant bleacher heaters	Replace the existing fuel fired infrared (IR) heaters with electric radiant heaters. This is an electrification measure.
Bleacher hydronic heating	Using heat recovery from ice plant to provide space hydronic heating bleacher seating area.
Hydronic AHU 1 - 3 conversion	Replace fuel-fired furnaces 1 - 3 with water to air WSHP using hydronic heating coils using heat recovery from ice plant to provide space heating. Natural gas boiler backup heat used when heat recovery is not available.
Hydronic AHU 4 - 6 conversion	Replace fuel-fired furnaces 4 - 6 with water to air WSHP using hydronic heating coils using heat recovery from ice plant to provide space heating. Natural gas boiler backup heat used when heat recovery is not available.
ASHP furnaces 1 – 3	Replace forced-air fuel-fired furnaces 1 - 3 with split air source heat pump (ASHP) to provide heating and cooling in space with appropriate backup heat source.
ASHP furnaces 4 – 6	Replace forced-air fuel-fired furnaces 4 - 6 with split air source heat pump (ASHP) to provide heating and cooling in space with appropriate backup heat source.
Electric furnace 1 - 3	Replace fuel-fired furnaces 1 - 3 with electric equivalent.
Electric furnace 4 - 6	Replace fuel-fired furnaces 4 - 6 with electric equivalent.
Electric unit heaters	Replace the existing fuel fired unit heaters 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).

Business-as-usual measures	Initial capital costs ($)	Total energy savings (ekWh)	Total net annual savings ($)	Annual GHG reduction (tCO_2e)	NPV ($) without funding
Fuel fired unit heaters like-for-like	$ 10,000	-	-	-	$ - 9,002
Electric unit heaters like-for-like	$ 3,100	-	-	-	$ - 2,713
Fuel fired furnaces (1 - 3) unit like-for-like	$ 31,300	-	-	-	$ - 23,985
Fuel fired furnaces (4 - 6) unit like-for-like	$ 36,300	-	-	-	$ - 50,496
Fuel fired infrared bleachers heaters like-for-like	$ 18,800	-	-	-	$ - 23,039
Low carbon measures	**Initial capital costs ($)**	**Total energy savings (ekWh)**	**Total net annual savings ($)**	**Annual GHG reduction (tCO_2e)**	**NPV ($) without funding**
Interlocking overhead doors	$ 13,400	941	$ 44	0.2	$ - 8,233
Electric radiant bleacher heaters	$ 36,300	2,919	$ - 1,800	1.7	$ - 65,663
Bleacher hydronic heating	$ 208,300	10,672	$ - 164	2.3	$ - 201,556
Hydronic AHU 1 - 3 conversion	$ 408,900	59,191	$ - 3,007	14.1	$ - 337,675
Hydronic AHU 4 - 6 conversion	$ 408,900	36,903	$ - 1,133	8.3	$ - 468,536
ASHP furnaces 1 - 3	$ 177,200	39,036	$ - 7,260	12.4	$ - 232,924
ASHP furnaces 4 - 6	$ 177,200	22,208	$ - 4,233	7.1	$ - 308,579
Electric furnace 1 - 3	$ 52,400	16,811	$ - 11,980	10.6	$ - 216,525
Electric furnace 4 - 6	$ 52,400	13,539	$ - 6,071	6.4	$ - 203,407
Electric unit heaters	$ 30,000	4,691	$ - 1,781	2.0	$ - 54,636
Space temperature setbacks	$ 16,700	35,023	$ 2,444	5.8	$ 65,864

5.2 Ventilation measures

The facility has 2 heat recovery ventilator (HRV) units that are coupled with 2 furnaces that serve the upper deck space. These units are the only dedicated ventilation systems, beyond the use of exhaust fans.

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

5.2.1 Install energy recovery ventilator (ERV)

Ventilation standards are adopted from ASHRAE 62.1. The ASHRAE standards have been adopted by building codes, and compliance with them will ensure a healthy space for occupants.

Air-side heat recovery is a key component in achieving low carbon emissions, as it can reduce the heating and cooling demands. Heat recovery will ease the peak loads and is essential when implementing electrification measures and managing electrical demand peaks.

An energy recovery ventilator (ERV) can provide fresh air ventilation while reducing heating and cooling loads through sensible and latent heat recovery (both temperature and humidity recovery). An ERV would reduce humidification needs and keep space conditions at a more comfortable level. It recovers exhaust air from spaces like washrooms, changerooms and general spaces to preheat or precool incoming fresh air, making it an energy-efficient option. Installing an ERV likely requires additional ducting, exhaust fan, diffusers, motors, and dampers, and should be done when the facility is unoccupied as it can be labor-intensive and disruptive. The ERV adds energy consumption in the form of fan energy use and reduces heating or cooling energy needs depending on the season. This measure is intended to replace existing HRV units, and as such costs can be minimized with using existing infrastructure. This measure will include the addition of ERV preheat for frost prevent and control, as required for latent heat recovery. Electrics preheat is assumed.

5.2.2 Ventilation measure summary

Table 9: Ventilation measure summary

Measures	Descriptions				
HRV units like-for-like	Replace HRV units providing ventilation, in addition to humidifier units coupled with units with like-for-like equivalents.				
Replace HRV units with ERV units	Add energy recovery ventilator (ERV) to recover sensible and latent heat from exhaust air to spaces. This measure may require additional ducting and air balancing and testing to maintain any pressurization requirements.				
Business-as-usual measures	**Initial capital costs ($)**	**Total energy savings (ekWh)**	**Total net annual savings ($)**	**Annual GHG reduction (tCO_2e)**	**NPV ($) without funding**
HRV units like-for-like	$ 22,500	-	-	-	$ - 31,299
Low carbon measures	**Initial capital costs ($)**	**Total energy savings (ekWh)**	**Total net annual savings ($)**	**Annual GHG reduction (tCO_2e)**	**NPV ($) without funding**
Replace HRV units with ERV units	$ 27,200	2,196	$ 92	0.4	$ - 32,953

5.3 Domestic hot water measures

The Arena has numerous hot water systems, where 3 tanked, gas-fired domestic hot water (DHW) units serve change rooms, and lower floor washrooms, 1 tanked, electric unit serves the upper deck space, and lastly there is a tankless, gas-fired floodwater heater for ice resurfacing. None of the gas-fired units are noted to be condensing type, and loop temperatures are approximately around 140°F.

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

5.3.1 Air source heat pump (ASHP) hot water heater

As ASHP DHW system is purposely built for water heating only, so they can offer improved efficiencies and easier maintenance than systems used for space heating and cooling. For high flowrate domestic hot water needs in commercial units, ASHP units should be equipped with auxiliary electrical and gas-fired heating due to low performance at the coldest outdoor temperatures. Larger commercial units require ducting to the outdoors to meet high outside air flowrates requirements and can use waste heat or preheated air if available. Units should be sized for the flowrate required to minimize the capacity needed. Commercial units are assumed to meet the floodwater peak demand.

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. Residential sized units are to replace existing domestic hot water system, using similar capacity tanks.

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

For this facility it is examined to switch from the existing tankless gas-fired floodwater heaters to suitably sized ASHP options. 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.

5.3.2 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.

5.3.3 Condensing fuel-fired hot water heater

Condensing fuel-fired hot water heaters are to be explored when aiming to achieve some emissions and energy savings, while avoiding the costs of electrification with higher electrical demands, and electrical infrastructure upgrades. This measure is investigated when existing fuel-fired water heaters operate at below optimal thermal efficiencies of <90%. Modern day condensing technologies allow for low-cost replacements of low efficiency how water heaters to condensing equivalents. If measures are implemented where hot water load is significantly reduced through heat recovery or demand reduction measures, the remaining hot water load will likely be below the threshold where electrification is cost effective. Condensing hot water heaters are a cost-effective solution when electricity costs exceed natural gas costs per unit energy.

5.3.4 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.

5.3.5 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 as 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.

5.3.6 Domestic hot water measure summary

Table 10: Domestic hot water measure summary

Measures	Descriptions
Electric DHW heater like-for-like	Like-for-like replacement of electric DHW boiler.
Fuel-fired DHW boilers like-for-like	Like-for-like replacement of fuel fired DHW at end of life.
Instantaneous floodwater heaters like-for-like	Like-for-like replacement of fuel fired non-condensing instantaneous floodwater heating.
ASHP floodwater heater	Replace the existing fuel fired floodwater heaters with air-source heat pump (ASHP) water heaters, which will have higher heating efficiency.
Electric flood water heater	Replace the existing fuel fired floodwater heaters with electric equivalent. This is an electrification measure.
Condensing tankless floodwater heater	Replace the existing fuel fired non-condensing instantaneous floodwater heater with condensing equivalent. This will improve system efficiency and reduce fuel consumption.
ASHP domestic hot water heater	Replace the existing fuel fired and electric DHW heaters with air-source heat pump (ASHP) water heaters, which will have higher heating efficiency.
Electric domestic hot water heater	Replace the existing fuel fired DHW heaters with electric water heaters. This is an electrification measure.
Condensing domestic HW heater	Replace the existing fuel fired non-condensing domestic hot water heater with condensing, instantaneous equivalent. This will improve system efficiency and reduce fuel consumption.
Condensing tankless domestic hot 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.
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$_2$e)	NPV ($) without funding
Electric DHW heater like-for-like	$ 2,900	-	-	-	$ - 4,638
Fuel-fired DHW boilers like-for-like	$ 23,400	-	-	-	$ - 37,426
Instantaneous floodwater heaters like-for-like	$ 8,100	-	-	-	$ - 10,381

Low carbon measures	Initial capital costs ($)	Total energy savings (ekWh)	Total net annual savings ($)	Annual GHG reduction (tCO_2e)	NPV ($) without funding
ASHP floodwater heater	$ 123,800	20,727	$ - 969	4.9	$ - 182,504
Electric flood water heater	$ 33,800	6,816	$ - 3,904	3.7	$ - 136,106
ASHP domestic hot water heater	$ 151,300	24,750	$ 257	5.0	$ - 182,499
Electric domestic hot water heater	$ 51,600	21,606	$ - 406	4.7	$ - 64,940
Condensing domestic HW heater	$ 25,100	4,627	$ 192	0.8	$ - 33,077
Condensing tankless domestic hot water heater	$ 16,300	22,975	$ 955	4.2	$ 14,204
Low flow water fixtures	$ 14,900	3,936	$ 431	0.6	$ 101

5.4 Refrigeration plant measures

The existing ammonia ice plant is controlled using slab sensors, and a Honeywell T775 controller, currently working to maintain 18°F ice temperatures. With 2 compressors totaling 80HP, where 1 motor is noted to need replacement twice in 7 years. The system is a classic shell and tube chiller configuration at end of life and has an evaporative condenser with VFD installed in the last 10-15 years. Operations staff has interest in upgrading the ice plant as most equipment is requiring more maintenance, and there is interest to explore options of combining the neighbouring ice plant into one package.

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:

5.4.1 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 4°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.

5.4.2 Cold water ice resurfacing

Reducing flood water temperatures saves energy and reduces load on the refrigeration plant, as hot water requires more energy to freeze and contains impurities that can further strain the plant. Using cold water for flood water improves water quality but may require improved ice shaving for smoothing. Methods used with hot water flooding may not be applicable with cold water flooding, as there will be different rates of freezing. Brine temperature resets and manage how the ice reacts to cold water and operator training is recommended to achieve high ice quality under these new conditions. As using hot water flooding is deeply engrained in flooding practices, discussing cold water ice resurfacing products with existing users/operators is highly recommended. With relatively low initial costs, this measure provides significant energy, cost, and GHG savings. It is recommended to have a mixing valve installed prior to the degassing device to enable moderate temperatures (65°F – 70°F) instead of water straight from the city mains.

5.4.3 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.

5.4.4 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.

The arena plant would make the most use of a desuperheater due to the higher hot water demand, primarily for floodwater.

5.4.5 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 with the neighbouring curling 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 future hydronic heat recovery conversions to maximize potential energy and demand reductions, to bring the facility to low carbon.

5.4.6 Refrigeration measure summary

Table 11: Refrigeration measure summary

Measures	Descriptions
Full refrigeration plant like-for-like	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
Cold water ice resurfacing system	Cold-water resurfacing system (REALice or equivalent) (assume mix of water to 65°F). Reduce flood temperature from 140°F to 65°F
Ice temperature optimization	Adjust temperature of the ice to be 4°F higher during night-time where it is not in use.

Measures	Descriptions
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.
Refrigeration plant desuperheaters	Optimize heat recovery with desuperheaters to recover heat from the ice plant for DHW
VFDs on brine pumps	Install new brine pumps with VFDs to modulate flow, this allows for tighter control of setback schedules.

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	$ 1,275,000	-	-	-	$ - 1,365,712
Brine pumps like-for-like	$ 46,800	-	-	-	$ - 59,979

Low carbon measures	Initial capital costs ($)	Total energy savings (ekWh)	Total net annual savings ($)	Annual GHG reduction (tCO_2e)	NPV ($) without funding
Cold water ice resurfacing system	$ 60,600	24,935	$ 1,521	4.3	$ - 1,070
Ice temperature optimization	$ 7,200	23,475	$ 4,325	2.3	$ 116,625
Refrigeration plant optimization - CO2	$ 1,483,000	6,181	$ 1,304	0.5	$ - 1,553,148
Refrigeration plant desuperheaters	$ 90,000	24,633	$ 1,024	4.5	$ - 77,718
VFDs on brine pumps	$ 58,600	31,024	$ 6,546	2.6	$ 102,395

5.5 Dehumidification measures

Dehumidification in the rink space is done through a gas-fired desiccant unit, that recirculates air within the space and does not provide any fresh air. Any fresh air used by the unit is used to reactive the desiccant wheel and exhaust the captured humidity outdoors. The unit was installed in 2009 and is to reach end of life soon.

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

5.5.1 Dehumidification controls - daytime scheduling

Ice rinks typically set dehumidification levels at 50-55% relative humidity (RH). However, during warm days with internal wall temperatures well above the dewpoint, it's recommended to increase RH to 60% or a value that will allow to reduce dehumidification energy while still avoiding condensation on the structure. This requires a BAS, HMI, or a smart controller to be able to calculate changing surface dewpoint temperatures through wall surface temperature sensors and measurements to program dynamic humidity setpoints that will avoid condensation. Fogging on ice should also be monitored, and adjustments made to BAS formulas if issues arise.

5.5.2 Dehumidification controls - night setback scheduling

During night-time, when the ice rink is unoccupied, there is no additional humidity being added to the space from occupants. During this time, it is recommended to schedule a dehumidification setback to 65% RH to save energy. This may cause slightly more condensation than normal, resulting in more pronounced uneven frozen surfaces, but can be resurfaced in the morning. A low-e ceiling can reduce condensation dripping from the ceiling if any exists. Coordination with other systems is needed to avoid increased energy demand from early morning start-up. A BAS can select an ideal setback value and schedule based on space dewpoint temperature to avoid condensation.

5.5.3 Electric dehumidifiers

Dehumidifiers play a key role in the operation of an ice rink; to maintain acceptable humidity levels to minimize condensation and fog they must continuously operate during the ice season. When existing desiccant dehumidifiers operate using indirect or direct fuel-fired burners for the reactivation heat needed to reject moisture, there are significant source of GHG emissions as a result. Although fuels such as natural gas are more cost effective than electricity currently, they will be less so with the implementation of carbon taxes and energy escalation. As an electrification measure, it is recommended to use electric desiccant dehumidifiers, which use electric elements for the reactivation heating needed. It should be noted that refrigeration-based dehumidifiers are also capable and are able to provide dehumidification for different ranges that may compliment an electric desiccant dehumidifier. Often there are two smaller dehumidifiers per large ice pad, to evenly distribute the dehumidifying effects. However, refrigeration-based dehumidifiers, due to the nature of using refrigerant, will likely have some annual refrigerant leakage, which will contribute to additional GHG emissions that are to be accounted for. This measure looks only to replace the existing gas unit with an equivalent capacity electric unit.

5.5.4 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. The leaving temperature of the condenser loop of the refrigeration plant is expected to be stable at approximately 95°F which will supply the heating coil and also meet the space heating requirements with the temperature setpoints which are relatively low. This would enable the system to replace the bleacher IR heaters. 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.

5.5.5 Dehumidification measure summary

Table 12: Dehumidification measure summary

Measures	Descriptions
Dehumidifier like-for-like	Like-for-like replacement of gas-fired desiccant dehumidifiers at end of life.
Dehumidifier controls – daytime scheduling	Increase relative humidity setpoints using dewpoint temperature control to avoid condensation while reducing dehumidifier use (i.e. dewpoint of space is below wall surface temperature). Must ensure fogging on ice is not problematic.
Dehumidifier controls – night setback scheduling	Higher overnight (midnight to 5am) humidity setpoint at 65% RH whenever the dewpoint of the space is below the wall surface temperature to avoid condensation and reduce dehumidifier use.
Mechanical hydronic dehumidifier	Replace existing dehumidifiers with CIMCO EcoDry 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.
Electric dehumidifier	Replace existing fuel-fired desiccant dehumidifiers with an electric desiccant dehumidifier

Business-as-usual measures	Initial capital costs ($)	Total energy savings (ekWh)	Total net annual savings ($)	Annual GHG reduction (tCO_2e)	NPV ($) without funding
Dehumidifier like-for-like	$ 39,000	-	-	-	$ - 42,373

Low carbon measures	Initial capital costs ($)	Total energy savings (ekWh)	Total net annual savings ($)	Annual GHG reduction (tCO_2e)	NPV ($) without funding
Dehumidifier controls – daytime scheduling	$ 4,800	1,127	$ 47	0.2	$ - 2,228
Dehumidifier controls – night setback scheduling	$ 4,800	2,138	$ 89	0.4	$ - 732
Mechanical hydronic dehumidifier	$ 740,300	28,098	$ - 1,382	6.7	$ - 743,812
Electric dehumidifier	$ 55,100	5,779	$ - 3,676	3.4	$ - 122,709

5.6 Ice resurfacing measures

Thessalon Arena uses a gasoline engine, Zamboni ice resurfacing machine that is nearly end of life but has been rebuilt to extend useful life.

The ice resurfacing system can be optimized by implementing the following measures:

5.6.1 Electric ice resurfacing machine

Replacing propane-fired ice resurfacers with electric rechargeable ones is a decarbonization measure that can save costs on fuel use, delivery and emissions. While electric ice surfacers have a higher initial cost, they consume only 2.4 kWh per event and require maintenance for significant components like battery replacements every 10-12 years, compared to annual maintenance for fuel-fired machines. The units come with a 3-phase charger, and the facility would need to provide the power supply.

An electric ice resurfacer will also reduce heat gain into the space as a result of internal combustion engine (ICE) operation, which in turn can impact ice plant load. With reduced flue gases emitted, exhaust fans operation can be minimized, and louvers sealed to reduce excessive infiltration within the rink space.

Every 10-12 years an engine and vehicle overhaul cost of $20,000 is assumed for the business-as-usual case, and battery replacements and tune up for the electric ice resurfacer are estimated at $25,000 for a similar time period. These units are typically traded in every 10-12 years if maintenance or refurbishment is not planned.

Furthermore, modern laser leveling for ice resurfacers provides precise control over ice thickness, leading to a smoother, more consistent playing surface. By using lasers to guide the resurfacing blade, operators can maintain uniform ice thickness across the rink, reducing high or low spots that affect gameplay. This precision helps reduce energy costs, as the ice plant doesn’t need to work harder to maintain inconsistent areas. Additionally, maintaining a consistent ice thickness reduces water and resurfacer usage over time, leading to further operational efficiencies and cost savings. This feature is not included in the costing but suggested for improved ice quality and thickness.

5.6.2 Ice surfacing measure summary

Table 13: Ice surfacing measure summary

Measures	Descriptions				
Resurfacing machine like-for-like	Like-for-like replacement of propane powered ice resurfacing machine				
Electric resurfacing machine	Replace ice resurfacing machine with rechargeable electric equivalent.				
Business-as-usual measures	**Initial capital costs ($)**	**Total energy savings (ekWh)**	**Total net annual savings ($)**	**Annual GHG reduction (tCO_2e)**	**NPV ($) without funding**
Resurfacing machine like-for-like	$ 132,000	-	-	-	$ - 248,321
Low carbon measures	**Initial capital costs ($)**	**Total energy savings (ekWh)**	**Total net annual savings ($)**	**Annual GHG reduction (tCO_2e)**	**NPV ($) without funding**
Electric resurfacing machine	$ 180,000	5,283	$ 696	1.7	$ - 310,818

5.7 Lighting, Receptacle, and Power measures

The facility has had a full LED lighting retrofit to replace all fluorescent lighting. Rink lighting is also LED and uses relatively low power for purpose. Currently the facility uses occupancy sensors in lobby spaces, washrooms and offices. Increased lighting controls such as dimming based on schedule and occupancy are evaluated for this study.

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

5.7.1 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 the lights will be dimmed at 25%. 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 and existing fixtures need to be compatible with such a strategy.

5.7.2 Lighting measure summary

Table 14: Lighting measure summary

Measures	**Descriptions**				
Lighting fixtures LED like-for-like	Replacing all LED lighting fixtures at end of life with like-for-like equivalents.				
Lighting Occupancy Controls	Install occupancy sensors and dimming controls to minimize lighting usage through dimming strategies when 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	$ 82,000	-	-	-	$ - 51,057
Low carbon measures	**Initial capital costs ($)**	**Total energy savings (ekWh)**	**Total net annual savings ($)**	**Annual GHG reduction (tCO_2e)**	**NPV ($) without funding**
Lighting Occupancy Controls	$ 5,400	84	$ 37	-	$ - 2,833

5.8 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:

5.8.1 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.

5.8.2 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.

5.8.3 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.

5.8.4 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.

5.8.5 Suspended low-e ceiling

Suspended low-e ceilings are a cost-effective way to save energy in recreation facilities with ice rinks. The ceiling in these spaces is usually warmer than the ice sheet due to solar radiation, lighting, and warm air. A suspended low-e ceiling reflects this radiation back to the ceiling and insulates the warm space from the rink below. Traditional ceiling materials like wood, metal, or paint have high emissivity, while a low-e ceiling has a low emissivity of 0.03, greatly reducing the radiation experienced by the ice sheet. A suspended ceiling also acts as a barrier for condensation drippings that could otherwise fall onto the ice sheet, creating stalagmites on the ice surface that both increase the ice plant load and serve as a hazard for user groups.

Facility currently has a reflective ceiling. This recommendation seeks to add a suspended low-e ceiling, to assist with avoidance of dripping from ceiling surface onto ice sheet and add an air gap between the immediate ceiling inside surface the suspended ceiling.

5.8.6 Overhead door insulation

A low-cost option available to improve the heat retention of spaces with high overhead door area, can be to use reflection mylar bubble wrap. This is a low-cost material that can be applied over all interior panels of the overhead doors, which will reflect radiant heat back into the space, and offer some thermal insulation from conduction losses. This material is also a vapor barrier and can reduce moisture introduced into the space if applied strategically. This is ideal to use on overhead doors that that are translucent or clear if insulation and heating energy reductions is a primary goal. Noise may be a concern as the material is not dampening, options may be explored to provide foam equivalents.

5.8.7 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.

5.8.8 Envelope measure summary

Table 15: 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 arena 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 arena 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.
Improve airtightness - Excluding rink	Improve infiltration (air tightness) with weather sealing. This measure applies to the entire facility, less the arena space.

Measures	Descriptions
Overhead door insulation	Adding reflective bubble insulation on translucent overhead doors to reduce heat losses at low cost.
Suspended low-e ceiling	Replace existing ceiling mounted low-e with a suspended option to further reduce refrigeration plant load and minimize condensation dripping onto ice.

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	$ 165,800	70	$ - 50	-	$ - 69,246
Exterior wall insulation - Excluding rink	$ 82,400	668	$ 18	0.1	$ - 33,706
Exterior roof insulation - Entire facility	$ 477,000	- 4,362	$ - 670	- 0.5	$ - 207,066
Exterior roof insulation upgrade - Excluding Rink	$ 165,800	1,024	$ - 35	0.2	$ - 68,805
Triple pane windows	-	93	$ 5	-	$ 84
Improve airtightness - Entire facility	$ 42,300	- 8,208	$ - 1,875	- 0.6	$ - 43,443
Improve airtightness - Excluding rink	$ 21,100	2,104	$ 95	0.4	$ - 6,988
Overhead door insulation	$ 2,800	466	$ 18	0.1	$ - 806
Suspended low-e ceiling	$ 82,700	- 41	$ 387	- 0.2	$ - 49,795

5.9 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 facility 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.

5.9.1 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. As the facility has a curved roof, structural assessments are essential. 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.

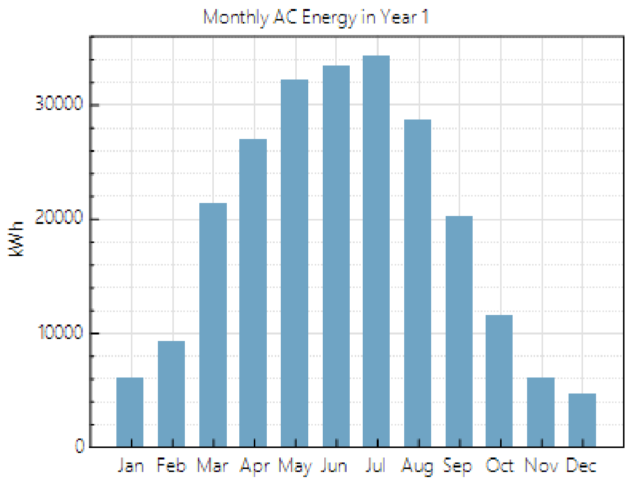

Figure 5. Monthly solar electricity generation from PV array ECM.

5.9.2 Renewable measure summary

Table 16: Renewable measure summary

Measures	Descriptions				
Solar PV - 224.4 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 - 224.4 kW array	$ 574,600	166,419	$ 35,114	13.8	$ 360,467

5.10 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 17: Measures considered but not recommended.

Measure	Description
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.
Battery storage	Significant material and associated electrical infrastructure costs, not critical to measures.
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.

Measure	Description
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.
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 (BAU) 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 for various reasons, the BAU 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 (BAU) 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. BAU equipment replacement under this scenario results in negligible energy savings and GHG emissions reduction.

Table 18: 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 ($)
Fuel fired furnaces (4 - 6) unit like-for-like	2026	$ 36,300	-	-	-	$ - 50,496
Electric DHW heater like-for-like	2026	$ 2,900	-	-	-	$ - 4,638
Fuel-fired DHW boilers like-for-like	2026	$ 23,400	-	-	-	$ - 37,426
Instantaneous floodwater heaters like-for-like	2026	$ 8,100	-	-	-	$ - 10,381
HRV units like-for-like	2026	$ 22,500	-	-	-	$ - 31,299
Full refrigeration plant like-for-like	2026	$ 1,275,000	-	-	-	$ - 1,365,712
Brine pumps like-for-like	2026	$ 46,800	-	-	-	$ - 59,979
Fuel fired infrared bleachers heaters like-for-like	2027	$ 18,800	-	-	-	$ - 23,039
Resurfacing machine like-for-like	2027	$ 132,000	-	-	-	$ - 248,321
Electric unit heaters like-for-like	2030	$ 3,100	-	-	-	$ - 2,713
Fuel fired unit heaters like-for-like	2033	$ 10,000	-	-	-	$ - 9,002
Dehumidifier like-for-like	2034	$ 39,000	-	-	-	$ - 42,373
Fuel fired furnaces (1 - 3) unit like-for-like	2037	$ 31,300	-	-	-	$ - 23,985
Lighting fixtures LED like-for-like	2039	$ 82,000	-	-	-	$ - 51,057
Total		**$ 1,731,200**	**-**	**-**	**-**	**$ - 1,960,421**

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 the 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 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, and low-e ceiling measures are recommended, which are lower cost, and easier to implement while retaining energy savings.
- **ASHP floodwater and 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 selected tankless condensing options.
- **Electric floodwater and 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 selected tankless condensing options.
- **Condensing domestic hot water heaters** – not selected in favour of the tankless equivalent to further reduce emissions and energy costs.
- Electric radiant bleacher heaters – hydronic bleacher conversions using heat recovery was selected in favour due to lower electric costs emissions reductions. This option does however have a more attractive NPV if seeking to go low carbon.
- **ASHP furnaces** – not selected in favour of taking advantage of the recommended CO_2 ice plant package which would enable high grade heat recovery, helping the facility reach lower carbon with less electrical demand increases and consumption.
- **Electric furnaces** – not selected in favour of taking advantage of the recommended CO_2 ice plant package which would enable high grade heat recovery, helping the facility reach lower carbon with less electrical demand increases and consumption.
- **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.
- **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 19: 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	$ 16,700	35,023	$ 2,444	5.8	$ 65,864	$ 69,045
Ice temperature optimization	2025	$ 7,200	23,475	$ 4,325	2.3	$ 116,625	$ 117,996
Electric DHW heater like-for-like	2026	$ 2,900	-	-	-	$ - 4,638	$ - 4,638
Hydronic AHU 4 - 6 conversion	2026	$ 408,900	36,903	$ - 1,133	8.3	$ - 468,536	$ - 369,882
Condensing tankless floodwater heater	2026	$ 8,600	4,978	$ 207	0.9	$ - 3,418	$ - 717
Condensing tankless domestic hot water heater	2026	$ 16,300	22,975	$ 955	4.2	$ 14,204	$ 19,322
Cold water ice resurfacing system	2026	$ 60,600	24,935	$ 1,521	4.3	$ - 1,070	$ 10,253
Refrigeration plant optimization - CO2	2026	$ 1,483,000	6,181	$ 1,304	0.5	$ - 1,553,148	$ - 1,104,724
Refrigeration plant desuperheaters	2026	$ 90,000	24,633	$ 1,024	4.5	$ - 77,718	$ - 49,455
VFDs on brine pumps	2026	$ 58,600	31,024	$ 6,546	2.6	$ 102,395	$ 120,797
Dehumidifier controls – daytime scheduling	2027	$ 4,800	1,127	$ 47	0.2	$ - 2,228	$ - 1,349
Dehumidifier controls – night setback scheduling	2027	$ 4,800	2,138	$ 89	0.4	$ - 732	$ 147
Bleacher hydronic heating	2027	$ 208,300	10,672	$ - 164	2.3	$ - 201,556	$ - 158,543
Low flow water fixtures	2027	$ 14,900	3,936	$ 431	0.6	$ 101	$ 2,832
Replace HRV units with ERV units	2027	$ 27,200	2,196	$ 92	0.4	$ - 32,953	$ - 24,441
Electric resurfacing machine	2027	$ 180,000	5,283	$ 696	1.7	$ - 310,818	$ - 253,102

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
Electric unit heaters like-for-like	2030	$ 3,100	-	-	-	$ - 2,713	$ - 2,713
Interlocking overhead doors	2030	$ 13,400	941	$ 44	0.2	$ - 8,233	$ - 5,915
Electric dehumidifier	2034	$ 55,100	5,779	$ - 3,676	3.4	$ - 122,709	$ - 107,267
Suspended low-e ceiling	2035	$ 82,700	- 41	$ 387	- 0.2	$ - 49,795	$ - 36,799
Hydronic AHU 1 - 3 conversion	2037	$ 408,900	59,191	$ - 3,007	14.1	$ - 337,675	$ - 257,831
Lighting fixtures LED like-for-like	2039	$ 82,000	-	-	-	$ - 51,057	$ - 51,057
Lighting Occupancy Controls	2039	$ 5,400	84	$ 37	-	$ - 2,833	$ - 2,047
Improve airtightness - Excluding rink	2040	$ 21,100	2,104	$ 95	0.4	$ - 6,988	$ - 3,976
Total [3]		**$ 3,264,500**	**191,193**	**$ 3,160**	**56.2**	**$ - 3,180,547**	**$ - 2,334,977**

6.3 Low carbon measures on aggressive implementation pathway with funding

Table 20 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 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 with one exception, that solar PV panels are selected as they are needed to meet the aggressive 80% emissions target in 5-years.

Table 20: 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 (tCO₂e)	NPV ($) with funding
Space temperature setbacks	2025	$ 16,700	35,023	$ 2,444	5.8	$ 69,045
Ice temperature optimization	2025	$ 7,200	23,475	$ 4,325	2.3	$ 117,996
Electric DHW heater like-for-like	2026	$ 2,900	-	-	-	$ - 4,638
Hydronic AHU 4 - 6 conversion	2026	$ 408,900	36,903	$ - 1,133	8.3	$ - 369,882
Condensing tankless floodwater heater	2026	$ 8,600	4,978	$ 207	0.9	$ - 717
Condensing tankless domestic hot water heater	2026	$ 16,300	22,975	$ 955	4.2	$ 19,322
Cold water ice resurfacing system	2026	$ 60,600	24,935	$ 1,521	4.3	$ 10,253
Refrigeration plant optimization - CO2	2026	$ 1,483,000	6,181	$ 1,304	0.5	$ - 1,104,724
Refrigeration plant desuperheaters	2026	$ 90,000	24,633	$ 1,024	4.5	$ - 49,455
VFDs on brine pumps	2026	$ 58,600	31,024	$ 6,546	2.6	$ 120,797
Dehumidifier controls – daytime scheduling	2027	$ 4,800	1,127	$ 47	0.2	$ - 1,349
Dehumidifier controls – night setback scheduling	2027	$ 4,800	2,138	$ 89	0.4	$ 147
Bleacher hydronic heating	2027	$ 208,300	10,672	$ - 164	2.3	$ - 158,543
Low flow water fixtures	2027	$ 14,900	3,936	$ 431	0.6	$ 2,832
Replace HRV units with ERV units	2027	$ 27,200	2,196	$ 92	0.4	$ - 24,441
Electric resurfacing machine	2027	$ 180,000	5,283	$ 696	1.7	$ - 253,102
Solar PV - 224.4 kW array	2028	$ 574,600	166,419	$ 35,114	13.8	$ 463,778
Electric unit heaters like-for-like	2030	$ 3,100	-	-	-	$ - 2,713
Electric dehumidifier	2030	$ 55,100	5,779	$ - 3,676	3.4	$ - 132,066
Interlocking overhead doors	2030	$ 13,400	941	$ 44	0.2	$ - 5,915

Low carbon measure	Year	Initial capital costs ($)	Total energy savings (ekWh)	Total net annual savings ($)	Annual GHG reduction (tCO_2e)	NPV ($) with funding
Hydronic AHU 1 - 3 conversion	2030	$ 408,900	59,191	$ - 3,007	14.1	$ - 348,213
Lighting Occupancy Controls	2030	$ 5,400	84	$ 37	-	$ - 3,329
Improve airtightness - Excluding rink	2030	$ 21,100	2,104	$ 95	0.4	$ - 8,491
Suspended low-e ceiling	2030	$ 82,700	- 41	$ 387	- 0.2	$ - 41,078
Lighting fixtures LED like-for-like	2039	$ 82,000	-	-	-	$ - 51,057
Total [3]		**$ 3,839,100**	**357,612**	**$ 38,275**	**54.7**	**$ - 2,039,057**

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 21: Financial summary year – Business-as-usual scenario

Business-as-Usual year of replacement	Initial outlay of costs with inflation ($)	NPV ($)	Measures (ID #)	Explanation
2026	$ 1,457,450	$ - 1,559,931	BAU-03B, BAU-05, BAU-06, BAU-07, BAU-08, BAU-10, BAU-11	End of life replacement(s).
2027	$ 159,984	$ - 271,359	BAU-04, BAU-09	End of life replacement(s).
2030	$ 3,594	$ - 2,713	BAU-02	End of life replacement(s).
2033	$ 12,668	$ - 9,002	BAU-01	End of life replacement(s).
2034	$ 50,886	$ - 42,373	BAU-12	End of life replacement(s).
2037	$ 44,626	$ - 23,985	BAU-03A	End of life replacement(s).
2039	$ 124,032	$ - 51,057	BAU-13	End of life replacement(s).
Total	**$ 1,853,240**	**$ - 1,960,421**		

Table 22: 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	$ 23,900	$ 182,489	$ 187,041	MEC-12, RFG-03	MEC-12, RFG-03 – Control optimization measures and can be implemented immediately
2026	$ 2,192,767	$ - 1,991,929	$ - 1,379,043	BAU-05, MEC-08B, MEC-15, MEC-19, RFG-02, RFG-04, RFG-05, RFG-06	BAU-05 – Measure(s) to be implemented at end of life or expected replacement. Feasible low carbon equivalent(s) not available. RFG-02, 04, 05, 06 – Implement new ice plant, and associated measures. Will enable the ability to tap into potential heat recovery for space and water heating. MEC-08B – First set of furnace replacements, conversion to hydronic units to be along side the ice plant replacement. MEC-15, 19 – Replace hot water heaters at end of life with condensing tankless options.
2027	$ 466,796	$ - 548,187	$ - 434,454	MEC-01, MEC-02, MEC-07, MEC-20, MEC-21, RFG-01	MEC-01, 02 – Implement new controls after installation of new ice plant, which should include additional ice rink BAS system for controls strategies. MEC-20 – Replace low fixtures after identifying priority spaces and procurement needs (investigating if full replacements are necessary) MEC-07 – Implement systems following prior required installations of ice plant and heat recovery systems. MEC-21, RFG-01 – Replacing equipment with low carbon equivalent at end of life, with focus on providing emissions and energy savings.
2030	$ 19,128	$ - 10,946	$ - 8,628	BAU-02, MEC-05	BAU-02 – Measure(s) to be implemented at end of life or expected replacement. Feasible low carbon equivalent(s) not available. MEC-05 – Implement systems following investigation of existing infrastructure and systems.
2034	$ 71,893	$ - 122,709	$ - 107,267	MEC-04	MEC-04 – Replacing equipment with low carbon equivalent at end of life, with focus on providing emissions and energy savings.
2035	$ 111,142	$ - 49,795	$ - 36,799	ENV-06	ENV-06 – Replacing ceiling with improved option at end of life, with focus on providing emissions and energy savings.

Typical pathway year of replacement	Initial capital costs with inflation ($)	NPV without Funding ($)	NPV with Funding ($)	Measures (ID #)	Explanation
2037	$ 582,994	$ - 337,675	$ - 257,831	MEC-08A	MEC-08B – Second set of furnace replacements, conversion to hydronic units. Ideally piping and infrastructure should be in place from original ice plant heat recovery installations.
2039	$ 132,200	$ - 53,890	$ - 53,104	BAU-13, ELE-01	BAU-13 – Measure(s) to be implemented at end of life or expected replacement. Feasible low carbon equivalent(s) not available. ELE-01 – Installing more comprehensive dimming and occupancy controls for additional lighting and energy savings.
2040	$ 32,873	$ - 6,988	$ - 3,976	ENV-04B	ENV-04B – Improving facility infiltration excluding the ice rink. Included after to provide time and resources to improve other systems prior.
Total	**$ 3,633,693**	**$ - 3,180,547**	**$ - 2,334,977**		

Table 23: 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	$ 23,900	$ 187,041	MEC-12, RFG-03	MEC-12, RFG-03 – Control optimization measures and can be implemented immediately
2026	$ 2,192,767	$ - 1,379,043	BAU-05, MEC-08B, MEC-15, MEC-19, RFG-02, RFG-04, RFG-05, RFG-06	BAU-05 – Measure(s) to be implemented at end of life or expected replacement. Feasible low carbon equivalent(s) not available. RFG-02, 04, 05, 06 – Implement new ice plant, and associated measures. Will enable the ability to tap into potential heat recovery for space and water heating. MEC-08B – First set of furnace replacements, conversion to hydronic units to be along side the ice plant replacement. MEC-15, 19 – Replace hot water heaters at end of life with condensing tankless options.

Aggressive pathway year of replacement	Initial capital costs with inflation ($)	NPV with Funding ($)	Measures (ID #)	Explanation
2027	$ 466,796	$ - 434,454	MEC-01, MEC-02, MEC-07, MEC-20, MEC-21, RFG-01	MEC-01, 02 – Implement new controls after installation of new ice plant, which should include additional ice rink BAS system for controls strategies. MEC-20 – Replace low fixtures after identifying priority spaces and procurement needs (investigating if full replacements are necessary) MEC-07 – Implement systems following prior required installations of ice plant and heat recovery systems. MEC-21, RFG-01 – Replacing equipment with low carbon equivalent at end of life, with focus on providing emissions and energy savings.
2028	$ 627,881	$ 463,778	RNW-01	RNW-01 – Solar PV is to be completed as soon as possible. It is scheduled in 2028 to give time to work with local distribution companies (LDCs) and to develop a net metering agreement. It should be noted that this ECM should be considered dependent on available grid capacity; to be determined by a Connection Impact Assessment (CIA) or equivalent through the LDC should the Municipality move forward with this measure.
2030	$ 683,624	$ - 541,806	BAU-02, MEC-04, MEC-05, MEC-08A, ELE-01, ENV-04B, ENV-06	BAU-02 – Measure(s) to be implemented at end of life or expected replacement. Feasible low carbon equivalent(s) not available. MEC-04, 05, 08A, ELE-01, ENV-04B, 06 – Measure implemented during the 5-year mark for aggressive pathway, to approach FCM GHG reduction targets of 80%.
2039	$ 124,032	$ - 51,057	BAU-13	BAU-13 – Measure(s) to be implemented at end of life or expected replacement. Feasible low carbon equivalent(s) not available.
Total	**$ 4,119,000**	**$ - 2,039,057**		

6.5 Comparative NPV by end-use category

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

Table 24. 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 ($)**
Dehumidification	MEC-01, MEC-02, MEC-04	$ - 125,670	$ - 108,468	BAU-12	$ - 42,373	$ - 83,297	$ - 66,095
Domestic Hot Water	BAU-05, MEC-15, MEC-19, MEC-20	$ 6,249	$ 16,799	BAU-05, BAU-06, BAU-07	$ - 52,445	$ 58,694	$ 69,244
Heating	BAU-02, MEC-05, MEC-07, MEC-08A, MEC-08B, MEC-12	$ - 952,850	$ - 725,839	BAU-01, BAU-02, BAU-03A, BAU-03B, BAU-04	$ - 109,235	$ - 843,614	$ - 616,603
Ventilation	MEC-21	$ - 32,953	$ - 24,441	BAU-08	$ - 31,299	$ - 1,654	$ 6,858
Lighting	BAU-13, ELE-01	$ - 53,890	$ - 53,104	BAU-13	$ - 51,057	$ - 2,833	$ - 2,047
Refrigeration	RFG-02, RFG-03, RFG-04, RFG-05, RFG-06	$ - 1,412,916	$ - 905,132	BAU-10, BAU-11	$ - 1,425,691	$ 12,775	$ 520,559
Ice Resurfacing	RFG-01	$ - 310,818	$ - 253,102	BAU-09	$ - 248,321	$ - 62,498	$ - 4,781
Envelope	ENV-04B, ENV-06	$ - 56,783	$ - 40,775	-	-	$ - 56,783	$ - 40,775
Total						**$ - 1,220,125**	**$ - 374,555**

Table 25. 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 ($)**
Dehumidification	MEC-01, MEC-02, MEC-04	$ - 151,705	$ - 133,268	BAU-12	$ - 42,373	$ - 109,331	$ - 90,894
Domestic Hot Water	BAU-05, MEC-15, MEC-19, MEC-20	$ 6,249	$ 16,799	BAU-05, BAU-06, BAU-07	$ - 52,445	$ 58,694	$ 69,244
Heating	BAU-02, MEC-05, MEC-07, MEC-08A, MEC-08B, MEC-12	$ - 1,054,737	$ - 816,221	BAU-01, BAU-02, BAU-03A, BAU-03B, BAU-04	$ - 109,235	$ - 945,502	$ - 706,985
Lighting	BAU-13, ELE-01	$ - 55,956	$ - 54,386	BAU-13	$ - 51,057	$ - 4,899	$ - 3,329
Refrigeration	RFG-02, RFG-03, RFG-04, RFG-05, RFG-06	$ - 1,412,916	$ - 905,132	BAU-10, BAU-11	$ - 1,425,691	$ 12,775	$ 520,559
Ice Resurfacing	RFG-01	$ - 310,818	$ - 253,102	BAU-09	$ - 248,321	$ - 62,498	$ - 4,781
Envelope	ENV-04B, ENV-06	$ - 76,375	$ - 49,569	-	-	$ - 76,375	$ - 49,569
Renewables	RNW-01	$ 360,467	$ 463,778	-	-	$ 360,467	$ 463,778
Dehumidification	MEC-01, MEC-02, MEC-04	$ - 151,705	$ - 133,268	BAU-12	$ - 42,373	$ - 109,331	$ - 90,894
Total						**$ - 1,051,839**	**$ - 78,635**

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 19 and Table 20.

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 Arena 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 26: 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)	14.6	0.1	-
Natural Gas emissions (tCO_2e)	48.5	22.1	8.7
Gasoline emissions (tCO_2e)	1.9	-	-
Total emissions (tCO_2e)	65.0	22.3	8.8
GHGI ($kgCO_2e/ft^2$)	1.92	0.66	0.26
$ILCC/$tCO_2e$	-	$ 2,485	$ - 4,266
% Saving	-	65.7%	86.5%

Table 27: 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)	14.6	1.6
Natural Gas emissions (tCO_2e)	48.5	8.7
Gasoline emissions (tCO_2e)	1.9	-
Total emissions (tCO_2e)	65.0	10.3
GHGI ($kgCO_2e/ft^2$)	1.92	0.31
$ILCC/$tCO_2e$	-	$ 2,368
% Saving	-	84.1%

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 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 $5.4M.

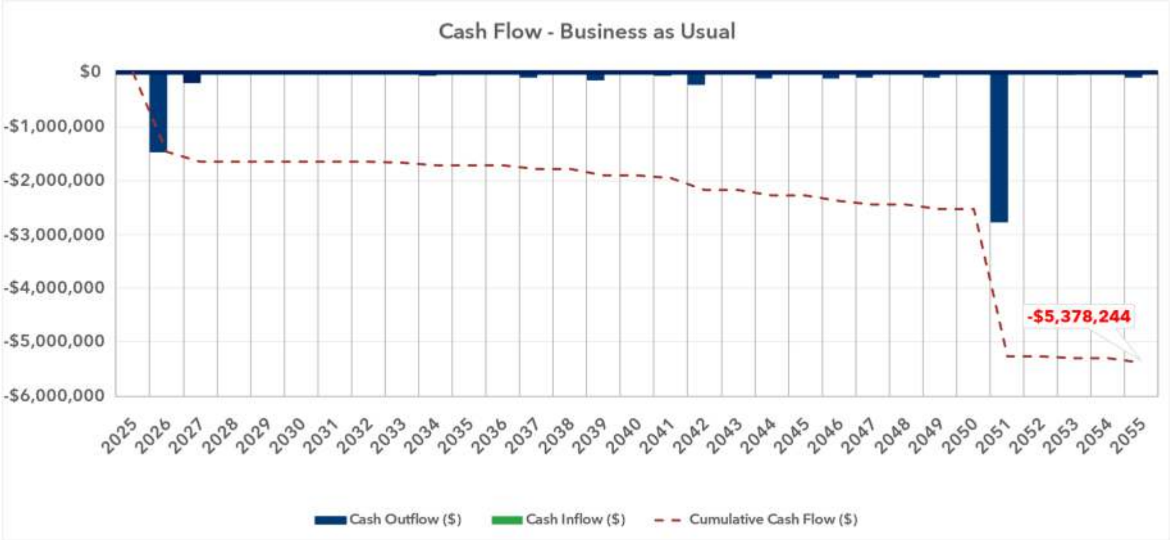

Figure 6: Cash Flow – Business-as-usual

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. Although a breakeven point is unlikely within the study period, the total cumulative cash flow of this pathway is close to negative $8.0M. 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.

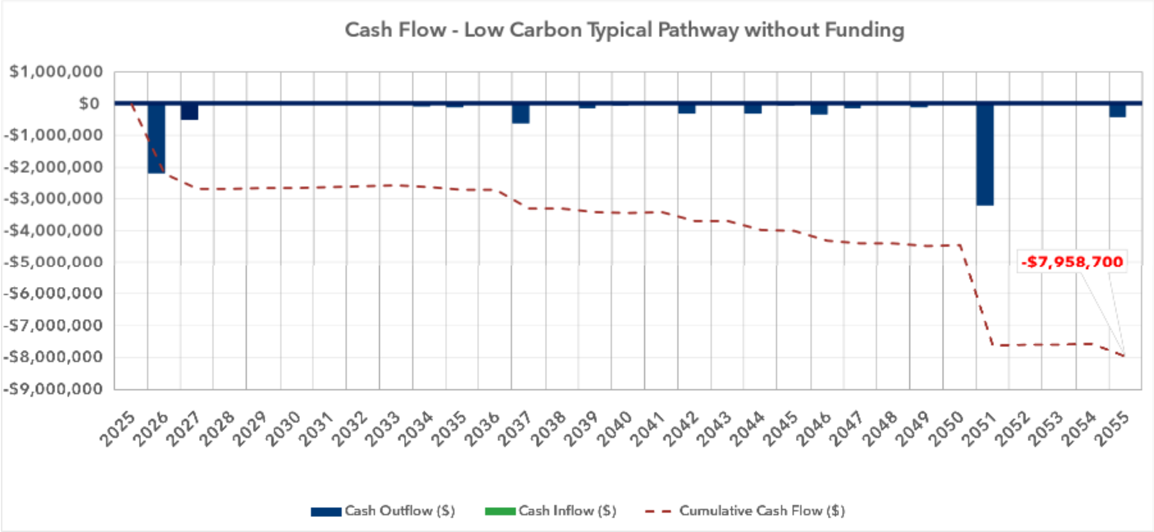

Figure 7: Cash Flow – Low Carbon Approach on Typical Pathway without Funding

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 $6.3M and negative $4.6M.

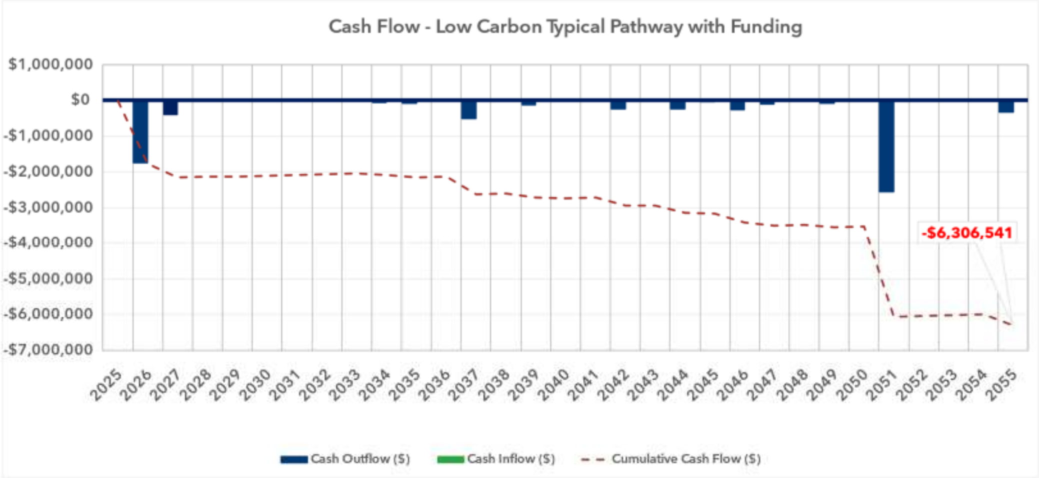

Figure 8. Cash Flow – Low Carbon Approach on Typical Pathway with Funding

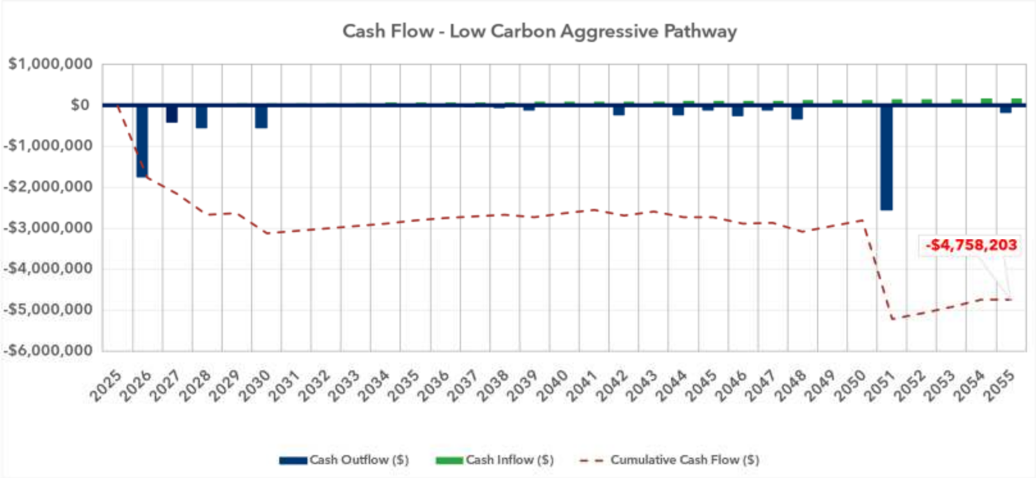

Figure 9: Cash Flow – Low Carbon Approach on Aggressive Pathway with Funding

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 $2.6 million without funding and negative $0.9 million with funding on the typical pathway, and positive $0.6 million for the aggressive pathway. Cashflow breakeven does not occur for any of the pathways.

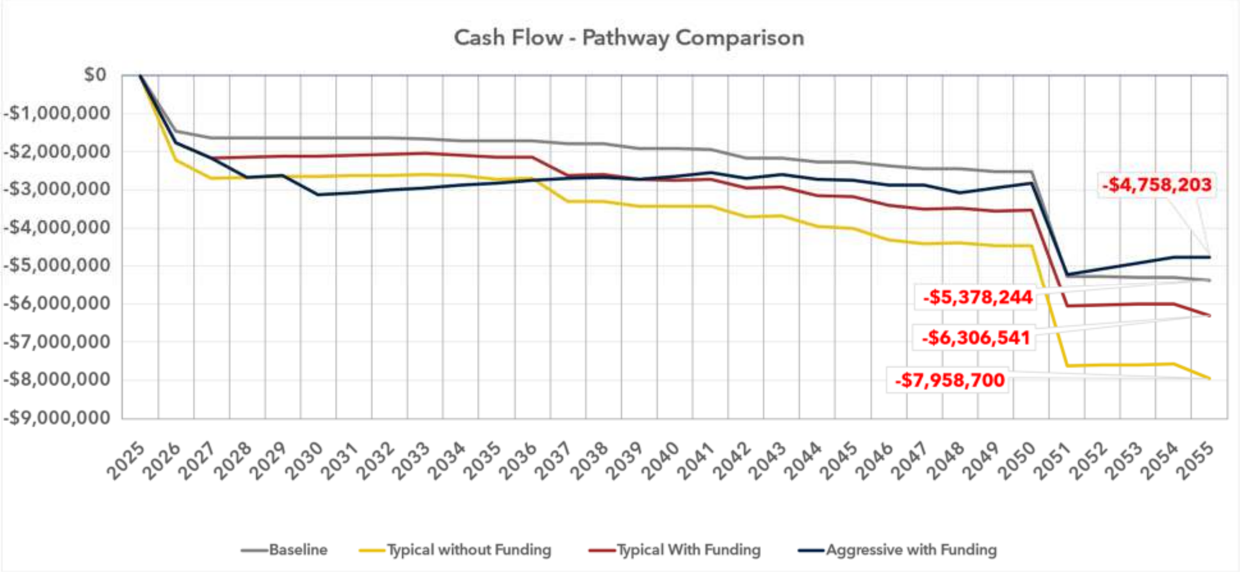

Figure 10. Cumulative cashflow comparison of the three pathways studied

8.1 Thessalon Arena 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), Town of Thessalon can expect to spend over $3.5M over the next 30 years due to utility and carbon price escalations. The measures recommended in this Roadmap will reduce that spend by almost 16% 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. Annual utility costs for the aggressive pathway are much lower than both the BAU and LCP pathways as a result of the recommendation for solar PV registered under a net-metering agreement. These values are accounted for in the NPV values presented in this report.

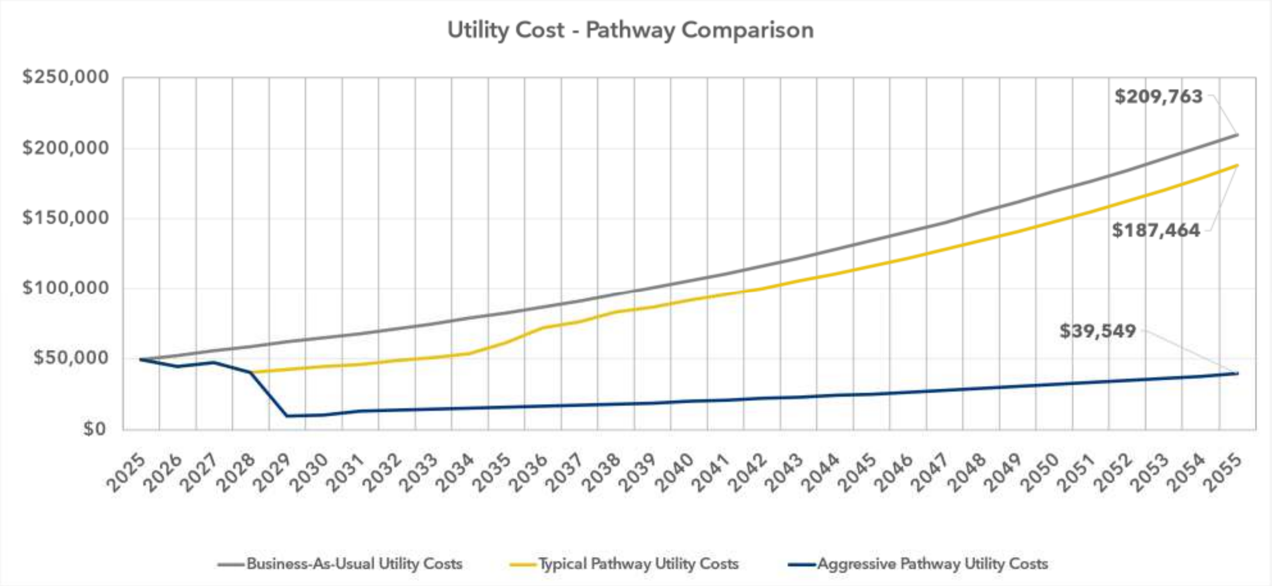

Figure 11. Annual utility cost comparison between pathways

9 Project implementation

This report lays out a strategic, phased approach for transforming Thessalon Arena 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 Thessalon Arena by comparing the expenditures under business-as-usual ($3.5M on utilities and nearly $1.9M 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 $1.8M of upfront capital but will reduce utility costs by almost 16% and yield a negative net present value with funding of only $375k relative to the BAU pathway over the 30-year period. Although taking this entire low carbon approach results in an overall increased cost of ownership for the Town of Thessalon, some energy end-uses, such as refrigeration and domestic hot water, result in a reduced overall cost of ownership, along with environmental and social benefits.

- The **environmental case** is equally compelling. The environmental benefits of this project are profound, offering a dramatic reduction in greenhouse gas emissions by over 86%. 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 Arena with heat pumps and heat recovery 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 Arena 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 $700k in grants. In Table 28 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 21 of this study. Measure IDs can be referenced from Appendix E and F.

Table 28. 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-12, RFG-03, MEC-01, MEC-02, ELE-01	12%	$ 42,253	$ 8,451	$ 8,451	$ 25,352
1	2026	BAU-05, MEC-08B, MEC-15, MEC-19, RFG-02, MEC-07, MEC-20, MEC-21, RFG-01, RFG-04, RFG-05, RFG-06	43%	$ 2,649,378	$ 529,278	$ 532,265	$ 1,587,835
2	2029	BAU-02, MEC-05	52%	$ 19,128	$ 3,107	$ 6,701	$ 9,321
3	2032	MEC-04, ENV-06	65%	$ 183,035	$ 36,607	$ 36,607	$ 109,821
Total			**86%**	**$ 3,633,693**	**$ 700,616**	**$ 831,229**	**$ 2,101,848**

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 an Implementation Workshop.

9.3 Procurement

This integrated project involves discrete elements of work – refrigeration plant and dehumidifiers, lighting, cold water ice resurfacing, 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 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 operating 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 end of life. 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 additional 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 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 Arena 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 Arena 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 Memorial Community Arena
Participants Performing Site Visit	Kajen Ethirveerasingham Sean Mitchinson
Date Performed	March 21, 2024

Building Details

Gross Floor Area	30,000 ft^2
Number of stories	1
Area of other significant spaces	Upper hall, ice rink
Construction Date	1940's for original building, 1991 Dressing room addition, 1999 Zamboni room addition, 2007 Upper Deck addition
Use of Facility	Ice Arena (hockey, figure skating, etc.…)

Systems to Consider

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

Drawings

Drawing	Drawings available	Notes
Architectural Drawings	☒	Plans for Dressing room additions, Zamboni room additions, and upper deck additions available
Electrical Drawings (Lighting Plan and Luminaire Schedules)	☒	Same as arch, schedules in master spec

Heading Drawings (including Boilers/DHW heating, riser diagrams)	☐	Same as arch, schedules in master spec
Ventilation Drawings (Fan Systems, risers)	☐	
Cooling System Drawings (Building Cooling if separate Cooling Plant, risers)	☐	

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)	
Wall construction for 'Upper Deck' and 'New Zamboni Room' are available through drawings. Remaining constructions will be assumed based on building vintage.	

Receptacles and Plug Loads

Kitchen Equipment and source?	Electric stove, electric range, canteen equipment, 3 fridges.
High use plug loads (data servers, commercial electric kitchens, etc.)	
Any variable loads in building? (Process loads, equipment, tools, transitional or seasonal)	Additonal electric heat is brought in during cold weather to prevent pipes from freezing.
Additional Notes:	

Heating

How many hot water systems are there in total?	5		
System Name	Purpose/Type: (space heating, DHW/ electric, gas)	Notes (loop temp, control, etc.)	Year Installed/ Condition
New Dressing Room HWT x 2	Rheem M# G75-125 S#URNG0210G00462 S#URNG0909G00673 75 Gal, 125 MBH input,	1 unit @ 155F, 1 unit @ 140F. Unit at 140F used most often	2010
Upper Deck DHWT x 1	Giant M#152ETE-3F7M Electric 4.5kW @ 40 Gal		2007

Floodwater Heater	Navien M# NPE-240A 199 MBH @ UEF 0.95 Tankless	140F	1999
Old Zamboni Room	GSW Series 6 M# G640S34FV-04 S# S0818 F702500 34 MBH input @ 80% 40 Gal	Serves Changeroom 5 and 6	2008

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 manual
Do they have their own controllers?	One per heater

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?
No. Zamboni doors stay open during resurfacing. Interior door open 10 minutes, exterior open 5 minutes per resurfacing for dumping.
Auxiliary Heaters (electric radiative, Gas Heaters, electric baseboard, etc.)

How many Gas Fired Heaters are there in total?	13

Heater Type	Capacity/Control	Location Served	Year Installed
Zamboni UH	Gas, Reznor M# UDX-60 60 MBH input @ 83% Has a manual switch	New Zamboni Rm	2021
Furnace x 2	Keeprite Room 1-2: M#G96VTN0801716A1 S# A214149423 80MBH max input @ 97.5% Room 3-4: M#G9MVE1002120A3 S# A164347554 100MBH max input @ 97%	Changeroom Addition Room 1 + 2 @ 68F, Room 3 + 4 @ 66F	2022, 2016
Furnace	Keeprite Gas M# G96VTN1202422A1 S# A194783891 120 MBH max input @ 97.5%	Lobby	2020

Furnace x 2	HVU 2: Carrier M# 58MCB140-20 S# 2107A04462 138 MBH input @ 92% HVU 1: Same as above	Upper Deck	2007
Furnace	Keeprite M# N9MP2075B12C2 S# A094260689 75 MBH input @ 90%	Original Changerooms	2009
UH	Reznor M#UDA545 S#BMH796EN37883X 45MBH @ 83%	Compressor room	2013
IR x 5	Re-Verber-Ray M# IR-60 NES-2 Input 160 MBH @ 80%	Spectators	EOL
How many Electric Heaters are there in total?			2
Heater Type	Capacity/Control	Location Served	Year Installed
~~Duct Heater~~	~~1.5kW x 2~~	~~New Dressing Rm Furnaces~~	Not found at visit
Electric UH	1.5 kW	Sound room (24/7), scorekeepers' box	
Electric UH		Brought in to prevent pipes from freezing	

Water Use

Space	Fixture Type/Qty/ Flow rate (low flow, etc.)	Controls (sensors)	Year Installed/ Condition
Women's WR	Low flow		2020
DHW	Standard flow		
Is there any seasonal water use? (Landscaping, cooling tower make-up, etc.)		No summer uses. Hot water used at end of ice season to burn plastic lines off ice.	
Is water used for cooling tower make-up?		Yes, evaporative condenser.	
Any replacements/upgrades of water fixtures planned?		No	
General notes on operation, concerns, opportunities			
Plumbing fixture schedule in Dressing Rm addition plans April high HW use from washing plastic lines on ice. Flat water rate.			

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	Area/Zone Served and Location	Operation/ Setpoint Schedule	Age/ Condition
Furnace-1/2	Keeprite Room 1-2: M#G96VTN0801716A1 S# A214149423 80MBH max input @ 97.5% Room 3-4: M#G9MVE1002120A3 S# A164347554 100MBH max input @ 97%		Dressing Rooms Additions	Per drawings: Occupied mode: 750 CFM OA, 500 CFM RA during occupied mode, 72F discharge Temp, fans run continuously. Unoccupied mode: EF off, 100% RA, fans cycle as needed	2022, 2016
EF-1,2,3,4	4 units total, B-80 Reversomatic EF		Washrooms Additions		1991
EF-5,6	1 unit per Dressing room HVU 770CFM @ 0.25in SP, 1/6HP		Dressing Rooms Additions		1991
HVU-1/2	HVU 2: Carrier M# 58MCB140-20 S# 2107A04462 138 MBH input @ 92% HVU 1: Same as above		New Upper Deck – Mezzanine Level		2007
Furnace-3	Gas furnaces		New Office, canteen, lobby washrooms		2007
HRV-1/2	Coupled with HVU-1/2 Venmar CES M# HRV 600i EAWXRN-VEN S#00090608-001430-20070808 M# HRV 1200i EAWXRN-VEN S#00090607-001429-20070809		New Upper Deck		2007
Ice Rink Dehumidifier	Munters ICEAIRE M# A5G, S# A09DA5G8341 NG Desiccant @ 100MBH regen heat OA provided by unit		Ice Rink		2009
Range Hood			Canteen		
Arena Exhaust Fans			Arena	Turned on when spectator heaters are used	

Schedules

Location/Tag HVAC zone or Space	Operation/Occupancy Schedule Weekday, weekend, seasonal operation/occupancy	Lighting (matches operation?)	HVAC (matches operation?)
Arena	Ice plant on 10/01, publicly available 10/15. Taken out end of March. Monday to Friday. Monday: 6-9 Tuesday and Thursday: 3-10 Wednesday: 4-8 Friday: 6-9 One 9h Saturday per Month. Practises: 45 occupants Games: May have 150 people in the facility. Public Skating: Couple Hundred	☒	☐
Ice-Off season	Pickle ball started 2023. 2 hours per week. May – September. Lighting follows, no DHW. Occupants: 20 at a time.	☒	☐
Changerooms	Follow arena operations.	☐	☐
Upper Deck	Once per month 9 hours. Rentals once per month (100 or so occupants). Busier during holidays (11-4)	☒	☐
Lobby	Follow arena operations	☒	☐
Canteen	Follow arena operations	☒	☐

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
Most of Facility	68 F	68 F	68 F
Arena	Unconditioned	Unconditioned	Unconditioned
Zamboni Room	70F	70F	70F
New Change Rooms	68-66F	68-66F	68-66F
Upper Deck	65F setpoint, reading 67F during visit	65F setpoint	65F setpoint
Ice Plant Room	20C	20C	20C

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*
Ice operation during ice season.

Lighting

What are the primary fixture types?	LED
Is there a lighting plan and schedule?	For additions, no luminaire schedule. None for rink, lower floor washrooms or old changerooms
Do unique spaces have different lighting, and what fixtures? (For pool decks, ice rinks, gymnasiums, convention centres, etc.)	Rink @ 109W/fixture
Have LED retrofits been completed, and when? (only for certain spaces or facility wide and year of completion)	~2019
Occupancy or daylighting sensors? (what spaces and how many)	Lower floor washrooms + lower lobby and office
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	
Upper deck washrooms have coupled EF and lights occupancy sensors	

Refrigeration System

Refrigerant Type	Ammonia, 82.1 kW Plant Rating
Type of Controls Ice IR sensors, ice slab sensor and/or brine water return temperature	Slab IR, Honeywell T775
Refrigeration Equipment *Compressors, Pumps, Evaporative Fans,*	

Equipment Name/Type/ Quantity	System Capacity	Year Installed/ Condition	Notes (Control methods, VFDs, etc.)
Compressor x 2 MYCOM N 6WA	50 HP, 30HP	2020, EOL	Electric motor 1 replaced twice in 7 years.

Brine Pump	15 HP NEMA Premium Motor	~2010	
Evaporative Condenser	BAC Metal-Air S#UI23874901-01-01 10HP	2010 – 2015	VFD on fan
Condenser Pump	3HP, 89.5% eff NEMA Premium motor Armstrong Pump 150 GPM @ 40ft	2010 – 2015	
Chiller Shell and Tube		EOL	
Dehumidifier	Gas Fired desiccant AG-5	2009	
Is there any heat recovery? For ice melting, underfloor, heating system? Is there a desuperheater or heat recovery heat pump system?			
No, no sub-floor pump			
What is the ice rink under slab setpoint temp (if this is used to control ice temperature)?			
None			
General Notes and Comments (Facility space, existing equipment, measures requested)			
Cracks in sub-floor.			

Ice Rink

When is the Ice In and Out?	Start of October to end of March
What kind of activity does the rink experience? *Ice hockey, figure skating, public skate etc.*	Ice hockey, figure skating, public skates.
Is there a low-e Ceiling? When was it installed?	Low-e, non-suspending, insulating
Number of Rinks	1
Dimensions of Rinks (ft)	85’ x 200’
Area of Rinks (ft²)	
Setpoints	
Temperature the ice is maintained at?	18 F slab from interview Slab sensor seemed to have issues, bouncing between 19-20F Ice temp was set to 22F in past seasons, only 18F this season.
Nighttime Setback temperature for Ice?	N/A

Space RH setpoint?	50-55% Measured at 43.5% RH average over 4h
Space temperature of the rink?	Not controlled Measured at -2C average over 4h
Space temperature setpoints based on activities?	N/A
Nighttime setback for space temperature?	N/A
Do the setpoints change during Winter and Summer season for temperature and RH?	N/A
Intended/Target Ice thickness? Any concerns with maintenance?	2” in flat areas 3” in corners. Ice maintenance once per week.
Spectator Occupancy	
Number of seats in spectator area and typical occupancy per game? *(How does it change throughout the season)*	Games (2 times per week): < 100 people Practices heaters are not used.
How are Spectator Areas heated? *(Gas fired Infrared, underfloor, via RTU, electric IR)*	Gas IR
How often and for how long is spectator heating used?	Only during games, 6-7 hours per month
Take pictures of entire space, ceiling, lighting, walls, windows. ☐	
Brine Headers	
Accessible? *(under concrete or wood boarding)*	Yes
Length (ft)	
Material *(steel/plastic)*	PVC
Insulated? *(covered in ice, foam insulation, etc.)*	No insulation

Ice Resurfacing Machine

Number of resurfacing machines and fuel source? When was it installed?	1 gasoline Zamboni Model# 440, S#6360 2000 (been rebuilt for roughly $5k, but nearing EOL)
How many times a day is the ice resurfaced?	
On typical Weekday	5 + maintenance
On typical Weekend	9 once per month
How many times does the machine need to be refueling/recharged per week?	
On typical Weekday	15 USG every two weeks.
On typical Weekend	

Water Temp in Ice resurfacing machine	140 F
Do they have REALice?	No. Cold city water was used for ice resurfacing prior to the 2023-2024 ice season. Switch to warm water was made to strive for better ice quality.
Is RO Water used for resurfacing?	No
What volume of water does Ice resurfacing machine hold?	166 Gal
Approximately what % of total water is used during resurfacing	75%
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	
No	
How do operators use the BAS?	
No	
Do they actively change setpoints or schedules?	
No	
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?	
No	

Appendix B – Monthly billing data

The table below lists monthly energy use and cost as per monthly billing.

Gasoline is purchased on an as-needed basis via local deliveries. As such, monthly data is not available, however annual values are presented below.

Prices below are exclusive of HST but include carbon pricing.

Table 29: Monthly energy use and costs for April 2023 – March 2024

Month	Electricity use (kWh)	Electricity cost ($)	Natural Gas use (m³)	Natural Gas cost ($)	Gasoline (L)	Gasoline cost ($)
Apr-23	2,215	$ 467	2,652	$ 1,245	-	-
May-23	1,115	$ 235	1,480	$ 680	-	-
Jun-23	1,102	$ 232	822	$ 174	-	-
Jul-23	1,378	$ 291	223	$ 144	-	-
Aug-23	1,007	$ 212	3	$ 50	-	-
Sep-23	14,947	$ 3,154	146	$ 111	-	-
Oct-23	34,111	$ 7,197	1,854	$ 835	-	-
Nov-23	23,350	$ 4,927	2,259	$ 1,004	-	-
Dec-23	24,017	$ 5,068	4,234	$ 1,829	-	-
Jan-24	21,874	$ 4,615	4,270	$ 1,770	-	-
Feb-24	23,812	$ 5,024	3,707	$ 1,522	-	-
Mar-24	18,802	$ 3,967	2,855	$ 1,186	-	-
Total	**167,730**	**$ 35,391**	**24,505**	**$ 10,550**	**833**	**$ 1,134**

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 – Utilities – Gasoline	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

Electricity utility rates are based on Hydro One Commercial General Service, with Time-of-Use pricing. Rates change bi-annually, 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%

There are two natural gas meters found at the facility. Utility rates of both natural gas meters at the facility are based on Enbridge Residential Rate 01 Union North West, the rates effective April 1st, 2024, can be found in the table below.

Utility rate structure – Natural gas, 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

Utility rate structure – Natural gas, Rate 01	
Cost Adjustment	-2.5676 ¢/m³
Components - Gas Supply	-2.9454 ¢/m³
Components - Transportation	0.3778 ¢/m³
GST/HST	13%

Gasoline utility rates based on annual billing provided by facility management is provided in the table below. Federal fuel charge rates are listed as stated by the Government of Canada for the period of April 1, 2023 to March 31, 2024.

Utility rate structure – Gasoline	
Commodity rate (including delivery)	1.2204 $/L
Federal Fuel Charge	0.1413 $/L
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
Gasoline	tCO_2e/kWh	0.002307

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 30: Electricity consumption (kWh) modelling error

Month	Model	Actual
1	19,943	22,302
2	20,024	21,729
3	21,870	20,377
4	4,241	5,452
5	3,924	1,497
6	1,858	1,066
7	1,252	1,259
8	1,199	1,164
9	11,678	12,671
10	27,801	29,690
11	27,085	26,219
12	25,540	24,255
Total	**166,415**	**167,679**
CV(RMSE)		10.9%
NMBE		0.8%

Table 31: Natural gas consumption (kWh) modelling error

Month	Model	Actual
1	40,916	40,501
2	34,651	34,582
3	35,383	33,285
4	24,262	25,454
5	14,381	14,541
6	3,386	7,276
7	2,268	1,796
8	2,296	355
9	4,126	4,280
10	24,540	20,291
11	36,638	30,193
12	41,719	45,914
Total	264,565	258,468
CV(RMSE)		14.2%
NMBE		- 2.6%

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.

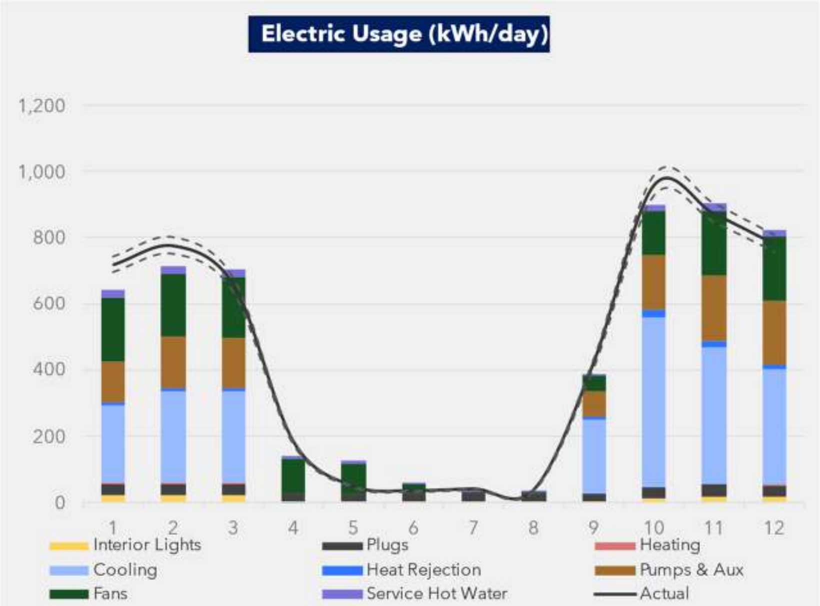

Figure 12: Calibrated Model Monthly End Uses vs Electricity Utility Billing Monthly Totals for April 2023 – March 2024

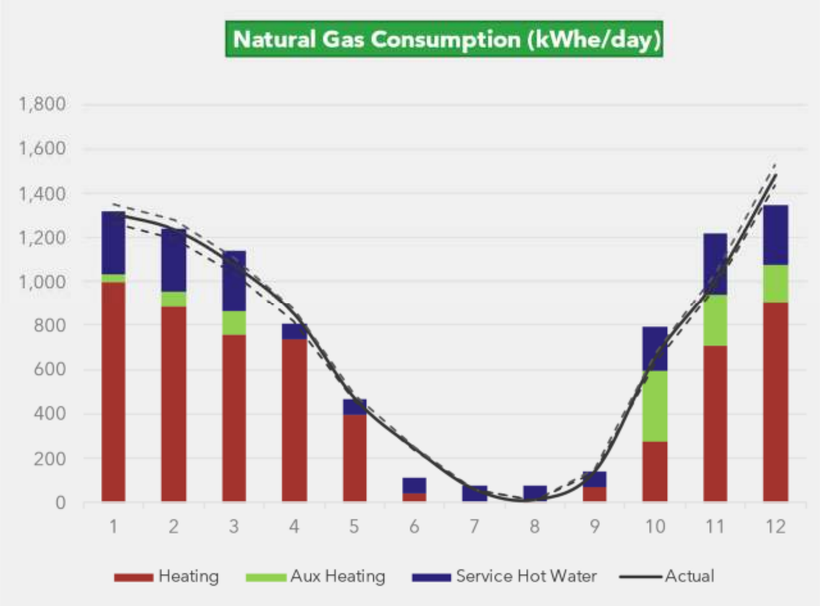

Figure 13: Calibrated Model Monthly End Uses vs Natural Gas Utility Billing Monthly Totals for April 2023 – March 2024

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	Like-for-like replacement of fuel fired unit heaters.	$ 10,000	-	The life expectancy of this measure until the next replacement is 20 years. Includes 25% contingency. Material and Equipment cost = $5,000 Labor and Installation cost = $3,000 Soft cost (Engineering and/or other services) not included.
BAU-02	Like-for-like replacement of electric unit heaters.	$ 3,100	-	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 = $1,000 Soft cost (Engineering and/or other services) not included.
BAU-03A	Like-for-like replacement of fuel fired furnaces 1 - 3.	$ 31,300	-	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 = $6,000 Soft cost (Engineering and/or other services) not included.
BAU-03B	Like-for-like replacement of fuel fired furnaces 4 - 6.	$ 36,300	-	The life expectancy of this measure until the next replacement is 18 years. Includes 25% contingency. Material and Equipment cost = $23,000 Labor and Installation cost = $6,000 Soft cost (Engineering and/or other services) not included.

ECM ID #	Measure	Initial cost ($)	Replacement and Maintenance Cost ($)	Breakdown
BAU-04	Like-for-like replacement of fuel fired infrared (IR) heaters.	$ 18,800	-	The life expectancy of this measure until the next replacement is 20 years. Includes 25% contingency. Material and Equipment cost = $10,000 Labor and Installation cost = $5,000 Soft cost (Engineering and/or other services) not included.
BAU-05	Like-for-like replacement of electric DHW boiler.	$ 2,900	-	The life expectancy of this measure until the next replacement is 15 years. Includes 25% contingency. Material and Equipment cost = $1,600 Labor and Installation cost = $750 Soft cost (Engineering and/or other services) not included.
BAU-06	Like-for-like replacement of fuel fired DHW at end of life.	$ 23,400	-	The life expectancy of this measure until the next replacement is 15 years. Includes 25% contingency. Material and Equipment cost = $13,500 Labor and Installation cost = $5,250 Soft cost (Engineering and/or other services) not included.
BAU-07	Like-for-like replacement of fuel fired instantaneous floodwater heating.	$ 8,100	-	The life expectancy of this measure until the next replacement is 20 years. Includes 25% contingency. Material and Equipment cost = $4,000 Labor and Installation cost = $2,500 Soft cost (Engineering and/or other services) not included.
BAU-08	Replace HRV units providing ventilation, in addition to humidifier units coupled with units with like-for-like equivalents.	$ 22,500	-	The life expectancy of this measure until the next replacement is 18 years. Includes 25% contingency. Material and Equipment cost = $12,500 Labor and Installation cost = $5,500 Soft cost (Engineering and/or other services) not included.

ECM ID #	Measure	Initial cost ($)	Replacement and Maintenance Cost ($)	Breakdown
BAU-09	Like-for-like replacement of propane powered ice resurfacing machine	$ 132,000	$ 20,000	The life expectancy of this measure until the next replacement is 15 years. Includes 20% contingency. Material and Equipment cost = $110,000 Labor and Installation cost = - Soft cost (Engineering and/or other services) not included. Additional Notes: Supply, Testing, and Commissioning
BAU-10	Like-for-like replacements of all systems in refrigeration plant at end of life.	$ 1,275,000	-	The life expectancy of this measure until the next replacement is 25 years. Includes 20% contingency. Material and Equipment cost = $850,000 Labor and Installation cost = $212,500 Soft cost (Engineering and/or other services) not included. Additional Notes: Decommissioning of existing plant + Supply, Installation, Testing & Commissioning of new plant
BAU-11	Like-for-like replacements of brine pumps	$ 46,800	-	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 = $9,000 Soft cost (Engineering and/or other services) not included. Additional Notes: Decommissioning of existing pump + Supply, Installation, Testing & Commissioning of new pump
BAU-12	Like-for-like replacement of gas-fired desiccant dehumidifiers at end of life.	$ 39,000	-	The life expectancy of this measure until the next replacement is 15 years. Includes 20% contingency. Material and Equipment cost = $25,000 Labor and Installation cost = $7,500 Soft cost (Engineering and/or other services) not included.

ECM ID #	Measure	Initial cost ($)	Replacement and Maintenance Cost ($)	Breakdown
BAU-13	Replacing all LED lighting fixtures at end of life with like-for-like equivalents.	$ 82,000	-	The life expectancy of this measure until the next replacement is 20 years. Includes 20% contingency. Material and Equipment cost = $10,928 Labor and Installation cost = $57,400 Soft cost (Engineering and/or other services) not included.
MEC-01	Increase relative humidity setpoints using dewpoint temperature control to avoid condensation while reducing dehumidifier use (i.e. dewpoint of space is below wall surface temperature). Must ensure fogging on ice is not problematic.	$ 4,800	-	This measure is only replaced as needed. Includes 20% contingency. Material and Equipment cost = $1,000 Labor and Installation cost = $1,500 Soft cost (Engineering and/or other services) = $1,500 Additional Notes: Includes the addition of a dew point temperature sensor, reprogramming, testing, commissioning, and verification of the revised SOOP
MEC-02	Higher overnight (midnight to 5am) humidity setpoint at 65% RH whenever the dewpoint of the space is below the wall surface temperature to avoid condensation and reduce dehumidifier use.	$ 4,800	-	This measure is only replaced as needed. Includes 20% contingency. Material and Equipment cost = $1,000 Labor and Installation cost = $1,500 Soft cost (Engineering and/or other services) = $1,500 Additional Notes: Includes the addition of a dew point temperature sensor, reprogramming, testing, commissioning, and verification of the revised SOOP

ECM ID #	Measure	Initial cost ($)	Replacement and Maintenance Cost ($)	Breakdown
MEC-03	Replace existing dehumidifiers with CIMCO EcoDry 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.	$ 740,300	$480,000	The life expectancy of this measure until the next replacement is 15 years. Includes 20% contingency. Material and Equipment cost = $470,000 Labor and Installation cost = $117,500 Soft cost (Engineering and/or other services) = $29,375 Additional Notes: Decommissioning of existing unit + Supply, Installation, Testing & Commissioning of EcoDry unit complete with ice banks, cooling/heating coils, pumps, piping, insulation, valves, wiring & controls
MEC-04	Replace existing fuel-fired desiccant dehumidifiers with an electric desiccant dehumidifier	$ 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
MEC-05	Turning off room radiant heaters when doors to ice rink is opened. Reduced heating usage and load introduced to ice rink.	$ 13,400	-	This measure is only replaced as needed. Includes 25% contingency. Material and Equipment cost = $7,000 Labor and Installation cost = $3,000 Soft cost (Engineering and/or other services) = $750
MEC-06	Replace the existing fuel fired infrared (IR) heaters with electric radiant heaters. This is an electrification measure.	$ 36,300	$ 15,000	The life expectancy of this measure until the next replacement is 25 years. Includes 25% contingency. Material and Equipment cost = $18,000 Labor and Installation cost = $9,000 Soft cost (Engineering and/or other services) = $2,025 Additional Notes: Initial installation cost includes provisions for electrical works. Replacement costs only include the electric radiant bleacher heater equipment and installation cost.

ECM ID #	Measure	Initial cost ($)	Replacement and Maintenance Cost ($)	Breakdown
MEC-07	Using heat recovery from ice plant to provide space hydronic heating bleacher seating area.	$ 208,300	$ 38,800	The life expectancy of this measure until the next replacement is 20 years. Includes 25% contingency. Material and Equipment cost = $110,000 Labor and Installation cost = $45,000 Soft cost (Engineering and/or other services) = $11,625 Additional Notes: Initial installation cost includes provisions for electrical, piping and hydronic heating elements. Replacement costs only include the HEXs and pumps equipment and installation cost.
MEC-08A	Replace fuel-fired furnaces 1 - 3 with water to air WSHP using hydronic heating coils using heat recovery from ice plant to provide space heating. Natural gas boiler backup heat used when heat recovery is not available.	$ 408,900	$ 168,400	The life expectancy of this measure until the next replacement is 18 years. Includes 25% contingency. Material and Equipment cost = $223,000 Labor and Installation cost = $102,500 Soft cost (Engineering and/or other services) = $1,628 Additional Notes: Initial installation cost includes provisions for electrical, piping, coil and structural support works, as well as 3 AHUs, 1 WSHP, HEX, pumps and boiler. Replacement costs only include the 3 AHUs, 1 WSHP, HEX, pumps and boiler equipment (at different timelines) and installation cost.
MEC-08B	Replace fuel-fired furnaces 4 - 6 with water to air WSHP using hydronic heating coils using heat recovery from ice plant to provide space heating. Natural gas boiler backup heat used when heat recovery is not available.	$ 408,900	$ 168,400	The life expectancy of this measure until the next replacement is 18 years. Includes 25% contingency. Material and Equipment cost = $223,000 Labor and Installation cost = $102,500 Soft cost (Engineering and/or other services) = $1,628 Additional Notes: Initial installation cost includes provisions for electrical, piping, coil and structural support works, as well as 3 AHUs, 1 WSHP, HEX, pumps and boiler. Replacement costs only include the 3 AHUs, 1 WSHP, HEX, pumps and boiler equipment (at different timelines) and installation cost.

ECM ID #	Measure	Initial cost ($)	Replacement and Maintenance Cost ($)	Breakdown
MEC-09A	Replace forced-air fuel-fired furnaces 1 - 3 with split air source heat pump (ASHP) to provide heating and cooling in space with appropriate backup heat source.	$ 177,200	$ 108,000	The life expectancy of this measure until the next replacement is 18 years. Includes 25% contingency. Material and Equipment cost = $109,000 Labor and Installation cost = $26,000 Soft cost (Engineering and/or other services) = $6,750 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-09B	Replace forced-air fuel-fired furnaces 4 - 6 with split air source heat pump (ASHP) to provide heating and cooling in space with appropriate backup heat source.	$ 177,200	$ 108,000	The life expectancy of this measure until the next replacement is 18 years. Includes 25% contingency. Material and Equipment cost = $109,000 Labor and Installation cost = $26,000 Soft cost (Engineering and/or other services) = $6,750 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-10A	Replace fuel-fired furnaces 1 - 3 with electric equivalent.	$ 52,400	$ 24,000	The life expectancy of this measure until the next replacement is 18 years. Includes 25% contingency. Material and Equipment cost = $25,500 Labor and Installation cost = $13,500 Soft cost (Engineering and/or other services) = $2,925 Additional Notes: Initial installation cost includes provisions for electrical works. Replacement costs only include the electric furnace equipment and installation cost.
MEC-10B	Replace fuel-fired furnaces 4 - 6 with electric equivalent.	$ 52,400	$ 24,000	The life expectancy of this measure until the next replacement is 18 years. Includes 25% contingency. Material and Equipment cost = $25,500

ECM ID #	Measure	Initial cost ($)	Replacement and Maintenance Cost ($)	Breakdown
				Labor and Installation cost = $13,500 Soft cost (Engineering and/or other services) = $2,925 Additional Notes: Initial installation cost includes provisions for electrical works. Replacement costs only include the electric furnace equipment and installation cost.
MEC-11	Replace the existing fuel fired unit heaters with electric unit heaters. This is an electrification measure.	$ 30,000	$ 16,000	The life expectancy of this measure until the next replacement is 25 years. Includes 25% contingency. Material and Equipment cost = $15,000 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 unit heaters equipment and installation cost.
MEC-12	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).	$ 16,700	-	This measure is only replaced as needed. Includes 20% contingency. Material and Equipment cost = $7,100 Labor and Installation cost = $5,325 Soft cost (Engineering and/or other services) = $1,500 Additional Notes: Includes smart switches and thermostats including wiring.
MEC-13	Replace the existing fuel fired floodwater heaters with air-source heat pump (ASHP) water heaters, which will have higher heating efficiency.	$ 123,800	$ 80,000	The life expectancy of this measure until the next replacement is 15 years. Includes 25% contingency. Material and Equipment cost = $65,000 Labor and Installation cost = $25,000 Soft cost (Engineering and/or other services) = $9,000 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.

ECM ID #	Measure	Initial cost ($)	Replacement and Maintenance Cost ($)	Breakdown
MEC-14	Replace the existing fuel fired floodwater heaters with electric equivalent. This is an electrification measure.	$ 33,800	$ 17,000	The life expectancy of this measure until the next replacement is 15 years. Includes 25% contingency. Material and Equipment cost = $19,000 Labor and Installation cost = $8,000 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 flood water heater equipment and installation cost.
MEC-15	Replace the existing fuel fired non-condensing instantaneous floodwater heater with condensing equivalent. This will improve system efficiency and reduce fuel consumption.	$ 8,600	-	The life expectancy of this measure until the next replacement is 20 years. Includes 25% contingency. Material and Equipment cost = $4,400 Labor and Installation cost = $2,500 Soft cost (Engineering and/or other services) not included.
MEC-16	Replace the existing fuel fired and electric DHW heaters with air-source heat pump (ASHP) water heaters, which will have higher heating efficiency.	$ 151,300	$ 90,000	The life expectancy of this measure until the next replacement is 15 years. Includes 25% contingency. Material and Equipment cost = $72,500 Labor and Installation cost = $37,500 Soft cost (Engineering and/or other services) = $11,000 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-17	Replace the existing fuel fired DHW heaters with electric water heaters. This is an electrification measure.	$ 51,600	$ 26,300	The life expectancy of this measure until the next replacement is 15 years. Includes 25% contingency. Material and Equipment cost = $28,500 Labor and Installation cost = $12,750 Soft cost (Engineering and/or other services) not included. Additional Notes: Initial installation cost includes provisions for

ECM ID #	Measure	Initial cost ($)	Replacement and Maintenance Cost ($)	Breakdown
				electrical works. Replacement costs only include the electric flood water heater equipment and installation cost.
MEC-18	Replace the existing fuel fired non-condensing domestic hot water heater with condensing, instantaneous equivalent. This will improve system efficiency and reduce fuel consumption.	$ 25,100	-	The life expectancy of this measure until the next replacement is 15 years. Includes 25% contingency. Material and Equipment cost = $14,850 Labor and Installation cost = $5,250 Soft cost (Engineering and/or other services) not included.
MEC-19	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.	$ 16,300	-	The life expectancy of this measure until the next replacement is 20 years. Includes 25% contingency. Material and Equipment cost = $10,000 Labor and Installation cost = $3,000 Soft cost (Engineering and/or other services) not included.
MEC-20	Low flow fixtures to reduce hot water load and water consumption.	$ 14,900	-	This measure is only replaced as needed. Includes 0% contingency. Material and Equipment cost = $11,140 Labor and Installation cost = $3,750 Soft cost (Engineering and/or other services) not included.
MEC-21	Add energy recovery ventilator (ERV) to recover sensible and latent heat from exhaust air to spaces. This measure may require additional ducting and air balancing and testing to maintain any pressurization requirements.	$ 27,200	-	The life expectancy of this measure until the next replacement is 18 years. Includes 25% contingency. Material and Equipment cost = $16,250 Labor and Installation cost = $5,500 Soft cost (Engineering and/or other services) not included.

ECM ID #	Measure	Initial cost ($)	Replacement and Maintenance Cost ($)	Breakdown
RFG-01	Replace ice resurfacing machine with rechargeable electric equivalent.	$ 180,000	$ 25,000	The life expectancy of this measure until the next replacement is 15 years. Includes 20% contingency. Material and Equipment cost = $150,000 Labor and Installation cost = - Soft cost (Engineering and/or other services) = - Additional Notes: Supply, Testing, and Commissioning + Provision of a charging station
RFG-02	Cold-water resurfacing system (REALice or equivalent) (assume mix of water to 65°F). Reduce flood temperature from 140°F to 65°F	$ 60,600	-	This measure is only replaced as needed. Includes 20% contingency. Material and Equipment cost = $38,500 Labor and Installation cost = $9,625 Soft cost (Engineering and/or other services) = $2,406 Additional Notes: Including supply, installation, start-up, testing and commissioning including plumbing provisions installation
RFG-03	Adjust temperature of the ice to be 4°F higher during night-time where it is not in use.	$ 7,200	-	This measure is only replaced as needed. Includes 20% contingency. Material and Equipment cost = $1,500 Labor and Installation cost = $2,000 Soft cost (Engineering and/or other services) = $2,500 Additional Notes: Including programming, testing and commissioning
RFG-04	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.	$ 1,483,000	-	The life expectancy of this measure until the next replacement is 25 years. Includes 20% contingency. Material and Equipment cost = $980,800 Labor and Installation cost = $196,160 Soft cost (Engineering and/or other services) = $58,848 Additional Notes: Decommissioning of existing plant + Supply, Installation, Testing & Commissioning of new plant

ECM ID #	Measure	Initial cost ($)	Replacement and Maintenance Cost ($)	Breakdown
RFG-05	Optimize heat recovery with desuperheaters to recover heat from the ice plant for DHW	$ 90,000	-	The life expectancy of this measure until the next replacement is 20 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 Additional Notes: Supply, Installation, Testing & Commissioning + Connection to DHW and heating systems
RFG-06	Install new brine pumps with VFDs to modulate flow, this allows for tighter control of setback schedules.	$ 58,600	-	The life expectancy of this measure until the next replacement is 20 years. Includes 20% contingency. Material and Equipment cost = $38,500 Labor and Installation cost = $8,000 Soft cost (Engineering and/or other services) = $2,325 Additional Notes: Decommissioning of existing unit + Supply, Installation, Testing & Commissioning of new unit
ELE-01	Install occupancy sensors and dimming controls to minimize lighting usage when natural daylight is abundant, and spaces are unoccupied.	$ 5,400	-	The life expectancy of this measure until the next replacement is 20 years. Includes 20% contingency. Material and Equipment cost = $2,500 Labor and Installation cost = $2,000 Soft cost (Engineering and/or other services) not included.
ENV-01A	Upgrade the exterior wall insulation to R26 or similar to increase U value of the overall wall. This measure applies to the entire facility.	$ 165,800	-	This measure is only replaced as needed. Includes 20% contingency. Material and Equipment cost = $128,556 Labor and Installation cost is included in Material costs. Soft cost (Engineering and/or other services) = $9,642

ECM ID #	Measure	Initial cost ($)	Replacement and Maintenance Cost ($)	Breakdown
ENV-01B	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 arena area.	$ 82,400	-	This measure is only replaced as needed. Includes 20% contingency. Material and Equipment cost = $63,857 Labor and Installation cost is included in Material costs. Soft cost (Engineering and/or other services) = $4,789
ENV-02A	Upgrade the roof insulation to R40 or similar to increase U value of the overall roof. This measure applies to the entire facility	$ 477,000	-	This measure is only replaced as needed. Includes 20% contingency. Material and Equipment cost = $369,768 Labor and Installation cost is included in Material costs. Soft cost (Engineering and/or other services) = $27,733
ENV-02B	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 arena space.	$ 165,800	-	This measure is only replaced as needed. Includes 20% contingency. Material and Equipment cost = $128,556 Labor and Installation cost is included in Material costs. Soft cost (Engineering and/or other services) = $9,642
ENV-03	Replace double pane windows at end of life with triple pane thermally broken, (U-0.46 to U-0.24).	-	-	This measure is only replaced as needed. Includes 20% contingency. No Material or Equipment costs. Labor and Installation cost is included in Material costs. Soft cost (Engineering and/or other services) not included.
ENV-04A	Improve infiltration (air tightness) with weather sealing. This measure applies to the entire facility.	$ 42,300	-	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) = $2,459
ENV-04B	Improve infiltration (air tightness) with weather sealing. This measure applies to the entire facility, less the arena space.	$ 21,100	-	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) = $1,229

ECM ID #	Measure	Initial cost ($)	Replacement and Maintenance Cost ($)	Breakdown
ENV-05	Adding reflective bubble insulation on translucent overhead doors to reduce heat losses at low cost.	$ 2,800	-	This measure is only replaced as needed. Includes 20% contingency. Material and Equipment cost = $2,160 Labor and Installation cost is included in Material costs. Soft cost (Engineering and/or other services) = $162
ENV-06	Replace existing ceiling mounted low-e with a suspended option to further reduce refrigeration plant load and minimize condensation dripping onto ice.	$ 82,700	-	The life expectancy of this measure until the next replacement is 25 years. Includes 20% contingency. Material and Equipment cost = $64,125 Labor and Installation cost is included in Material costs. Soft cost (Engineering and/or other services) = $4,809
RNW-01	Provide solar panels on the available roof area to optimize electricity generation and savings through utility net metering.	$ 574,600	$ 33,700	This measure is only replaced as needed. Includes 20% contingency. Material and Equipment cost = $448,800 Labor and Installation cost = - Soft cost (Engineering and/or other services) = $30,000 Additional Notes: Including supply, installation, start-up, testing and commissioning

Appendix F – Energy Conservation Measure (ECM) savings breakdown

ECM ID #	Low carbon measure	Electricity savings (kWh)	Electricity cost savings ($)	Natural gas savings (m³)	Natural gas cost savings ($)	Propane savings (L)	Propane cost savings ($)
MEC-01	Dehumidifier controls – daytime scheduling	-	-	109	$ 47	-	-
MEC-02	Dehumidifier controls – night setback scheduling	-	-	206	$ 89	-	-
MEC-03	Mechanical hydronic dehumidifier	- 15,049	$ - 3,175	4,164	$ 1,793	-	-
MEC-04	Electric dehumidifier	- 23,110	$ - 4,876	2,788	$ 1,200	-	-
MEC-05	Interlocking overhead doors	28	$ 6	88	$ 38	-	-
MEC-06	Electric radiant bleacher heaters	- 11,339	$ - 2,393	1,376	$ 592	-	-
MEC-07	Bleacher hydronic heating	- 3,586	$ - 757	1,376	$ 592	-	-
MEC-08A	Hydronic AHU 1 - 3 conversion	- 32,262	$ - 6,807	8,827	$ 3,800	-	-
MEC-08B	Hydronic AHU 4 - 6 conversion	- 15,734	$ - 3,320	5,080	$ 2,187	-	-
MEC-09A	ASHP furnaces 1 - 3	- 52,417	$ - 11,060	8,827	$ 3,800	-	-
MEC-09B	ASHP furnaces 4 - 6	- 30,430	$ - 6,421	5,080	$ 2,187	-	-
MEC-10A	Electric furnace 1 - 3	- 74,823	$ - 15,788	8,844	$ 3,808	-	-
MEC-10B	Electric furnace 4 - 6	- 39,146	$ - 8,260	5,085	$ 2,189	-	-
MEC-11	Electric unit heaters	- 11,663	$ - 2,461	1,578	$ 680	-	-

ECM ID #	Low carbon measure	Electricity savings (kWh)	Electricity cost savings ($)	Natural gas savings (m³)	Natural gas cost savings ($)	Propane savings (L)	Propane cost savings ($)
MEC-12	Space temperature setbacks	5,836	$ 1,231	2,817	$ 1,213	-	-
MEC-13	ASHP floodwater heater	- 10,800	$ - 2,279	3,043	$ 1,310	-	-
MEC-14	Electric flood water heater	- 24,711	$ - 5,214	3,043	$ 1,310	-	-
MEC-15	Condensing tankless floodwater heater	-	-	480	$ 207	-	-
MEC-16	ASHP domestic hot water heater	- 4,552	$ - 960	2,828	$ 1,218	-	-
MEC-17	Electric domestic hot water heater	- 7,696	$ - 1,624	2,828	$ 1,218	-	-
MEC-18	Condensing domestic HW heater	-	-	447	$ 192	-	-
MEC-19	Condensing tankless domestic hot water heater	-	-	2,217	$ 955	-	-
MEC-20	Low flow water fixtures	1,578	$ 333	228	$ 98	-	-
MEC-21	Replace HRV units with ERV units	4	$ 1	212	$ 91	-	-
RFG-01	Electric resurfacing machine	- 1,951	$ - 412	- 1	$ -	814	$ 1,108
RFG-02	Cold water ice resurfacing system	2,863	$ 604	2,130	$ 917	-	-
RFG-03	Ice temperature optimization	19,765	$ 4,170	358	$ 154	-	-
RFG-04	Refrigeration plant optimization - CO2	6,181	$ 1,304	-	-	-	-
RFG-05	Refrigeration plant desuperheaters	-	-	2,377	$ 1,024	-	-
RFG-06	VFDs on brine pumps	31,024	$ 6,546	-	-	-	-

ECM ID #	Low carbon measure	Electricity savings (kWh)	Electricity cost savings ($)	Natural gas savings (m³)	Natural gas cost savings ($)	Propane savings (L)	Propane cost savings ($)
ELE-01	Lighting Occupancy Controls	200	$ 42	- 11	$ - 5	-	-
ENV-01A	Exterior wall insulation - Entire facility	- 314	$ - 66	37	$ 16	-	-
ENV-01B	Exterior wall insulation - Excluding rink	- 58	$ - 12	70	$ 30	-	-
ENV-02A	Exterior roof insulation - Entire facility	- 2,884	$ - 609	- 143	$ - 61	-	-
ENV-02B	Exterior roof insulation upgrade - Excluding Rink	- 457	$ - 96	143	$ 62	-	-
ENV-03	Triple pane windows	5	$ 1	8	$ 4	-	-
ENV-04A	Improve airtightness - Entire facility	- 9,054	$ - 1,910	82	$ 35	-	-
ENV-04B	Improve airtightness - Excluding rink	43	$ 9	199	$ 86	-	-
ENV-05	Overhead door insulation	- 6	$ - 1	46	$ 20	-	-
ENV-06	Suspended low-e ceiling	2,294	$ 484	- 225	$ - 97	-	-
RNW-01	Solar PV - 224.4 kW array	166,419	$ 35,114	-	-	-	-