Roadmap to Net Zero Final Report
Eganville Arena and Eganville Curling Club

March 22, 2023

Executive summary

CIMCO and Enerlife Consulting have worked with Eganville staff to develop this plan to reduce carbon emissions, save energy and costs for the Eganville Arena and Eganville Curling Club. The plan and low carbon measures are aligned with the Green and Inclusive Community Buildings (GICB) Program from Infrastructure Canada, which can potentially offer up to 80% funding for project costs up to $3 million. This program could provide funding for these measures, if the application is successful.

This plan summarizes the current energy and greenhouse gas (GHG) performance of the buildings and outlines the following three potential scenarios:

1. Business-as-usual which incorporates like-for-like replacements of equipment when they reach 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 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 1: Facility emissions shown by scenario

Facility	2019 Baseline emissions (tonnes of carbon equivalent (tCO2e))	Typical timeline approach		Aggressive timeline approach
		10-year emissions (tCO2e [% reduction])	20-year emissions (tCO2e [% reduction])	5-year emissions (tCO2e [% reduction])
Arena	44.6	5.7 [87.3%]	0.9 [98.1%]	6.7 [85.0%]
Curling Club	24.3	0.06 [99.8%]	0.13 [99.5%][1]	0.05 [99.8%]

[1] The slight increase between the 10- and 20-year forecasts for the Eganville Curling Club is due to the addition of ventilation equipment that will bring the building up to current ventilation standards.

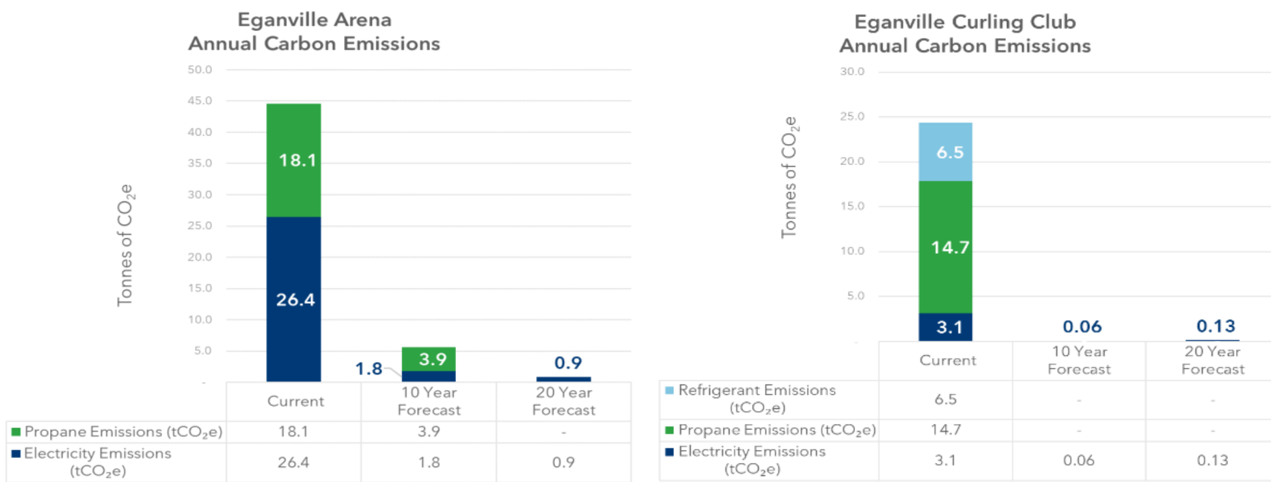

Figure 1:2019 and forecasted carbon emissions by facility

The proposed solutions outlined below are the culmination of an engagement process with municipal stakeholders that determined their ultimate goals, facility equipment and operational needs, and preferred measures. The presentation of the solutions includes analysis of emission savings, costs (adjusted for inflation), and net present value savings compared to a 2019 baseline.

The key measures to achieving the Eganville Arena GHG emission reduction goals are as follows:

- Refrigeration plant heat recovery: The heat from the refrigeration plant can be repurposed to reduce the heating load of the facility and would save 9.5 tCO_2e (21%) annually.
- Solar photovoltaics (PV) - 272 kW array: This is the largest quantity of solar panels that would be able to fit on the roof and will offset 22 tCO_2e (49%) annually.
- Air source heat pump (ASHP) domestic hot water heater: Utilizing an ASHP to heat water will reduce emissions by 12 tCO_2e (26%) annually.

The key measures to achieving the Eganville Curling Club GHG emissions reduction goals are as follows:

- Air source heat pump (ASHP) replacement of gas fired furnace: Switching to an ASHP will save 12.3 tCO_2e (50%) annually.
- Solar PV – 67.9 kW array: The capacity of the solar panels will meet the requirements of the entire Curling Club including accounting for increased electrical demand from other measures. This will offset 5.5 tCO_2e (22%) annually.
- Converting refrigerant to ammonia: This will eliminate 6.9 tCO_2e (28%) annually and will stop refrigerant leakage.

The tables below outline when capital funding would be required, the years when the identified measures would be implemented (both with and without funding) for each of the scenarios for each facility.

Table 2: Financial summary by year for the Arena – Business-as-usual scenario

Business-as-usual year of replacement	Initial outlay of costs with inflation ($)	Net Present Value (NPV) ($)
2024	$12,073	-$11,389
2025	$506,000	-$699,674
2030	$112,200	-$111,149
2035	$18,480	-$12,713
2040	$163,300	-$97,316
Grand total	$812,053	-$932,241

Table 3: Financial summary by year for the Arena – Low carbon without funding scenario

Low carbon without funding year of replacement	Initial outlay of costs with inflation ($)	NPV without funding ($)
2024	$35,200	$112,309
2025	$1,286,657	$478,260
2030	$169,500	-$141,400
2035	$39,600	$41,131
2040	$253,828	$4,472
Grand total	$1,784,785	$494,771

Table 4: Financial summary by year for the Arena – Low carbon with funding scenario

Low carbon with funding year of replacement	Initial outlay of costs with inflation ($)	NPV with funding ($)
2024	$35,200	$138,875
2025	$1,547,057	$1,689,725
2030	$169,500	-$141,400
2040	$33,028	-$2,125
Grand total	$1,784,785	$1,685,074

Table 5: Financial summary by year for the Curling Club – Business-as-usual scenario

Business-as-usual year of replacement	Initial outlay of costs with inflation ($)	NPV ($)
2025	$4,323	-$3,963
2030	$247,500	-$410,067
2040	$26,400	-$15,733
Grand total	$278,223	-$429,762

Table 6: Financial summary by year for the Curling Club – Low carbon without funding scenario

Low carbon without funding year of replacement	Initial outlay of costs with inflation ($)	NPV with funding ($)
2024	$0	$748
2025	$177,645	$141,088
2030	$972,500	-$953,586
2040	$123,200	$87,354
2045	$20,000	-$9,730
Grand total	$1,293,345	-$734,136

Table 7: Financial summary by year for the Curling Club – Low carbon with funding scenario

Low carbon with funding year of replacement	Initial outlay of costs with inflation ($)	NPV without funding ($)
2024	$0	$748
2025	$1,240,545	$57,904
2040	$52,800	-$52,775
Grand total	$1,293,345	$5,877

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1 Background

Municipalities across Canada are looking to accelerate action on climate change and reduce energy use and emissions in their facilities. Investing in energy reduction is often a financially wise decision, and with external funding opportunities and technological advancements it is becoming more feasible every year.

This study identifies a low carbon scenario implementing the best possible retrofit and operational measures to take Eganville Arena from baseline emissions of 44.6 tonnes of carbon equivalent (tCO_2e) per year (2019) to 0.9 tCO_2e, and Eganville Curling Club from its baseline emissions of 24.3 tCO_2e per year (2019) to 0.011 tCO_2e for reductions exceeding the 80% reduction target in each facility. 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 for each facility is the culmination of three phases of work which incorporate reviewing building information, site visits, and two integrated design workshops. It maps the retrofit and operational changes required to reduce emissions by at least 80% within 20 years.

An initial review of building data and characteristics was conducted looking at key drawings, trend logs (as available), and capital plans. Site visits were conducted on October 27, 2022 to confirm details, collect additional information, and interview the building operator and facility manager to ensure that operational conditions and potential issues were adequately addressed. Refer to the site visit assessment report in Appendix A for details.

Two integrated design workshops were conducted, which brought together building management, operators, and finance staff to determine the best possible solutions and plans for the building. The aim of the first workshop was to review 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 that everyone had input at an early stage. This avoided costly omissions and helped to get municipal stakeholder buy-in. In the second integrated design workshop, the measures and associated costs were reviewed with finance staff to get their input and feedback.

2 Building characteristics

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

- Utility billing data
- Available drawings and plans
- Equipment specifications
- Site visit and operator interviews

2.1 Eganville Arena building information

The Eganville Arena building has an area of 27,260 ft^2 and includes amenities such as an ice rink and an event space known as the Eagles Nest which includes a banquet hall, a bar, and a kitchen. The building is equipped with one refrigeration plant, three propane domestic hot water heaters (DHWs), some propane fired heating elements, two dehumidifiers, and two condensing units that serve the Eagles Nest. The facility largely operates during September to March, when the ice sheets are in use, approximately 40-45 hours a week.

2.1.1 Heating, cooling, and ventilation

The heating for the arena is provided by eight propane infrared (IR) heaters that serve the spectator area, changerooms, and the ice resurfacer technical room. It is ventilated in the summer during events by wall mounted supply and exhaust fans. The lobby area is heated by two wall mounted electrical heaters. The Eagles Nest banquet hall, kitchen, and bar is served by two fan coil units (FCU) that use electric heating and cooling. All systems operate on standalone controls linked to thermostats.

2.1.2 Domestic hot water

The kitchen and five of the changerooms are served by two propane fired domestic hot water heaters (DHWH). A third propane fired DHWH is specifically for the ice surfacing equipment, and the last two changerooms.

2.1.3 Ice rink refrigeration

The ice rink refrigeration system is a shell and tube, ammonia-based refrigeration system comprised of two Mycom compressors, a CIMCO brine pump and tank, and a Baltimore Aircoil condenser unit. The ice is maintained yearly between September and March and the temperature setpoint varies between 15°F and 19°F depending on the outside temperature.

2.1.4 Lighting

The ice rink was retrofitted with 32 LED fixtures in 2016 with dimming capability, the rest of the facility has T8 lighting.

2.1.5 Building envelope

The building exterior is primarily corrugated steel, with angled steel roofing. The roof was replaced in 2014 and has standard insulation. There is infiltration especially in the ice rink area from exhaust and supply fan dampers and from the rolling shutter door for the ice resurfacer. The arena ice rink is currently equipped with a low-e ceiling.

2.1.6 Process and plug loads

The only fuel-fired load to be accounted for in the facility, excluding the propane fired DHW heaters described previously, is a propane fired deep frier present in the Eagles Nest kitchen. Electrical plug loads come in the form of kitchen equipment, freezers, beverage coolers, etc.

2.1.7 Building automation system (BAS)

The facility does not have a centralized building automation system.

2.2 Eganville Curling Club building information

The Eganville Curling Club building has an area of 8,750 ft^2 and contains two ice sheets for curling. The building is equipped with one refrigeration plant, two propane heating furnaces, and one EWH (electric water heater). The facility typically operates during October to April, when the ice sheets are in use, approximately 40-45 hours a week.

2.2.1 Heating, cooling, and ventilation

There are two propane furnaces in the facility: one serving the curling (ice) rink and the other serving the other building spaces. The other spaces also utilize electric baseboard heating. All heating systems are controlled via standalone thermostats. The facility has a wall mounted exhaust fan in the curling rink, and a ceiling mounted diffuser fan that exhausts air from the toilets in the basement. This building is currently not meeting ventilation standards but has been grandfathered based on older standards. There are no central space heating or cooling plants in this facility.

2.2.2 Domestic hot water (DHW)

There is a small wall mounted electric domestic hot water heater that serves the washrooms in the facility. The ice rink is a curling rink, so hot water is not required for flooding.

2.2.3 Refrigeration

The Eganville Curling Club refrigeration system was recently refurbished and had new pumps installed, but currently uses an R-22 (Freon) based refrigerant. The ice rink refrigeration system is comprised of a Carlyle compressor, 2-speed WEG brine pump, and a Larkin air-cooled condenser unit. The ice is maintained yearly between September and March with a temperature setpoint of 19°F during operation with a nighttime setback temperature of 24°F.

2.2.4 Lighting

The curling rink lighting has been upgraded to 16 LED fixtures, while the other spaces in the facility still have incandescent and fluorescent lighting.

2.2.5 Building envelope

The building exterior is primarily corrugated steel, with angled steel roofing. The curling ice rink does not have a low-e ceiling.

2.2.6 Process and plug loads

There are no significant process or plug loads, beyond typical appliances used for club activities and kitchen use.

2.2.7 Building automation system (BAS)

The facility does not have a centralized building automation system.

3 Historical building performance

3.1 Data summary

Both facilities were evaluated for GHG emissions reduction pathways using the 2019 baseline year. This baseline year was selected because it was the last full operating year of the facilities with no impact of occupancy or operational changes due to the COVID-19 pandemic.

Table 8: Annual energy use and costs (2019)

Facility	Electricity use (kWh)	Electricity cost ($)	Heating oil use (L)	Heating oil cost ($)	Propane use (L)	Propane cost ($)
Eganville Arena	413,414	$10,783.28	-	-	12,493	$6,476.63
Eganville Curling Club	47,732	$9,397.62	2,389	$2,988.02	6,113	$1,312.96

Note: In 2019 Eganville Curling Club used heating oil for some appliances but has since switched over to all propane. Analysis and measures assume all energy provided by oil was converted to propane use where 1 L of heating oil is approximately 0.67 L of propane.

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

3.2 Total energy benchmarks 2019

To better understand how to improve the energy consumption of each facility and areas where reduction is possible, it is important to benchmark the total energy use (including electricity and thermal) with other similar buildings. Energy use intensities (EUIs) for each facility are shown in Table 9 below along with the top decile.

Table 9: Energy intensity comparison

	Total energy intensity (ekWh/ft²/year)	Electrical energy intensity (kWh/ft²/year)	Gas (thermal) energy intensity (ekWh/ft²/year)
Top decile target	17.5	7.2	5.1
Eganville Arena	19.1	15.7	3.4
Eganville Curling Club	14.6	6.6	8.0

The top decile is derived from the benchmark charts below, which show the performance of Eganville Arena and Eganville Curling Club relative to similar recreation centres with ice rinks. The benchmark database is comprised of facilities across Ontario that reported to the Ministry of Energy's broader public sector database. Weather dependent variables were normalized to Toronto for comparison purposes.

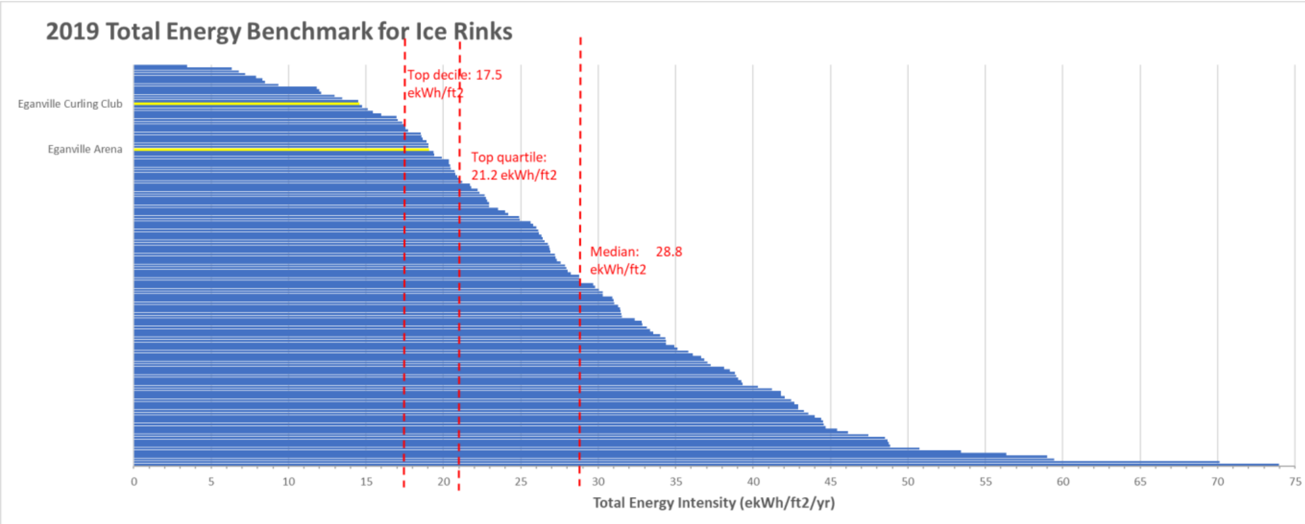


Figure 2: 2019 Total energy weather normalized to Toronto

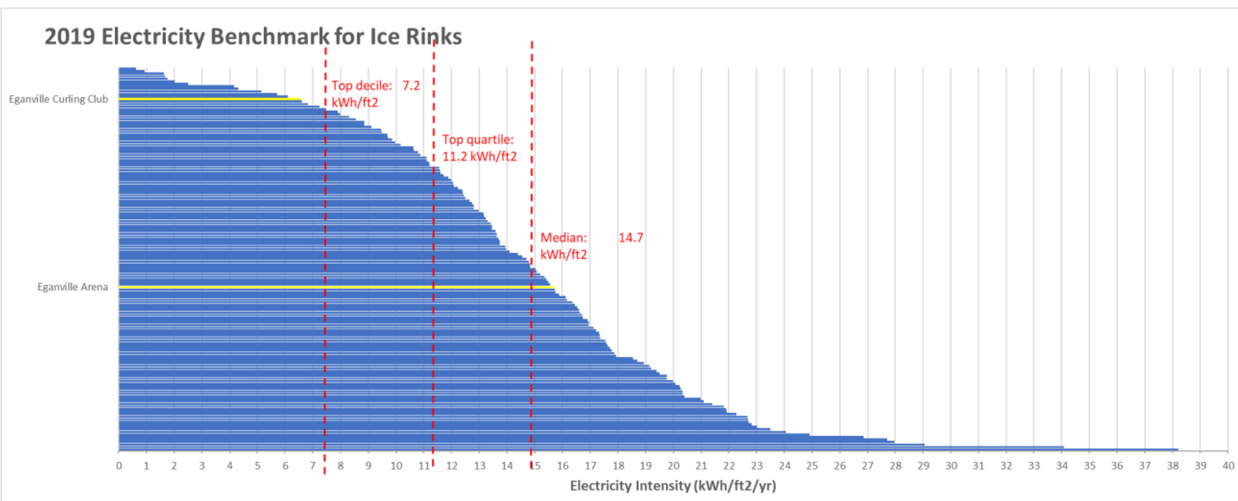


Figure 3: 2019 Total electricity weather normalized to Toronto

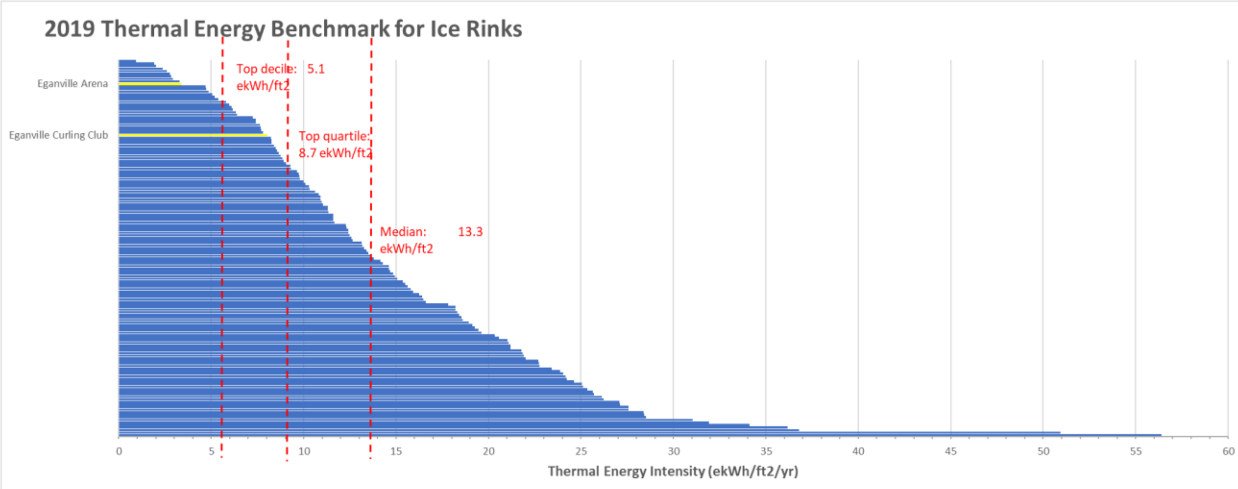
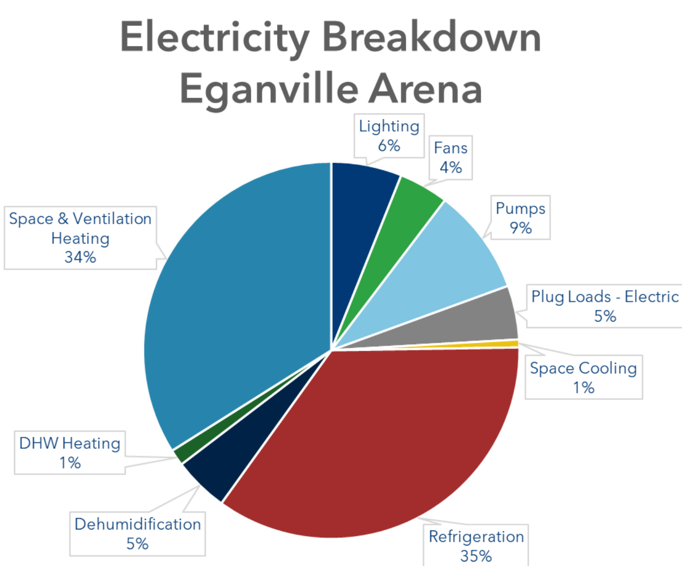


Figure 4: 2019 Total thermal weather normalized to Toronto

3.3 Total energy breakdown 2019

To better understand how to improve the efficiency of each facility and reduce their overall carbon emissions, it is important to know where the energy is being consumed. An energy balance was performed for each facility based on energy data collected and site visit information gathered on the operation of the buildings systems. The graphs below show the energy (electricity and thermal) breakdown by end use for each facility.



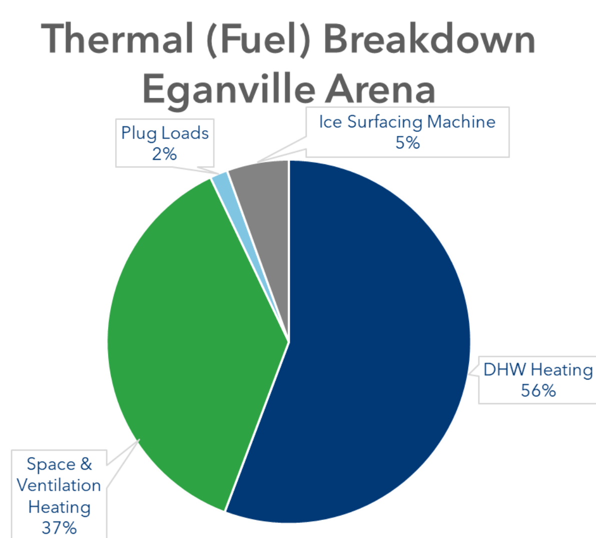


Figure 5: Energy (ekWh) consumption by end use for Arena

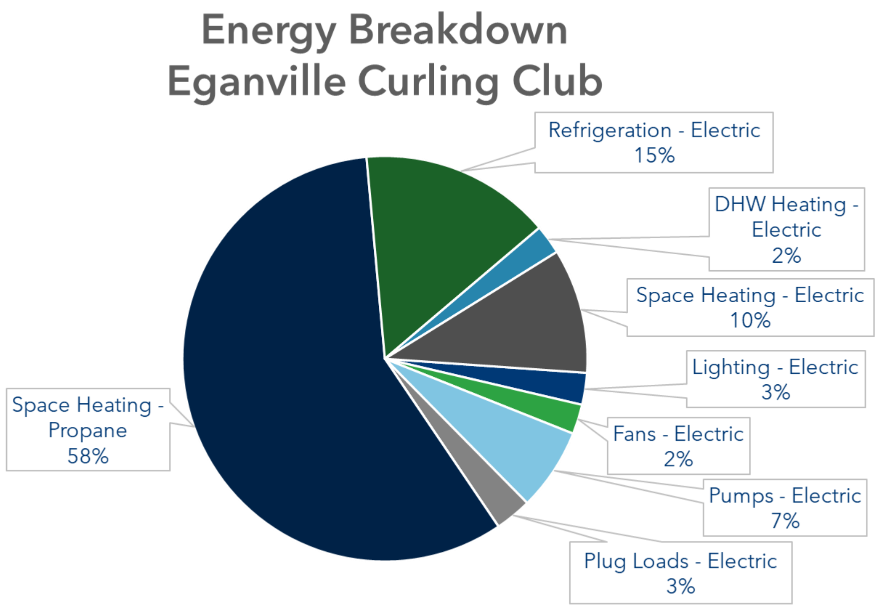


Figure 6 Energy (ekWh) consumption by end use for Curling Club

A thermal fuel breakdown for the Curling Club was not provided because the only fuel used for heating is propane.

3.4 Energy use intensity (EUI) 2019

If all the recommended measures are implemented, the energy use intensity (EUI) will be reduced to 8.10 ekWh/ft^2 at minimum in the Arena. Due to the addition of ventilation measures to meet building code if all of the proposed measures are implemented the EUI of the Curling Club would increase to 18.43 ekWh/ft².

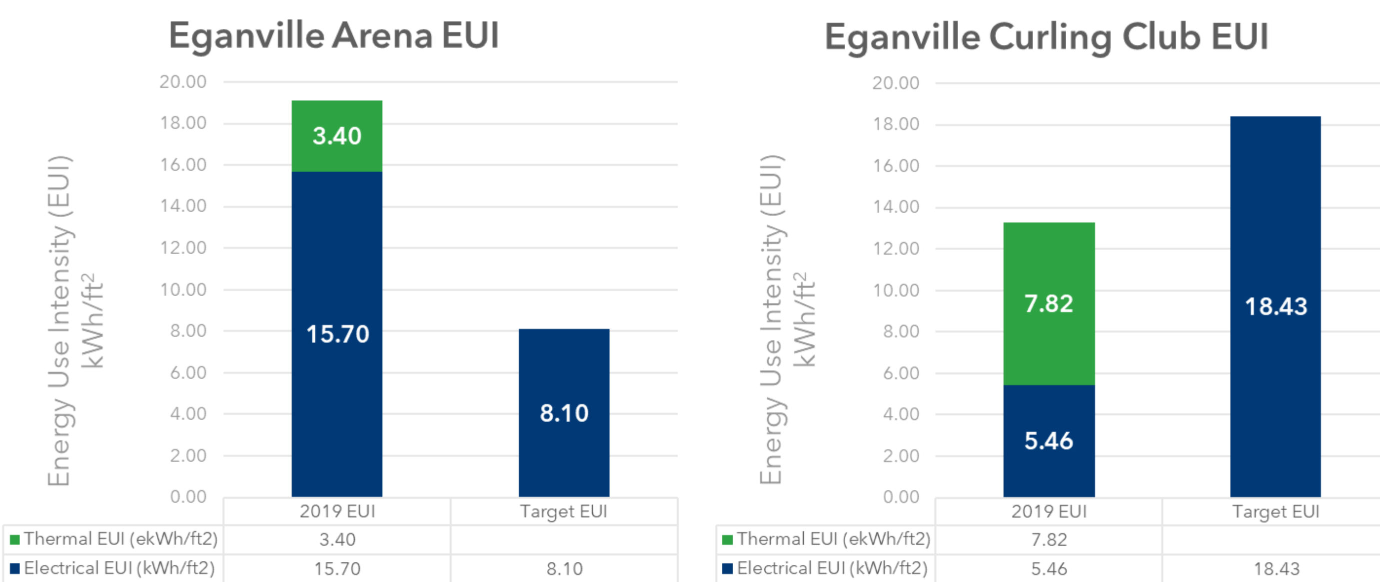
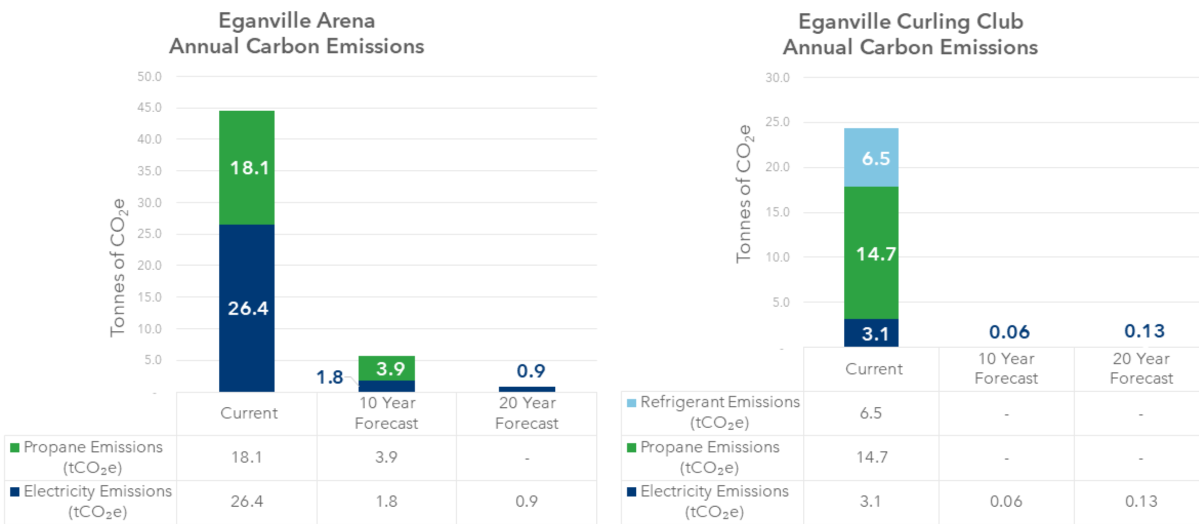


Figure 7: 2019 and target annual energy use intensity

3.5 Annual carbon emissions 2019

The following is a breakdown of carbon emissions in 2019, based solely on building energy consumption. Note that emissions of embodied carbon of materials has not been included.



	Current	10 Year Forecast	20 Year Forecast
Propane Emissions (tCO_2e)	18.1	3.9	-
Electricity Emissions (tCO_2e)	26.4	1.8	0.9

	Current	10 Year Forecast	20 Year Forecast
Refrigerant Emissions (tCO_2e)	6.5	-	-
Propane Emissions (tCO_2e)	14.7	-	-
Electricity Emissions (tCO_2e)	3.1	0.06	0.13

Figure 8: 2019 and forecast annual carbon emissions

3.6 Observations and opportunities

The site visit and interviews with the facility staff provided insights into how the buildings operate. Some actionable opportunities for energy reduction and greenhouse gas emission reduction were identified.

Key observations for Eganville Arena are as follows:

- The arena rink operates for about 40-45 hours a week during regular season (mid-September to end of March).
- Propane is being used for DHW, IR heaters and a deep fryer.
- LED lighting upgrade completed for arena lighting only. Fixtures have occupancy sensor dimming capabilities.
- There is significant electric heating in the building. The Eagles Nest heating is completely electric with no setback and programmed seasonally.
- No under slab or hydronic heating in building, which makes it difficult to centralize heating or cooling systems.
- Heat recovery potential is limited due to the need for long stretches of piping.
- There are no onsite renewables.

Potential opportunities for improvement include:

- Installing a Building Automation System (BAS) will provide greater control of operations, enable integrated controls and scheduling.
- Using lower temperature flood water for ice resurfacing on the rink can save money and greenhouse gas emissions.

- Reducing water use through glycol loop cooling, instead of using city water on compressors.
- Improving the building envelope would reduce infiltration/air leakage and make occupants more comfortable, although it would increase refrigeration load.
- Great potential for solar PV given the large roof area.
- Some of the propane-using equipment, such as DHW, IR heaters and deep fryer, can be electrified.

Key observations and potential improvements for Eganville Curling Club are as follows:

- The curling club is currently being renovated, so envelope and glazing in the renovated section should be upgraded.
- In the absence of a defined schedule, for this report, it is assumed that the Curling Club facility operates all year round while the curling ice only operates from October till April. There is no fixed schedule of operation during the summer season.
- No mechanical cooling was found. There is a lack of dedicated outdoor air systems, required to meet current code standards.
- No heat recovery option will be considered at the refrigeration plant due to space limitations and limited possible recovery usage.
- The building is heated using two gas furnaces: one for the curling rink and the second serving the curling club. The electrical data modelling indicated some electrical heating as well in 2019.
- Chilled water pump is running with triple duty valve throttled, so it is a potential VFD candidate. The existing pump is a two-stage pump.
- LED lighting is currently used at the Curling Rink. It is assumed that the Curling Club, which is currently being renovated, will be equipped with LED lights. The basement area is the only place where LED lights need to be installed.
- There are no onsite renewables but great potential for solar PV. Solar PV Panels can be either installed on the roof or fixed on the ground depending on the roof integrity.
- No ice resurfacing machine was observed.

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.

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 are to be optimized as much as possible considering potential end-of-life upgrades. Where feasible heat

recovery in all forms should be considered as it is essential to reducing heating requirements and offsetting high-emissions gas consumption.

iii. On-site renewable energy generation
   - Many options have been examined for technical and financial suitability for renewable energy generation. 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 (NPV), comparative costs and NPV by system

Net present value (NPV) is pivotal in evaluating which measures to implement. It lays out the total cost savings over a 30-year period, as compared to current operations, using 2019 calendar year as the baseline.

Net present value considers initial costs, delayed costs (end-of-life replacements), annual operation and maintenance costs. When a measure has a positive NPV, it is recommended. When the NPV is negative, the decision is less straightforward and should be based on 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.

4.2 Energy modelling approach

To model the performance of the building and calibrate a baseline, utility data from a standard year of operation was used. Demand was provided in kVA, but without an accompanying power factor in the billing so kW demand was not available.

Using hourly data analysis, a baseline model was developed to identify the baseload electrical energy consumption and weather dependent thermal demand. Using this data, and an extensive benchmarking data set of recreational buildings, achievable weather-normalized top decile energy and GHG targets were identified for the facility's performance.

Using hourly bin models, the energy consumption of all significant systems was calculated. A monthly summary of these models is presented to reflect the heating and cooling savings as per the current building operation. Thermal energy demand intensity (TEDI) was calculated using ambient conditions and its impact on the building envelope, infiltration, solar gains, internal gains, and ventilation on an hourly basis. These results allowed for the evaluation of heating and cooling demand reduction measures. Calibration results are presented in Appendix D.

4.3 Carbon factor forecasting

Greenhouse gas emissions can only be reduced by so much at the site when using electricity from the electrical grid. Improvements to electrical grids and means of generating electricity are expected to improve GHG emissions over time through infrastructure improvements and clean energy resources.

Environment and Climate Change Canada (ECCC) 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.

5 Details of identified measures

For each of the measures investigated, a description of the measure, upfront costs, carbon equivalent savings, energy savings, and net present value are presented.

The analysis includes both upfront costs (initial outlay of costs) and life cycle cost analysis. Budgets for each measure are based on costs from suppliers, rules of thumb and previous experience. NPV was calculated using life cycle costing, which is the total cost of the measure including initial, operational, and carbon costs, incorporating inflation and other considerations. Life cycle costing assumptions are provided in Appendix C.

5.1 Heating and cooling measures

The Eganville Arena primarily uses electric heating system elements to meet heating needs and uses propane fired heaters for bleachers and unit heaters in service spaces. There is no centralized hydronic space heating or cooling system so heat recovery from the refrigeration plant is limited. The Eagles Nest equipment will be due for replacement in the next 10 years. The bleacher radiant heaters were replaced in 2017 and will not require a replacement for about 15 years.

Eganville Curling Club currently uses propane-fired furnaces to meet the ice rink and basement heating needs. The multipurpose space has electrical baseboard heating (as noted by the facility operator) but was under renovation during the site visit so this could not be confirmed.

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

5.1.1 ASHP replacement of air conditioning and electric duct heating

Air source heat pumps (ASHP) split units are a viable option when seeking to decarbonize a heating and cooling system such as furnaces or AC units. The offer significantly improved efficiency over 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. Although it should be noted, that 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 Eagles Nest (second floor event space in the Arena) uses electrical duct heating and provides cooling with an outdoor air conditioning unit during the summer.

Since the Arena facility uses electric duct heating, the electric capacity should already be available, as an ASHP unit reduces the consumption of electricity to deliver the same amount of heating. This will improve demand costs and may allow for electric capacity to be available for other electrification measures in the facility depending on the use of electric auxiliary heating. The ASHP unit will also replace both heating and cooling equipment in the space, minimizing equipment needing maintenance, and avoiding the cost of replacing each system. Duct heating can remain in place as auxiliary heating, only requiring the outdoor air conditioning units to be replaced.

The Eganville Curling Club currently uses propane-fired furnaces for heating, which is the only point of propane use in the facility, as noted from site visit interviews. When replacing the furnaces in the Eganville Curling Club with ASHP systems, the facility will be able to eliminate the primary source of GHG emissions.

Both facilities will have increased electric demand, and capacity upgrades are needed. Increasing electrical capacity is a primary bottleneck when decarbonizing buildings.

5.1.2 Electric radiant heaters

Electric radiant heaters are an option where hydronic heating is not available, and when there is not enough heating demand to justify an ASHP unit for the space. With no viable options that would enable heat recovery for other systems to meet the heating demand of the system, a full electric equivalent of the existing fuel-fired radiant heaters is proposed. These electric units will operate at 100% efficiency, and 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.

The Eganville Arena ice rink currently has 5 propane fired, radiant heaters mounted above the audience bleachers space, and 3 smaller ceiling mounted units in the technical room and change rooms. These units are the only propane fired space heating equipment in the facility. As they serve specialized spaces, or spaces that do not have consistent heating demand, decarbonization strategies are limited. Replacing them with electric radiant heaters is electrification measure.

This measure is not applicable to the Eganville Curling Club.

5.1.3 Nighttime space heating setback

Night setback can be scheduled through existing controls if capability exists, or through manual setbacks during facility closing hours. It is recommended to install a BAS that can automate intelligent scheduling based on facility operation, occupancy, and scheduled events in the spaces. This will allow for a more hands-off control strategy that will save significant heating energy use in the spaces being controlled with reduced overnight space temperatures. Higher heating demand will occur in the morning when systems 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.

The Eganville Arena lobby and Eagles Nest spaces have the highest capacity electric heating units currently operational. Neither system is regularly scheduled. From utility benchmarking and reviewing electric heating trends, scheduling can provide significant savings to the facility.

As the lobby and Eagles Nest spaces have the largest occupancy in the facility with heating, controls such as smart thermostats with BAS integration and scheduling capability are to be prioritized for these locations. Reducing the heating demand will result in significant electrical savings.

This measure is not applicable to the Eganville Curling Club.

5.1.4 Arena heating and cooling measure summary

Table 10: Arena heating measures

Measures	Descriptions
Propane infrared heaters like-for-like replacement	Like-for-like replacement of propane infrared (IR) heaters.
Electric heating and cooling equipment like-for-like replacement	Like-for-like replacement of air conditioning and electric duct heating equipment serving the Eagles Nest.
Electric radiant heaters	Replace the existing propane IR heaters with electric radiant heaters. This is an electrification measure.
Nighttime space heating setback	Maintain lower overnight (midnight to 5am) setpoint temperature through BAS scheduling.
ASHP replacement of air conditioning and electric duct heating	Replace existing air conditioning and electric duct heating with air source heat pump units. This will improve heating efficiency and can be integrated with the BAS.

Business-as-usual measure	Initial outlay of costs ($)	Total energy savings (ekWh)	Annual GHG reduction (tCO_2e)	Total net annual savings ($)	NPV ($) without funding
Propane infrared heaters like-for-like replacement	$ 19,200	0	-	$ -	-$ 11,442
Electric heating and cooling equipment like-for-like replacement	$ 18,480	0	-	$ -	-$ 12,713
Low carbon measures	**Initial outlay of costs ($)**	**Total energy savings (ekWh)**	**Annual GHG reduction (tCO_2e)**	**Total net annual savings ($)**	**NPV ($) without funding**
Electric radiant heaters	$ 33,028	2,420	2.4	-$ 422	-$ 2,125
Nighttime space heating setback	$ 12,100	22,680	1.5	$ 3,930	$ 84,165
ASHP replacement of air conditioning and electric duct heating	$ 39,600	27,394	0.8	$ 4,771	$ 41,131

5.1.5 Curling Club heating and cooling measure summary

Table 11: Curling Club heating measures

Measures	Descriptions				
Propane furnaces like-for-like replacement	Like-for like replacement of 2 propane furnaces.				
ASHP replacement of propane fired furnace	Replacement of the existing propane fire furnaces (one serving the curling rink and the other serving the curling club spaces) with two electrical heat pumps of similar heating capacities.				
Business-as-usual Measure	Initial outlay of costs ($)	Total energy savings (ekWh)	Annual GHG reduction (tCO_2e)	Total net annual savings ($)	NPV ($) without funding
Propane furnaces like-for-like replacement	$ 26,400	0	0.0	$ -	-$ 15,733
Low carbon measures	Initial outlay of costs ($)	Total energy savings (ekWh)	Annual GHG reduction (tCO_2e)	Total net annual savings ($)	NPV ($) without funding
ASHP replacement of propane fired furnace	$ 70,400	37,149	12.8	$ 1,429	$ 140,130

5.2 Ventilation measures

Ventilation in the Eganville Arena is provided with fan coil units in the Eagles Nest and infiltration induced by exhaust fans throughout the building. Eganville Curling Club does not have any ventilation in the basement space or amenity club space as noted from the site visit. The ice rinks do not have any ventilation systems beyond exhaust fans.

The Ventilation System at the Eganville Curling Club can be optimized by implementing the following measures:

5.2.1 Install ERV to provide space ventilation

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.

An energy recovery ventilator (ERV) can provide efficient fresh air ventilation while minimizing heating loads. It recovers exhaust air from spaces like washrooms and changerooms to preheat incoming fresh air, making it an energy-efficient option. Installing an ERV requires new 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 additional heating or cooling energy depending on the season in this case, since there is no existing mechanical ventilation.

Currently, the Eganville Curling Club does not have any dedicated fresh air ventilation system, as noted from the site visit. It is recommended to provide ventilation as per ASHRAE 62.1, to improve occupant health and wellness.

This measure is not critical in the Eganville Arena as spaces are exhausted and have some ventilation.

5.2.2 Curling club ventilation measure summary

Table 12: Curling club ventilation measures

Measures	Descriptions				
Install ERV to provide space ventilation	Install new ERV to provide make up air to the curling club spaces (including basement areas).				
Low carbon measures	Initial outlay of costs ($)	Total energy savings (ekWh)	Annual GHG reduction (tCO_2e)	Total net annual savings ($)	NPV ($) without funding
Install ERV to provide space ventilation	$ 52,800	-7,629	-1.5	-$ 810	-$ 52,775

5.3 Domestic hot water (DHW) measures

In the Arena facility there are approximately 40 or more floods every week, with each flood using 190 US gallons of domestic hot water (DHW). The primary load for heating DHW comes from floodwater heating while the remaining smaller loads are for kitchen and occupant sanitary use. Therefore, the most significant opportunity in the Arena facility for fuel and GHG savings is in the DHW heating process. The Eganville Curling Club currently uses an electric hot water heater and is not a significant contributor to emissions.

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

5.3.1 Air source heat pump (ASHP) domestic hot water heater

For high flowrate DHW needs in commercial units, dedicated ASHP units should be equipped with auxiliary electrical heating. Indoor ASHP DHW heaters can use excess heat from high heat gain spaces and can utilize local heat for smaller capacity units, resulting in localized cooling. Larger commercial units require ducting to receive outside air and can use preheated air if available. Available electrical capacity must be investigated for electrification measures and any upgrades to electrical infrastructure examined before proceeding with this measure.

Given the current DHW system is fuel-fired, there is an opportunity for significant GHG savings through electrification measures such as using ASHP DHW heaters.

The machine room has ample space, but ducting is necessary to avoid triggering the heating system due to the radiant heaters present. Exploring the possibility of ducting air from the rink could improve ice rink operation, but this requires further examination during the design stage. Storage tanks are necessary since the commercial DHW unit serves both floodwater and two adjacent change rooms with inconsistent demand.

This measure is only applicable to the Eganville Arena as it uses a significant volume of domestic hot water.

5.3.2 Electric domestic hot water heater

To electrify fuel-fired DHW heater systems, a 100% electric unit with equivalent heating capacity can be provided, typically using electric elements in hot water tanks. Different sizes and equipment footprints are available based on DHW demand. Electrical capacity upgrades are necessary for this measure. Compared to ASHP systems, full electrical DHW heaters have higher consumption but lower initial costs and do not require ducting for outside air.

This measure is only applicable to the Eganville Arena as it uses a significant volume of domestic hot water.

5.3.3 Arena domestic hot water measure summary

Table 13: Arena domestic hot water measures

Measures	Descriptions
Propane DHW with like-for-like replacement	Like-for-like replacements of all 3 DHW propane units.
ASHP domestic hot water heater	Replace the existing propane DHW heaters serving both the building and the ice resurfacing machine with air source heat pump (ASHP) water heaters, which have higher heating efficiency.
Electric domestic hot water heater	Replace the existing propane DHW heaters serving both the building and the ice resurfacing machine with electric water heaters. This is an electrification measure.

Business-as-usual measures	Initial outlay of costs ($)	Total energy savings (ekWh)	Annual GHG reduction (tCO_2e)	Total net annual savings ($)	NPV ($) without funding
Replace DHW with like-for-like propane units	$ 23,100	0	-	$ -	-$ 13,766
Low carbon measures	**Initial outlay of Costs ($)**	**Total energy savings (ekWh)**	**Annual GHG reduction (tCO_2e)**	**Total net annual Savings ($)**	**NPV ($) without funding**
ASHP domestic hot water heater	$ 220,800	36,127	13.9	$ 1,340	$ 6,598
Electric domestic hot water heater	$ 40,600	11,242	13.6	-$ 2,994	$ 69,435

5.4 Refrigeration plant measures

The compressors, condensers, and heat exchangers are reaching the end of life in the Eganville Arena and will require immediate replacement. The Eganville Curling Club facility uses equipment that must be replaced due to the phase out of R-22 refrigerant.

The Refrigeration Plant operation can be optimized by implementing the following measures:

5.4.1 Ice thickness optimization

Optimizing ice thickness in the rink can reduce the load on the refrigeration plant and save energy. Less ice mass is needed to maintain temperatures for rink activities, resulting in lower load for the brine pumps and/or refrigeration plant throughout the season. Industry standard ice thickness is 1.25 inches but reducing it will require review by facility operators for their ice building process and painting depths as well as ice surface uniformity.

Facility operators at the Eganville Arena noted that cleanup of the paint was more challenging when the initial layer of ice is thinner, so the opportunity would be mostly in the middle and final layer of ice.

Using a thinner sealing ice coat/spray to maintain the whitewash and painting the lines immediately after, would reduce the ice thickness by 0.25 inches with minimum change to the ice thickness above the paint, which is most susceptible to resurfacing requirements.

Curling club ice sheet may be reduced to meet standard thickness and is recommended to use similar methods.

5.4.2 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 will 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.

Currently ice temperatures in the Arena are optimized provide 'hard' ice to meet the needs of hockey players, at 18-19°F. The set point is reduced to 15-16°F when the weather is mild, and the ice rink space is warmer. The lower setpoint results in higher load during the warmer months and would result in a higher load ice plant and may result in ice harder than needed. There is no night setback on the ice temperatures as there are no sophisticated controls or building automation system currently implemented at the ice rink. Eganville Curling Club does employ ice temperature setbacks but can be further optimized as 19°F is the operating setpoint and can be reduced for curling activities.

Since the Arena also operates with a lower ice temperature during the milder months, it should be reviewed if ice temperatures are being maintained at the optimal ice hardness/temperature, or if temperatures are kept colder than necessary, resulting in higher refrigeration load that will have diminishing returns on benefits to occupants. A BAS will be able to monitor the temperature space and ice temperature to automate schedule changes to the plant to maintain the desired setpoints.

Eganville Curling Club does employ ice temperature setbacks but can be further optimized as the current operating setpoint of 19°F provides harder ice than that may be needed for curling activities. Increasing these setpoints to 23-24°F, and a setback of 4°F overnight can have significant savings.

5.4.3 Cold water ice resurfacing

Cold water flood technologies can eliminate the need for hot water in the flooding process and achieve similar results while reducing carbon and energy use. REALice is an example of cold-water flood technology that is compact and removes microbubbles and limescale deposits on piping creating pressure through its unique geometry ultimately leading to the ability to raise ice temperatures to achieve the same strength. Our recommendation is if you proceed with this, install a mixing valve with the DHW giving the option to temper it slightly to help meet ice quality standards.

Currently flooding frequency at the Eganville Arena is 40+ times a week for ice resurfacing, using 160-190 USGal per instance, with 155°F water. Water heating is accomplished using propane-fired DHW heaters and is a source of GHG emissions.

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 shaver and towel performance for smoothing. Despite initial costs, this measure provides significant energy, cost, and GHG savings. This technology would significantly reduce the demand for DHW as the DHW heater would mainly serve the change rooms. Heat recovery should be directed to other systems in the facility.

This measure is not implemented in the Eganville Curling Club as flooding is not required at the same frequency as the Arena facility.

5.4.4 Glycol loop upgrade for compressor cooling

Using a closed loop glycol cooling system to replace a water-cooling system has two primary benefits. It will reduce water use in the facility during compressor operation and it will provide a point of heat recovery for the facility. With a closed loop system, this configuration would be easier to maintain and can be easily fitted with other technologies, such as a desuperheater, to take advantage of the heat. This recovered heat can be used for DHW heating, or other space heating needs provided the distance from the glycol loop and desuperheater is not a barrier. It is also important to note that most current building codes do not allow for direct water-cooled systems for normal operation. They are typically allowed for backup only. As such, in addition to cost benefits and increased heat recovery potential, this measure would bring the compressor cooling system up to current standards.

Currently municipal water is used to cool the compressors for the Eganville Arena, as there is no glycol cooling loop in the facility. This results in excess water use, increased costs, and operation that is not up to par with current best practices. As cooling water used is discarded, this is another source of heat that cannot be recovered.

This measure only captures the implementation of the closed loop glycol cooling system and infrastructure needed. As this change will primarily reduce water use and bring the compressor up to current standards, there are not significant GHG savings. This measure is included in measure 5.4.6 and outlined here to describe benefits and potential water savings.

This measure is not implemented at the Eganville Curling Club as it is not required.

5.4.5 Variable frequency drives (VFDs) on brine pumps

Controlling the brine pump flow rate will provide granular temperature control and load modulation. A VFD-equipped pump can manage load better by operating at peak load during the warmest months and lowest during the coldest months. Scheduling and setbacks can further reduce load during off-peak hours and increase load during morning start-up. A VFD with an appropriate control strategy can significantly save energy in rinks that currently use constant speed pumps. For 2-speed pumps, a VFD will allow better load management and ice temperature control during shoulder season months and winter months. Though VFDs cost more than 2-speed options, they increase control capabilities when integrated with a BAS. Heat recovery systems can also help the ice plant operate at lower loads and ensure steady operation while recovering reliable heat as needed.

The current brine loop in the Eganville Arena operates at a constant speed and does not vary ice temperature or use set back schedules regularly. This measure would complement setback schedules and heat recovery strategies through BAS integration.

The Eganville Curling Club has a 2-speed pump that operated at high speed during the warmest months and low speed during the coldest months. This measure would provide tighter control on the brine loop but will not be as significant going from an existing 2-speed pump. This measure is recommended only if external funding is available.

5.4.6 Refrigeration plant heat recovery

Desuperheaters are a useful addition to ice plants, capturing heat from the glycol loop used for compressor cooling and providing high-grade heating to nearby sources. They can offset significant energy use if optimized for facility heating needs and connected to a central hydronic system. However, if the facility has no central hydronic plant, the number of opportunities for heat recovery will depend on proximity to the refrigeration plant. Long piping distances can be disruptive and cost prohibitive.

Plate and frame heat exchangers (PHEs) offer more value than shell and tube equivalents with reduced refrigerant charge, smaller footprint, higher performance, and lower maintenance costs. They can also provide increased capacities for undersized plants or facilities with higher cooling loads or heat recovery needs.

Eganville Arena needs a refrigeration plant replacement, presenting an opportunity to implement low carbon technologies for building operation. Higher efficiency components like premium compressors and plate and frame heat exchangers can be integrated with a BAS to replace the older, less efficient ones.

The desuperheater can offset DHW demand for floodwater and changerooms. Higher efficiency refrigeration equipment allows for lower load operation while maintaining ice hardness. Savings from measure 5.4.4 are included here which account for about 1,800 m^3 of water savings annually. Upgrades include PHE, brine pump assembly, new condenser, compressors with increased capacity, CIMCO 6000E controller, and wall-mounted desuperheater connected to a new glycol loop.

This measure is not implemented in the Eganville Curling Club.

5.4.7 Convert refrigerant to ammonia

The Montreal Protocol mandated the phasing out of artificial refrigerants with high greenhouse gas warming potential (GWP) and ozone depleting potential (ODP), resulting in a ban on R-22 production and import in Canada since January 1st, 2020. R-22 has a GWP of 1,760 and is costly to maintain due to its limited supply. Annual top-up is required due to leaks, resulting in significant GHG emissions during the system's life cycle.

Ammonia, a refrigerant with 0 GWP, is being used as a replacement for HFCs like R-22. ammonia systems have higher performance and heat transfer, resulting in electrical savings. However, ammonia plants tend to have larger footprints and may require mechanical room expansions.

A business-as-usual refrigeration plant would be modified to use R-449A refrigerant due to phase-out of R-22. R-449A can be used with current equipment until its eventual phase-out. R-22 cost per pound is unsustainable therefore prompting the switch. However, R-449A has a 17% lower performance and requires more hours of operation, increasing annual energy consumption.

Converting Eganville Curling Club's R-22 based plant to an ammonia plant will save energy and reduce GHG emissions. A prefabricated mechanical room expansion is required to accommodate the new plant. Ammonia plants have minimal leakage, reducing maintenance costs compared to R-22 plants. The new plant includes an advanced controller for improved scheduling and system integration.

Maintenance fees of $10,000 annually are assumed for both cases of refrigeration plant replacements.

Eganville Arena is already using an ammonia based refrigeration plant, so this measure is not applicable to that facility.

5.4.8 Arena refrigeration measure summary

Table 14: Arena refrigeration measures

Measures	Descriptions
Full refrigeration plant like-for-like replacement	Like-for-like replacements of all systems in refrigeration plant at end of life.
Ice thickness optimization	Reduce ice thickness to reduce the load on the refrigeration system.
Ice temperature optimization	Adjust temperature of the ice to be 4°F higher during night-time where it is not in use.
Cold water ice resurfacing	Cold-water resurfacing system (REALice or equivalent) assuming a mix of water to 65°F. Reduce flood temperature from 155°F to 70°F
Glycol loop upgrade for compressor cooling	Replace current configuration using city water to cool compressors with glycol loop. Significantly reduce water consumption.
VFDs on brine pumps	Equip brine pumps with VFDs to modulate flow, this allows for tighter control of setback schedules.
Refrigeration plant heat recovery	Add desuperheater to existing plant, in addition to newer equipment (compressor, condenser, heat exchanger, etc.) which will provide better performance, and flood water heating through plant heat recovery.

Business-as-usual measures	Initial outlay of costs ($)	Total energy savings (ekWh)	Annual GHG reduction (tCO_2e)	Total net annual savings ($)	NPV ($) without funding
Full refrigeration plant like-for-like replacement	$ 506,000	0	-	-$ 10,000	-$ 699,674
Low carbon measures	**Initial outlay of costs ($)**	**Total energy savings (ekWh)**	**Annual GHG reduction (tCO_2e)**	**Total net annual savings ($)**	**NPV ($) without funding**
Ice thickness optimization	$ -	863	0.1	$ 149	$ 3,635
Ice temperature optimization	$ -	1,903	0.1	$ 330	$ 8,019
Cold water ice resurfacing	$ 42,790	3,0861	5.9	$ 3,474	$ 108,167
Glycol loop upgrade for compressor cooling	$ 23,000	0	0.2	$ 5,703	$ 273,867
VFDs on brine pumps	$ 36,369	16,303	1.3	$ 2,839	$ 32,701
Refrigeration plant heat recovery	$ 610,500	48,612	9.5	$ 1,193	-$ 268,557

5.4.9 Curling Club refrigeration measures

Table 15: Curling Club refrigeration measures

Measures	Descriptions
Full refrigeration plant like-for-like replacement	Replacements of all systems in refrigeration plant at end of life with equivalent systems to those currently in the facility.
Ice thickness optimization	Reduce ice thickness to reduce the load on the refrigeration system.
Ice temperature optimization	Adjust temperature of the ice to be 4°F higher during night-time where it is not in use.
VFDs on brine pumps	Equip brine pumps with VFDs to modulate flow, this allows for tighter control of setback schedules.
Convert refrigerant to ammonia[2]	Replace the R-22 based refrigeration plant to a more efficient ammonia-based system. Requires expansion of building mechanical room.

[2] GHG emissions as a result of refrigerant leakage are assumed to be taxed in the sale price and included in the NPV as a penalty. The low carbon refrigeration measure includes the carbon avoided from the original refrigerant leakage when the plant used R-22.

Business-as-usual measures	Initial outlay of costs ($)	Total energy savings (ekWh)	Annual GHG reduction (tCO_2e)	Total net annual savings ($)	NPV ($) without funding
Full refrigeration plant like-for-like replacement	$ 247,500	-2909	-5.6	-$ 11,015	-$ 410,067
Low carbon measures	**Initial outlay of costs ($)**	**Total energy savings (ekWh)**	**Annual GHG reduction (tCO_2e)**	**Total net annual savings ($)**	**NPV ($) without funding**
Ice thickness optimization	$ -	178	0.0	$ 31	$ 748
Ice Temperature optimization	$ -	344	0.0	$ 60	$ 1,391
VFDs on brine pumps	$ 20,000	530	0.0	$ 92	-$ 9,730
Convert refrigerant to ammonia	$ 912,000	5,347	6.8	-$ 8,549	-$ 885,120

Note that only energy savings are presented in the above tables. The annual cost savings for measures 5.4.4 and 5.4.6 also include cost savings from reduced water consumption of about 1,800 m³ of water use reduction annually, which does not appear in the tables above.

5.5 Dehumidification measures

Eganville Arena has two electric dehumidifiers that work to provide a relative humidity of 40-55% during the operating season. Eganville Curling Club does not have any dehumidification in the ice rink space.

The dehumidification system at the Arena 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. However, during warm days with internal wall temperatures well above the dewpoint, it is recommended to increase RH to 60% to reduce dehumidification energy while still avoiding condensation on the structure. This requires a BAS and dewpoint sensing devices.

With improved BAS controls that would be implemented with a refrigeration plant upgrade, dehumidifier controls can be part of the solution. This measure is to be implemented in the arena and could be implemented if a dehumidifier is installed in the curling club.

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. At night, it is recommended to schedule a dehumidification setback to 65% relative humidity 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 that happens. 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.

This measure is to be implemented in the Arena and could be implemented if a dehumidifier is installed in the Curling Club.

5.5.3 Install dehumidifier

Controlling humidity in an ice rink is vital to maintaining good ice quality. High humidity can lead to condensation on the ice sheet, increasing impurities and requiring more ice surfacing events. Additionally, condensation on the roof and beams can form bumps on the ice that are difficult to even out. Standard practice is to maintain humidity levels between 50-55% RH during occupied periods. However, ice rinks have high latent heat and humidity due to active occupants and ice melt, which can lead to mold and mildew if not managed properly. While improving humidity control can enhance ice quality, adding a new system will increase energy use and could raise overall building energy consumption and emissions, depending on the unit's energy source.

This measure applies to the Eganville Curling Club as it has no dehumidifier in the rink space. If condensation issues exist in the space, adding a dehumidifier will improve the refrigeration load and occupancy comfort, but will add electricity consumption.

5.5.4 Arena dehumidification measure summary

Table 16: Arena dehumidification measures

Measures	Descriptions				
Dehumidifiers like-for-like replacement	Like-for-like replacement of dehumidifier at end of life.				
Dehumidifier controls – daytime scheduling	Increase relative humidity setpoints during times where the dewpoint temperature is higher, where condensation can be avoided, and reduce dehumidifier use.				
Dehumidifier controls – night setback scheduling	Higher overnight (midnight to 5am) humidity setpoint at 65% RH or slightly above the dewpoint to avoid condensation and reduce dehumidifier use.				
Business-as-usual measures	Initial outlay of costs ($)	Total energy savings (ekWh)	Annual GHG reduction (tCO_2e)	Total net annual savings ($)	NPV ($) without funding
Dehumidifiers like-for-like replacement	$ 121,000	0	-	$ -	-$ 72,108
Low carbon measures	Initial outlay of costs ($)	Total energy savings (ekWh)	Annual GHG reduction (tCO_2e)	Total net annual savings ($)	NPV ($) without funding
Dehumidifier controls – daytime scheduling	$ 6,325	2,460	0.2	$ 428	$ 4,168
Dehumidifier controls – night setback scheduling	$ 6,325	4,668	0.4	$ 813	$ 13,112

5.5.5 Curling Club dehumidification measure summary

Table 17: Curling Club dehumidification measures

Measures	Descriptions				
Dehumidifier controls – daytime scheduling	Increase relative humidity setpoints during times where the dewpoint temperature is higher, where condensation can be avoided, and reduce dehumidifier use.				
Dehumidifier controls – night setback scheduling	Higher overnight (midnight to 5am) humidity setpoint at 65% RH or slightly above the dewpoint to avoid condensation and reduce dehumidifier use.				
Install dehumidifier	Currently the rink has no dehumidification, this runs the risk of condensation and fogging on ice, and higher loads on rink as a result.				
Low carbon measures	Initial outlay of costs ($)	Total energy savings (ekWh)	Annual GHG reduction (tCO_2e)	Total net annual savings ($)	NPV ($) without funding
Dehumidifier controls – daytime scheduling	$ -	276	0.0	$ 48	$ 898
Dehumidifier controls – night setback scheduling	$ -	524	0.0	$ 91	$ 1,704
Install dehumidifier	$ 60,500	-7,084	-0.4	-$ 1,234	-$ 71,068

5.6 Ice resurfacing measures

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

5.6.1 Electric ice resurfacing machine

Replacing a propane-fired ice resurfacer with an electric rechargeable version is a decarbonization measure that can save costs on fuel transportation and delivery. While electric ice resurfacers 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.

Maintenance fees of $600 annually have been assumed for the propane-fired ice resurfacing machine (business as usual replacements). This measure only applies to the Eganville Arena as the Curling Club does not use an ice resurfacer.

5.6.2 Arena ice surfacing measure summary

Table 18: Arena ice surfacing measures

Measures	Descriptions
Resurfacing machine like-for-like replacement	Like-for-like replacement of propane ice resurfacing machine at end of life.
Electric ice resurfacing machine	Ice resurfacing machine (replace with rechargeable electric equivalent).

Business-as-usual measures	Initial outlay of costs ($)	Total energy savings (ekWh)	Annual GHG reduction (tCO_2e)	Total net annual savings ($)	NPV ($) without funding
Resurfacing machine like-for-like replacement	$ 112,200	0	-	-$ 600	-$ 111,149
Low carbon measures	**Initial outlay of costs ($)**	**Total energy savings (ekWh)**	**Annual GHG reduction (tCO_2e)**	**Total net annual savings ($)**	**NPV ($) without funding**
Electric ice resurfacing machine	$ 167,200	1,457	0.8	-$ 85	-$ 140,005

5.7 Lighting measures

The lighting systems at both the Eganville Arena and Eganville Curling Club can be optimized by implementing the following measures:

5.7.1 Facility-wide LED upgrade

LED lighting is an affordable way to reduce electricity consumption and demand in a facility. To minimize costs when transitioning from fluorescent or incandescent lighting, it's best to minimize changes to ballasts and panels. Reevaluating lighting density during a retrofit can identify areas where fixtures can be removed to further improve lighting. Reducing lighting power also reduces internal heat gains, which can increase heating demand but decrease cooling demand depending on the spaces they serve. These secondary effects need to be factored into the overall energy savings analysis for this measure.

There is opportunity to implement LED lighting at both the Arena and the Curling Club. As the spaces are primarily heated using propane or electricity, there will be an energy penalty associated with any increase in heating demand. Since these facilities are not heavily used during the summer months, any decrease in cooling demand will likely be negligible.

5.7.2 Arena lighting measure summary

Table 19: Arena lighting measures

Measures	Descriptions
Lighting fixtures like-for-like replacement	Replacing all lighting fixtures with like-for-like fluorescent and LED equivalents.
Facility-wide LED upgrade	Replace the existing fluorescent and incandescent lighting fixtures in the Curling Club with LED fixtures.

Business-as-usual measures	Initial outlay of costs ($)	Total energy savings (ekWh)	Annual GHG reduction (tCO_2e)	Total net annual savings ($)	NPV ($) without funding
Lighting fixtures like-for-like replacement	$ 12,073	0	-	$ -	-$ 11,389
Low carbon measures	**Initial outlay of costs ($)**	**Total energy savings (ekWh)**	**Annual GHG reduction (tCO_2e)**	**Total net annual savings ($)**	**NPV ($) without funding**
Facility-wide LED upgrade	$ 23,100	9,138	0.6	$ 1,604	$ 16,489

5.7.3 Curling Club lighting measure summary

Table 20: Curling Club lighting measures

Measures	Descriptions
Lighting fixtures like-for-like replacement	Replacing all lighting fixtures with like-for-like fluorescent and LED equivalents.
Facility-wide LED upgrade	Replace the existing fluorescent and incandescent lighting fixtures in the Curling Club with LED fixtures.

Business-as-usual measures	Initial outlay of costs ($)	Total energy savings (ekWh)	Annual GHG reduction (tCO_2e)	Total net annual savings ($)	NPV ($) without funding
Lighting fixtures like-for-like Replacement	$ 4,323	0	0.0	$ -	-$ 3,963
Low carbon measures	**Initial outlay of costs ($)**	**Total energy savings (ekWh)**	**Annual GHG reduction (tCO_2e)**	**Total net annual savings ($)**	**NPV ($) without funding**
Facility-wide LED upgrade	$ 4,180	1,252	-0.1	$ 310	$ 154

5.8 Envelope 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 is to increase wall insulation using spray foam to R-26 from an estimated R-15. This upgrade will decrease heating demand, prevent thermal bridging, and seal infiltration/exfiltration points. The retrofit will also reduce cooling demand and should be done during a deep facility retrofit due to its cost and intrusive nature.

As both facilities have an ice rink that operates seasonally and not year-round, improving envelope insulation may retain heat during the coldest months, increasing refrigeration plant load.

5.8.2 Exterior roof insulation upgrade

The roof of each building has an estimated effective thermal performance of R-20 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 is 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. Ideally, they should be completed at the end of the building's life or during a deep retrofit project, where feasible.

The Eganville Arena and Curling Club each have a pitched metal roof, which causes thermal bridging between the support structure and the insulation below the sheet metal.

The roof in the Eganville Arena was recently replaced in 2014. The next upgrade should be considered when replacement is necessary or at end of life.

5.8.3 Improve air tightness of machine room overhead door

Air tightness is crucial for managing envelope losses and gains, which affects the heating and cooling demand in a facility. This is achieved by identifying hot or cold spots and evaluating air leakage through pressurization and smoke testing.

The overhead door connecting the ice rink to the machine room at the Eganville Arena leaks warm air into the rink, reducing the efficiency of the ice plant. Towels are currently used to minimize the impact, but it is recommended to install rubber seals to eliminate the increased cooling load caused by warm air leakage.

This measure is not applicable to the Eganville Curling Club.

5.8.4 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.

Implementing a low-e ceiling at the Eganville Curling Club will reduce the load on the refrigeration plant. As the facility has a relatively low energy consumption for ice plant operation, the savings are not in the same magnitude as a larger dedicated facility. The Eganville Arena already has a low-e ceiling so this measure is not applicable.

5.8.5 Arena envelope measure summary

Table 21: Arena envelope measures

Measures	Descriptions
Exterior wall insulation upgrade	Upgrade the exterior wall insulation to R26 or similar to increase U value of the overall wall.
Exterior roof insulation upgrade	Upgrade the roof insulation to R40 or similar to increase U value of the overall roof.
Increase air tightness of machine room overhead door	Air tightness / infiltration to be improved with better weather sealing

Low carbon measures	Initial outlay of costs ($)	Total energy savings (ekWh)	Annual GHG reduction (tCO_2e)	Total net annual savings ($)	NPV ($) without funding
Exterior wall insulation upgrade	$ 379,155	228	0.0	$ 39	-$ 195,480
Exterior roof insulation upgrade	$ 595,723	1,869	0.0	$ 324	-$ 305,440
Increase air tightness of machine room overhead door	$ 3,900	3,325	0.3	$ 576	$ 9,892

5.8.6 Curling Club envelope measure summary

Table 22: Curling Club envelope measures

Measures	Descriptions
Exterior wall insulation upgrade	Upgrade the exterior wall insulation to R26 or similar to increase U value of the overall wall.
Exterior roof insulation upgrade	Upgrade the roof insulation to R40 or similar to increase U value of the overall roof.
Suspended low-e ceiling	Install low-e suspended ceilings in ice rink to reduce refrigeration plant load.

Low carbon measures	Initial outlay of costs ($)	Total energy savings (ekWh)	Annual GHG reduction (tCO_2e)	Total net annual savings ($)	NPV ($) without funding
Exterior wall insulation upgrade	$ 141,843	2,787	0.6	$ 289	-$ 67,796
Exterior roof insulation upgrade	$ 201,148	4,628	0.9	$ 516	-$ 95,250
Suspended low-e ceiling	$ 17,380	5,302	0.3	$ 918	$ 5,545

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 Hydro One, 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.

As ice rink facilities have most of their electrical consumption during the winter season due to the ice rink operation, most electricity consumption will 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.

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 to also minimize any thermal bridging on the roof structures.

5.9.1 Solar PV (photovoltaics)

Full roof solar PV coverage (272 kW array) for Eganville Arena will be able to meet about 70% of its 2019 annual electric energy consumption. Recurring costs of maintenance and inverter replacements every 10 years are accounted for in cost analysis.

Partial roof coverage (45.3 kW array) of Eganville Curling Club can meet its entire 2019 electricity consumption. Full roof coverage (81 kW array) will provide more than enough capacity to offset the additional electricity use that is added from the electrification measures, or new equipment to meet the low carbon pathways, with remainder available for other nearby facilities. For this study, the PV array was sized to 67.9 kW to meet the electricity consumption and increased demand from electrification and additional equipment of the selected measures, with no annual excess. Recurring costs of maintenance and inverter replacements every 10 years were accounted for.

5.9.2 Arena measure summary

Table 23: Arena renewable measures

Measures	Descriptions
Solar PV - 272 kW Array	Provide solar panels on the entire roof area to make use of the maximum possible savings in electricity consumption.

Low carbon measure	Initial outlay of costs ($)	Total energy savings (ekWh)	Annual GHG reduction (tCO_2e)	Total net annual savings ($)	NPV ($) without funding
Solar PV - 272 kW array	$ 580,448	286,717	22.0	$ 49,932	$ 578,777

5.9.3 Curling Club measure summary

Table 24: Curling Club renewable measures

Measures	Descriptions				
Solar PV - 67.9 kW array	Provide solar panels on the roof area to meet the current electricity consumption and expected increase due to electrification				
Low carbon measure	Initial outlay of costs ($)	Total energy savings (ekWh)	Annual GHG reduction (tCO_2e)	Total net annual savings ($)	NPV ($) without funding
Solar PV - 67.9 kW array	$ 156,085	71,517	5.5	$ 12,455	$ 133,997

5.10 Other measures

5.10.1 Convert deep fryer to electric

To eliminate all GHG emissions in the Eganville Arena facility, the fuel-fired deep fryer will need to be replaced with an electric equivalent. This measure would require capping propane lines, and ensuring there is enough electric capacity in the kitchen space to meet the load.

This measure is not implemented in the Eganville Curling Club as propane-fired equipment was not noted during the renovations.

5.10.2 Arena other measure summary

Table 25: Other Arena measures

Measures	Descriptions				
Convert deep fryer to electric	Replace current deep fryer in kitchen space with electric equivalent. This is an electrification measure.				
Low carbon measures	Initial outlay of costs ($)	Total energy savings (ekWh)	Annual GHG reduction (tCO_2e)	Total net annual savings ($)	NPV ($) without funding
Convert deep fryer to electric	$ 2,300	0	0.1	-$ 28	-$ 1,395

5.11 Measures considered but not recommended

The following list of measures were considered or investigated, but not recommended due to factors identified in the descriptions.

Table 26: Measures considered but not recommended.

Measure	Description
Geothermal plant	Great energy savings opportunity but NPV is not attractive, and implementation will be disruptive.
Solar wall	Not feasible for location and existing facility.
Battery storage	Significant material and associated electrical infrastructure costs, not critical to measures.
Dedicated heat recovery chiller	Space limitations in mechanical room, other solutions can meet heat recovery gap.
Waste-water heat pump	No significant DHW use, no pool areas.
Daylighting and occupancy sensors	Owners and operators advised against due to current scheduling system and programming variation. Payback would not be attractive
Mechanical dehumidifier with fresh air ventilation	Infrastructure not available to implement and NPV is not attractive.
Triple glazed windows	Very little glazing in the facility would not make a significant impact given the high cost of this measure. NPV is not attractive.

6 Summary of measures

This section provides three different scenarios of measures, timing, and actions for both Eganville Arena and Eganville Curling Club with initial outlay of costs, emission savings, total net annual savings, simple payback, and net present value (NPV). Each of these scenarios considers a 30-year implementation timeline, taking the facility to the end date for most municipal greenhouse gas reduction goals. These scenarios are as follows:

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

ii) Low Carbon approach without funding. This scenario incorporates all reviewed low carbon measures based on maximizing energy efficiency, utilizing heat recovery and replacement of equipment at end of life. It includes implementing operational measures in 2024, 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 Green and Inclusive Community Building (GICB) funding from Infrastructure Canada, according to the projects' implementation timelines. Low carbon measures would be implemented to meet the GICB requirement of completion on or before March 2026.

The Low Carbon with funding scenario is similar to the Low Carbon approach without funding scenario, except measures are planned to be implemented sooner to take advantage of GICB funding that requires completion on or before March 2026. For some measures, two capital outlays for replacement were included in the scenario, as the equipment would need to be replaced twice based on recommended lifespan. If the second equipment replacement was due on or before 2054, the cost was included, and the amortization period extended beyond the timelines of this study to include the savings associated with the last equipment change for the full life of the equipment. Note that the initial funding covers the first replacement only.

GHG emissions savings were only attributed to energy reductions as a result of the measures implemented. If there were no energy savings, the GHG reductions were not considered.

Measure details were provided in Section 5.

6.1 Eganville Arena – measure summaries

6.1.1 Business-as-usual measures

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

Table 27: Business-as-usual measures for arena

Business-as-usual measure	Year	Initial outlay of costs ($)	Total energy savings (ekWh)	Annual GHG reduction (tCO_2e)	Total net annual savings ($)	NPV ($)
Lighting fixtures like-for-like replacement	2024	$ 12,073	0	0.0	$ -	-$ 11,389
Full refrigeration plant like-for-like replacement	2025	$ 506,000	0	0.0	-$ 10,000	-$ 699,674
Resurfacing machine like-for-like replacement	2030	$ 112,200	0	0.0	-$ 600	-$ 111,149
Replace space heating and cooling equipment in Eagles Nest	2035	$18,480	0	0.0	$ -	-$ 12,713
Propane DHW with like-for-like replacement	2040	$ 23,100	0	0.0	$ -	-$ 13,766
Propane IR heaters like-for-like replacement	2040	$ 19,200	0	0.0	$ -	-$ 11,442
Dehumidifiers like-for-like replacement	2040	$ 121,000	0	0.0	$ -	-$ 72,108
Grand total		$ 812,053	0	-	-$ 10,600	-$ 932,241

6.1.2 Low Carbon measures without funding (based on equipment end of life)

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

For low carbon measures, the following measures are not recommended in the final implementation plan:

- Electric domestic hot water heater

- Not included as ASHP has better performance which will keep electric demand down. This option does have the more attractive NPV without funding, but this may be offset through electrical infrastructure upgrades needed.

- Exterior wall insulation upgrade
  - Not recommended due to high cost, poor NPV and disruptive to facility activities. Only recommended if the facility is required to meet low energy use intensity (EUI) and thermal energy demand intensity (TEDI) targets.
- Exterior roof insulation upgrade
  - Not recommended due to high cost, poor NPV and disruptive to facility activities. Only recommended if facility is required to meet low EUI and TEDI targets.

Table 28: Low carbon measure without funding based on typical timeline for Arena

Low carbon measure	Year	Initial outlay of costs ($)	Total energy savings (ekWh)	Annual GHG reduction (tCO_2e)	Total net annual savings ($)	NPV ($) without funding
Nighttime space heating setback	2024	$ 12,100	22,680	1.5	$ 3,930	$ 84,165
Facility-wide LED upgrade	2024	$ 23,100	9,137	0.6	$ 1,604	$ 16,489
Ice thickness optimization	2024	$ -	863	0.1	$ 149	$ 3,635
Ice temperature optimization	2024	$ -	1,903	0.1	$ 330	$ 8,019
Improve air tightness of machine room overhead door	2025	$ 3,900	3,325	0.3	$ 579	$ 9,892
Cold water ice resurfacing	2025	$ 42,790	30,860	5.9	$ 3,474	$ 108,167
VFDs on brine pumps	2025	$ 36,369	16,303	1.3	$ 2,839	$ 32,701
Refrigeration plant heat recovery	2025	$ 610,500	48,612	9.5	$ 1,193	-$ 268,557
Dehumidifier controls – daytime scheduling	2025	$ 6,325	2,460	0.2	$ 428	$ 4,168
Dehumidifier controls – night setback scheduling	2025	$ 6,325	4,668	0.4	$ 813	$ 13,112
Solar PV - 272 kW array	2025	$ 580,448	286,717	22.0	$ 49,932	$ 578,777
Electric ice resurfacing machine	2030	$ 167,200	1,457	0.8	-$ 85	-$ 140,005
Convert deep fryer to electric	2030	$ 2,300	0	0.1	-$ 28	-$ 1,395
ASHP replacement of air conditioning and electric duct heating	2035	$ 39,600	27,394	0.8	$ 4,771	$ 41,131
ASHP domestic hot water heater	2040	$ 220,800	36,126	13.9	$ 1,340	$ 6,598
Electric radiant heaters	2040	$ 33,028	2,419	2.4	-$ 422	-$ 2,125
Grand total		$ 1,784,785	494,925	43.7[3]	$ 70,847	$ 494,771

[3] The individual measures listed cannot be simply summed up to determine the total GHG reduction, as their interactive effects need to be considered. The grand total here accounts for the interactive effects of the 20-year scenario (refer to Table 1)

6.1.3 Low carbon measures with funding

The following scenario incorporates low/zero carbon measures with funding from the Green and Inclusive Community Buildings (GICB) initiative available from Infrastructure Canada until February 28, 2023. This assumes the municipality will apply for the available funding of 80% of the costs for projects up to a maximum of $3 million in project costs. The scenario covers an aggregate of low carbon measures with a total initial cost outlay of $1,784,785 (in 2023 dollars, excluding inflation and other market effects).

The table below compares the costs of implementing the same measures with funding in an aggressive timeline (less than 5 years if eligible for funding), summarized by system type. The measures not eligible for external funding are recommended to be installed at the current equipment end-of-life. The low carbon measures with funding scenario has the highest NPV, delivering the highest cost savings over the current baseline for the 30-year period examined.

The annual GHG reduction is calculated based on the year in which the measure is installed. It's important to note that since emissions from the grid are expected to decrease over time, the annual GHG reduction of certain measures may vary depending on the year they are implemented. Therefore, the figures below may reflect different Annual GHG reductions for different implementation years.

Table 29: Low carbon measures with funding based on aggressive timeline for Arena

Low carbon measure	Year	Initial outlay of costs ($)	Total energy savings (ekWh)	Annual GHG reduction (tCO_2e)	Total net annual savings ($)	NPV ($) with funding
Nighttime space heating setback	2024	$ 12,100	22,680	1.5	$ 3,930	$ 93,297
Facility-wide LED upgrade	2024	$ 23,100	9,137	0.6	$ 1,604	$ 33,923
Ice thickness optimization	2024	$ -	863	0.1	$ 149	$ 3,635
Ice temperature optimization	2024	$ -	1,903	0.1	$ 330	$ 8,019
Improve air tightness of machine room overhead door	2025	$ 3,900	3,325	0.3	$ 579	$ 12,752
Cold water ice resurfacing	2025	$ 42,790	30,860	5.9	$ 3,474	$ 139,548
VFDs on brine pumps	2025	$ 36,369	16,303	1.3	$ 2,839	$ 59,372
Refrigeration plant heat recovery	2025	$ 610,500	48,612	9.5	$ 1,193	$ 179,157
Dehumidifier controls – daytime scheduling	2025	$ 6,325	2,460	0.2	$ 428	$ 8,806
Dehumidifier controls – night setback scheduling	2025	$ 6,325	4,668	0.4	$ 813	$ 17,750
Solar PV - 272 kW array	2025	$ 580,448	286,717	22.0	$ 49,932	$ 1,004,453
ASHP Replacement of air conditioning and electric duct heating	2025	$ 39,600	27,394	2.1	$ 4,771	$ 103,707
ASHP domestic hot water heater	2025	$ 220,800	36,126	12.0	$ 1,340	$ 164,180
Electric ice resurfacing machine	2030	$ 167,200	1,457	0.8	-$ 85	-$ 140,005
Convert deep fryer to electric	2030	$ 2,300	0	0.1	-$ 28	-$ 1,395
Electric radiant heaters	2040	$ 33,028	2,419	2.4	-$ 422	-$ 2,125
Grand total		$1,784,785	494,925	41.2[3]	$ 70,847	$ 1,685,074

6.2 Eganville Curling Club – measure summaries

6.2.1 Business-as-usual measures

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

Table 30: Business-as-usual measures for Curling Club

Business-as-usual measure	Year	Initial outlay of costs ($)	Total energy savings (ekWh)	Annual GHG reduction (tCO_2e)	Total net annual savings ($)	NPV ($)
Lighting fixtures like-for-like replacement	2025	$ 4,323	0	0.0	$ -	-$ 3,963
Full refrigeration plant like-For-like Replacement	2030	$ 247,500	-2,909	-5.6	-$ 11,015	-$ 410,067
Propane furnaces like-for-like Replacement	2040	$ 26,400	0	0.0	$ -	-$ 15,733
Grand total		$ 278,223	-2,909	-5.6	-$ 11,015	-$ 429,762

6.2.2 Low carbon measures without funding (based on equipment end of life)

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.

For low carbon measures, the following measures are not recommended in the final implementation plan:

- Exterior wall insulation upgrade
    - Not recommended due to high cost, poor NPV and disruptive to facility activities. Only recommended if the facility is required to meet low energy use intensity (EUI) and thermal energy demand intensity (TEDI) targets.
- Exterior roof insulation upgrade
    - Not recommended due to high cost, poor NPV and disruptive to facility activities. Only recommended if facility is required to meet low EUI and TEDI targets.

Table 31: Low carbon measure without funding based on typical timeline for Curling Club

Low carbon measure	Year	Initial outlay of costs ($)	Total energy savings (ekWh)	Annual GHG reduction (tCO_2e)	Total net annual savings ($)	NPV ($) without funding
Ice thickness optimization	2024	$ -	178	0.0	$ 31	$ 748
Suspended low e-ceiling	2025	$ 17,380	5,302	0.4	$ 923	$ 5,545
Facility-wide LED upgrade	2025	$ 4,180	1,252	-0.1	$ 310	$ 154
Ice temperature optimization	2025	$ -	344	0.0	$ 60	$ 1,391
Solar PV - 67.9 kW Array	2025	$ 156,085	71,517	5.5	$ 12,455	$ 133,997
ASHP replacement of propane fired furnace	2030	$ 70,400	37,149	12.8	$ 1,429	$ 140,130
Convert refrigerant to ammonia	2030	$ 912,000	5,347	6.8	-$ 8,549	-$ 885,120
Install dehumidifier	2030	$ 60,500	-7,084	-0.4	-$ 1,234	-$ 71,068
Dehumidifier controls – Daytime scheduling	2030	$ -	276	0.0	$ 48	$ 898
Dehumidifier Controls – Night setback scheduling	2030	$ -	524	0.0	$ 91	$ 1,704
Install ERV to provide space ventilation	2040	$ 52,800	-7,629	-1.5	-$ 810	-$ 52,775
VFDs on brine pumps	2045	$ 20,000	530	0.0	$ 92	-$ 9,730
Grand Total		$ 1,293,345	107,706	24.2[3]	$ 4,848	-$ 734,126

6.2.3 Low carbon measures with funding

The following scenario also incorporates low/zero carbon measures with funding from the Green and Inclusive Community Buildings (GICB) initiative. This assumes the municipality will apply for the available funding of 80% of the costs for projects up to a maximum of $3 million in project costs. The scenario covers an aggregate of low carbon measure with a total initial cost outlay of $1,293,345 (in 2023 dollars, excluding inflation and other market effects).

The table below compares the costs of implementing the same measures with funding in an aggressive timeline (less than 5 years if eligible for funding). The measures not eligible for external funding are recommended to be installed at the current equipment end-of-life. The "Low carbon measures with funding" scenario has the highest NPV, delivering the highest cost savings over the current baseline for the 30-year period examined.

The annual GHG reduction is calculated based on the year in which the measure is installed. It's important to note that since emissions from the grid are expected to decrease over time, the annual GHG reduction of certain measures may vary depending on the year they are implemented. Therefore, the figures below may reflect different annual GHG reductions for different implementation years.

Table 32: Low carbon measures with funding based on aggressive timeline for Curling Club

Low carbon measure	Year	Initial outlay of costs ($)	Total energy savings (ekWh)	Annual GHG reduction (tCO_2e)	Total net annual savings ($)	NPV ($) with funding
Ice thickness optimization	2024	$ -	178	0.0	$ 31	$ 748
Suspended low-e ceiling	2025	$ 17,380	5,302	0.4	$ 923	$ 18,291
Facility-wide LED upgrade	2025	$ 4,180	1,252	-0.1	$ 310	$ 3,220
Ice temperature optimization	2025	$ -	344	0.0	$ 60	$ 1,391
Solar PV - 67.9 kW array	2025	$ 156,085	71,517	5.5	$ 12,455	$ 242,566
ASHP replacement of propane fired furnace	2025	$ 70,400	37,149	12.3	$ 1,429	$ 196,935
Convert refrigerant to ammonia	2025	$ 912,000	5,347	6.9	-$ 8,549	-$ 366,434
Install dehumidifier	2025	$ 60,500	-7,084	-0.5	-$ 1,234	-$ 39,787
Dehumidifier controls – Daytime scheduling	2025	$ -	276	0.0	$ 48	$ 1,119
Dehumidifier controls – Night setback scheduling	2025	$ -	524	0.0	$ 91	$ 2,123
VFDs on brine pumps	2025	$ 20,000	530	0.0	$ 92	-$ 1,520
Install ERV to provide space ventilation	2040	$ 52,800	-7,629	-1.5	-$ 810	-$ 52,775
Grand total		$ 1,293,345	107,706	24.3[3]	$4,848	$ 5,877

6.3 Comparative costs and NPV by year – Eganville Arena

The following table highlights capital requirements by year for the first replacement of equipment, taking into consideration inflation, annual energy emission savings, and cost escalations into the NPV calculation. The costs of maintenance and scheduled equipment replacements, such as plant maintenance or PV inverter replacements are not listed but are accounted for in the NPV presented.

Table 33: Financial summary year for the Arena – Business-as-usual scenario

Business-as-usual year of replacement	Initial outlay of costs with inflation ($)	NPV ($)
2024	$ 12,073	-$ 11,389
2025	$ 506,000	-$ 699,674
2030	$ 112,200	-$ 111,149
2035	$ 18,480	-$ 12,713
2040	$ 163,300	-$ 97,316
Grand total	$ 812,053	-$ 932,241

Table 34: Financial summary by year for the Arena – Low carbon without funding scenario

Low carbon without funding year of replacement	Initial outlay of costs with inflation ($)	NPV without funding ($)
2024	$ 35,200	$ 112,309
2025	$ 1,286,657	$ 478,260
2030	$ 169,500	-$ 141,400
2035	$ 39,600	$ 41,131
2040	$ 253,828	$ 4,472
Grand total	$ 1,784,785	$ 494,771

Table 35: Financial summary by year for the Arena – Low carbon with funding scenario

Low carbon year of replacement with funding	Initial outlay of costs with inflation ($)	NPV with funding ($)
2024	$ 35,200	$ 138,875
2025	$ 1,547,057	$ 1,689,725
2030	$ 169,500	-$ 141,400
2040	$ 33,028	-$2,125
Grand total	$ 1,784,785	$1,685,074

For the aggressive pathway, the electric ice resurfacing machine, electric IR heaters and electric deep fryer are included for capital planning even though the ice resurfacing machine and deep fryer are not eligible for funding. The electric IR heaters are not recommended in the first 5 years as they would add significant electric demand and can be replaced on a typical timeline.

6.4 Comparative costs and NPV by year – Eganville Curling Club

The following table highlights capital requirements by year for the first replacement of equipment, taking into consideration inflation, annual energy emission savings, and cost escalations into the NPV calculation. The costs of maintenance and scheduled equipment replacements, such as plant maintenance or PV inverter replacements are not listed but are accounted for in the NPV presented.

Table 36: Financial summary year for the Curling Club – Business-as-usual scenario

Business-as-usual year of replacement	Initial outlay of costs with inflation ($)	NPV ($)
2025	$ 4,323	-$ 3,963
2030	$ 247,500	-$ 410,067
2040	$ 26,400	-$ 15,733

Grand total	$ 278,223	-$ 429,762

Table 37: Financial summary by year for the Curling Club – Low carbon without funding scenario

Low carbon without funding year of replacement	Initial outlay of costs with inflation ($)	NPV with funding ($)
2024	$0	$748
2025	$177,645	$141,088
2030	$972,500	-$953,586
2040	$123,200	$87,354
2045	$20,000	-$9,730
Grand total	$1,293,345	-$734,136

Table 38: Financial summary by year for the Curling Club – Low carbon with funding scenario

Low carbon with funding year of replacement	Initial outlay of costs with inflation ($)	NPV without funding ($)
2024	$0	$748
2025	$1,240,545	$57,904
2040	$52,800	-$52,775
Grand total	$1,293,345	$5,877

The ERV is included for capital planning even though it is not implemented in the first 5 years of the aggressive pathway. It does not provide GHG or energy reductions but is instead recommended for occupant health and wellness.

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 Section 6.

Sections 7.1 and 7.2 present the current and projected greenhouse gas intensities (GHGI). The 10 and 20 year marks are solved using projected GHG factors for 2034 and 2044 respectively. For the 5 year aggressive approach, the projected GHG factor for 2029 was used.

7.1 Eganville Arena 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.

Table 39: Projected GHG emissions reductions to meet 50% GHG reductions in 10 years and 80% GHG reductions in 20 years (typical timeline)

GHG emission savings	Current	10 year forecast	20 year forecast
Electricity emissions (tCO_2e)	26.4	1.8	0.9
Propane emissions (tCO_2e)	18.1	3.9	-
Total emissions (tCO_2e)	44.6	5.7	0.9
GHGI ($kgCO_2e/ft^2$)	1.6	0.2	0.0
ILCC/tCO_2e (in dollars)	-	$32,682	$55,561
% Saving	-	87.3%	98.1%

Table 40: Projected GHG emissions reductions with aggressive 5-year timeline[4]

GHG emission savings	Current	5 year forecast
Electricity emissions (tCO_2e)	26.4	3.0
Propane emissions (tCO_2e)	18.1	3.7
Total emissions (tCO_2e)	44.6	6.7
GHGI ($kgCO_2e/ft^2$)	1.6	0.2
ILCC/tCO_2e (in dollars)	-	$69,920
% Saving	-	85.0%

The Eganville Arena has significantly positive incremental life cycle cost which shows that for each tonne of CO_2e reduced, there is a financially attractive NPV and cashflow for both pathways.

For the aggressive pathway, the energy use and GHG savings of the electric ice resurfacing machine, electric IR heaters and electric deep fryer are not included, as the ice resurfacing machine and deep fryer are not eligible for funding. The electric IR heaters are not recommended as they would add significant electric demand. They can be avoided while still meeting the 80% GHG savings target.

7.2 Eganville Curling Rink pathways

The tables below show the low carbon greenhouse gas emissions intensity (GHEI) 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.

[4] Only measures eligible for funding sources are presented in the aggressive scenario results (first 5 years).

Table 41: 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)	3.1	0.06	0.13
Propane emissions (tCO_2e)	14.7	-	-
Refrigerant emissions (tCO_2e)	6.5	-	-
Total emissions (tCO_2e)	24.3	0.06	0.13
GHGI ($kgCO_2e/ft^2$)	2.8	0.006	0.015
$ILCC/$tCO_2e$	-	-$16,395	N/A
% savings	-	99.8%	99.5%

As the emissions in the Eganville Curling Club facility are largely due to R-22 refrigerant leakage and the propane-fired furnace use, essentially all on-site emissions are eliminated. The rooftop PV array would offset the electricity consumption to help bring the facility to a near net-zero facility. It should be noted that the PV array capacity was specifically sized to meet the electricity needs of these measures, as there is more roof space than required to meet the facility needs.

Electricity emissions decrease as the electric grid gets cleaner over the study period, which adds to the overall savings from the first year. At Year 20, the typical pathway shows an increase in emissions due to the addition of an energy recovery ventilator (ERV), which adds heating, cooling, and fan power consumption.

Incremental Life Cycle Cost is negative at the 10-year mark, largely due to the significant cost of the ammonia plant replacement, which will be required as HFCs are phased out. $ILCC/$tCO_2e$ is not listed for the 20-year mark, as there is an increase in emissions from the addition of the ERV.

Table 42: Projected GHG emissions reductions where most measures are implemented in first 5 years to take advantage off funding opportunities (aggressive timeline)[4]

GHG emissions savings	Current	5 year
Electricity emissions (tCO_2e)	3.1	0.05
Propane emissions (tCO_2e)	14.7	-
Refrigerant emissions (tCO_2e)	6.5	-
Total emissions (tCO_2e)	24.3	0.05
GHGI ($kgCO_2e/ft^2$)	2.8	0.006
$ILCC/$tCO_2e$	-	$20,143
% Saving	-	99.8%

In the aggressive pathway, funding is applied for measures that are eligible and shows a much improved $ILCC/tCO$_2$e. This is largely due to external funding which improves the NPV of the ammonia plant replacement of the existing R-22 plant.

The energy use of the ERV is not included in the aggressive pathway as it does not provide GHG or energy reductions but is instead implemented for occupant health and wellness.

8 Cash flows

The following graphs show the changes in cash flow and reduction in emissions over time for the three scenarios described. Inflation rates, escalation rates, operations and maintenance and cost savings are embedded in the NPV analysis which is presented through the cashflow diagrams.

8.1 Eganville Arena

Under the Business-as-usual scenario, cash flow remains negative for the entire period since no savings are achieved. Cashflow trends downwards due to the addition of maintenance costs annually.

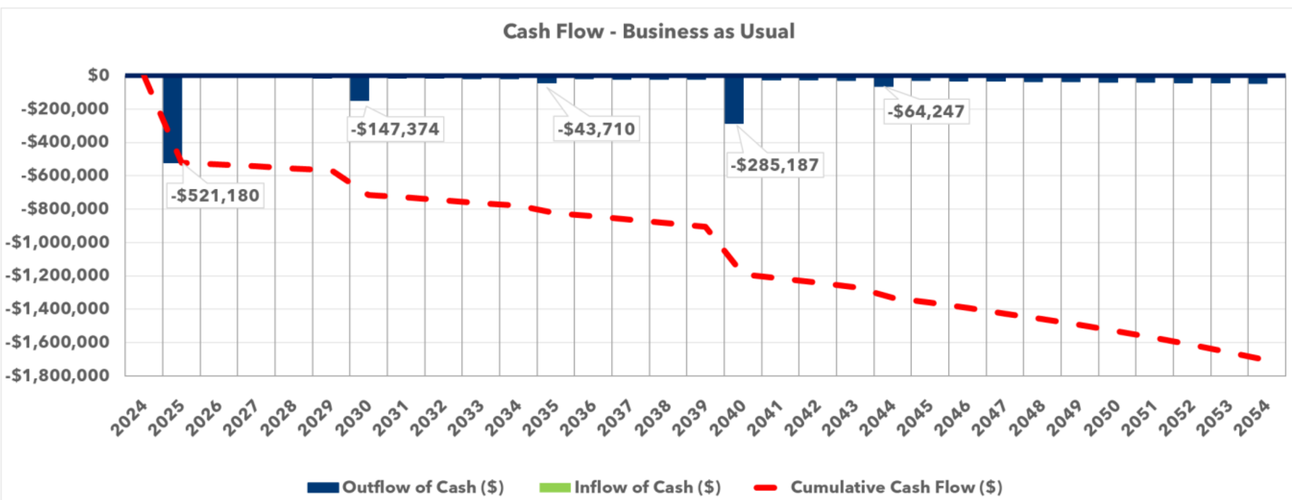


Figure 9: Cash Flow – Business as usual – Eganville Arena

In the Low Carbon without funding scenario, the targeted emission savings are achieved. The highest capital investment is required in the year 2025 and in 2040. The breakeven point is reached in 2043. Cumulative cashflow at the end of the study period is approximately $4M.

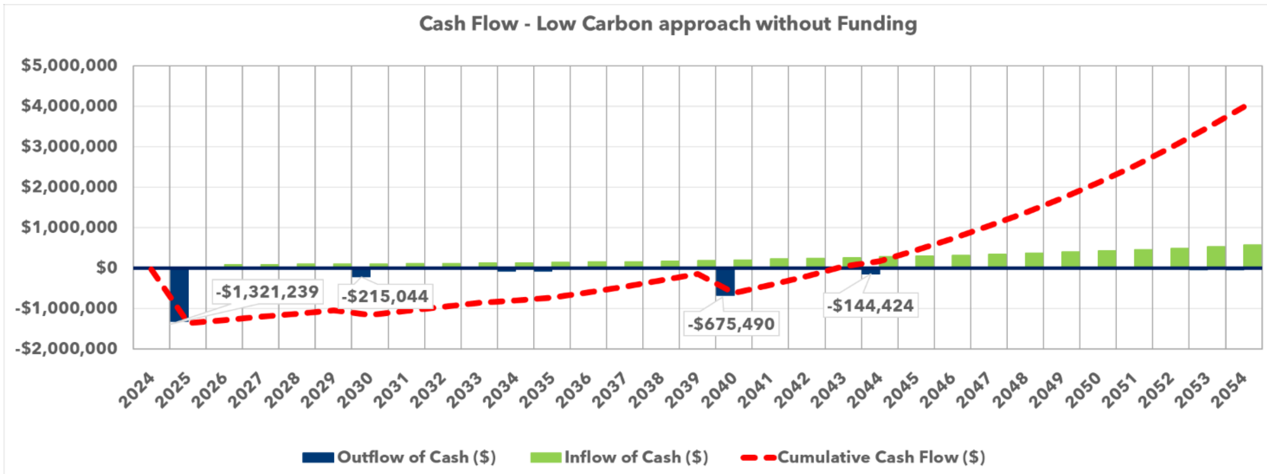


Figure 10: Cash flow – Low carbon approach without funding

Cash flows for the low carbon with funding scenario are similar but less initial capital investment is required with external funding, as most measures are implemented in the first 5 years with 80% funding. The breakeven year is 2029, and again in 2031, after ice resurfacing machine replacements. Cumulative cashflow at the end of the study period is approximately $5.6M.

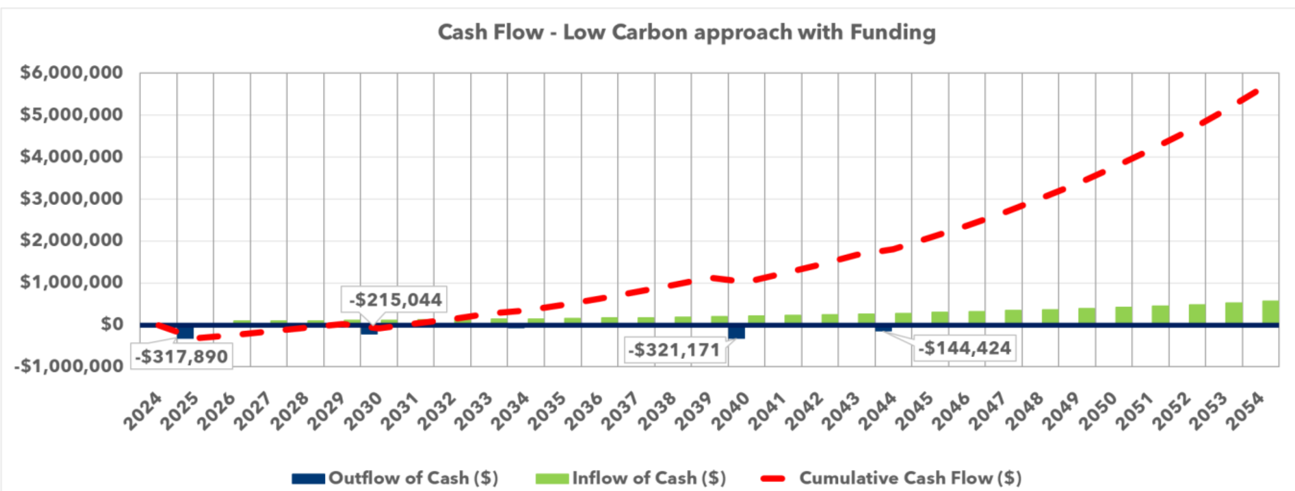


Figure 11: Cash flow – Low carbon approach with funding

8.2 Eganville Curling Club

Under the Business-as-usual scenario, cash flow remains negative for the entire period since no savings are achieved. Cash flow trends downwards due to the addition of maintenance costs annually.

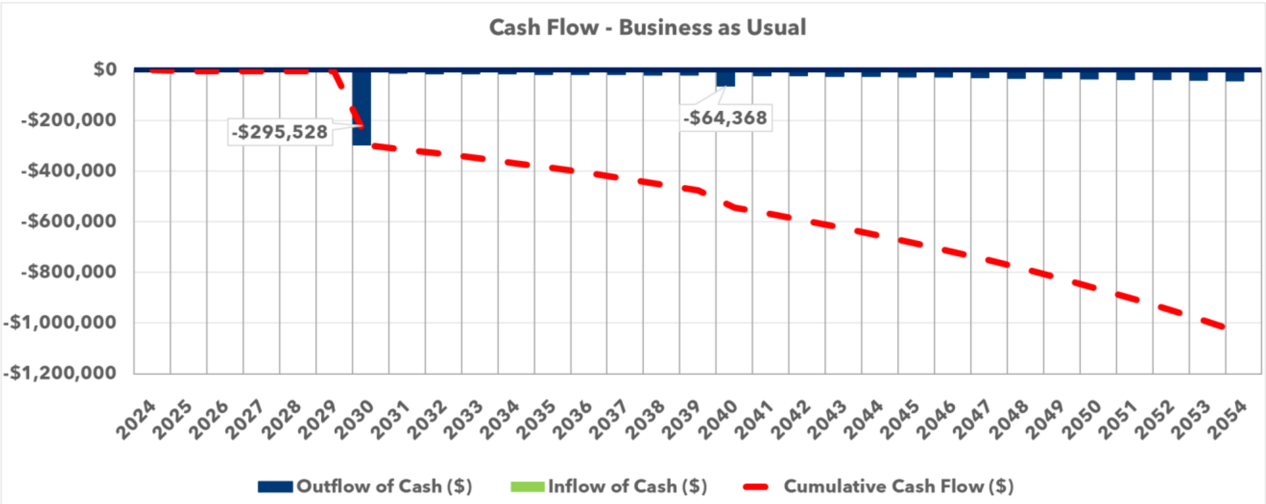


Figure 12: Cash flow – Business as usual – Eganville Arena

In the low carbon without funding scenario, the targeted emission savings are achieved. The highest capital investment is required in the year 2025 and in 2030. There is no breakeven point reached within the study period due to the significant cost of conversion of the ice plant to be ammonia based.

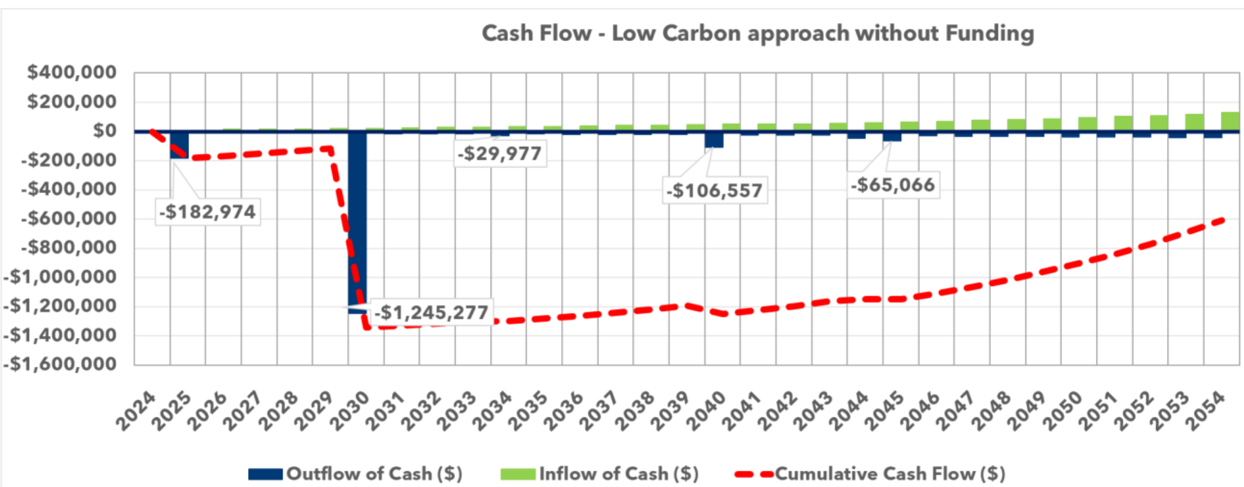


Figure 13: Cash flow – Low carbon approach without funding

Cash flows for the low carbon with funding scenario are similar but less initial capital investment is required with external funding, as most measures are implemented in the first 5 years with 80% funding. The breakeven year is 2045, after the ERV addition. Cumulative cashflow at the end of the study period is approximately $550,000.

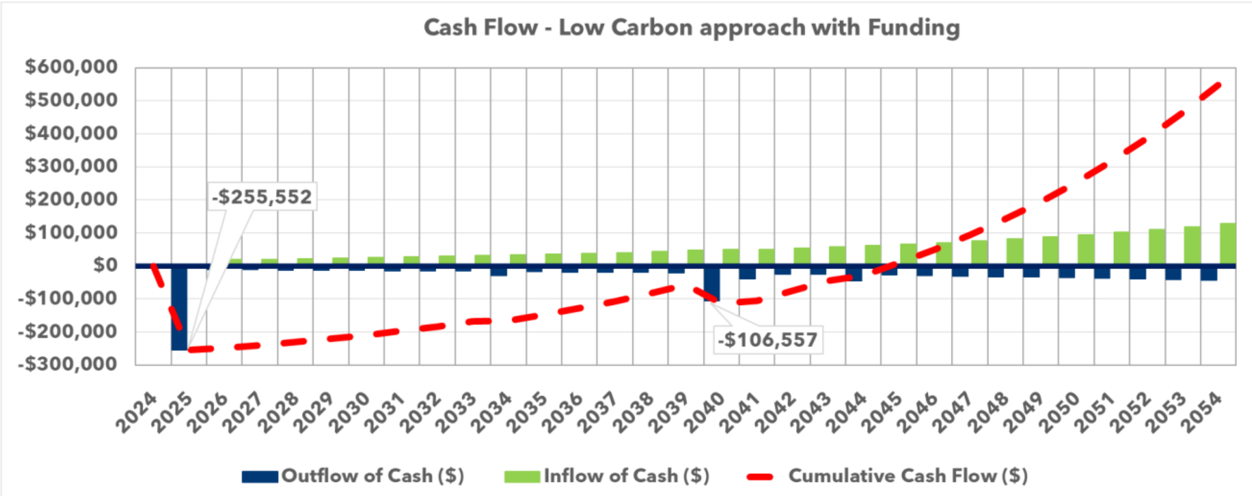


Figure 14: Cash Flow – Low carbon approach with funding

9 Implementation support

Implementation support is essential to bringing this and other related plans to life. This was discussed with the municipal team during the integrated design workshops. Areas identified included funding for the measures/projects (and support for the associated funding applications), training and procurement.

9.1 Funding opportunities

There are several funding opportunities currently available to financially support the implementation of the plan. These funding opportunities (at the time of the study) include the following:

9.1.1 Infrastructure Canada Green and Inclusive Community Buildings (GICB) Program funding

https://www.infrastructure.gc.ca/gicb-bcvi/index-eng.html

Funding is provided for 80% of eligible project costs. Applicants with small and medium retrofit projects to existing community buildings ranging in total eligible cost from $100,000 to $3 million were accepted until February 28, 2023. All retrofit projects must be planned to be completed before March 31, 2026. Additional support may be needed for the funding application.

9.1.2 Canada Community Revitalization Fund (CCRF)

https://www.wd-deo.gc.ca/eng/20176.asp

Funding is provided for up to $750,000 but projects must be completed on or before March 31, 2023.

9.1.3 Federation of Canadian Municipalities Community Buildings Retrofit (CBR) funding

The project must have a minimum of 30% reduction in GHG emissions. Financing (loan and grant) is provided up to $5 million dollars. Application details are on the CBR webpage **(https://fcm.ca/en/programs/green-municipal-fund/community-buildings-retrofit-initiative).**

9.2 Ongoing support through the Mayors' Megawatt Challenge (MMC) program

As part of this study, the municipality can participate in the Mayors' Megawatt Challenge (MMC), a program working directly with municipalities to reduce energy use and greenhouse gas emissions in their own municipal buildings. In consultation with participating municipalities and experts, the MMC program will be developing implementation and procurement support – such as identifying outside help that might be needed, training needs, business cases and RFP support. Through the program, facility staff, particularly building operators, can share best practices with other operators (both from within and outside of our municipality).

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, the views expressed are the personal views 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 visit data collection

Site name	Eganville Arena
Participants performing site visit	Frank Cammalleri; Ahmad Nasrallah; Kajen Ethirveerasingham
Date performed	27-10-2022

Building details

Gross floor area	27,260 ft2
Number of stories	1 floor
Number of rinks	1 rink
Area of rinks	13,884 ft2
Dimensions of rinks	178 ft x 78 ft
Area of other significant spaces	Sqft
Construction date	1966
Use of facility	Ice rink

Systems to consider

System	Present	Drawings available	Notes
Fan Systems (AHUs/RTU)	☐	☐	Arena dehumidifiers: 2 York 13 SEER 5-ton r-4117 refrigerant condensing units and 2 York 5-ton fan coils with evaporators. purchased from Temp-Tech (2009) no air-conditioning in other spaces except in eaglenest which is served by units mounted above reflected ceiling (nameplates will be provided by rink operators)
Refrigeration Plant	☐	☐	*Ammonia chillers (2003) *Ammonia plant valve upgrade – CIMCO (2019) *1st dry solution dehumidifier (2017) serving ice rink arena *2nd dry solution dehumidifier (2017) serving ice rink arena *~~40hp~~ mycom compressor ~~(1998)~~ #2 model n6wa with a weg 40 hp motor; date 2018 *~~47hp~~ mycom compressor #1~~(2018)~~ model n4wa with a leeson 30hp motor; date 2002 *CIMCO brine pump and tank ~~(1979)~~; weg motor 15hp; sn

System	Present	Drawings available	Notes
			1023768733; model 01518ot3h254t-s *baltimore aircoil condenser ~~(1979)~~; model no. vc1-72, serial no. c02034980, belno. b78, crn no. 0h7705.5
Heating (boilers, DHW)	☐	☐	*Arena - five propane heaters (2017) *One propane heater I each of changing rooms 6 and 7 *One propane heater in Zamboni technical room *RSME16-11-2 - duct heating 2011 (Eagle's Nest) (2011) *Two domestic hot water propane heaters located in the front technical room and serving changing room (1 TO 5) toilets and kitchen at GF. *One hot water propane heater serving Zamboni equipment and changing rooms 6&7 toilet. Water temp measured at Zamboni connection was about 68 deg C
Solar PV	☐	☐	NO solar PV on site
Geothermal (GSHP)	☐	☐	NO geothermal on site
Water	☐	☐	Refrigeration compressors are water cooled. ¾" pipe branches to two ½" pipes (one to each compressor) running for around 3000 hrs/year
Lighting	☐	☐	Arena (ice rink)- LED lighting (2016); 32 round fixtures Other areas are still using T8 lighting
BAS	☐	☐	
Other:			*Arena - Eagles Nest (1984) *Arena - new boards, glass, and timekeepers booth – (2017) *Arena - Roof replacement – 2014 *Nevco 4720 scoreboard (2010) *Generac generator (2021) *Arena - front entrance (1984) *2 x electric wall mounter heaters in lobby

System	Present	Drawings available	Notes
Other: Ice Rink Floor	☐	☐	*Arena - inline hockey flooring (2011) *Arena - brine lines, header pipe, cement pad (2017) *

Drawings

Drawing	Drawings available	Notes
Architectural Drawings	☐	*There are no as built drawings. The only available drawings are the fire plans. *Wall construction material specifically Insulation type is unknown *There is not much glazing on the façade. Limited to few windows at Eagles Nest. *Floor areas with room types/functions: GF main functions are main entrance, main lobby, office, ice rink, two technical rooms, refrigeration plant room, kitchen, toilets, seven Locker and changing rooms with their toilets room. FF main functions are the Eagles Nest main Hall, a kitchen, a bar, male and female toilets. *Doors and building tightness / infiltration. There is infiltration especially in the ice rink area from exhaust and supply fan dampers and from Zamboni rolling shutter door.
Heating Drawings (including Boilers/DHW heating)	☐	*No As-builts *Check Equipment nameplates and main valves
Heating Riser Diagram	☐	*No As-builts *Generate a basic schematic if as-builts are not available
Ventilation Drawings (Fan Systems)	☐	*No As-builts *Check all Exhaust, Supply, Return and make-up fans
Ventilation Riser Diagram	☐	*No As-builts

Drawing	Drawings available	Notes
		*Generate a basic schematic if as-builts are not available
Cooling System Drawings (Building Cooling if separate Cooling Plant)	☐	*No As-builts *Check for chillers, AHUs, RTUs, FCUs, Split units, chilled water pumps, main valves etc.
Chilled Water Riser Diagram	☐	*No As-builts *Generate a basic schematic if as-builts are not available
Refrigeration Plant	☐	*No As-builts *Check for refrigeration system equipment such as chillers, pumps, main valves, etc.
Refrigeration system riser diagram	☐	*No as-builts *Generate a basic schematic if as-builts are not available

Architectural

Photos Photos were taken since there are no architectural drawings	
Building Exterior (different faces show wall finish and windows)	☒
Interior (typical wall construction, window types, ceiling)	☒
Roof (if easily accessible)	☐
Is there a low e-ceiling over the rink?	yes
General notes on architectural details related to the building envelope (doors, windows, insulation, etc. to determine its current condition)	
*There are no as builts. The only available drawings are the fire plans. *Wall construction material specifically Insulation type is unknown *Glazing areas - there is not much glazing on the façade. Limited to few windows at Eagles Nest. type, U-Value, and shading coefficient? *Floor areas with room types/functions: GF main functions are main entrance, main lobby, office, ice rink, two technical rooms, refrigeration plant room, kitchen, toilets, seven locker and changing rooms with their toilets room. FF main functions are the Eagles Nest main hall, a kitchen, a bar, male and female toilets. *Doors and building tightness / infiltration. There is infiltration especially in the ice rink area from exhaust and supply fan dampers and from Zamboni rolling shutter door. From site visit: - Walls originally wood structure, upgraded to have estimated 6in batt insulation with metal siding, with studs.	

Heating

Boilers			
How many boilers are there in total?	There are no boilers in the building		
Boiler name	Purpose: (space heating, DHW, both)	Temp setpoint	Current temp reading
Describe the age/condition of heating components including boiler type *(I.e., atmospheric, fan assisted, power burners)*			
Is there an unoccupied temperature set back in place? If so, describe the set points during unoccupied periods.			

Boilers	☐
Pumps	☒
VFDs	☐
Motors	☒
Gas fired heaters	☒
Other ____condenser units serving the Eagles Nest_______	☒
Other ____electric baseboard, electric fan heaters, electric wall heaters_______	☐

How is heating system controlled? *(BAS, manually, or other)*	Manually
Do they have their own controllers?	Yes, there are thermostats
Are the controllers integrated with BAS?	No
Are there standalone thermostats	Yes, there are standalone thermostats
How is the spectator area heated?	
The spectator area is heated using 5 IR gas fired heaters	
Are there any air curtains on the doors (typically with overhead doors)?	
No	
Are the doors interlocked with any heating (typically with overhead doors)?	
No	
Approximate frequency and duration for doors opening?	
Not available	

Gas fired heaters		
How many gas fired heaters are there in total?		
Name	Capacity	Location served
		5 serving the arena
		1 in changing room 6
		1 in changing room 7
		1 in Zamboni technical room

Ventilation and air conditioning table

Please include all motors, fans, chillers, cooling towers, pumps, AHUs, RTUs, FCUs, humidifiers, recovery units, etc.

Name	Photo of nameplate	Control method (BAS or standalone)	Location	Area/zone served	Operation schedule	Age/ condition
Arena supply fan	☐	Standalone	Arena wall	Ice rink	In summer during events	Old
Arena exhaust fan	☐	Standalone	Arena wall	Ice rink	In summer during events	Old
FCU-1 with DX Condenser CU-1	☐	Standalone	Ceiling of Eagles Nest hall	Eagles Nest Hall and Eagles Nest kitchen and bar	When the hall is occupied	Not old
FCU-2 with DX Condenser CU-2	☐	Standalone	Ceiling of Eagles Nest Hall	Eagles Nest Hall and Eagles Nest Kitchen and Bar	When the hall is occupied	Not old
Dehumidifier-1	☐	Standalone	Arena- mezzanine	Ice rink arena	When ice rink is operated	New
Dehumidifier-2	☐	Standalone	Arena- mezzanine	Ice rink arena	When ice rink is operated	New
Other exhaust fans in toilets and kitchens	☐					
	☐					
	☐					
	☐					
	☐					
	☐					
	☐					

Refrigeration system

Capacity of system			
Type of controls Ice IR sensors, ice slab sensor and/or brine water return temperature			
Compressors, pumps, evaporative fans			
Name	Type	Photo of nameplate	Control method (BAS or Standalone)
Mycom Compressor #2 Model	N6WA with a Weg 40 HP motor; Date 2018	☐	
Mycom Compressor #1	Model N4WA with a LEESON 30HP motor; Date 2002	☐	
CIMCO brine pump and tank	WEG motor 15HP; SN 1023768733; model 01518OT3H254T-S	☐	
*Baltimore aircoil condenser	Model no. VC1-72, Serial No. C02034980, BelNo. B78, CRN No. 0H7705.5	☐	
		☐	
		☐	
		☐	
		☐	
		☐	
What are the ice temp set points during different activities?			
No			
What are the ice set back temperatures?			
The ice slab temp is18 to 19 deg F when the weather is cold, 15-16F when warm			
Is there any heat recovery? For ice melting, underfloor, heating system?			
NO			
What is the under slab setpoint temp (if this is used to control ice temperature)?			
Age and condition of existing equipment			
Varies from 1979 to 2017			
Are there any VFDs on any refrigeration equipment (pumps, compressors, cooling tower fans) and if so, specify on which equipment?			

Are there trend logs? What for? Approximate date range?
NO

Ice rink

When is the ice in and out?	Second week of September to end of March, rink is operational
What kind of activity does the rink experience? *Ice hockey, figure skating, public skate etc.*	
Ice hockey, figure skating, public skate	
Temperature at which the ice is maintained?	18 to 19 when it is cold and 15 to 16 when it is mild
Nighttime setback temperature for ice?	
RH is the rink controlled to	Initially at 40% but settles at 55%
Space temp of the rink	30-40F estimation
Setpoints based on activities	
Nighttime setback for space temp	
Setpoints for summer	
Setpoints for winter	
Intended/target ice thickness	½ in ice + whitewash + ¼ in ice + lines + ¾ in ice Learned recently that this rink was the only rink to add layer of ice between whitewash and lines. More cleanup needed when paint is closer to concrete
Take pictures of	
Lighting layout	☒
Lighting fixtures	☒
Ceiling	☒
Walls	☒
Any windows	☒
What types of lighting are in the rink? (i.e., fluorescent T8/T5, LED)	
Dimmable LEDs	
Spectator Areas	
How are they heated? *Gas fired Infrared*	5 x Gas Fired IR, ice rink does not have heated slab underneath
How often and for how long is spectator heating used	
Coldest months	

Ice Resurfacing Machine

Number of resurfacing machines	1 Zamboni machine (Olympia Millennium SD)
How are they powered? *gas, electric, propane, etc.*	
How many times a day is the ice resurfaced?	
On typical weekday	Every 1 hr for 10 min period (1x an hour) If there are junior games,1 every 20 mins for 10 min (2x an hour)
On typical weekend	Every 1 hr for 10 min period (1x an hour) If there are junior games,1 every 20 mins for 10 min (2x an hour)
Water temp in ice resurfacing machine	Setpoint is 180F with setback of 140F. Measured temp out of hose was 155F.
Do they have REALice?	No
Is RO water used for resurfacing?	No
What volume of water does Ice resurfacing machine hold?	Was told between 160 and 180 gallons. Model allows up to 210 USGal, from picture on water level, it is filled about 90% or 190 USGal
Approximately what % of total water is used during resurfacing	90%
Take a picture of the nameplate and model number	Picture of shop drawing and brochure specs available

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 BAS	
How do operators use the BAS?	
NO BAS	
Do they actively change setpoints?	
NO BAS	
Do they update schedules for activities* on an ongoing basis and edit the equipment schedules accordingly or do they leave the schedules and setpoints alone regardless of activities on ice? **Activities meaning Ice hockey, figure skating, public skate etc.*	
NO BAS	

Site visit data collection

Site name	Eganville Curling Club
Participants performing site visit	Frank Cammalleri; Ahmad Nasrallah; Kajen Ethirveerasingham
Date performed	27-10-2022

Building details

Gross floor area	8,750 ft2
Number of stories	2
Number of rinks	1
Area of rinks	2 x 144 x 15 = 2 x 2,160 ft2 = 4,320ft2
Dimensions of rinks	
Area of other significant spaces	Curling Club upper floor (one large open space currently being renovated, area was estimated from google earth) = 51 x 30 = 1,530 ft2 Curling Club basement (constitutes of several smaller rooms) = 1530 ft2
Construction date	
Use of facility	Public recreation

Systems to consider

System	Present	Drawings available	Notes
Fan systems (AHUs/RTU)	☐	☐	No mechanical cooling provided. There is an exhaust system in the curling club basement. There is one wall mounted exhaust fans at the curling ring and on FA louver with damper on the other end of the rink. There are also two wall mounted air circulating fans in the curling rink.
Refrigeration plant	☐	☐	There is an air-cooled refrigeration system
Heating (boilers, DHW)	☐	☐	There are no boilers in the facility. There are two furnace heaters; one serving the curling rink and the other serving the curling club.
Solar PV	☐	☐	No Solar PV
Geothermal (GSHP)	☐	☐	No Geothermal
Water	☐	☐	
Lighting	☐	☐	There is LED lighting in the curling Rink.

System	Present	Drawings available	Notes
			The curling club main hall (@ main floor) is currently being renovated and most probably will have LED lights when completed. The basement floor under the curling club has different type of lighting lamps, most of which are not LED.
BAS	☐	☐	No BAS
Other:	☐	☐	

Drawings

Drawing	Drawings available	Notes
Architectural Drawings	☐	*There are no as builts. *Wall construction material specifically Insulation type is unknown *Glazing areas - there is no glazing on the façade of the curling rink. *Floor areas with room types/functions: GF main functions are technical room housing curling rink furnace, refrigeration room, curling rink and curling club (upper ground floor). Curling Club basement consists of several rooms and toilets in addition to a small technical room which houses the furnace.
Heating drawings (including boilers/DHW heating)	☐	*No as-builts *Check equipment nameplates and main valves *There are two propane furnaces in the facility; one serving curling rink and the other serving the curling club.
Heating riser diagram	☐	*No riser diagram available.
Ventilation drawings (fan systems)	☐	*No as-builts *There is a wall mounted exhaust fan serving the curling rink. *There are small ceiling diffuser exhaust fans in the curling club rooms.

Drawing	Drawings available	Notes
Ventilation riser diagram	☐	*No riser diagram available.
Cooling system drawings (Building cooling if separate cooling plant)	☐	No cooling chilled water system
Chilled water riser diagram	☐	No cooling chilled water system
Refrigeration plant	☐	Cimco to check. Check nameplates pics. Air cooled refrigeration plant compressor.
Refrigeration system riser diagram	☐	*No riser diagram available.

Architectural

Photos If architectural drawings are available, photos are not required	
Building exterior (Different faces show wall finish and windows)	☐x
Interior (typical wall construction, window types, ceiling)	☐x
Roof (if easily accessible)	☐
Is there a low e-ceiling over the rink?	(Y/N)
General notes on architectural details related to the building envelope (doors, windows, insulation, etc. to determine its current condition)	
*There are no as builts. *Wall construction material specifically Insulation type is unknown *There is no glazing on the façade of the curling rink. *Floor areas with room types/functions: GF main functions are technical room housing curling rink furnace, refrigeration room, curling rink and curling club (upper ground floor). The Curling Club basement consists of several rooms and toilets in addition to a small technical room which houses the furnace. From site visit: - Assumed 6in batt added to curling rink walls	

Heating

Boilers			
How many boilers are there in total?	There are no boilers in the building		
Boiler name	Purpose/type: (space heating, DHW, ice resurfacing/electric, gas)	Temp setpoint	Current temp reading
Describe the age/condition of heating components including boiler type *(I.e., atmospheric, fan assisted, power burners)*			

Is there an unoccupied temperature set back in place? If so, describe the set points during unoccupied periods.
Air setback temp is 33F
Take pictures of nameplates *Remember to include the equipment name in the photo*

Boilers	☐
Pumps	☐
VFDs	☐
Motors	☐
Gas fired heaters (2 x propane furnace)	☐x
Other	☐
Other ___________	☐

How is heating system controlled? *(BAS, manually, or other)*	Manually
Do they have their own controllers?	
Are the controllers integrated with BAS?	No
If there are standalone controllers, take pictures	Yes, there are standalone thermostats

Are there any air curtains on the doors (typically with overhead doors)?
No
Are the doors interlocked with any heating (typically with overhead doors)?
No
Approximate frequency and duration for doors opening?
Not available
Auxiliary Heaters (electric radiative, gas heaters, electric baseboard, etc.)

How many gas fired heaters are there in total?			
Heater name	Heater type	Capacity	Location served
	Propane furnace (2020) – was oil based prior		Curling rink
	Propane furnace (2016)		Curling club different spaces
Heater Name	Heater type	Capacity	Location served

Ventilation and air conditioning table

Please include all motors, fans, chillers, cooling towers, pumps, AHUs, RTUs, FCUs, humidifiers, recovery units, etc.

Equipment name	Equip type	Photo of name-plate	Control method (BAS or standalone)	Location	Area/zone served	Operation schedule	Age/ condition
Wall exhaust fan serving curling rink	Wall mounted fan	☐	Manual	Curling rink wall	Curling rink	Unknown	Unknown
Ceiling mounted exhaust diffuser fans		☐	Manual	Curling Club	Curling Club toilets in basement		
		☐					
		☐					
		☐					
		☐					
		☐					
		☐					
		☐					
		☐					
		☐					
		☐					
		☐					
		☐					
		☐					

Refrigeration system

Capacity of system			
Type of controls Ice IR sensors, ice slab sensor and/or brine water return temperature			
Refrigeration equipment *compressors, pumps, evaporative fans,*			
Equipment name	Equipment type	Photo of nameplate	Control method (BAS or standalone)
Carlyle compressor	Model number 06ET250-160	☐	
Refrigeration pump	Weg pump (2 speed – 3 phase) Model 213T; 7.5HP – 1.88HP; 1750 RPM – 850 RPM; 7.45 Amps – 3.5 Amps	☐	
HT industrial	RF-12048-800; 400 psi at 400 F	☐	
Air cooled condenser		☐	
		☐	
		☐	
		☐	
		☐	
		☐	
		☐	
		☐	
		☐	
What are the ice temperature set points during different activities?			
19F Operates 18h a week			
What are the ice set back temperatures?			
24F Setback 150h a week			
Is there any heat recovery? For ice melting, underfloor heating, building heating system?			
NO			
What is the under slab setpoint temp (if under slab floor heating exists)?			
N/A			
Age and condition of existing equipment			
Equipment was recently refurbished or changed (pumps), Freon based refrigerant, no ammonia			
Are there any VFDs on any refrigeration equipment (pumps, compressors, cooling tower fans) and if so, specify on which equipment?			

N/A
Are there Trend logs? What for? Approximate date range?
N/A

Ice rink

When is the ice in and out? *For example, ice out March 15 to Oct 1; ice in Oct 1 to March 14*	Check operation schedule in pics
What kind of activity does the rink experience? *Ice hockey, figure skating, public skate etc.*	
Curling	
Temperature at which the ice is maintained?	19F during operation
Nighttime setback temperature for Ice?	24F setback
RH is the rink controlled to	
Space temp of the rink	37F during operation
Setpoints based on activities	
Nighttime setback for space temp	33F Setback
Setpoints for summer	
Setpoints for winter	
Intended/target ice thickness	
Take pictures of	

Lighting layout	☐x
Lighting fixtures	☐x
Ceiling	☐x
Walls	☐x
Any windows	☐

What types of lighting are in the rink? (i.e., Fluorescent T8/T5, LED)	
16 Round LED lights x 40W each (per operator interview)	
Spectator Areas (N/A)	
How are they heated? *Gas fired infrared, underfloor, via RTU, electric IR*	No spectator areas but rink is heated by a Trane furnace
How often and for how long is spectator heating used?	
N/A	

Ice resurfacing machine

Number of resurfacing machines	None
How are they powered? *Gas, electric, propane, etc.*	
How many times a day is the ice resurfaced?	
On typical weekday	
On typical weekend	
Water temp in ice resurfacing machine	
Do they have REALice?	
Is RO water used for resurfacing?	
What volume of water does ice resurfacing machine hold?	
Approximately what % of total water is used during resurfacing	
Take a picture of the nameplate & model number	☐

BAS

Please take pictures or screenshots of all BAS pages	☐
Are there trend logs? If so, please describe how they are set up, and what they are recording	
N/A	
How do operators use the BAS?	
N/A	
Do they actively change setpoints?	
N/A	
Do they update schedules for activities* on an ongoing basis and edit the equipment schedules accordingly or do they leave the schedules and setpoints alone regardless of activities on ice? **Activities meaning Ice hockey, figure skating, public skate etc.*	
Check refrigeration plant schedule in pics	

Appendix B – Monthly billing data

The tables below list monthly energy use and cost as per monthly billing. Propane use and cost have been normalized using heating degree days (HDD) as it is billed irregularly throughout the year.

Table 43: Monthly energy use and costs (2019) for Eganville Arena

Month	Electricity consumption (kWh)	Electricity cost ($)	Propane consumption (L)	Propane Cost ($)
1	56,912	$1,671.14	1,918	$958.75
2	50,751	$1,488.57	2,316	$1,157.67
3	42,830	$1,239.87	1,962	$991.34
4	22,325	$531.71	439	$230.13
5	25,687	$538.97	52	$26.05
6	7,774	$167.34	66	$32.93
7	3,642	$109.64	-	$-
8	5,674	$154.22	9	$4.50
9	35,263	$838.96	208	$125.17
10	40,909	$790.15	1,046	$585.65
11	65,342	$1,675.96	2,387	$1,235.19
12	56,304	$1,576.75	2,091	$1,129.24
Total	413,414	$10,783.28	12,493	$6,476.63

Table 44: Monthly energy use and costs (2019) for Eganville Curling Club[5]

Month	Electricity Use (kWh)	Electricity Cost ($)	Heating oil use (L)	Heating oil cost ($)	Propane Use (L)	Propane Cost ($)
1	7,210	$1,107.23	527	$658.67	1,311	$281.60
2	6,342	$1,088.09	358	$448.00	1,415	$303.83
3	6,294	$1,072.80	318	$397.71	876	$188.09
4	3,048	$522.02	198	$248.18	524	$112.61
5	1,143	$273.95	106	$132.68	185	$39.76
6	520	$227.01	26	$32.80	46	$9.83
7	1,041	$296.90	-	$-	-	$-
8	573	$176.59	3	$3.92	5	$1.17
9	444	$161.48	52	$64.72	90	$19.40
10	5,485	$1,447.89	93	$116.68	249	$53.49
11	8,391	$1,740.78	82	$102.50	513	$110.15
12	7,241	$1,282.89	625	$782.16	899	$193.02
Total	47,732	$9,397.62	2,389	$2,988.02	6,113	$1,312.96

[5] In 2019 Eganville Curling Club used heating oil for some appliances but has since switched over to all propane. Analysis and measures assume all energy provided by oil was converted to propane use where 1 L of heating oil is approximately 0.67 L of propane.

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 – Gas	10.00%
Escalation rate – Utilities – Water	10.0%
Escalation rate – Labor and maintenance	5.00%
Discount 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 General Service Energy – Effective January 1st, 2023, can be found in the table below.

Utility rate structure – electricity, standard rate	
Monthly charge	$32.78
Consumption (first 750 kWh)	0.0870 $/kWh
Consumption (remaining kWh)	0.1030 $/kWh
Distribution volumetric rate	0.0688 $/kWh
Regulatory service fees	0.0004 $/kWh
Ontario electricity rebate	11.7%
GST/HST	13%

Propane utility rates are based on billing provided by facility management is provided in the table below. Propane is provided by local distributer McCarthy Propane Inc on an as needed basis.

Utility rate structure – propane	
Commodity rate	0.588 $/L
Commodity rate	$33.50 per 30lb tank
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 Government of Canada source below:

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

Year	Electricity emissions factor (tCO_2e/kWh)
2024	0.000066
2025	0.000077
2026	0.000093
2027	0.000081
2028	0.000067
2029	0.000064
2030	0.000062
2031	0.000060
2032	0.000058
2033	0.000041
2034	0.000035
2035	0.000030
2036	0.000024
2037	0.000021
2038	0.000019
2039	0.000017
2040	0.000016
2041	0.000015
2042	0.000015
2043	0.000015
2044	0.000014
2045	0.000013
2046	0.000011
2047	0.000009
2048	0.000009
2049	0.000011
2050	0.000013
2051	0.000011
2052	0.000011
2053	0.000011
2054	0.000011

Fuel fired emissions are provided in the table below:

Fuel emission factors (tCO_2e/kWh)		
Natural gas	tCO_2e/m^3	0.001915
Propane	tCO_2e/m^3	1.51513

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.

Eganville Arena

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

Table 45: Electricity consumption (kWh) modelling error

Month	Model	Actual
1	61,361	56,456
2	52,510	49,034
3	42,884	38,950
4	22,618	27,154
5	16,505	24,230
6	5,176	6,024
7	5,659	5,355
8	5,469	4,869
9	32,197	38,026
10	38,427	39,660
11	67,918	68,980
12	53,648	50,788
Total	404,373	409,526
RMSE	11.7%	
NMBE	1.3%	

Table 46: Natural gas consumption (kWh) modelling error

Month	Model	Actual
1	14,713	13,532
2	15,533	16,340
3	13,834	13,844
4	2,996	3,100
5	225	368
6	217	465
7	-	0
8	-	63
9	1,593	1,471
10	5,020	7,378
11	15,820	16,842
12	14,429	14,755
Total	84,379	88,157
RMSE	12.0%	
NMBE	4.7%	

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.

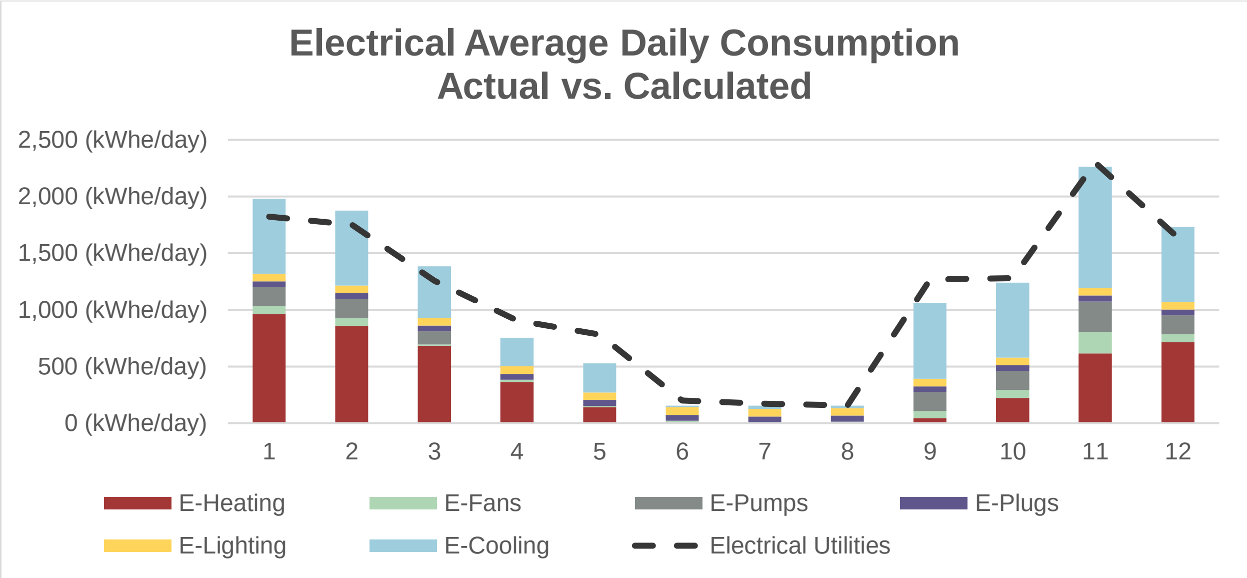


Figure 15. Calibrated model monthly end use vs electricity utility billing monthly totals for 2019

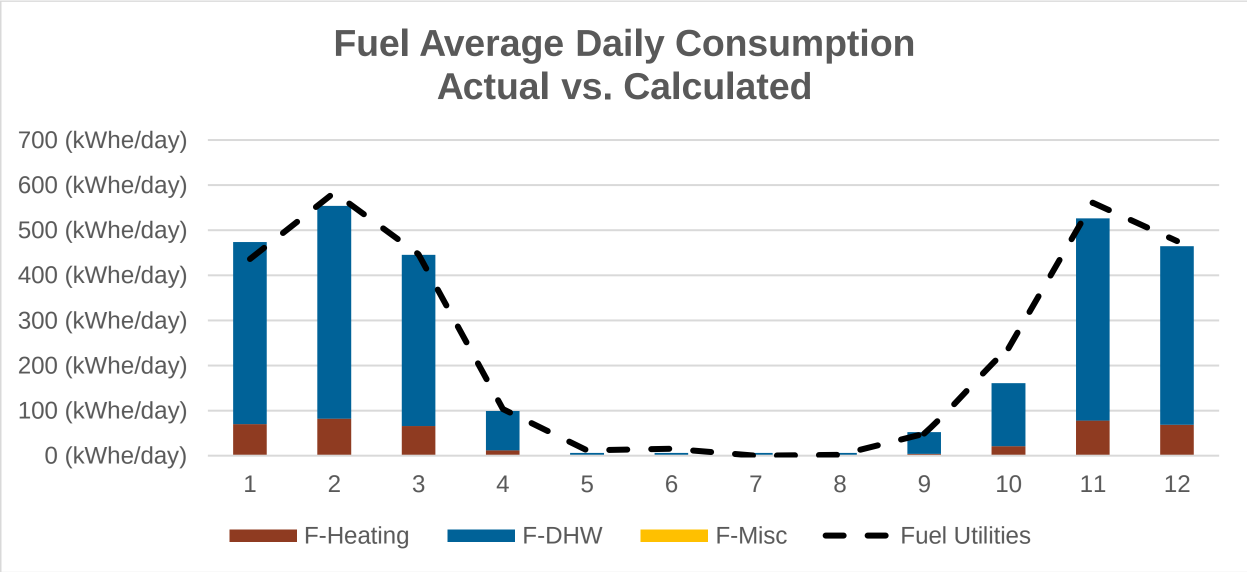


Figure 16. Calibrated model monthly end use vs natural gas utility billing monthly totals for 2019

Eganville Curling Club

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

Table 47: Electricity consumption (kWh) modelling error

Month	Model	Actual
1	7,378	6,494
2	6,423	6,111
3	6,659	5,700
4	2,568	2,400
5	1,019	909
6	684	677
7	660	894
8	660	551
9	1,772	1,932
10	5,474	6,316
11	7,510	8,388
12	8,015	8,017
Total	48,823	48,390
RMSE	14.8%	
NMBE	-1.6%	

Table 48: Natural gas consumption (ekWh) modelling error

Month	Model	Actual
1	14,569	14,828
2	11,736	13,775
3	10,331	9,546
4	5,347	5,801
5	2,111	2,430
6	263	601
7	-	0
8	-	72
9	661	1,185
10	3,354	2,745
11	5,589	4,487
12	13,533	12,963
Total	67,495	68,432
RMSE	13.8%	
NMBE	1.5%	

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.

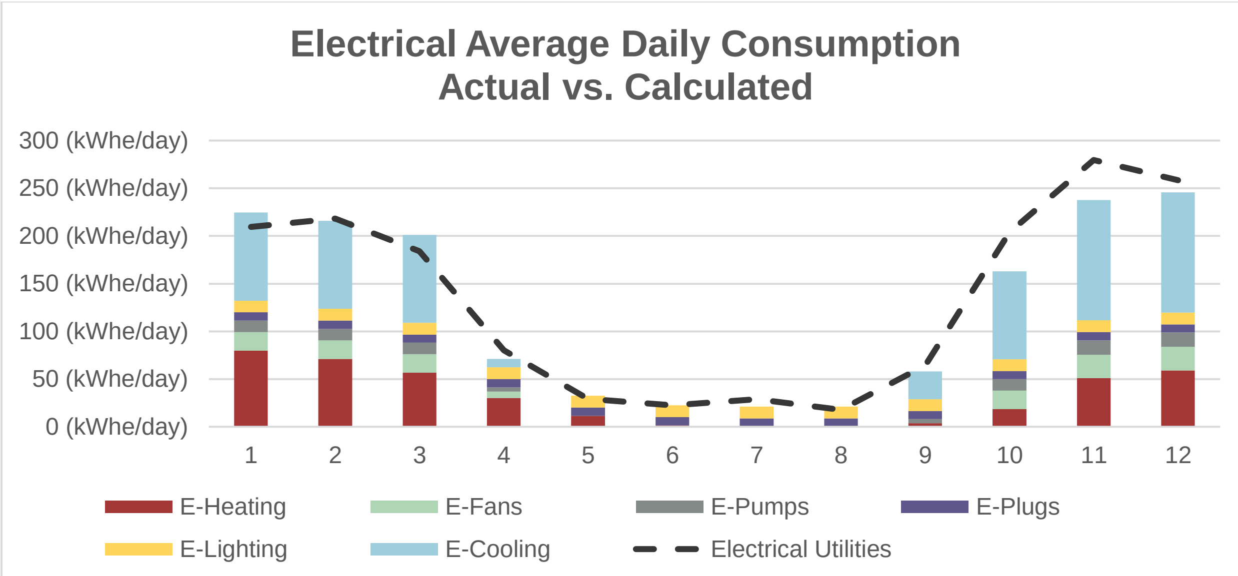


Figure 17: Calibrated model monthly end uses vs electricity utility billing monthly totals for 2019

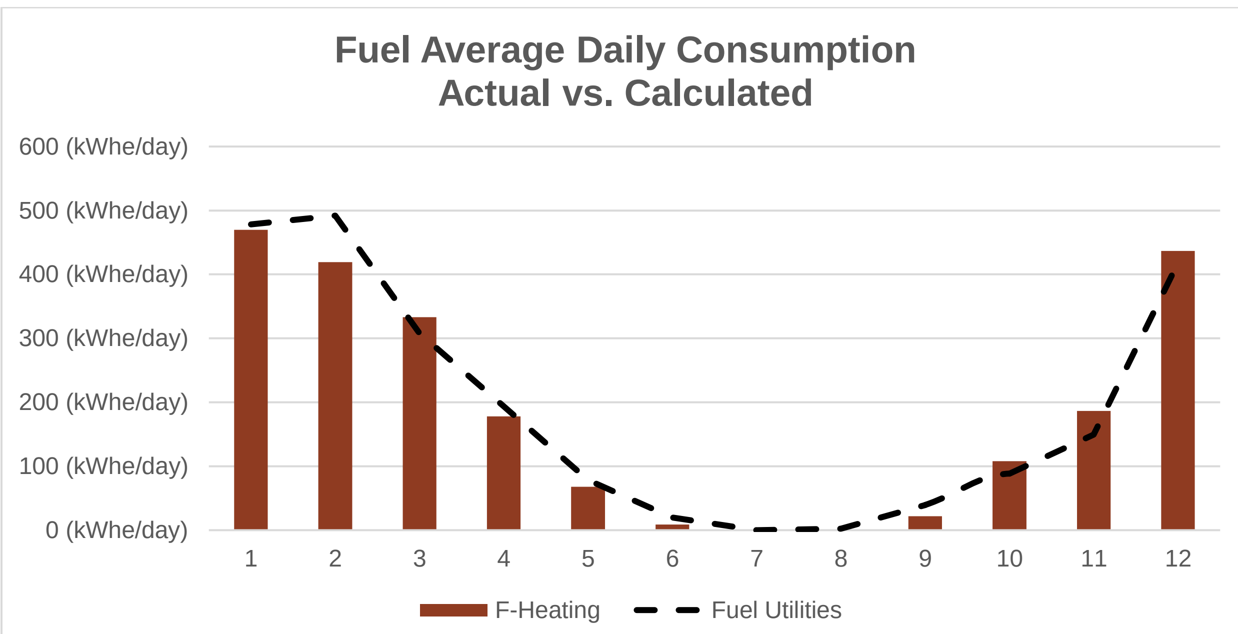


Figure 18: Calibrated model monthly end uses vs natural gas utility billing monthly totals for 2019