June 13, 2024

MERP Level 2 Energy Assessment for

Municipal Energy Resilience Program
Fenton Chester Ice Arena
Lyndon, Vermont

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Table of Contents

I. Executive Summary

Cx Associates has performed a MERP[1] Level 2 energy assessment for the Fenton Chester Ice Arena in Lyndon, Vermont. This assessment included a detailed building survey and energy analysis of the building systems to identify and quantify savings opportunities.

The energy assessment consisted of a comprehensive review of the building systems and controls, analysis of historical utility data, a mechanical and building envelope on-site assessment, a blower-door measurement, and a detailed investigation of the energy consumption of the building by end use.

Based on this in-depth analysis, Cx Associates developed a recommended package of building envelope improvements and energy saving measures that will:

- Cost-effectively reduce energy consumption
- Reduce building air leakage
- Extend equipment life
- Increase comfort
- Improve resiliency

Table 1 provides an overview of recommended measures, the implementation of which would improve occupant comfort due to the improved building envelope as well as achieve an estimated energy cost savings of over $4,500 annually. Measures investigated but not recommended are also documented[2].

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[1] Municipal Energy Resilience Program

[2] Measures are generally listed as not recommended if the simple payback period exceeds the expected measure life. However, these measures can still be considered if included as part of a larger upgrade package or upon failure of existing equipment.

Table 1: Energy Efficiency Measure Summary

ID	Measure Description	Electricity Savings	Peak Demand Reduction	Fuel Oil Savings	Propane Savings	Energy Cost Savings	Measure Cost	Return on Investment (ROI)	Recommended
		kWh/yr	kW	gal/yr	gal/yr	$/yr	$	%	Y/N
1	Insulation at Conditioned Spaces	-	-	250	-	$975	$12,000	8%	Y
2	Upgrading Doors at Conditioned Spaces	-	-	324	-	$1,264	$8,500	15%	Y
3	Reducing Air Leakage at Conditioned Spaces	-	-	34	-	$133	$600	22%	Y
4	Finish LED lighting and controls upgrade	91	0.2	-	-	$43	$1,180	4%	Y
5a	Waste heat recovery for DHW	-	(0.1)	237	-	$910	$20,600	4%	Y
5b	Heat Recovery Refrigeration Plant	18,585	6.9	2,961	-	$14,560	$660,000	2%	N
6	Heat Pump Water Heater	(711)	-	94	-	$296	$2,700	11%	Y
7	Boiler Outdoor Air Temperature Reset	-	-	98	-	$382	$1,060	36%	Y
8	Web-based Thermostats	-	-	130	-	$507	$2,100	24%	y
9	New Refrigerator	525	-		-	$52	$800	7%	Y
10	Heating System Pipe Insulation	-	-	26	-	$101	$970	10%	Y
11	Heat Pumps for Space Heating	(30,405)	(15.0)	1,935	-	$2,005	$50,600	4%	N
12	Electric Ice Resurfacing	(9,747)	(1.0)		482	$298	$175,000	0%	N
	Recommended Total[1]	**(95)**	**0.1**	**1,193**	**-**	**$4,662**	**$50,510**	**9%**	

[1] Note that savings for these measures are compared to existing conditions, savings would be lower depending on which measures are implemented due to interactive effects.

II. Introduction

Cx Associates has been retained by the State of Vermont to provide building energy assessment services for municipal buildings across the state as part of the Municipal Energy Resilience Program (MERP).

This report focuses on the energy assessment performed for the Fenton Chester Ice Arena in Lyndon, Vermont (Figure 1). The assessment team spent one day on site (February 19, 2024) gathering detailed information on all energy-using equipment in the building.

Figure 1: Ice Arena interior

The report details the findings of the existing facility operating conditions, along with recommendations on energy efficiency opportunities and associated energy savings estimates and project implementation costs. These findings have been developed using the following sources:

- In depth conversations with facilities staff and occupants
- Detailed observations from the February 19, 2024 site visit
- Blower door and envelope assessment conducted on February 19, 2024
- Historical electricity and fuel oil data

III. Facility Description

GENERAL INFORMATION

The Fenton Chester Ice Arena is a municipal ice arena located at 145 College Road in Lyndon, Vermont, and is home to a community ice arena. The facility is 1 story (with some spaces above enclosed first floor spaces) and comprises approximately 26,190 square feet. The building was originally constructed in/around 1979. Since then, it has been run by two separate entities serving the town that have kept the facility running and open to the community. The arena is currently run by Rescue Ice Hockey in the Northeast Kingdom (RINK) Inc.

The primary functional space types in the building include an ice rink, locker rooms, concession stand, and pro shop. Ancillary spaces include refs hut, announcing booth, mechanical rooms, storage, and office.

Building occupancy varies by season. During the winter the arena is typically occupied from 9:00 a.m. to 9:00 p.m. with peak occupancy from 3:30 p.m. to 9:30 p.m. On weekends the ice may be in use from 7:00 a.m. to 10:00 p.m. During shoulder seasons the occupancy is mainly after school from 3:30 pm to 8:00 p.m. with indoor turf. Occupancy is typically lower during the summer. There may be up to 500 people at the facility at a time (especially with hockey games and community events).

BUILDING ENVELOPE

The foundation of the building is poured concrete footings and a poured concrete slab on grade. The building structure is primarily steel, with concrete masonry unit (CMU) walls present to separate spaces. The building has several exterior person doors, and several overhead doors which are not all in use. The exterior of the building is finished with metal siding, and the roof is standing seam metal.

The majority of the building consists of ice arena space, which is unconditioned. There are smaller conditioned spaces such as locker rooms and bathrooms. The exterior walls and ceilings within conditioned spaces appear to be insulated with fiberglass batts. Fiberglass insulation is also present at the exterior walls and roof slope of the arena, however there are some areas of inconsistency.

The exterior metal siding appears to be in fair condition, however there are some locations where damage is visible. The standing seam metal roof also appears to be in fair condition, however building staff explained that some roof leaks are present. There are also instances where both person doors and overhead doors are not performing well, which are detailed further in a later section of this report.

ELECTRICAL SYSTEMS

Electrical Distribution

Electrical service for the building consists of 3-phase 600- amp service at 480 V. The utility meter and main electrical panel are in the refrigeration plant room. There are many sub-panels in the building, including in the concession stand, behind the scorekeeper's bench, in the refrigeration plant room, and in the main lobby. Voltage is stepped down to 208/120V for many of the panels. No backup power is present at the facility.

Lighting

Interior lighting at the Fenton Chester Ice Arena has mostly been upgraded to LED fixtures. These are primarily 48" fixtures located in the ice hall, most of the locker rooms, concession stand, bathrooms, and Zamboni room. Some fixtures are also 96" fixtures - these are in locker room D, the main lobby and corridor, the Zamboni room, and refrigeration plant room. There are also a few high performance T8 (HPT8) and T8 fixtures in lower use spaces. These are in the referee room, pro shop, and costume closet. Most interior lights are controlled manually with switches, although there are occupancy sensors for automatic control found in the concession stand, restrooms, and locker rooms. There are also a few other screw base bulbs in the building that have been upgraded to LED. Examples of LED lighting and T8 light fixtures is shown in Figure 2.

Figure 2: Example lighting, a new LED fixture with cover (left), and an older T8 fixture (right)

Exterior lighting is controlled by a timer and was set to run from 4:00 p.m. to midnight at the time of the site visit.

Plug Loads

Plug loads consist of many concessions stand loads, auxiliary heaters, skate sharpeners, and some office loads. In the concession stand the evaluation team observed a coffee maker, popcorn popper, microwave, fridge, and drink cooler. There were three ice skate sharpening machines found in the building, and several TVs, two computers, and a printer. There are also many electric tools at the facility. Most notably is an electric ice edger, but there are also many electric hand tools.

MECHANICAL SYSTEMS

Space Heating

Space heating is provided by a fuel oil fired 256.0 MBh Buderus cast iron boiler installed in 2022, which is in excellent condition. The boiler generates 180°F hot water that is used for heating. The unit has an efficiency of 88% and a combustion analysis completed in October of 2023 indicated a combustion efficiency of 87.10%. Hot water generated by the boiler is circulated throughout the building by a Taco ECM high efficiency circulator pump to Trane and Modine unit heaters. Temperature is controlled manually in building spaces by analog thermostats. During the site visit most of these thermostats were set at 60°F, but building managers noted that they are often turned up by building users. An example thermostat and unit heater are shown in Figure 3.

There is an auxiliary propane fired vertical heating unit in the pro shop that heats that location, and five portable electric heaters were identified throughout the building during the site walkthrough.

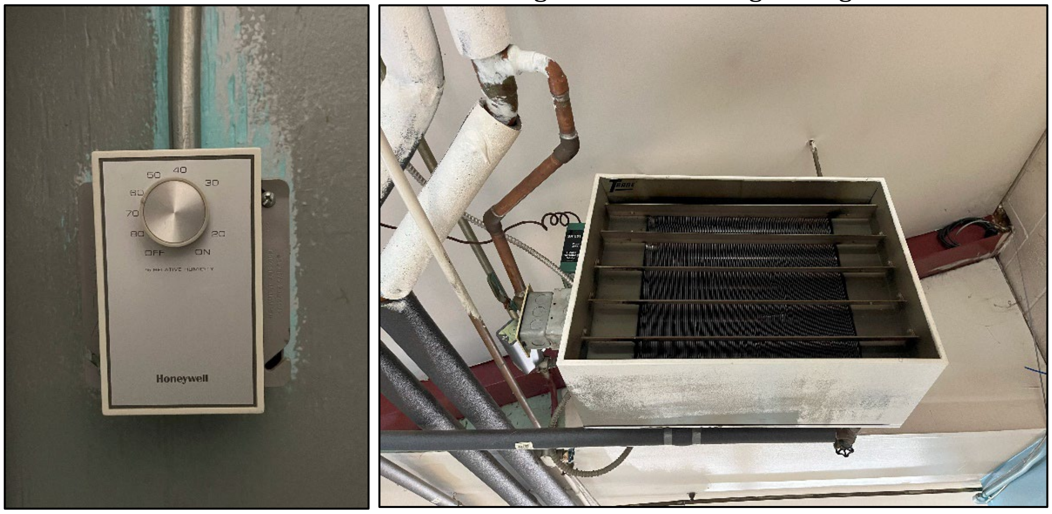

Figure 3: An example building thermostat (left) and unit heater (right). There was a large variety of both thermostats and unit heaters in the building.

Space Cooling

Currently the arena does not have any space cooling.

Ventilation and Exhaust

Ventilation at the ice arena is provided by one large ventilation fan on the north side of the building. There is also a vent hood in the concession stand. Details could not be obtained during the site visit for either of these fans.

Domestic Hot Water

Domestic hot water is provided by an indirect 119-gallon Triangle Tube tank set at 134°F during the site visit. Domestic hot water is used in the concession stand and bathrooms, and for ice resurfacing in the Zamboni. Most faucets had 1.8 GPM or 2.2 GPM aerators on them. It is estimated that resurfacing the ice uses 37,500 gallons of DHW each year as well.

Dehumidification

Two dehumidifiers are installed in the main ice hall. These are both ARID-Dry MS 2600 units that dehumidify 2,600 CFM of air and appear to run continuously. It was noted during the site interview that the dehumidification systems do not keep up with the load, especially during the shoulder seasons when warmer outdoor air temperatures allow for larger humidity loads to infiltrate the building.

Refrigeration Plant

Ice in the arena is generated using a 150-ton air-cooled reciprocating chiller that produces cold (~22°F) brine/glycol fluid to circulate throughout the ice sheet. The refrigeration plant at the Fenton Chester Ice Arena uses R-22 in a typical refrigeration cycle powered by two lead-lag 60-hp reciprocating compressors. These compressors were rebuilt in 2015 and 2017. Heat from this cycle is rejected to the environment in an air-cooled condenser, and the heat is absorbed from the brine loop in a shell and tube heat exchanger. The two 60-hp compressors are cooled using a simple cooling loop where the coolant is circulated to a storage tank and to an outdoor air-cooled heat rejection fan using three 1/8-hp Taco circulator pumps. The brine loop is circulated under the arena at around 22°F to keep the ice cool using a 15-hp brine pump. There was a VFD (variable frequency drive) for the Brine pump but it was not being used at the time of the site visit.

Ice Resurfacing

The Ice Arena currently uses a propane-fired Zamboni ice resurfacing machine. Data from Fred's Energy indicates that the current ice resurfacing machine uses around 500 gallons of propane per year at a cost from the 2021/2022 season of $1,038.

Cooking Equipment

The concession stand has a propane cooktop and exhaust hood above. The cook top is a Garland griddle-top model with three burners and an oven.

IV. Historical Energy Consumption

DESCRIPTION OF METERS AND TARIFFS

There is one electric meter serving the building. The electric utility is the Lyndonville Electric Department. Electric rate structure details for the Lyndonville Electric Department Off-Peak Contract Service Rate (assumed) tariff is shown in Table 2. There is a monthly customer charge, an energy charge, and a demand charge. The marginal electric cost is $0.09958 per kWh and $16.93/kW. The facility pays a high cost for their demand use because the rate structure includes a ratchet whereby the demand charge cannot be lower than 70% of the peak from the previous year. The high demand during the winter months when the refrigeration plant is running increases the demand charges into the summer and shoulder months despite much lower demand during these times.

Fuel oil and Propane are delivered by Fred's Energy. Fuel oil costs have ranged from $2.699/gallon to $5.259/gallon over the three years for which data was provided. A value of $3.90/gallon of fuel oil is used for future analysis in this report. Propane costs in 2021 and 2022 have ranged from $1.83/gallon to $2.46/gallon. A value of $2.98/gallon is used for future analysis in this report, consistent with Vermont average fuel prices at the beginning of 2024.

Table 2: Electric rate description

Utility:	Lyndonville Electric Department
Meter ID:	000005754
Tariff:	Off-Peak Contract Service Rate
Customer Charge:	$175.81
Energy Charge:	$0.09958 / kWh
Demand Charge:	$16.93/ kW not less than 70% of highest 11-month period peak

ENERGY USAGE AND COST ANALYSIS

Utility Data

Analyzing historical utility data can yield valuable insight into how the building is operating and can help to identify and address any issues that may improve energy performance and/or reduce costs. Table 3 shows the annual utility summary for the year ending July 2023, except for propane where only values from the 2021-2022 season were available and those values are used here. Annual energy cost is around $63,000 per year, with an energy cost index (ECI) of $2.84/sf-yr.

Table 3: Annual energy consumption and cost

Commodity	Consumption	Cost
Electricity (kWh)	290,570	$48,429
Fuel Oil (gal)	3,055	$12,436
Propane (gal)	1,319	$2,840
Total		**$63,706**

Figure 4 and Figure 5 show the energy cost and use breakdown by commodity. The main source of energy and cost is electricity, accounting for 76% of the cost and 65% of the energy used at the facility. Fuel oil accounts for a sizable fraction of the energy use (27%) but a smaller fraction of the cost (20%). This is consistent with fuel oil being relatively inexpensive over the year of data included here (Sept 2021 – August 2022). Fuel oil is used for heating at the facility. Propane, which is used for both cooking in the concessions stand and the ice resurfacing machine accounts for a small fraction of the energy use (8%) and the cost (4%). These results are consistent with a facility with a large process load (ice making in this case), and some heating load.

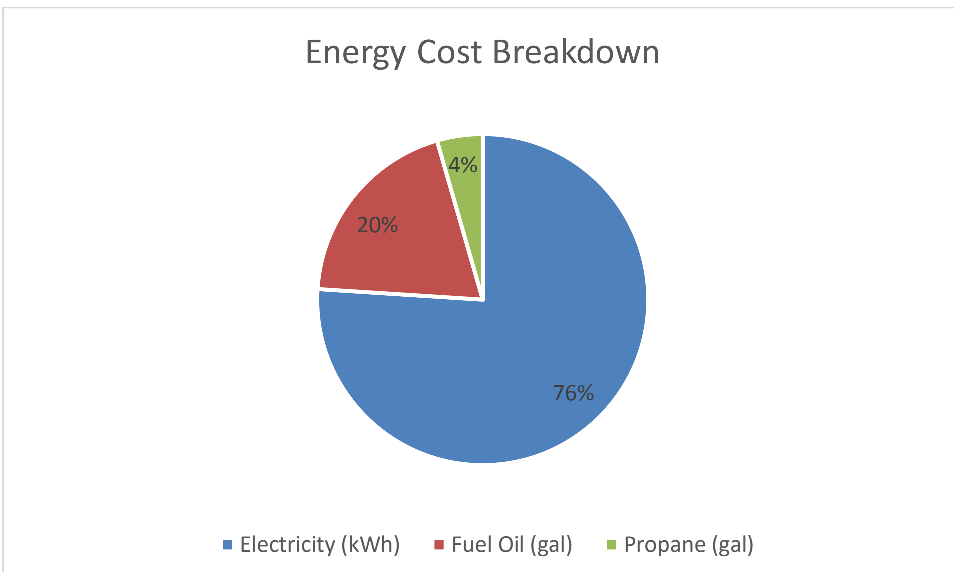

Figure 4: Energy cost breakdown

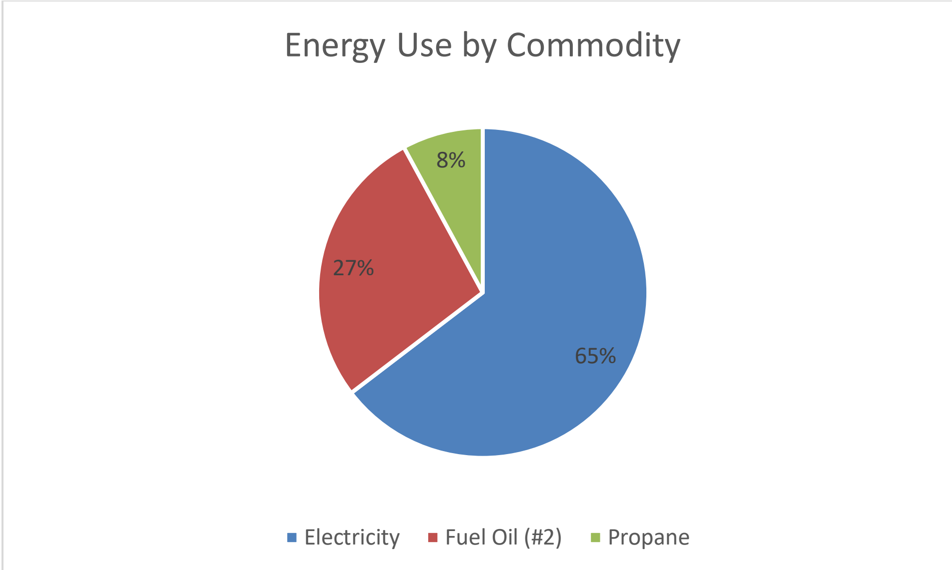

Figure 5: Energy use by commodity

Figure 6 shows monthly electric consumption over the past two years. Electricity use is relatively constant over the two years. This graph makes clear that the main use of electricity at the facility is the refrigeration plant that operates during the winter months. This load increases electricity consumption from a low of under 1,000 kWh/month to a peak of close to 57,000 kWh/month. The increase and decrease match well with when ice making begins and ends at the facility. The demand also increases significantly during the winter when the refrigeration plant is running - electricity demand peaks at 96 kW, and decreases to 8 kW during the summer. Due to a change in the way demand was reported, we see the ratchet (70% minimum demand charge) in August and September in the graph below, but not again after the ice season. The rink is still charged for the ratchet but that is not reported in the data beginning in 2023.

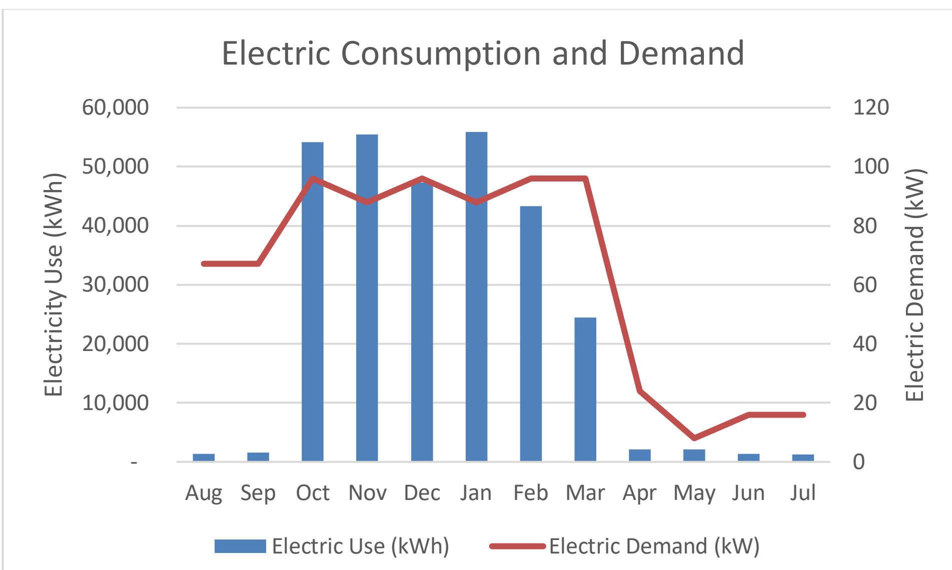

Figure 6: Monthly Electric Consumption and Peak Demand for 2022-2023

BENCHMARKING

Benchmarking involves comparing a building's energy performance to other buildings of similar type in a similar climate. The utility data for the year ending March 2023 was used to calculate the overall building performance in ENERGY STAR Portfolio Manager (Figure 7). The site Energy Use Intensity (EUI) is 54.2 kBtu/sf/yr, which compares to the national median of 49.6 kBtu/sf/yr for buildings with a primary property type of "Ice/Curling Rink" located in similar climates. The ENERGY STAR score of this building could not be calculated due to a lack of comparator buildings, but it is noteworthy that this site has an above average energy intensity. There may be some opportunities available for improvement, as discussed in Section V.

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ENERGY STAR® Statement of Energy Performance

N/A

ENERGY STAR® Score[1]

Lyndon Fenton Chester Ice Arena

Primary Property Type: Ice/Curling Rink
Gross Floor Area (ft²): 26,190
Built: 1979

For Year Ending: March 31, 2023
Date Generated: May 01, 2024

1. The ENERGY STAR score is a 1-100 assessment of a building's energy efficiency as compared with similar buildings nationwide, adjusting for climate and business activity.

Property & Contact Information

Property Address	Property Owner	Primary Contact
Lyndon Fenton Chester Ice Arena 145 College Rd. Lyndon, Vermont 05850 **Property ID**: 34014552	________________ , (___)___-_____	____ _______ , (___)___-_____ ________________

Energy Consumption and Energy Use Intensity (EUI)

Site EUI
54.2 kBtu/ft²

Source EUI
122.3 kBtu/ft²

Annual Energy by Fuel	
Fuel Oil (No. 2) (kBtu)	421,645 (30%)
Propane (kBtu)	7,728 (0%)
Electric - Grid (kBtu)	989,260 (70%)

National Median Comparison	
National Median Site EUI (kBtu/ft²)	49.6
National Median Source EUI (kBtu/ft²)	112
% Diff from National Median Source EUI	9%
Annual Emissions	
Total (Location-Based) GHG Emissions (Metric Tons CO2e/year)	103

Figure 7: ENERGY STAR Statement of Energy Performance

END USE BREAKDOWN

An energy model was created to disaggregate energy end uses at the building. The model is informed by historical utility data, equipment nameplate and data gathered on site, and engineering estimates. An energy end use breakdown is useful for identifying the end uses with the largest consumption and thereby targeting those areas for improvements. Additionally, the model can be used as a baseline to which energy savings estimates can be compared to ensure reasonability. Figure 8 shows the percentage attributable to each end use. The major electric end uses for the building are the refrigeration plant, lighting, dehumidification, and space heating.

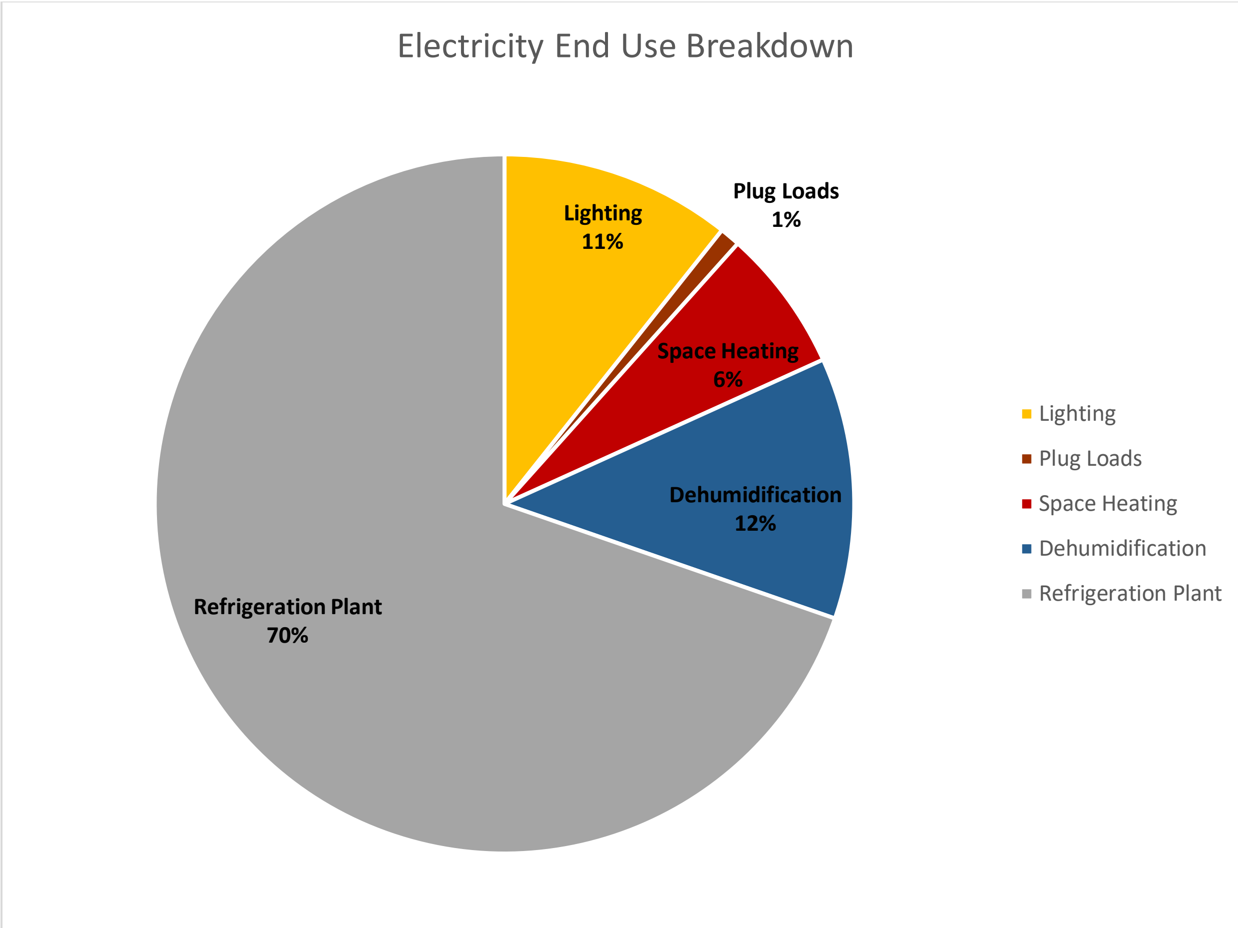

Figure 8: Annual Electric End Use Breakdown

Fuel oil use at the facility is used for space heating and for water heating. Engineering estimates were used to divide the annual fuel oil consumption into water and space heating. This breakdown is shown in Figure 9.

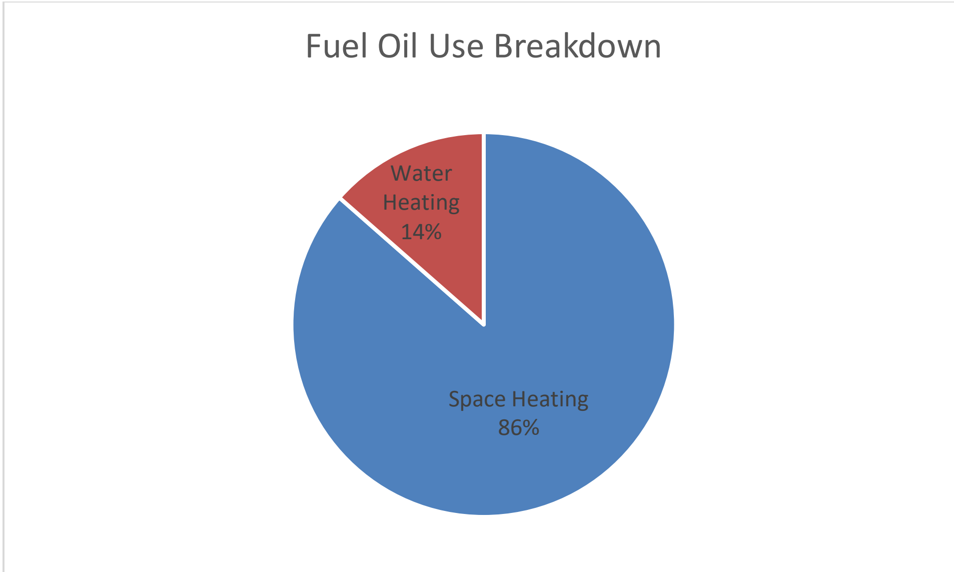

Figure 9: Annual fuel oil use breakdown

Fred's Energy delivers propane separately to the concession stand and the Zamboni. The use for these two from the 2021-2022 season are seen in Figure 10.

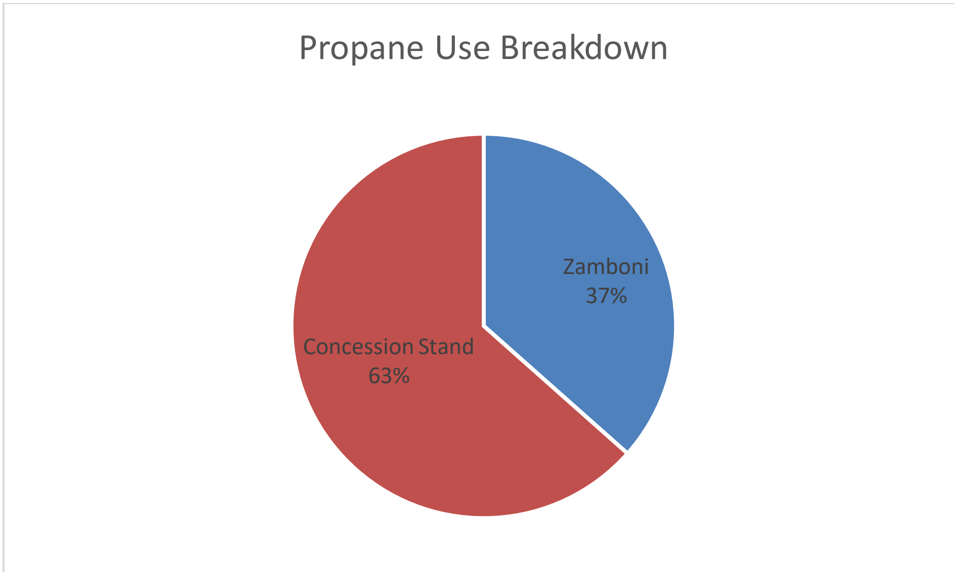

Figure 10: Annual propane use breakdown

V. Energy Efficiency and Resiliency Opportunities

As presented in Table 1 (shown again below), if all recommended energy efficiency opportunities are implemented, there would be an estimated energy cost savings of over $4,500/yr.

Table 4: Energy Efficiency Measure Summary

ID	Measure Description	Electricity Savings	Peak Demand Reduction	Fuel Oil Savings	Propane Savings	Energy Cost Savings	Measure Cost	Return on Investment (ROI)	Recommended
		kWh/yr	kW	gal/yr	gal/yr	$/yr	$	%	Y/N
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	Recommended Total[1]	**(95)**	**0.1**	**1,193**	**-**	**$4,662**	**$50,510**	**9%**	

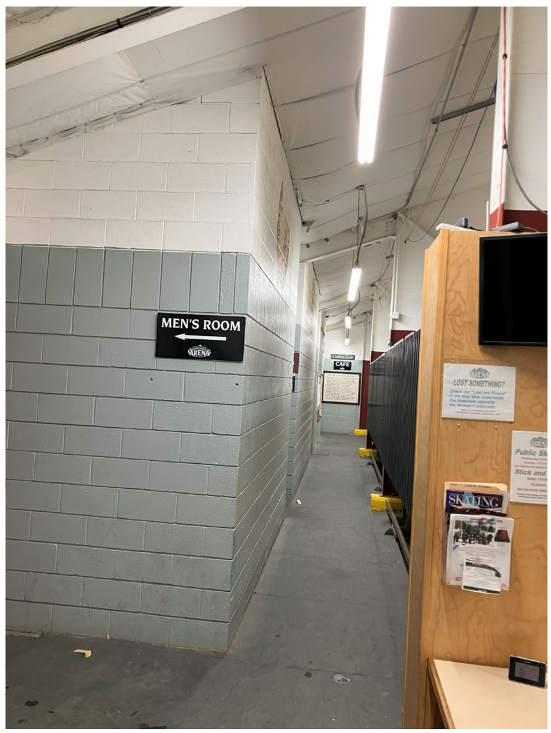
[1] Note that savings for these measures are compared to existing conditions, savings would be lower depending on which measures are implemented due to interactive effects.

This section provides a description of the energy efficiency measures that have been analyzed. For each measure, high-level implementation costs were estimated by Cx Associates using RS Means and/or previous project experience. The measures are quantified in the previous summary table and described in the text below.

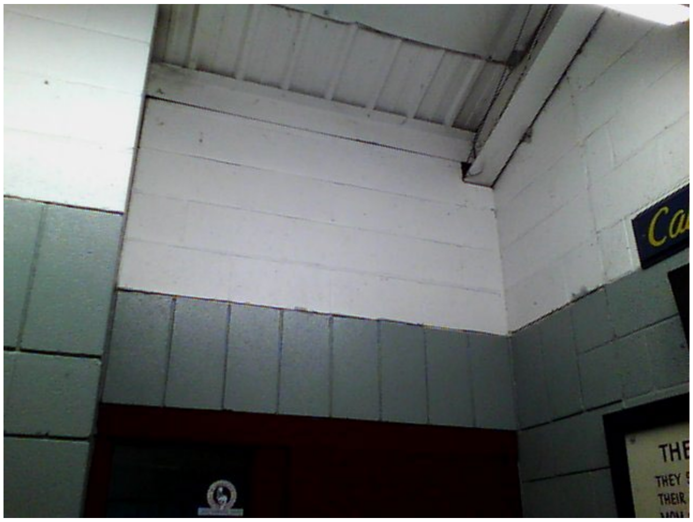
MEASURES RECOMMENDED FOR INCLUSION IN AN UPGRADE

1: Insulation at Conditioned Spaces

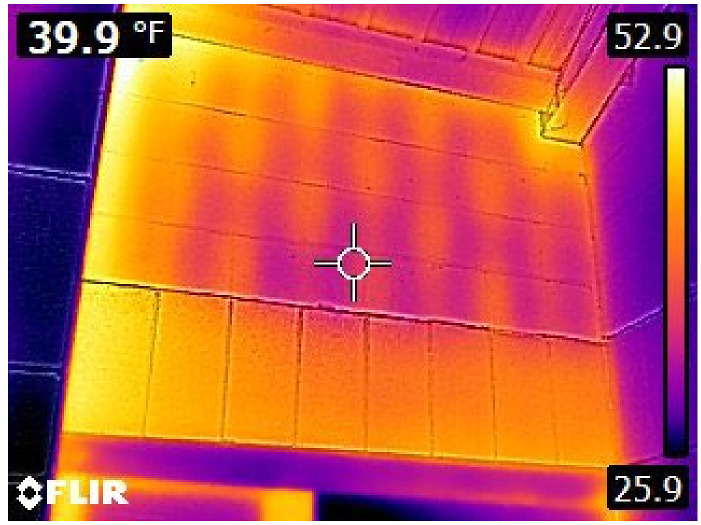
The majority of the arena is considered unconditioned space, as it is not heated throughout the winter or cooled in the summer. However, there are spaces along the east elevation such as locker rooms and bathrooms which do have heaters inside. CMU walls currently separate these conditioned and unconditioned spaces, however, there did not appear to be insulation present. Original drawings indicate that some locations were to have insulated CMU (likely vermiculite filled), but the presence of insulation was not obvious to Cx Associates through infrared imaging, or when inspecting the blocks at top of wall locations in the attic space. The lack of insulation (or insufficient amounts) results in a low R-value for these wall assemblies and significant heat loss through thermal bridging.



Looking down a section of CMU wall that separates the bathrooms and locker rooms from the unconditioned arena space.



A section of this CMU wall, looking from the arena side.



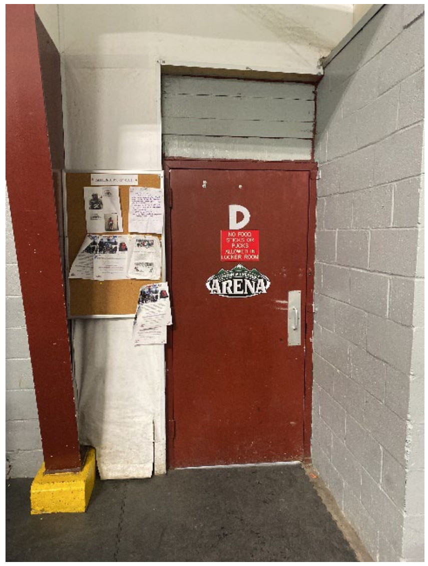
The same location as the previous photo with IR imaging. This shows that the face of the CMU wall has temperatures near 53 degrees on the area side, while the temperature in the arena was approximately 24 degrees. This shows heat from the conditioned space is being lost through the CMU.

Recommended Actions

To further separate the conditioned and unconditioned spaces and prevent heat loss, Cx Associates recommends installing insulation on the CMU walls. The most effective method would likely be rigid insulation such as XPS on the arena side of the CMU. The insulation can be fastened or glued to the CMU, and then a finish such as wood sheathing or fiber reinforced plastic (FRP) can be installed over the insulation for protection and aesthetics. Without vermiculite in the CMU blocks the effective R-value of the wall is approximately R-2, adding 2" of XPS insulation would increase this to R-12. If vermiculite is present in the CMU, the existing R-value would still only be approximately R-5.7 and increasing to R-15.7 would still result in improvement. To be conservative, Cx Associates modeled energy savings off the assumption that the CMU walls are insulated as described in the drawings, but if they are not the estimated savings would be even higher.

2: Upgrading Doors at Conditioned Spaces

The conditioned spaces are typically separated from the arena with metal doors as shown in the photos below. These doors were found to not have any insulation or weather-stripping present. The lack of insulation allows heat to be lost through the doors and frames, and the lack of weather stripping allows air infiltration around the perimeter of the door.



Looking at a typical door separating the conditioned spaces such as the locker rooms and bathrooms from the arena. No door bottom is present, a gap is visible at the base of the door.

Warm air is visible around the perimeter of the door.

Another example of warm air and thermal bridging around the door and frame.

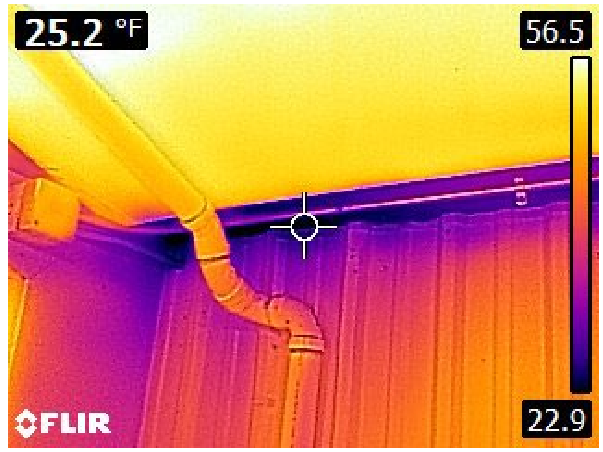
<u>*Recommended Actions*</u>

Since these doors separate the unconditioned arena from other conditioned spaces, they should be exterior grade with insulation and weather stripping, and ideally insulated metal frames. The hollow doors should be replaced with insulated doors, typically 2" thick with an R-value of approximately 12. Weather stripping should also be installed around the perimeter of the frames, including a door bottom. Door closers should then be adjusted to ensure a tight seal against the weather stripping when doors are closed. Ideally the metal frames would also be insulated, however this is much easier when done before or during installation. The cost of removing the metal frames and replacing them with insulation installed would add significant cost and reduce the cost effectiveness of this recommendation. Replacing the doors and installing weather stripping is what Cx Associates recommends at this time.

3: Air Leakage Conditioned Spaces

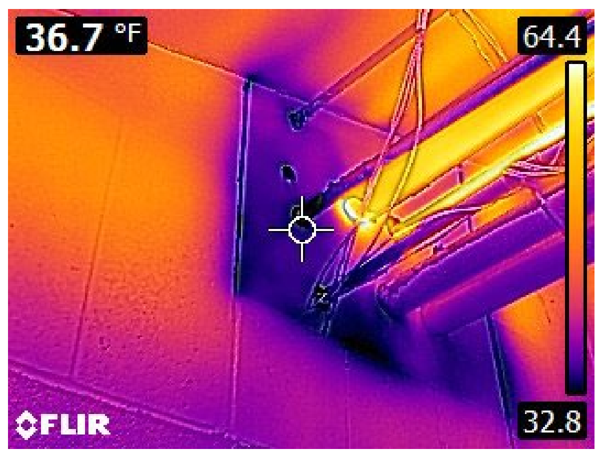
Some air leakage and locations were also identified in conditioned spaces. Both the duct penetration for the exhaust fan, and the fan opening itself in the kitchen area showed signs of air leakage. The transition from the ceiling to the exterior wall in the kitchen also had much cooler temperatures, indicating air leakage is present or simply low insulation resulting in low R-value. There are other miscellaneous penetrations present in the conditioned spaces, such as conduit and piping.

Air leakage was observed around this duct penetration for the kitchen exhaust.



A view of the wall to roof transition inside the kitchen, the cooler temperatures indicate air leakage and/or low R-value.

Cold air infiltration at the kitchen exhaust itself. It is unclear if this exhaust fan has a damper that can be closed.



Penetration in conditioned space "E", these penetration lead to the unconditioned vestibule.

Recommended Actions

Similar to the previously described findings, Cx Associates recommends that all penetrations leading to the exterior or unconditioned spaces are sealed to reduce air leakage. Reducing the air leakage in conditioned spaces such as the kitchen will prevent heat loss and reduce energy costs. Canned spray foam can be used to seal smaller penetrations such as conduit, piping or ductwork. Insulating and sealing the transition from the ceiling to the exterior wall in the kitchen can also be achieved with closed cell spray foam. Since this is a larger gap a 2-part product such as a froth pak may be more effective. Applying spray foam to this interior transition would improve the performance of the space, however it would have an impact on aesthetics unless it was covered or finished someway. The large hood/exhaust in the kitchen also had cold air infiltration. It is unclear if this fan has a damper that can be closed. If so, it is recommended that this damper be closed when the fan is not in use to reduce this air leakage.

4: Finish LED Lighting and Controls Upgrade

A significant LED lighting upgrade was completed at the Fenton Chester Ice arena in 2021. This has included new LED fixtures in almost all of the spaces at the arena. During the site visit nine remaining T8 and HPT8 fixtures were identified. These were in the referee hut, the pro shop, the broadcast booth storage area, and the costume closet. We recommend completing the LED upgrade in these remaining areas.

Along with the benefit of lower wattage compared to fluorescents, most LED fixtures have advanced control capabilities, including options for continuous dimming and integration of occupancy sensors and daylighting control. Incorporating these controls could result in additional energy savings, as well as allowing for adjusting light levels to exactly meet illuminance requirements. LED lamps also have a longer life than fluorescent lamps, leading to maintenance savings on lamp and ballast replacements. We recommend procuring LED products with dimming capability, so that light levels can be fine-tuned as needed, and ensuring that any retrofits meet the rating requirements of ENERGY STAR or the Design Lights Consortium (DLC), which set criteria for minimum efficacy levels and equipment life.

There are several options for LED upgrades, including the following, listed in order from lowest to highest capital cost and potential energy savings:

- Lamp-only replacements that leave the ballast in place (TLEDs)
- Fixture retrofits that include integral LED lamps and drivers installed in the existing fixture housing
- Complete fixture replacements

Cx Associates recommends using retrofit kits as a minimum, as lamp-only replacements are less efficient, along with the fact that fluorescent ballasts vary and not all ballasts will work with all TLEDs.

While building occupants appear to be diligent about turning off lights when not in use, we also recommend installing occupancy sensors in areas that are used intermittently such as restrooms and storage rooms. This way, lights will turn off automatically when no occupants are present. These can also be configured as “vacancy” sensors (i.e. manual on, auto off), so that manual input is required to turn on the controlled lighting, but the control automatically turns the lighting off, potentially leading to additional energy savings.

Savings and costs for this measure were estimated based on assuming one-for-one fixture retrofits. A more detailed lighting design analysis and illumination study may be warranted prior to implementation to ensure illuminance targets are met, but not exceeded, and occupant visual comfort is maintained.

5: Waste Heat Recovery

The refrigeration plant generates significant heat during the winter that is rejected to the outdoor environment through the condenser. There are many options for recovering this heat to offset heating costs in the building during the winter. On the simplest side a heat recovery unit could be added to the refrigeration plant that could heat domestic hot water. We estimated that the saturation temperature on the high side of this system is ~120°F. The refrigeration plant would be capable of providing all the heat necessary for the domestic hot water system while the refrigeration plant is operating and could likely offset some of the fuel oil use in the heating system as well with the proper configuration. This would require a heat recovery unit and some additional piping. These systems can also reduce the refrigeration plant costs as the condenser units do not have to work as frequently, and the refrigerant can be cooled more easily. There are systems on the market that will work for the existing refrigerant, and we recommend working with a refrigeration specialist to evaluate if there is space to install such equipment.

A more comprehensive option would be to upgrade the entire refrigeration plant with heat recovery chillers that would be capable of providing both cooling for the brine and all necessary heating (both space and water) during the ice season. This would require replacing the majority of the refrigeration plant components as well as some heating system components. Such a system would also reduce the overall cost of the refrigeration plant by installing more efficient equipment. While this overhaul does not economically make sense independently, because the current refrigeration system is nearing its end-of-life it would make sense as a refrigeration plant replacement. Modern systems can use more environmentally friendly refrigerants including CO_2 which poses low risk to human health and has drastically lower global warming potential than other refrigerants.

If a refrigeration plant upgrade is pursued Cx would recommend including a back-up heating system for when heating at the facility is desired and the refrigeration plant is not running (especially in the early spring). This could be the existing boiler system or a new heat pump system. Details on heat pump systems for space and domestic hot water are included in separate measures later in this report.

6: Heat Pump Water Heater

The existing domestic hot water heater is a 119-gallon indirect unit fed from the boilers. Heat pump water heaters are much more efficient than oil-fired water heaters. We recommend using waste heat from the refrigeration plant to heat water during the ice season, and installing a secondary heat pump water heater for use when the refrigeration plant is not operating. For the type of use in this building, the unit could operate in heat pump only mode, which has a slower recovery time but is three times more efficient than an electric water heater. Hybrid mode uses the heat pump for most hours but will also use an electric resistance element to achieve faster recovery times if required. We recommend procuring a heat pump water heater that exceeds the minimum ENERGY STAR requirements.

This measure is not recommended for use during the ice making season when peak demand electric prices are high and carry through the summer months. If waste heat recovery for domestic hot water is not pursued we recommend only using this system when the ice plant is not running.

7: Boiler Outside Air Temperature Reset

The existing boiler operates at a constant hot water supply temperature setpoint of ~180°F. The hot water supply temperature setpoint for the boiler can be reset based on outdoor air temperature (OAT). This means that hotter supply temperature water can be used when the outside air is very cold, and a cooler hot water supply temperature can be used when the OAT is warmer but heating is still needed. This saves heating energy during the shoulder seasons. We would recommend a linear outside air temperature reset schedule of 180°F at 20°F OAT and below to 130°F at 50°F OAT and above. Implementation of this measure will require the installation of an additional boiler controller. The most common of these are Tekmar controllers which are relatively inexpensive. Note that this measure only applies if installing heat pumps for space heating (Measure 11) is not pursued.

8: Web-based thermostats

Currently, space heating temperature setpoints are controlled manually through wall-mounted thermostats. The site contact indicated that the heating temperature setpoints are typically set around 60°F continuously and that building occupants often adjust the set-points. We recommend installing web-based thermostats to automatically enable unoccupied temperature setbacks during un-scheduled times at the arena, prevent tampering, and allow for remote adjustment of set-points. Temperature setpoints could be set back to 55°F or so (adjustable) during unoccupied times when the specific area is unoccupied, resulting in energy savings of around 1% per eight-hour setback period. Web-connected thermostats provide standalone 'smart' thermostat control options along with a uniform interface, web connectivity, and scheduling (either programmed or self-learning). If installed in each space, these thermostats can be used to set occupancy schedules and programmed with temperature setbacks. A web interface would also allow for remote monitoring of space temperatures and setpoints and the ability to adjust setpoints without being onsite.

<u>Note that temperature setbacks are not recommended with heat pump systems, so this measure would not apply if heat pumps are installed as described in Measure 8.</u>

9: New Refrigerator

The top-freezer refrigerator that is currently in the concession stand was manufactured in 1996. New refrigerators have significantly higher efficiencies and increased insulation resulting in lower operating costs. Given the old age of the existing refrigerator it makes economic sense to replace it with a similar but new and ENERGY STAR rated refrigerator.

10: Heating System Pipe Insulation

In general pipes throughout the Ice Arena were insulated, but there were some exceptions, notably in the boiler room. We estimate only about 30 ft of pipe overall is uninsulated, but a complete system survey may find a higher amount of uninsulated piping. We recommend installing insulation on all the bare heating system piping, especially in places that are already overly warm or are otherwise unconditioned.

MEASURES INVESTIGATED BUT NOT RECOMMENDED

The measures described below were investigated but ultimately not recommended due to poor economic performance, whereby the simple payback period exceeds the expected life of the measure.

11: Heat Pumps for Space Heating

It is important to note that before exploring any major heating system upgrades, we recommend first implementing any feasible building envelope improvements that are described above. By reducing the building heating load as much as possible through air sealing and insulation, any new equipment can be sized appropriately to meet the reduced load, potentially resulting in a lower first cost.

The existing heating system consists of a fuel oil fired boiler that distributes hot water to unit heaters in conditioned spaces. Since this boiler is only two years old, it may not make sense to replace it with an entirely new system at this time. One option that could result in a significant reduction in the consumption of fuel oil would be to install ductless mini-split or multi-split air-source heat pumps throughout the space. This would also have the ancillary benefit of providing cooling to the conditioned spaces of the building.

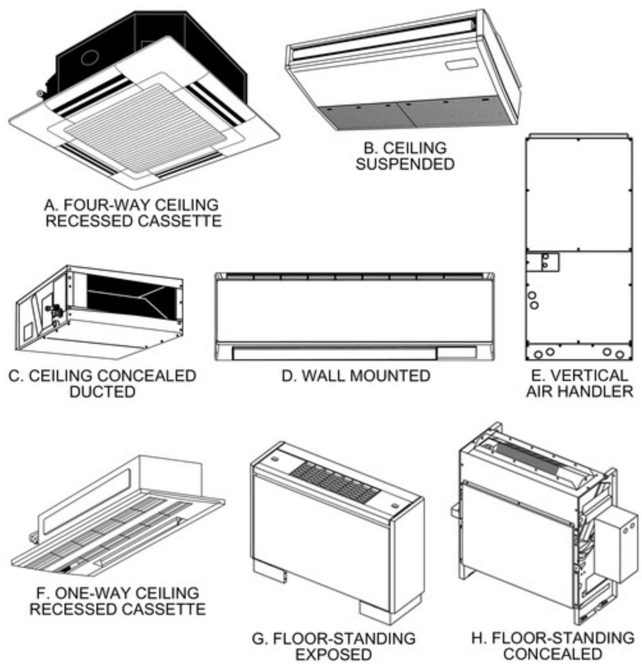


Figure 11: Heat pump indoor unit types

Our analysis and sizing assume that recommended building envelope measures (described above) are implemented. If these are not implemented, then the costs of this system will likely be higher both up-front and during operation.

While air-source heat pump systems lose capacity and efficiency as outdoor air temperature decreases, major strides have been made in recent years to mitigate these effects in cold climates. Heat pumps designed for cold climates utilize technology that allows for operation at 100% nominal heating capacity down to 5°F and can operate at temperatures as low as -13°F. Therefore, while a heat pump could meet the heating requirements for most of the year, in a climate like Vermont's it is important to have some form of backup or supplemental heating, and in the case of the ice arena we recommend using the existing boiler system. The building can be heated using a hybrid approach, whereby the heat pumps provide heating under most conditions, but during very cold weather the boiler will kick on to provide the heat. This is typically accomplished using an outdoor air switchover temperature, so that the heat pumps will operate when the outdoor air temperature is above the switchover, and the boiler will operate below. The optimal switchover temperature from an energy cost standpoint is dependent on the relative prices of electricity and fuel oil, so may change over time. Table 5 shows a comparison of electric and fuel oil consumption and cost for various switchover temperatures. In this case the lowest total heating cost occurs at a switchover temperature of 0°F, essentially allowing the heat pumps to operate for almost all hours.

Table 5: Heat Pump / Furnace Switchover Temp Comparison

Switchover Temp (°F)	Electric Consumption (kWh)	Fuel Oil Consumption (gal)	Electric Cost	Fuel Oil Cost	Total Cost
70	0	990	$0	$3,356	$3,356
60	78	982	$14	$3,329	$3,343
50	740	917	$134	$3,109	$3,243
40	2082	800	$378	$2,712	$3,090
30	5670	513	$1,029	$1,739	$2,768
20	7926	363	$1,438	$1,231	$2,669
10	10778	191	$1,956	$647	$2,603
0	12948	69	$2,350	$234	$2,583
-10	13979	17	$2,537	$58	$2,594

12: Electric Ice Resurfacing

The Fenton Chester Ice Arena currently uses a propane fired Zamboni for ice resurfacing. Electric models nearly identical to the existing machine are available and would reduce propane use at the facility and improve indoor air quality by removing a source of unventilated combustion from the facility. An electric ice resurfacing machine could increase peak electrical demand due to charging, but these impacts could be reduced by charging during hours without a peak demand charge or charging during lower electricity use times.

OTHER COMMENTS

Roof Replacement to Prevent Water Infiltration and Improve Humidity Control Through Reduced Air Loss

Speaking with building staff, there are several issues with the current roof system that impact the usefulness and potentially the durability of this space. However, since this is an unconditioned space these improvements will not results in energy savings related to heating or cooling. There may be some energy savings related to the use of the dehumidification system, however estimating that savings would be very difficult and somewhat negligible given the potential cost and was therefore not modeled or considered cost effective.

Water infiltration issues through the roof were mentioned, however our inspection did not align with a wetting event so we were unable to observe these conditions to have a better understanding of their location or extent. Similarly, the building staff described that in shoulder seasons dehumidification issues arise when ice is being made but the exterior air is still warm and humid. The facility has a dehumidification system in place, however given the size of the building and the air leakage rate exterior air infiltration can make it difficult to maintain the desired humidity inside the facility. Per the building staff, at times water has been observed dripping from the ceiling due to the high humidity.

Depending on the location and extent of the water infiltration issues, it is possible these could be repaired without a major roof replacement. However, reducing the air leakage rate to improve the humidity concerns and improving the R-value to maintain a desired temperature would require significant renovations. If a roof replacement is pursued, Cx Associates would recommend either of the options listed below. Please know that both of these options would require engineering and design services, and a more detailed roof assessment/analysis would be recommended since that was not the primary focus of this assessment.

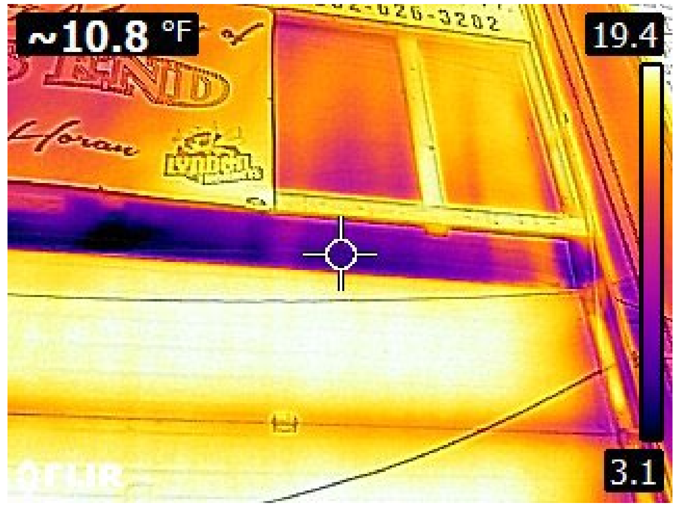
Insulated Metal Panel Roof System
One option to consider for a full roof replacement would be the installation of an insulated metal panel (IMP) roof system. Insulated metal panels are commonly used on exterior walls on large steel buildings such as this one and can also be utilized as roofing systems. IMPs provide R-value, air barrier, weather barrier, and exterior finish through one system. Depending on the desired R-value of this assembly, IMPs could remove the need for insulation on the interior side of the roof slope.

Roof Replacement with Dedicated Air Control Layer
Another option for a roof replacement would be removing the existing metal roof and installing a subbase such as steel decking with a dedicated air control layer material. Self-adhered air/vapor barrier materials are commonly used for this application. A metal roof system similar to the one in place could then be installed over the top of this new subbase. Assuming the existing roof insulation is protected, this could be left in place and not require replacement. This approach would still be very labor intensive, but it would likely be slightly less expensive than the IMP roof system.

Air Sealing Arena to Improve Humidity Control

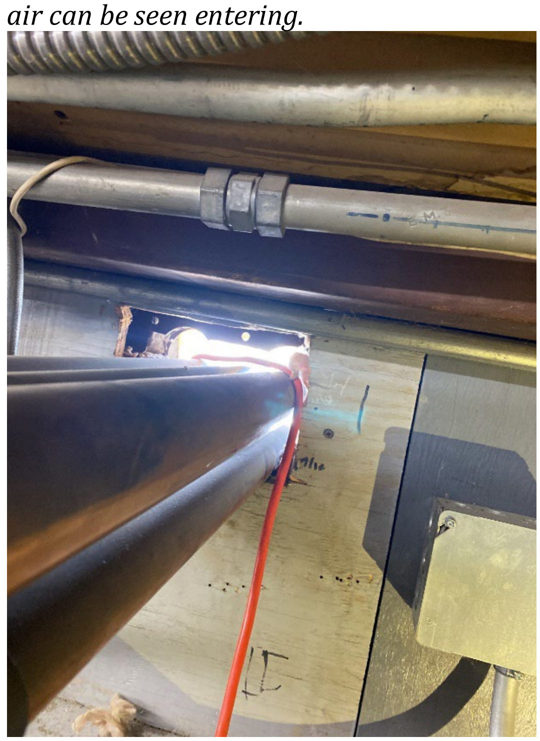
The arena space is not actively heated or cooled, however equipment is in place to dehumidify the space. Blower door test results indicate that the arena is relatively leaky which can make it more difficult to maintain a consistent humidity, even with equipment in place. Reducing air leakage in the unconditioned space will not result in energy savings regarding heating or cooling, but it may increase the efficiency of the dehumidifier. If the humidity in the arena is able to remain more constant, issues such as condensation on the roof will also be improved. Doors are a consistent leakage point, both person doors and overhead doors. Many of the overhead doors are blocked and not in use, however they are still quite leaky. Other consistent leakage areas include penetrations such as conduit, piping, and ductwork.

This overhead door does not seal well at the bottom, this is partially due to ice build-up.



IR Imaging of the top of an overhead door where cool air can be seen entering.

Daylight is visible at the latch connection of these door doors.



An example of a penetration in the mechanical room that is not sealed.

<u>*Recommended Actions*</u>

To improve the building's air leakage rate, Cx Associates recommends that improvements are made to seal all exterior doors and exterior penetrations. There are currently 8 overhead doors around the perimeter of the arena, many of which are covered and not in use. Adjusting these doors and adding/replacing perimeter gasketing as needed to ensure a tight seal will reduce air leakage. Doors that are not used or used infrequently can be sealed more aggressively if there is no concern of impact to the operability. Similarly, person doors should have weather stripping around the perimeter, and hardware replaced and replaced as needed to prevent air infiltration. Other penetrations such as piping, conduit, and ductwork can be sealed with a product such as canned spray foam.

Re-instate VFD on Brine Pump

There is a VFD for the Brine Pump mounted on the wall of the refrigeration plant room. This VFD has been disconnected but the reasoning for that was unclear. VFDs can save significant energy without compromising performance by adjusting the speed of the pump for actual conditions instead of cycling the pump. We recommend investigating the re-installation of the VFD for the brine pump to reduce energy and power consumption by this pump.

Tamper-resistant thermostats

During the site visit building managers noted that thermostats in the bathrooms and locker rooms will be turned up as high as they go as space users want warmer temperatures. While the thermostats are already in difficult to reach places we recommend obtaining and installing tamper resistant thermostat covers. These would prevent building users from drastically increasing space temperatures. Alternatively, thermostat limits could be put in place to prevent users from controlling space temperature outside a set limit. If web-based thermostats are installed we recommend choosing a model that limits or removes control at the actual thermostat.

Energy Recovery Ventilator

Currently there is no mechanical ventilation for the building other than the fan in the concession area. While the space is currently well ventilated by a leaky building, improving air sealing is highly recommended which would reduce this ventilation. Continuing to ventilate the spaces for enhancing occupant well-being is recommended if this is pursued.

While adding mechanical ventilation will increase energy consumption due to the additional fan energy and conditioning of outdoor air, this can be mitigated by using efficient equipment and smart control strategies.

Energy recovery ventilators (ERVs) use heat from exhaust air to pre-condition incoming outdoor air, significantly reducing the amount of energy needed to condition the outdoor air (Figure 12). These can reduce conditioning loads by up to 80%. Additionally in the ice arena where humidity is the largest concern and enthalpy-wheel type energy recovery ventilator can help dehumidify incoming air in addition to pre-conditioning it.

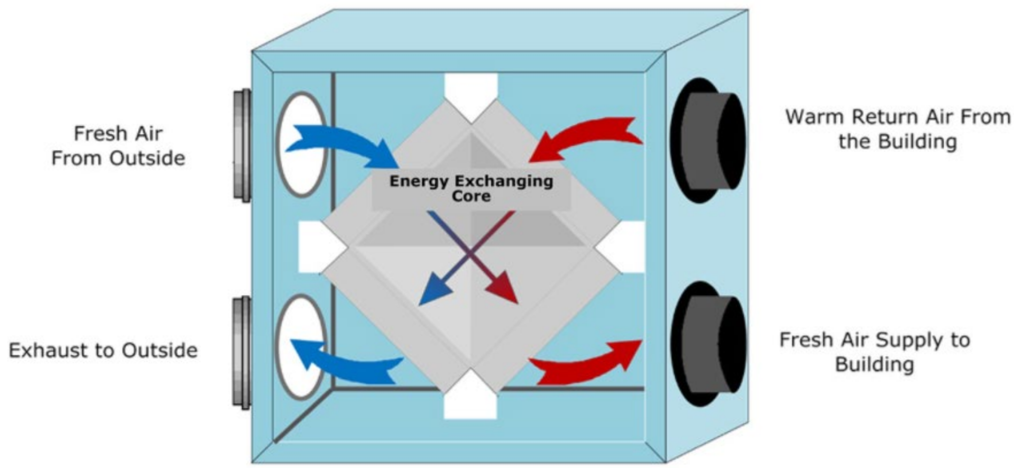


Figure 12: Energy recovery ventilation diagram

We recommend installing an enthalpy wheel to provide fresh air for building occupants, improving indoor air quality and reducing humidity. This is especially important if recommended air sealing measures are implemented, resulting in reduced uncontrolled infiltration of outdoor air.

RESILIENCY MEASURES

Battery Storage

Battery storage is increasingly being used in buildings as costs decline and potential applications increase. Some of the benefits may not be immediately available, but it is worth considering installing battery storage so that the building can take advantage in the future. Potential applications include the following:

- During power outages, use battery storage to provide power to the building.
- Currently, the utility tariff includes a peak demand component. Batteries can be charged during off-peak hours when prices are lower, and then discharged during peak hours to save on energy costs, and can help reduce peak demand by charging during lower demand period and discharging during higher demand periods.
- Batteries can contribute to grid stability, by providing power to the grid during periods of high demand, and absorbing power during periods of excess renewable energy production. Green Mountain Power, the largest utility in Vermont, is pursuing a strategy of installing battery storage in the buildings it serves to help manage power outages and the load on the grid.
- If on-site renewable energy generation is installed, excess energy can be stored in the battery.

There does not appear to be sufficient space in the mechanical / electrical room or refrigeration plant room to install a battery, but there are other locations around the building where one could be installed. A single lithium-ion battery has a capacity of around 14 kWh, which would be able to meet the facility's electricity needs for around 8 hours when the refrigeration plant is not running, and much less than one hour when the refrigeration plant is running[3] . Battery costs may amount to around $1,200 per kWh, so an installation may cost around $17,000, for a single battery. The

[3] Based on existing conditions.

Fenton Chester Ice Arena would benefit from installing a large capacity battery, and economically this may be advantageous given the high cost of peak demand that a battery can help mitigate.

Electric Vehicle Charging

As electric vehicles become more common, it will be useful to have electric vehicle charging stations located at buildings for staff and visitors. There are three types of chargers available (Level 1, 2, and 3) – Level 2 chargers would be most appropriate for the facility, which charge at 240V and can typically add 10-20 miles per hour of range to the battery. There may be room in the electrical panel to add circuits for EV chargers, which typically require 40-amp circuits for Level 2 chargers. There is room in the parking lot for chargers (Figure 13). Level 2 chargers cost around $800 for just the hardware, but total installation costs can be significantly higher as electrical service will need to be provided through a trench from the main panel to the charging area ($5,000-10,000).

Figure 13: Potential area for EV chargers

On-Site Renewable Energy Generation

Photovoltaic panels for solar power generation could be placed on the east or west side of the building's roof. The roof is very large, and choosing only the best available space gives a photovoltaic system size of 33.0 kW. This would result in an annual production of around 34,000 kWh. At a cost of $3 per installed watt, the system cost would be around $100,000.

Standing seam metal roofs such as the one currently at the ice arena are ideal for installing PV systems, and the large roof is not constrained by area, as other roofs may be. However, the orientation of the roof is not ideal for solar panels, and a ground mount system could be investigated. Additionally, we recommend investigating the structural integrity of the roof before installing a photovoltaic system on the roof.

VI. Conclusion

The Fenton Chester Ice Arena has multiple opportunities to reduce operating costs and concurrently upgrade aging infrastructure in a cost-effective manner.

Cx Associates' recommendations are based on a fundamental operational strategy to mitigate the equipment operating efficiency penalties while maintaining a very high level of indoor environmental quality. Cx Associates suggests the following fundamental core practices:

- Consider the building from a holistic perspective. The different systems must all work together.
- Size equipment based on current building loads and use.
- Establish a market opportunity practice of replacing failed equipment with new correctly-sized, high efficiency equipment.
- Include a quality assurance program (building commissioning) for building expansion/ renovation and equipment replacement.

The steps necessary to begin to reduce energy use and improve comfort at the Fenton Chester Ice Arena are:

1. Select the desired measure package from this report and arrange for funding.
2. Retain the services of a design engineering firm[4] having the skills, knowledge and experience with efficient execution of high-performance systems.
3. Obtain specifications and engineering design for the opportunities and any other projects prioritized for immediate implementation.
4. Procure contractor and commissioning pricing, and review pricing with the designer.
5. Ensure thorough review of contractor-proposed equipment and control sequences to confirm the design intent is being fulfilled and all assumptions within the audit analysis are included. This review should be undertaken by Cx Associates to help ensure the building upgrades will deliver the expected savings.
6. Implement measures and commission installation to ensure equipment is optimized and operates as designed.
7. Perform measurement and verification of savings and survey occupants regarding thermal comfort.
8. Report out to stakeholders on the project outcomes.

End of report.

[4] Cx Associates offers design engineering services for energy retrofits to building HVAC and control systems.

VII. Appendix A: Building Envelope Test Results

BLOWER DOOR TEST RESULTS

The whole-building air leakage was measured and normalized, resulting in an air leakage rate of **0.34**cubic feet per minute at 50 pascals of pressure per square foot (CFM50/SF) of exterior building shell, based on 6 quantified sides of the envelope.

Field Measured CFM @ 50 Pascals	Temperature Adjusted CFM @ 50 Pascals*	Square Feet of Building Shell (6 sides)	CFM50/SF (6 sides)	CFM75/SF (6 sides)**
22,280	22,072	64,159	**0.34**	**0.43**

* Temperature adjusted CFM50 is a more accurate measurement of air flow as it accounts for air density differentials between conditioned and outdoor ambient space.
** Extrapolated using values obtained at -50 pascals and -67 pascals.

Environmental Conditions & Building Configurations

1. All exterior doors were closed.
2. All interior doors were propped open.
3. Unit heaters in the locker rooms and snack bar were shut down.
4. One (1) blower door setup was installed at the north end of the building and one (1) blower door setup was installed on the south end of the building.

Outside Temperature	**15 °F**
Inside Temperature	**24 °F**
Wind Conditions	**0-5mph**
Time of Test	**10:00am**

RESULT BENCHMARKING

The table below is used to compare the results of this building to common whole-building air tightness benchmarks, as normalized by the indicated number of sides.

Air Tightness Benchmarks for Envelopes w/ 6-sided Surface Area Calculations	CFM50/SF of Shell	CFM75/SF of Shell
Fenton Chester Ice Arena	**0.34**	**0.43**
US Passive House (PHIUS+ 2021 – prescriptive)	0.06	0.08
Beyond High-Performance Air Barriers (approx.)	<0.11	<0.15
2020 VT CBES Reduced Air Infiltration (C406.9)		<0.25
High Performance Air Barriers (approx.)	<0.21	<0.25
US Army Corps of Engineers Air Leakage Test Protocol		0.25
2020 VT CBES Code Minimum (C402.4.1.1)		<0.30
2021 International Energy Conservation Code (C402.5.3)		0.40
Leaky Construction (approx.)	>0.45	>0.50

These results indicate that the building's air barrier is relatively leaky when compared to today's code standards. Some improvements would be needed to reach 2020 VT CBES Code Minimum of 0.30 CFM75/SF of shell. This would require a reduction of 8,469 CFM of air leakage, approximately 31%.

VIII. Appendix B: Project Stakeholder Information

Table B1: Contact Information for Project Stakeholders

Name	Affiliation	Role	E-mail	Phone
Brian Sewell	State of Vermont Buildings and General Services	State Energy Program Manager	brian.sewell@vermont.gov	(802) 622-4291
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