PATHWAY TO DECARBONIZATION FEASIBILITY STUDY

CITY OF TEMISKAMING SHORES

DON SHEPHERDSON MEMORIAL ARENA
75 Wellington Street South, New Liskeard, ON

WalterFedy Project No: 2023-0734-10

September 16, 2025

WALTERFEDY

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Project Number: 2023-0734-10

September 16, 2025

Mathew Bahm
Director of Recreation
City of Temiskaming Shores
325 Farr Drive
Haileybury, ON P0J 1K0

Dear Mathew,

RE: Pathway to Decarbonization Feasibility Study

WalterFedy is pleased to submit the attached Pathway to Decarbonization Feasibility Study report to the City of Temiskaming Shores. This study covers the agreed-upon scope and provides a Pathway to Decarbonization Feasibility Study for the Don Shepherdson Memorial Arena, which is located at 75 Wellington Street South in New Liskeard, ON. Certain parts of this report are designed to be viewed in digital/PDF format. This approach will enable the reader to zoom in on images and navigate the document using the provided hyperlinks.

The report was completed based on the information provided by the City of Temiskaming Shores, using the supplied and collected data, engineering judgment, and various analysis tools to arrive at the final recommendations.

All of which is respectfully submitted,

WALTERFEDY

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EXECUTIVE SUMMARY

WalterFedy was engaged by the City of Temiskaming Shores to complete a Pathway to Decarbonization Feasibility Study for the Don Shepherdson Memorial Arena. The objective of this engagement is to identify and analyze measures that reduce utility use, GHG emissions, and utility costs at the Don Shepherdson Memorial Arena, and to analyze various GHG Reduction Pathways consisting of combinations of measures. Based on these analyses, the objective is also to recommend the preferred GHG Reduction Pathway for implementation. To achieve this objective, the following steps were taken.

1. **Facility description**. The existing conditions of the facility were reviewed through available documentation and a site survey completed on 2024-04-15 to gain an understanding of the facility and its operations. A facility description, summarizing findings, is provided in Section 2.
2. **Utility use baseline**. Metered utility data provided by the City of Temiskaming Shores was reviewed to understand historical utility use trends, and to establish the utility use baseline for the Don Shepherdson Memorial Arena. Findings are documented in Section 3.
3. **Energy model development**. A calibrated energy model was developed from a bottom-up hourly analysis considering historical weather patterns, and the insight gained from reviewing the facility's existing conditions and historical utility use data. Findings are documented in Section 4.
4. **Measure analysis**. Measures intended to achieve the City of Temiskaming Shores's goals were identified and analyzed. Analysis includes conceptual design development and utility analysis quantifying utility use impacts, GHG emissions and utility costs for each measure. Findings are documented in Section 5.
5. **Scenario analysis**. Scenario analysis was completed to estimate the costs and benefits expected from implementing various combinations (i.e. scenarios) of the measures that were individually analyzed in Section 5, accounting for the interactive effects between measures within each scenario. Findings are documented in Section 6.

All analysis was completed using the calibrated energy model, which matches metered yearly electricity and natural gas utilities used by the Don Shepherdson Memorial Arena by precisely capturing existing conditions of the building within the model. The model tracks each utility end use for every hour of a complete year.

Based on the analysis completed and discussions with the client, the GHG reduction pathway that is recommended for implementation is as follows.

- **Minimum performance scenario**

The recommended plan scenario composition is presented in Figure 1, which is a measure implementation timeline plot indicating which measures were assumed to be implemented in which plan scenarios and when, and the estimated project cost of each measure. The measures are also colour-coded according to measure group.

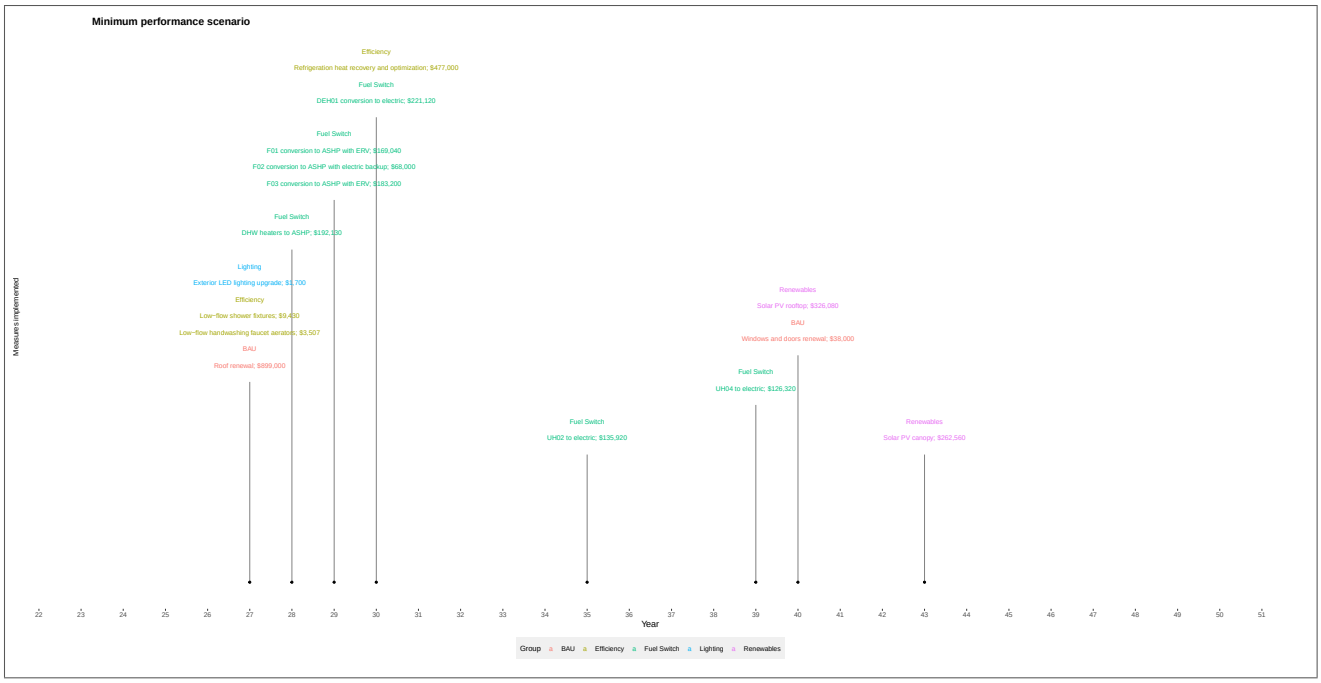


Figure 1: Recommended plan scenario composition, indicating which measures are implemented when and at what cost in each plan scenario

The following plots in Figure 2 show the results for the recommended GHG reduction pathway.

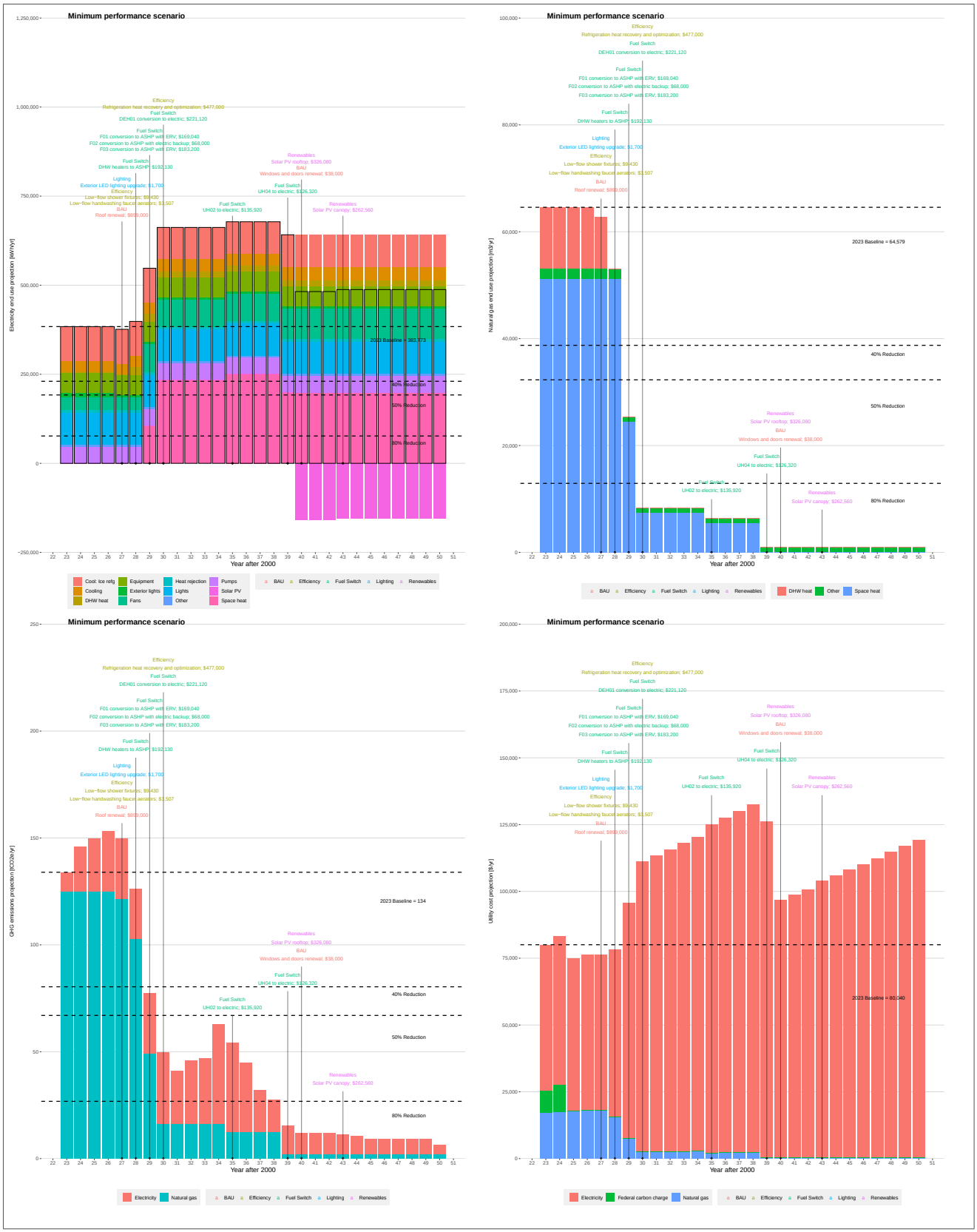


Figure 2: Recommended scenario performance

Table 1 summarizes the performance of all the plan scenarios with respect to utility use, GHG emissions, utility cost, and financial metrics. The recommended plan scenario is in **bold**. The first half of Table 1 represents the estimated performance in the final year (2050) of the evaluation period. The second half of Table 1 represents the estimated cumulative performance across the entire evaluation period (present to 2050). All final year dollar values are in the value of today's currency. All cumulative dollar values presented in Table 1 are calculated as the simple sum of expenditures over the evaluation period, except for the life cycle cost, which is discounted to present value (as illustrated in Figure 2).

Table 1: Recommended plan scenario performance summary

Section	Description	Unit	Minimum performance scenario	Aggressive deep retrofit	Comprehensive	Organizational goal alignment	Business as usual
Utility use final	Electricity use	[kWh/yr]	**487,728**	487,728	399,220	481,257	383,773
	Electricity monthly peak (av)	[kW]	**174**	174	157	172	85
	Electricity yearly peak (max)	[kW]	**375**	375	338	369	144
	Natural gas use	[m3/yr]	**953**	953	953	1,682	64,579
GHG emissions final	Electricity GHGs	[tCO2e/yr]	**4.6**	4.6	3.8	4.6	3.6
	Natural gas GHGs	[tCO2e/yr]	**2**	2	2	3	125
	Carbon offsets GHGs	[tCO2e/yr]	**0.00**	0.00	0.00	0.00	0.00
	Total GHGs	[tCO2e/yr]	**6**	6	6	8	128
Utility cost final	Electricity utility cost	[$/yr]	**118,908**	118,908	97,330	117,330	93,564
	Natural gas utility cost	[$/yr]	**432**	432	432	761	29,228
	Carbon offsets utility cost	[$/yr]	**0.00**	0.00	0.00	0.00	0.00
	Federal carbon charge	[$/yr]	**0.00**	0.00	0.00	0.00	0.00
	Total utility cost	[$/yr]	**119,340**	119,340	97,761	118,092	122,792
Utility use cumulative	Electricity use	[kWh]	**14,870,103**	13,467,390	13,900,805	14,725,494	10,745,653
	Natural gas use	[m3]	**478,088**	311,110	475,304	494,288	1,808,210
GHG emissions cumulative	Electricity GHGs	[tCO2e]	**544**	492	520	540	394
	Natural gas GHGs	[tCO2e]	**924**	601	918	955	3,494
	Carbon offsets GHGs	[tCO2e]	**0.00**	0.00	0.00	0.00	0.00
	Total GHGs	[tCO2e]	**1,468**	1,093	1,439	1,495	3,888
Utility cost cumulative	Electricity utility cost	[$]	**2,816,183**	2,555,684	2,612,762	2,787,365	2,031,082
	Natural gas utility cost	[$]	**138,396**	87,547	137,431	144,392	634,456
	Carbon offsets utility cost	[$]	**0.00**	0.00	0.00	0.00	0.00
	Federal carbon charge	[$]	**18,094**	18,094	18,094	18,094	18,094
	Total utility cost	[$]	**2,972,673**	2,661,325	2,768,288	2,949,851	2,683,632
Financial cumulative	Project cost	[$]	**4,042,303**	3,702,054	9,806,873	4,018,706	1,542,679
	Replacement cost	[$]	**1,926,625**	1,986,493	1,283,884	1,910,746	1,100,410
	Life cycle cost	[$]	**4,294,026**	4,605,106	4,794,662	4,264,163	3,001,818

1 INTRODUCTION

1.1 Overview

WalterFedy was engaged by the City of Temiskaming Shores to complete a Pathway to Decarbonization Feasibility Study for the Don Shepherdson Memorial Arena. This engagement aims to identify a recommended Greenhouse gas (GHG) reduction pathway by examining GHG reduction measures and various scenario developments. Based on a review of the Request For Proposal Document, the City's Corporate Greenhouse Gas Reduction Plan (GHGRP), and the Federation of Canadian Municipalities (FCM) Community Buildings Retrofit (CBR) funding program, the following scenarios will be developed:

- **Business as usual**: To follow the existing capital renewal plan and replace equipment at the end of its life with like-for-like equipment, meeting minimum energy-efficiency requirements of ASHRAE 90.1.
- **Minimum performance**: To achieve a 50% reduction in operational GHG emissions within 10 years and 80% within 20 years. This scenario addresses the minimum performance scenario of FCM's CBR program.
- **Aggressive deep retrofit**: Implement the same measures as in the minimum performance scenario but achieve an 80% reduction in GHG emissions within five years. This scenario addresses the additional scenario requirement of FCM's CBR program.
- **Organizational goal alignment**: To reduce emissions by 40% GHG emissions from 2019 levels by 2033 and 80% reduction by 2050 of on-site emissions. The remaining 20% is to be addressed through carbon offsets, as noted in the City's GHGRP.
- **Comprehensive**: To understand the limit of GHG reductions possible by implementing all measures with the greatest reduction on GHG emissions that are mutually exclusive.

1.2 Background

1.2.1 Corporate Greenhouse Gas Reduction Plan

The City of Temiskaming Shores has been dedicated to taking a leading role in the battle against climate change. As a committed member of the Partners for Climate Protection (PCP) program, they achieved Milestone 3 in May 2023 by creating the City's Corporate Greenhouse Gas Reduction Plan. The plan includes ambitious targets, aiming for a 40% reduction below 2019 levels by 2033 and striving for net zero emissions operations by 2050. After conducting an inventory of its greenhouse gas (GHG) emissions in 2019, the City discovered that its buildings and facilities accounted for 813 tCO2e, representing 41.6% of its total GHG emissions inventory. A significant portion of these GHG emissions comes from natural gas, which makes up 41.7% of all energy sources for the City. To reach these sustainability goals, the City has implemented several measures, including:

- Establishing a Climate Action Committee
- Implementing a Climate Lens with regular reporting
- Utilizing a combination of EnergyCAP and ENERGY STAR Portfolio Manager to monitor and report building utility use, including electricity, natural gas, and propane
- Transitioning its fleet to biodiesel
- Initiating decarbonization studies of its buildings

This study will contribute to the decarbonization studies of its buildings. The Don Shepherdson Memorial Arena is one of fourteen buildings being examined. Of these fourteen buildings, they represent over 77% of the buildings and facilities GHG emissions. In particular, the Don Shepherdson Memorial Arena represented 146 tCO2e in 2019, or 7.5% of the overall inventory.

1.2.2 Asset Management Plan

The City of Temiskaming Shores released Version 1.2 of their Asset Management Plan in 2024, providing a framework for prioritizing and optimizing asset management efforts from 2024 to 2034. The building and facility

assets are estimated to have a total replacement cost of $76,178,722, with City Hall alone having an estimated replacement cost of $8,613,308. The average annual financial requirements, including capital and operational expenditures, is $2,153,014. Furthermore, the 2031 budget will see a significant increase in capital needs, nearing $44 million. In 2032, this figure will exceed $25 million, and in 2033, it will be more than $5 million. Figure 2 summarizes the asset management data for the Don Shepherdson Memorial Arena.

Table 2: Asset management summary for this facility

Group	Metric	Unit	Value
Financial	Content Value Estimated	[$]	918,955
	Building Land Tank	[$]	14,775,606
	Replacement Cost	[$]	15,694,561
Information	Install Date	[yr]	1971
	Age	[yrs]	54
Condition Rating	Structure Condition Score	[-]	3.9
	Final Condition Score	[-]	3.9
Risk	Probability of Failure	[-]	2
	Consequence of Failure	[-]	5
	Risk Score	[-]	2.6

1.3 Contact information

Contact information for WalterFedy (the Consultant) and City of Temiskaming Shores (the Client) is provided in Table 3.

Table 3: Contact information

Description	Consultant	Client
Organization	WalterFedy	City of Temiskaming Shores
Address	Suite 111, 675 Queen St South	325 Farr Drive
Location	Kitchener, ON	Haileybury, ON
Postal code	N2M 1A1	P0J 1K0
Contact name	Jordan Mansfield	Mathew Bahm
Credentials	P.Eng., M.Eng., CEM, CMVP	-
Title	Energy Engineer	Director of Recreation
Phone	519 576 2150 x 336	705 672 3363 x 4106
Email	jmansfield@walterfedy.com	mbahm@temiskamingshores.ca

2 FACILITY DESCRIPTION

2.1 Facility description methodology

The facility was reviewed and described according to the following methodology. The intent of reviewing and describing the facility is to understand the pertinent operations and systems in the facility that use utilities so that the baseline (i.e. existing) utility use can be accurately quantified.

1. **Facility document review**. Facility documents from the following list were reviewed, if available. Further information on available documentation are available in Section 2.3.
    - Building drawings.
    - Building automation system graphics and points lists.
    - Previously completed Engineering studies, including Energy Audits, Feasibility Studies, and Building Condition Assessments.
    - Historical utility use data.
    - Other documentation made available by the City of Temiskaming Shores.
2. **Site survey**. A site survey was completed on 2024-04-15 to review the energy systems applicable to the desired retrofit scenario.

2.2 Facility overview

An overview of the Don Shepherdson Memorial Arena is provided in Table 4.

Table 4: Facility overview

Description	Unit	Value
Name	[-]	Don Shepherdson Memorial Arena
Address	[-]	75 Wellington Street South
Location	[-]	New Liskeard, ON
Type	[-]	Arena
Construction year	[-]	1971
Gross floor area	[m2]	3,717
Gross floor area	[ft2]	40,010

An aerial view of the Don Shepherdson Memorial Arena is provided in Figure 3.

Figure 3: Don Shepherdson Memorial Arena aerial view

2.3 Building information

Renovations

The following renovations are known:

- **Lighting retrofit (2013)**: an estimated 28 high bay T5 fixtures were installed in the ice rink.
- **Dehumidifier (2014)**: it's presumed that the Dehumidifier was replaced in 2014.
- **Lighting retrofit (2019)**: 28 high bay LED fixtures were installed.
- **Ice resurfacer replacement (2022)**: an electric ice resurfacer was purchased for this facility.
- **Evaporative condenser replacement (2023)**: the evaporative condenser was replaced for the ice plant.
- **Roof cut test (2023)**: a roof cut test was conducted at this facility and found that the roof had three inches of polyisocyanurate (ISO) insulation.

Additions

There was one addition in 1999 that added changerooms to the south elevation of the building. Furthermore, a vestibule was added for the front entrance. However, it is unknown when this occurred.

Energy use not within the gross floor area

The following energy use is located outside the gross floor area of this building:

- Building-mounted exterior light fixtures
- Parking lot pole lighting

Utility bill responsibility

Utility bill responsibility is as follows:

- Natural gas meter: the City
- Electricity meter: the City

Commissioning history

No commissioning history has been documented.

Previous studies

The following is a summary of known previous studies:

- Energy audits: None
- Engineering studies: Roof inspection by STS Ltd.
- Building condition assessments: None

Documentation availability

In conjunction with the site survey, the following documents are being used to help us better understand this facility:

- Mechanical drawings: no original drawing set was provided. However, M1-M3 of the 1999 renovation was provided.
- Fire alarm upgrade, E-1 to E-4, dated October 2013.
- Electrical drawings: no original drawing set was provided. However, E1 of the 1999 renovation was provided.

- Architectural drawings: no original drawing set was provided. However, A1 to A3 of the 1999 renovation was provided.

2.4 Space use

Type summary

The following spaces were identified during the site survey and review of documentation.

- Storage rooms
- Changerooms
- Mechanical rooms
- Washrooms
- Ice resurfacer room
- Offices
- Concession
- Stairwells
- Multi-purpose room

The second-floor multi-purpose room is now being used for gymnastics. However, it was once a hall.

Occupancy scheduling

The facility operation hours are typically based on rentals. During the site visit, no occupants other than staff were present.

Based on the GFA, it is assumed that this building has a peak occupancy of 372 people.

Space use breakdown

A space use breakdown, which was estimated via calibrated measurements performed on available facility floor plans, is presented in Table 5.

Table 5: Space use summary

Space name	Floor area of space	HVAC System	Data source
-	[m2]	-	-
Lobby and West Changerooms	497.7	F01	Drawings.
Ice Resurfacer and Referee Changeroom	81.5	F02	Drawings.
South Changerooms	547.1	F03	Drawings.
Ice Rink	2,085.3	DEH01/DEH02	Drawings.
Bleachers	271.3	UH02	Drawings.
Gymnastics	561.1	UH04	Drawings.
Stairwells	17.1	UH03	Drawings.
Refrigeration room	33.2	UH01	Drawings.

Space use documentation

Space use documentation, including available drawings and photos taken during the site survey, is provided in the following images. Most drawings in this report are high-quality, embedded PDF documents, enabling the reader to review details by zooming in on the figures.

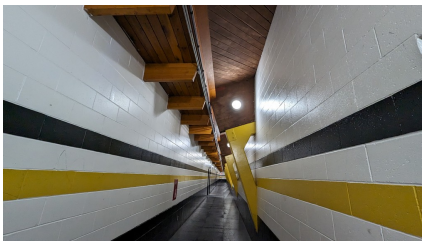


Figure 4: Corridor along addition

Figure 5: Ice rink

Figure 6: Temiskaming Tumblers Gymnastics Club

2.5 Building Envelope

Building envelope area data summary

Building envelope areas are summarized in Table 6.

Table 6: Building envelope summary

Area of roof	Area of exterior walls net	Area of exterior walls	Area of exterior windows	Area of exterior doors
[m2]	[m2]	[m2]	[m2]	[m2]
3,455	1,701	1,685	16.6	34.0

Overview

No architectural drawings were available for the original building. However, drawings were available for the 1999 addition.

Roof

- The exterior layer of the roof is a modified bitumen membrane, which is due for replacement. A cut test was conducted at this site, and the original roof was found to have three inches of polyisocyanurate insulation. Furthermore, the additional drawings show either three or four inches of polyisocyanurate.
- The overall roof assembly for the original is assumed to have a U-Value of 0.3155 W/m2K, while the addition is assumed to have a U-Value of 0.1893 W/m2K.
- The roof was in poor condition, as it is slated to be replaced.

Opaque Walls (above ground)

- The exterior walls comprised either an outer layer of architectural concrete block or metal siding. The addition shows three inches of rigid insulation between the concrete block and the architectural concrete block. It's assumed that the original building has two inches of rigid insulation.
- The overall wall assembly for the original is assumed to have a U-Value of 0.5679 W/m2K, while the addition is assumed to have a U-Value of 0.3786 W/m2K.
- The wall condition of the metal siding and concrete block was good.

Fenestration

Windows

- Most windows are double-pane aluminum windows.
- Windows appear in good condition, with one notable exception being the staff lunchroom window, which is deteriorating.
- The overall U-Value is assumed to be 3.786 W/m2K for the window system with a SHGC of 0.35.

Doors

- The overall fenestration-to-wall ratio is estimated to be 1%.

Overall Enclosure Tightness

Determining a building's infiltration rate is difficult without performing a blower door test. However, an infiltration rate is required for energy modelling purposes. Based on the site survey, an infiltration rate of 0.35 Lps/m2 of the above-grade building envelope area will be assumed here.

Building Envelope documentation

Building envelope documentation, including available drawings and photos from the site survey, is provided in the following images.

Figure 7: Aluminum-framed windows for south changerooms

Figure 8: Concrete block from original and addition

Figure 9: Damage to the south-facing wall

Figure 10: Door sweeps on the gymnastics entrance are in poor condition

Figure 11: Gymnastics entrance

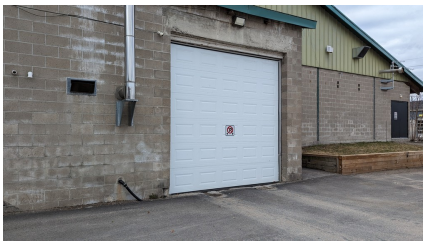


Figure 12: Ice resurfacer overhead door

Figure 13: North elevation

Figure 14: Office window

Figure 15: Office window seals in good condition

Figure 16: Overhead door

Figure 17: Soffit requires refinishing

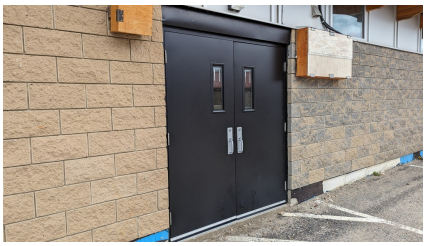


Figure 18: South entrance

Figure 19: The office on the north elevation is in poor condition

2.6 HVAC

HVAC equipment summary

HVAC systems are summarized in Table 7, Table 8, Table 9, and Table 10.

Table 7: Air distribution systems summary

Tag	Make	Model	Serves	Design flow	Motor output	Data source
-	-	-	-	[cfm]	[hp]	-
F01	-	-	West changerooms	1,800	3.00	Assumption.
F02	Payne	PG95SA	Referee and announcer's booth	800	0.50	Assumption.
F03	ICE	UPB-12-500 QGR	South changerooms	3,600	3.00	Assumption.
EF01	-	-	Ice plant	-	-	-
EF02	-	-	Room 13	-	-	-
EF03	Penn	P-8	Changeroom 4	800	0.17	Assumption.
EF04	Penn	P-8	Changeroom 3	800	0.17	Assumption.
EF05	Jen Fan	TXB08MH1S	Storage room	480	0.25	Assumption.
EF06	Penn	P-8	Changeroom 2	800	0.17	Assumption.
EF07	Penn	P-8	Changeroom 1	800	0.17	Assumption.
EF08	-	-	Ice rink	-	-	-
EF09	-	CWD07	Ice resurfacer	-	0.04	Assumption.
EF10	-	-	Changeroom 8	-	-	-
EF11	-	-	Lobby men's washroom	-	-	-
EF12	-	-	Lobby women's washroom	-	-	-
EF13	-	-	Changeroom 7	-	-	-
EF14	-	-	Changeroom 6	-	-	-
EF15	-	-	Kitchen rangehood	-	-	-
REF01	-	-	Ice Rink	-	-	-
DEH01	Munters	IceAire A5G	Ice rink	5,700	-	Assumption.
DEH02	Dectron	DA2-035-8	Ice rink	5,700	3.00	Assumption.

Table 8: Water distribution systems summary

Tag	Serves	Flow	Head	Motor output	Data source
-	-	[gpm]	[ft]	[hp]	-
P01	Glycol cooling	720	65	20	Nameplate.
P02	Water spray pump	220	40	5	Nameplate.
P03	Subfloor heating	130	30	3	Nameplate.

Table 9: Heating systems summary

Tag	Serves	Utility	Efficiency	Output	Data source
-	-	-	[decimal]	[btuh]	-
F01_HEAT	F01	Natural gas	0.80	240,000	Assumption.
F02_HEAT	F02	Natural gas	0.97	58,000	Nameplate.
F03_HEAT	F03	Natural gas	0.80	400,000	Nameplate.
DHW01	Changerooms and washrooms	Natural gas	0.80	159,920	Nameplate.
DHW02	Changerooms and washrooms	Natural gas	0.80	159,920	Nameplate.
DHW03	Ice resurfacer and referee changeroom	Natural gas	0.80	159,920	Nameplate.
DHW04	Ice resurfacer and referee changeroom	Natural gas	0.80	159,920	Nameplate.
DHW05	Changerooms and washrooms	Natural gas	0.80	159,920	Nameplate.
UH01	Ice plant room	Electricity	1.00	-	-
UH02_HEAT	Bleachers	Natural gas	0.82	205,000	Nameplate.
UH03	South stairwell	Electricity	1.00	-	-
UH04_HEAT	Gymnastics Club	Natural gas	0.83	249,000	-
DEH01_HT	Ice rink	Natural gas	-	-	Nameplate.

Table 10: Cooling systems summary

Tag	Serves	Efficiency	Output	Data source
-	-	[decimal]	[ton]	-
EC01	Ice plant	-	190	Literature.
CH01	Ice rink	3	68	Assumption.

System type

The facility utilizes two dehumidifiers, three furnaces, unit heaters, and exhaust fans. Supplementary heating is provided via electric baseboards in some areas. However, staff indicated that they attempt to minimize electricity use for heating. The ice rink has unit heaters above the ice. However, they are no longer used. No space conditioning cooling is present at this facility. A summary of this system is as follows:

- F01 serves the front lobby, change rooms 5-8, the front office, the concession stand, the west washrooms, and the lunch room. The unit appears original to the building and utilizes natural gas burners for heating. There are plans to replace this unit soon. Lastly, there was a noted concern about the insulation on the exterior ductwork being asbestos-containing material (ACM).
- F02 serves the referee's change room, press room, and ice resurfacer room. The unit is a condensing furnace equipped with a natural gas-fired burner and does not have cooling capabilities.
- F03 is a unit heater serving the south changerooms. It features a natural gas-fired burner with no cooling system.
- UH01 is an electric unit heater serving the ice plant room.
- UH02 and UH04 are natural gas-fired unit heaters serving the bleachers and the gymnastics club, respectively.
- UH03 is an electric unit heater serving the south stairwell.
- A second unit heater is present in the gymnastics room. However, it is no longer operational and is scheduled for removal.

- DEH01 utilizes a solid desiccant wheel with natural gas-fired reactivation. Air from the ice rink passes through the desiccant wheel, which collects moisture. As the wheel becomes loaded with moisture, it is reactivated (i.e., dried out) via a natural gas burner and a separate air stream. The unit is not equipped with post-cooling.
- DEH02 utilizes a cooling coil to lower the air temperature below its dew point, inducing condensation. The air is then passed over a condenser to be reheated. This process is done using electricity only.

Central Plant

There is no central plant for this facility.

Distribution system

There are no pumps present within the building relating to the HVAC system.

Air distribution ductwork is present in this facility. A summary of such systems are summarized here:

- F01 supply distribution is via underfloor ductwork. The ductwork was accidentally struck during a renovation to replace the main drain line and was found to be made of a paper-like material. This ductwork supplies to registers mounted on the floor or in the wall. Return air comes via the hallway.
- F02 has supplied ductwork to all the spaces served. The return appears to come from the ice resurfacing room. No outdoor air is present.
- F03 has round ductwork supplied to each changeroom. The return comes from the hallway outside of the changerooms.
- UH02 has supply ductwork along the west bleachers.

Controls

The following components were noted during the site survey:

- No BAS is present at this facility.
- F01 and F02 are presumed to be controlled via thermostat. However, the thermostats were not observed during the site survey.
- F03 is controlled by a thermostat located in the maintenance shop. It is a non-programmable thermostat set to 67F.
- It is unclear how DEH01 is controlled. It's presumed to be via a humidistat that is set between 50-60%.
- DEH02 utilizes a humidistat mounted on the side of the unit. It is presumed to be set between 50-60% RH.
- UH01 is set to approximately 18C on a non-programmable thermostat.
- UH02 has a setpoint of 8C and was reading out 3C during the site visit. The thermostat is non-programmable, and there is a master switch to turn the unit ON/OFF. During the site survey, it was in the OFF position. Staff indicated that the unit heater is typically turned on in the late afternoon or early evening and left on until the last rental.
- UH03 is set to 15C and is on a non-programmable thermostat.
- UH04 has a programmable thermostat. However, it was set to 68F and not on a schedule.
- EF03, EF04, EF06, and EF07 each serve a changeroom on the south side of the building. They are controlled by non-programmable thermostats located in each of the changerooms. Furthermore, there is a master switch to turn them ON/OFF. They were ON during the site visit.
- EF11 and EF12 are controlled by timers located in the mechanical room containing F01.
- Electric heat in the press room has a built-in thermostat. It was set to the lowest setting.

HVAC system documentation

HVAC system documentation, including available drawings and photos from the site survey, is provided in the following images.


Figure 20: Air curtain in the main entrance


Figure 21: Air intake for DEH01


Figure 22: Air intake for the ice rink


Figure 23: Bleachers ductwork


Figure 24: Cabinet heater - 4kW

Figure 25: DEH01


Figure 26: DEH02 - sensor


Figure 27: DEH02


Figure 28: The ductwork in changeroom 4


Figure 29: EF01 - ice plant room


Figure 30: EF02 - Room 13


Figure 31: EF03 - thermostat


Figure 32: EF03 - Changeroom 4


Figure 33: EF03 - from the exterior


Figure 34: EF04 - Changeroom 3


Figure 35: EF04 - from the exterior


Figure 36: EF05 - Storage room


Figure 37: EF06 - Changeroom 2


Figure 38: EF07 - Changeroom 1


Figure 39: EF08 - ice rink exhaust


Figure 40: EF09 - ice surfacer room exhaust


Figure 41: EF11 and EF12 timers

Figure 42: EF10-EF14


Figure 43: Electric baseboard heater in the press room


Figure 44: Electric heater in changeroom 5


Figure 45: Electric heater in 2nd floor washroom


Figure 46: Electric heater in the former cloakroom

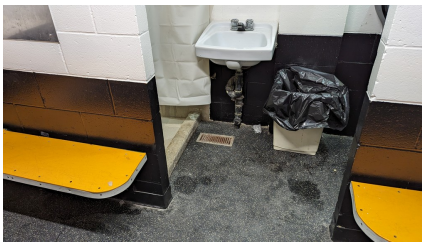


Figure 47: F01 - supply register in changeroom 5


Figure 48: F01


Figure 49: F01 ductwork should be checked for asbestos


Figure 50: F02


Figure 51: F03


Figure 52: F03 thermostat

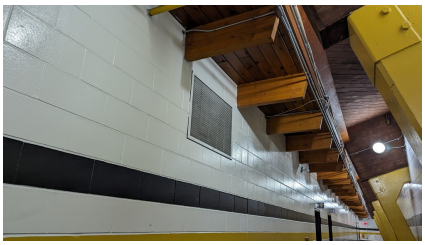


Figure 53: F3 - return register


Figure 54: Intake louvre for F03

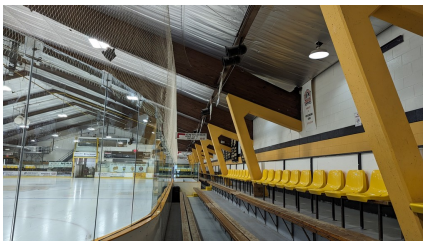


Figure 55: No heating on the south bleachers


Figure 56: REF01

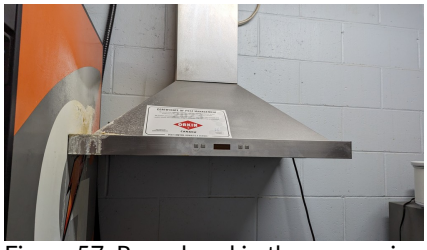


Figure 57: Rangehood in the concession stand

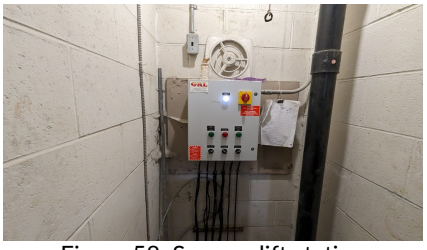


Figure 58: Sewage lift station


Figure 59: Supply register to the press room


Figure 60: Supply vents for the ice rink


Figure 61: Timer for men's and women's washroom exhaust fan


Figure 62: UH01

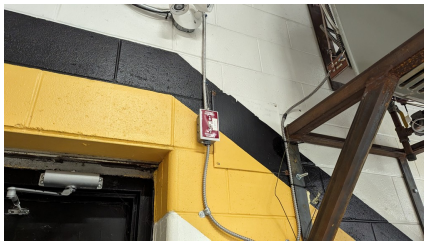


Figure 63: UH-02 - switch


Figure 64: UH02 - thermostat


Figure 65: UH02

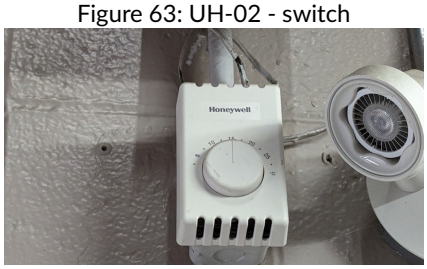


Figure 66: UH03 - thermostat

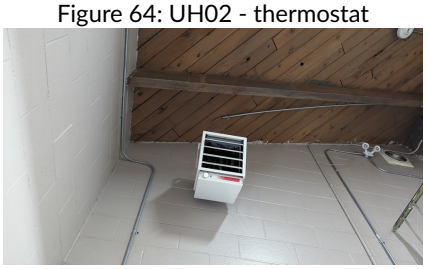


Figure 67: UH03

Figure 68: UH04 - thermostat

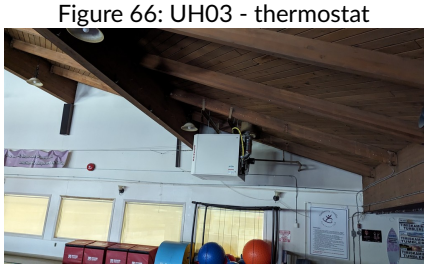


Figure 69: UH04

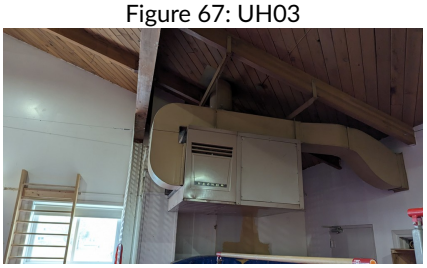


Figure 70: UH05 - no longer working

Figure 71: UH05 - thermostat not on

2.7 Domestic hot water

Overview

There are five DHW tanks, all of the same size (76 USG) and capacity (199,900 BTUH). DHW01 and DHW02 are connected with DHW05. However, DHW03 and DHW04 are standalone.

Domestic Hot Water documentation

Domestic Hot Water documentation, including available drawings and photos from the site survey, is provided in the following images.


Figure 72: DHW01 and DHW02


Figure 73: DHW03 and DHW04


Figure 74: DHW05

2.8 Lighting

Lighting system summary

Lighting systems are summarized in Table 11.

Table 11: Lighting systems summary

Space name	Floor area of space	Light power density	Light power input	Data source
-	[m2]	[W/m2]	[W]	-
Lobby and West Changerooms	497.7	8.8	4,380	Assumption.
Ice Resurfacer and Referee Changeroom	81.5	8.8	717	Assumption.
South Changerooms	547.1	8.8	4,814	Assumption.
Ice Rink	2,085.3	8.8	18,350	Assumption.
Bleachers	271.3	8.8	2,387	Assumption.
Gymnastics	561.1	8.8	4,938	Assumption.
Stairwells	17.1	8.8	151	Assumption.
Refrigeration room	33.2	8.8	292	Assumption.

Interior lighting

Fixtures

The following interior light fixtures were observed during the site survey:

- Type A: LED pot light
- Type B: Linear fixture, surfaced-mounted, two lamps, T8 fluorescent
- Type B1: Linear fixture, surfaced-mounted, two lamps, LED retrofitted
- Type C: Strip light, surfaced-mounted, LED
- Type D: Socket with LED lamp
- Type E: Linear fixture, surfaced-mounted, two lamps, LED retrofit
- Type F: High bay fixture, suspended, LED
- Type G: High bay fixture with reflector, suspended, LED
- Type H: Strip light, surfaced-mounted to wall, LED
- Type I: 2x4 troffer fixture, surface-mounted, two lamps, T8 or T12 fluorescent
- Type J: Bulkhead fixture, wall surface-mounted, one lamp, CFL (assumed)
- Type K: Strip light, surfaced-mounted, LED
- Type L: Vapour tight fixture, surface mounted, CFL (assumed)
- Type M: pendant-mounted high bays, suspended, LED (assumed)

Controls

Interior lighting control is done through ceiling-mounted occupancy sensors and manual switches. Occupancy sensors were present in the changerooms and washrooms.

Exterior lighting

Fixtures

The following exterior light fixtures were observed during the site survey:

- Type N: wall pack with dedicated photocell, CFL
- Type O: LED wall pack with dedicated photocell.
- Type P: LED wall pack with no photocell.
- Type Q: Bulkhead fixture. Presumed to be CFL.
- Type R: Area lighting with metal halide lamp.
- Type S: LED wall pack with dedicated photocell.
- Type T: LED wall pack with no photocell.
- Type U: Metal halide flood light.

Controls

The exterior fixtures are controlled by a dedicated photocell or a timer in the ice plant room.

Lighting system documentation

Lighting system documentation, including available drawings and photos taken during the site survey, is provided in the following images.

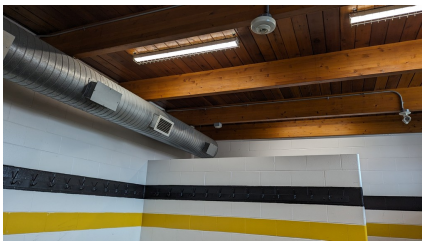


Figure 75: Ceiling-mounted occupancy sensor in changeroom 4

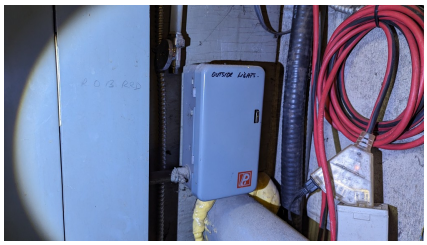


Figure 76: Exterior lighting control

Figure 77: Occupancy sensor in the women's washroom

Figure 78: Type A - LED pot lights

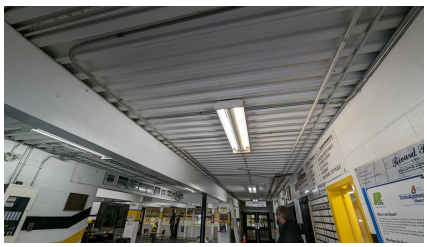


Figure 79: Type B1 - LED retrofitted fixture

Figure 80: Type B - T8 fluorescent

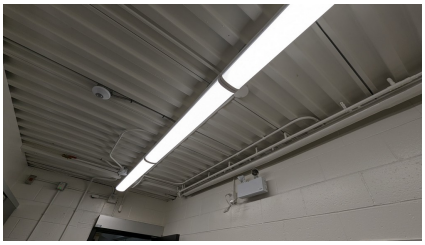


Figure 81: Type C - LED strip light

Figure 82: Type D - socket with LED lamp

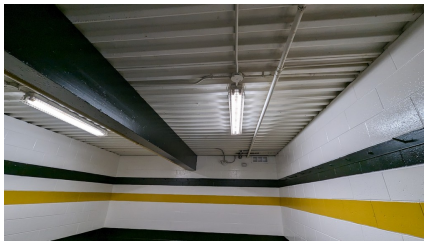


Figure 83: Type E - LED retorfitted


Figure 84: Type F - LED high bays


Figure 85: Type G - LED lamp


Figure 86: Type H - LED wall-mounted


Figure 87: Type I - 2x4 fixture


Figure 88: Type J - bulkhead light


Figure 89: Type K - LED strip light

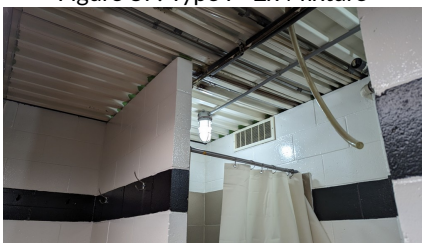


Figure 90: Type L - shower light in changeroom 5


Figure 91: Type M - Gymnastics lighting


Figure 92: Type N - wall pack with photocell


Figure 93: Type O - LED wall pack with photocell


Figure 94: Type P - wall pack light


Figure 95: Type Q - bulkhead light

Figure 96: Type R - Area light


Figure 97: Type S - LED wall pack


Figure 98: Type T - LED wall pack


Figure 99: Type U - Parking pole lights

2.9 Process and plug loads

Process - General

Various process loads are present at the facility, including:

- 1 x Stove - Electric
- Commercial kitchen appliances (e.g., hot chocolate machine, pizza warmer, Slurpee machine, etc.)
- IT equipment

Ice plant

The ice plant has an estimated 300 TR (tons of refrigeration). A summary of the system is as follows:

- Two reciprocating compressors, CMP1 and CMP2, both rated for 50 hp each.
- There is one glycol chiller that was recently replaced.
- The ammonia hot gas is cooled via an evaporative condenser.
- A VFD is present that is presumed to modulate the fan speed of the cooling tower. This approach is a common strategy to improve system efficiency through a floating head pressure approach.
- P01 serves as the cooling glycol loop for the ice rink.
- P02 is a spray pump for the evaporative condenser. It typically is not in operation during the winter. Water treatment has been added.
- P03 serves the underfloor heating to prevent ice heave. The underfloor heating loop gets its heat from the ammonia hot gas via a heat exchanger.
- There is no heat recovery on this system other than the subfloor heating.
- The ice temperature is 19F, and the glycol return is 17F.
- The subfloor temperature is 41F.
- A low emissivity ceiling has already been installed.

Ice resurfacer

- The facility has one ice resurfacer that operates on electricity.
- The ice resurfacer utilizes a laser ice leveller.
- The ice resurfacer water is heated to approximately 140F via either DHW03 or DHW04.

Plug loads

Various plug loads are present at the facility, including:

- Office equipment (printers)
- Personal computers
- Appliances (e.g., refrigerator, coolers, microwave, etc.)
- Vending machines

Process and plug loads documentation

Process and plug loads documentation, including available drawings and photos from the site survey, is provided in the following images.


Figure 100: Ammonia gas detector

Figure 101: Automatic ice leveler


Figure 102: CMP01


Figure 103: CMP02

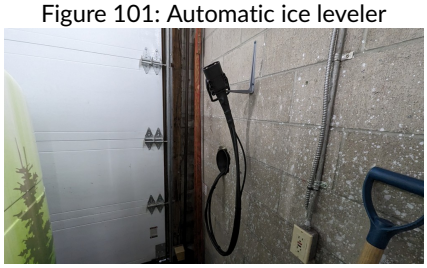


Figure 104: Charging station for ice resurfacer

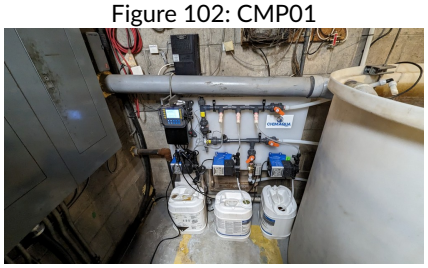


Figure 105: Chemical treatment for the evaporative condenser

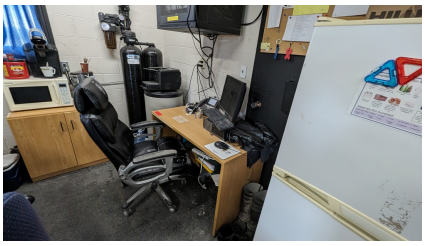


Figure 106: Computer


Figure 107: Cooler


Figure 108: Cooling tower tank


Figure 109: Deep freezer


Figure 110: Electric stove


Figure 111: Fryer


Figure 112: Hot chocolate machine

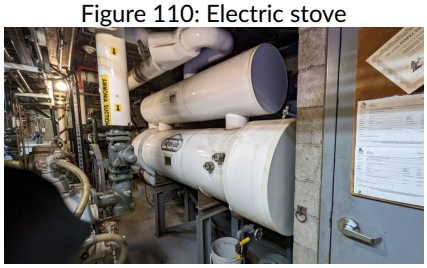


Figure 113: Ice plant chiller and surge drum

Figure 114: Ice resurfacer


Figure 115: Ice resurfacer charger


Figure 116: Ice resurfacer water fill station


Figure 117: IT equipment


Figure 118: P01 - glycol cooling

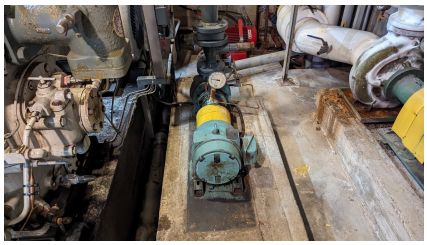


Figure 119: P02 - subfloor glycol


Figure 120: P03 - water spray pump


Figure 121: Pizza warmer

Figure 122: Slab and glycol return temperature

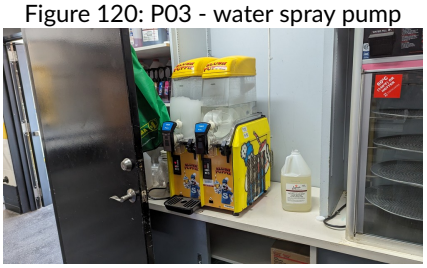


Figure 123: Slurpee machine


Figure 124: Snow disposal


Figure 125: Staff room appliances


Figure 126: Subfloor heat exchanger


Figure 127: Vending machines


Figure 128: VFD for the evaporative condenser fan


Figure 129: Water softener


Figure 130: Water softener in the maintenance shop

2.10 Water fixtures

Water fixture summary

Water fixtures at Don Shepherdson Memorial Arena are summarized in Table 12.

Table 12: Water fixture summary

Serves	Unit count	Flow	Volume	Data source
-	-	[gpm]	[gpc]	-
Kitchen faucets	1	2.2	-	Assumption.
Washroom faucets	15	1.5	-	Aerators.
Toilets	13	-	1.6	Assumption.
Urinals	4	-	1.0	Assumption.
Showers	13	2.0	-	Assumption.

Overview

A summary of water fixtures is as follows:

- 15 handwashing faucets. Some fixtures were equipped with motion sensors.
- 1 kitchen sink.
- 1 slop sink.
- 13 toilets.
- 4 urinals.
- 13 showers.

Water fixture documentation

Water fixture documentation, including available drawings and photos taken during the site survey, is provided in the following images.

Figure 131: 2nd-floor washroom faucets

Figure 132: Handwashing faucet in changeroom 4

Figure 133: Handwashing faucet in changeroom 5

Figure 134: Handwashing faucet in changeroom no 8

Figure 135: Handwashing faucet in changeroom 4 - flow rate

Figure 136: Low-flow handwashing faucets


Figure 137: Referee changeroom


Figure 138: Shower in changeroom 5


Figure 139: Showerhead in changeroom no 8


Figure 140: Slop sink in mechanical room

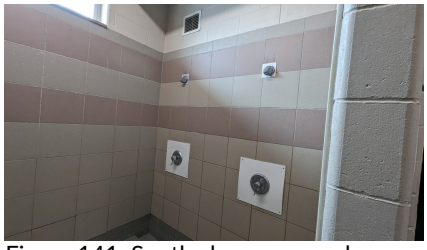


Figure 141: South changeroom showers


Figure 142: Toilet


Figure 143: Toilet in changeroom 5


Figure 144: Toilet in changeroom no 8


Figure 145: Urinals in 2nd floor washroom


Figure 146: Water fountain

2.11 Utility services

Utility services summary

Overview

The building utilizes electricity from Hydro One Networks Inc. and natural gas from Enbridge.

The one electricity meter operates on a General Service - Demand structure. A second meter is dedicated to the sewage lift station, which is not in scope.

There is one natural gas meter at this facility.

Utility services documentation

Utility services documentation, including available drawings and photos from the site survey, is provided in the following images.

Figure 147: Electricity meter for the whole building

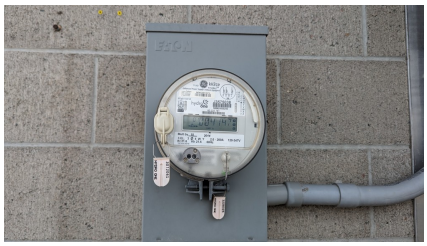


Figure 148: Electricity meter for the sewage lift station

Figure 149: Natural gas meter

Figure 150: Propane tanks - ice resurfacer replaced with electric

2.12 Onsite energy sources

Overview

There are no stationary generators or renewable energy systems present at this facility.

2.13 Electrical infrastructure

Overview

The 400A main disconnect for the building is located in the ice plant room. The existing system is a 400A, 600V service running at a maximum load of 156.36 kW, which is approximately 47% of the building's full load of 332.55 kW. The 400A service enters through a main disconnect to a 600V 400A splitter, then to large equipment loads and a couple of transformers for branch panels.

Panel summary

The seven panels at this site are summarized below:

- Concession stand panel. 120/240V, 100A. This panel serves the concession equipment and receptacles.
- E1 Panel. 120/240V, 200A. This panel serves receptacles and the concession stand panel.
- Panel 22A. 60A. Serves the air curtain, door operators, exhaust fans, and gas detection system.
- Panel A. Serves Figure skating panel, lights, receptacles, UH01, F01, washroom fans, heating in both stairwells, sewage lift station, panel 22A, and upstairs panel.
- Panel B. Serves lighting, receptacles, unit heaters,
- Maintenance workshop panel, 125A. This panel serves the event panel, dryer, hallway heaters, receptacles, F02, and the welder.
- Gymnastics panel. This panel serves the furnaces, electric heater in the cloakroom, receptacles, electric heater in the washrooms, and the lights. Based on the panel, there used to be air conditioning in the gymnastics space. However, this no longer appears to be the case.

Electrical infrastructure documentation

Electrical infrastructure documentation, including available drawings and photos from the site survey, is provided in the following images.


Figure 151: Concession panel


Figure 152: E1 Panel


Figure 153: Gymnastics panel


Figure 154: Main disconnect and electricity meter cabinet


Figure 155: Maintenance workshop panel

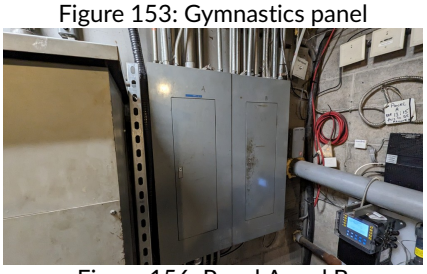


Figure 156: Panel A and B

Figure 157: Transformer 1 - rated for 75 kVA

3 UTILITY USE ANALYSIS

3.1 Utility analysis methodology

The utility use analysis was completed according to the following methodology. Note that the results achieved from applying this methodology are presented in the same order in Sections 3.2 through 3.8.

1. **Utility analysis assumptions**. Assumptions applied in the utility use analysis were identified and summarized in Section 3.2.
2. **Metered utility use**. Metered utility use data, as available, were analyzed and summarized in a subsection corresponding to the utility. Metered utility use data were available for the following utilities for Don Shepherdson Memorial Arena.
    - Electricity; see Section 3.3.
    - Natural gas; see Section 3.4.
3. **Utility use baseline**. The utility use baseline was summarized in Section 3.5, and includes the following.
    - Baseline year: A baseline year was determined as the most recent year with the fewest anomalies in facility operations and utility metering. The baseline year was used to establish the historical weather data used for the energy model development, as explained in Section 4.1. If valid metered utility data was available for the baseline year, then the metered utility use data for the baseline year was used to establish baseline performance and for energy model calibration.
    - Baseline performance: Yearly utility use, GHG emissions and utility costs. For each utility, the baseline performance was derived from the metered utility use for the baseline year if available for that utility, or from the energy model described in Section 4 if metered data were unavailable or invalid for that utility. Table 13 summarizes the data source of the baseline performance for each utility.

Table 13: Baseline performance data source for each utility

Utility	Source
Electricity	Meter
Natural gas	Meter

4. **Benchmarking analysis**. The yearly baseline energy use and GHG emissions of Don Shepherdson Memorial Arena was compared with those of similar facilities in Section 3.6. Data for similar facilities were obtained from the Government of Ontario's website, made available for the Broader Public Sector (BPS) through O. Reg. 25/23. The list below includes all municipalities considered for the benchmarking process. If this building is the only one presented, it indicates that similar buildings are not being reported to the database.
    - City of Greater Sudbury
    - City of North Bay
    - City of Temiskaming Shores
    - City of Timmins
    - Municipality of Temagami
    - Municipality of West Nipissing
    - Town of Iroquois Falls
    - Town of Kirkland Lake
    - Township of Armstrong
    - Township of Black River-Matheson
    - Township of Brethour
    - Township of Casey

- Township of Chamberlain
- Township of Gauthier
- Township of Harley
- Township of Harris
- Township of Hilliard
- Township of Hudson
- Township of James
- Township of Kerns
- Township of Larder Lake
- Township of Matachewan
- Township of McGarry

5. **Portfolio benchmarking analysis**. A portfolio benchmarking analysis was also performed, where Energy Star Portfolio Manager was used to benchmark the energy analysis of Don Shepherdson Memorial Arena.
6. **Utility use analysis discussion**. Results of the utility use analysis were studied and discussed in Section 3.8.

3.2 Utility analysis assumptions

Assumptions applied throughout the methodology are summarized as follows.

- GHG emissions factors were assumed as per Table 14.

Table 14: GHG emissions factor assumptions

Utility	Unit	Value	Source
Electricity	[tCO2e/kWh]	0.0000239	Environment and Climate Change Canada Data Catalogue, Electricity Grid Intensities-1
Natural gas	[tCO2e/m3]	0.0019324	National Inventory Report, 1990-2023, Table 1-1, Table A61.1-1 and Table A61.1-3

- Utility cost rates for the baseline year of 2023 were assumed as per Table 15. Electricity utility cost rates were assumed based on typical wholesale rates for the General Service Demand billing structure. Throughout this document, the Federal Carbon Charge ("FCC") was treated separately with respect to applicable fuels, rather than being blended into the utility cost rate for those fuels. As such, all other utility cost rates exclude the federal carbon charge. The Federal Carbon Charge was removed on April 1, 2025, as such, this document has been updated to have the FCC set to $0/tCO2e for 2025 and onward.

Table 15: Utility cost rate assumptions for the baseline year (2023)

Utility	Line item	Unit	Value
Electricity	Electricity consumption - Class B	[$/kWh]	0.0200
Electricity	Global adjustment - Class B	[$/kWh]	0.0735
Electricity	Regulatory	[$/kWh]	0.0057
Electricity	Delivery	[$/kW]	12.1217
Natural gas	Natural gas (blended)	[$/m3]	0.2600
GHG emissions	Federal carbon charge	[$/tCO2e]	50.0000

3.3 Electricity metered utility use

Hourly electricity use is plotted in Figure 158.

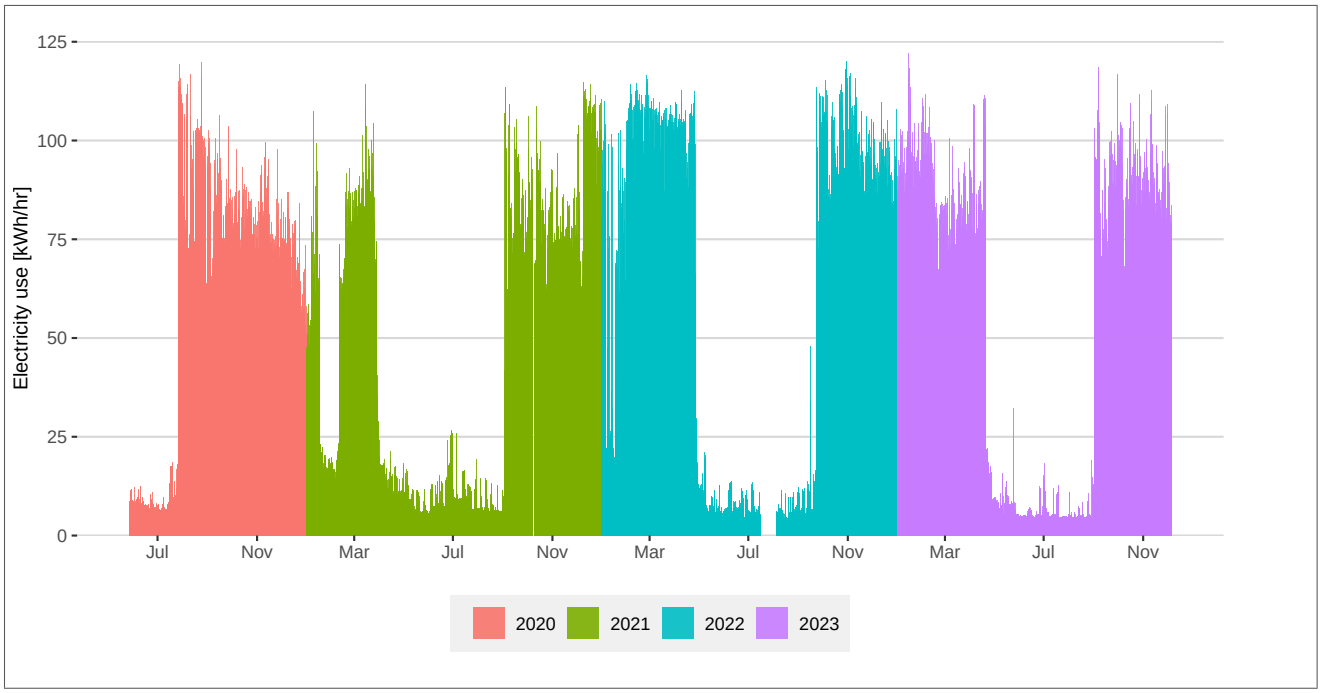


Figure 158: Hourly electricity use

The same hourly electricity use data is plotted in Figure 159, which highlights how electricity use is influenced by year, season, day of week and hour of day. The vertical axis on Figure 159 may be rescaled relative to in Figure 158 for greater resolution.

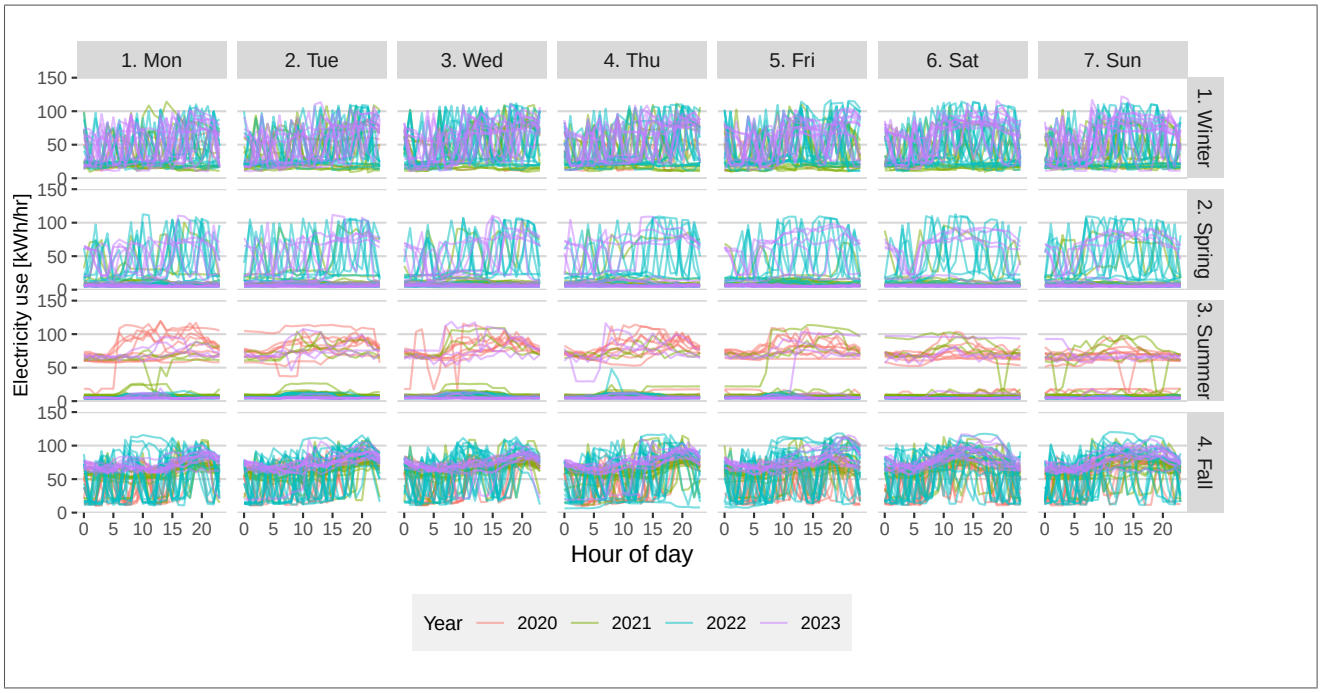


Figure 159: Hourly electricity use hairball plot

Monthly electricity use is plotted in Figure 160.

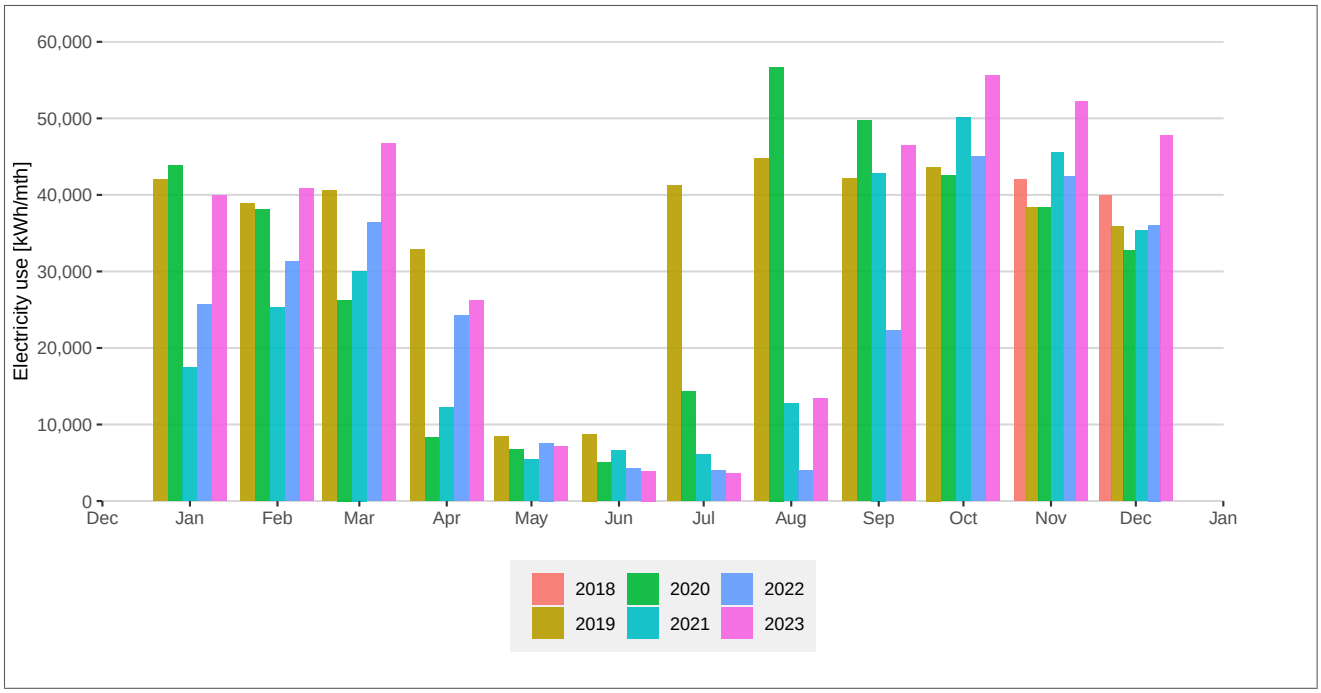


Figure 160: Monthly electricity use

3.4 Natural gas metered utility use

Monthly natural gas use is plotted in Figure 161.

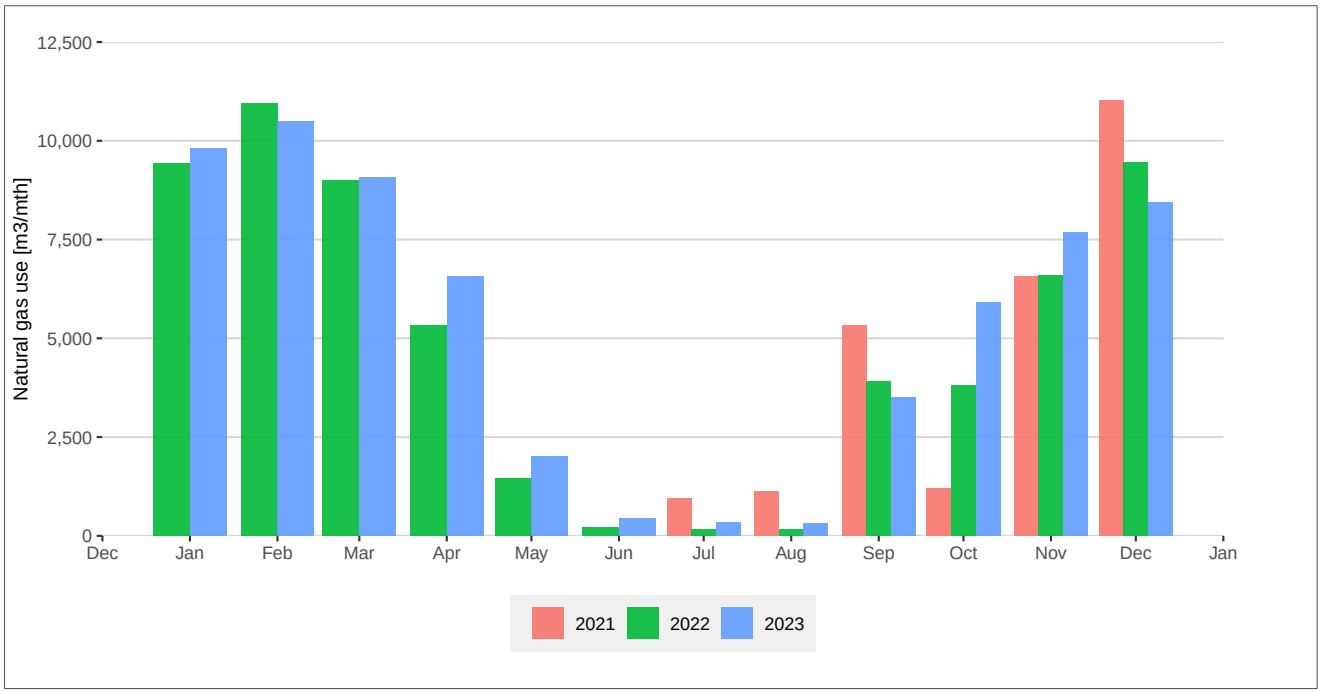


Figure 161: Monthly natural gas use

3.5 Utility use baseline

Baseline year

The baseline year for Don Shepherdson Memorial Arena, which is used to establish the baseline performance through the metered utility use data from that year, is as follows.

- **Baseline year**: 2023.

Baseline performance

Baseline utility use performance for the baseline year of 2023 is summarized in Table 16.

Table 16: Baseline utility use performace

Category	Utility	Unit	Value
Utility use	Electricity use	[kWh/yr]	383,773
	Natural gas use	[m3/yr]	64,579
	Carbon offset use	[tCO2e/yr]	0
Equivalent energy use	Electricity energy	[kWh/yr]	383,773
	Natural gas energy	[kWh/yr]	681,741
	Total energy	[kWh/yr]	1,065,515
GHG emissions	Electricity GHGs	[tCO2e/yr]	9
	Natural gas GHGs	[tCO2e/yr]	125
	Carbon offsets GHGs	[tCO2e/yr]	0
	Total GHGs	[tCO2e/yr]	134
Utility cost	Electricity utility cost	[$/yr]	50,391
	Natural gas utility cost	[$/yr]	16,791
	Carbon offsets utility cost	[$/yr]	0
	Federal carbon charge	[$/yr]	6,240
	Total utility cost	[$/yr]	73,421

3.6 Benchmarking analysis

Benchmarking analysis results are presented in the following figures.

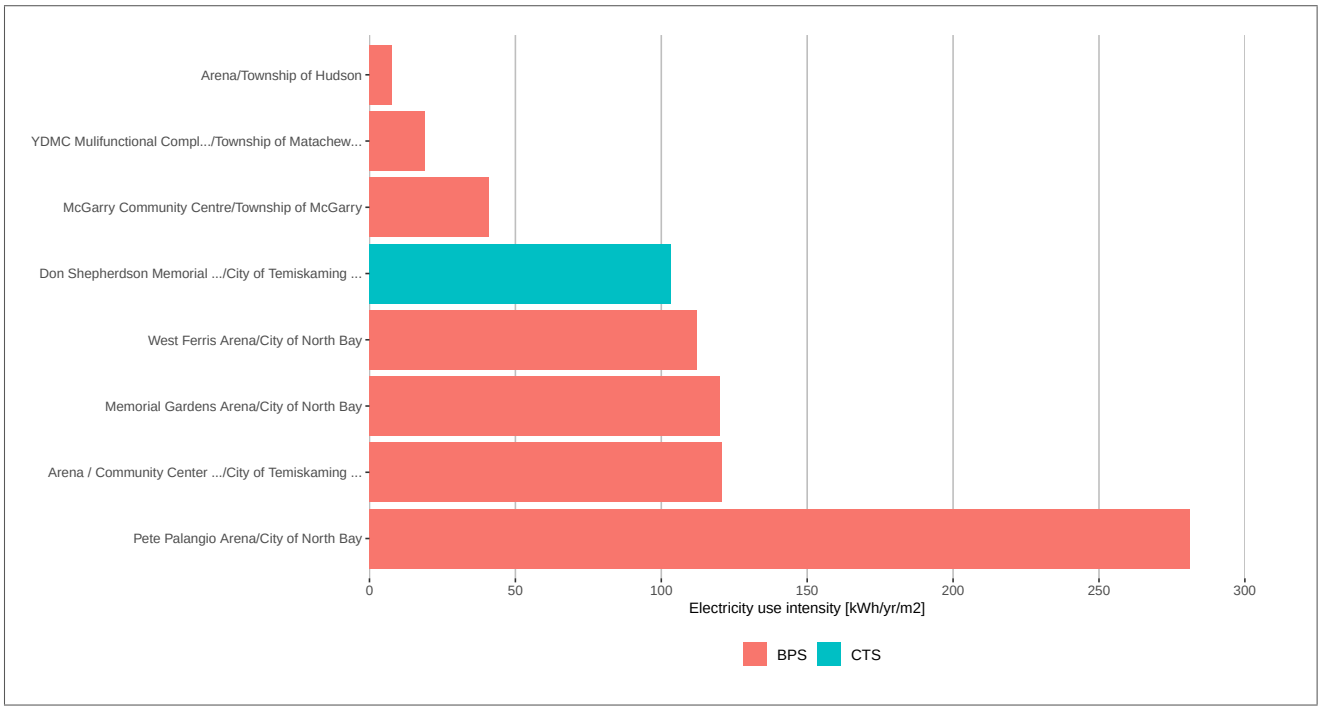


Figure 162: Electricity use intensity benchmarking analysis comparison

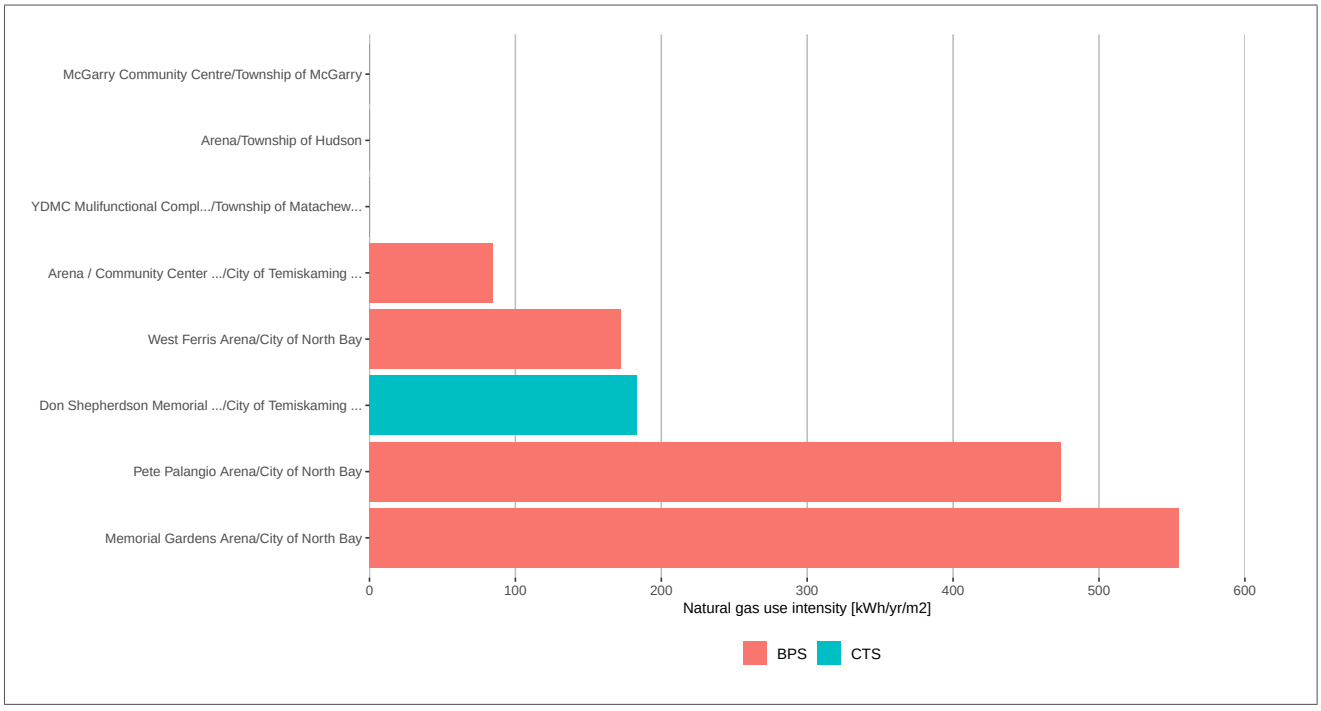


Figure 163: Natural gas use intensity benchmarking analysis comparison

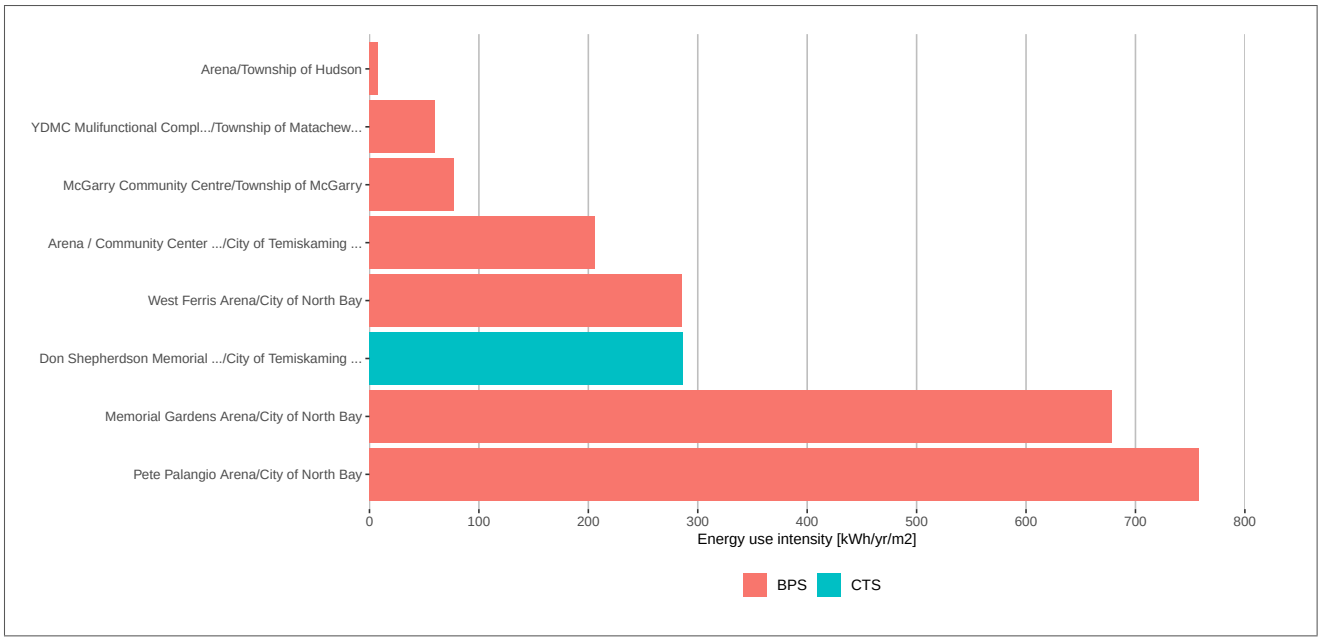


Figure 164: Total energy use intensity benchmarking analysis comparison

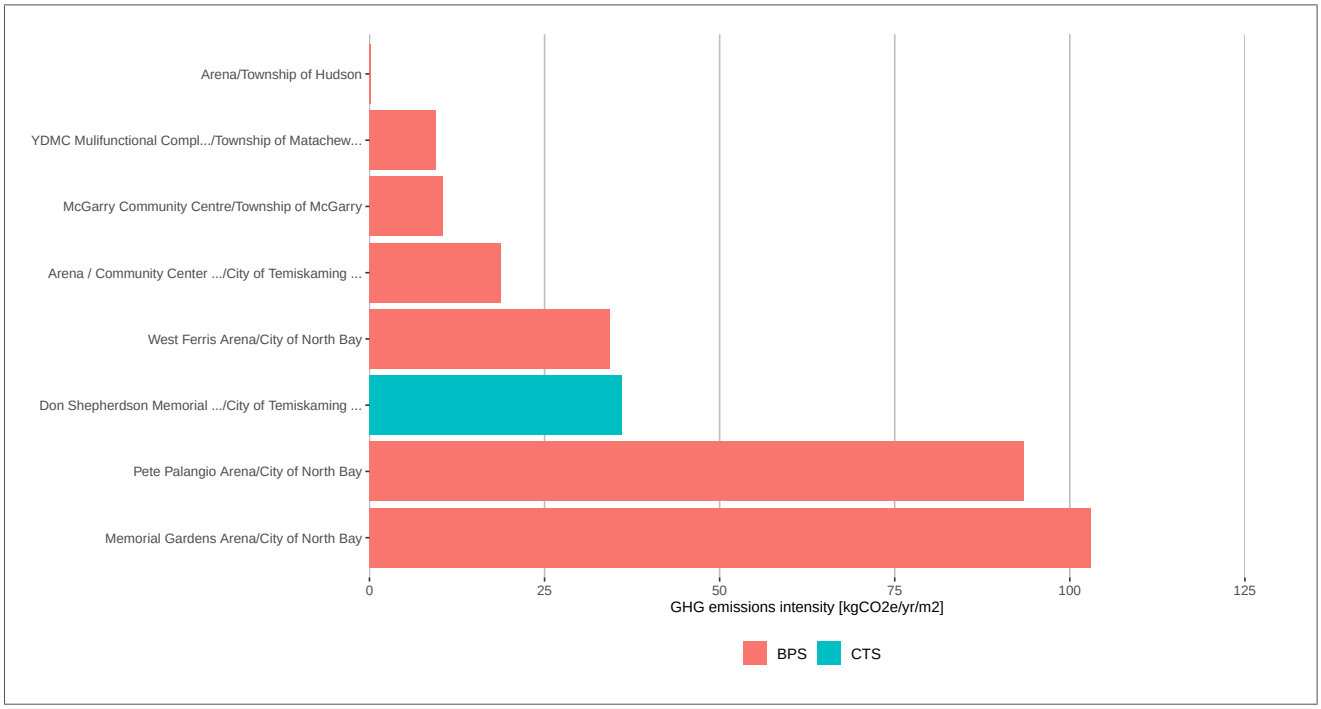


Figure 165: GHG emissions intensity benchmarking analysis comparison

3.7 ENERGY STAR Portfolio Manager benchmarking analysis

The scorecard is shown in Figure 166.

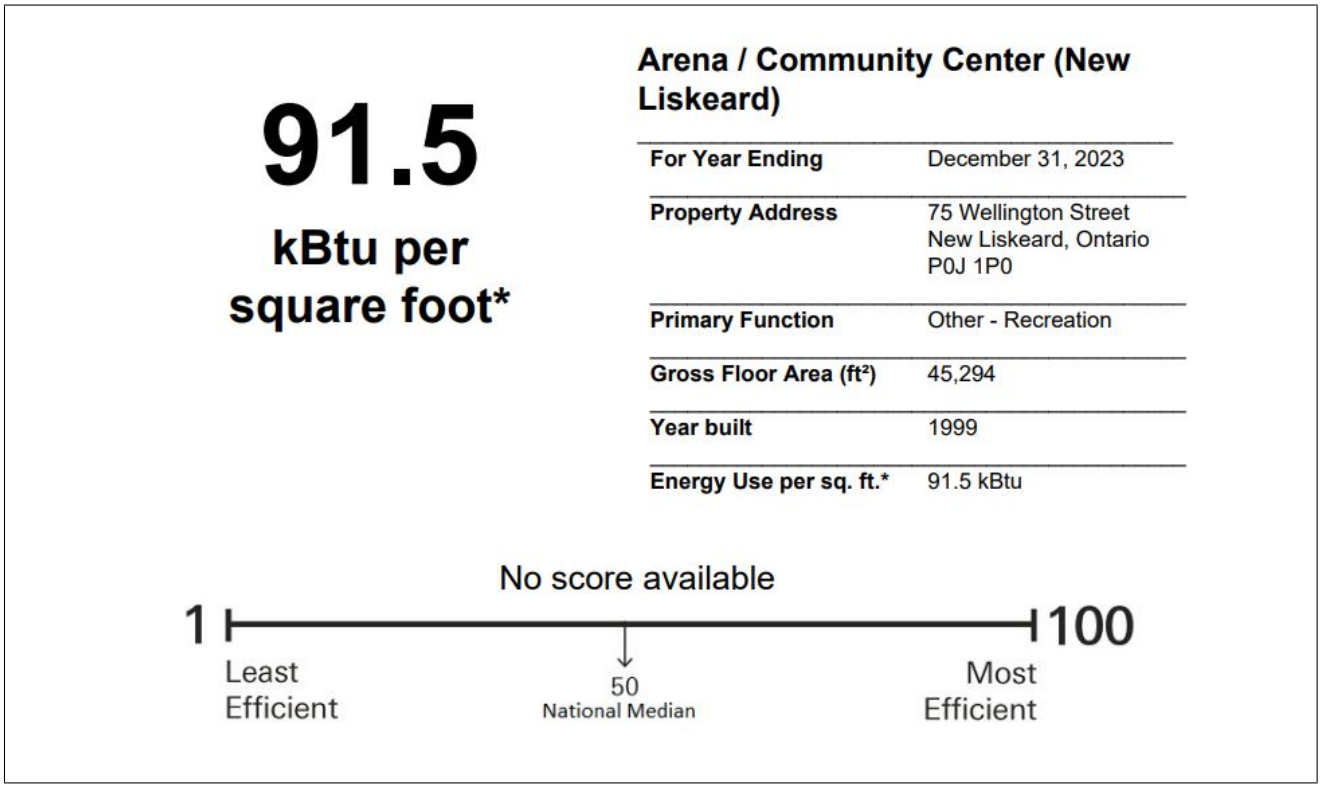


Figure 166: Energy Star energy performance scorecard.

3.8 Utility use analysis discussion

General

The following discussion aims to explain the trends in utility use observed in the metered data, based on our understanding of the building systems and their operations, as presented in 2.

Electricity - Hourly

- Hourly electricity consumption typically peaks during the fall, winter, and spring due to the refrigeration load of the ice plant.
- Hourly consumption is typically between 5 kWh and 122 kWh.

Electricity - Monthly

- July and August 2019 and 2020 saw a significant increase in electricity consumption, which implies that the ice plant was operational during these periods.
- April 2022 and 2023 saw a higher consumption than previous years. This outcome is most likely due to the ice rink season being extended.
- January 2021 and 2022 saw very low consumption compared to other years. The ice plant was most likely down during this time.
- 2023 had the highest consumption for several months of the year.
- Electricity consumption is minimal during the summer as no space cooling equipment exists.

Natural gas

- Natural gas consumption has maintained a consistent profile year over year. It is highest during the heating season and very low during the summer.
- This facility uses natural gas for space heating, dehumidification, and water heating. Given the ice is out during the summer, it is clear that DEH01 is also turned off.
- Natural gas consumption in the summer is likely due to domestic hot water heating only.
- Of the 26 data points available for monthly natural gas consumption, only 12 were actual readings, not estimates. This observation can lead to calibration issues, as the model may not pass ASHRAE Guideline 14.

4 ENERGY MODEL DEVELOPMENT

4.1 Energy model development methodology

The utility use profile was developed from an hourly analysis, spanning one year, of the following energy systems. The analysis reflects the existing conditions of the facility as documented in Section 2.

The energy model was created in eQUEST v3.65, build 7175, using the DOE2.3 engine. The inputs were established to match the existing conditions as closely as possible. The following sources were used as background information to inform energy model inputs:

- Observations from site survey and conversations with facility staff.
- Schedules and setpoints from the BAS. As-built drawings provided by the City of Temiskaming Shores.
- References from the Ontario Building Code (OBC) SB-12, ASHRAE90.1, and NECB where the above data was not available.

1. **Hourly utility use profiles**. An hourly utility use profile for each utility was developed according to the following methodology. Results were presented in Section 4.2.

   (a) *Utilities and end uses*. Hourly utility use profiles developed through this analysis were assigned to both utilities and end uses. The utilities and end uses that were modelled are summarized in Table 17.

Table 17: Utility and end use summary and definitions

Utility	End use	Definition of end use
Electricity	Cool: Ice refg	Cooling energy use from ice refrigeration compressor motors.
	Cooling	Cooling energy use.
	Equipment	Equipment energy use.
	Exterior lights	Exterior lighting energy use.
	Fans	Fan motor energy use.
	Heat rejection	Energy use by heat rejection equipment (e.g. cooling towers).
	Lights	Lighting energy use.
	Other	Metered use less modelled use.
	Pumps	Pump motor energy use.
	Space heat	Space heating energy use.
Natural gas	DHW heat	Domestic hot water heating energy use.
	Other	Metered use less modelled use.
	Space heat	Space heating energy use.

   (b) *Weather data*. Hourly weather data was obtained from the Earlton-Cimate weather station, ID 712130S.

   (c) *Facility spaces*. Facility spaces were grouped according to activities in the spaces and HVAC systems serving them. The thermal characteristics of the exterior building envelope components for each space were assumed based on findings documented in Section 2.7. Thermal loads within each space were calculated based on assumed space temperature and humidity setpoints, hourly weather data, and activities in the space that affect thermal conditions (e.g. lighting or equipment that generates heat).

   (d) *Primary systems*. Primary systems are defined as systems whose utility use can be predicted independent from other systems; examples include lighting, equipment (e.g. office and process equipment), pumps, etc. The hourly utility demand of primary systems was modelled based on assumed time-of-day operating schedules, peak power input and average loads relative to the peak power input. Peak power input was estimated from findings documented throughout Section 2, including lighting power or power density, nameplate horsepower of motors, etc.

   (e) *HVAC systems*. HVAC system energy use was modelled based on hourly weather data and space condition setpoints defined for the various spaces. The analysis also accounted for system-specific ventilation controls and activities and primary systems that have thermal influences on spaces

(e.g. occupancy, lighting, equipment, processes that add heat to spaces). The analysis quantified hourly energy use of fans, heating (e.g. sensible, humidification, reheat) and cooling (e.g. sensible, dehumidification).

(f) *Generators*. The utility use and generation of on-site systems that generate energy or utilities was modelled based on the assumed capacities and operations of those systems according to findings documented in Section 2; examples include solar PV, CHP, etc. Utilities generated on site were treated as negative utility consumption relative to utilities consumed on site so that the consumption, generation and the aggregate use of utilities could be tracked accordingly.

(g) *Other*. For each utility having valid metered utility use data available for the baseline year, the Other end use was modelled from the top down to reconcile results of the above utility-consuming systems that were modelled from the bottom up with metered utility use data for the baseline year. This end use was called Other.

2. **Monthly utility use profiles**. A monthly utility use profile for each utility was developed by grouping and summing up the hourly utility use profiles by end use and by month. Results were presented in Section 4.3.
3. *Calibration analysis*. After explicitly modeling the above systems, the model was calibrated for each of the following utilities (utilities for which valid metered data for the baseline year was available) through the Other end use, which was calculated as the difference of metered and modeled utility use. The above modeling steps were iterated as required to achieve reasonable calibration.
    - Electricity
    - Natural gas
4. **End use analysis**. An end use analysis of each utility was completed. Since the hourly utility use profiles already track the hourly utility use by each end use, the end use analysis involved summarizing data from the hourly utility use profiles to obtain yearly utility use by each end use. Results were presented in Section 4.5.

4.2 Hourly utility use profiles

The hourly utility use profiles are presented graphically in this Section 4.2 in a format called a stacked bar plot. For each hour of the year, the utility use for all end uses active during that hour is presented in a single bar pertaining to that hour. The end uses are identified by colour, and all end uses are “stacked” on top of each other within each hour-specific bar such that the total height of each bar represents the total utility use of all end uses combined in that hour.

Electricity

The hourly electricity utility use profile by end use made by the energy model is plotted in Figure 167. See Table 17 for end use definitions.

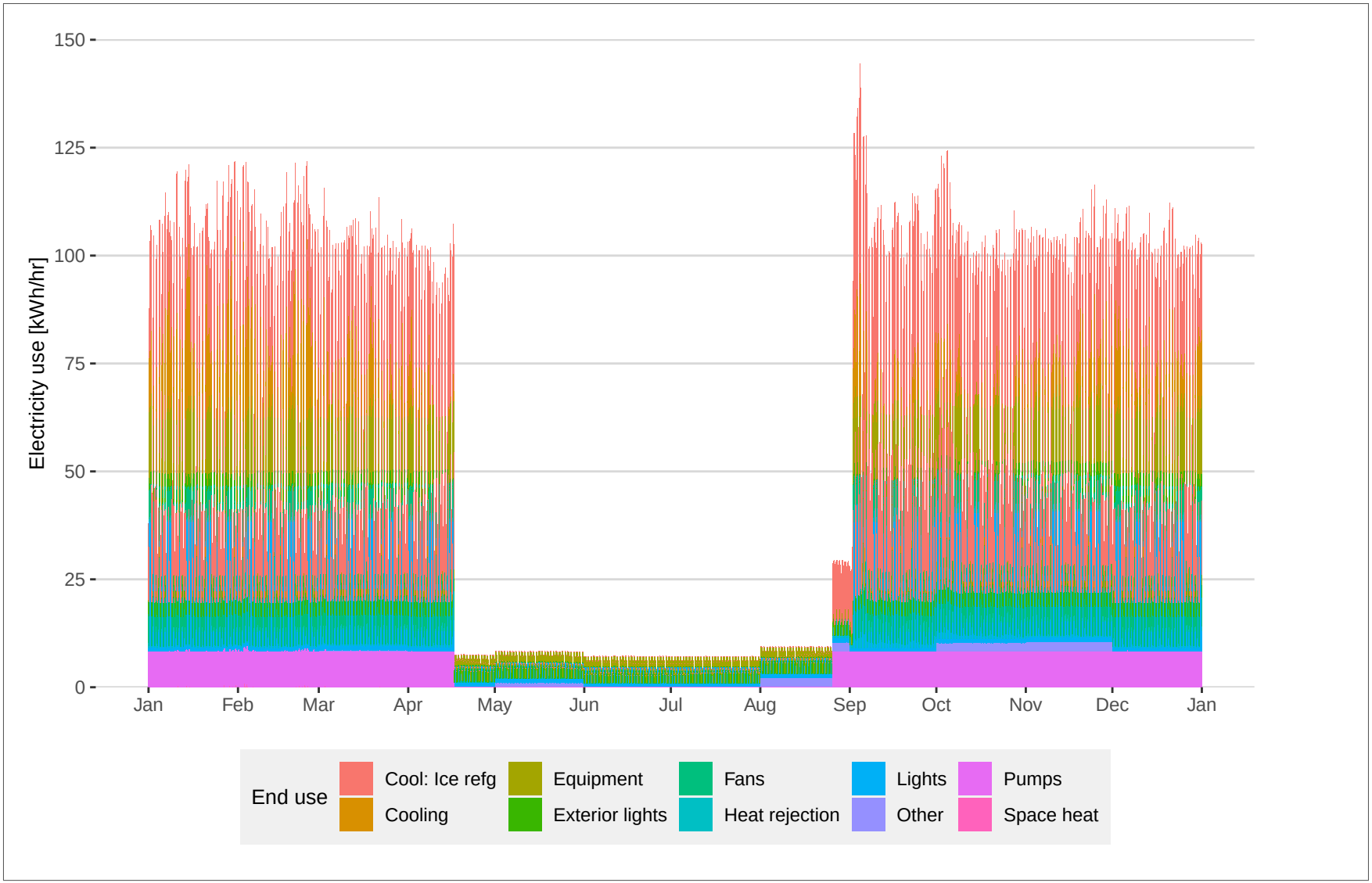


Figure 167: Hourly electricity utility use by end use (made by calibrated energy model)

Natural gas

The hourly natural gas utility use profile by end use made by the energy model is plotted in Figure 168. See Table 17 for end use definitions.

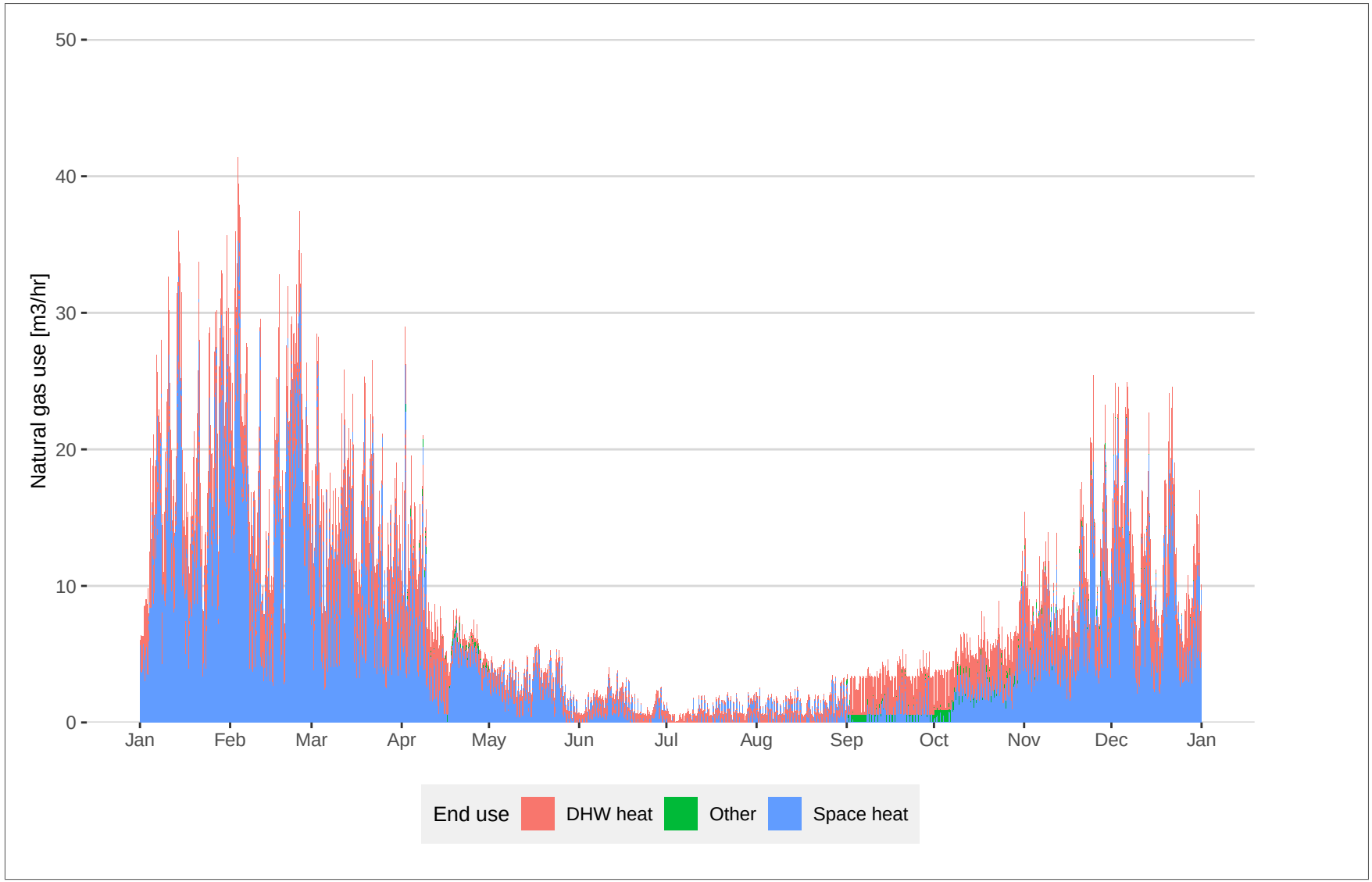


Figure 168: Hourly natural gas utility use by end use (made by calibrated energy model)

4.3 Monthly utility use profiles

Monthly utility use profiles for each modelled utility are presented in Figure 169.

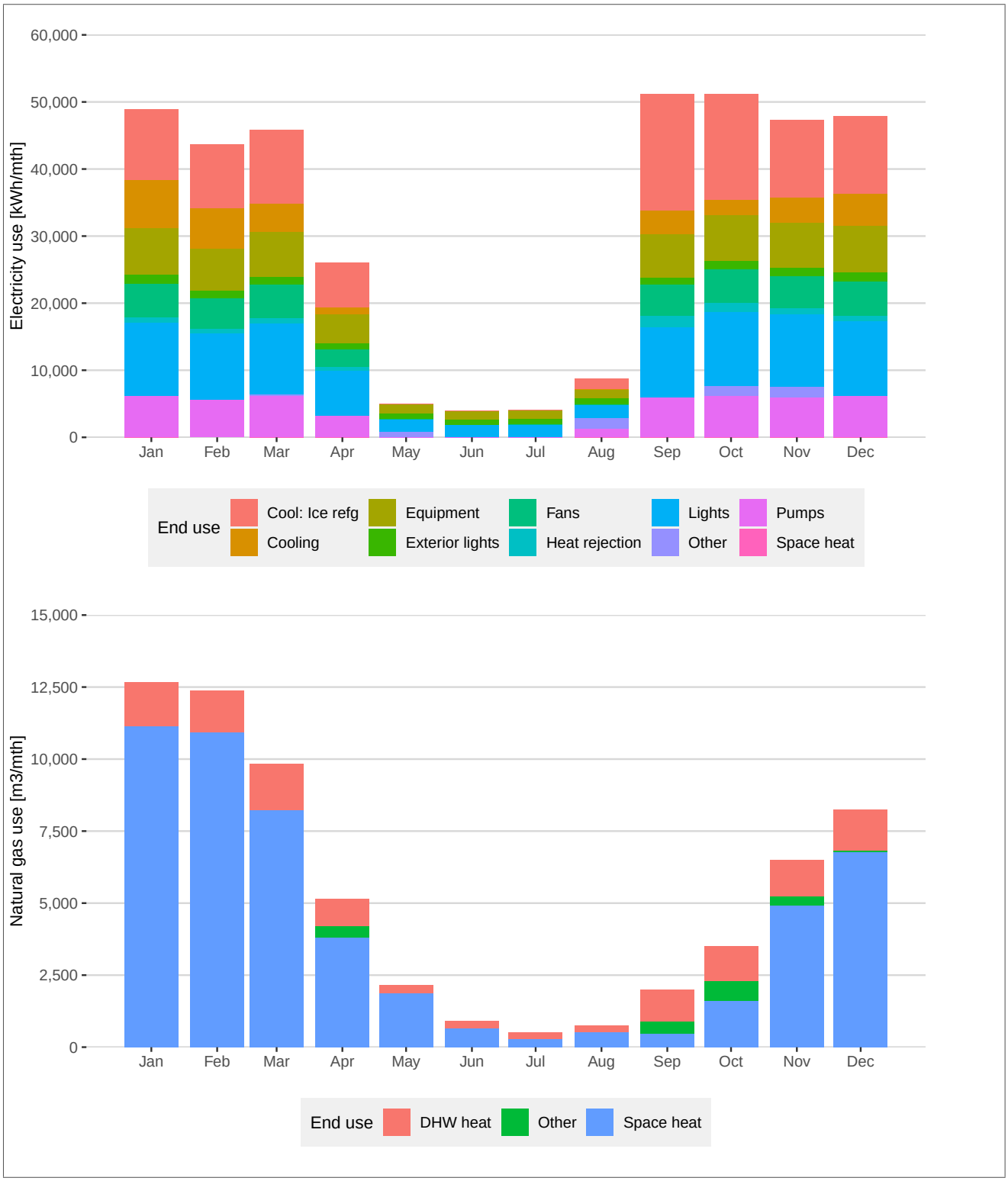


Figure 169: Monthly utility use profiles for each modelled utility

4.4 Calibration analysis

Electricity

Figure 170 compares the metered utility use with the modelled use to check how well the model is calibrated.

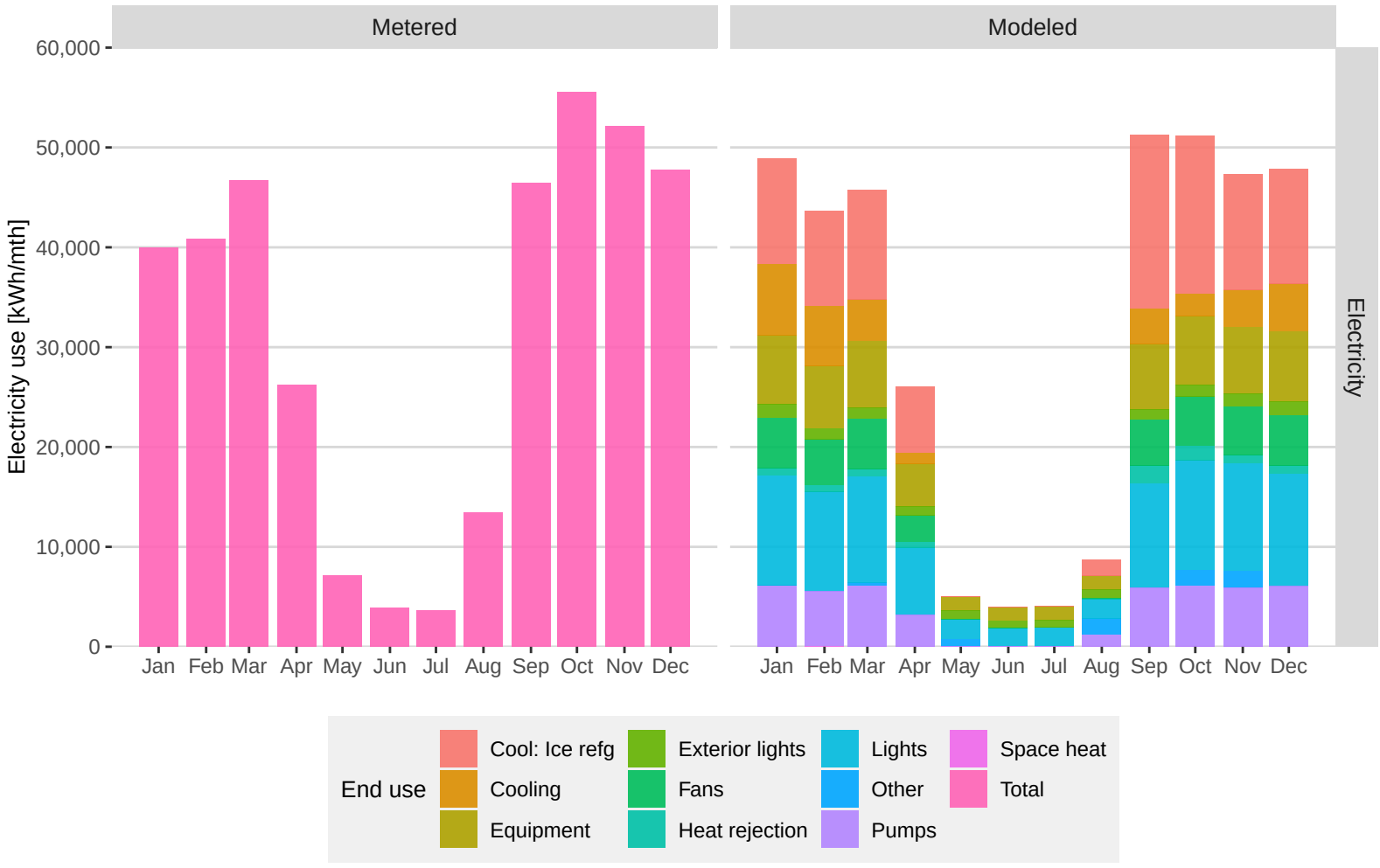


Figure 170: Electricity calibration analysis (metered vs modelled utility use)

Natural gas

Figure 171 compares the metered utility use with the modelled use to check how well the model is calibrated.

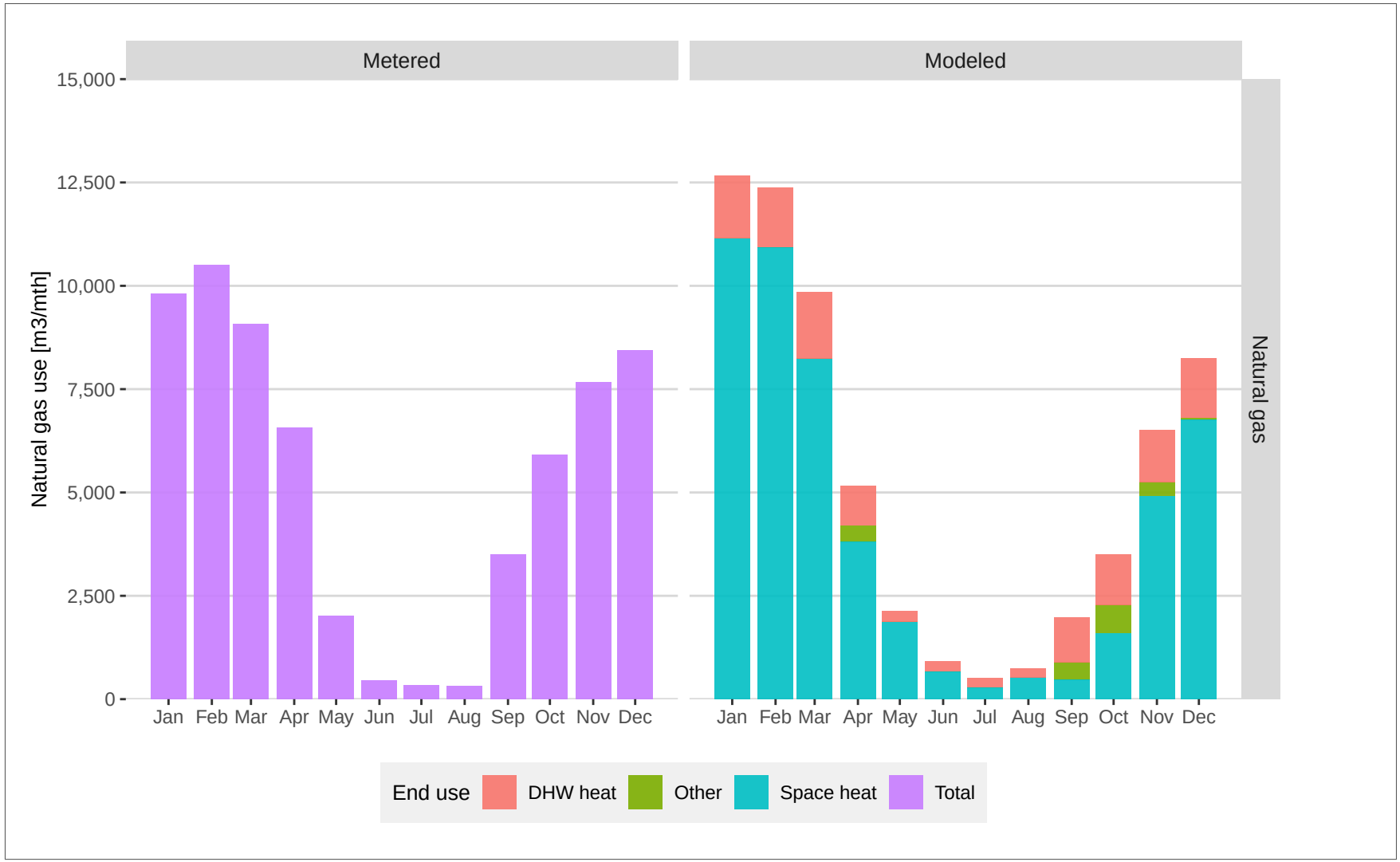


Figure 171: Natural gas calibration analysis (metered vs modelled utility use)

Statistical calibration analysis

ASHRAE Guideline 14 suggests maximum allowable values for the mean bias error, and the root mean bias error, which are defined as follows with respect to energy model calibration.

- **Mean bias error (MBE)**. The average monthly error between modelled and metered utility use as a percentage of the mean monthly metered utility use. This metric indicates the ability of the model to accurately predict yearly utility use, despite month-to-month errors, by capturing the direction of all month-to-month errors.
- **Root mean square error (RMBE)**. The square root of the sum of all squared monthly errors as a percentage of the mean monthly metered utility use. This metric indicates the ability of the model to accurately predict month-specific utility use.

Statistical calibration analysis results were calculated and are summarized in Table 18.

Table 18: Statistical calibration analysis summary

Utility	Description	Unit	ASHRAE 14	Model	Pass/Fail
Electricity	Mean bias error	[%]	< +/- 5	-0.0	Pass
	Root mean square error	[%]	< 15	12.7	Pass
Natural gas	Mean bias error	[%]	< +/- 5	-0.0	Pass
	Root mean square error	[%]	< 15	27.6	Fail

It should be noted that the root mean square error test suggested by ASHRAE Guideline 14 places undue emphasis on months that have relatively little utility use (e.g. natural gas or steam use in the summer). This is because the root mean square error test is calculated based on relative errors between monthly metered and modelled utility use. Because of this, a small absolute error between metered and modelled utility use for a certain month may also be a large relative error, causing a significant increase in the root mean square error. Practically, though, the ability of the energy model to accurately quantify utility use overall has little dependence on its ability to quantify utility use in months with relatively little metered use, because overall utility use is more heavily influenced by those months with greater utility use. Therefore, it may not always be suitable for the model to pass the root mean square error test, provided that it reasonably captures utility use in the months of greater use.

A discussion of the energy model calibration analysis is as follows.

- Figures 170 and 171 both demonstrate a strong agreement between monthly trends observed in the metered utility use data and the monthly utility use predicted by the calibrated energy model.
- Electricity usage was successfully calibrated according to the standards outlined in ASHRAE Guideline 14. Note that the mean bias error is zero for electricity and natural gas because the Other end-use ensures that the yearly modelled utility use matches the yearly metered utility use. This process also maintains consistency between the baseline utility use derived from the metered utility data and all measure and scenario analyses.
- Natural gas consumption fails to follow Guideline 14 on the root mean square error. One notable issue is that consumption is higher in the model from January through March. There is also a discrepancy in September and October. Another note is that only 5 of 10 natural gas readings are actual readings, and some of these readings encompass more than one month. This issue makes it difficult to calibrate the model, especially when compared to estimated data that the LDC typically underestimates.
- The successful energy model calibration is largely due to the methodology used in developing the calibrated energy model. Under this methodology, the major systems affecting utility use were studied in detail (see Section 2), including their operations, so that these systems could be explicitly modelled one-to-one, precisely reflecting the unique operations associated with each system. Examples of such major systems

include all furnaces (F1, F2, and F3) and the ice plant. The methodology also integrates the Other end-use category, which reflects the exact difference between metered and modelled utility use in a top-down calculation after all systems have been modelled from the bottom-up.

- Therefore, there can be confidence that the utility use impacts quantified in the various measures and scenario analyses under this report are reasonable.

Electricity

- Figure 170 indicates strong agreement between modelled and metered data.
- The peak and trough hourly consumption align with the metered interval data.
- Based on metered electricity data, it is assumed that the ice-making process started at the beginning of September 2023.

Natural gas

- Figure 171 indicates good agreement between modelled and metered data.
- The annual amount of natural gas consumption in the model is very close to the annual amount of the metered data. However, there are variances within several months. That being said, there are several estimated readings for this particular dataset.

4.5 End use analysis

Electricity

The yearly electricity end use breakdown calculated by the energy model is plotted in Figure 172. See Table 17 for end use definitions.

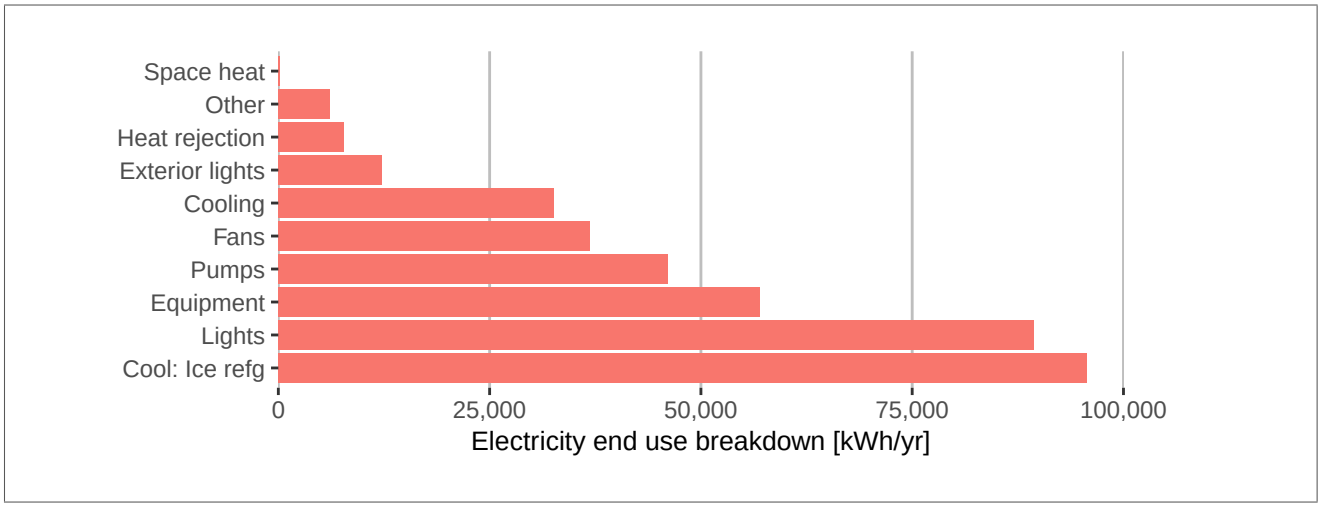


Figure 172: Electricity end use breakdown (calculated by calibrated energy model)

Natural gas

The yearly natural gas end use breakdown calculated by the energy model is plotted in Figure 173. See Table 17 for end use definitions.

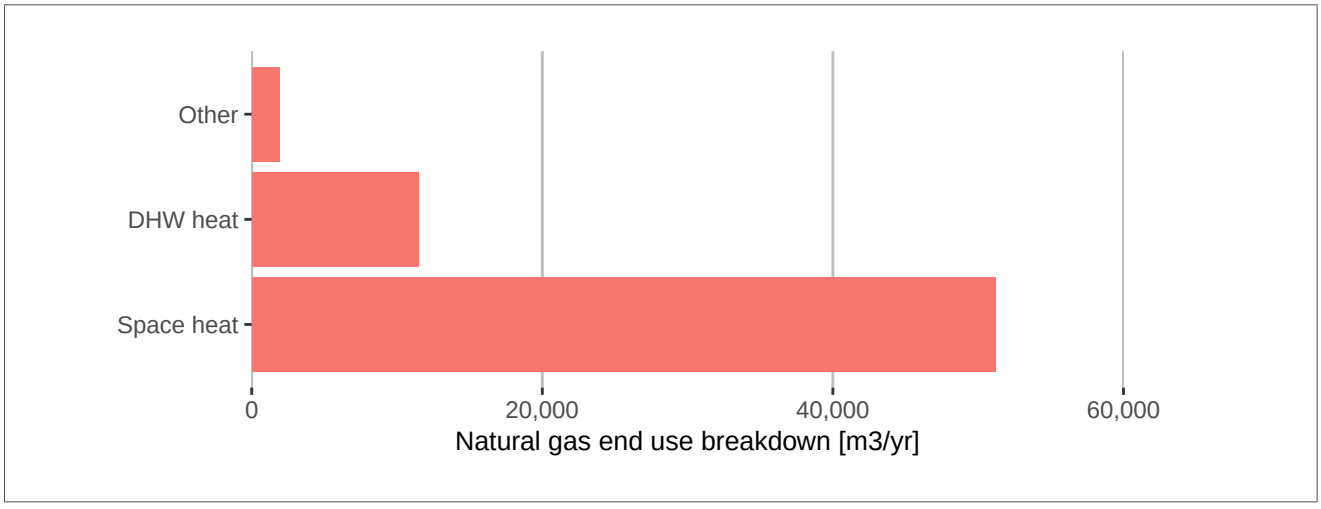


Figure 173: Natural gas end use breakdown (calculated by calibrated energy model)

5 MEASURE ANALYSIS

5.1 Measure analysis methodology

The measure analysis was completed according to the following methodology.

1. **Measure identification and triaging**. Measures that could be implemented to help achieve City of Temiskaming Shores's goals were identified based on the findings documented in Sections 2 and 3. Identified measures were triaged by labeling each one as either 'Analyzed' or 'Not analyzed'. The intent of triaging was to focus efforts on analyzing measures for which analysis was considered most valuable (typically for measures that are more complex or more impactful). Results are summarized in Section 5.3.
2. **Measure analysis**. For each 'Analyzed' measure, the analysis completed for that measure was summarized in a dedicated sub-section named after that measure (see Sections 5.4 through 5.22). In each sub-section, the following was documented.
    - *Measure description*. The relevant existing condition was summarized, an opportunity for improving the stated existing condition was described, and the intended utility-savings mechanism associated with the opportunity was described.
    - *Design description*. A conceptual design description was provided, including a written description of the proposed design concept and the associated project cost estimate.
    - *Utility analysis*. A utility analysis was completed using the energy model introduced in Section 4. Measure-specific assumptions applied in calculating the impacts on utility use were provided for each measure. For each measure, the expected GHG emissions, utility costs and financial incentives associated with implementing the measure were calculated based on utility use, using the assumptions outlined in Section 5.2. A life cycle cost analysis was completed, applying the assumptions summarized in Tables 15 and 21 according to the following methodology.
        (a) The life cycle cost for each measure was calculated based on the assumed implementation year of 2026 for each measure. The life cycle cost for each measure was calculated as the sum of the following future financial cost expenditures, discounted back to present value using the discount rate from Table 21, over the evaluation period of present to 2050.
        (b) Project costs: The future value of project costs was calculated based on the project cost estimate of each measure, inflated to future value associated with the assumed implementation year using the general inflation rate from Table 21. In the life cycle cost calculation, the project cost was amortized over the expected life of the measure such that the yearly present value is constant over every year of the expected life of the measure. This results in the net present value of the project cost being equal to what it would be if the owner was to pay for it via lump sum in the implementation year for that measure.
        (c) Replacement costs: The future value of replacement costs was calculated assuming that a financial cost was incurred to replace equipment associated with each measure at the end of the expected life of that measure equal to 50% of the initial project cost, inflated to future value associated with the estimated time of replacement using the general inflation rate from Table 21. The same amortization approach as for project costs was used.
        (d) Utility costs: The future value of yearly utility costs of the entire facility was accounted for in the life cycle cost calculation for each measure. The future value of yearly utility costs was calculated by applying the future utility cost rates from Table 19 to the utility use of the entire facility for that year as predicted by the calibrated energy model for each measure and scenario.
3. **Measure risk analysis**. A risk analysis of each individual measure was completed to test how the performance of that measure might be affected by changes to certain risk parameters. In this risk analysis, each of the risk parameters defined in Table 22 was tested under each risk case also defined in Table 22 for that risk parameter. For each risk case of each risk parameter, the expected performance of each measure was quantified, and the results were summarized using box and whisker plots indicating the range over

which performance might be expected to vary. Findings from the risk analysis were summarized in Section 5.23.

4. **Measure analysis summary**. Measure analysis results for all measures were summarized in table format in Section 5.24.

5.2 Measure analysis assumptions

Assumptions general to all measures are as follows.

- GHG emissions factor assumptions are summarized in Table 14, in Section 3.2.
- Utility cost rate assumptions applied to quantify yearly utility cost impacts relative to the baseline are summarized in Table 15, in Section 3.2. Utility cost rate future assumptions applied in the life cycle analysis for each measure are summarized in Table 19. Note that throughout this Pathway to Decarbonization Feasibility Study the Federal Carbon Charge is treated separately (if applicable) with respect to associated fuels (rather than being accounted for within the rates of the applicable fuels, the federal carbon charge line item is calculated separately based on the estimated yearly GHG emissions for that fuel). As such, all other utility cost rates exclude the federal carbon charge.

Table 19: Utility cost rate future assumptions

Year	Natural gas	Federal carbon charge	Carbon offsets	Class B HOEP	Class B GA	Class B regulatory	Class B Delivery
-	[$/m3]	[$/tCO2e]	[$/tCO2e]	[$/kWh]	[$/kWh]	[$/kWh]	[$/kW]
2023	0.2652	65	30	0.0204	0.075	0.0058	12.36
2024	0.2705	80	30.6	0.0208	0.0765	0.0059	12.61
2025	0.2759	0	31.21	0.0212	0.078	0.006	12.86
2026	0.2814	0	31.84	0.0216	0.0796	0.0061	13.12
2027	0.287	0	32.47	0.022	0.0812	0.0062	13.38
2028	0.2927	0	33.12	0.0224	0.0828	0.0063	13.65
2029	0.2986	0	33.78	0.0228	0.0845	0.0064	13.92
2030	0.3046	0	34.46	0.0233	0.0862	0.0065	14.2
2031	0.3107	0	35.15	0.0238	0.0879	0.0066	14.49
2032	0.3169	0	35.85	0.0243	0.0897	0.0067	14.78
2033	0.3232	0	36.57	0.0248	0.0915	0.0068	15.07
2034	0.3297	0	37.3	0.0253	0.0933	0.0069	15.37
2035	0.3363	0	38.05	0.0258	0.0952	0.007	15.68
2036	0.343	0	38.81	0.0263	0.0971	0.0071	15.99
2037	0.3499	0	39.58	0.0268	0.099	0.0072	16.31
2038	0.3569	0	40.38	0.0273	0.101	0.0073	16.64
2039	0.364	0	41.18	0.0278	0.103	0.0074	16.97
2040	0.3713	0	42.01	0.0284	0.1051	0.0075	17.31
2041	0.3787	0	42.85	0.029	0.1072	0.0077	17.66
2042	0.3863	0	43.7	0.0296	0.1093	0.0079	18.01
2043	0.394	0	44.58	0.0302	0.1115	0.0081	18.37
2044	0.4019	0	45.47	0.0308	0.1137	0.0083	18.74
2045	0.4099	0	46.38	0.0314	0.116	0.0085	19.11
2046	0.4181	0	47.31	0.032	0.1183	0.0087	19.5
2047	0.4265	0	48.25	0.0326	0.1207	0.0089	19.89
2048	0.435	0	49.22	0.0333	0.1231	0.0091	20.28
2049	0.4437	0	50.2	0.034	0.1256	0.0093	20.69
2050	0.4526	0	51.21	0.0347	0.1281	0.0095	21.1

- Financial incentive assumptions are summarized in Table 20.

Table 20: Financial incentive assumptions

Incentive program	Incentive calculation rules
Enbridge custom	0.25 $/m3/yr of natural gas reduction
	Up to a maximum of 50% of eligible project costs Up to a maximum of $100,000
FCM CBR GHG reduction pathway grant	Up to 80% of project costs (grant + loan)
	Up to $5 million (grant + loan) Up to 25% of funding can be grant

- Life cycle cost analysis assumptions are summarized in Table 21.

Table 21: Life cycle cost analysis assumptions

Description	Unit	Value
General cost inflation	[%]	2
Discount rate	[%]	5

- Risk analysis assumptions, including risk parameters and risk cases that were tested in the measure risk analysis are summarized in Table 22.

Table 22: Risk parameter and case definitions

Parameter	Description	Methodology	Case	X	Unit
Project cost	Project cost may differ from the estimated values.	The case project cost = x TIMES the initial project cost estimate.	Very low|Low|High|Very high	0.75|.9|1.1|1.25	[decimal]
Replacement cost	Replacement cost may differ from the estimated values.	The case replacement cost = x TIMES the initial replacement cost estimate.	Very low|Low|High|Very high	0.75|.9|1.1|1.25	[decimal]
Utility use change	Changes to utility use and thermal energy demand in a measure or scenario may differ from reality.	The case utility use profile is the baseline profile plus x TIMES the difference between the initial proposed profile and the baseline profile.	Very low|Low|High|Very high	0.75|.9|1.1|1.25	[decimal]
Electricity GHG factor	Future GHG factors for electricity may differ than those assumed.	For each year for which the GHG factor is projected, the case GHG factor for that year = the current year factor PLUS (x TIMES the difference between the initial value for that year, and the factor for the current year).	Very low|Low|High|Very high	0.75|.9|1.1|1.25	[decimal]
Incentive rates	Actual incentives may be different from estimated ones. While project cost and utility use affects incentive amounts, this risk parameter seeks to identify the risk in changes to the financial rates used in incentive amount calculations (e.g.\ if saveon energy provides incentives at 0.05 \$/kWh rather than 0.04 $/kWh, etc).	For each financial rate used in incentive amount calculations, the case rate is x TIMES the initial rate.	Very low|Low|High|Very high	0.75|.9|1.1|1.25	[decimal]
Federal carbon charge	Future federal carbon charge rates may differ than those assumed.	The default federal carbon charge increases to 170 $/tCO2e by 2030 and to 300 $/tCO2e by 2050. The case federal carbon charge follows the default trend but limited to a maximum value of x.	Very low|Low|High|Very high	0|100|240|300	[$/tCO2e]
Utility cost inflation	Future utility cost rates may differ than what was assumed.	The case utility cost inflation rate for all utilities is x (as a decimal) compounded yearly.	Very low|Low|High|Very high	0.01|0.015|0.025|0.03	[decimal]
General cost inflation	General cost inflation may differ from what was assumed. Note that general cost inflation is applied ONLY to project costs, replacement costs, and maintenance costs (future utility cost rates are handled separately).	The case general cost inflation rate is x.	Very low|Low|High|Very high	0.01|0.015|0.025|0.03	[decimal]
Discount rate	It is worth testing the sensitivity of the discount rate on life cycle cost / net present value calculations.	The case discount rate is x.	Very low|Low|High|Very high	0.05|0.06|0.08|0.09	[decimal]

- This building has not undergone a building condition assessment, and therefore, business as usual (BAU) measures were not available. WalterFedy utilized previous reports to gauge the potential costing of BAU renewal measures. These measures are provided for reference only and are not intended for use in budgetary

requirements. It's recommended that the City of Temiskaming Shores undertake a Building Condition Assessment of this building.

5.3 Measure identification

Results of the measure identification and triaging process are summarized in Table 23.

Table 23: Measure identification and triaging summary

Measure name	Triage for analysis
Baseline	
Carbon offsets 20	Analyzed.
Cold water flooding	Analyzed.
DEH01 conversion to electric	Analyzed.
DHW heaters to ASHP	Analyzed.
Exterior LED lighting upgrade	Analyzed.
F01 conversion to ASHP with ERV	Analyzed.
F02 conversion to ASHP with electric backup	Analyzed.
F02 conversion to ASHP with natural gas backup	Analyzed.
F03 conversion to ASHP with ERV	Analyzed.
Low-flow handwashing faucet aerators	Analyzed.
Low-flow shower fixtures	Analyzed.
Refrigeration heat recovery and optimization	Analyzed.
Roof upgrade to high performance	Analyzed.
Solar PV canopy	Analyzed.
Solar PV rooftop	Analyzed.
UH02 to electric	Analyzed.
UH04 to electric	Analyzed.
Wall upgrade to high performance	Analyzed.
Windows and doors to high performance	Analyzed.
Compressor renewal	Business as usual.
DEH01 renewal	Business as usual.
DHW renewal	Business as usual.
Exterior lighting renewal	Business as usual.
Exterior walls renewal	Business as usual.
F01 renewal	Business as usual.
F02 renewal	Business as usual.
F03 renewal	Business as usual.
Interior lighting renewal	Business as usual.
Roof renewal	Business as usual.
Shower renewal	Business as usual.
Sinks renewal	Business as usual.
UH02 renewal	Business as usual.
UH04 renewal	Business as usual.
Windows and doors renewal	Business as usual.
DEH02 conversion to electric	Not analyzed: the dehumidifier is already electric.
Implement a laser ice leveler	Not analyzed: the ice resurfacer already has a laser ice leveler.
Ice resurfacer conversion	Not analyzed: the ice resurfacer is already electric.
Interior LED lighting upgrade	Not analyzed: the majority of lights at this facility have been converted to LED. It is recommended that staff continue to replace fixtures with LED equivalents moving forward.

5.4 Carbon offsets 20

Measure description

Existing condition

The facility is currently purchasing no carbon offsets.

Opportunity

After implementing other measures, purchase carbon offsets to offset 20% of the remaining GHG emissions.

Utility-savings mechanism

Energy use is not affected by purchasing carbon offsets. Yearly GHG emissions accounted against the facility will be reduced by the same quantity as those purchased for that year.

Design description

Net zero definition

The Canadian Green Building Council (CAGBC) defines net carbon emissions for a facility as in the following formula.

Net emissions = Embodied carbon + Operational carbon - Avoided emissions

The terms of this formula are defined as follows.

- **Embodied carbon**. GHG emissions associated with the construction, maintenance and final end-of-life disposal of the facility.
- **Operational carbon**. GHG emissions are associated with the energy used by the facility during its operation.
- **Avoided emissions**. GHG emissions are avoided through activities such as exporting green power to local grids or purchasing carbon offsets.

Net Zero emissions as achieved when the Net emissions from this formula are zero or less.

This measure focuses on the ongoing use of avoided emissions (as defined above) to offset operational carbon associated with ongoing energy use at the facility. Note that embodied carbon emissions tend to be a one-time event, in contrast to the ongoing emissions associated with operations, which must also be accounted for through avoided emissions.

Renewable energy certificates

As defined above, emission avoidance activities recognized by the CaGBC's definition of net zero include exporting green power or purchasing carbon offsets. Green power exports encompass the export of on-site renewable energy, as well as the injection of renewable energy into local grids through off-site renewable energy generation facilities. The latter approach is typically accomplished through the purchase of Renewable Energy Certificates (RECs). RECs are utility-specific and are purchased by unit energy of the utility in question (e.g. kWh for electricity, or m^3 for natural gas) and can only be used to offset GHG emissions associated with the specific utility in question. For example, electricity RECs can be purchased to offset up to 100% of the electricity used by the building, but they cannot be used to offset natural gas used by the building (and vice versa). RECs are typically considered best practice because they facilitate an immediate injection of renewable energy into grids. RECs can be purchased through REC providers such as Bullfrog Power.

Carbon offsets

The purchase of carbon offsets is the second approach for avoiding emissions recognized by CaGBC. Carbon offsets are purchased on a per-tonne basis of GHG emissions. They can be used to offset either direct (e.g. natural gas combustion on-site) or indirect (e.g. electricity use on-site, which is generated offsite) GHG emissions. Carbon offsets must be certified as stipulated within the CaGBC's Zero Carbon Building Standard, which is required to

uphold the quality standards of the carbon offsets. Carbon offsets can be purchased through certified providers such as Less Emissions Inc.

Cost rates

Cost rates for RECs and carbon offsets are summarized as follows.

- Electricity REC cost rate (Bullfrog Power): 0.025 $/kWh.
- Natural gas REC cost rate (Bullfrog Power): 0.186 $/m3.
- Carbon offset cost rate (Less Emissions Inc.): 30 $/mtCO2e.

Utility analysis

Utility analysis methodology

Energy use is not affected by purchasing carbon offsets. Yearly GHG emissions accounted against the facility will be reduced by the same quantity as those purchased for that year.

Baseline. It is assumed that no carbon offsets are purchased.

Proposed. Carbon offsets are assumed to be purchased in the quantity equal to 20% of remaining GHG emissions. Note that as an individual measure, the analysis indicates the impact of offsetting baseline GHG emissions with carbon offsets. When considered as part of the scenario analyses in Section 6, this measure will cause 20% of remaining GHG emissions to be offset.

Utility analysis results

Table 24: Carbon offsets 20 analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	383,773	383,773	0	0
	Natural gas use	[m3/yr]	64,579	64,579	0	0
	Carbon offset use	[tCO2e/yr]	0	26.8	-26.8	—
Equivalent energy use	Electricity energy	[kWh/yr]	383,773	383,773	0	0
	Natural gas energy	[kWh/yr]	681,741	681,741	0	0
	Total energy	[kWh/yr]	1,065,515	1,065,515	0	0
GHG emissions	Electricity GHGs	[tCO2e/yr]	9.2	9.2	0	0
	Natural gas GHGs	[tCO2e/yr]	125	125	0	0
	Carbon offsets GHGs	[tCO2e/yr]	0	-26.8	26.8	—
	Total GHGs	[tCO2e/yr]	134	107	26.8	20
Utility cost	Electricity utility cost	[$/yr]	50,391	50,391	0	0
	Natural gas utility cost	[$/yr]	16,791	16,791	0	0
	Carbon offsets utility cost	[$/yr]	0	804	-804	—
	Federal carbon charge	[$/yr]	6,240	6,240	0	0
	Total utility cost	[$/yr]	73,421	74,225	-804	-1.1
Financial	Assumed life	[yrs]	15	20	—	—
	Project cost	[$]	0	—	—	—
	Incentive amount	[$]	0	0	—	—
	Incremental project cost	[$]	0	—	—	—
	Life cycle cost	[$]	1,550,214	1,565,712	—	—
	Net present value	[$]	0	-15,498	—	—
	Project cost per GHG reduction	[$yr/tCO2e]	—	—	—	—
	Simple payback period	[yr]	—	—	—	—

5.5 Cold water flooding

Measure description

Existing condition

Domestic hot water is currently used for ice resurfacing.

Opportunity

Implement a cold-water flooding strategy similar to "REALice" to reduce water heating and ice plant energy.

Utility-savings mechanism

Reduced domestic hot water heating use due to avoiding heating the ice resurfacing water. Reduced refrigeration energy use due to avoiding the load associated with cooling the hot water down.

Design description

Overview

Purchase and install a water de-aeration system similar to the REALice system to allow ice resurfacing to be completed using cold water. A single system is to be installed and piped to the ice resurface area for refilling the machine when needed. Ice resurfacing procedures may require updates as deemed necessary by staff.

Review with operations staff before installation. Staff training and process adjustments are required for the success of this measure. Implementing this measure as a pilot project on recreational ice surfaces is also recommended before implementing ice pads used for competition.

Project cost estimate

Table 25: Project cost estimate (Cold water flooding)

Category	Line item	Unit	Value
Materials and labour	Equipment and Installation	[$]	45,000
Contingency	Subtotal after Materials and labour	[$]	45,000
	General Contingency (50%)	[$]	22,500
Total	Total	[$]	67,500

Utility analysis

Utility analysis methodology

Baseline: Ice resurfacing water temperature is assumed to be 60C (140F).

Proposed: The water temperature is applied at 15C (ambient). Energy impacts with both DHW heating and refrigeration plant are captured.

Utility analysis results

Table 26: Cold water flooding analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	383,773	373,323	10,451	2.7
	Natural gas use	[m3/yr]	64,579	58,826	5,752	8.9
	Carbon offset use	[tCO2e/yr]	0	0	0	—
Equivalent energy use	Electricity energy	[kWh/yr]	383,773	373,323	10,451	2.7
	Natural gas energy	[kWh/yr]	681,741	621,014	60,727	8.9
	Total energy	[kWh/yr]	1,065,515	994,337	71,178	6.7
GHG emissions	Electricity GHGs	[tCO2e/yr]	9.2	8.9	0.30	3.3
	Natural gas GHGs	[tCO2e/yr]	125	114	11.1	8.9
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	—
	Total GHGs	[tCO2e/yr]	134	123	11.4	8.5
Utility cost	Electricity utility cost	[$/yr]	50,391	49,074	1,317	2.6
	Natural gas utility cost	[$/yr]	16,791	15,295	1,496	8.9
	Carbon offsets utility cost	[$/yr]	0	0	0	—
	Federal carbon charge	[$/yr]	6,240	5,685	555	8.9
	Total utility cost	[$/yr]	73,421	70,054	3,367	4.6
Financial	Assumed life	[yrs]	15	15	—	—
	Project cost	[$]	0	67,500	—	—
	Incentive amount	[$]	0	0	—	—
	Incremental project cost	[$]	0	67,500	—	—
	Life cycle cost	[$]	1,550,214	1,574,897	—	—
	Net present value	[$]	0	-24,683	—	—
	Project cost per GHG reduction	[$yr/tCO2e]	—	5,921	—	—
	Simple payback period	[yr]	—	>20	—	—

5.6 DEH01 conversion to electric

Measure description

Existing condition

DEH01 utilizes a solid desiccant wheel with natural gas-fired reactivation. Air from the ice rink passes through the desiccant wheel, which collects moisture. As the wheel becomes loaded with moisture, it is reactivated (i.e., dried out) via a natural gas burner and a separate air stream. The unit is not equipped with post-cooling.

Opportunity

Replace dehumifier to electic desicant unit.

Utility-savings mechanism

This measure will convert the heat fuel from natural gas to electricity. This will result in an overall energy reduction due to the higher efficiency of the electric desiccant wheel compared to that of the natural gas, as well as a reduction in GHG intensity.

Design description

Overview

Install a new electric dehumidifier on a new mezzanine in the corner of the ice rink. The model would be similar to CIMCO MS-2600.

Costing for this measure involves the addition of a smaller electric dehumidifier. The existing dehumidifier is assumed to be removed. However, it can remain to act as a second stage of dehumidification if a longer ice season is desired.

A contingency for structural review for the mezzanine is included. This does not include any additional structural upgrades that may be required as a result of the review.

Electrical

The DEH01 conversion to electric will add approximately 21 kW of power to the existing system, bringing the total to 177.36 kW, which is approximately 53% of the building's full electrical capacity. The estimated cost for this upgrade is allocated to the measure proportionally, with the full cost of the service upgrade captured in the plan scenario analysis.

Project cost estimate

Table 27: Project cost estimate (DEH01 conversion to electric)

Category	Line item	Unit	Value
Construction	Cimco MS-2600 Dehumidifiers (2)	[$]	70,000
	Installation	[$]	50,000
	Structural Review	[$]	10,000
	Electrical	[$]	10,000
	General requirements (25%)	[$]	35,000
Contingency	Subtotal after Construction	[$]	175,000
	Design Contingency (25%)	[$]	43,800
	Construction Contingency (10%)	[$]	17,500
Design, Contractors, PM	Subtotal after Contingency	[$]	236,300
	Engineering Design and Field Review (10%)	[$]	23,600
	Contractor Fee (7%)	[$]	16,500
Total	Total	[$]	276,400

Utility analysis

Utility analysis methodology

The following assumptions were applied to the energy model to estimate utility use impacts.

- **Baseline**. Dehumidification is gas-fired.
- **Proposed**. Dehumidification is electric.

Utility analysis results

Table 28: DEH01 conversion to electric analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	383,773	517,809	-134,035	-34.9
	Natural gas use	[m3/yr]	64,579	46,610	17,969	27.8
	Carbon offset use	[tCO2e/yr]	0	0	0	—
Equivalent energy use	Electricity energy	[kWh/yr]	383,773	517,809	-134,035	-34.9
	Natural gas energy	[kWh/yr]	681,741	492,045	189,697	27.8
	Total energy	[kWh/yr]	1,065,515	1,009,853	55,662	5.2
GHG emissions	Electricity GHGs	[tCO2e/yr]	9.2	12	-2.8	-30.4
	Natural gas GHGs	[tCO2e/yr]	125	90	34.8	27.9
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	—
	Total GHGs	[tCO2e/yr]	134	102	32	23.9
Utility cost	Electricity utility cost	[$/yr]	50,391	74,007	-23,617	-46.9
	Natural gas utility cost	[$/yr]	16,791	12,118	4,672	27.8
	Carbon offsets utility cost	[$/yr]	0	0	0	—
	Federal carbon charge	[$/yr]	6,240	4,500	1,740	27.9
	Total utility cost	[$/yr]	73,421	90,626	-17,205	-23.4
Financial	Assumed life	[yrs]	15	15	—	—
	Project cost	[$]	0	276,400	—	—
	Incentive amount	[$]	0	55,280	—	—
	Incremental project cost	[$]	0	221,120	—	—
	Life cycle cost	[$]	1,550,214	2,085,219	—	—
	Net present value	[$]	0	-535,005	—	—
	Project cost per GHG reduction	[$yr/tCO2e]	—	6,910	—	—
	Simple payback period	[yr]	—	—	—	—

5.7 DHW heaters to ASHP

Measure description

Existing condition

There are five DHW tanks, all of the same size (76 USG) and capacity (199,900 BTUH). DHW01 and DHW02 are connected with DHW05. However, DHW03 and DHW04 are standalone.

Opportunity

Replace the gas-fired DHW heaters with ASHP (air source heat pump) equivalents.

Utility-savings mechanism

This measure will convert the heat fuel from natural gas to electricity. This will result in an overall energy reduction due to the higher efficiency of the heat pump compared to that of the natural gas DHW tanks, as well as a reduction in GHG intensity.

Design description

Design concept

It is recommended that each of the hot water tanks be replaced with a hybrid heat pump hot water heater that extracts heat from the surrounding space to provide hot water. The units will serve DHW and ice resurfacing water.

The water heaters shall be equivalent to an AO Smith model CAHP-120 and provided with the following features:

- Nominal capacity 119 gal (450L)
- First-hour rating hybrid 179 gal (677L)

Electrical

The ASHP will add approximately 48 kW of power to the existing system, bringing the total to 204.36 kW, which is approximately 61.4% of the building's full electrical capacity.

Project cost estimate

Table 29: Project cost estimate (DHW heaters to ASHP)

Category	Line item	Unit	Value
Materials and labour	AO Smith CAHP-120 (Qty 4)	[$]	60,000
	Installation	[$]	40,000
	Electrical work	[$]	30,000
Contingency	Subtotal after Materials and labour	[$]	130,000
	General Contingency (50%)	[$]	65,000
Total	Total	[$]	195,000

Utility analysis

Utility analysis methodology

The following assumptions were applied to the energy model to estimate utility use impacts.

- **Baseline**. DHW heating is provided by gas-fired tanks at an efficiency of 80%.
- **Proposed**. DHW heating is provided by an ASHP at a COP of 3.5.

Utility analysis results

Table 30: DHW heaters to ASHP analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	383,773	410,454	-26,681	-7.0
	Natural gas use	[m3/yr]	64,579	53,101	11,478	17.8
	Carbon offset use	[tCO2e/yr]	0	0	0	—
Equivalent energy use	Electricity energy	[kWh/yr]	383,773	410,454	-26,681	-7.0
	Natural gas energy	[kWh/yr]	681,741	560,571	121,170	17.8
	Total energy	[kWh/yr]	1,065,515	971,026	94,489	8.9
GHG emissions	Electricity GHGs	[tCO2e/yr]	9.2	9.8	-0.60	-6.5
	Natural gas GHGs	[tCO2e/yr]	125	103	22.2	17.8
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	—
	Total GHGs	[tCO2e/yr]	134	112	21.6	16.1
Utility cost	Electricity utility cost	[$/yr]	50,391	53,485	-3,094	-6.1
	Natural gas utility cost	[$/yr]	16,791	13,806	2,984	17.8
	Carbon offsets utility cost	[$/yr]	0	0	0	—
	Federal carbon charge	[$/yr]	6,240	5,130	1,110	17.8
	Total utility cost	[$/yr]	73,421	72,421	1,000	1.4
Financial	Assumed life	[yrs]	15	15	—	—
	Project cost	[$]	0	195,000	—	—
	Incentive amount	[$]	0	2,870	—	—
	Incremental project cost	[$]	0	192,131	—	—
	Life cycle cost	[$]	1,550,214	1,791,734	—	—
	Net present value	[$]	0	-241,519	—	—
	Project cost per GHG reduction	[$yr/tCO2e]	—	8,895	—	—
	Simple payback period	[yr]	—	>20	—	—

5.8 Exterior LED lighting upgrade

Measure description

Existing condition

The building's exterior lighting utilizes LED and CFL lighting.

Opportunity

Replace all non-LED fixtures with LED equivalent fixtures.

Utility-savings mechanism

Reduced lighting energy use through more energy-efficient lamps. Given the fixtures are exterior to the building (i.e. unconditioned spaces), there are no effects on heating and cooling.

Design description

Overview

The lighting system shall be designed to meet the latest ASHRAE 90.1 energy codes, IESNA standards, the Don Shepherdson Memorial Arena standards and other applicable regulations and standards.

The existing site has gone through some recent LED upgrades. The project scope will be to replace all remaining fixtures with LED alternatives.

LED luminaires shall be provided with an expected service life of over 50,000 hours, dark-sky compliant, and be listed on the Energy Star Qualified Commercial Lighting List or the Design Lights Consortium List (DLC) for incentive eligibility from the IESOs Save on Energy Program.

With the extended lifespan associated with LED fixtures, the likelihood of a complete fixture failure is significantly lower than that of previous fixture types. Rather, the user would witness a slow degradation of the lighting output

of the fixtures. It is recommended that an annual lighting review be conducted to measure lighting levels after dusk or before dawn. At the 70% output level, the owner would expect a much quicker decline in the loss of lighting output in each fixture. As such, at the 70% lighting level, it would be recommended that the fixtures be replaced.

Type P, Q, and U fixtures should be replaced.

Project cost estimate

Table 31: Project cost estimate (Exterior LED lighting upgrade)

Category	Line item	Unit	Value
Materials and labour	Exterior LED lighting upgrade	[$]	1,100
Contingency	Subtotal after Materials and labour	[$]	1,100
	General Contingency (50%)	[$]	600
Total	Total	[$]	1,700

Utility analysis

Utility analysis methodology

The following assumptions were applied to the calibrated energy model to estimate utility use impacts.

- **Baseline**: Exterior lighting is assumed to consume 2.8 kW.
- **Proposed**: It is assumed that the exterior lighting is replaced with an LED equivalent which consumes 1.075 kW.

Utility analysis results

Table 32: Exterior LED lighting upgrade analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	383,773	376,249	7,524	2.0
	Natural gas use	[m3/yr]	64,579	64,579	0	0
	Carbon offset use	[tCO2e/yr]	0	0	0	–
Equivalent energy use	Electricity energy	[kWh/yr]	383,773	376,249	7,524	2.0
	Natural gas energy	[kWh/yr]	681,741	681,741	0	0
	Total energy	[kWh/yr]	1,065,515	1,057,990	7,525	0.71
GHG emissions	Electricity GHGs	[tCO2e/yr]	9.2	9	0.20	2.2
	Natural gas GHGs	[tCO2e/yr]	125	125	-0.20	-0.16
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	–
	Total GHGs	[tCO2e/yr]	134	134	0	0
Utility cost	Electricity utility cost	[$/yr]	50,391	49,519	872	1.7
	Natural gas utility cost	[$/yr]	16,791	16,791	0	0
	Carbon offsets utility cost	[$/yr]	0	0	0	–
	Federal carbon charge	[$/yr]	6,240	6,250	-10	-0.16
	Total utility cost	[$/yr]	73,421	72,559	862	1.2
Financial	Assumed life	[yrs]	15	20	–	–
	Project cost	[$]	0	1,700	–	–
	Incentive amount	[$]	0	0	–	–
	Incremental project cost	[$]	0	1,700	–	–
	Life cycle cost	[$]	1,550,214	1,532,381	–	–
	Net present value	[$]	0	17,834	–	–
	Project cost per GHG reduction	[$yr/tCO2e]	–	–	–	–
	Simple payback period	[yr]	–	2.0	–	–

5.9 F01 conversion to ASHP with ERV

Measure description

Existing condition

F01 serves the front lobby, change rooms 5-8, the front office, concession stand, the west washrooms, and the lunch room. The unit appears original to the building and utilizes natural gas burners for heating. There are plans to replace this unit soon. Lastly, there was a noted concern about the insulation on the exterior ductwork being asbestos-containing material (ACM).

Opportunity

Replace the furnace and use air-source heat pump as the heating and cooling source with an ERV.

Utility-savings mechanism

The primary intent of this measure is to reduce GHG emissions by converting the fuel used for heating from natural gas to electricity due to electricity having a lower GHG intensity than natural gas. Reduced natural gas use and increased electricity use would be expected as a result.

Design description

Design concept

This measure replaces F01 with a multi-split air-source heat pump (ASHP) option and adds an indoor ERV to provide ventilation to change rooms 6-8 and the main lobby. The available heating output from an air source heat pump decreases as the outdoor air temperature decreases. The following units shall be provided:

- Install a 5-ton Moovair Condensing unit on the ground (west elevation).
- Install a wall-hung 1-ton indoor unit in each of the change rooms and the front lobby.

- Replace the existing furnace and change room exhaust fans with a 500CFM ERV. The ERV shall be ducted with multiple 4" ducts across the hallway to serve the change rooms. The ERV shall include a 10kW post heater to temper outside air to a minimum delivery temperature.

Electrical

The ASHP will add approximately 22 kW of power to the existing system, bringing the total to 178.36 kW, which is approximately 54% of the building's full electrical capacity.

Project cost estimate

Table 33: Project cost estimate (F01 conversion to ASHP with ERV)

Category	Line item	Unit	Value
Construction	Equipment	[$]	30,000
	Installation	[$]	40,000
	Electrical work	[$]	37,000
	General requirements (25%)	[$]	26,800
Contingency	Subtotal after Construction	[$]	133,800
	Design Contingency (25%)	[$]	33,400
	Construction Contingency (10%)	[$]	13,400
Design, Contractors, PM	Subtotal after Contingency	[$]	180,600
	Engineering Design and Field Review (10%)	[$]	18,100
	Contractor Fee (7%)	[$]	12,600
Total	Total	[$]	211,300

Utility analysis

Utility analysis methodology

The following assumptions were applied to the calibrated energy model to estimate utility use impacts.

- **Baseline**: The furnace provides space heating through natural gas-fired burners. The existing heating efficiency is 85%. There is no heat recovery.
- **Proposed**: The furnace provides space heating and cooling through air-source heat pumps. The proposed average heating and cooling COPs are 3 and 4.1 (14 EER), respectively. Heat is assumed to be recovered at an efficiency of 60%.

Utility analysis results

Table 34: F01 conversion to ASHP with ERV analysis results summary

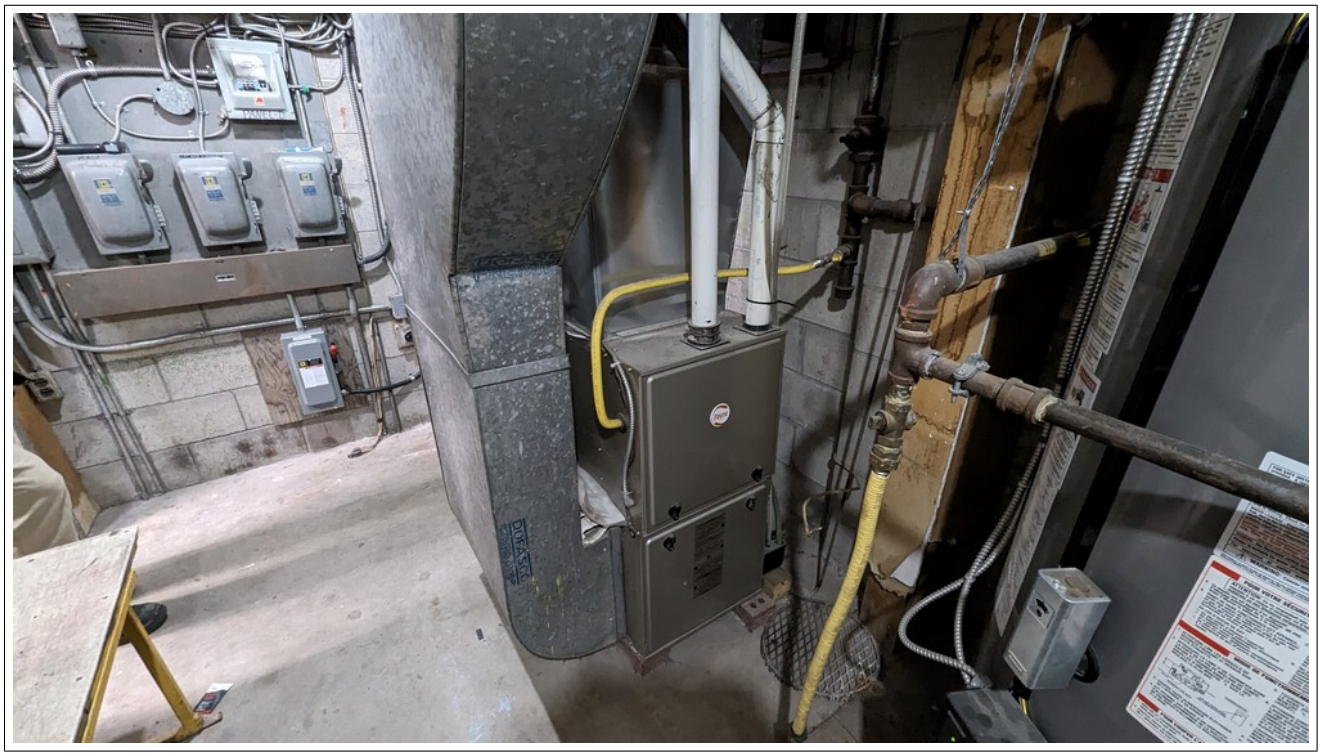
Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	383,773	430,780	-47,007	-12.2
	Natural gas use	[m3/yr]	64,579	56,177	8,402	13.0
	Carbon offset use	[tCO2e/yr]	0	0	0	—
Equivalent energy use	Electricity energy	[kWh/yr]	383,773	430,780	-47,007	-12.2
	Natural gas energy	[kWh/yr]	681,741	593,045	88,697	13.0
	Total energy	[kWh/yr]	1,065,515	1,023,825	41,690	3.9
GHG emissions	Electricity GHGs	[tCO2e/yr]	9.2	10	-0.80	-8.7
	Natural gas GHGs	[tCO2e/yr]	125	109	15.8	12.7
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	—
	Total GHGs	[tCO2e/yr]	134	119	15	11.2
Utility cost	Electricity utility cost	[$/yr]	50,391	56,327	-5,936	-11.8
	Natural gas utility cost	[$/yr]	16,791	14,606	2,184	13.0
	Carbon offsets utility cost	[$/yr]	0	0	0	—
	Federal carbon charge	[$/yr]	6,240	5,450	790	12.7
	Total utility cost	[$/yr]	73,421	76,383	-2,962	-4.0
Financial	Assumed life	[yrs]	15	15	—	—
	Project cost	[$]	0	211,300	—	—
	Incentive amount	[$]	0	42,260	—	—
	Incremental project cost	[$]	0	169,040	—	—
	Life cycle cost	[$]	1,550,214	1,840,541	—	—
	Net present value	[$]	0	-290,327	—	—
	Project cost per GHG reduction	[$yr/tCO2e]	—	11,269	—	—
	Simple payback period	[yr]	—	—	—	—

5.10 F02 conversion to ASHP with electric backup

Measure description

Existing condition

F02 serves the referee's change room, the press room, and the ice resurfacer room. The unit is a condensing furnace equipped with a natural gas-fired burner and does not include cooling.



Opportunity

Replace the furnace and use air-source heat pump as the heating and cooling source with electric backup.

Utility-savings mechanism

The primary intent of this measure is to reduce GHG emissions by converting the fuel used for heating from natural gas to electricity due to electricity having a lower GHG intensity than natural gas. Reduced natural gas use and increased electricity use would be expected as a result.

Design description

Design concept

This measure replaces F02 with an air-source heat pump (ASHP). The available heating output from an air source heat pump decreases as the outdoor air temperature decreases. The units will be equipped with an electric resistance backup heating section to supplement the operation of the heat pump. The following units shall be provided:

- A 4-ton Moovair Condensing unit and AHU with 10kW electric resistance.

Electrical

The ASHP, with the electric backup, will add approximately 17.5 kW of power to the existing system, bringing the total to 173.86 kW, which is approximately 52% of the building's full electrical capacity.

Project cost estimate

Table 35: Project cost estimate (F02 conversion to ASHP with electric backup)

Category	Line item	Unit	Value
Construction	Equipment	[$]	10,000
	Installation	[$]	15,000
	Electrical work	[$]	18,000
	General requirements (25%)	[$]	10,800
Contingency	Subtotal after Construction	[$]	53,800
	Design Contingency (25%)	[$]	13,400
	Construction Contingency (10%)	[$]	5,400
Design, Contractors, PM	Subtotal after Contingency	[$]	72,600
	Engineering Design and Field Review (10%)	[$]	7,300
	Contractor Fee (7%)	[$]	5,100
Total	Total	[$]	85,000

Utility analysis

Utility analysis methodology

The following assumptions were applied to the calibrated energy model to estimate utility use impacts.

- **Baseline**: The furnace provides space heating through natural gas-fired burners. The existing heating efficiency is 97%.
- **Proposed**: The furnace provides space heating and cooling through air-source heat pumps. The proposed average heating and cooling COPs are 3 and 4.1 (14 EER), respectively. Backup heating is provided through electric resistance when the outdoor air temperature is below -15 C.

Utility analysis results

Table 36: F02 conversion to ASHP with electric backup analysis results summary

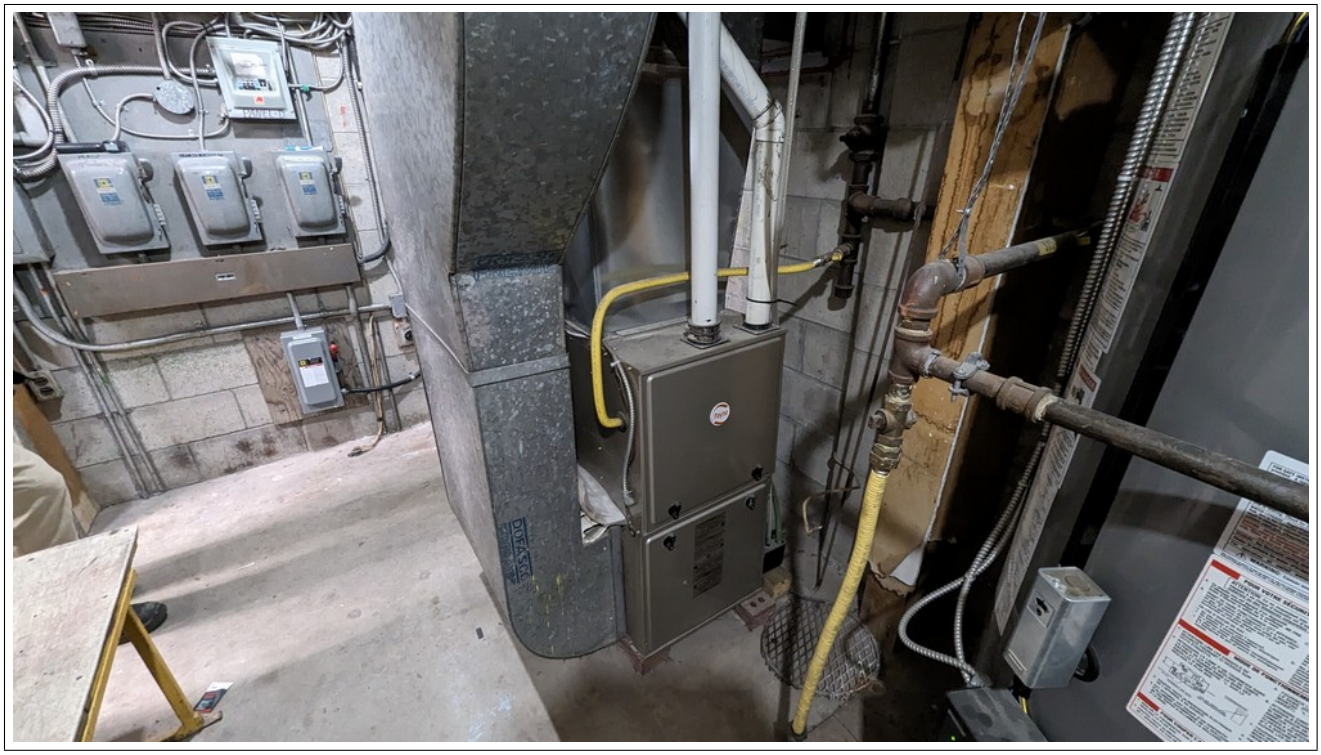
Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	383,773	400,458	-16,684	-4.3
	Natural gas use	[m3/yr]	64,579	62,092	2,487	3.9
	Carbon offset use	[tCO2e/yr]	0	0	0	–
Equivalent energy use	Electricity energy	[kWh/yr]	383,773	400,458	-16,684	-4.3
	Natural gas energy	[kWh/yr]	681,741	655,488	26,254	3.9
	Total energy	[kWh/yr]	1,065,515	1,055,945	9,570	0.90
GHG emissions	Electricity GHGs	[tCO2e/yr]	9.2	9.6	-0.40	-4.3
	Natural gas GHGs	[tCO2e/yr]	125	120	4.8	3.8
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	–
	Total GHGs	[tCO2e/yr]	134	130	4.4	3.3
Utility cost	Electricity utility cost	[$/yr]	50,391	52,491	-2,101	-4.2
	Natural gas utility cost	[$/yr]	16,791	16,144	647	3.9
	Carbon offsets utility cost	[$/yr]	0	0	0	–
	Federal carbon charge	[$/yr]	6,240	6,000	240	3.8
	Total utility cost	[$/yr]	73,421	74,635	-1,214	-1.7
Financial	Assumed life	[yrs]	15	15	–	–
	Project cost	[$]	0	85,000	–	–
	Incentive amount	[$]	0	17,000	–	–
	Incremental project cost	[$]	0	68,000	–	–
	Life cycle cost	[$]	1,550,214	1,665,526	–	–
	Net present value	[$]	0	-115,311	–	–
	Project cost per GHG reduction	[$yr/tCO2e]	–	15,455	–	–
	Simple payback period	[yr]	–	–	–	–

5.11 F02 conversion to ASHP with natural gas backup

Measure description

Existing condition

F02 serves the referee's change room, the press room, and the ice resurfacer room. The unit is a condensing furnace equipped with a natural gas-fired burner and does not have cooling capabilities.



Opportunity

Replace the furnace and use air-source heat pump as the heating and cooling source with natural gas backup.

Utility-savings mechanism

The primary intent of this measure is to reduce GHG emissions by converting the fuel used for heating from natural gas to electricity due to electricity having a lower GHG intensity than natural gas. Reduced natural gas use and increased electricity use would be expected as a result.

Design description

Design concept

This measure replaces F02 with an air-source heat pump (ASHP) add-on coil to the existing furnace. The available heating output from an air source heat pump decreases as the outdoor air temperature decreases. The existing furnace will provide supplemental heating. The following unit shall be provided:

- A 4-ton Moovair Condensing unit and a coil will be added to the existing furnace.

Electrical

The ASHP, with the gas backup, will add approximately 7.5 kW of power to the existing system, bringing the total to 163.86 kW, which is approximately 49% of the building's full electrical capacity.

Project cost estimate

Table 37: Project cost estimate (F02 conversion to ASHP with natural gas backup)

Category	Line item	Unit	Value
Construction	Equipment	[$]	7,500
	Installation	[$]	12,500
	Electrical work	[$]	12,000
	General requirements (25%)	[$]	8,000
Contingency	Subtotal after Construction	[$]	40,000
	Design Contingency (25%)	[$]	10,000
	Construction Contingency (10%)	[$]	4,000
Design, Contractors, PM	Subtotal after Contingency	[$]	54,000
	Engineering Design and Field Review (10%)	[$]	5,400
	Contractor Fee (7%)	[$]	3,800
Total	Total	[$]	63,200

Utility analysis

Utility analysis methodology

The following assumptions were applied to the calibrated energy model to estimate utility use impacts.

- **Baseline**: The furnace provides space heating through natural gas-fired burners. The existing heating efficiency is 97%.
- **Proposed**: The furnace provides space heating and cooling through air-source heat pumps. The proposed average heating and cooling COPs are 3 and 4.1 (14 EER), respectively. Backup heating is provided through electric resistance when the outdoor air temperature is below -15 C.

Utility analysis results

Table 38: F02 conversion to ASHP with natural gas backup analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	383,773	393,783	-10,010	-2.6
	Natural gas use	[m3/yr]	64,579	62,837	1,742	2.7
	Carbon offset use	[tCO2e/yr]	0	0	0	–
Equivalent energy use	Electricity energy	[kWh/yr]	383,773	393,783	-10,010	-2.6
	Natural gas energy	[kWh/yr]	681,741	663,354	18,387	2.7
	Total energy	[kWh/yr]	1,065,515	1,057,137	8,378	0.79
GHG emissions	Electricity GHGs	[tCO2e/yr]	9.2	9.4	-0.20	-2.2
	Natural gas GHGs	[tCO2e/yr]	125	121	3.4	2.7
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	–
	Total GHGs	[tCO2e/yr]	134	131	3.2	2.4
Utility cost	Electricity utility cost	[$/yr]	50,391	51,522	-1,131	-2.2
	Natural gas utility cost	[$/yr]	16,791	16,338	453	2.7
	Carbon offsets utility cost	[$/yr]	0	0	0	–
	Federal carbon charge	[$/yr]	6,240	6,070	170	2.7
	Total utility cost	[$/yr]	73,421	73,930	-508	-0.69
Financial	Assumed life	[yrs]	15	15	–	–
	Project cost	[$]	0	63,200	–	–
	Incentive amount	[$]	0	12,640	–	–
	Incremental project cost	[$]	0	50,560	–	–
	Life cycle cost	[$]	1,550,214	1,630,230	–	–
	Net present value	[$]	0	-80,016	–	–
	Project cost per GHG reduction	[$yr/tCO2e]	–	15,800	–	–
	Simple payback period	[yr]	–	–	–	–

5.12 F03 conversion to ASHP with ERV

Measure description

Existing condition

F03 is a unit heater serving the south changerooms. It features a natural gas-fired burner without cooling.

Opportunity

Replace the furnace and use air-source heat pump as the heating and cooling source with an ERV.

Utility-savings mechanism

The primary intent of this measure is to reduce GHG emissions by converting the fuel used for heating from natural gas to electricity due to electricity having a lower GHG intensity than natural gas. Reduced natural gas use and increased electricity use would be expected as a result.

Design description

Design concept

This measure replaces F03 with an air-source heat pump (ASHP) and adds an indoor energy recovery ventilator (ERV) to provide ventilation. The available heating output from an air source heat pump decreases as the outdoor air temperature decreases. The unit will be equipped with an electric resistance backup heating section to supplement the operation of the heat pump. The following units will be provided:

- A 5-ton Moovair Condensing unit and an AHU with 20kW of electric resistance.
- Replace the existing furnace and change room exhaust fans with a 500CFM ERV. The ERV shall be ducted with multiple 4" ducts across the hallway to serve the change rooms. The ERV shall include a 10kW post heater to temper outside air to a minimum delivery temperature.

Electrical

The ASHP, with the electric backup, will add approximately 43 kW of power to the existing system, bringing the total to 200 kW, which is approximately 60% of the building's full electrical capacity.

Project cost estimate

Table 39: Project cost estimate (F03 conversion to ASHP with ERV)

Category	Line item	Unit	Value
Construction	Equipment	[$]	30,000
	Installation	[$]	40,000
	Electrical work	[$]	46,000
	General requirements (25%)	[$]	29,000
Contingency	Subtotal after Construction	[$]	145,000
	Design Contingency (25%)	[$]	36,200
	Construction Contingency (10%)	[$]	14,500
Design, Contractors, PM	Subtotal after Contingency	[$]	195,700
	Engineering Design and Field Review (10%)	[$]	19,600
	Contractor Fee (7%)	[$]	13,700
Total	Total	[$]	229,000

Utility analysis

Utility analysis methodology

The following assumptions were applied to the calibrated energy model to estimate utility use impacts.

- **Baseline**: The furnace provides space heating through natural gas-fired burners. The existing heating efficiency is 96%. There is no heat recovery.
- **Proposed**: The furnace provides space heating and cooling through air-source heat pumps. The proposed average heating and cooling COPs are 3 and 4.1 (14 EER), respectively. Heat is assumed to be recovered at an efficiency of 60%.

Utility analysis results

Table 40: F03 conversion to ASHP with ERV analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	383,773	470,193	-86,419	-22.5
	Natural gas use	[m3/yr]	64,579	47,710	16,869	26.1
	Carbon offset use	[tCO2e/yr]	0	0	0	—
Equivalent energy use	Electricity energy	[kWh/yr]	383,773	470,193	-86,419	-22.5
	Natural gas energy	[kWh/yr]	681,741	503,658	178,083	26.1
	Total energy	[kWh/yr]	1,065,515	973,851	91,664	8.6
GHG emissions	Electricity GHGs	[tCO2e/yr]	9.2	11	-1.8	-19.6
	Natural gas GHGs	[tCO2e/yr]	125	92	32.8	26.3
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	—
	Total GHGs	[tCO2e/yr]	134	103	31	23.1
Utility cost	Electricity utility cost	[$/yr]	50,391	61,215	-10,824	-21.5
	Natural gas utility cost	[$/yr]	16,791	12,405	4,386	26.1
	Carbon offsets utility cost	[$/yr]	0	0	0	—
	Federal carbon charge	[$/yr]	6,240	4,600	1,640	26.3
	Total utility cost	[$/yr]	73,421	78,219	-4,798	-6.5
Financial	Assumed life	[yrs]	15	15	—	—
	Project cost	[$]	0	229,000	—	—
	Incentive amount	[$]	0	45,800	—	—
	Incremental project cost	[$]	0	183,200	—	—
	Life cycle cost	[$]	1,550,214	1,919,730	—	—
	Net present value	[$]	0	-369,516	—	—
	Project cost per GHG reduction	[$yr/tCO2e]	—	5,910	—	—
	Simple payback period	[yr]	—	—	—	—

5.13 Low-flow handwashing faucet aerators

Measure description

Existing condition

Handwashing faucets were mostly manually controlled, and aerators were rated at 2.0 gpm.

Opportunity

Install low flow faucets aerators on handwashing faucets throughout the facility.

Utility-savings mechanism

Reduced water use and reduced natural gas required for DHW heating.

Design description

Overview

Remove existing handwashing faucet aerators and replace them with low-flow aerators. The proposed flow rate for the new aerators would be 0.5 to 1 gallons per minute (gpm), depending on user preferences.

Project cost estimate

Project cost parameters

The following table outlines the parameters on which project costs were assumed to depend and the assumed values of each parameter.

Table 41: Project cost parameters (Low-flow handwashing faucet aerators)

Line item	Unit	Value
Aerators quantity to be replaced	[aerator]	10

Project cost estimate

The project cost estimate is summarized in the following table.

Table 42: Project cost estimate (Low-flow handwashing faucet aerators)

Category	Line item	Unit	Value
Materials and labour	New aerator materials	[$]	500
	New aerator installation	[$]	2,000
Contingency	Subtotal after Materials and labour	[$]	2,500
	General Contingency (50%)	[$]	1,200
Total	Total	[$]	3,700

Utility analysis

Utility analysis methodology

The following assumptions were applied to the energy model to estimate utility use impacts.

- **Baseline**. Average faucet flow rate of 1.5 GPM.
- **Proposed**. Faucet flow rate of 0.5 GPM.

Utility analysis results

Table 43: Low-flow handwashing faucet aerators analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	383,773	383,773	0	0
	Natural gas use	[m3/yr]	64,579	63,807	772	1.2
	Carbon offset use	[tCO2e/yr]	0	0	0	–
Equivalent energy use	Electricity energy	[kWh/yr]	383,773	383,773	0	0
	Natural gas energy	[kWh/yr]	681,741	673,593	8,148	1.2
	Total energy	[kWh/yr]	1,065,515	1,057,367	8,148	0.76
GHG emissions	Electricity GHGs	[tCO2e/yr]	9.2	9.2	0	0
	Natural gas GHGs	[tCO2e/yr]	125	123	1.5	1.2
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	–
	Total GHGs	[tCO2e/yr]	134	132	1.5	1.1
Utility cost	Electricity utility cost	[$/yr]	50,391	50,391	0	0
	Natural gas utility cost	[$/yr]	16,791	16,590	201	1.2
	Carbon offsets utility cost	[$/yr]	0	0	0	–
	Federal carbon charge	[$/yr]	6,240	6,165	75	1.2
	Total utility cost	[$/yr]	73,421	73,146	276	0.38
Financial	Assumed life	[yrs]	15	15	–	–
	Project cost	[$]	0	3,700	–	–
	Incentive amount	[$]	0	193	–	–
	Incremental project cost	[$]	0	3,507	–	–
	Life cycle cost	[$]	1,550,214	1,550,665	–	–
	Net present value	[$]	0	-450	–	–
	Project cost per GHG reduction	[$yr/tCO2e]	–	2,338	–	–
	Simple payback period	[yr]	–	13	–	–

5.14 Low-flow shower fixtures

Measure description

Existing condition

Shower heads were mostly manually controlled and were assumed to have a flow rate of 2.5 gpm.

Opportunity

Install low-flow shower fixtures to replace existing fixtures.

Utility-savings mechanism

Reduce DHW heating energy use through reduced use of heated water.

Design description

Overview

This measure examines the lower-flow fixtures serving showers throughout the building. Lower water flow at these fixtures reduces hot water usage, resulting in energy savings and potential capital savings in the heat pump sizing for domestic hot water heating systems.

Sizing and Design

The building currently consists of approximately 13 shower heads throughout the facility.

Project cost estimate

Table 44: Project cost estimate (Low-flow shower fixtures)

Category	Line item	Unit	Value
Materials and labour	Supply (300 $/fixture; showerhead only)	[$]	3,900
	Installation (200 $/fixture; showerhead only)	[$]	2,600
Contingency	Subtotal after Materials and labour	[$]	6,500
	General Contingency (50%)	[$]	3,200
Total	Total	[$]	9,700

Utility analysis

Utility analysis methodology

The following assumptions were applied to the energy model to estimate utility use impacts.

- **Baseline**. Shower fixture flow rate of 2.5 GPM.
- **Proposed**. Shower fixture flow rate of 1.5 GPM.

Utility analysis results

Table 45: Low-flow shower fixtures analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	383,773	383,773	0	0
	Natural gas use	[m3/yr]	64,579	63,499	1,080	1.7
	Carbon offset use	[tCO2e/yr]	0	0	0	–
Equivalent energy use	Electricity energy	[kWh/yr]	383,773	383,773	0	0
	Natural gas energy	[kWh/yr]	681,741	670,343	11,399	1.7
	Total energy	[kWh/yr]	1,065,515	1,054,116	11,399	1.1
GHG emissions	Electricity GHGs	[tCO2e/yr]	9.2	9.2	0	0
	Natural gas GHGs	[tCO2e/yr]	125	123	2.1	1.7
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	–
	Total GHGs	[tCO2e/yr]	134	132	2.1	1.6
Utility cost	Electricity utility cost	[$/yr]	50,391	50,391	0	0
	Natural gas utility cost	[$/yr]	16,791	16,510	281	1.7
	Carbon offsets utility cost	[$/yr]	0	0	0	–
	Federal carbon charge	[$/yr]	6,240	6,135	105	1.7
	Total utility cost	[$/yr]	73,421	73,036	386	0.53
Financial	Assumed life	[yrs]	15	15	–	–
	Project cost	[$]	0	9,700	–	–
	Incentive amount	[$]	0	270	–	–
	Incremental project cost	[$]	0	9,430	–	–
	Life cycle cost	[$]	1,550,214	1,556,187	–	–
	Net present value	[$]	0	-5,973	–	–
	Project cost per GHG reduction	[$yr/tCO2e]	–	4,491	–	–
	Simple payback period	[yr]	–	>20	–	–

5.15 Refrigeration heat recovery and optimization

Measure description

Existing condition

There is an opportunity to improve the efficiency of the refrigeration system and recover heat.

Opportunity

Replace the compreessors with higher efficiency models. Install a desuperheater to provide preheating to the DHW system.

Utility-savings mechanism

The primary intent of this measure is to reduce the amount of waste heat by re-directing it to be used with DHW. This approach will result in lower natural gas relating to DHW and lower electricity consumption due to less heat rejection. Pumps end use will increase to allow for circulation between the desuperheater and DHW. Furthermore, replacing the reciprocating compressors will result in a higher ice plant COP, reducing electricity consumption.

Design description

Overview

Install a new desuperheater on the existing ice plant to reject heat to a domestic hot water pre-heat tank. The pre-heat tank will provide hot water for the ice resurfacer and domestic hot water uses. Please note that the cost below is based on a high-level budget estimate for a complete turn-key installation of a desuperheater. Furthermore, include the replacement of the existing refrigeration compressors with higher efficiency units. Retrofit to account for modifications to piping.

Project cost estimate

Table 46: Project cost estimate (Refrigeration heat recovery and optimization)

Category	Line item	Unit	Value
Materials and labour	Compressor upgrade (x2)	[$]	180,000
	Equipment and Installation	[$]	120,000
	Electrical upgrades (miscellaneous power connections)	[$]	18,000
Contingency	Subtotal after Materials and labour	[$]	318,000
	General Contingency (50%)	[$]	159,000
Total	Total	[$]	477,000

Utility analysis

Utility analysis methodology

The following assumptions were applied to the calibrated energy model to estimate utility use impacts.

- **Baseline:** No heat recovery from the refrigeration plant other than subfloor heating. Compressors provide cooling to the cold brine at a COP of 3.1.
- **Proposed:** It is assumed that the desuperheater can recover heat to serve as preheat for the DHW plant. Compressors provide cooling to the cold brine at a COP of 3.3.

Utility analysis results

Table 47: Refrigeration heat recovery and optimization analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	383,773	377,880	5,893	1.5
	Natural gas use	[m3/yr]	64,579	62,992	1,586	2.5
	Carbon offset use	[tCO2e/yr]	0	0	0	—
Equivalent energy use	Electricity energy	[kWh/yr]	383,773	377,880	5,893	1.5
	Natural gas energy	[kWh/yr]	681,741	664,994	16,748	2.5
	Total energy	[kWh/yr]	1,065,515	1,042,873	22,642	2.1
GHG emissions	Electricity GHGs	[tCO2e/yr]	9.2	9	0.20	2.2
	Natural gas GHGs	[tCO2e/yr]	125	122	2.8	2.2
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	—
	Total GHGs	[tCO2e/yr]	134	131	3	2.2
Utility cost	Electricity utility cost	[$/yr]	50,391	49,656	735	1.5
	Natural gas utility cost	[$/yr]	16,791	16,378	412	2.5
	Carbon offsets utility cost	[$/yr]	0	0	0	—
	Federal carbon charge	[$/yr]	6,240	6,100	140	2.2
	Total utility cost	[$/yr]	73,421	72,134	1,287	1.8
Financial	Assumed life	[yrs]	15	15	—	—
	Project cost	[$]	0	477,000	—	—
	Incentive amount	[$]	0	0	—	—
	Incremental project cost	[$]	0	477,000	—	—
	Life cycle cost	[$]	1,550,214	2,090,556	—	—
	Net present value	[$]	0	-540,342	—	—
	Project cost per GHG reduction	[$yr/tCO2e]	—	159,000	—	—
	Simple payback period	[yr]	—	>20	—	—

5.16 Roof upgrade to high performance

Measure description

Existing condition

The exterior layer of the roof is modified bitumen membrane, which is due for replacement. A cut test was conducted at this site, and the original roof was found to have three inches of polyisocyanurate insulation. Furthermore, the addition drawings show either three or four inches of polyisocyanurate.

Opportunity

Upgrade upon the end of useful life or as required to meet scenario criteria.

Utility-savings mechanism

Reduced heating energy use through improved thermal performance of the roof.

Design description

Overview

The existing sloped roof is finished with a mod bit membrane, which is at the end of its life. The roof structure consists of glulam beams, which appear to have some insulation and liner fabric between them, with 3 inches of polyiso insulation on top of what we assume is a steel deck with plywood sheathing and a vapour barrier. The smaller flat-roofed section, we assume, rests on a steel deck supported on the block walls.

We recommend that the existing mod bit membrane, insulation, sheathing and vapour barrier be removed. At least 8-9 inches of rigid insulation be provided on top of a new layer of sheathing, a new air barrier, and a new PVC or TPO roof membrane in place of the existing membrane, which will bring the roof performance to around R41-R45 (the current code requirement is R41 for continuous insulation above a deck). The joints between walls and the roof should be examined to ensure that no air leakage or thermal bridging is occurring. Sealants and/or spray foam should be provided where leaks are occurring, as they can significantly affect thermal performance. The parapet flashing and membrane flashing will need to be reworked around the parapets and eaves to accommodate the extra thickness of the roof insulation.

Project cost estimate

Table 48: Project cost estimate (Roof upgrade to high performance)

Category	Line item	Unit	Value
Construction	Roof replacement	[$]	1,449,000
	General requirements (25%)	[$]	362,200
Contingency	Subtotal after Construction	[$]	1,811,200
	Design Contingency (25%)	[$]	452,800
	Construction Contingency (10%)	[$]	181,100
Design, Contractors, PM	Subtotal after Contingency	[$]	2,445,100
	Engineering Design and Field Review (10%)	[$]	244,500
	Contractor Fee (7%)	[$]	171,200
Total	Total	[$]	2,860,800

Utility analysis

Utility analysis methodology

The following assumptions were applied to the calibrated energy model to estimate utility use impacts.

- **Baseline**. An average roof U-value of 0.033 BTU/hr.ft2.F (R30) was assumed for the original, and an average roof U-value of 0.027 BTU/hr.ft2.F (R37) was assumed for the addition.

- **Proposed**. An average roof U-value of 0.033 BTU/hr.ft2.F (R70) was assumed for the original, and an average roof U-value of 0.027 BTU/hr.ft2.F (R70) was assumed for the addition.

Utility analysis results

Table 49: Roof upgrade to high performance analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	383,773	385,405	-1,632	-0.43
	Natural gas use	[m3/yr]	64,579	56,058	8,520	13.2
	Carbon offset use	[tCO2e/yr]	0	0	0	—
Equivalent energy use	Electricity energy	[kWh/yr]	383,773	385,405	-1,632	-0.43
	Natural gas energy	[kWh/yr]	681,741	591,793	89,948	13.2
	Total energy	[kWh/yr]	1,065,515	977,198	88,317	8.3
GHG emissions	Electricity GHGs	[tCO2e/yr]	9.2	9.2	0	0
	Natural gas GHGs	[tCO2e/yr]	125	108	16.5	13.2
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	—
	Total GHGs	[tCO2e/yr]	134	118	16.5	12.3
Utility cost	Electricity utility cost	[$/yr]	50,391	50,562	-171	-0.34
	Natural gas utility cost	[$/yr]	16,791	14,575	2,215	13.2
	Carbon offsets utility cost	[$/yr]	0	0	0	—
	Federal carbon charge	[$/yr]	6,240	5,415	825	13.2
	Total utility cost	[$/yr]	73,421	70,552	2,869	3.9
Financial	Assumed life	[yrs]	15	20	—	—
	Project cost	[$]	0	2,860,800	—	—
	Incentive amount	[$]	0	572,160	—	—
	Incremental project cost	[$]	0	2,288,640	—	—
	Life cycle cost	[$]	1,550,214	3,931,062	—	—
	Net present value	[$]	0	-2,380,848	—	—
	Project cost per GHG reduction	[$yr/tCO2e]	—	138,706	—	—
	Simple payback period	[yr]	—	>20	—	—

5.17 Solar PV canopy

Measure description

Existing condition

There is no canopy solar PV. Some parking lot space is available.

Opportunity

Install a solar PV system on canopies in the parking lot where feasible. A net-metering agreement is recommended so that the reduced GHG emissions associated with the electricity generated by the system can be retained by the City of Temiskaming Shores or exported to the grid if on-site electricity consumption is fulfilled.

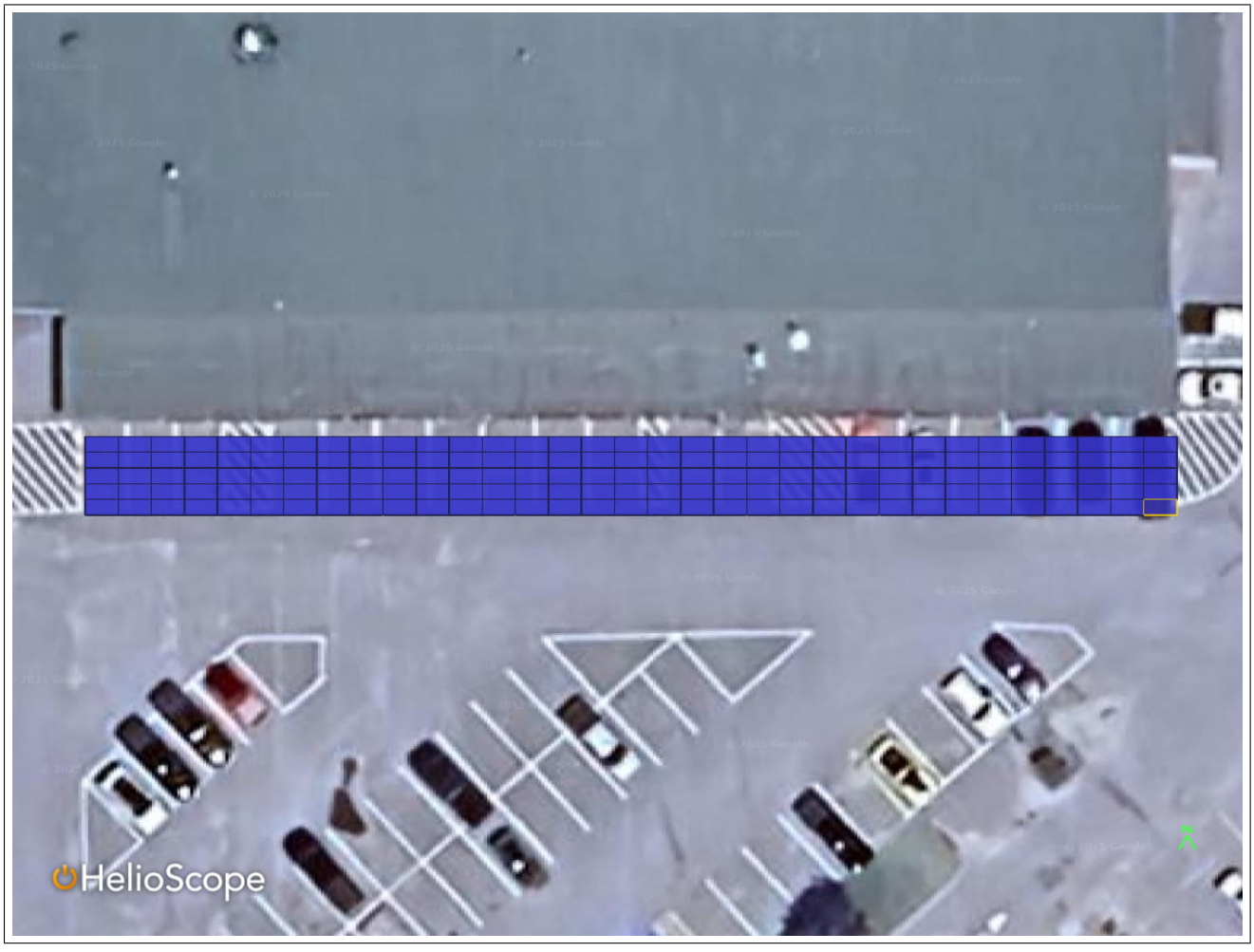
Utility-savings mechanism

The solar PV system will reduce the electricity use from the grid, GHG emissions, and utility costs.

Design description

Helioscope overview

Helioscope was used to determine a preliminary design concept for the proposed solar PV system depicted in the following image.



Based on the results from the Helioscope model, the proposed solar PV system was assumed to have the following output capacity.

- Total system output capacity (DC) = 70 kW.

Proposed scope

Supply and install a canopy solar PV electricity generation system, including the following.

- Solar PV modules.
- Parking lot canopy structures for mounting the solar panels onto.
- DC to AC inverters.
- Wiring, disconnects, meters, panels and transformers. The AC output from inverters is to be wired into a dedicated solar PV electrical panel before being connected to the main switchboard via a new breaker.
- Connection impact assessment and other requirements to satisfy the utility provider for executing a Net Metering agreement.
- Installation of the above.

Electrical

With the existing system, the main splitter is rated high enough to accommodate the additional 70 kW of solar.

Project cost estimate

Table 50: Project cost estimate (Solar PV canopy)

Category	Line item	Unit	Value
Materials and labour	Solar PV electricity system installed (assuming 70 kW at 3500 $/kW)	[$]	245,000
	Electrical	[$]	7,500
Contingency	Subtotal after Materials and labour	[$]	252,500
	General Contingency (20%)	[$]	50,500
	Design Contingency (10%)	[$]	25,200
Total	Total	[$]	328,200

Utility analysis

Utility analysis methodology

The following assumptions were applied to the calibrated energy model to estimate utility use impacts.

- **Baseline**. There is no solar PV present at this site.
- **Proposed**. The proposed solar PV electricity generation system described above was assumed to be implemented. Helioscope was used to model the hourly electricity output from the solar PV system. All electricity generated by the system was assumed to be used on-site, directly reducing grid electricity consumption, GHG emissions and utility costs.

Utility analysis results

Table 51: Solar PV canopy analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	383,773	317,931	65,842	17.2
	Natural gas use	[m3/yr]	64,579	64,579	0	0
	Carbon offset use	[tCO2e/yr]	0	0	0	—
Equivalent energy use	Electricity energy	[kWh/yr]	383,773	317,931	65,842	17.2
	Natural gas energy	[kWh/yr]	681,741	681,741	0	0
	Total energy	[kWh/yr]	1,065,515	999,673	65,842	6.2
GHG emissions	Electricity GHGs	[tCO2e/yr]	9.2	7.6	1.6	17.4
	Natural gas GHGs	[tCO2e/yr]	125	125	0	0
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	—
	Total GHGs	[tCO2e/yr]	134	132	1.6	1.2
Utility cost	Electricity utility cost	[$/yr]	50,391	43,683	6,708	13.3
	Natural gas utility cost	[$/yr]	16,791	16,791	0	0
	Carbon offsets utility cost	[$/yr]	0	0	0	—
	Federal carbon charge	[$/yr]	6,240	6,240	0	0
	Total utility cost	[$/yr]	73,421	66,714	6,708	9.1
Financial	Assumed life	[yrs]	15	30	—	—
	Project cost	[$]	0	328,200	—	—
	Incentive amount	[$]	0	65,640	—	—
	Incremental project cost	[$]	0	262,560	—	—
	Life cycle cost	[$]	1,550,214	1,591,250	—	—
	Net present value	[$]	0	-41,036	—	—
	Project cost per GHG reduction	[$yr/tCO2e]	—	164,100	—	—
	Simple payback period	[yr]	—	>20	—	—

5.18 Solar PV rooftop

Measure description

Existing condition

There is no solar PV on the roof. Some rooftop space is available.

Opportunity

Install a solar PV system on the remaining roof where feasible. A net-metering agreement is recommended so that the reduced GHG emissions associated with the electricity generated by the system can be retained by the City of Temiskaming Shores or exported to the grid if on-site electricity consumption is fulfilled.

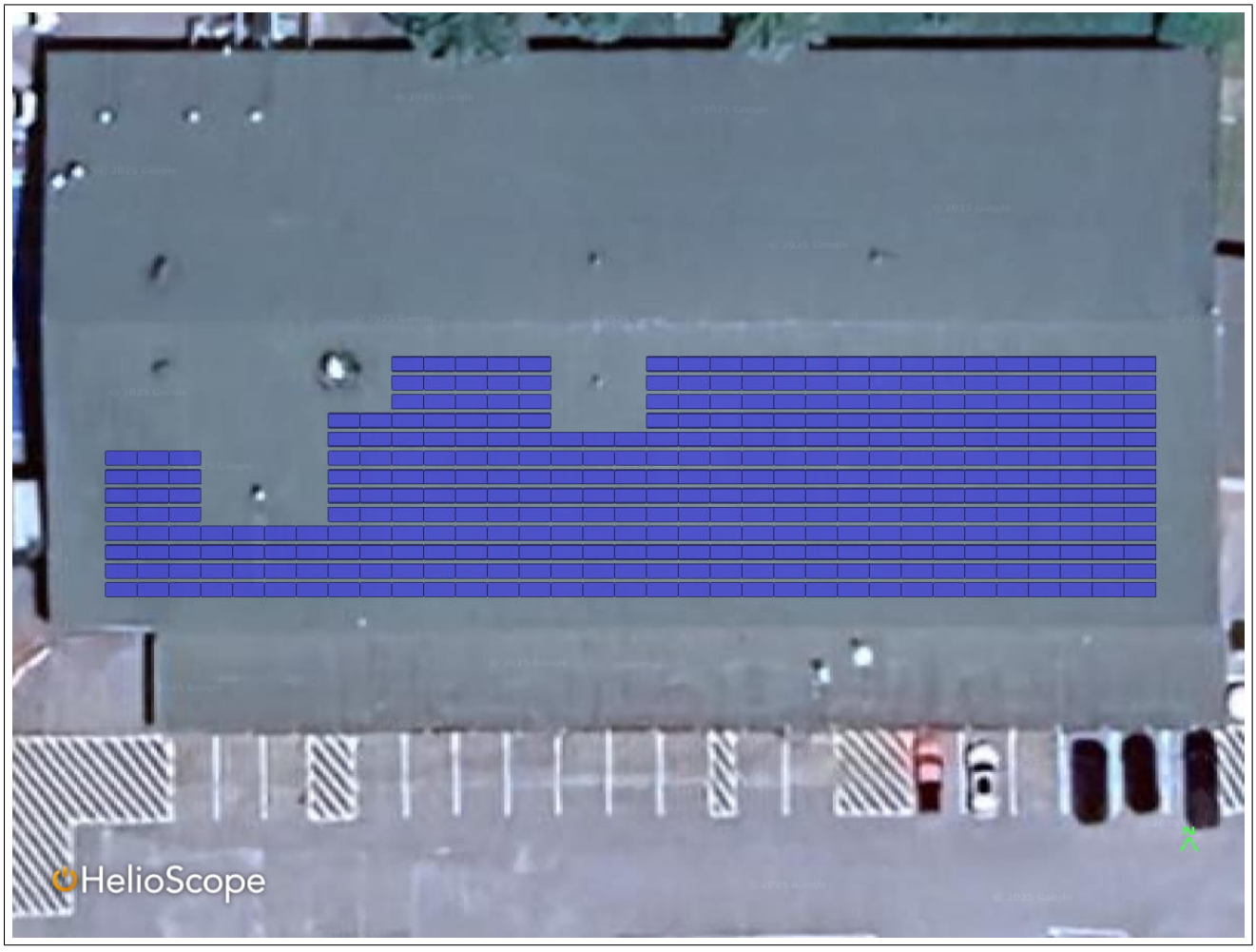
Utility-savings mechanism

The solar PV system will reduce the electricity use from the grid, GHG emissions, and utility costs.

Design description

Helioscope overview

Helioscope was used to determine a preliminary design concept for the proposed solar PV system. The Helioscope model is depicted in the following image.



Based on the results from the Helioscope model, the proposed solar PV system was assumed to have the following output capacity.

- Total system output capacity (DC) = 153 kW.

Proposed scope

Supply and install a rooftop solar PV electricity generation system, including the following.

- Solar PV modules.
- Racking system for mounting the solar panels onto.
- DC to AC inverters.
- Wiring, disconnects, meters, panels and transformers. The AC output from inverters is to be wired into a dedicated solar PV electrical panel before being connected to the main switchboard via a new breaker.
- Connection impact assessment and other requirements to satisfy the utility provider for executing a Net Metering agreement.
- Installation of the above.

Electrical

With the existing system, the main splitter is rated high enough to accommodate the additional 153 kW of solar.

Project cost estimate

Table 52: Project cost estimate (Solar PV rooftop)

Category	Line item	Unit	Value
Materials and labour	Solar PV electricity system installed (assuming 153 kW at 2000 $/kW)	[$]	306,000
	Electrical	[$]	7,500
Contingency	Subtotal after Materials and labour	[$]	313,500
	General Contingency (20%)	[$]	62,700
	Design Contingency (10%)	[$]	31,400
Total	Total	[$]	407,600

Utility analysis

Utility analysis methodology

The following assumptions were applied to the calibrated energy model to estimate utility use impacts.

- **Baseline**. There is no solar PV present at this site.
- **Proposed**. The proposed solar PV electricity generation system described above was assumed to be implemented. Helioscope was used to model the hourly electricity output from the solar PV system. All electricity generated by the system was assumed to be used on-site, directly reducing grid electricity consumption, GHG emissions and utility costs.

Utility analysis results

Table 53: Solar PV rooftop analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	383,773	224,304	159,469	41.6
	Natural gas use	[m3/yr]	64,579	64,579	0	0
	Carbon offset use	[tCO2e/yr]	0	0	0	—
Equivalent energy use	Electricity energy	[kWh/yr]	383,773	224,304	159,469	41.6
	Natural gas energy	[kWh/yr]	681,741	681,741	0	0
	Total energy	[kWh/yr]	1,065,515	906,045	159,469	15.0
GHG emissions	Electricity GHGs	[tCO2e/yr]	9.2	5.4	3.8	41.3
	Natural gas GHGs	[tCO2e/yr]	125	125	0	0
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	—
	Total GHGs	[tCO2e/yr]	134	130	3.8	2.8
Utility cost	Electricity utility cost	[$/yr]	50,391	34,387	16,004	31.8
	Natural gas utility cost	[$/yr]	16,791	16,791	0	0
	Carbon offsets utility cost	[$/yr]	0	0	0	—
	Federal carbon charge	[$/yr]	6,240	6,240	0	0
	Total utility cost	[$/yr]	73,421	57,417	16,004	21.8
Financial	Assumed life	[yrs]	15	30	—	—
	Project cost	[$]	0	407,600	—	—
	Incentive amount	[$]	0	81,520	—	—
	Incremental project cost	[$]	0	326,080	—	—
	Life cycle cost	[$]	1,550,214	1,398,780	—	—
	Net present value	[$]	0	151,434	—	—
	Project cost per GHG reduction	[$yr/tCO2e]	—	85,811	—	—
	Simple payback period	[yr]	—	>20	—	—

5.19 UH02 to electric

Measure description

Existing condition

UH02 is a natural gas-fired unit heater serving the bleachers.

Opportunity

Replace the natural gas unit heater with electric radiant tubes.

Utility-savings mechanism

The primary intent of this measure is to reduce GHG emissions by converting the fuel used for heating from natural gas to electricity due to electricity having a lower GHG intensity than natural gas. Reduced natural gas use and increased electricity use would be expected as a result.

Design description

Overview

Remove the ceiling-hung, gas-fired unit heaters currently serving the arena spectators and provide electric replacements. To match the existing service area of the gas-fired units, six ceiling-hung 4.5 kW electric units will be required and located accordingly. The new unit controls are to be implemented using a combination of occupancy and motion detection, along with manual enablement. Electrical upgrades may be required to accommodate the new units.

Electrical

This measure will add approximately 27 kW of power to the existing system, bringing the total to 183.36 kW, which is approximately 55% of the building's full electrical capacity. A new 200 A, 600 V branch panel will need to be required from the main splitter to provide enough breaker space for each of the units.

Project cost estimate

Table 54: Project cost estimate (UH02 to electric)

Category	Line item	Unit	Value
Construction	Supply and install	[$]	36,000
	Electrical service upgrade allotment	[$]	50,000
	General requirements (25%)	[$]	21,500
Contingency	Subtotal after Construction	[$]	107,500
	Design Contingency (25%)	[$]	26,900
	Construction Contingency (10%)	[$]	10,800
Design, Contractors, PM	Subtotal after Contingency	[$]	145,200
	Engineering Design and Field Review (10%)	[$]	14,500
	Contractor Fee (7%)	[$]	10,200
Total	Total	[$]	169,900

Utility analysis

Utility analysis methodology

The following assumptions were applied to the calibrated energy model to estimate utility use impacts.

- **Baseline**. UH02 is a gas-fired unit heater with an average burner thermal efficiency of 82%.
- **Proposed**. UH02 is replaced with electric radiant, with an efficiency of 100%.

Utility analysis results

Table 55: UH02 to electric analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	383,773	399,714	-15,940	-4.2
	Natural gas use	[m3/yr]	64,579	62,630	1,949	3.0
	Carbon offset use	[tCO2e/yr]	0	0	0	—
Equivalent energy use	Electricity energy	[kWh/yr]	383,773	399,714	-15,940	-4.2
	Natural gas energy	[kWh/yr]	681,741	661,168	20,574	3.0
	Total energy	[kWh/yr]	1,065,515	1,060,881	4,634	0.43
GHG emissions	Electricity GHGs	[tCO2e/yr]	9.2	9.6	-0.40	-4.3
	Natural gas GHGs	[tCO2e/yr]	125	121	3.8	3.0
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	—
	Total GHGs	[tCO2e/yr]	134	131	3.4	2.5
Utility cost	Electricity utility cost	[$/yr]	50,391	53,844	-3,453	-6.9
	Natural gas utility cost	[$/yr]	16,791	16,284	507	3.0
	Carbon offsets utility cost	[$/yr]	0	0	0	—
	Federal carbon charge	[$/yr]	6,240	6,050	190	3.0
	Total utility cost	[$/yr]	73,421	76,178	-2,756	-3.8
Financial	Assumed life	[yrs]	15	15	—	—
	Project cost	[$]	0	169,900	—	—
	Incentive amount	[$]	0	33,980	—	—
	Incremental project cost	[$]	0	135,920	—	—
	Life cycle cost	[$]	1,550,214	1,749,966	—	—
	Net present value	[$]	0	-199,752	—	—
	Project cost per GHG reduction	[$yr/tCO2e]	—	39,976	—	—
	Simple payback period	[yr]	—	—	—	—

5.20 UH04 to electric

Measure description

Existing condition

UH04 is a natural gas-fired unit heater serving the gymnastics club.

Opportunity

Replace the natural gas unit heater with a mini-split system to serve as the first stage of heating and an electric resistance unit heater as the second stage of heating.

Utility-savings mechanism

The primary intent of this measure is to reduce GHG emissions by converting the fuel used for heating from natural gas to electricity due to electricity having a lower GHG intensity than natural gas. Reduced natural gas use and increased electricity use would be expected as a result.

Design description

Overview

Replace the natural gas unit heater with two 3-ton ductless mini-split with indoor units mounted along the west wall. Remove the existing natural gas unit heater and replace it with a pair of 20kW electric unit heaters set to operate as second-stage heating to the heat pumps.

Electrical

This measure will add approximately 49 kW of power to the existing system, bringing the total to 205.36 kW, which is approximately 62% of the building's full electrical capacity. A new 200 A, 600 V branch panel will need to be required from the main splitter to provide enough breaker space for each of the units.

Project cost estimate

Table 56: Project cost estimate (UH04 to electric)

Category	Line item	Unit	Value
Construction	Unit heater supply	[$]	25,000
	Installation of mini-split and unit heaters	[$]	25,000
	Electrical service upgrade allotment	[$]	30,000
	General requirements (25%)	[$]	20,000
Contingency	Subtotal after Construction	[$]	100,000
	Design Contingency (25%)	[$]	25,000
	Construction Contingency (10%)	[$]	10,000
Design, Contractors, PM	Subtotal after Contingency	[$]	135,000
	Engineering Design and Field Review (10%)	[$]	13,500
	Contractor Fee (7%)	[$]	9,400
Total	Total	[$]	157,900

Utility analysis

Utility analysis methodology

The following assumptions were applied to the calibrated energy model to estimate utility use impacts.

- **Baseline**. Unit heater provides natural gas space heating to service the gymnastics club. The average burner thermal efficiency is 83%.
- **Proposed**. Primary heating is provided from a mini-split with a COP of 2.8. Backup heating is provided by electric resistance, with an efficiency of 100%.

Utility analysis results

Table 57: UH04 to electric analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	383,773	422,704	-38,931	-10.1
	Natural gas use	[m3/yr]	64,579	49,385	15,194	23.5
	Carbon offset use	[tCO2e/yr]	0	0	0	—
Equivalent energy use	Electricity energy	[kWh/yr]	383,773	422,704	-38,931	-10.1
	Natural gas energy	[kWh/yr]	681,741	521,340	160,401	23.5
	Total energy	[kWh/yr]	1,065,515	944,045	121,470	11.4
GHG emissions	Electricity GHGs	[tCO2e/yr]	9.2	10	-0.80	-8.7
	Natural gas GHGs	[tCO2e/yr]	125	95	29.8	23.9
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	—
	Total GHGs	[tCO2e/yr]	134	105	29	21.6
Utility cost	Electricity utility cost	[$/yr]	50,391	55,362	-4,971	-9.9
	Natural gas utility cost	[$/yr]	16,791	12,840	3,950	23.5
	Carbon offsets utility cost	[$/yr]	0	0	0	—
	Federal carbon charge	[$/yr]	6,240	4,750	1,490	23.9
	Total utility cost	[$/yr]	73,421	72,952	469	0.64
Financial	Assumed life	[yrs]	15	15	—	—
	Project cost	[$]	0	157,900	—	—
	Incentive amount	[$]	0	31,580	—	—
	Incremental project cost	[$]	0	126,320	—	—
	Life cycle cost	[$]	1,550,214	1,733,968	—	—
	Net present value	[$]	0	-183,753	—	—
	Project cost per GHG reduction	[$yr/tCO2e]	—	4,356	—	—
	Simple payback period	[yr]	—	>20	—	—

5.21 Wall upgrade to high performance

Measure description

Existing condition

The exterior walls comprised either an outer layer of architectural concrete block or metal siding. The addition shows three inches of rigid insulation between the concrete block and architectural concrete block. It's assumed that the original building has two inches of rigid insulation.

Opportunity

Upgrade upon the end of useful life or as required to meet scenario criteria.

Utility-savings mechanism

Reduced heating energy use through improved thermal performance of exterior walls.

Design description

Overview

The existing wall performance is unknown; however, if there is no insulation inside the concrete block exterior, the thermal performance is less than R10, which is considerably lower than the current building code requires (R20). To improve it, an EIFS (insulated stucco) system would need to be applied to the face of the existing block.

The EIFS system could provide almost R30 if applied directly to the block, with its air barrier included in the system that could then be tied to the new barrier on the roof. The projecting glulam beams should be clad, and the joints between them and the wall should be sealed to prevent thermal bridging and air leakage. The EIFS system can be supplied with a masonry veneer finish if desired; however, the block would need to be assessed to determine if it can handle the additional weight. Typically, adding an additional 150mm of EIFS with an acrylic stucco finish to an existing brick or block structure does not present structural issues concerning the brick ties.

If the decision is made not to add insulation to the exterior walls, we recommend conducting thermal imaging and blower door testing to identify any significant air leaks or thermal bridging. These issues can be addressed locally using sealants and spray foam.

Project cost estimate

Table 58: Project cost estimate (Wall upgrade to high performance)

Category	Line item	Unit	Value
Construction	Add EIFS system to existing exterior wall	[$]	872,000
	General requirements (25%)	[$]	218,000
Contingency	Subtotal after Construction	[$]	1,090,000
	Design Contingency (25%)	[$]	272,500
	Construction Contingency (10%)	[$]	109,000
Design, Contractors, PM	Subtotal after Contingency	[$]	1,471,500
	Engineering Design and Field Review (10%)	[$]	147,200
	Contractor Fee (7%)	[$]	103,000
Total	Total	[$]	1,721,700

Utility analysis

Utility analysis methodology

The following assumptions were applied to the calibrated energy model to estimate utility use impacts.

- **Baseline**. An average wall U-value of 0.5679 BTU/hr.ft2.F (R10) was assumed for the original, and an average wall U-value of 0.3786 BTU/hr.ft2.F (R15) was assumed for the addition.
- **Proposed**. An average wall U-value of 0.5679 BTU/hr.ft2.F (R40) was assumed for the original, and an average wall U-value of 0.3786 BTU/hr.ft2.F (R45) was assumed for the addition.

Utility analysis results

Table 59: Wall upgrade to high performance analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	383,773	384,461	-687	-0.18
	Natural gas use	[m3/yr]	64,579	57,010	7,568	11.7
	Carbon offset use	[tCO2e/yr]	0	0	0	—
Equivalent energy use	Electricity energy	[kWh/yr]	383,773	384,461	-687	-0.18
	Natural gas energy	[kWh/yr]	681,741	601,843	79,898	11.7
	Total energy	[kWh/yr]	1,065,515	986,304	79,211	7.4
GHG emissions	Electricity GHGs	[tCO2e/yr]	9.2	9.2	0	0
	Natural gas GHGs	[tCO2e/yr]	125	110	14.6	11.7
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	—
	Total GHGs	[tCO2e/yr]	134	119	14.6	10.9
Utility cost	Electricity utility cost	[$/yr]	50,391	50,425	-33.8	-0.07
	Natural gas utility cost	[$/yr]	16,791	14,823	1,968	11.7
	Carbon offsets utility cost	[$/yr]	0	0	0	—
	Federal carbon charge	[$/yr]	6,240	5,510	730	11.7
	Total utility cost	[$/yr]	73,421	70,757	2,664	3.6
Financial	Assumed life	[yrs]	15	75	—	—
	Project cost	[$]	0	1,721,700	—	—
	Incentive amount	[$]	0	344,340	—	—
	Incremental project cost	[$]	0	1,377,360	—	—
	Life cycle cost	[$]	1,550,214	1,961,410	—	—
	Net present value	[$]	0	-411,196	—	—
	Project cost per GHG reduction	[$yr/tCO2e]	—	94,340	—	—
	Simple payback period	[yr]	—	>20	—	—

5.22 Windows and doors to high performance

Measure description

Existing condition

Most windows are double-pane aluminum windows. The facility has hollow metal and overhead doors.

Opportunity

Upgrade upon the end of useful life or as required to meet scenario criteria.

Utility-savings mechanism

Reduced heating energy use through improved thermal performance of windows and doors.

Design description

Windows

We recommend replacing all windows with Passive House Certified Triple-glazed, thermally broken windows. These could be framed in aluminum, vinyl or fibreglass. This will improve the thermal performance of the windows, which comprise a significant portion of the building envelope, from approximately R2 or R3 to at least R7 or R8.

Doors

Doors are a significant source of heat loss and air infiltration. To minimize their impact, we recommend the following measures:

- **Hollow Metal Doors:** Replace existing hollow metal doors with insulated doors in thermally broken frames.
- **Overhead Doors:** Replace the existing overhead doors with high-performance sectional insulated roll-up doors that use systems with polyurethane cores and a full perimeter seal.

Project cost estimate

Table 60: Project cost estimate (Windows and doors to high performance)

Category	Line item	Unit	Value
Construction	Window and door replacement	[$]	157,000
	General requirements (25%)	[$]	39,200
Contingency	Subtotal after Construction	[$]	196,200
	Design Contingency (25%)	[$]	49,000
	Construction Contingency (10%)	[$]	19,600
Design, Contractors, PM	Subtotal after Contingency	[$]	264,800
	Engineering Design and Field Review (10%)	[$]	26,500
	Contractor Fee (7%)	[$]	18,500
Total	Total	[$]	309,800

Utility analysis

Utility analysis methodology

The following assumptions were applied to the calibrated energy model to estimate utility use impacts.

- **Baseline**. The average U-value of all windows and doors was assumed to be 0.667 BTU/hr.ft2.F and 0.5 BTU/hr.ft2.F, respectively.
- **Proposed**. The average U-value of all windows and doors was assumed to be 0.125 BTU/hr.ft2.F (R8). Infiltration flow was assumed to be reduced by 10% in total relative to the Baseline for affected spaces.

Utility analysis results

Table 61: Windows and doors to high performance analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	383,773	383,278	495	0.13
	Natural gas use	[m3/yr]	64,579	61,001	3,578	5.5
	Carbon offset use	[tCO2e/yr]	0	0	0	–
Equivalent energy use	Electricity energy	[kWh/yr]	383,773	383,278	495	0.13
	Natural gas energy	[kWh/yr]	681,741	643,970	37,772	5.5
	Total energy	[kWh/yr]	1,065,515	1,027,248	38,267	3.6
GHG emissions	Electricity GHGs	[tCO2e/yr]	9.2	9.2	0	0
	Natural gas GHGs	[tCO2e/yr]	125	118	6.9	5.5
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	–
	Total GHGs	[tCO2e/yr]	134	127	6.9	5.1
Utility cost	Electricity utility cost	[$/yr]	50,391	50,321	69.8	0.14
	Natural gas utility cost	[$/yr]	16,791	15,860	930	5.5
	Carbon offsets utility cost	[$/yr]	0	0	0	–
	Federal carbon charge	[$/yr]	6,240	5,895	345	5.5
	Total utility cost	[$/yr]	73,421	72,076	1,345	1.8
Financial	Assumed life	[yrs]	15	40	–	–
	Project cost	[$]	0	309,800	–	–
	Incentive amount	[$]	0	61,960	–	–
	Incremental project cost	[$]	0	247,840	–	–
	Life cycle cost	[$]	1,550,214	1,682,098	–	–
	Net present value	[$]	0	-131,884	–	–
	Project cost per GHG reduction	[$yr/tCO2e]	–	35,919	–	–
	Simple payback period	[yr]	–	>20	–	–

5.23 Measure risk analysis

Utility use sensitivity

Figure 174 indicates how sensitive cumulative electricity and natural gas use are to variations in each risk parameter.

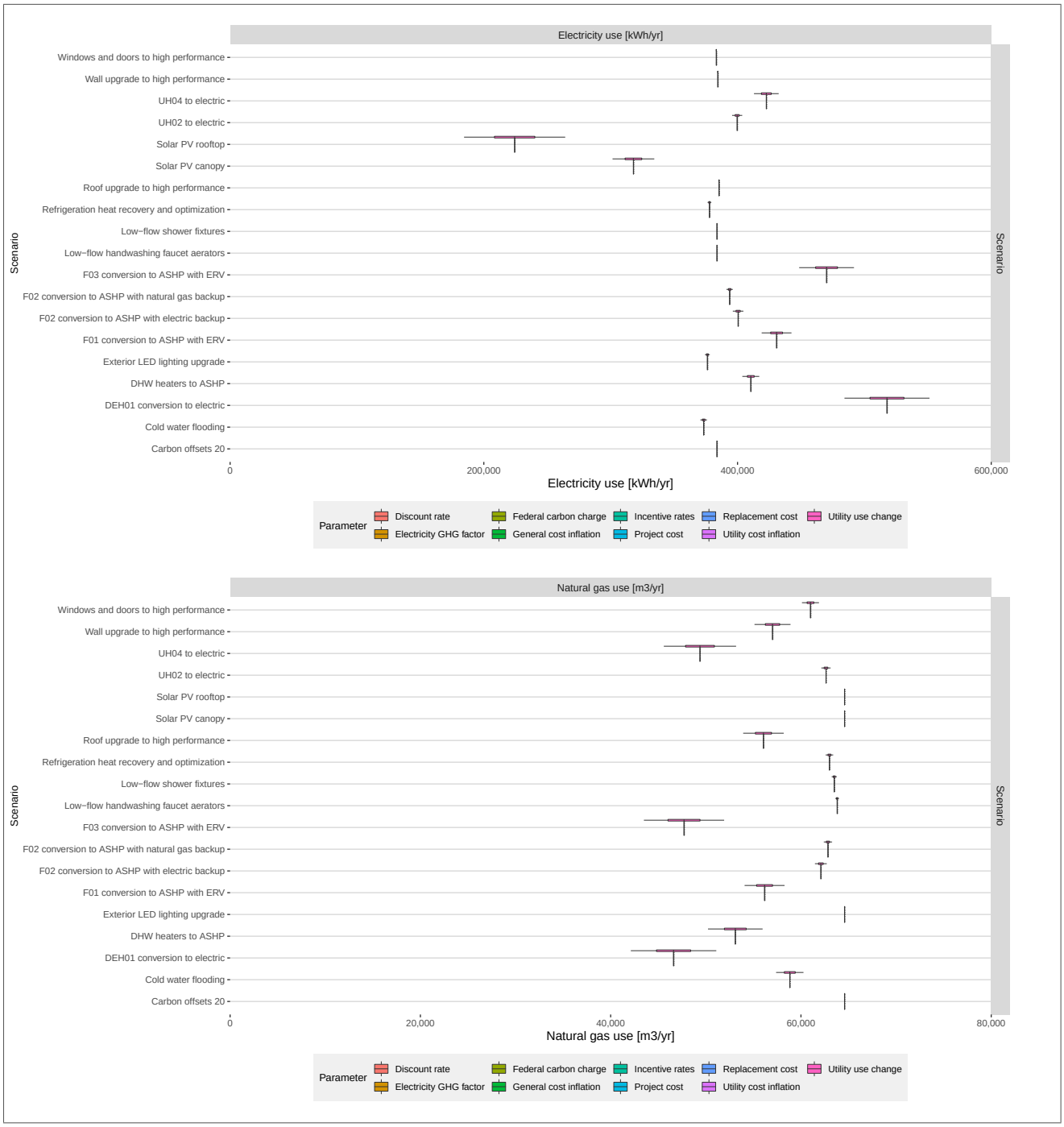


Figure 174: Utility cumulative use sensitivity analysis

GHG emissions and life cycle cost sensitivity

Figure 175 indicates how sensitive cumulative GHG emissions and life cycle costs are to variations in each risk parameter.

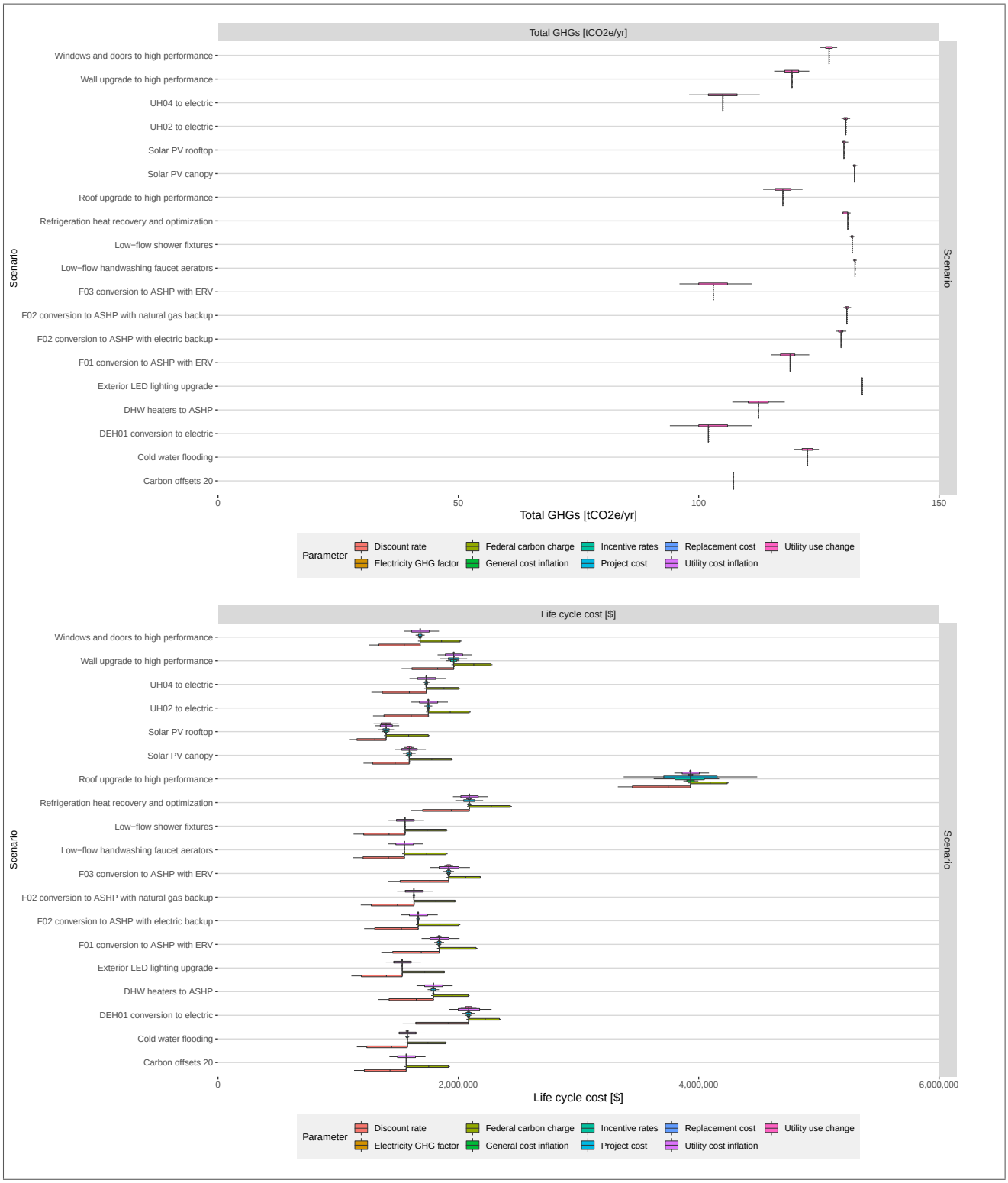


Figure 175: GHG cumulative emissions and life cycle cost sensitivity analysis

5.24 Measure analysis summary

For each analyzed measure, the analysis results are summarized in Table 62.

Table 62: Measure analysis summary

Measure ID	Utility use				Equivalent energy use		GHG emissions		Utility cost		Financial							
Measure name	**Electricity use reduction**	**Electricity use reduction**	**Natural gas use reduction**	**Natural gas use reduction**	**Total energy reduction**	**Total energy reduction**	**Total GHG reduction**	**Total GHG reduction**	**Utility cost reduction**	**Utility cost reduction**	**Assumed life**	**Project cost**	**Incentive amount**	**Incremental project cost**	**Life cycle cost**	**Net present value**	**Project cost per GHG reduction**	**Simple payback period**
-	[kWh/yr]	[%]	[m3/yr]	[%]	[kWh/yr]	[%]	[tCO2e/yr]	[%]	[$/yr]	[%]	[yrs]	[$]	[$]	[$]	[$]	[$]	[$yr/tCO2e]	[yr]
Baseline	383,773	100.0	64,579	100.0	1,065,515	100.0	134	100.0	73,421	100.0	15	0	0	0	1,550,214	0	-	-
Carbon offsets 20	0	0.0	0	0.0	0	0.0	27	20.0	-804	-1.1	20	-	0	-	1,565,712	-15,498	-	-
Cold water flooding	10,451	2.7	5,752	8.9	71,178	6.7	11	8.5	3,367	4.6	15	67,500	0	67,500	1,574,897	-24,683	5,921	20
DEH01 conversion to electric	-134,035	-34.9	17,969	27.8	55,662	5.2	32	23.9	-17,205	-23.4	15	276,400	55,280	221,120	2,085,219	-535,005	6,910	-13
DHW heaters to ASHP	-26,681	-7.0	11,478	17.8	94,489	8.9	22	16.1	1,000	1.4	15	195,000	2,870	192,130	1,791,734	-241,519	8,895	192
Exterior LED lighting upgrade	7,524	2.0	0	0.0	7,524	0.7	0	0.0	862	1.2	20	1,700	0	1,700	1,532,381	17,834	-	2
F01 conversion to ASHP with ERV	-47,007	-12.2	8,402	13.0	41,690	3.9	15	11.2	-2,962	-4.0	15	211,300	42,260	169,040	1,840,541	-290,327	11,269	-57
F02 conversion to ASHP with electric backup	-16,684	-4.3	2,487	3.9	9,569	0.9	4	3.3	-1,214	-1.7	15	85,000	17,000	68,000	1,665,526	-115,311	15,455	-56
F02 conversion to ASHP with natural gas backup	-10,010	-2.6	1,742	2.7	8,377	0.8	3	2.4	-508	-0.7	15	63,200	12,640	50,560	1,630,230	-80,016	15,800	-99
F03 conversion to ASHP with ERV	-86,419	-22.5	16,869	26.1	91,664	8.6	31	23.1	-4,798	-6.5	15	229,000	45,800	183,200	1,919,730	-369,516	5,910	-38
Low-flow handwashing faucet aerators	0	0.0	772	1.2	8,148	0.8	2	1.1	276	0.4	15	3,700	193	3,507	1,550,665	-450	2,338	13
Low-flow shower fixtures	0	0.0	1,080	1.7	11,399	1.1	2	1.6	386	0.5	15	9,700	270	9,430	1,556,187	-5,972	4,491	24
Refrigeration heat recovery and optimization	5,893	1.5	1,586	2.5	22,641	2.1	3	2.2	1,287	1.8	15	477,000	0	477,000	2,090,556	-540,342	159,000	371
Roof upgrade to high performance	-1,631	-0.4	8,520	13.2	88,317	8.3	16	12.3	2,869	3.9	20	2,860,800	572,160	2,288,640	3,931,062	-2,380,848	138,705	798
Solar PV canopy	65,842	17.2	0	0.0	65,842	6.2	2	1.2	6,708	9.1	30	328,200	65,640	262,560	1,591,250	-41,036	164,100	39
Solar PV rooftop	159,469	41.6	0	0.0	159,469	15.0	4	2.8	16,004	21.8	30	407,600	81,520	326,080	1,398,780	151,434	85,811	20
UH02 to electric	-15,940	-4.2	1,949	3.0	4,634	0.4	3	2.5	-2,756	-3.8	15	169,900	33,980	135,920	1,749,966	-199,752	39,976	-49
UH04 to electric	-38,931	-10.1	15,194	23.5	121,470	11.4	29	21.6	469	0.6	15	157,900	31,580	126,320	1,733,968	-183,753	4,356	269
Wall upgrade to high performance	-687	-0.2	7,568	11.7	79,211	7.4	15	10.9	2,664	3.6	75	1,721,700	344,340	1,377,360	1,961,410	-411,196	94,340	517
Windows and doors to high performance	495	0.1	3,578	5.5	38,267	3.6	7	5.1	1,345	1.8	40	309,800	61,960	247,840	1,682,098	-131,884	35,919	184
Total project cost	-	-	-	-	-	-	-	-	-	-	-	7,575,400	-	-	-	-	-	-
Compressor renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	20	120,000	0	120,000	1,674,946	-124,732	-	-
DEH01 renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	173,000	0	173,000	1,737,665	-187,450	-	-
DHW renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	15	20,000	0	20,000	1,573,835	-23,621	-	-
Exterior lighting renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	20	0	0	0	1,550,214	0	-	-
Exterior walls renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	75	10,000	0	10,000	1,553,452	-3,238	-	-
F01 renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	15	30,000	0	30,000	1,585,646	-35,432	-	-
F02 renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	15	6,000	0	6,000	1,557,301	-7,086	-	-
F03 renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	66,000	0	66,000	1,621,727	-71,513	-	-
Interior lighting renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	20	56,000	0	56,000	1,608,423	-58,208	-	-
Roof renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	20	899,000	0	899,000	2,484,665	-934,450	-	-
Shower renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	7	7,000	0	7,000	1,563,113	-12,898	-	-
Sinks renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	10	27,000	0	27,000	1,589,929	-39,715	-	-
UH02 renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	11,000	0	11,000	1,562,133	-11,919	-	-
UH04 renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	13,000	0	13,000	1,564,300	-14,086	-	-
Windows and doors renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	40	38,000	0	38,000	1,573,286	-23,071	-	-
BAU measure totals	-	-	-	-	-	-	-	-	-	-	-	1,476,000	-	-	-	-	-	-

6 SCENARIO ANALYSIS

6.1 Cluster scenario analysis methodology

A scenario analysis was completed to estimate the costs and benefits expected from implementing various combinations (i.e. scenarios) of the measures that were individually analyzed in Section 5. Whereas in Section 5, each measure was individually analyzed as though implemented by itself, in Section 6, scenarios of multiple measures being implemented together were analyzed, and the interactive effects between measures within each scenario were accounted for. The scenario analysis was completed according to the following methodology.

1. **Cluster scenario objectives**. All scenarios that were analyzed and their objectives were defined as summarized in Table 63.
2. **Cluster scenario composition**. Each scenario was composed by iteratively assigning measures to that scenario to achieve the objectives of that scenario as closely as possible. Results are presented in Section 6.3.
3. **Cluster scenario performance analysis**. Each scenario was analyzed using the energy model to estimate the overall performance that implementing all measures in that scenario would have on utility use, equivalent energy use, GHG emissions, utility costs and several financial performance metrics. Results are presented in Section 6.4.
4. **Cluster scenario analysis discussion**. Results of the scenario analysis were discussed in Section 6.4.

6.2 Cluster scenario objectives

The cluster scenarios that were analyzed and their objectives are summarized in Table 63.

Table 63: Scenario objectives

Scenario	Objectives
Control optimization	To estimate the impact of all control optimization measures combined.
Envelope upgrades	To estimate the impact of all envelope upgrade measures combined.
Load minimization	To estimate the impact of all controls optimization, envelope upgrades, and other measures intended to reduce the thermal and electrical load of the facility, which would ideally reduce the capacity requirements of new equipment.
Comprehensive cluster	To understand the limit of GHG reductions possible by implementing all measures that have the greatest reduction on GHG emissions.

6.3 Cluster scenario composition

In the scenario composition exercise, individual measures were assigned to each scenario in an iterative process to achieve the objectives of that scenario as closely as possible. Figure 176 and Table 64 present the results of this exercise, indicating which measures were assigned to which scenario.

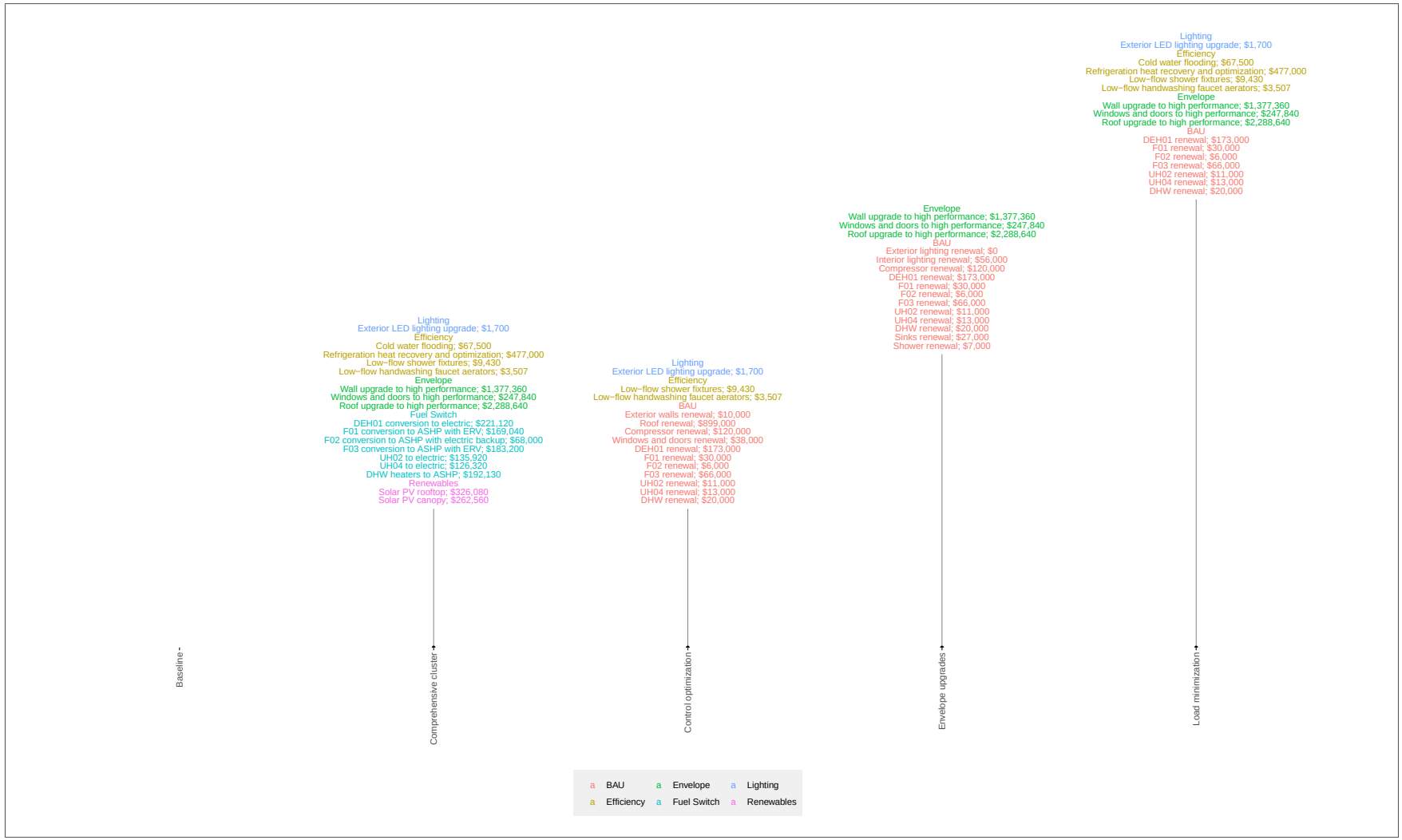


Figure 176: Scenario composition

Table 64: Cluster composition

Measure	Control optimization	Envelope upgrades	Load minimization	Comprehensive cluster
Carbon offsets 20	✖	✖	✖	✖
Cold water flooding	✖	✖	✔	✔
DEH01 conversion to electric	✖	✖	✖	✔
DHW heaters to ASHP	✖	✖	✖	✔
Exterior LED lighting upgrade	✔	✖	✔	✔
F01 conversion to ASHP with ERV	✖	✖	✖	✔
F02 conversion to ASHP with electric backup	✖	✖	✖	✔
F02 conversion to ASHP with natural gas backup	✖	✖	✖	✖
F03 conversion to ASHP with ERV	✖	✖	✖	✔
Low-flow handwashing faucet aerators	✔	✖	✔	✔
Low-flow shower fixtures	✔	✖	✔	✔
Refrigeration heat recovery and optimization	✖	✖	✔	✔
Roof upgrade to high performance	✖	✔	✔	✔
Solar PV canopy	✖	✖	✖	✔
Solar PV rooftop	✖	✖	✖	✔
UH02 to electric	✖	✖	✖	✔
UH04 to electric	✖	✖	✖	✔
Wall upgrade to high performance	✖	✔	✔	✔
Windows and doors to high performance	✖	✔	✔	✔
Compressor renewal	✔	✔	✖	✖
DEH01 renewal	✔	✔	✔	✖
DHW renewal	✔	✔	✔	✖
Exterior lighting renewal	✖	✔	✖	✖
Exterior walls renewal	✔	✖	✖	✖
F01 renewal	✔	✔	✔	✖
F02 renewal	✔	✔	✔	✖
F03 renewal	✔	✔	✔	✖
Interior lighting renewal	✖	✔	✖	✖
Roof renewal	✔	✖	✖	✖
Shower renewal	✖	✔	✖	✖
Sinks renewal	✖	✔	✖	✖
UH02 renewal	✔	✔	✔	✖
UH04 renewal	✔	✔	✔	✖
Windows and doors renewal	✔	✖	✖	✖

6.4 Cluster scenario performance analysis

The scenario performance analysis was completed by using the energy model (see Section 4) to determine the expected performance of implementing all measures in each scenario. Results are presented throughout Section 6.4.

Cluster scenario performance analysis summary

Results of the scenario analysis are summarized in Table 65, which indicates all individual measures that were considered to be implemented under each scenario, the measure-specific impacts that each measure was estimated to have if implemented by itself, and the combined impacts that implementing all measures in each scenario is expected to have, accounting for the interactive effects between measures within each scenario.

Table 65: Scenario analysis summary

Measure ID		Utility use				Equivalent energy use		GHG emissions		Utility cost		Financial							
Scenario	**Measure name**	**Electricity use reduction**	**Electricity use reduction**	**Natural gas use reduction**	**Natural gas use reduction**	**Total energy reduction**	**Total energy reduction**	**Total GHG reduction**	**Total GHG reduction**	**Utility cost reduction**	**Utility cost reduction**	**Assumed life**	**Project cost**	**Incentive amount**	**Incremental project cost**	**Life cycle cost**	**Net present value**	**Project cost per GHG reduction**	**Simple payback period**
-	-	[kWh/yr]	[%]	[m3/yr]	[%]	[kWh/yr]	[%]	[tCO2e/yr]	[%]	[$/yr]	[%]	[yrs]	[$]	[$]	[$]	[$]	[$]	[$yr/tCO2e]	[yr]
Comprehensive cluster	Combined	-15,442	-4.0	63,625	98.5	656,234	61.6	123	91.6	10,693	14.6	-	7,512,200	1,354,852	6,157,348	6,515,915	-4,965,700	50,182	576
Comprehensive cluster	Exterior LED lighting upgrade	7,524	2.0	0	0.0	7,524	0.7	0	0.0	862	1.2	20	1,700	0	1,700	1,532,381	17,834	-	2
Comprehensive cluster	Cold water flooding	10,451	2.7	5,752	8.9	71,178	6.7	11	8.5	3,367	4.6	15	67,500	0	67,500	1,574,897	-24,683	5,921	20
Comprehensive cluster	Wall upgrade to high performance	-687	-0.2	7,568	11.7	79,211	7.4	15	10.9	2,664	3.6	75	1,721,700	344,340	1,377,360	1,961,410	-411,196	94,340	517
Comprehensive cluster	Windows and doors to high performance	495	0.1	3,578	5.5	38,267	3.6	7	5.1	1,345	1.8	40	309,800	61,960	247,840	1,682,098	-131,884	35,919	184
Comprehensive cluster	Roof upgrade to high performance	-1,631	-0.4	8,520	13.2	88,317	8.3	16	12.3	2,869	3.9	20	2,860,800	572,160	2,288,640	3,931,062	-2,380,848	138,705	798
Comprehensive cluster	Refrigeration heat recovery and optimization	5,893	1.5	1,586	2.5	22,641	2.1	3	2.2	1,287	1.8	15	477,000	0	477,000	2,090,556	-540,342	159,000	371
Comprehensive cluster	DEH01 conversion to electric	-134,035	-34.9	17,969	27.8	55,662	5.2	32	23.9	-17,205	-23.4	15	276,400	55,280	221,120	2,085,219	-535,005	6,910	-13
Comprehensive cluster	F01 conversion to ASHP with ERV	-47,007	-12.2	8,402	13.0	41,690	3.9	15	11.2	-2,962	-4.0	15	211,300	42,260	169,040	1,840,541	-290,327	11,269	-57
Comprehensive cluster	F02 conversion to ASHP with electric backup	-16,684	-4.3	2,487	3.9	9,569	0.9	4	3.3	-1,214	-1.7	15	85,000	17,000	68,000	1,665,526	-115,311	15,455	-56
Comprehensive cluster	F03 conversion to ASHP with ERV	-86,419	-22.5	16,869	26.1	91,664	8.6	31	23.1	-4,798	-6.5	15	229,000	45,800	183,200	1,919,730	-369,516	5,910	-38
Comprehensive cluster	UH02 to electric	-15,940	-4.2	1,949	3.0	4,634	0.4	3	2.5	-2,756	-3.8	15	169,900	33,980	135,920	1,749,966	-199,752	39,976	-49
Comprehensive cluster	UH04 to electric	-38,931	-10.1	15,194	23.5	121,470	11.4	29	21.6	469	0.6	15	157,900	31,580	126,320	1,733,968	-183,753	4,356	269
Comprehensive cluster	Solar PV rooftop	159,469	41.6	0	0.0	159,469	15.0	4	2.8	16,004	21.8	30	407,600	81,520	326,080	1,398,780	151,434	85,811	20
Comprehensive cluster	Solar PV canopy	65,842	17.2	0	0.0	65,842	6.2	2	1.2	6,708	9.1	30	328,200	65,640	262,560	1,591,250	-41,036	164,100	39
Comprehensive cluster	DHW heaters to ASHP	-26,681	-7.0	11,478	17.8	94,489	8.9	22	16.1	1,000	1.4	15	195,000	2,870	192,130	1,791,734	-241,519	8,895	192
Comprehensive cluster	Low-flow shower fixtures	0	0.0	1,080	1.7	11,399	1.1	2	1.6	386	0.5	15	9,700	270	9,430	1,556,187	-5,973	4,491	24
Comprehensive cluster	Low-flow handwashing faucet aerators	0	0.0	772	1.2	8,148	0.8	2	1.1	276	0.4	15	3,700	193	3,507	1,550,665	-450	2,338	13
Control optimization	Combined	7,524	2.0	1,852	2.9	27,071	2.5	4	3.0	1,543	2.1	-	1,401,100	463	1,400,637	2,915,438	-1,365,223	350,159	908
Control optimization	Exterior LED lighting upgrade	7,524	2.0	0	0.0	7,524	0.7	0	0.0	862	1.2	20	1,700	0	1,700	1,532,381	17,834	-	2
Control optimization	Low-flow shower fixtures	0	0.0	1,080	1.7	11,399	1.1	2	1.6	386	0.5	15	9,700	270	9,430	1,556,187	-5,973	4,491	24
Control optimization	Low-flow handwashing faucet aerators	0	0.0	772	1.2	8,148	0.8	2	1.1	276	0.4	15	3,700	193	3,507	1,550,665	-450	2,338	13
Control optimization	Exterior walls renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	75	10,000	0	10,000	1,553,452	-3,238	-	-
Control optimization	Roof renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	20	899,000	0	899,000	2,484,665	-934,450	-	-
Control optimization	Compressor renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	20	120,000	0	120,000	1,674,946	-124,732	-	-
Control optimization	Windows and doors renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	40	38,000	0	38,000	1,573,286	-23,071	-	-
Control optimization	DEH01 renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	173,000	0	173,000	1,737,665	-187,450	-	-
Control optimization	F01 renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	15	30,000	0	30,000	1,585,646	-35,432	-	-
Control optimization	F02 renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	15	6,000	0	6,000	1,557,301	-7,086	-	-
Control optimization	F03 renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	66,000	0	66,000	1,621,727	-71,513	-	-
Control optimization	UH02 renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	11,000	0	11,000	1,562,133	-11,919	-	-
Control optimization	UH04 renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	13,000	0	13,000	1,564,300	-14,086	-	-
Control optimization	DHW renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	15	20,000	0	20,000	1,573,835	-23,621	-	-
Envelope upgrades	Combined	-2,003	-0.5	18,464	28.6	192,913	18.1	36	26.6	6,391	8.7	-	5,421,300	978,460	4,442,840	4,899,360	-3,349,146	124,449	695
Envelope upgrades	Wall upgrade to high performance	-687	-0.2	7,568	11.7	79,211	7.4	15	10.9	2,664	3.6	75	1,721,700	344,340	1,377,360	1,961,410	-411,196	94,340	517
Envelope upgrades	Windows and doors to high performance	495	0.1	3,578	5.5	38,267	3.6	7	5.1	1,345	1.8	40	309,800	61,960	247,840	1,682,098	-131,884	35,919	184
Envelope upgrades	Roof upgrade to high performance	-1,631	-0.4	8,520	13.2	88,317	8.3	16	12.3	2,869	3.9	20	2,860,800	572,160	2,288,640	3,931,062	-2,380,848	138,705	798
Envelope upgrades	Exterior lighting renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	20	0	0	0	1,550,214	0	-	-
Envelope upgrades	Interior lighting renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	20	56,000	0	56,000	1,608,423	-58,208	-	-
Envelope upgrades	Compressor renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	20	120,000	0	120,000	1,674,946	-124,732	-	-
Envelope upgrades	DEH01 renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	173,000	0	173,000	1,737,665	-187,450	-	-
Envelope upgrades	F01 renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	15	30,000	0	30,000	1,585,646	-35,432	-	-
Envelope upgrades	F02 renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	15	6,000	0	6,000	1,557,301	-7,086	-	-
Envelope upgrades	F03 renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	66,000	0	66,000	1,621,727	-71,513	-	-
Envelope upgrades	UH02 renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	11,000	0	11,000	1,562,133	-11,919	-	-
Envelope upgrades	UH04 renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	13,000	0	13,000	1,564,300	-14,086	-	-
Envelope upgrades	DHW renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	15	20,000	0	20,000	1,573,835	-23,621	-	-
Envelope upgrades	Sinks renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	10	27,000	0	27,000	1,589,929	-39,715	-	-
Envelope upgrades	Shower renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	7	7,000	0	7,000	1,563,113	-12,898	-	-
Load minimization	Combined	21,439	5.6	27,017	41.8	306,652	28.8	53	39.3	12,293	16.7	-	5,770,900	978,923	4,791,977	5,207,068	-3,656,854	90,929	390
Load minimization	Exterior LED lighting upgrade	7,524	2.0	0	0.0	7,524	0.7	0	0.0	862	1.2	20	1,700	0	1,700	1,532,381	17,834	-	2
Load minimization	Cold water flooding	10,451	2.7	5,752	8.9	71,178	6.7	11	8.5	3,367	4.6	15	67,500	0	67,500	1,574,897	-24,683	5,921	20
Load minimization	Wall upgrade to high performance	-687	-0.2	7,568	11.7	79,211	7.4	15	10.9	2,664	3.6	75	1,721,700	344,340	1,377,360	1,961,410	-411,196	94,340	517
Load minimization	Windows and doors to high performance	495	0.1	3,578	5.5	38,267	3.6	7	5.1	1,345	1.8	40	309,800	61,960	247,840	1,682,098	-131,884	35,919	184
Load minimization	Roof upgrade to high performance	-1,631	-0.4	8,520	13.2	88,317	8.3	16	12.3	2,869	3.9	20	2,860,800	572,160	2,288,640	3,931,062	-2,380,848	138,705	798
Load minimization	Refrigeration heat recovery and optimization	5,893	1.5	1,586	2.5	22,641	2.1	3	2.2	1,287	1.8	15	477,000	0	477,000	2,090,556	-540,342	159,000	371
Load minimization	Low-flow shower fixtures	0	0.0	1,080	1.7	11,399	1.1	2	1.6	386	0.5	15	9,700	270	9,430	1,556,187	-5,973	4,491	24
Load minimization	Low-flow handwashing faucet aerators	0	0.0	772	1.2	8,148	0.8	2	1.1	276	0.4	15	3,700	193	3,507	1,550,665	-450	2,338	13
Load minimization	DEH01 renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	173,000	0	173,000	1,737,665	-187,450	-	-
Load minimization	F01 renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	15	30,000	0	30,000	1,585,646	-35,432	-	-
Load minimization	F02 renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	15	6,000	0	6,000	1,557,301	-7,086	-	-
Load minimization	F03 renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	66,000	0	66,000	1,621,727	-71,513	-	-
Load minimization	UH02 renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	11,000	0	11,000	1,562,133	-11,919	-	-
Load minimization	UH04 renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	13,000	0	13,000	1,564,300	-14,086	-	-
Load minimization	DHW renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	15	20,000	0	20,000	1,573,835	-23,621	-	-

Utility use comparison

The following figures compare the total expected yearly utility use by end use between each scenario.

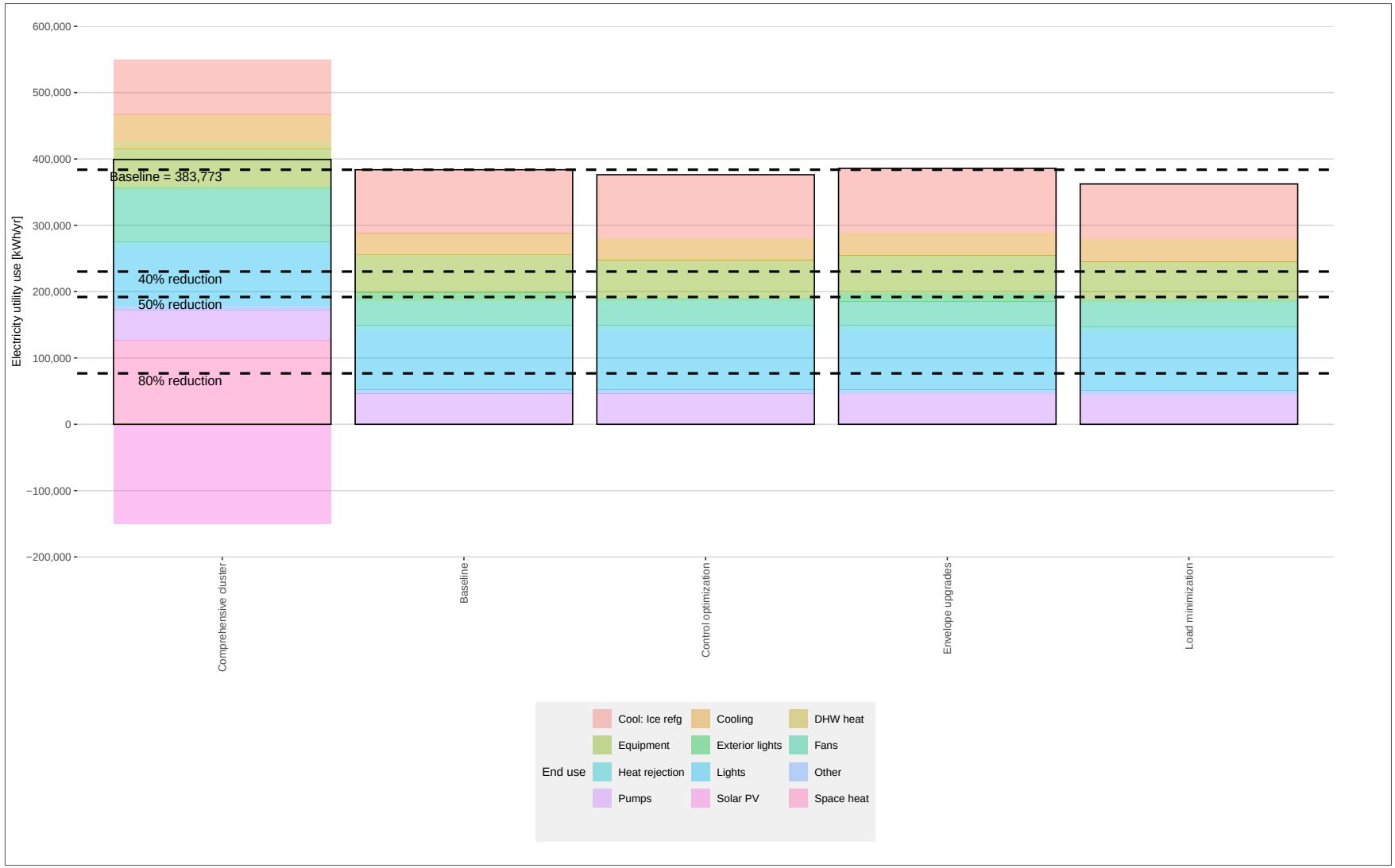


Figure 177: Electricity utility use expected yearly for each scenario by end use

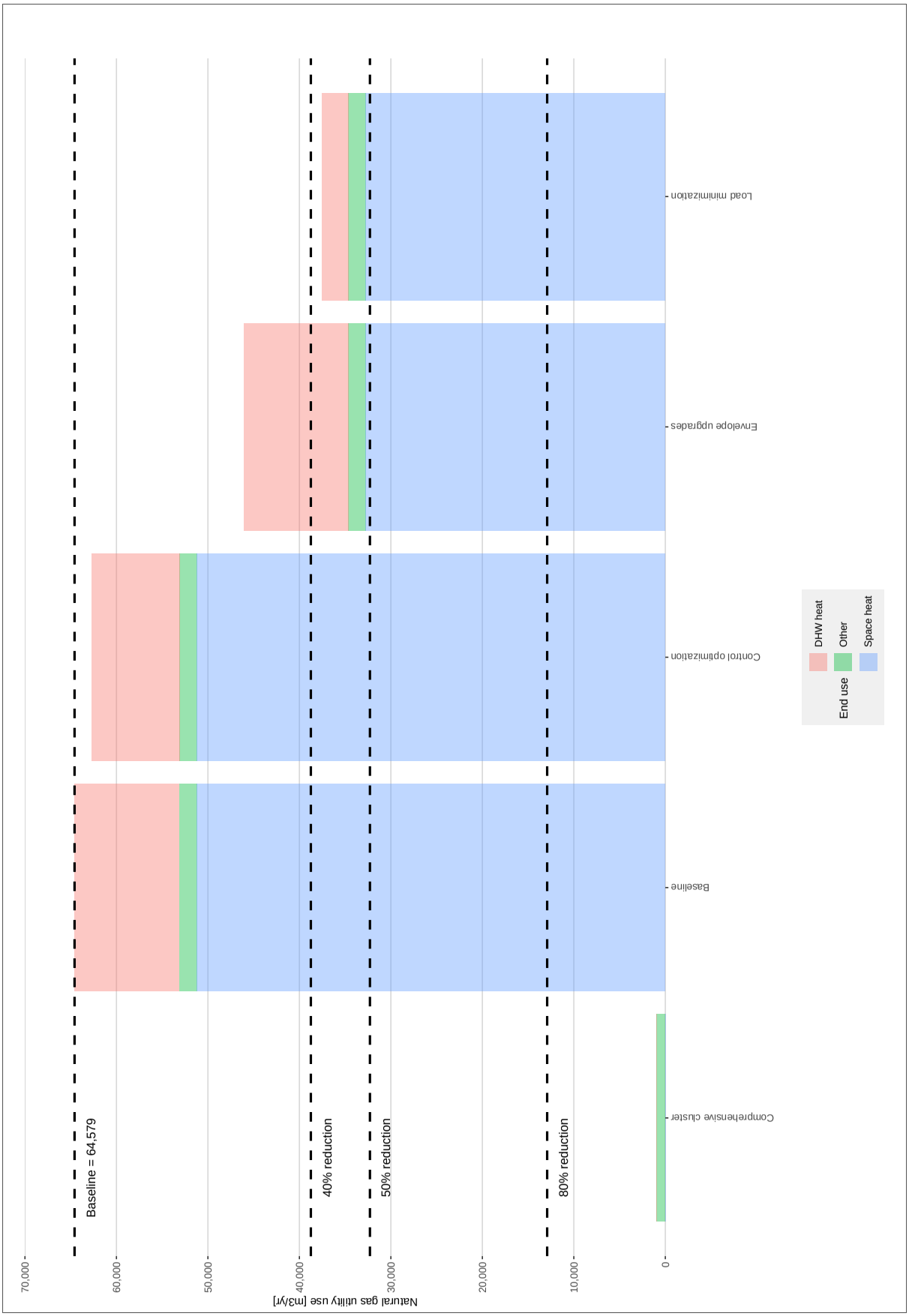


Figure 178: Natural gas utility use expected yearly for each scenario by end use

Energy, GHG and utility cost comparison

The following figures compare the total expected yearly equivalent energy use, GHG emissions and utility costs between each scenario.

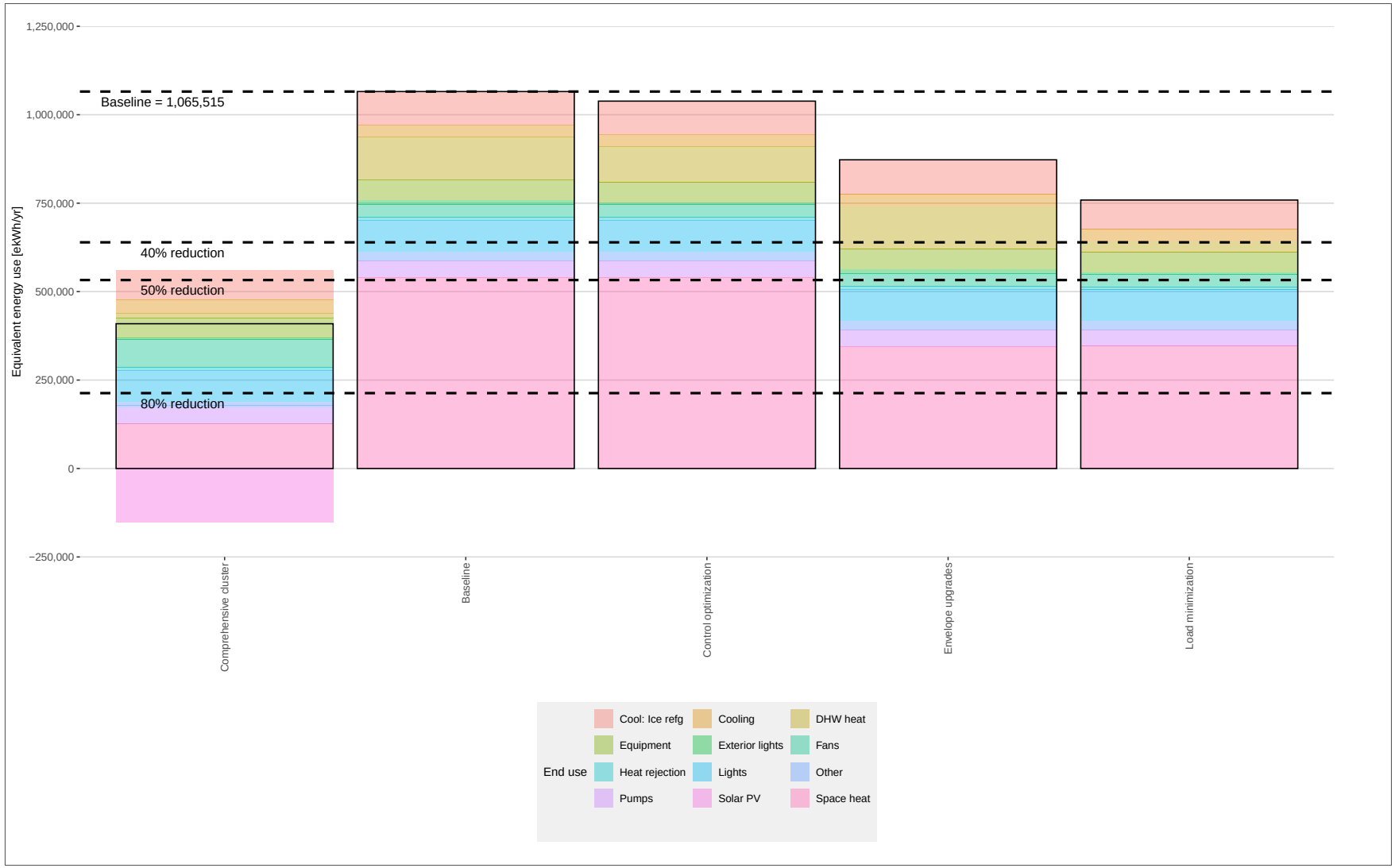


Figure 179: Equivalent energy use expected yearly for each scenario by end use

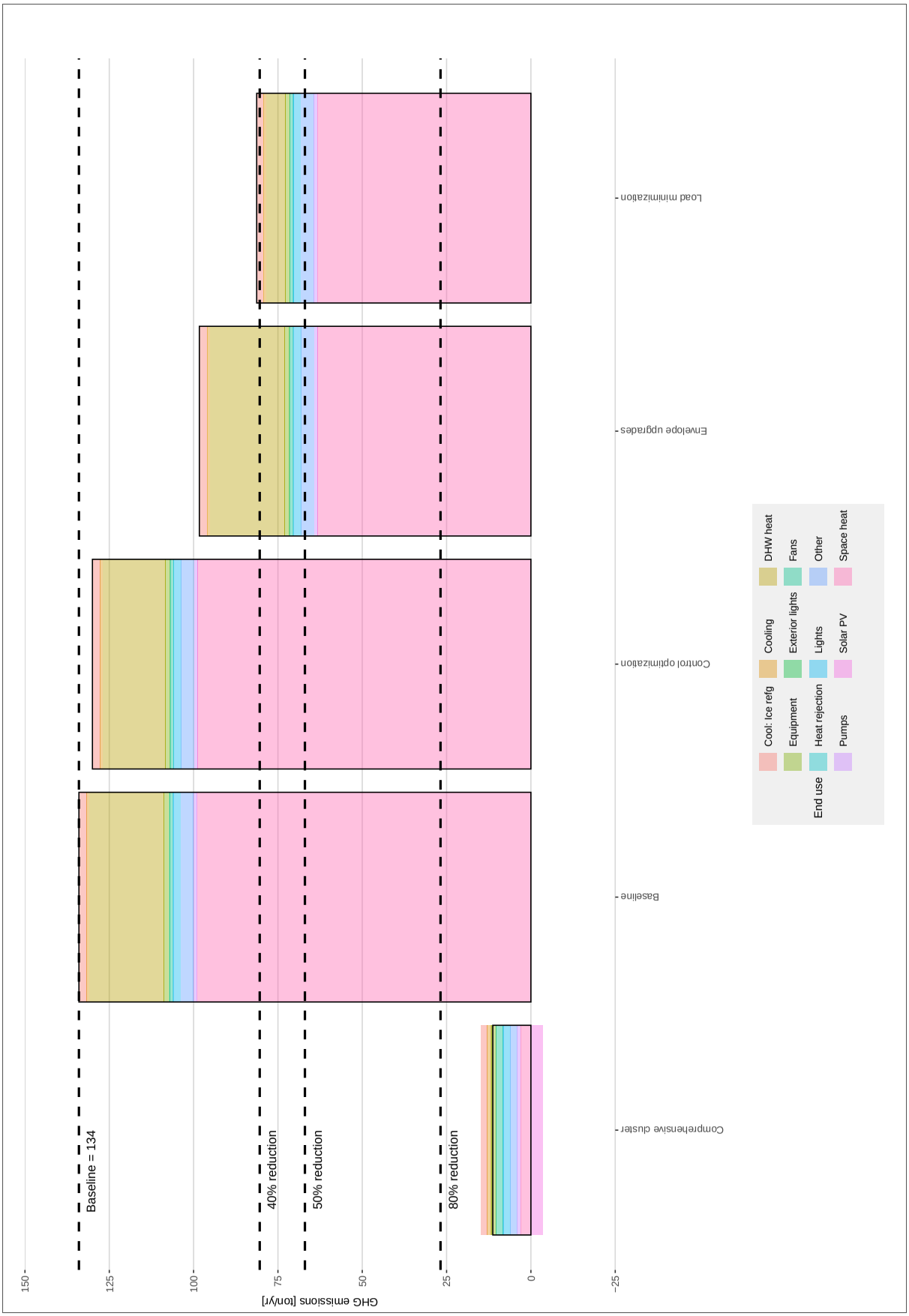


Figure 180: GHG emissions expected yearly for each scenario by end use

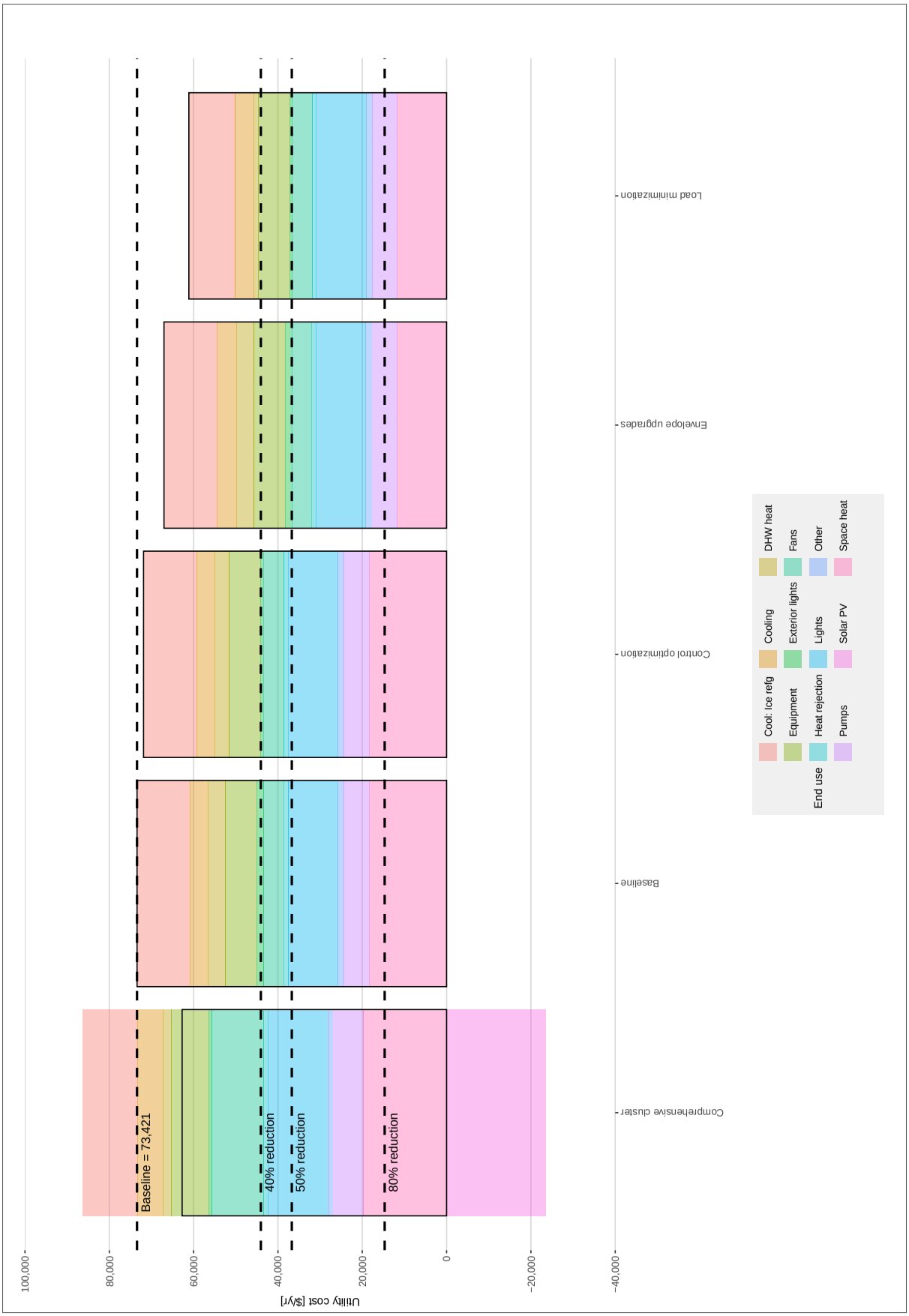


Figure 181: Utility costs expected yearly for each scenario by end use

Financial performance comparison

The following figures compare the financial performance between each scenario.

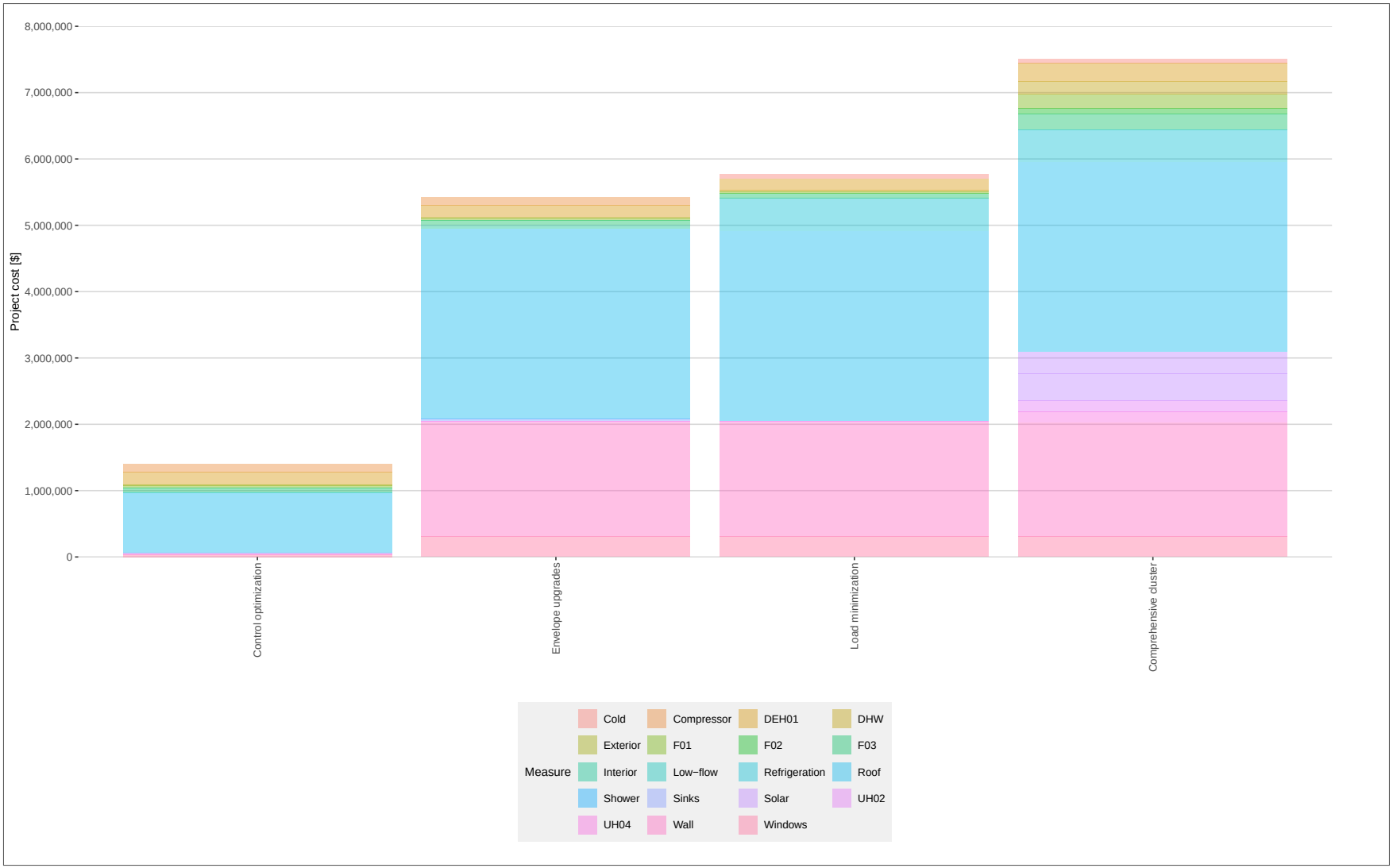


Figure 182: Project cost expected for each scenario by measure

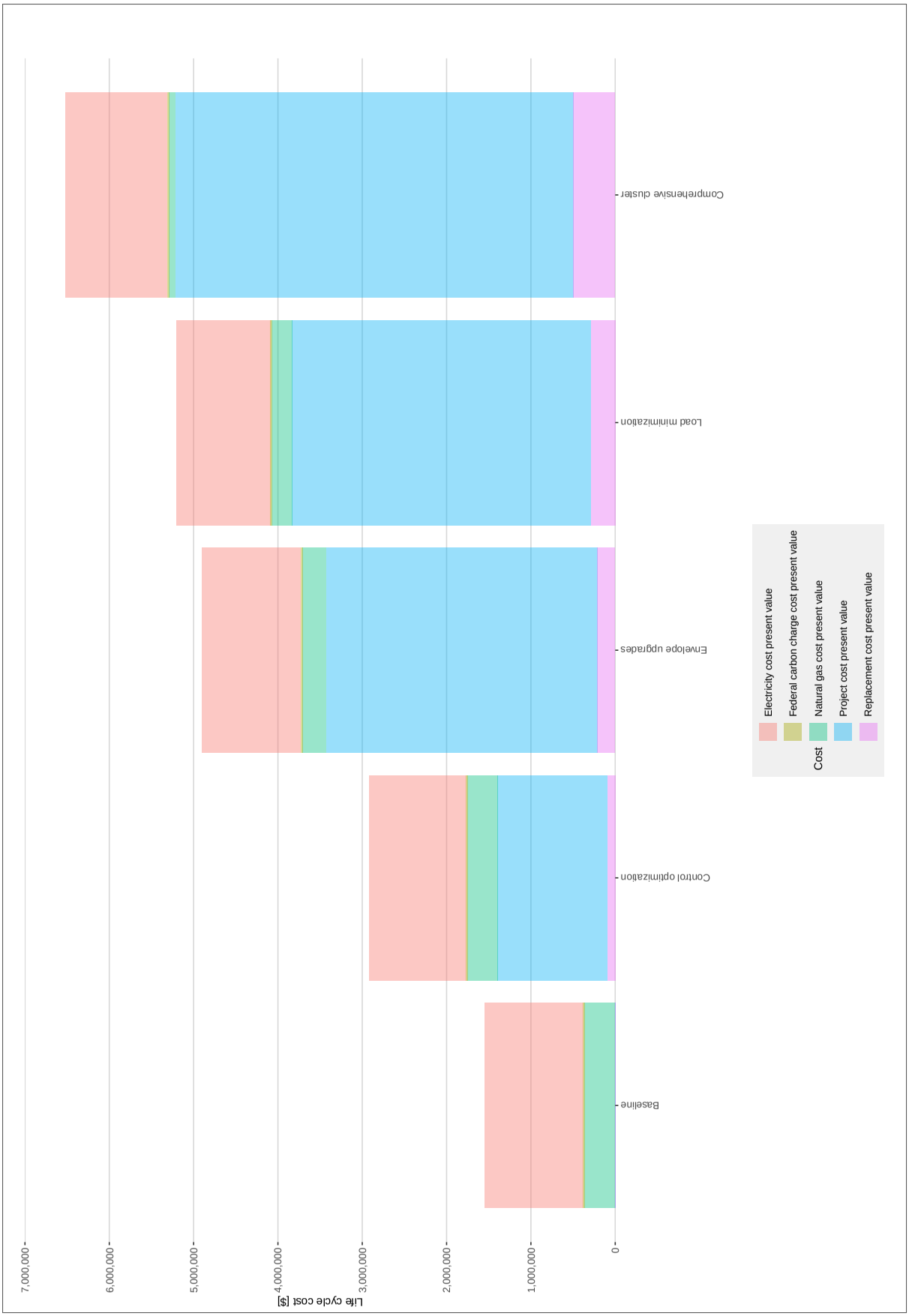


Figure 183: Life cycle cost expected for each scenario by cost item

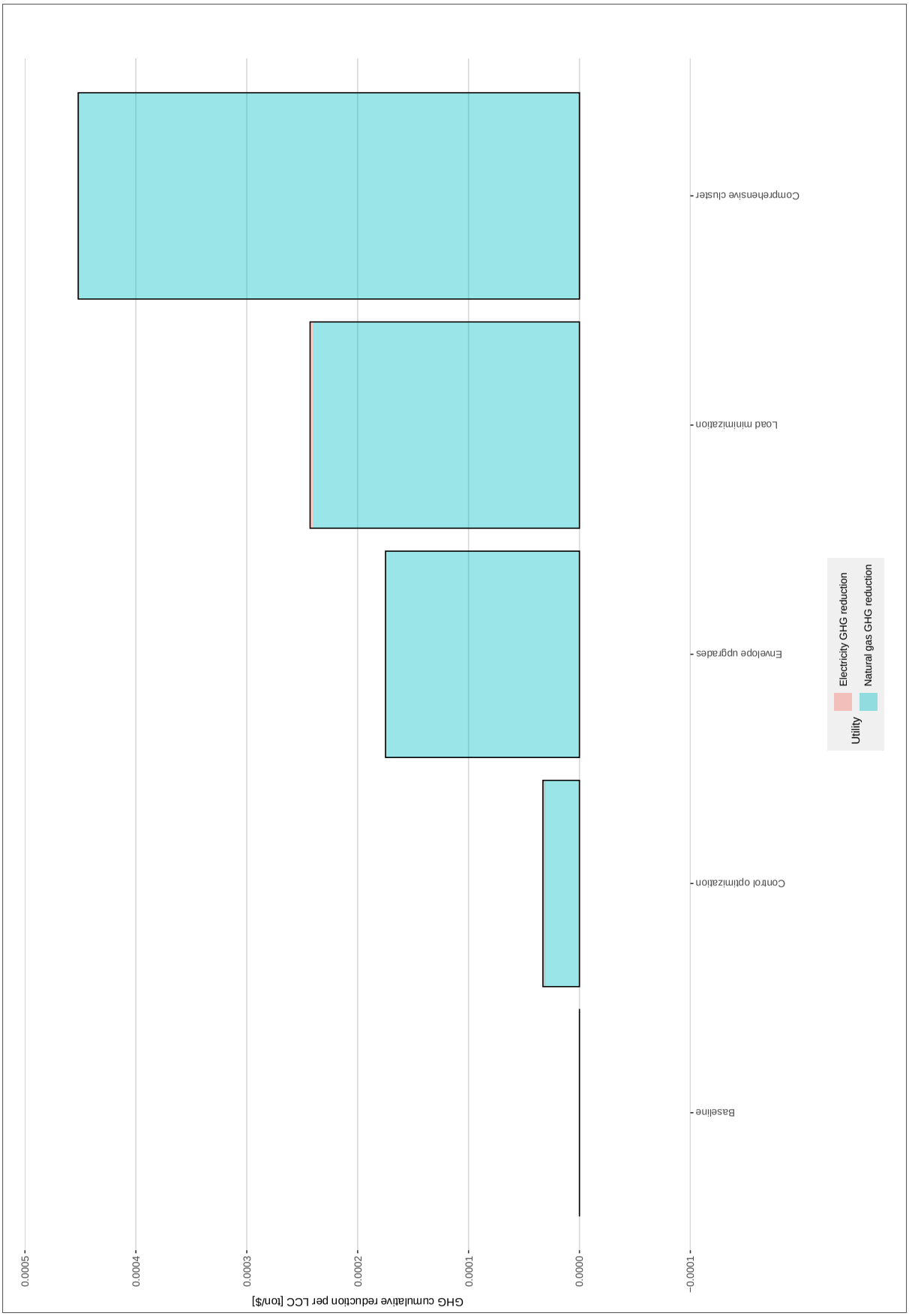


Figure 184: GHG cumulative reduction per life cycle cost (LCC) dollar expected for each scenario by utility

6.5 Plan scenario development

Plan scenario identification and objectives

The plan scenarios that were analyzed and their objectives are summarized in Table 66.

Table 66: Plan scenario identification and objectives

Plan scenario	Objectives
Minimum performance scenario	To achieve a 50% reduction in operational GHG emissions within 10 years and 80% within 20 years. This scenario addresses the minimum performance scenario of FCM's CBR program.
Aggressive deep retrofit	Implement the same measures as in the minimum performance scenario but achieve an 80% reduction in GHG emissions within five years. This scenario addresses the additional scenario requirement of FCM's CBR program.
Comprehensive	To understand the limit of GHG reductions possible by implementing all mutually exclusive measures that have the greatest reduction on GHG emissions and excluding the use of carbon offsets.
Organizational goal alignment	To reduce emissions by 40% GHG emissions from 2019 levels by 2033 and 80% reduction by 2050 of on-site emissions. The remaining 20% is to be addressed through carbon offsets, as noted in the City's Corporate Greenhouse Gas Reduction Plan (GHGRP).
Business as usual	To follow the existing capital renewal plan and replace equipment at the end of its life with like-for-like equipment, meeting minimum energy-efficiency requirements of ASHRAE 90.1.

Plan scenario composition

The plan scenarios were composed with the intent of achieving the objective of each plan scenario, as outlined in Table 66. Results of the plan scenario composition are presented in Figure 185, which is a measure implementation timeline plot indicating which measures were assumed to be implemented in which plan scenarios and when, and the estimated project cost of each measure. The measures are also colour-coded according to measure group. The same information is included in plan performance analysis results figures in Section 6.6 for ease of reference. The plan scenario composition is also presented in Tables 67 to 72.

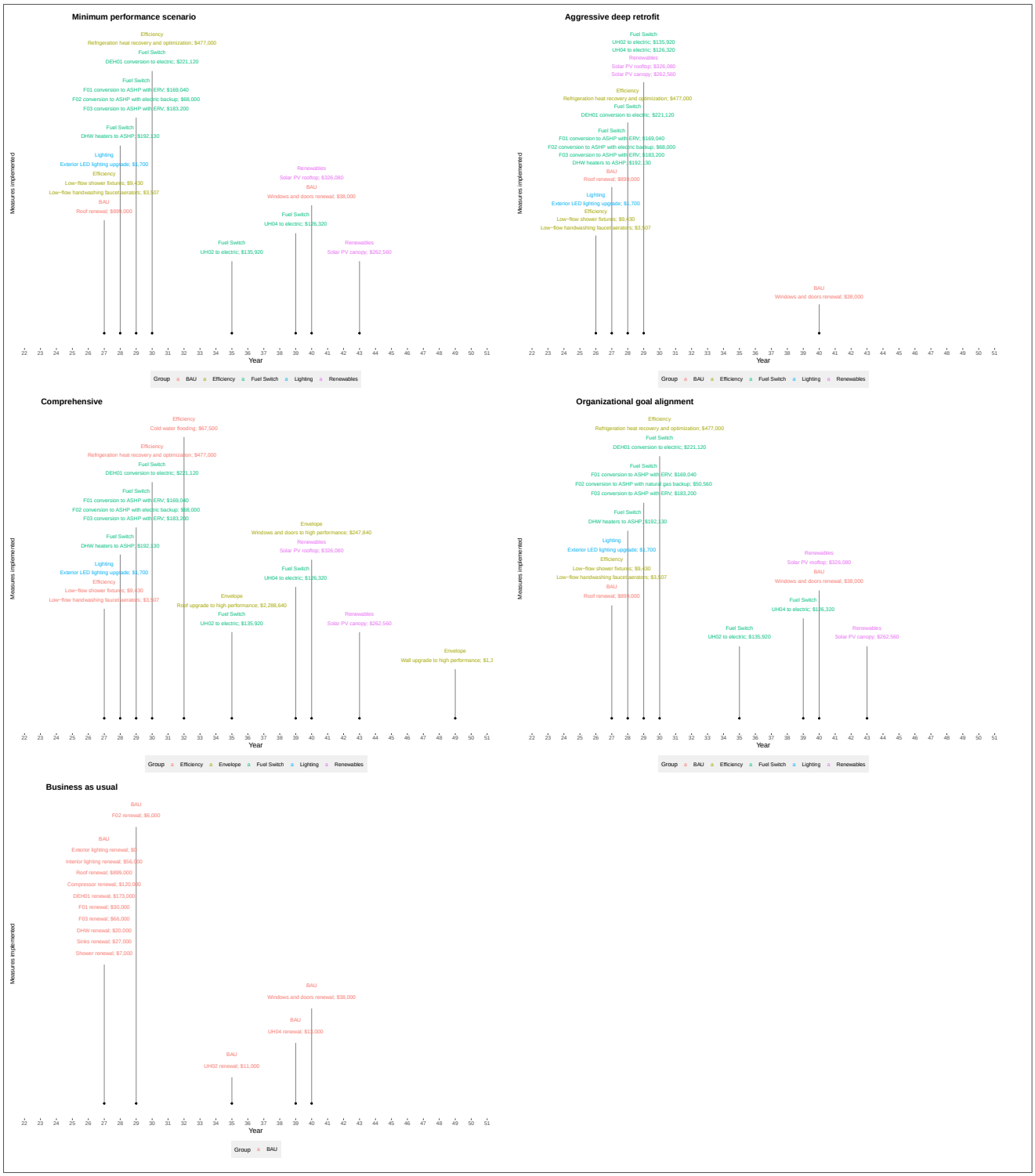


Figure 185: Plan scenario composition, indicating which measures are implemented when and at what cost in each plan scenario

Table 67: Scenario composition summary

Measure	Minimum performance scenario	Aggressive deep retrofit	Comprehensive	Organizational goal alignment
Carbon offsets 20	✖	✖	✖	✖
Cold water flooding	✖	✖	✔	✖
DEH01 conversion to electric	✔	✔	✔	✔
DHW heaters to ASHP	✔	✔	✔	✔
Exterior LED lighting upgrade	✔	✔	✔	✔
F01 conversion to ASHP with ERV	✔	✔	✔	✔
F02 conversion to ASHP with electric backup	✔	✔	✔	✖
F02 conversion to ASHP with natural gas backup	✖	✖	✖	✔
F03 conversion to ASHP with ERV	✔	✔	✔	✔
Low-flow handwashing faucet aerators	✔	✔	✔	✔
Low-flow shower fixtures	✔	✔	✔	✔
Refrigeration heat recovery and optimization	✔	✔	✔	✔
Roof upgrade to high performance	✖	✖	✔	✖
Solar PV canopy	✔	✔	✔	✔
Solar PV rooftop	✔	✔	✔	✔
UH02 to electric	✔	✔	✔	✔
UH04 to electric	✔	✔	✔	✔
Wall upgrade to high performance	✖	✖	✔	✖
Windows and doors to high performance	✖	✖	✔	✖
Compressor renewal	✖	✖	✖	✖
DEH01 renewal	✖	✖	✖	✖
DHW renewal	✖	✖	✖	✖
Exterior lighting renewal	✖	✖	✖	✖
Exterior walls renewal	✔	✔	✖	✔
F01 renewal	✖	✖	✖	✖
F02 renewal	✖	✖	✖	✖
F03 renewal	✖	✖	✖	✖
Interior lighting renewal	✖	✖	✖	✖
Roof renewal	✔	✔	✖	✔
Shower renewal	✖	✖	✖	✖
Sinks renewal	✖	✖	✖	✖
UH02 renewal	✖	✖	✖	✖
UH04 renewal	✖	✖	✖	✖
Windows and doors renewal	✔	✔	✖	✔

Table 68: Minimum performance scenario measure implementation timeline

Measure	Year
Exterior LED lighting upgrade	2027
Low-flow handwashing faucet aerators	2027
Low-flow shower fixtures	2027
Roof renewal	2027
DHW heaters to ASHP	2028
F01 conversion to ASHP with ERV	2029
F02 conversion to ASHP with electric backup	2029
F03 conversion to ASHP with ERV	2029
DEH01 conversion to electric	2030
Refrigeration heat recovery and optimization	2030
UH02 to electric	2035
UH04 to electric	2039
Solar PV rooftop	2040
Windows and doors renewal	2040
Solar PV canopy	2043
Exterior walls renewal	2055

Table 69: Aggressive deep retrofit measure implementation timeline

Measure	Year
Exterior LED lighting upgrade	2026
Low-flow handwashing faucet aerators	2026
Low-flow shower fixtures	2026
DHW heaters to ASHP	2027
F01 conversion to ASHP with ERV	2027
F02 conversion to ASHP with electric backup	2027
F03 conversion to ASHP with ERV	2027
Roof renewal	2027
DEH01 conversion to electric	2028
Refrigeration heat recovery and optimization	2028
Solar PV canopy	2029
Solar PV rooftop	2029
UH02 to electric	2029
UH04 to electric	2029
Windows and doors renewal	2040
Exterior walls renewal	2055

Table 70: Comprehensive measure implementation timeline

Measure	Year
Exterior LED lighting upgrade	2027
Low-flow handwashing faucet aerators	2027
Low-flow shower fixtures	2027
DHW heaters to ASHP	2028
F01 conversion to ASHP with ERV	2029
F02 conversion to ASHP with electric backup	2029
F03 conversion to ASHP with ERV	2029
DEH01 conversion to electric	2030
Refrigeration heat recovery and optimization	2030
Cold water flooding	2032
Roof upgrade to high performance	2035
UH02 to electric	2035
UH04 to electric	2039
Solar PV rooftop	2040
Windows and doors to high performance	2040
Solar PV canopy	2043
Wall upgrade to high performance	2049

Table 71: Organizational goal alignment measure implementation timeline

Measure	Year
Exterior LED lighting upgrade	2027
Low-flow handwashing faucet aerators	2027
Low-flow shower fixtures	2027
Roof renewal	2027
DHW heaters to ASHP	2028
F01 conversion to ASHP with ERV	2029
F02 conversion to ASHP with natural gas backup	2029
F03 conversion to ASHP with ERV	2029
DEH01 conversion to electric	2030
Refrigeration heat recovery and optimization	2030
UH02 to electric	2035
UH04 to electric	2039
Solar PV rooftop	2040
Windows and doors renewal	2040
Solar PV canopy	2043
Exterior walls renewal	2055

Table 72: Business as usual measure implementation timeline

Measure	Year
Compressor renewal	2027
DEH01 renewal	2027
DHW renewal	2027
Exterior lighting renewal	2027
F01 renewal	2027
F03 renewal	2027
Interior lighting renewal	2027
Roof renewal	2027
Shower renewal	2027
Sinks renewal	2027
F02 renewal	2029
UH02 renewal	2035
UH04 renewal	2039
Windows and doors renewal	2040
Exterior walls renewal	2055

6.6 Plan performance analysis

Figures 186 through 189 present the projected yearly electricity use, natural gas use, GHG emissions and life cycle costs associated with each plan scenario.

Figure 186: Electricity yearly utility use projection for each scenario

Figure 187: Natural gas yearly utility use projection for each scenario

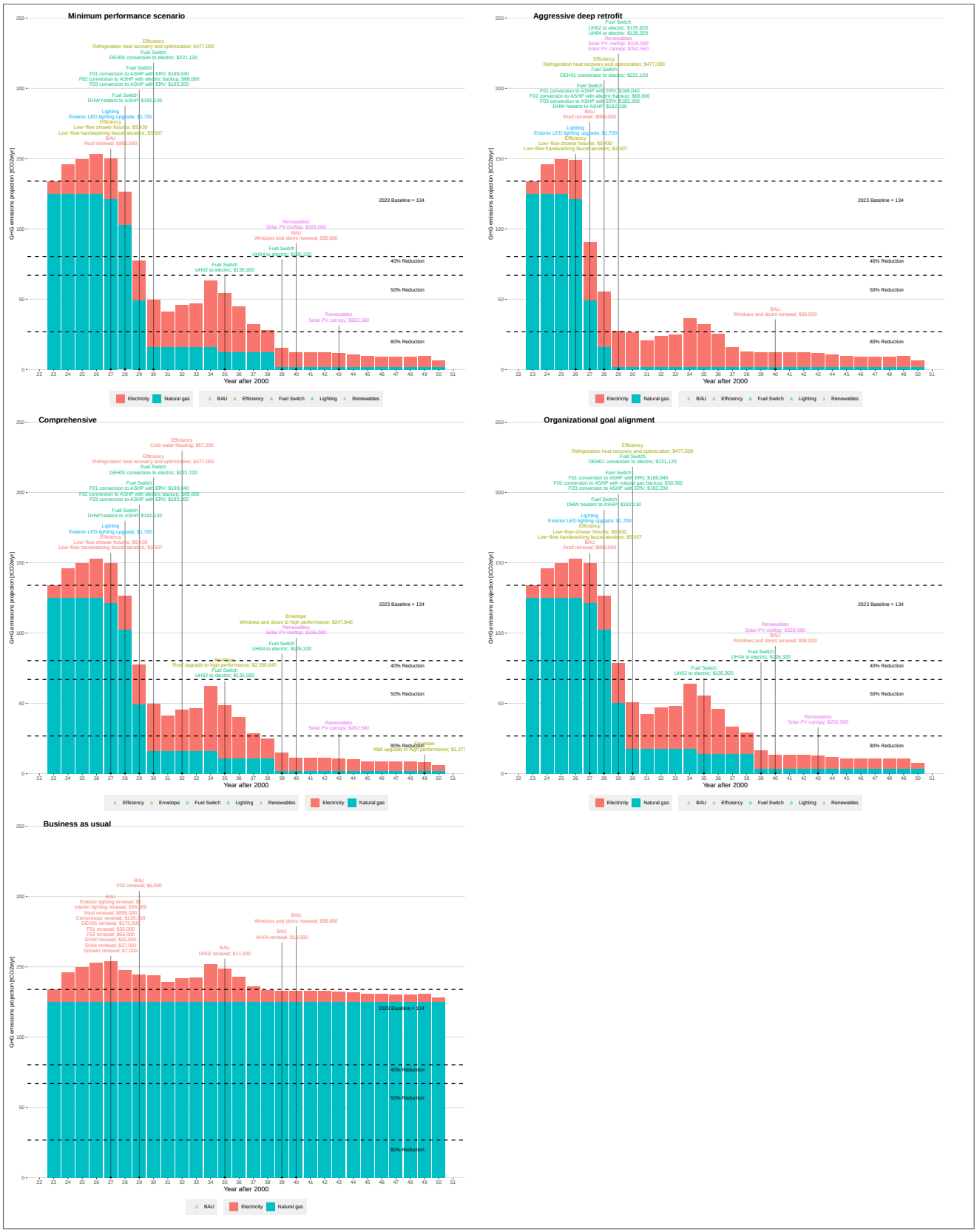


Figure 188: GHG yearly emissions projection for each scenario

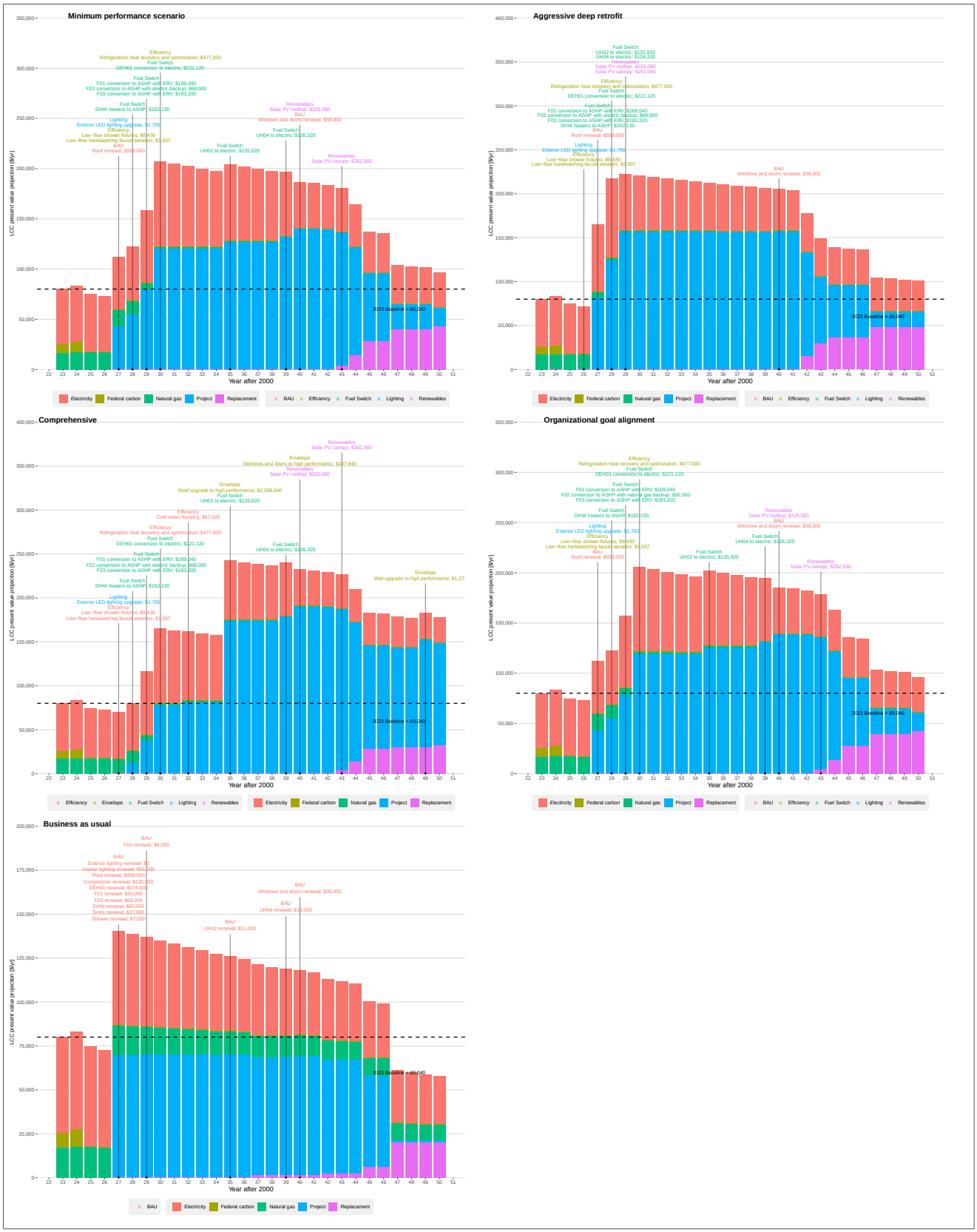


Figure 189: Life cycle yearly cost (after discounting to present value) projection for each scenario

6.7 Plan performance summary

Plan performance summary

Table 73 summarizes the performance of each plan scenario with respect to utility use, GHG emissions, utility cost, and financial metrics. The first half of Table 73 represents the estimated performance in the final year (2050) of the evaluation period. The second half of Table 73 represents the estimated cumulative performance across the entire evaluation period (present to 2050). All final year dollar values are in the value of today's currency. All cumulative dollar values presented in Table 73 are calculated as the simple sum of expenditures over the evaluation period, except for the life cycle cost, which is discounted to present value (as illustrated in Figure 189).

Table 73: Plan performance summary

Section	Description	Unit	Minimum performance scenario	Aggressive deep retrofit	Comprehensive	Organizational goal alignment	Business as usual
Utility use final	Electricity use	[kWh/yr]	487,728	487,728	399,220	481,257	383,773
	Electricity monthly peak (av)	[kW]	174	174	157	172	85
	Electricity yearly peak (max)	[kW]	375	375	338	369	144
	Natural gas use	[m3/yr]	953	953	953	1,682	64,579
GHG emissions final	Electricity GHGs	[tCO2e/yr]	4.6	4.6	3.8	4.6	3.6
	Natural gas GHGs	[tCO2e/yr]	2	2	2	3	125
	Carbon offsets GHGs	[tCO2e/yr]	0.00	0.00	0.00	0.00	0.00
	Total GHGs	[tCO2e/yr]	6	6	6	8	128
Utility cost final	Electricity utility cost	[$/yr]	118,908	118,908	97,330	117,330	93,564
	Natural gas utility cost	[$/yr]	432	432	432	761	29,228
	Carbon offsets utility cost	[$/yr]	0.00	0.00	0.00	0.00	0.00
	Federal carbon charge	[$/yr]	0.00	0.00	0.00	0.00	0.00
	Total utility cost	[$/yr]	119,340	119,340	97,761	118,092	122,792
Utility use cumulative	Electricity use	[kWh]	14,870,103	13,467,390	13,900,805	14,725,494	10,745,653
	Natural gas use	[m3]	478,088	311,110	475,304	494,288	1,808,210
GHG emissions cumulative	Electricity GHGs	[tCO2e]	544	492	520	540	394
	Natural gas GHGs	[tCO2e]	924	601	918	955	3,494
	Carbon offsets GHGs	[tCO2e]	0.00	0.00	0.00	0.00	0.00
	Total GHGs	[tCO2e]	1,468	1,093	1,439	1,495	3,888
Utility cost cumulative	Electricity utility cost	[$]	2,816,183	2,555,684	2,612,762	2,787,365	2,031,082
	Natural gas utility cost	[$]	138,396	87,547	137,431	144,392	634,456
	Carbon offsets utility cost	[$]	0.00	0.00	0.00	0.00	0.00
	Federal carbon charge	[$]	18,094	18,094	18,094	18,094	18,094
	Total utility cost	[$]	2,972,673	2,661,325	2,768,288	2,949,851	2,683,632
Financial cumulative	Project cost	[$]	4,042,303	3,702,054	9,806,873	4,018,706	1,542,679
	Replacement cost	[$]	1,926,625	1,986,493	1,283,884	1,910,746	1,100,410
	Life cycle cost	[$]	4,294,026	4,605,106	4,794,662	4,264,163	3,001,818

6.8 Scenario analysis discussion

Baseline

- This scenario reflects existing conditions.

Minimum performance scenario

- To meet the FCM minimum performance scenario, significant capital retrofits would be required, including electrification of gas-fired equipment.

Aggressive deep retrofit

- For the aggressive deep retrofit, the same measures as the minimum performance scenario need to be implemented, but on a shorter timeframe.

Organizational goal alignment

- To meet organizational goals, significant capital retrofits would be required. Gas-fired equipment should be electrified, although natural gas backups can be used.

Comprehensive

- The comprehensive scenario demonstrates the upper limit of energy-efficiency that the Don Shepherdson Memorial Arena could achieve, based on the measures that were analyzed under this Pathway to Decarbonization Feasibility Study.

7 END