PATHWAY TO DECARBONIZATION FEASIBILITY STUDY

CITY OF TEMISKAMING SHORES

TEMISKAMING SHORES LIBRARY
285 Whitewood Avenue W, New Liskeard, ON

WalterFedy Project No: 2023-0734-11

July 21, 2025

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Project Number: 2023-0734-11

July 21, 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 Temiskaming Shores Library, which is located at 285 Whitewood Avenue W 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

Jordan Mansfield, P.Eng., M.Eng., CEM, CMVP
Energy Engineer
Energy and Carbon Solutions

jmansfield@walterfedy.com
519 576 2150 x 336

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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 Temiskaming Shores Library. The objective of this engagement is to identify and analyze measures that reduce utility use, GHG emissions, and utility costs at the Temiskaming Shores Library, 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 Temiskaming Shores Library. 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 Temiskaming Shores Library 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.

- **Organizational goal alignment**

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.

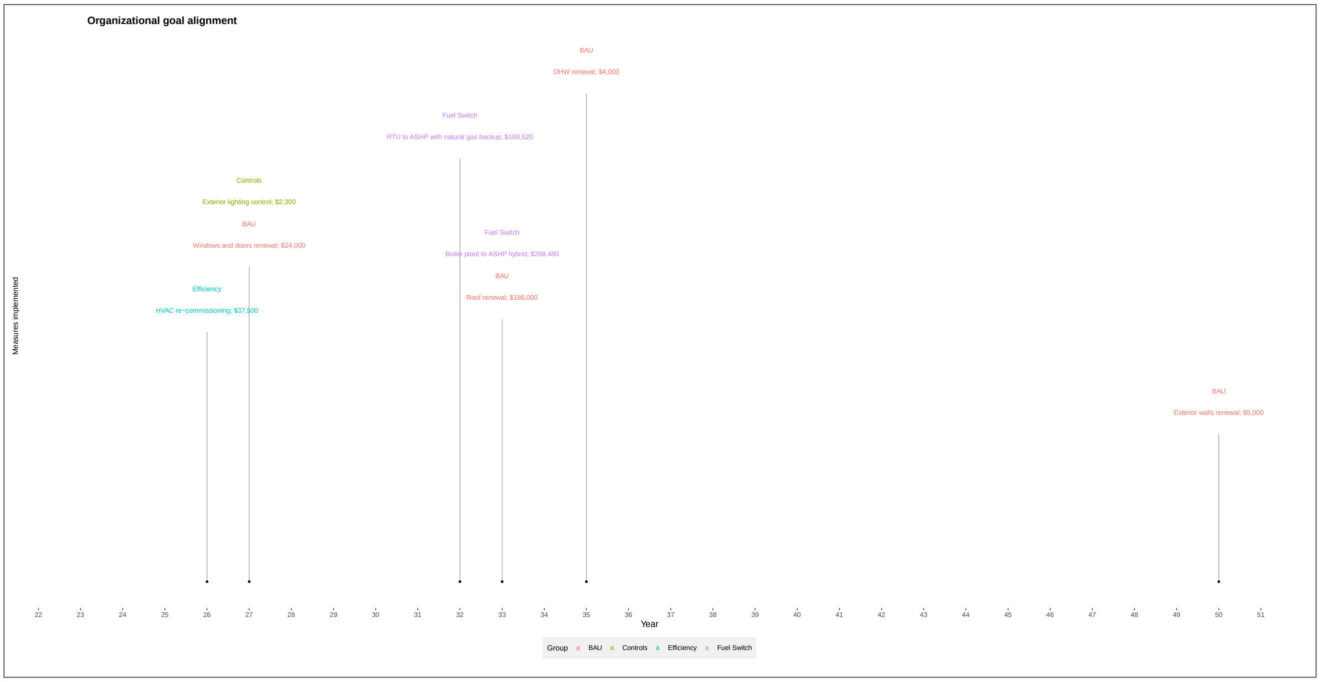


Figure 1: Recommended plan scenario composition, indicating which measures are implemented when and at what cost in each plan scenario

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

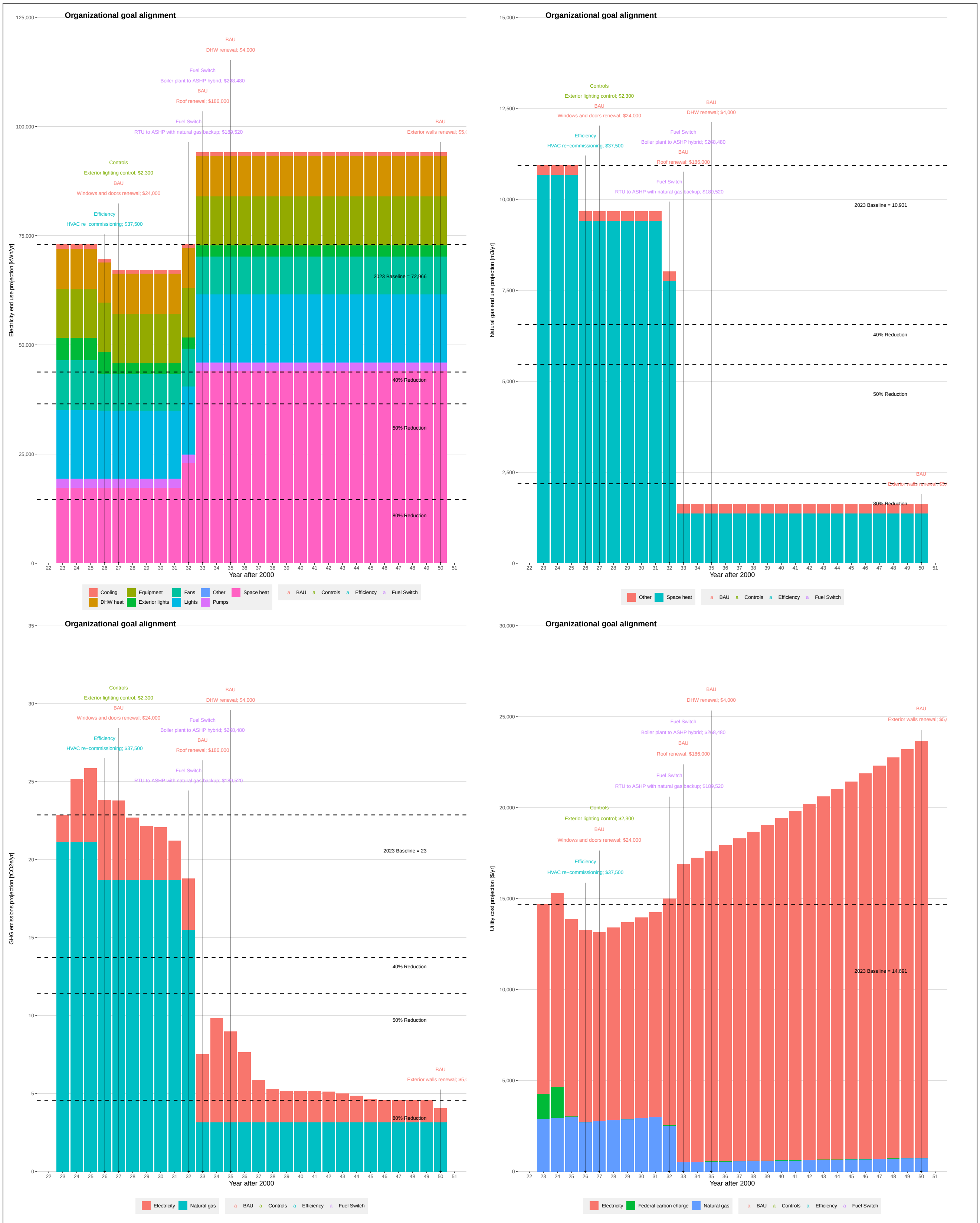


Figure 2: Recommended scenario performance

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]	96,367	96,367	65,247	**94,067**	72,966
	Electricity monthly peak (av)	[kW]	24.2	24.2	20.1	**24.1**	17.8
	Electricity yearly peak (max)	[kW]	35.7	35.7	30.1	**35.3**	19.8
	Natural gas use	[m3/yr]	1,358	1,358	1,341	**1,633**	10,931
GHG emissions final	Electricity GHGs	[tCO2e/yr]	0.92	0.92	0.62	**0.89**	0.69
	Natural gas GHGs	[tCO2e/yr]	2.6	2.6	2.6	**3.2**	21.1
	Carbon offsets GHGs	[tCO2e/yr]	0.00	0.00	0.00	**0.00**	0.00
	Total GHGs	[tCO2e/yr]	3.5	3.5	3.2	**4.0**	21.8
Utility cost final	Electricity utility cost	[$/yr]	23,494	23,494	15,907	**22,933**	17,789
	Natural gas utility cost	[$/yr]	614	614	607	**739**	4,947
	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	[$/yr]	24,109	24,109	16,514	**23,672**	22,736
Utility use cumulative	Electricity use	[kWh]	2,434,369	2,598,844	2,277,316	**2,390,435**	2,043,039
	Natural gas use	[m3]	122,934	75,042	122,702	**128,183**	306,072
GHG emissions cumulative	Electricity GHGs	[tCO2e]	84.5	93.4	81.9	**83.3**	74.9
	Natural gas GHGs	[tCO2e]	238	145	237	**248**	591
	Carbon offsets GHGs	[tCO2e]	0.00	0.00	0.00	**0.00**	0.00
	Total GHGs	[tCO2e]	322	238	319	**331**	666
Utility cost cumulative	Electricity utility cost	[$]	468,656	495,353	433,119	**459,648**	386,164
	Natural gas utility cost	[$]	37,868	23,446	37,775	**39,866**	107,393
	Carbon offsets utility cost	[$]	0.00	0.00	0.00	**0.00**	0.00
	Federal carbon charge	[$]	3,063	3,063	3,063	**3,063**	3,063
	Total utility cost	[$]	509,586	521,862	473,957	**502,576**	496,619
Financial cumulative	Project cost	[$]	959,885	890,330	2,686,104	**961,953**	422,819
	Replacement cost	[$]	488,088	440,233	488,088	**489,565**	3,281
	Life cycle cost	[$]	872,703	1,010,159	888,152	**870,662**	484,169

1 INTRODUCTION

1.1 Overview

WalterFedy was engaged by the City of Temiskaming Shores to complete a Pathway to Decarbonization Feasibility Study for the Temiskaming Shores Library. 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 Temiskaming Shores Library 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 Temiskaming Shores Library represented 2.4 tCO2e in 2019, or 0.12% 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 Temiskaming Shores Library.

Table 2: Asset management summary for this facility

Group	Metric	Unit	Value
Financial	Content Value Estimated	[$]	185,615
	Building Land Tank	[$]	3,093,584
	Replacement Cost	[$]	3,279,199
Information	Install Date	[yr]	1975
	Age	[yrs]	50
Condition Rating	Structure Condition Score	[-]	4.5
	Final Condition Score	[-]	4.5
Risk	Probability of Failure	[-]	1
	Consequence of Failure	[-]	5
	Risk Score	[-]	1.8

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 Temiskaming Shores Library is provided in Table 4.

Table 4: Facility overview

Description	Unit	Value
Name	[-]	Temiskaming Shores Library
Address	[-]	285 Whitewood Avenue W
Location	[-]	New Liskeard, ON
Type	[-]	Library
Construction year	[-]	1975
Gross floor area	[m2]	452
Gross floor area	[ft2]	4,870

An aerial view of the Temiskaming Shores Library is provided in Figure 3.

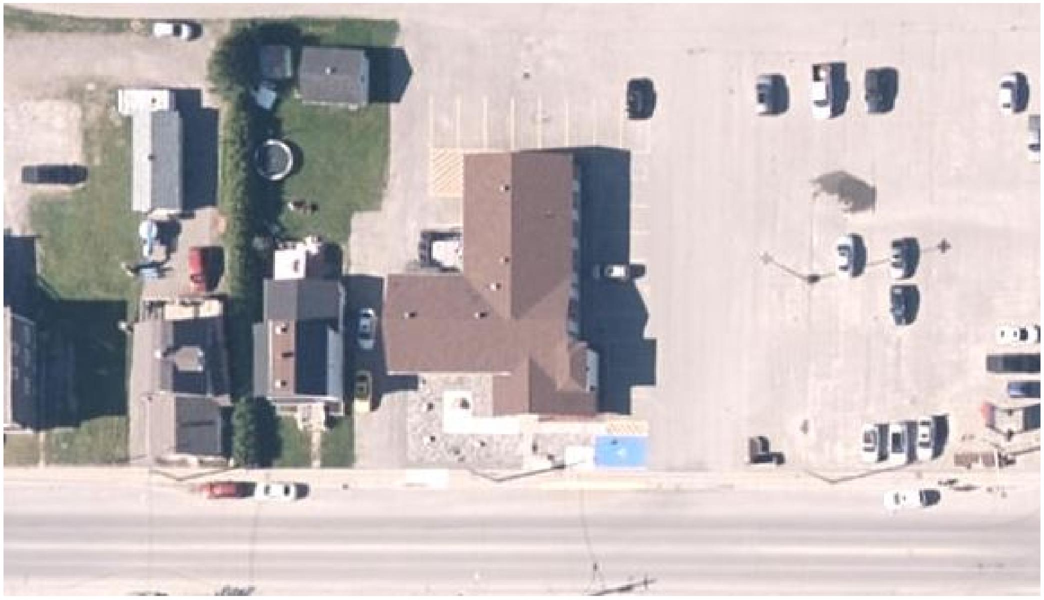


Figure 3: Temiskaming Shores Library aerial view

2.3 Building information

Renovations

The following renovations are known:

- **Window replacement (1995)**: replaced all windows with vinyl-framed dual pane windows.
- **Elevator installation (2000)**: the elevator was added to the building in 2000.
- **Roof replacement (2013)**: all shingles, underlayment materials, and potentially plywood were replaced based on the scope of work provided in the tender document.
- **Major renovation (2020)**: the facility underwent a major renovation in 2020 that converted the space from a medical office to a library.

Additions

There have been no additions to this building.

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

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. However, it is possible that a commissioning process occurred following the major renovation in 2020.

Previous studies

The following is a summary of known previous studies:

- Energy audits: none
- Engineering studies: none.
- 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:

- Renovation drawings (2020), including architectural, mechanical, structural, and electrical.
- Renovation (2020) construction manual
- Floor plans before the 2020 renovation
- Roof tender document from 2013.
- Building history document.
- Building Automation System (BAS)

2.4 Space use

Type summary

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

- Open area with book storage
- Reception
- Computer/Server room
- Multipurpose rooms
- Electrical/Mechanical room
- Lobby
- Office, enclosed and open
- Washroom
- Storage
- Lunchroom

The building was formerly a medical building. In 2020, a major renovation at this facility converted it into a library.

Occupancy scheduling

The facility operation hours are as follows:

- **Operation hours**: 10:00-17:00 Monday; 10:00-20:00 Tuesday to Thursday; 10:00-17:00 Friday; 10:00-16:00 Saturday; Closed Sunday. The schedule is based on the library's website.

Based on the renovation drawings, it is assumed that this building has a peak occupancy of 144 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]	-	-
Lower floor - east	181	AHU1 (VVT 1.1)	Drawings.
Lower floor - west	100	AHU1 (VVT 1.2)	Drawings.
Multifunction room - 105	49	AHU1 (VVT 1.3)	Drawings.
Upper floor open area	119	AHU1 (VVT 1.4)	Drawings.
Meeting room - 104	21	AHU1 (VVT 1.5)	Drawings.
Upper floor - Offices and storage	35	AHU1 (VVT 1.6)	Drawings.
Work area and lunchroom	41	AHU1 (VVT 1.7)	Drawings.
Digital creator lab - room 117	28	AHU1 (VVT 1.8)	Drawings.
Stairwells and lobbies	87	Electric heaters	Drawings.
WR 014	4	EF1	Drawings.
WRs 107, 108, and 109	18	EF2	Drawings.
WR 006	7	EF3	Drawings.
IT room	4	EF4	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.

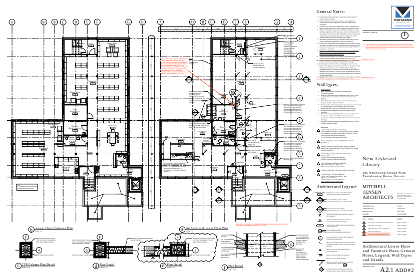


Figure 4: Lower floor plan

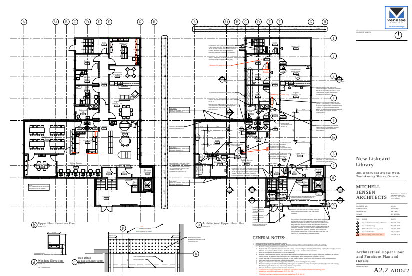


Figure 5: Upper floor plan

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]
714	777	745	30.3	1.6

Overview

Original architectural drawings were not available, and the renovation did not include any major work to the exterior wall and roof assemblies.

Roof

- The roof exterior layer is shingles. The renovation drawings indicate mineral wool insulation being used within the voids of the joists, which are assumed to be 2x10.
- It is assumed that above the main interior spaces, the gable roof is composed of wood trusses with batt insulation in the attic/truss space. The attic is believed to be unconditioned.
- The overall roof assembly is assumed to have a U-Value of 0.199 W/m2K.
- The roof condition was not observed while on site. However, the roof was replaced in 2013, indicating that it is approximately halfway through its life.

Opaque Walls (above ground)

- The exterior walls comprised either an outer layer of veneer brick or vinyl siding.
- The walls are assumed to be wood stud constructions with batt insulation inside the stud cavity.
- The overall wall assembly is assumed to have a U-Value of 0.273 W/m2K.
- The wall condition was good for the brick walls. However, there was some damage on the vinyl siding.

Fenestration

Windows

- The renovation drawings imply some of the windows on the west elevation were replaced. However, observation of the envelope suggests that they were not. It appears most windows were replaced circa 1995 with double-pane vinyl windows. The lobby area has aluminum-framed, double pane windows.
- Windows appeared to be in fair condition, including sealant around windows.
- The overall U-Value is assumed to be 2.7 W/m2K for the window system with a SHGC of 0.35.

Doors

- The facility has two exterior entry points. The front doors are double swing doors with glazing, and the rear entry point is a single hollow metal door with glazing.
- There is a gap between the front entrance doors, suggesting that new weatherstripping is required. Doors are in fair condition.
- The overall fenestration-to-wall ratio is estimated to be 4%, as elevation drawings were not made available.

Overall Enclosure Tightness

It is difficult to determine a building's infiltration rate 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 0.25 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 6: Aluminum-framed windows in lobby area


Figure 7: Brick and vinyl siding on the west elevation


Figure 8: Damaged vinyl siding on the east elevation


Figure 9: Front entrance


Figure 10: Front entrance with gap between doors


Figure 11: Hollow metal door at the rear


Figure 12: Roof


Figure 13: Sealant failing on aluminium windows


Figure 14: South elevation

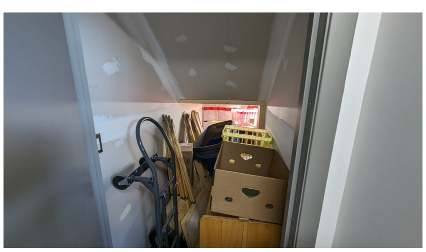


Figure 15: Storage room reveals batt insulation


Figure 16: Vinyl window to the lower level


Figure 17: Vinyl window framing 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]	-
AHU1	Carrier	48HCFD17A3A 5A2D0J0	Entire building	5,000	3.00	Drawings.
EF1	JencoFan Canada	PC110X	WR 014	82	0.06	Manual.
EF2	JencoFan Canada	FF250S	WR 107, 108, and 109	210	0.10	Manual.
EF3	JencoFan Canada	PC110X	WR 006	82	0.06	Manual.
EF4	JencoFan Canada	FF250S	IT Exhaust	250	0.10	Manual.
EF5	-	-	Elevator room	-	-	-

Table 8: Water distribution systems summary

Tag	Serves	Flow	Head	Motor output	Data source
-	-	[gpm]	[ft]	[hp]	-
P1	B1	14.5	15	0.12	Assumption.
P2	B2	14.5	15	0.12	Assumption.
P3a	Hydronic heating loop	10.5	36	1.00	Assumption.
P3b	Hydronic heating loop	10.5	36	1.00	Assumption.
P4	DHW recirc	-	-	1.00	-

Table 9: Heating systems summary

Tag	Serves	Utility	Efficiency	Output	Data source
-	-	-	[decimal]	[btuh]	-
B1	Hot water loop	Natural gas	0.91	218,000	Assumption.
B2	Hot water loop	Natural gas	0.91	218,000	Assumption.
AHU1	Building	Natural gas	0.81	324,000	Assumption.
DHW1	DHW	Electricity	1.00	15,355	Nameplate.

Table 10: Cooling systems summary

Tag	Serves	Efficiency	Output	Data source
-	-	[decimal]	[ton]	-
AHU1_COOL	Building	4.9	15	Nameplate.

System type

The facility utilizes AHU1, which is located on the ground outside. A summary of this system is as follows:

- AHU1 is a variable volume and temperature (VVT) unit with a bypass return damper to maintain constant air through AHU1. No VFD is present in the supply fan.
- AHU1 has a natural gas-fired burner with two stages, and DX cooling with two stages.
- AHU1 operates with a dry-bulb economizer mode.
- The IT room utilizes EF4 to cool the space.
- The stairwells and the lobby utilize electric heat with built-in thermostats.
- Three additional exhaust fans serve corresponding washrooms.
- All ventilation equipment appeared to be in excellent condition, as it was replaced in 2020.

Central Plant

- Two condensing boilers provide hot water to radiant panels. The radiant panels are divided into 8 zones.

Distribution system

A total of 5 pumps circulate the working fluid throughout the building. They serve the following:

- Two pumps (P1 and P2) serve the primary boiler loop. Each pump is interlocked with a corresponding boiler.
- Two pumps (P3a and P3b) serve the secondary hot water loop. Both pumps operate in a lead/lag configuration, which serves the radiant panel heating.
- The remaining pump (P4) is DHW recirculation.

The air distribution throughout the building uses a single-duct approach to VVT boxes serving the eight zones.

Controls

AHU1

- There is one thermostat in each of the eight zones.
- The bypass damper modulates to maintain a duct static pressure. This information was not readily available in the BAS.
- Each VVT box modulates its airflow to maintain the zone temperature.
- The AHU determines if it is in heating or cooling mode based on the needs of each zone. It will changeover modes as required.
- The AHU is equipped with an optimal start for warm-up and pre-cool settings, which will allow each zone to meet the occupied temperature setpoint at the start of the occupied schedule. Therefore, it's important to set an occupancy schedule to match the actual occupancy schedule of the building.
- The heating setpoint is 21C for both unoccupied and occupied setpoints. The drawings indicate that the heating unoccupied temperature is to be 64F (17.8C).
- The cooling setpoint is 23C for both unoccupied and occupied setpoints. This approach does not allow for a temperature setback.
- In the BAS, AHU1's schedule appears to be linked to RTU1 at City Hall.

VVT boxes

- Based on a review of the BAS, the minimum air flow entering the space is 30% of the overall design flow.

Hot water loop

- When the OAT drops below 70F, the hot water system is enabled, with the lead secondary pump (P3a or P3b), the lead boiler, and the corresponding lead boiler's pump.

- The boiler plant is a lead-lag configuration (2-week lead period) and operates on an OAT reset schedule. The supply water temperature (SWT) ranges from 110F to 190F, corresponding linearly to an OAT of 70F to -15F.
- P3a and P3b are equipped with VFDs to maintain system differential pressure.

Radiant heating

- Each zone valve for the radiant panels modulate based on zone temperature setpoint, which is adjustable at the thermostat.
- When in unoccupied mode, the room temperature is to be set to 64F. However, this setpoint has been overriden in the BAS.
- The radiant panels are controlled by two-way zone valves, which are connected to a separate thermostat from the VVT air distribtion system.

IT room

- EF4 is enabled when the space temperature reaches 76F.

HVAC system documentation

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


Figure 18: AHU1


Figure 19: B1 and B2

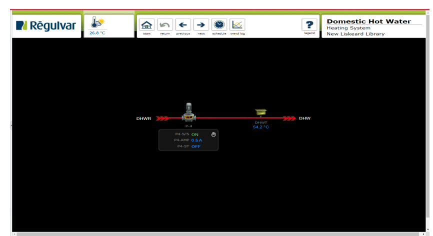


Figure 20: BAS - DHW

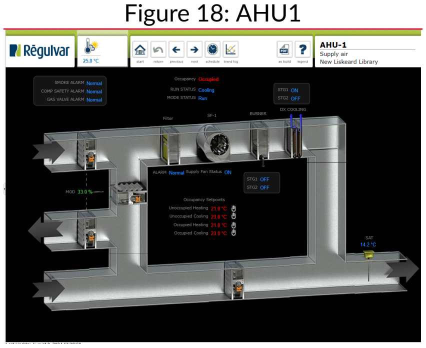


Figure 21: BAS - AHU1

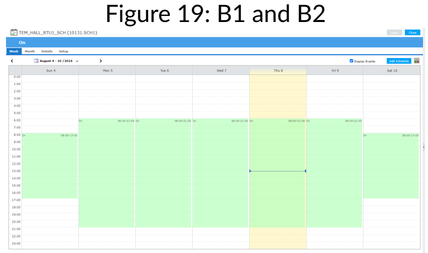


Figure 22: BAS - AHU1 schedule

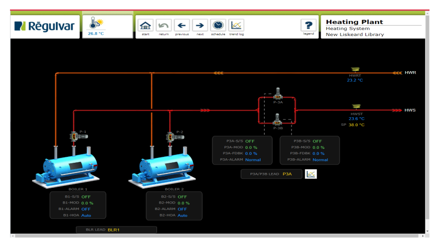


Figure 23: BAS - Hot water loop

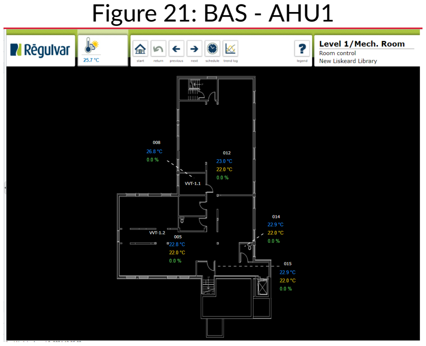


Figure 24: BAS - 1st Floor Zone Control

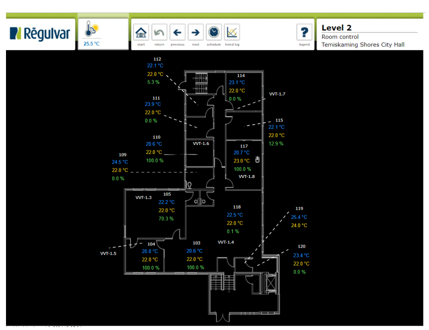


Figure 25: BAS - 2nd Floor Zone Control

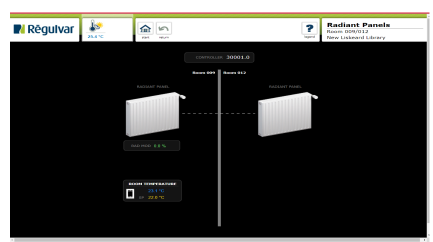


Figure 26: BAS - Radiant Panels - Rooms 009, 012

Figure 27: BAS - Radiant Panels - Rooms 015, 013

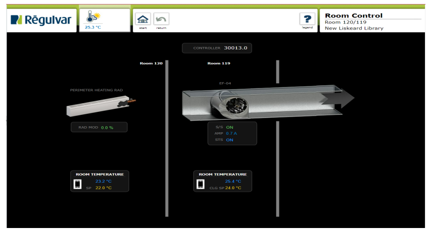


Figure 28: BAS - Radiant Panels - Rooms 120, 119 and EF4


Figure 29: EF4

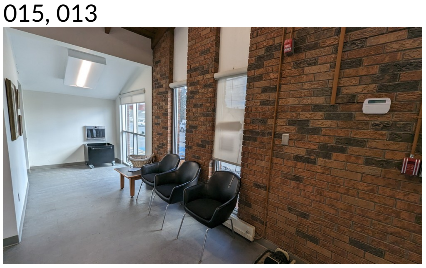


Figure 30: Electric baseboard heater in the lobby

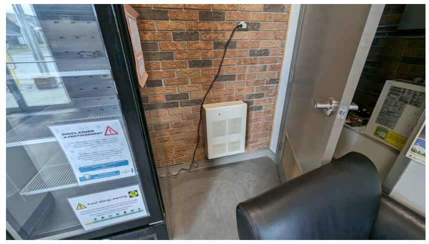


Figure 31: Electric forced flow heater in the lobby


Figure 32: Elevator exhaust fan


Figure 33: Hydronic baseboard heating


Figure 34: P1


Figure 35: P2

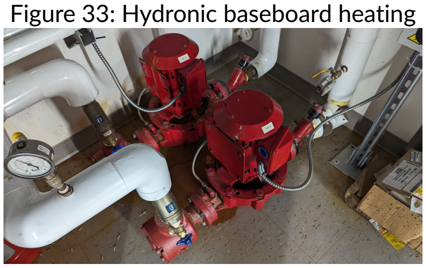


Figure 36: P3a and P3b

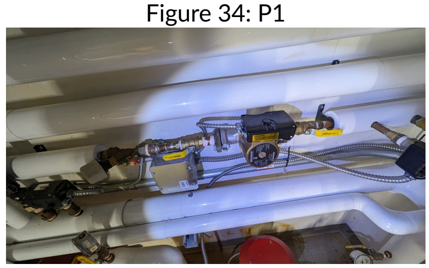


Figure 37: P4

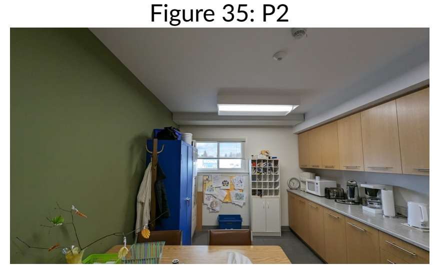


Figure 38: Radiant panel in the ceiling

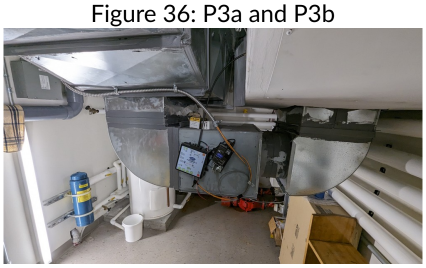


Figure 39: System bypass damper

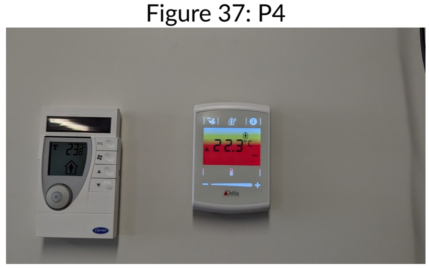


Figure 40: Two thermostats in the creator lab


Figure 41: Typical thermostat

Figure 42: VVT1.1

Figure 43: VVT1.2

Figure 44: VVT1.3 - unable to obtain control point info

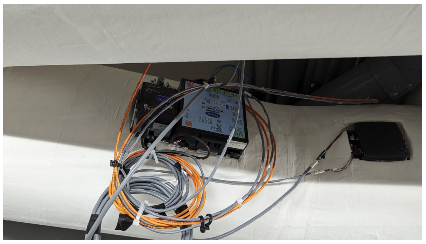


Figure 45: VVT1.3 Zone Damper

Figure 46: VVT1.4 - unable to obtain control point info

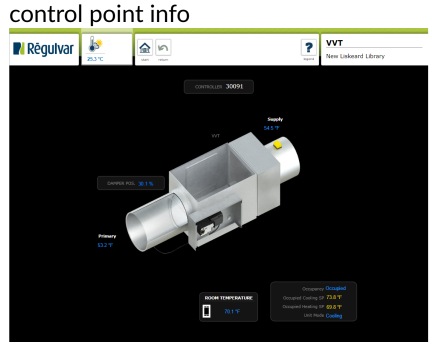


Figure 47: VVT1.5

Figure 48: VVT1.6

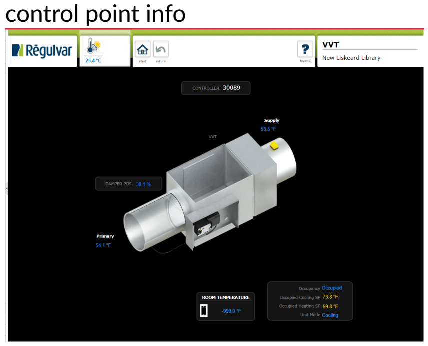


Figure 49: VVT1.7

Figure 50: VVT1.8

2.7 Domestic hot water

Overview

One electric DHW heater serves this building, which is located in the mechanical room and has a capacity of 73.7 USG. P4 provides recirculation to the DHW loop. When the building is in occupied mode, and if the loop temperature drops below 55C, the pump will be enabled for a minimum of 5 minutes.

Domestic Hot Water documentation

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

Figure 51: DHW1

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]	-
Lower floor - east	181	4.7	851	Lighting takeoff.
Lower floor - west	100	4.7	470	Lighting takeoff.
Multifunction room - 105	49	5.9	289	Lighting takeoff.
Upper floor open area	119	5.9	702	Lighting takeoff.
Meeting room - 104	21	5.9	124	Lighting takeoff.
Upper floor - Offices and storage	35	5.9	206	Lighting takeoff.
Work area and lunchroom	41	5.9	242	Lighting takeoff.
Digital creator lab - room 117	28	5.9	165	Lighting takeoff.
Stairwells and lobbies	87	4.7	409	Lighting takeoff.
WR 014	4	4.7	19	Lighting takeoff.
WRs 107, 108, and 109	18	5.9	106	Lighting takeoff.
WR 006	7	4.7	33	Lighting takeoff.
IT room	4	5.9	24	Lighting takeoff.

Interior lighting

Fixtures

Per the renovation drawings, there are 11 fixture types present in the building. A summary of each fixture is as follows:

- Type A: 1'x4' recessed, LED, 32 W, 120V, dimmable
- Type B: 1'x4' surface, LED, 32 W, 120V, dimmable
- Type C: 2'x4' recessed, LED, 39 W, 120V, dimmable
- Type F: surface linear fixture, LED, 4.4W/ft, 120V, dimmable
- Type G: similar to F with different mounting option
- Type H: strip fixture, surface, LED, 34 W, 120V
- Type I: 4 inch potlight, LED, 21 W, 120V, dimmable
- Type J: 4 inch potlight, LED, 13 W, 120V, dimmable
- Type K: 2'x4' recessed, low profile centre basket, LED, 39 W, 120V, dimmable
- Type M: 5 inch downlight, LED, 10 W, 120V, dimmable
- Type N: 7 inch downlight, LED, 10 W, 120V, dimmable

Controls

Interior lighting control is done through switch-mounted occupancy sensors and ceiling-mounted occupancy sensors. There are several fixtures that are on an emergency circuit (i.e., on continuously).

Exterior lighting

Fixtures

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

- Type AA: wall-mounted, LED, 39 W
- Type BB: wall-mounted, LED, 20 W

Controls

The exterior lights are controlled by a photocell sensor on the north elevation of the building. The lights were on during the site visit with the sun present.

Lighting system documentation

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

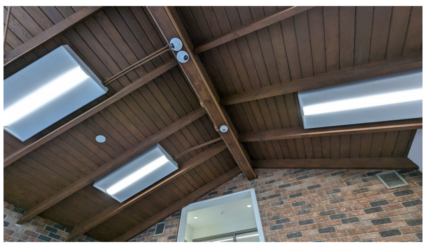


Figure 52: Ceiling-mounted occupancy sensor in the lobby

Figure 53: Control switch in the lobby

Figure 54: Light switch with occupancy sensor

Figure 55: Light switch with dimmer in an office

Figure 56: Photocell on the north elevation

Figure 57: Task lighting

Figure 58: Type AA - fixture on during the day

Figure 59: Type BB - west elevation

Figure 60: Type F8 in lower floor

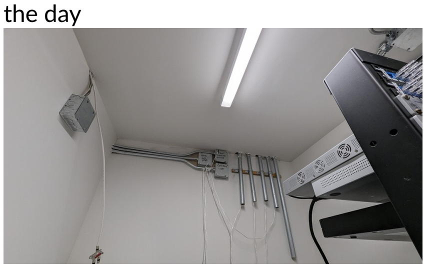


Figure 61: Type H - in IT room

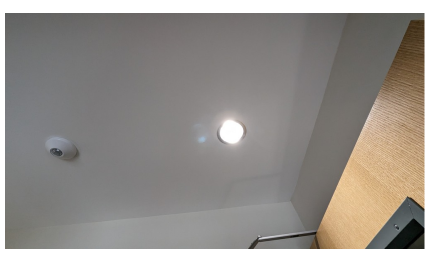


Figure 62: Type I

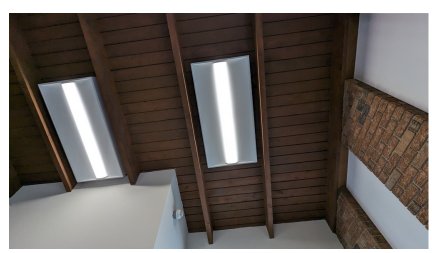


Figure 63: Type K - lobby


Figure 64: Type K - in creator space

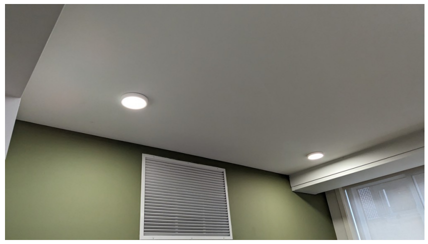


Figure 65: Type M

2.9 Process and plug loads

Process

Various process loads are present at the facility, including:

- Elevator
- IT equipment

Plug loads

Various plug loads are present at the facility, including:

- Office equipment (photocopier, 3D printers, etc.)
- Personal computers
- Appliances (e.g., dishwasher, kettle, etc.)

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 66: 3D printers and computers

Figure 67: Elevator

Figure 68: IT equipment

Figure 69: Kitchen appliances

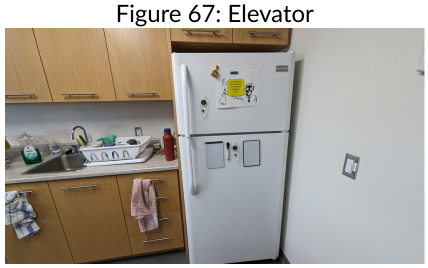


Figure 70: Refrigerator

Figure 71: Refrigerator in the lobby

Figure 72: Typical office

2.10 Water fixtures

Water fixture summary

Water fixtures at Temiskaming Shores Library are summarized in Table 12.

Table 12: Water fixture summary

Serves	Unit count	Flow	Volume	Data source
-	-	[gpm]	[gpc]	-
Kitchen faucets	1	2.20	-	Assumption.
Washroom faucets	5	0.50	-	Assumption.
Toilets	5	-	1.6	Assumption.
Slop sink	1	5.00	-	-

Overview

A summary of water fixtures is as follows:

- Five handwashing faucets. They are equipped with manual levers and are low-flow.
- One kitchen sink.
- One slop sink.
- Five toilets.

Water fixture documentation

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

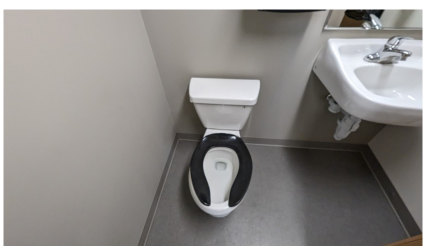


Figure 73: Faucet in WR 108

Figure 74: Kitchen sink

Figure 75: Kitchen sink with 2.2 gpm

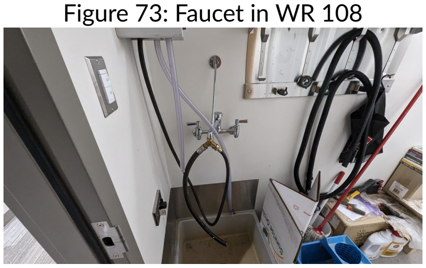


Figure 76: Slop sink

Figure 77: Toilet in WR 108

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 Energy rate structure.

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 78: Electricity meter

Figure 79: Natural gas meter

2.12 Onsite energy sources

Overview

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

2.13 Electrical infrastructure

Overview

The existing systems is 400A at 208 V - 3Ph service running at a maximum load of 47.4 kW, which is approximately 41% of the full load of 115.3 kW of the building. The main incoming switchboard has three available 3 pole spaces. There are two panels present.

Panel summary

The two panels at this site are summarized below:

- Panel A, 120/208V, 3 ph, 4W, 225A. Serves receptacles, lighting, elevator, electric heating, and exhaust fans.
- Panel B, 120/208V, 3 ph, 4W, 225A. Serves receptacles, lighting, pumps, hot water tank, and boilers.

Electrical infrastructure documentation

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


Figure 80: 400A main breaker


Figure 81: Meter cabinet


Figure 82: Panel A and B - both labelled incorrectly

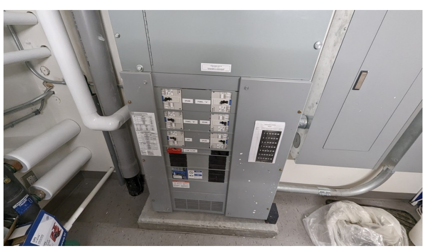


Figure 83: Switchboard

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 Temiskaming Shores Library.
    - 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 Temiskaming Shores Library 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 Temiskaming Shores Library.
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 Energy 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	[$/kWh]	0.0057
Natural gas	Natural gas (blended)	[$/m3]	0.2600
GHG emissions	Federal carbon charge	[$/tCO2e]	50.0000

3.3 Electricity metered utility use

Hourly electricity use is plotted in Figure 84.

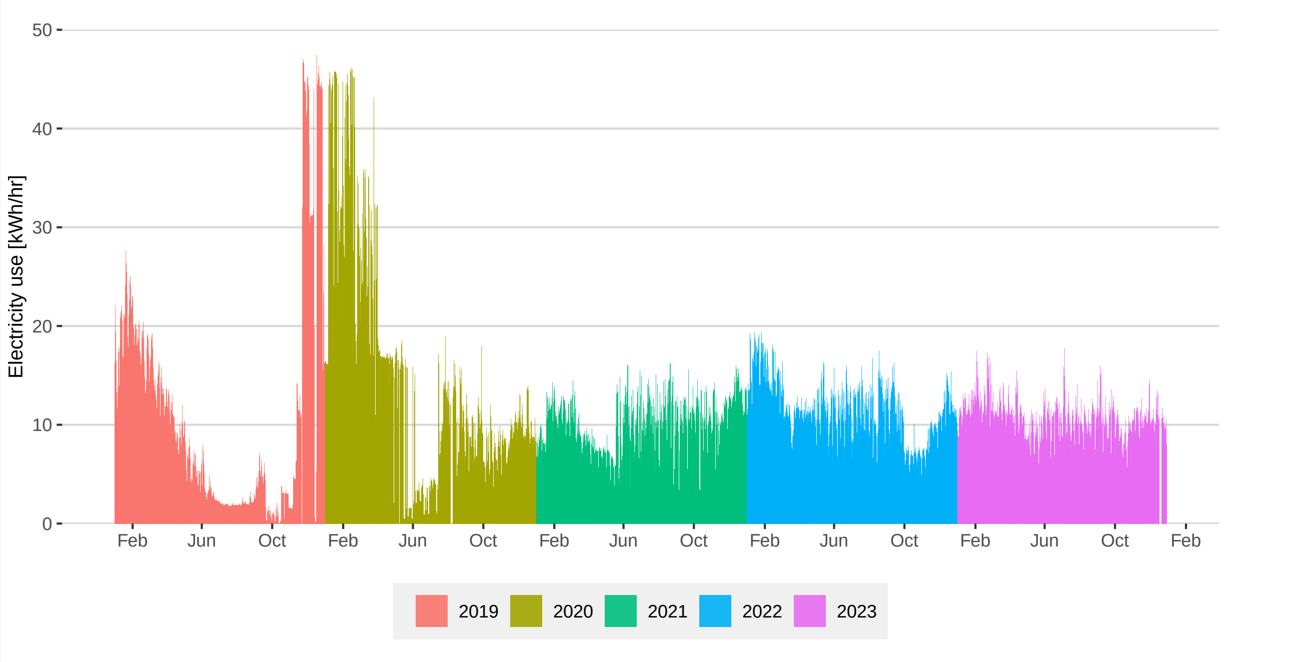


Figure 84: Hourly electricity use

The same hourly electricity use data is plotted in Figure 85, which highlights how electricity use is influenced by year, season, day of week and hour of day. The vertical axis on Figure 85 may be rescaled relative to in Figure 84 for greater resolution.

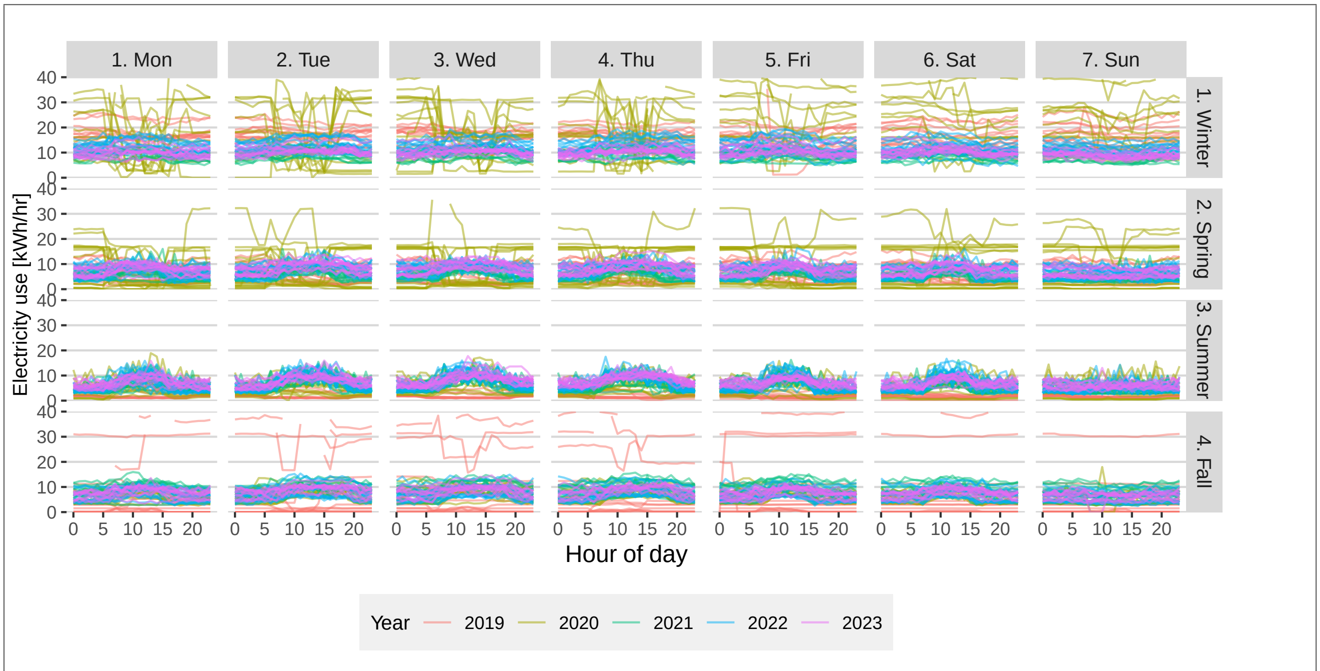


Figure 85: Hourly electricity use hairball plot

Monthly electricity use is plotted in Figure 86.

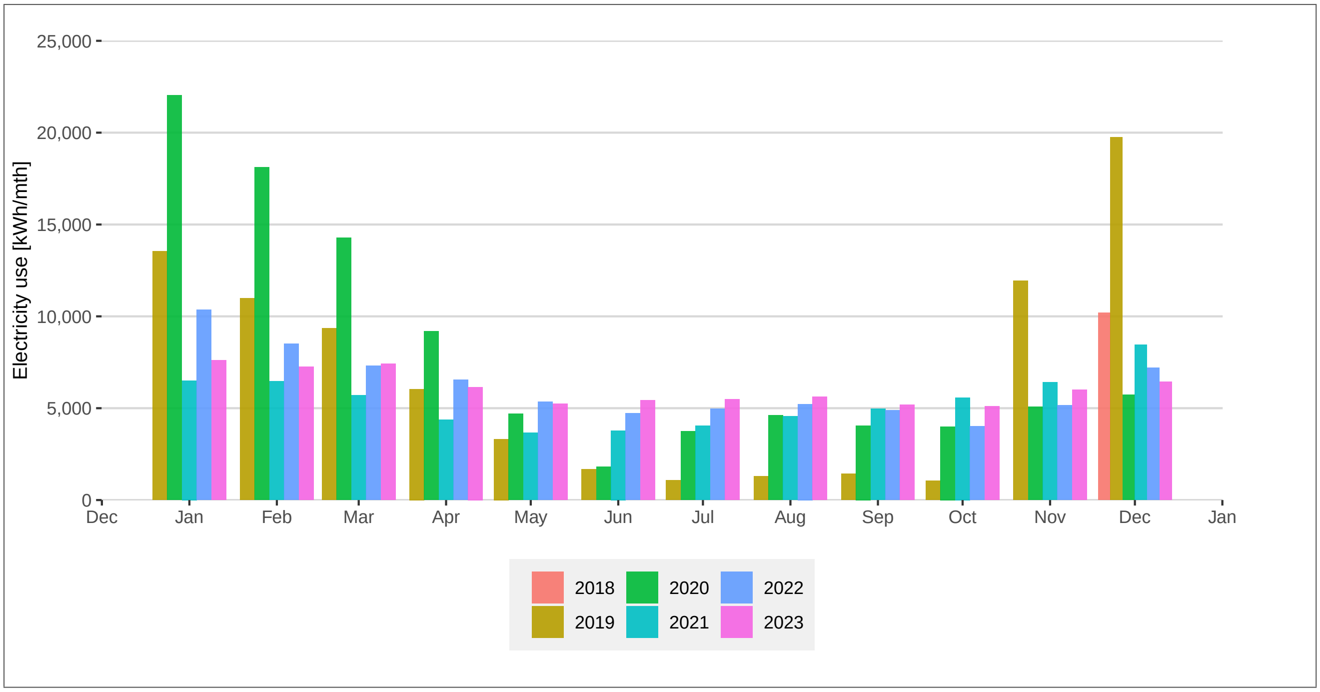


Figure 86: Monthly electricity use

3.4 Natural gas metered utility use

Monthly natural gas use is plotted in Figure 87.

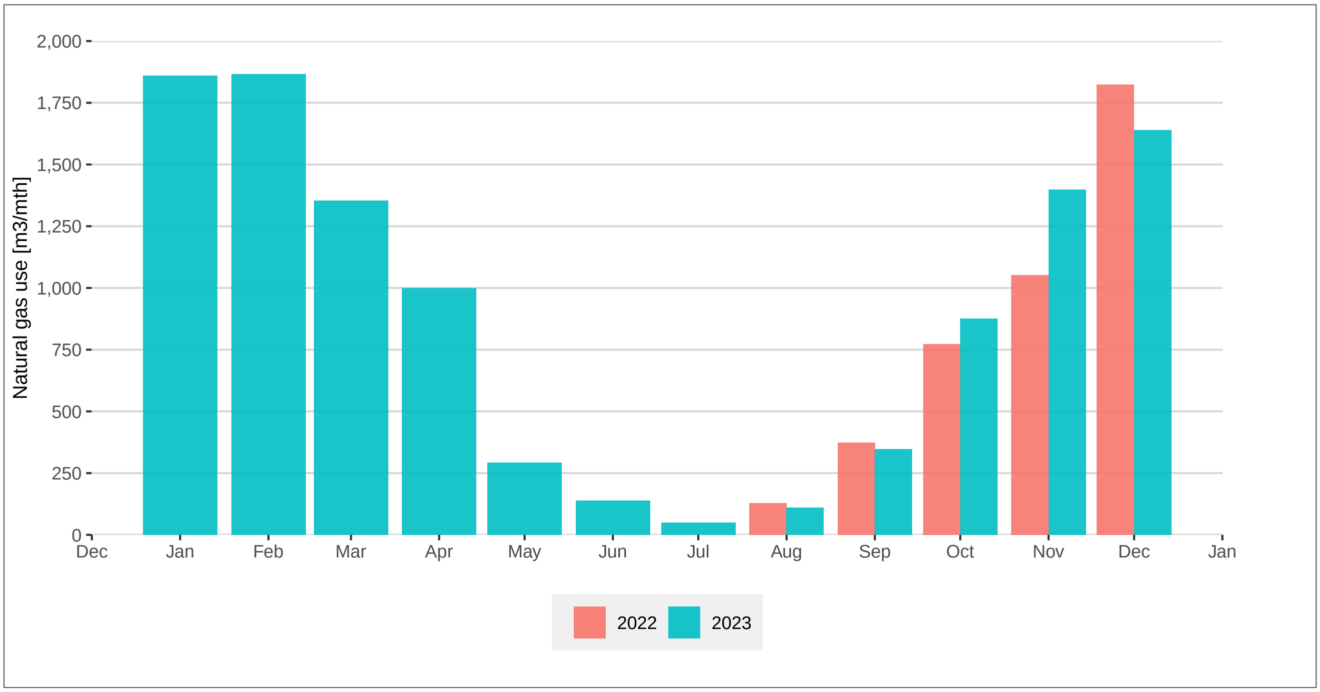


Figure 87: Monthly natural gas use

3.5 Utility use baseline

Baseline year

The baseline year for Temiskaming Shores Library, 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]	72,966
	Natural gas use	[m3/yr]	10,931
	Carbon offset use	[tCO2e/yr]	0
Equivalent energy use	Electricity energy	[kWh/yr]	72,966
	Natural gas energy	[kWh/yr]	115,397
	Total energy	[kWh/yr]	188,363
GHG emissions	Electricity GHGs	[tCO2e/yr]	2
	Natural gas GHGs	[tCO2e/yr]	21
	Carbon offsets GHGs	[tCO2e/yr]	0
	Total GHGs	[tCO2e/yr]	23
Utility cost	Electricity utility cost	[$/yr]	7,238
	Natural gas utility cost	[$/yr]	2,842
	Carbon offsets utility cost	[$/yr]	0
	Federal carbon charge	[$/yr]	1,056
	Total utility cost	[$/yr]	11,136

3.6 Benchmarking analysis

Benchmarking analysis results are presented in the following figures.

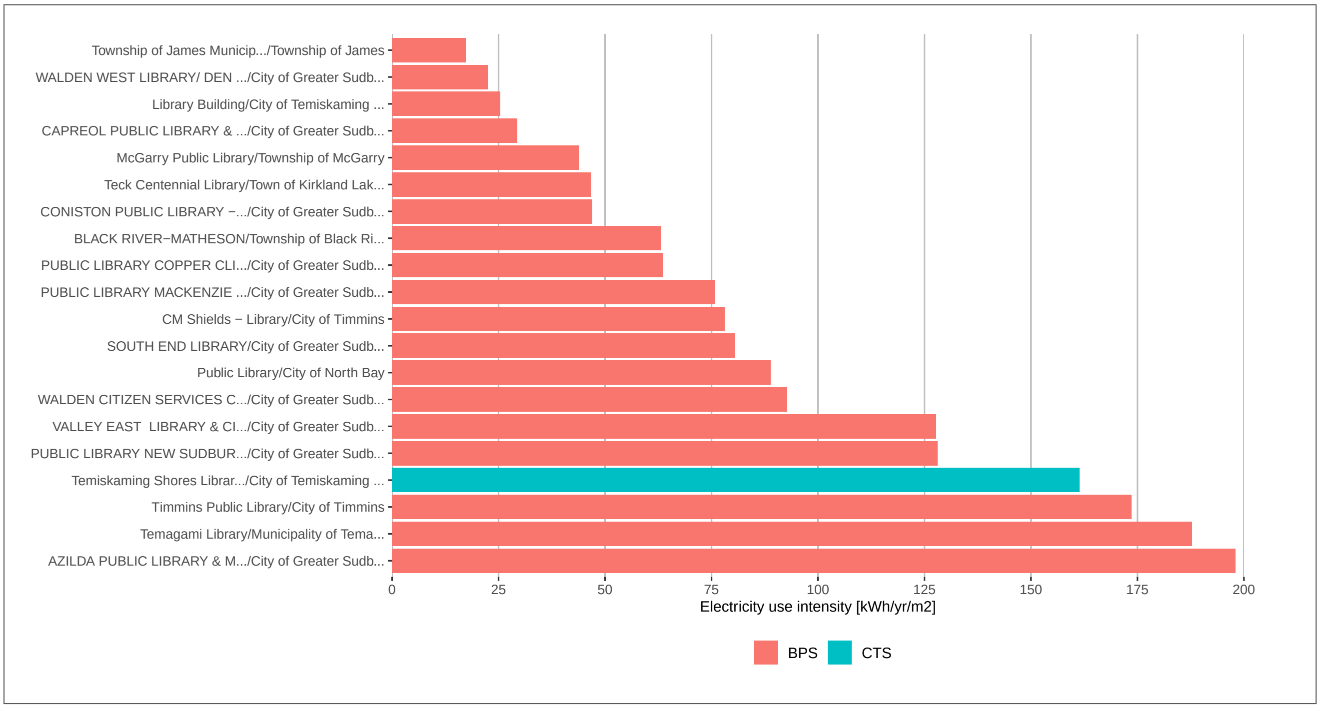


Figure 88: Electricity use intensity benchmarking analysis comparison

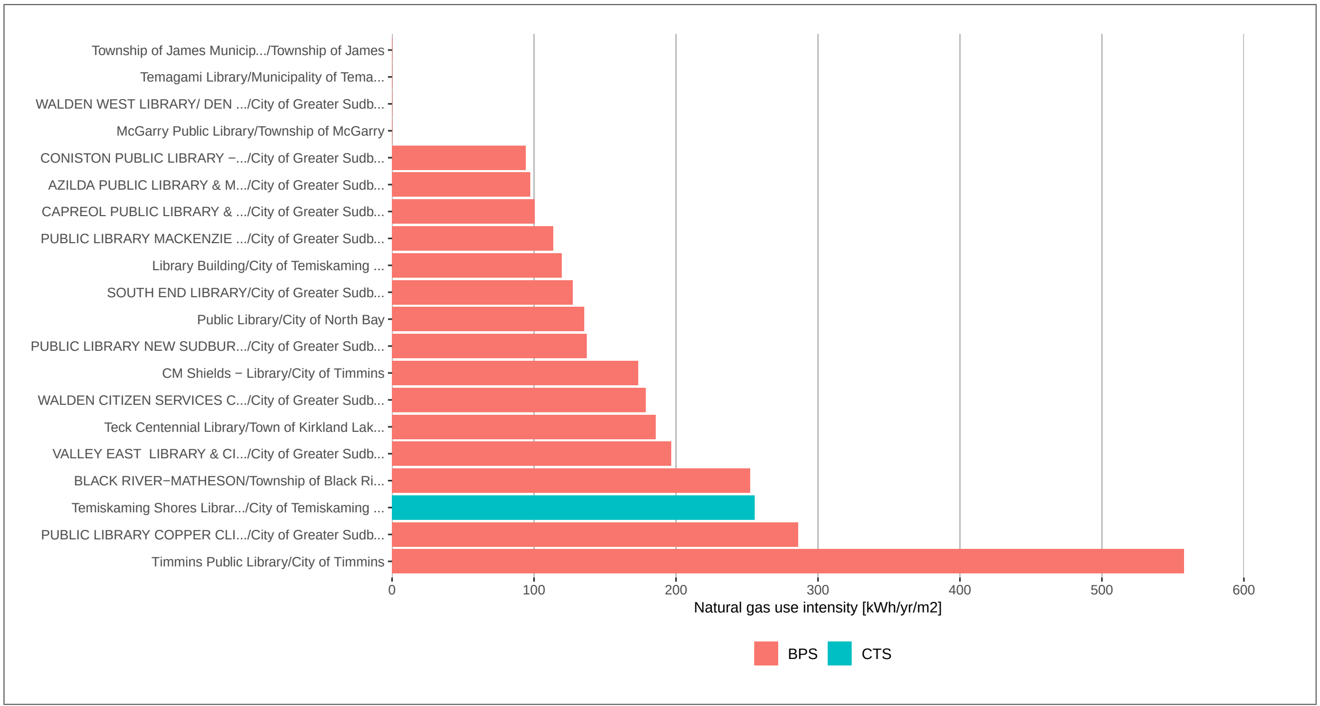


Figure 89: Natural gas use intensity benchmarking analysis comparison

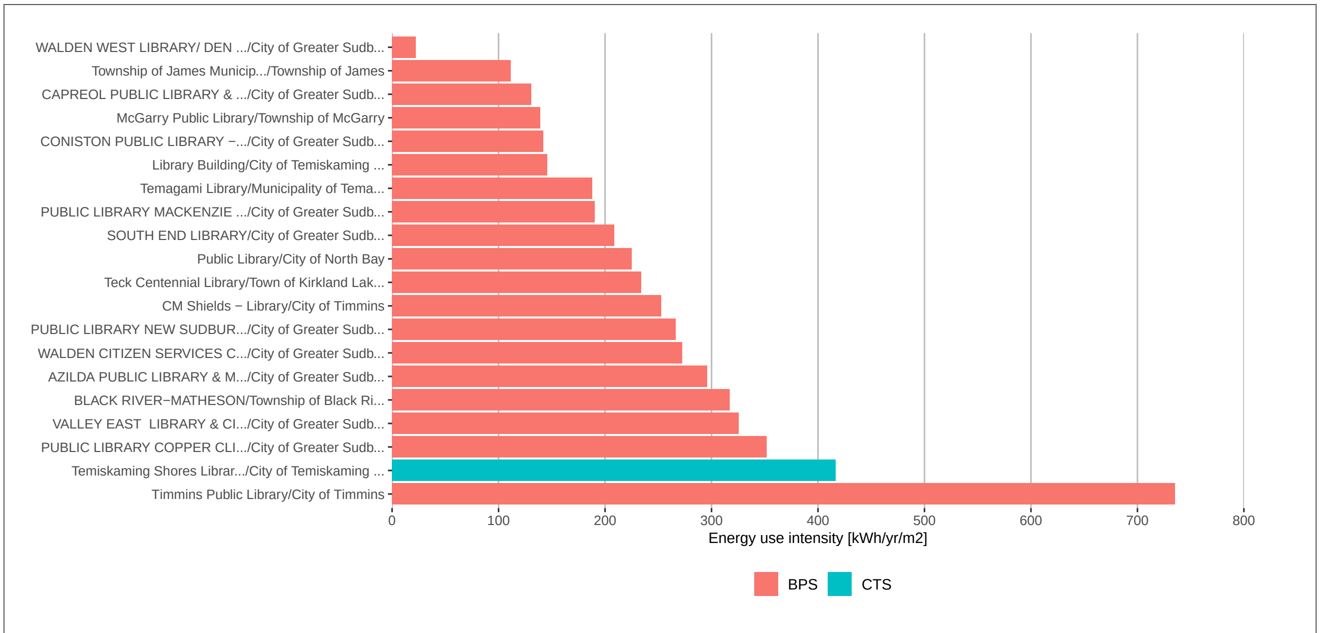


Figure 90: Total energy use intensity benchmarking analysis comparison

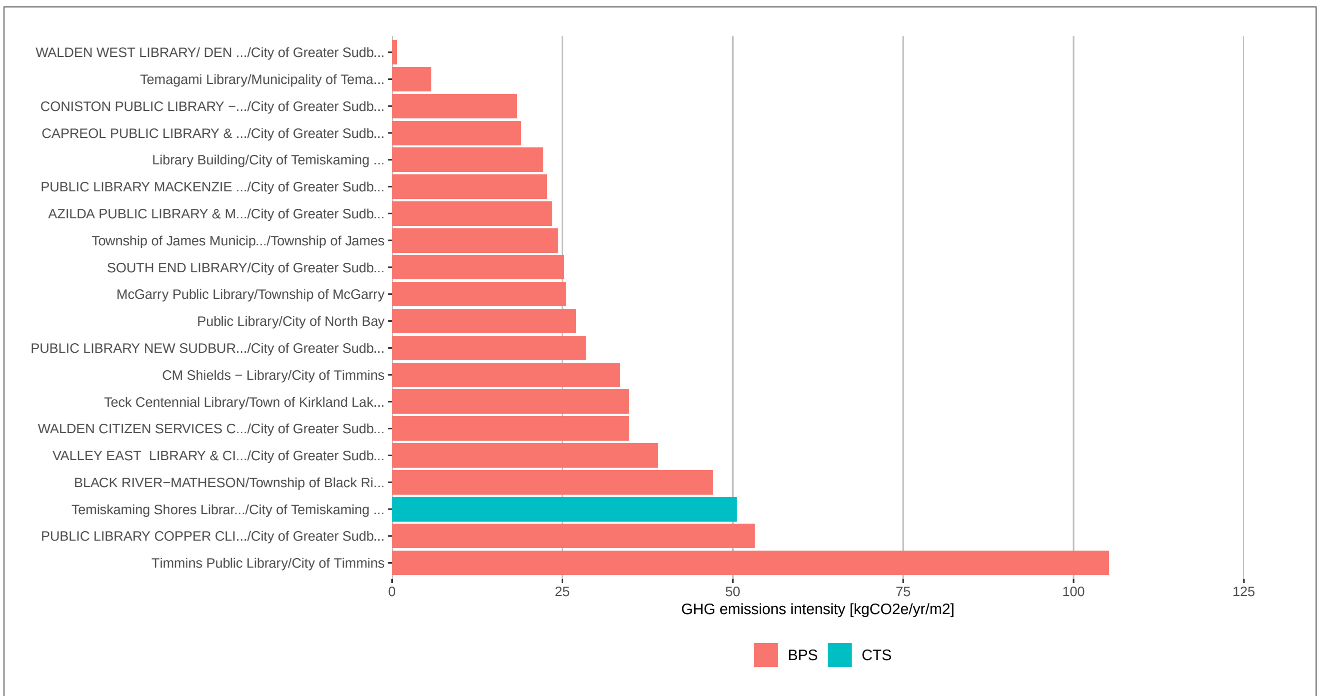


Figure 91: GHG emissions intensity benchmarking analysis comparison

3.7 ENERGY STAR Portfolio Manager benchmarking analysis

The scorecard is shown in Figure 92.

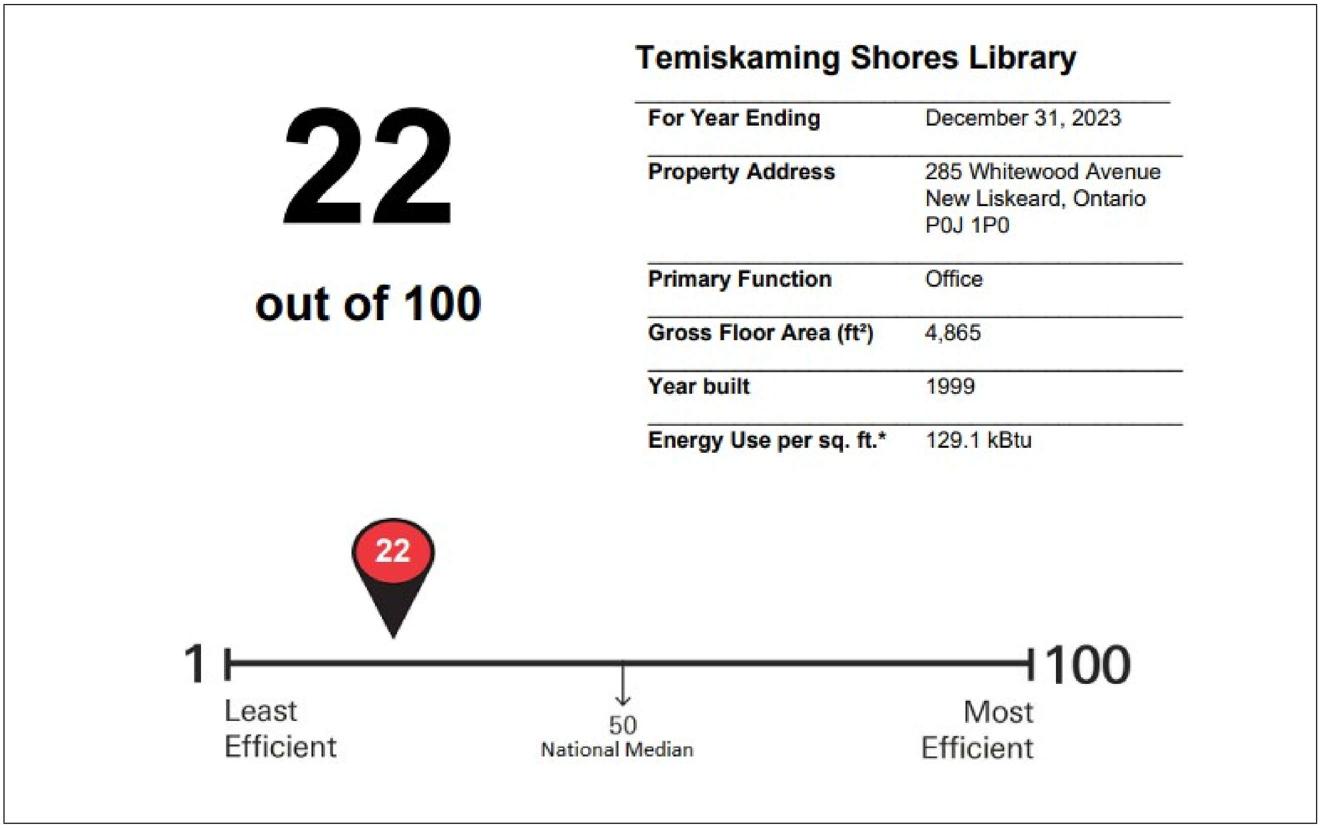


Figure 92: Energy Star energy performance scorecard.

3.8 Utility use analysis discussion

General

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

Electricity - Hourly

- Hourly electricity consumption typically peaks during the winter and summer, most likely due to heating and cooling.
- Hourly consumption is typically under 20 kWh and above 5 kWh
- A "W-shape" profile suggests heating in the winter and cooling in the summer.

Electricity - Monthly

- **2019**: Consumption dropped from January to May and stayed low from June to October, as the facility (which used to be a medical centre) closed down. Consumption spiked in November and December, which is likely due to the renovations to turn the facility into a library.
- **2020**: Consumption was high from January to April and dropped in May and June, which is likely the result of building renovations. In July, the electricity use increases and remains fairly constant for the rest of the year as the facility is opened as a library.
- **2021**: The electricity consumption reaches a relatively stable value, with peaks in the winter months due to electric heating.
- **2022**: Consumption is similar to 2021.
- **2023**: Consumption is similar to 2021 and 2022.

Natural gas

- Data is not available for natural gas consumption before August 2022. However, from what is visible, natural gas consumption appears to have maintained a consistent profile. It is highest during the heating season and very low during the cooling season.
- Natural gas consumption in the summer is likely due to the boiler plant operating during cooler nights.
- Of the seventeen data points available for monthly natural gas consumption, only 7 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	Cooling	Cooling energy use.
	DHW heat	Domestic hot water heating energy use.
	Equipment	Equipment energy use.
	Exterior lights	Exterior lighting energy use.
	Fans	Fan motor energy use.
	Lights	Lighting energy use.
	Other	Metered use less modelled use.
	Pumps	Pump motor energy use.
	Space heat	Space heating energy use.
Natural gas	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 93. See Table 17 for end use definitions.

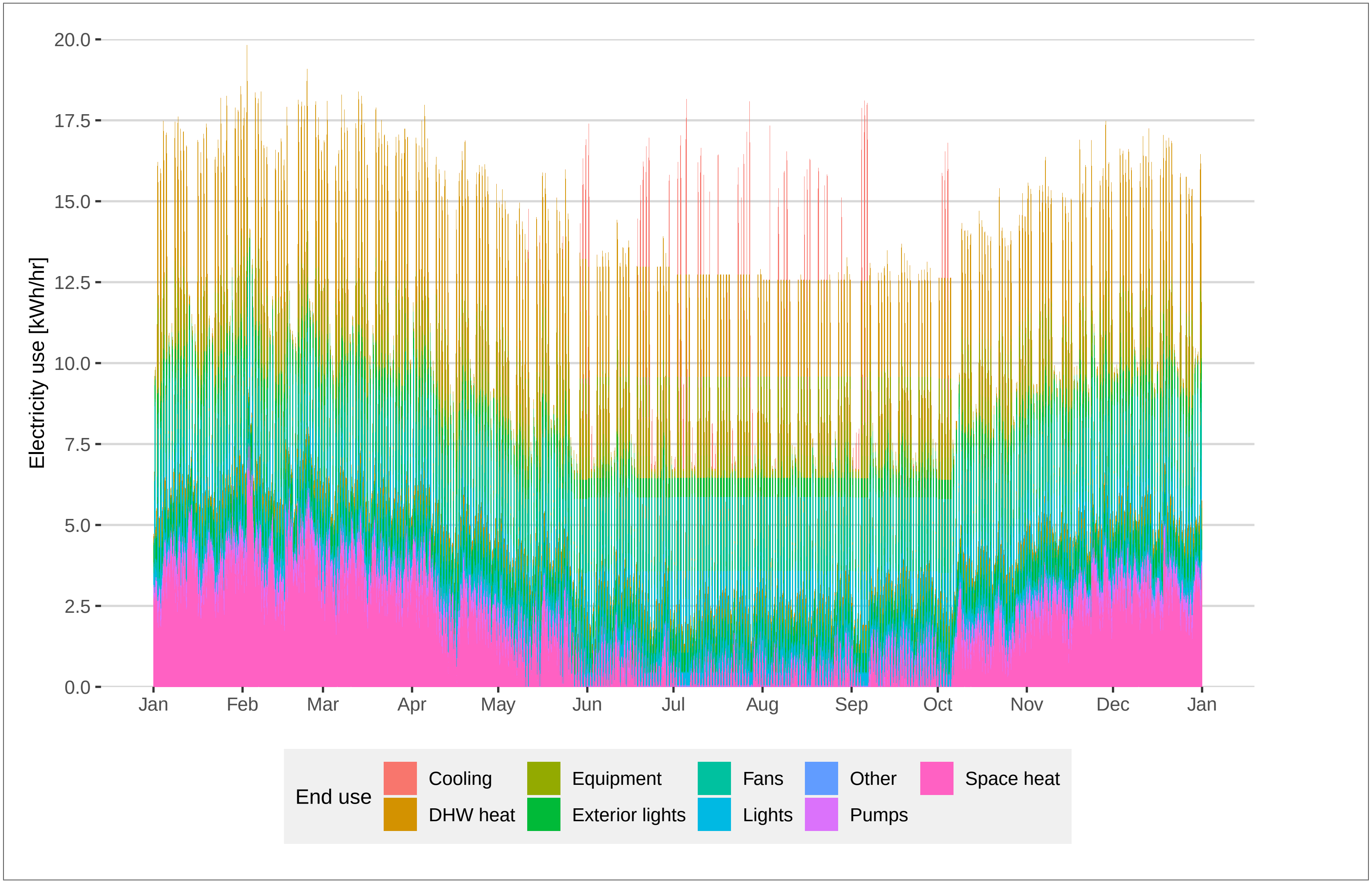


Figure 93: Hourly electricity utility use by end use (made by calibrated energy model)

Natural gas

The hourly natural gas utility use profile by end use made by the energy model is plotted in Figure 94. See Table 17 for end use definitions.

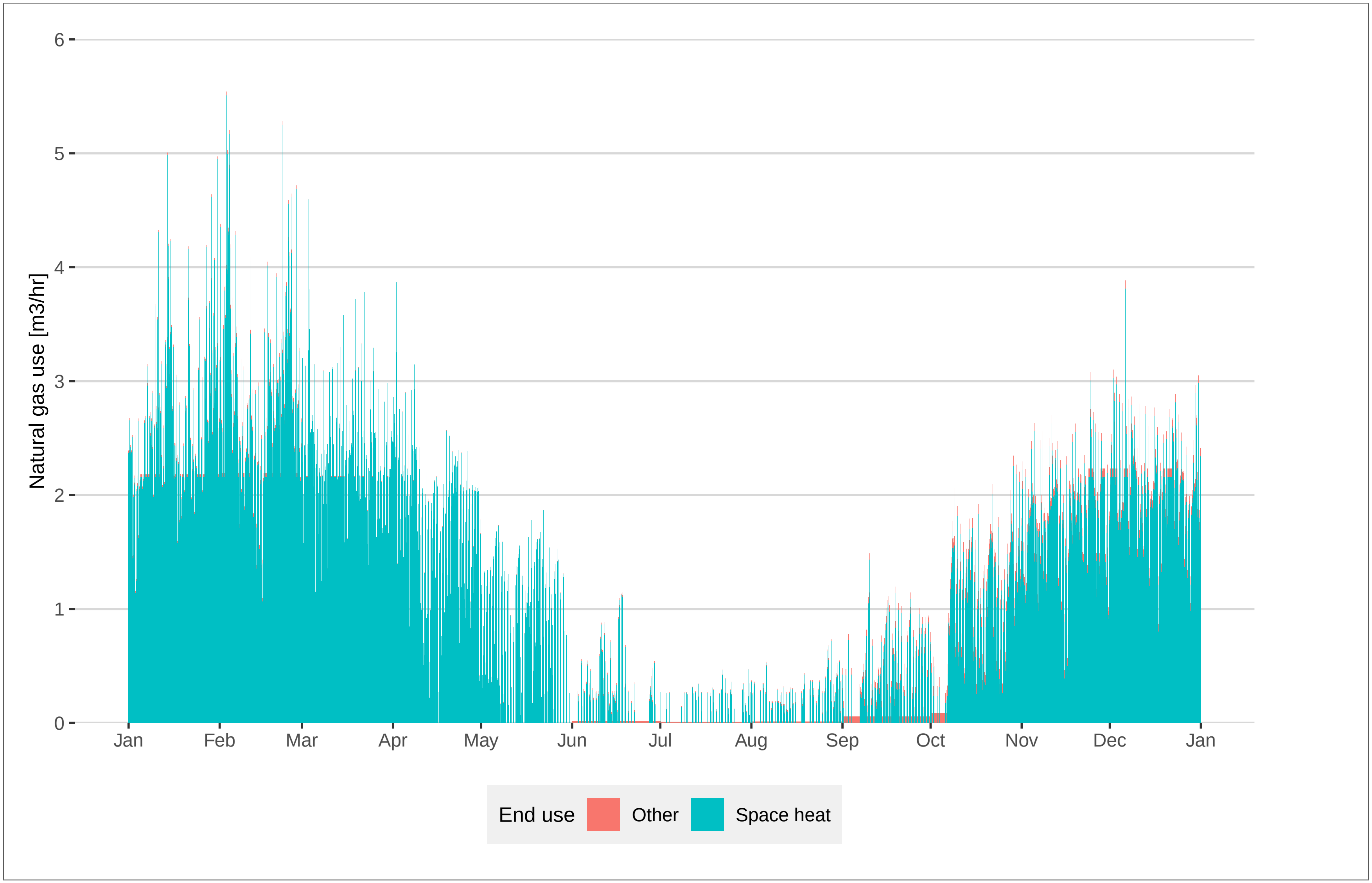


Figure 94: Hourly natural gas utility use by end use (made by calibrated energy model)

4.3 Monthly utility use profiles

Monthly utility use profiles for each modelled utility are presented in Figure 95.

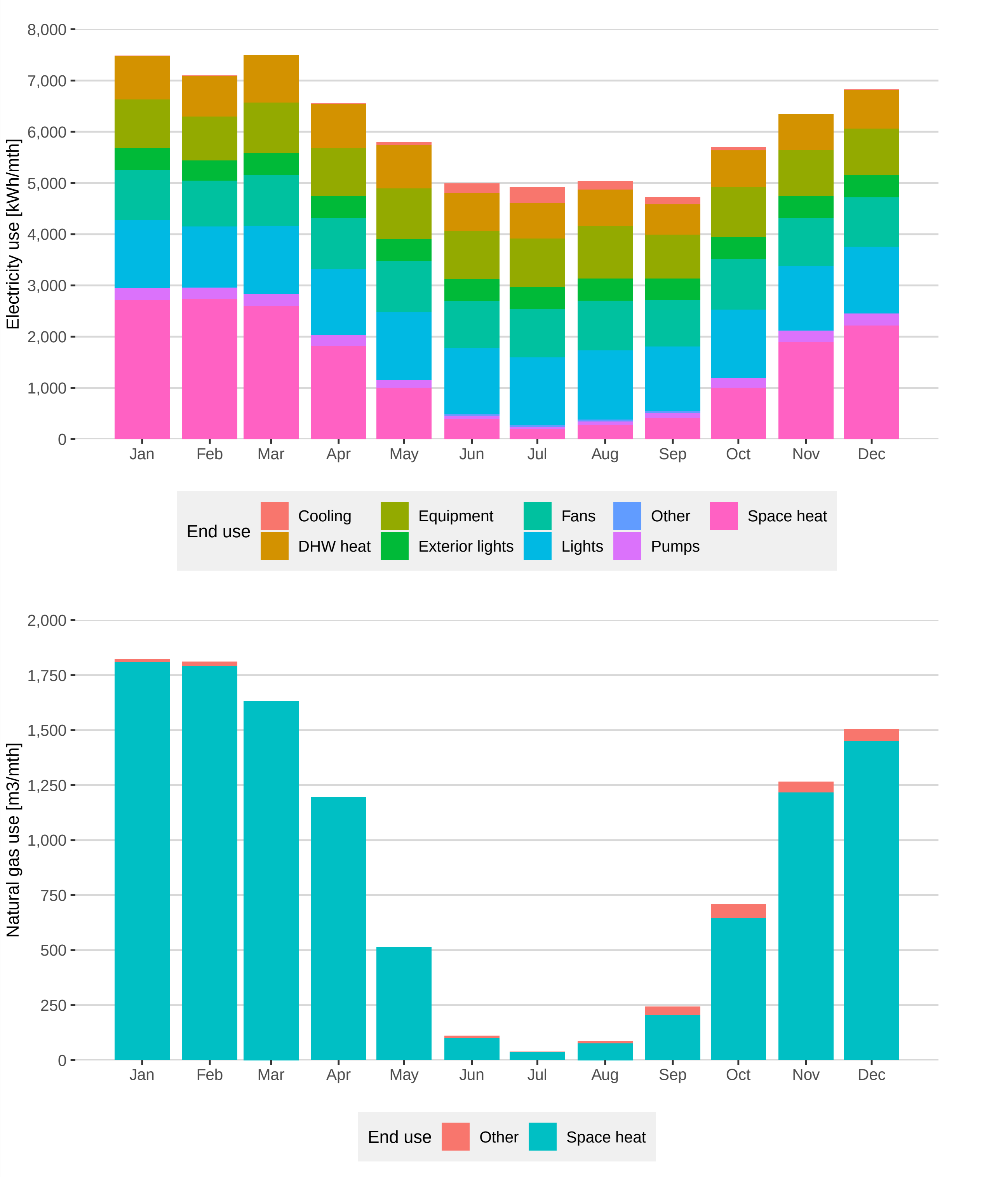


Figure 95: Monthly utility use profiles for each modelled utility

4.4 Calibration analysis

Electricity

Figure 96 compares the metered utility use with the modelled use to check how well the model is calibrated.

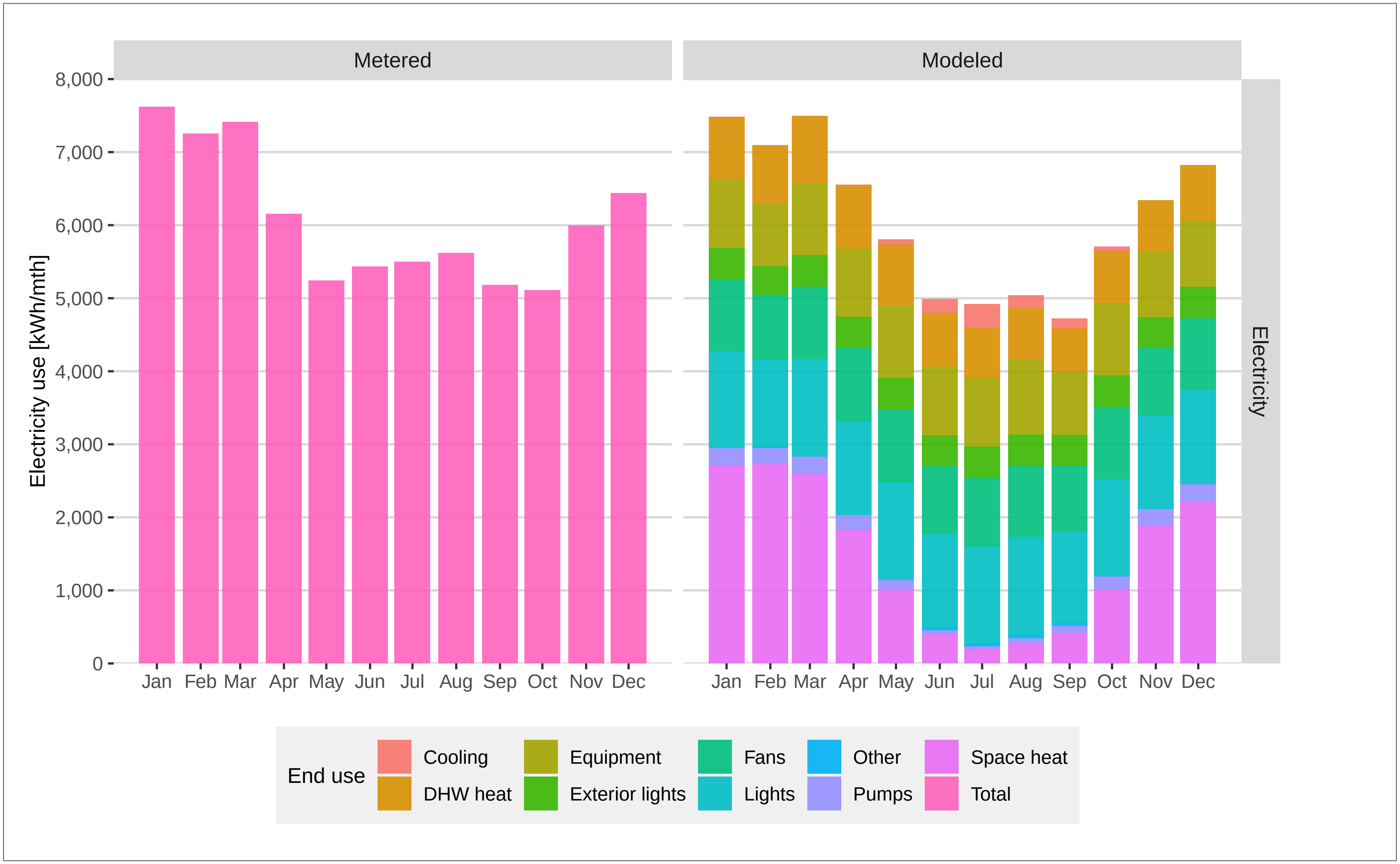


Figure 96: Electricity calibration analysis (metered vs modelled utility use)

Natural gas

Figure 97 compares the metered utility use with the modelled use to check how well the model is calibrated.

Figure 97: 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	7.4	Pass
Natural gas	Mean bias error	[%]	< +/- 5	0.0	Pass
	Root mean square error	[%]	< 15	16.4	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 96 and 97 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 use was successfully calibrated according to the standards of ASHRAE Guideline 14.
- Natural gas consumption fails to follow Guideline 14 on the root mean square error. Some notable issues are that consumption is higher in the model from March through May. Another note is that only 6 of 12 natural gas readings are actual readings. This issue makes it difficult to calibrate the model, especially against 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 and control sequences from analyzing the building automation system (BAS), so that these systems could be explicitly modelled one-to-one, precisely reflecting the unique operations associated with each system.
- Therefore, there can be confidence that the utility use impacts quantified in the various measure and scenario analyses under this report are reasonable.

Electricity

- Figure 96 indicates strong agreement between modelled and metered data.
- The peak and trough hourly consumption align with the metered interval data.

Natural gas

- Figure 97 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 98. See Table 17 for end use definitions.

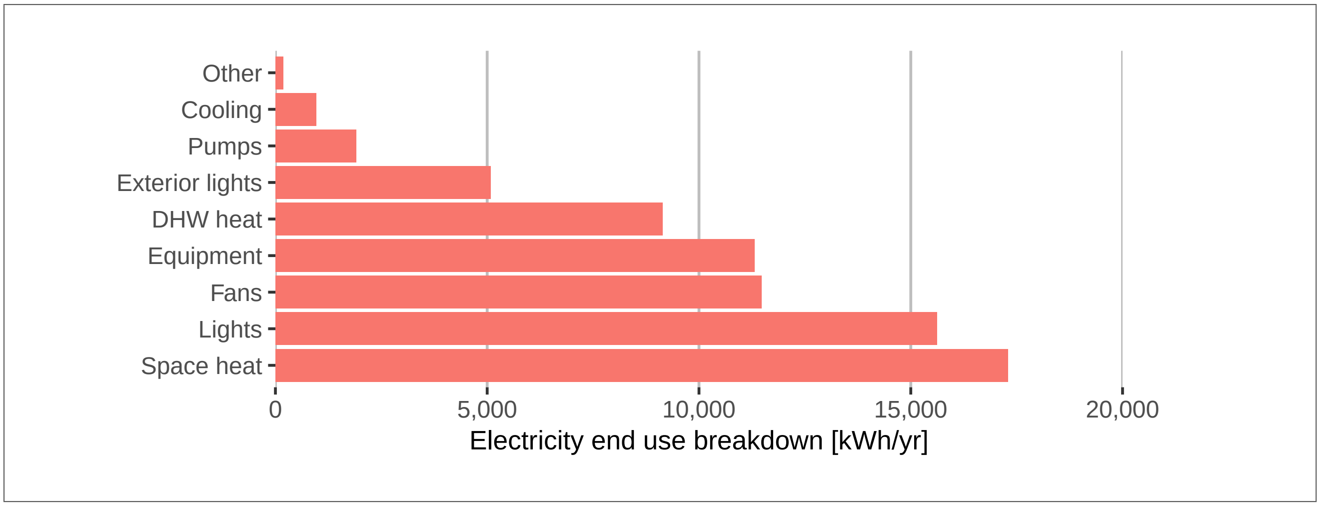


Figure 98: Electricity end use breakdown (calculated by calibrated energy model)

Natural gas

The yearly natural gas end use breakdown calculated by the energy model is plotted in Figure 99. See Table 17 for end use definitions.

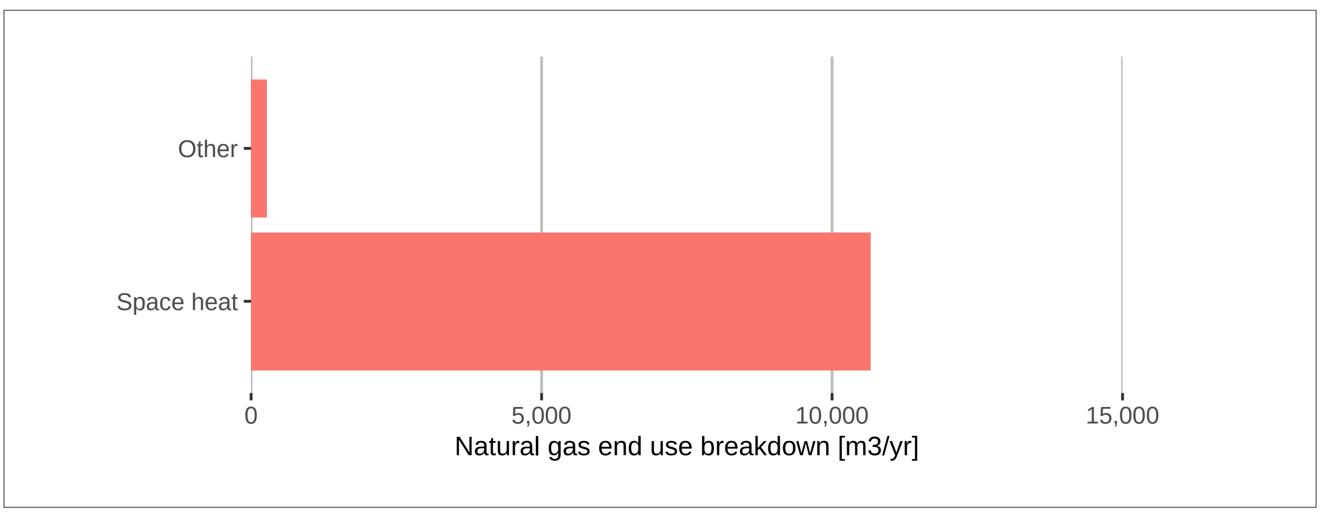


Figure 99: Natural gas end use breakdown (calculated by calibrated energy model)

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 5.14). 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 5.15.

4. **Measure analysis summary**. Measure analysis results for all measures were summarized in table format in Section 5.16.

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

- 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	
Boiler plant to ASHP hybrid	Analyzed.
Carbon offsets 20	Analyzed.
Envelope air sealing	Analyzed.
Exterior lighting control	Analyzed.
HVAC re-commissioning	Analyzed.
Roof upgrade to high performance	Analyzed.
RTU to ASHP with electric backup	Analyzed.
RTU to ASHP with natural gas backup	Analyzed.
Solar PV rooftop	Analyzed.
Wall upgrade to high performance	Analyzed.
Windows and doors to high performance	Analyzed.
Boiler renewal	Business as usual.
DHW renewal	Business as usual.
Exterior walls renewal	Business as usual.
Roof renewal	Business as usual.
RTU renewal	Business as usual.
Windows and doors renewal	Business as usual.
Exterior LED lighting upgrade	Not analyzed: already LED.
Interior LED lighting upgrade	Not analyzed: already LED.
Faucet aerators	Not analyzed: already low flow.
DHW to ASHP	Not analyzed: DHW is already electric.
Solar PV canopy	Not analyzed: there is limited parking at this facility.

5.4 Boiler plant to ASHP hybrid

Measure description

Existing condition

Two natural gas-fired condensing boilers provide hot water to radiant panels. The radiant panels are divided into 8 zones.

Opportunity

Convert the boiler plant to a hybrid ASHP and natural gas-fired boiler plant, in which ASHP is the primary heat source, and natural gas is the backup. This option is considered a potentially more cost-efficient option for GHG abatement than complete conversion to ASHP.

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 lead boiler with a 20T ASHP and 200USG buffer tank. The unit shall be sized to provide baseload heating for hydronic coils, radiant floor and snow-melt systems. Maintain an existing boiler for supplemental heating.

The new A2W heat pump shall be installed at grade outside of the mechanical room. Glycol piping shall be routed back to the mechanical room and tie into the existing hydronic system. Loading for this measure assumes the existing loads will be operated at a lower temperature and the Air Handler is replaced with an ASHP such that the associate load on the hot water plant is reduced. The existing mechanical room has limited space and may not be able to support the buffer tank. Other areas of the building should be considered before proceeding with this measure.

The sequence of operations shall be as follows:

- The heat pump shall be operated to maintain the buffer tank temperature based on an outdoor reset.
- A warm weather shut down temperature shall ensure the system does not operate in heating when the outdoor temperature exceeds 12C.
- The boiler shall be controlled based on an outdoor reset to maintain a supply temperature to the building and shall optimized to based on the building load and capacity of the heat pump.

Electrical

Electrically this measure may be possible, however a fluke meter recording peak demand at maximum 15-minute intervals is required to ensure sufficient capacity. The ASHP will add approximately 30 kW of power to the existing system, putting the system at 77.4 kW, which is approximately 67% of the full load of the electrical capacity of the building.

Project cost estimate

Table 24: Project cost estimate (Boiler plant to ASHP hybrid)

Category	Line item	Unit	Value
Construction	Supply	[$]	90,000
	Install	[$]	60,000
	Electrical contingency (does not include service upgrade)	[$]	20,000
	General requirements (25%)	[$]	42,500
Contingency	Subtotal after Construction	[$]	212,500
	Design Contingency (25%)	[$]	53,100
	Construction Contingency (10%)	[$]	21,200
Design, Contractors, PM	Subtotal after Contingency	[$]	286,800
	Engineering Design and Field Review (10%)	[$]	28,700
	Contractor Fee (7%)	[$]	20,100
Total	Total	[$]	335,600

Utility analysis

Utility analysis methodology

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

- **Baseline**. The boilers have a thermal efficiency of 91%.
- **Proposed**. One boiler is replaced by an air-source heat pump with an average heating COP of 3. Backup heating is provided through natural gas when the outdoor air temperature is below -15 C.

Utility analysis results

Table 25: Boiler plant to ASHP hybrid analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	72,966	94,748	-21,783	-29.9
	Natural gas use	[m3/yr]	10,931	4,367	6,564	60.0
	Carbon offset use	[tCO2e/yr]	0	0	0	—
Equivalent energy use	Electricity energy	[kWh/yr]	72,966	94,748	-21,783	-29.9
	Natural gas energy	[kWh/yr]	115,397	46,104	69,293	60.0
	Total energy	[kWh/yr]	188,363	140,852	47,511	25.2
GHG emissions	Electricity GHGs	[tCO2e/yr]	1.7	2.3	-0.52	-29.9
	Natural gas GHGs	[tCO2e/yr]	21.1	8.4	12.7	60.0
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	—
	Total GHGs	[tCO2e/yr]	22.9	10.7	12.2	53.2
Utility cost	Electricity utility cost	[$/yr]	7,238	9,399	-2,161	-29.9
	Natural gas utility cost	[$/yr]	2,842	1,135	1,707	60.0
	Carbon offsets utility cost	[$/yr]	0	0	0	—
	Federal carbon charge	[$/yr]	1,056	422	634	60.0
	Total utility cost	[$/yr]	11,136	10,956	180	1.6
Financial	Assumed life	[yrs]	15	15	—	—
	Project cost	[$]	0	335,600	—	—
	Incentive amount	[$]	0	67,120	—	—
	Incremental project cost	[$]	0	268,480	—	—
	Life cycle cost	[$]	286,753	642,917	—	—
	Net present value	[$]	0	-356,164	—	—
	Project cost per GHG reduction	[$yr/tCO2e]	—	22,073	—	—
	Simple payback period	[yr]	—	>20	—	—

5.5 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 associated with the use of energy of the facility while in operation.
- **Avoided emissions**. GHG emissions avoided through activities such as exporting green power to local grids, or the purchase of carbon offsets.

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

This measure focuses on the on-going 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 on-going 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 definition of Net-Zero include exporting green power, or the purchase of carbon offsets. Green power exports include the exporting 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 electricity used by the building, but cannot be used to offset natural gas used by the building (and vice versa). RECs are typically considered best practise 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 avoided emissions recognized by CaGBC. Carbon offsets are purchased per tonne of GHG emissions, and 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 CaGBCs Zero Carbon Building Standard, which is required to uphold 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 26: Carbon offsets 20 analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	72,966	72,966	0	0
	Natural gas use	[m3/yr]	10,931	10,931	0	0
	Carbon offset use	[tCO2e/yr]	0	4.6	-4.6	–
Equivalent energy use	Electricity energy	[kWh/yr]	72,966	72,966	0	0
	Natural gas energy	[kWh/yr]	115,397	115,397	0	0
	Total energy	[kWh/yr]	188,363	188,363	0	0
GHG emissions	Electricity GHGs	[tCO2e/yr]	1.7	1.7	0	0
	Natural gas GHGs	[tCO2e/yr]	21.1	21.1	0	0
	Carbon offsets GHGs	[tCO2e/yr]	0	-4.6	4.6	–
	Total GHGs	[tCO2e/yr]	22.9	18.3	4.6	20.0
Utility cost	Electricity utility cost	[$/yr]	7,238	7,238	0.00	0.00
	Natural gas utility cost	[$/yr]	2,842	2,842	-0.00	-0.00
	Carbon offsets utility cost	[$/yr]	0	137	-137	–
	Federal carbon charge	[$/yr]	1,056	1,056	0	0
	Total utility cost	[$/yr]	11,136	11,274	-137	-1.2
Financial	Assumed life	[yrs]	15	20	–	–
	Project cost	[$]	0	–	–	–
	Incentive amount	[$]	0	0	–	–
	Incremental project cost	[$]	0	–	–	–
	Life cycle cost	[$]	286,753	289,255	–	–
	Net present value	[$]	0	-2,502	–	–
	Project cost per GHG reduction	[$yr/tCO2e]	–	–	–	–
	Simple payback period	[yr]	–	–	–	–

5.6 Envelope air sealing

Measure description

Existing condition

There is opportunity to improve the air tightness of the facility.

Opportunity

Improve the air tightness of the facility by sealing lap gaps in the interior and exterior.

Utility-savings mechanism

Reduced heating load due to reduce infiltration.

Design description

Overview

Seal large gaps on interior and exterior identified by air tightness testing.

Poor air tightness can result in increased outdoor air infiltration and increased thermal loads on the building. This problem is exacerbated in extreme weather events, during which maintaining thermal comfort in the facility will be difficult. By sealing gaps in the building envelope, thermal performance can be enhanced. This will allow the building to maintain indoor air temperatures in periods of extreme hot/cold weather. Additionally, air sealing can protect the building against extreme weather events such as heavy rain and winds.

Project cost estimate

Table 27: Project cost estimate (Envelope air sealing)

Category	Line item	Unit	Value
Materials and labour	Leak mitigation in focused areas	[$]	30,000
Contingency	Subtotal after Materials and labour	[$]	30,000
	General Contingency (50%)	[$]	15,000
Total	Total	[$]	45,000

Utility analysis

Utility analysis methodology

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

- **Baseline**. Infiltration through the exterior wall was assumed to take place at an average flow rate of 0.25 Lps/m2 of exposed envelope area.
- **Proposed**. Infiltration through exterior walls was assumed to be reduced by 20% relative to what was assumed for the baseline scenario.

Utility analysis results

Table 28: Envelope air sealing analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	72,966	72,945	20.6	0.03
	Natural gas use	[m3/yr]	10,931	10,198	733	6.7
	Carbon offset use	[tCO2e/yr]	0	0	0	—
Equivalent energy use	Electricity energy	[kWh/yr]	72,966	72,945	20.6	0.03
	Natural gas energy	[kWh/yr]	115,397	107,660	7,737	6.7
	Total energy	[kWh/yr]	188,363	180,605	7,758	4.1
GHG emissions	Electricity GHGs	[tCO2e/yr]	1.7	1.7	0.00	0.03
	Natural gas GHGs	[tCO2e/yr]	21.1	19.7	1.4	6.7
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	—
	Total GHGs	[tCO2e/yr]	22.9	21.4	1.4	6.2
Utility cost	Electricity utility cost	[$/yr]	7,238	7,236	2.0	0.03
	Natural gas utility cost	[$/yr]	2,842	2,652	191	6.7
	Carbon offsets utility cost	[$/yr]	0	0	0	—
	Federal carbon charge	[$/yr]	1,056	985	70.8	6.7
	Total utility cost	[$/yr]	11,136	10,873	263	2.4
Financial	Assumed life	[yrs]	15	15	—	—
	Project cost	[$]	0	45,000	—	—
	Incentive amount	[$]	0	183	—	—
	Incremental project cost	[$]	0	44,817	—	—
	Life cycle cost	[$]	286,753	336,125	—	—
	Net present value	[$]	0	-49,372	—	—
	Project cost per GHG reduction	[$yr/tCO2e]	—	31,633	—	—
	Simple payback period	[yr]	—	>20	—	—

5.7 Exterior lighting control

Measure description

Existing condition

Exterior lighting was observed to be ON during the site visit while the sun was out.

Opportunity

Implement photocell control for exterior lighting.

Utility-savings mechanism

Reduced electricity use by turning lights off when possible.

Design description

Overview

Install a photocell on the south elevation of the building and wire back to the exterior lighting circuit in the janitor room. The exterior lighting is on circuit 4 of Panel A. A contractor can be installed to enable or disable power to the lights.

Project cost estimate

Table 29: Project cost estimate (Exterior lighting control)

Category	Line item	Unit	Value
Materials and labour	Supply and install	[$]	1,500
Contingency	Subtotal after Materials and labour	[$]	1,500
	General Contingency (50%)	[$]	800
Total	Total	[$]	2,300

Utility analysis

Utility analysis methodology

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

- **Baseline**. The exterior light was ON 24/7.
- **Proposed**. The exterior light was controlled by a photocell, and turned OFF during the day.

Utility analysis results

Table 30: Exterior lighting control analysis results summary

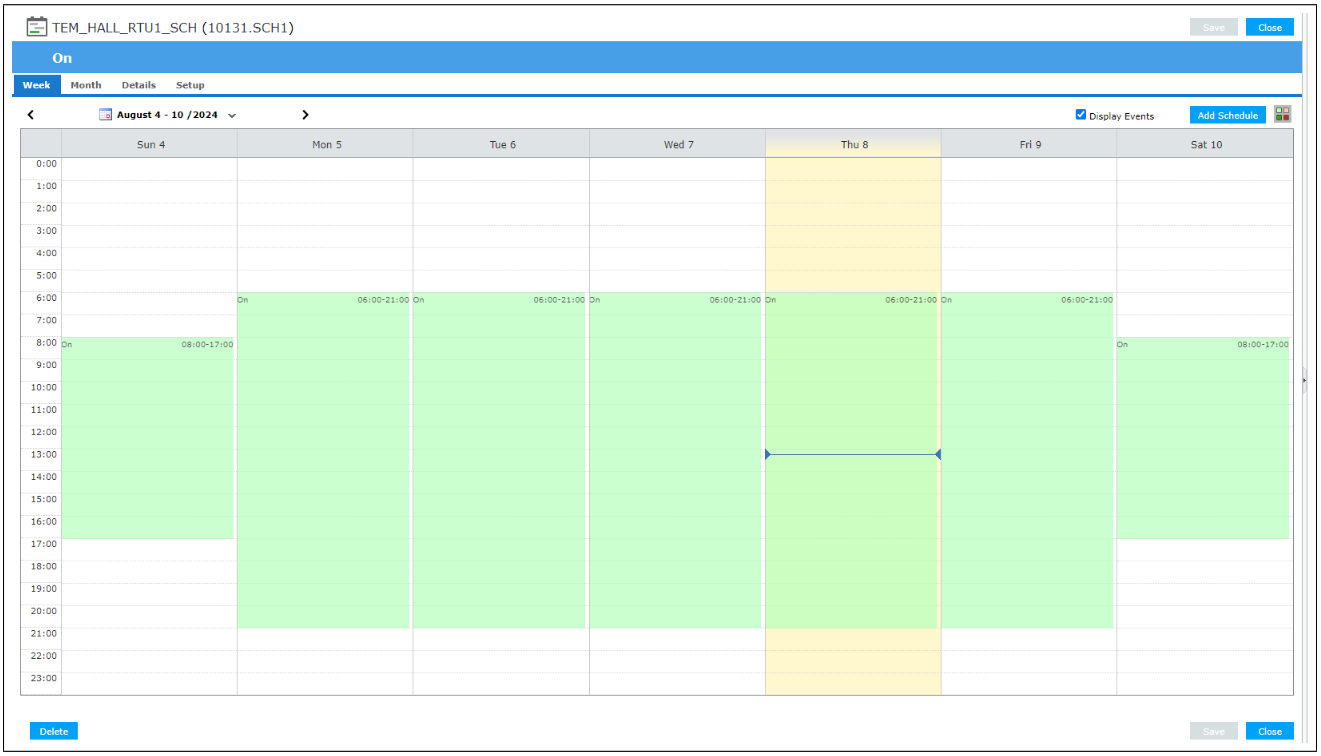
Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	72,966	70,415	2,551	3.5
	Natural gas use	[m3/yr]	10,931	10,931	0	0
	Carbon offset use	[tCO2e/yr]	0	0	0	–
Equivalent energy use	Electricity energy	[kWh/yr]	72,966	70,415	2,551	3.5
	Natural gas energy	[kWh/yr]	115,397	115,397	0	0
	Total energy	[kWh/yr]	188,363	185,812	2,551	1.4
GHG emissions	Electricity GHGs	[tCO2e/yr]	1.7	1.7	0.06	3.5
	Natural gas GHGs	[tCO2e/yr]	21.1	21.1	0	0
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	–
	Total GHGs	[tCO2e/yr]	22.9	22.8	0.06	0.27
Utility cost	Electricity utility cost	[$/yr]	7,238	6,985	253	3.5
	Natural gas utility cost	[$/yr]	2,842	2,842	0	0
	Carbon offsets utility cost	[$/yr]	0	0	0	–
	Federal carbon charge	[$/yr]	1,056	1,056	0	0
	Total utility cost	[$/yr]	11,136	10,883	253	2.3
Financial	Assumed life	[yrs]	15	15	–	–
	Project cost	[$]	0	2,300	–	–
	Incentive amount	[$]	0	0	–	–
	Incremental project cost	[$]	0	2,300	–	–
	Life cycle cost	[$]	286,753	282,825	–	–
	Net present value	[$]	0	3,928	–	–
	Project cost per GHG reduction	[$yr/tCO2e]	–	37,726	–	–
	Simple payback period	[yr]	–	9.1	–	–

5.8 HVAC re-commissioning

Measure description

Existing condition

On the BAS, the occupancy schedule for AHU1 appeared to be linked to RTU1 at City Hall, and did not match the library's occupancy hours. AHU1's occupied and unoccupied setpoints are the same, with no temperature setbacks.



Opportunity

The City is recommended to undergo a formal re-commissioning program to optimize existing BAS controls.

Utility-savings mechanism

Implementing this measure will save natural gas and electricity by optimizing BAS controls.

Design description

Overview

Conduct a retro-commissioning exercise for the HVAC systems serving the facility.

It is recommended that the commissioning exercise be conducted according to the following steps.

- Meet with the users of the space and the building operators to identify and document the specific requirements of the spaces in terms of occupancy, setpoints, and airflow requirements.
- Investigate the existing project documentation, including design drawings, controls as-builts, testing and balancing information, and commissioning reports to learn how the systems were originally set up to operate.
- Execute virtual functional testing on the systems to confirm the proper operation of individual components and overall systems.

- Identify opportunities for the repair of failed components and for the improvement of control sequences with respect to energy efficiency and to better meet the goals of the facility.
- Implement agreed-upon measures with the assistance of a controls contractor and other contractors as required.
- Ensure that the building operators and occupants are trained on changes that are implemented and trained on how to optimally operate the systems and make required changes.

As part of the process, the following items are to be optimized at a minimum:

- Scheduling of air handling units according to user requirements
- Limiting the OA provided at each air handler to the unit to the occupancy requirements
- Coordination of heating and cooling setpoints between adjacent units to prevent simultaneous heating and cooling
- Setback of temperature setpoints during unoccupied periods.
- Economizer control on air handling units.
- Boiler supply water reset schedules.
- Boiler cycling periods.

The costing provided below is an estimate for the investigation phase of the work. Costs for implementing any energy-saving measures would be in addition to the pricing below. Pricing is based on a virtual review of the existing BAS, and must include the recommissioning measures noted in the City Hall and Waterfront Pool and Fitness Centre reports.

- Virtual meeting with the controls contractor supplied by the City.
- Provide action items in a brief report to be provided to the controls contractor.
- Virtual meeting with the controls contractor to clarify any issues.

Exclusions:

- This work does not include pricing for the controls contractor or replacement parts.
- Does not include a site visit by the controls engineer.

Project cost estimate

Table 31: Project cost estimate (HVAC re-commissioning)

Category	Line item	Unit	Value
Materials and labour	EBCx Consultant Fee (Desktop review)	[$]	5,000
	Allowance for Controls Contractor Assistance - Investigation Phase	[$]	20,000
Contingency	Subtotal after Materials and labour	[$]	25,000
	General Contingency (50%)	[$]	12,500
Total	Total	[$]	37,500

Utility analysis

Utility analysis methodology

Baseline: The HVAC controls remain as is.

Proposed: Optimize schedules to follow occupancy and turn on only to meet the temperature. Implement temperature setbacks of 2F during unoccupied hours.

Utility analysis results

Table 32: HVAC re-commissioning analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	72,966	69,680	3,286	4.5
	Natural gas use	[m3/yr]	10,931	9,665	1,266	11.6
	Carbon offset use	[tCO2e/yr]	0	0	0	—
Equivalent energy use	Electricity energy	[kWh/yr]	72,966	69,680	3,286	4.5
	Natural gas energy	[kWh/yr]	115,397	102,031	13,366	11.6
	Total energy	[kWh/yr]	188,363	171,711	16,652	8.8
GHG emissions	Electricity GHGs	[tCO2e/yr]	1.7	1.7	0.08	4.5
	Natural gas GHGs	[tCO2e/yr]	21.1	18.7	2.4	11.6
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	—
	Total GHGs	[tCO2e/yr]	22.9	20.3	2.5	11.0
Utility cost	Electricity utility cost	[$/yr]	7,238	6,912	326	4.5
	Natural gas utility cost	[$/yr]	2,842	2,513	329	11.6
	Carbon offsets utility cost	[$/yr]	0	0	0	—
	Federal carbon charge	[$/yr]	1,056	934	122	11.6
	Total utility cost	[$/yr]	11,136	10,359	777	7.0
Financial	Assumed life	[yrs]	15	15	—	—
	Project cost	[$]	0	37,500	—	—
	Incentive amount	[$]	0	0	—	—
	Incremental project cost	[$]	0	37,500	—	—
	Life cycle cost	[$]	286,753	316,361	—	—
	Net present value	[$]	0	-29,608	—	—
	Project cost per GHG reduction	[$yr/tCO2e]	—	14,851	—	—
	Simple payback period	[yr]	—	>20	—	—

5.9 Roof upgrade to high performance

Measure description

Existing condition

The gable roof likely consists of two components: (a) above the main interior spaces, there are wood trusses with batt insulation in the attic/truss space, topped with an asphalt shingle finish; and (b) above the entry vestibule, there are angled wood joists with rigid or semi-rigid insulation attached to the sheathing, also finished with asphalt shingles.

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 current thermal performance of the existing assembly is likely no better than R20, which is only half of the minimum requirement set by the current building code for exterior insulation. Moreover, it is less than one-third of the minimum required value for attic insulation.

We recommend adding extra batt insulation to the existing truss spaces, as well as additional rigid insulation to the roof assembly above the entry vestibule. The batt insulation within the trusses should have a total depth of at least 24 inches to meet the current building code standard of R71 for attic spaces. Additionally, the rigid insulation on the entry roof should be at least 8 inches thick to achieve the minimum required R40 for this type of roof according to the current building code.

Project cost estimate

Table 33: Project cost estimate (Roof upgrade to high performance)

Category	Line item	Unit	Value
Construction	Roof replacement	[$]	284,000
	General requirements (25%)	[$]	71,000
Contingency	Subtotal after Construction	[$]	355,000
	Design Contingency (25%)	[$]	88,800
	Construction Contingency (10%)	[$]	35,500
Design, Contractors, PM	Subtotal after Contingency	[$]	479,300
	Engineering Design and Field Review (10%)	[$]	47,900
	Contractor Fee (7%)	[$]	33,600
Total	Total	[$]	560,800

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 0.035 BTU/hr.ft2.F (R26) was assumed.
- **Proposed**. An average roof U-value of 0.025 BTU/hr.ft2.F (R40) was assumed.

Utility analysis results

Table 34: Roof upgrade to high performance analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	72,966	72,909	56.2	0.08
	Natural gas use	[m3/yr]	10,931	10,497	434	4.0
	Carbon offset use	[tCO2e/yr]	0	0	0	–
Equivalent energy use	Electricity energy	[kWh/yr]	72,966	72,909	56.2	0.08
	Natural gas energy	[kWh/yr]	115,397	110,818	4,579	4.0
	Total energy	[kWh/yr]	188,363	183,727	4,636	2.5
GHG emissions	Electricity GHGs	[tCO2e/yr]	1.7	1.7	0.00	0.08
	Natural gas GHGs	[tCO2e/yr]	21.1	20.3	0.84	4.0
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	–
	Total GHGs	[tCO2e/yr]	22.9	22.0	0.84	3.7
Utility cost	Electricity utility cost	[$/yr]	7,238	7,233	5.6	0.08
	Natural gas utility cost	[$/yr]	2,842	2,729	113	4.0
	Carbon offsets utility cost	[$/yr]	0	0	0	–
	Federal carbon charge	[$/yr]	1,056	1,014	41.9	4.0
	Total utility cost	[$/yr]	11,136	10,976	160	1.4
Financial	Assumed life	[yrs]	15	20	–	–
	Project cost	[$]	0	560,800	–	–
	Incentive amount	[$]	0	112,160	–	–
	Incremental project cost	[$]	0	448,640	–	–
	Life cycle cost	[$]	286,753	758,468	–	–
	Net present value	[$]	0	-471,715	–	–
	Project cost per GHG reduction	[$yr/tCO2e]	–	534,361	–	–
	Simple payback period	[yr]	–	>20	–	–

5.10 RTU to ASHP with electric backup

Measure description

Existing condition

AHU1 is a variable volume and temperature (VVT) unit with a bypass return damper to maintain constant air through AHU1. Therefore, no VFD is present in the supply fan. AHU1 has a natural gas-fired burner with two stages, and DX cooling with two stages.

Opportunity

Replace the RTU and use an 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

Overview

This measure involves replacing the current pad mounted AHU with a packaged air source heat pump (ASHP) model equipped with electric resistance heating for cold ambient conditions when the heat pump capacity would be insufficient for the entire heating load. For the initial selection of the unit, the heating and cooling capacities were selected to match the existing equipment. As an initial selection, a Daiken 12.5 ton rooftop unit similar to model DPS012A was considered for this application. It should be noted that other manufacturers also provide similar models.

The unit is to be equipped with the following features:

- ECM variable speed supply fan motors
- Full economizer for free cooling
- Air source heat pump section
- Electric heating section
- Full controls.

The unit will control the economizer and the heat pump to satisfy cooling requests based on the space temperature setpoints. For heating, the unit can be configured to provide heating from the air-source heat pump. Once the heat pump is operating at capacity, the electric resistance will be enabled as a second stage of heat. Note that heat pump heating and electric resistance heating can be on simultaneously, allowing the heat pump to always contribute as much as possible to the heating.

The rooftop unit is provided with integral controls to efficiently control the heat pump, free cooling economizer, and electric heating. The space thermostat will be located within the facility in the same location as the current thermostat for the existing rooftop units. Thermostats and controls should be programmed to allow for scheduling, including temperature setpoint setbacks during unoccupied periods. The thermostat for the rooftop unit would be used to control the unit itself, while the existing thermostats within the individual zones would control the existing bypass dampers.

Consideration should be given to the replacement of the zone controls at the same time as the rooftop unit for an integrated control package. Zone controls should ensure that local thermostats control the bypass boxes serving the spaces as well as the electric perimeter heat in an integrated package. This option has not been included in the price estimate below.

Note that due to the extra electric resistance heating, the distribution to the unit will have to be upgraded. Replace the existing electrical feed to the unit with one (1) 200A, 208V 3-phase feed from the main service.

Electrical

The ASHP with the electric backup will add approximately 38.75 kW of power to the existing system, which will put the system at 86.15 kW, which is approximately 75% of the full load of the electrical capacity of the building.

Project cost estimate

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

Category	Line item	Unit	Value
Construction	Daiken 12.5T ASHP with Electric Resistance Back-up Heating	[$]	70,000
	Installation Cost	[$]	35,000
	Electrical distribution to unit	[$]	14,000
	General requirements (25%)	[$]	29,800
Contingency	Subtotal after Construction	[$]	148,800
	Design Contingency (25%)	[$]	37,200
	Construction Contingency (10%)	[$]	14,900
Design, Contractors, PM	Subtotal after Contingency	[$]	200,900
	Engineering Design and Field Review (10%)	[$]	20,100
	Contractor Fee (7%)	[$]	14,100
Total	Total	[$]	235,100

Utility analysis

Utility analysis methodology

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

- **Baseline**: AHU1 provides space heating and cooling through natural gas-fired burners and DX, respectively. The existing heating efficiency is 81%, and the cooling COP is 4.9.
- **Proposed**: This AHU provides space heating and cooling through air-source heat pumps. The proposed average heating and cooling COPs are 3 and 5, respectively. Backup heating is provided through electric resistance when the outdoor air temperature is below -15 C.

Utility analysis results

Table 36: RTU to ASHP with electric backup analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	72,966	86,989	-14,023	-19.2
	Natural gas use	[m3/yr]	10,931	7,835	3,096	28.3
	Carbon offset use	[tCO2e/yr]	0	0	0	–
Equivalent energy use	Electricity energy	[kWh/yr]	72,966	86,989	-14,023	-19.2
	Natural gas energy	[kWh/yr]	115,397	82,715	32,682	28.3
	Total energy	[kWh/yr]	188,363	169,704	18,659	9.9
GHG emissions	Electricity GHGs	[tCO2e/yr]	1.7	2.1	-0.34	-19.2
	Natural gas GHGs	[tCO2e/yr]	21.1	15.1	6.0	28.3
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	–
	Total GHGs	[tCO2e/yr]	22.9	17.2	5.6	24.7
Utility cost	Electricity utility cost	[$/yr]	7,238	8,629	-1,391	-19.2
	Natural gas utility cost	[$/yr]	2,842	2,037	805	28.3
	Carbon offsets utility cost	[$/yr]	0	0	0	–
	Federal carbon charge	[$/yr]	1,056	757	299	28.3
	Total utility cost	[$/yr]	11,136	11,423	-287	-2.6
Financial	Assumed life	[yrs]	15	18	–	–
	Project cost	[$]	0	235,100	–	–
	Incentive amount	[$]	0	47,020	–	–
	Incremental project cost	[$]	0	188,080	–	–
	Life cycle cost	[$]	286,753	517,374	–	–
	Net present value	[$]	0	-230,620	–	–
	Project cost per GHG reduction	[$yr/tCO2e]	–	33,305	–	–
	Simple payback period	[yr]	–	–	–	–

5.11 RTU to ASHP with natural gas backup

Measure description

Existing condition

AHU1 is a variable volume and temperature (VVT) unit with a bypass return damper to maintain constant air through AHU1. Therefore, no VFD is present in the supply fan. AHU1 has a natural gas-fired burner with two stages, and DX cooling with two stages.

Opportunity

Replace the RTU and use an 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

Overview

This measure involves replacing the current pad mounted AHU with a packaged air source heat pump (ASHP) model equipped with natural gas backup heating for cold ambient conditions when the heat pump capacity would be insufficient for the entire heating load. For the initial selection of the unit, the heating and cooling capacities were selected to match the existing equipment. As an initial selection, a Daiken 12.5 ton rooftop unit similar to model DPS012A was considered for this application. It should be noted that other manufacturers also provide similar models.

The unit is to be equipped with the following features:

- ECM variable speed supply fan motors
- Full economizer for free cooling
- Air source heat pump section
- Natural gas heating section
- Full controls.

The unit will control the economizer and the heat pump to satisfy cooling requests based on the space temperature setpoints. For heating, the unit can be configured to provide heating from the air-source heat pump. Once the heat pump is operating at capacity, the natural gas heater will be enabled as a second stage of heat. Note that heat pump heating and the natural gas heating can be on simultaneously, allowing the heat pump to always contribute as much as possible to the heating.

The rooftop unit is provided with integral controls to efficiently control the heat pump, free cooling economizer, and natural gas heating. The space thermostat will be located within the facility in the same location as the current thermostat for the existing rooftop units. Thermostats and controls should be programmed to allow for scheduling, including temperature setpoint setbacks during unoccupied periods. The thermostat for the rooftop unit would be used to control the unit itself, while the existing thermostats within the individual zones would control the existing bypass dampers.

Consideration should be given to the replacement of the zone controls at the same time as the rooftop unit for an integrated control package. Zone controls should ensure that local thermostats control the bypass boxes serving the spaces as well as the electric perimeter heat in an integrated package. This option has not been included in the price estimate below.

Electrical

The ASHP with the gas backup will add approximately 18.75 kW of power to the existing system, which will put the system at 66.15 kW, which is approximately 57% of the full load of the electrical capacity of the building.

Project cost estimate

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

Category	Line item	Unit	Value
Construction	Daiken 12.5T ASHP with Natural Gas Back-up Heating	[$]	75,000
	Installation Cost	[$]	35,000
	Electrical distribution to unit	[$]	10,000
	General requirements (25%)	[$]	30,000
Contingency	Subtotal after Construction	[$]	150,000
	Design Contingency (25%)	[$]	37,500
	Construction Contingency (10%)	[$]	15,000
Design, Contractors, PM	Subtotal after Contingency	[$]	202,500
	Engineering Design and Field Review (10%)	[$]	20,200
	Contractor Fee (7%)	[$]	14,200
Total	Total	[$]	236,900

Utility analysis

Utility analysis methodology

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

- **Baseline**: AHU1 provides space heating and cooling through natural gas-fired burners and DX, respectively. The existing heating efficiency is 81%, and the cooling COP is 4.9.

- **Proposed**: This AHU provides space heating and cooling through air-source heat pumps. The proposed average heating and cooling COPs are 3.2 and 5, respectively. Backup heating is provided from the existing gas-fired furnaces when the outdoor air temperature is below -15 C.

Utility analysis results

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

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	72,966	83,104	-10,138	-13.9
	Natural gas use	[m3/yr]	10,931	8,293	2,638	24.1
	Carbon offset use	[tCO2e/yr]	0	0	0	—
Equivalent energy use	Electricity energy	[kWh/yr]	72,966	83,104	-10,138	-13.9
	Natural gas energy	[kWh/yr]	115,397	87,549	27,848	24.1
	Total energy	[kWh/yr]	188,363	170,653	17,710	9.4
GHG emissions	Electricity GHGs	[tCO2e/yr]	1.7	2.0	-0.24	-13.9
	Natural gas GHGs	[tCO2e/yr]	21.1	16.0	5.1	24.1
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	—
	Total GHGs	[tCO2e/yr]	22.9	18.0	4.9	21.2
Utility cost	Electricity utility cost	[$/yr]	7,238	8,244	-1,006	-13.9
	Natural gas utility cost	[$/yr]	2,842	2,156	686	24.1
	Carbon offsets utility cost	[$/yr]	0	0	0	—
	Federal carbon charge	[$/yr]	1,056	801	255	24.1
	Total utility cost	[$/yr]	11,136	11,201	-65.0	-0.58
Financial	Assumed life	[yrs]	15	18	—	—
	Project cost	[$]	0	236,900	—	—
	Incentive amount	[$]	0	47,380	—	—
	Incremental project cost	[$]	0	189,520	—	—
	Life cycle cost	[$]	286,753	511,069	—	—
	Net present value	[$]	0	-224,315	—	—
	Project cost per GHG reduction	[$yr/tCO2e]	—	39,035	—	—
	Simple payback period	[yr]	—	—	—	—

5.12 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 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) = 28 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 panel is rated high enough to accommodate the additional 28 kW of the solar.

Project cost estimate

Table 39: Project cost estimate (Solar PV rooftop)

Category	Line item	Unit	Value
Materials and labour	Solar PV electricity system installed (assuming 28 kW at 2000 $/kW)	[$]	56,000
	Electrical	[$]	18,000
Contingency	Subtotal after Materials and labour	[$]	74,000
	General Contingency (20%)	[$]	14,800
	Design Contingency (10%)	[$]	7,400
Total	Total	[$]	96,200

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 40: Solar PV rooftop analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	72,966	48,042	24,924	34.2
	Natural gas use	[m3/yr]	10,931	10,931	0	0
	Carbon offset use	[tCO2e/yr]	0	0	0	–
Equivalent energy use	Electricity energy	[kWh/yr]	72,966	48,042	24,924	34.2
	Natural gas energy	[kWh/yr]	115,397	115,397	0	0
	Total energy	[kWh/yr]	188,363	163,439	24,924	13.2
GHG emissions	Electricity GHGs	[tCO2e/yr]	1.7	1.1	0.60	34.2
	Natural gas GHGs	[tCO2e/yr]	21.1	21.1	0	0
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	–
	Total GHGs	[tCO2e/yr]	22.9	22.3	0.60	2.6
Utility cost	Electricity utility cost	[$/yr]	7,238	4,766	2,472	34.2
	Natural gas utility cost	[$/yr]	2,842	2,842	0	0
	Carbon offsets utility cost	[$/yr]	0	0	0	–
	Federal carbon charge	[$/yr]	1,056	1,056	0	0
	Total utility cost	[$/yr]	11,136	8,664	2,472	22.2
Financial	Assumed life	[yrs]	15	30	–	–
	Project cost	[$]	0	96,200	–	–
	Incentive amount	[$]	0	19,240	–	–
	Incremental project cost	[$]	0	76,960	–	–
	Life cycle cost	[$]	286,753	284,131	–	–
	Net present value	[$]	0	2,623	–	–
	Project cost per GHG reduction	[$yr/tCO2e]	–	129,198	–	–
	Simple payback period	[yr]	–	>20	–	–

5.13 Wall upgrade to high performance

Measure description

Existing condition

The exterior walls appear to be a cavity wall type construction with either brick veneer or siding as an exterior finish on what is assumed to be wood stud construction with batt insulation inside the stud cavity.

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 exterior walls appear to be a cavity wall type construction with either brick veneer or siding as an exterior finish on what we assume to be wood stud construction with batt insulation inside the stud cavity. The existing thermal performance of this assembly is likely to be around R10, which is half of what the current building code calls for as a minimum standard.

In order to avoid having to rework and remove interior finishes, we recommend adding an EIFS system to the exterior walls, to a depth of 6 inches. This system comes with its own air barrier, which will help to reduce air leakage if the proper flashing is applied at all door and window opening. The new thermal performance value should be at least R20 if not more, depending on how much insulation is in the existing walls.

Project cost estimate

Table 41: Project cost estimate (Wall upgrade to high performance)

Category	Line item	Unit	Value
Construction	Add EIFS system to existing exterior wall	[$]	322,000
	General requirements (25%)	[$]	80,500
Contingency	Subtotal after Construction	[$]	402,500
	Design Contingency (25%)	[$]	100,600
	Construction Contingency (10%)	[$]	40,200
Design, Contractors, PM	Subtotal after Contingency	[$]	543,300
	Engineering Design and Field Review (10%)	[$]	54,300
	Contractor Fee (7%)	[$]	38,000
Total	Total	[$]	635,600

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 0.0481 BTU/hr.ft2.F (R20) was assumed.
- **Proposed**. An average wall U-value of 0.0345 BTU/hr.ft2.F (R29) was assumed. Infiltration flow was assumed to be reduced by 10% in total relative to the Baseline for affected spaces.

Utility analysis results

Table 42: Wall upgrade to high performance analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	72,966	72,413	552	0.76
	Natural gas use	[m3/yr]	10,931	9,760	1,171	10.7
	Carbon offset use	[tCO2e/yr]	0	0	0	–
Equivalent energy use	Electricity energy	[kWh/yr]	72,966	72,413	552	0.76
	Natural gas energy	[kWh/yr]	115,397	103,031	12,366	10.7
	Total energy	[kWh/yr]	188,363	175,445	12,918	6.9
GHG emissions	Electricity GHGs	[tCO2e/yr]	1.7	1.7	0.01	0.76
	Natural gas GHGs	[tCO2e/yr]	21.1	18.9	2.3	10.7
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	–
	Total GHGs	[tCO2e/yr]	22.9	20.6	2.3	10.0
Utility cost	Electricity utility cost	[$/yr]	7,238	7,183	54.8	0.76
	Natural gas utility cost	[$/yr]	2,842	2,538	305	10.7
	Carbon offsets utility cost	[$/yr]	0	0	0	–
	Federal carbon charge	[$/yr]	1,056	943	113	10.7
	Total utility cost	[$/yr]	11,136	10,664	473	4.2
Financial	Assumed life	[yrs]	15	75	–	–
	Project cost	[$]	0	635,600	–	–
	Incentive amount	[$]	0	127,120	–	–
	Incremental project cost	[$]	0	508,480	–	–
	Life cycle cost	[$]	286,753	444,301	–	–
	Net present value	[$]	0	-157,548	–	–
	Project cost per GHG reduction	[$yr/tCO2e]	–	223,345	–	–
	Simple payback period	[yr]	–	>20	–	–

5.14 Windows and doors to high performance

Measure description

Existing condition

It appears most windows were replaced circa 1995 with double-pane vinyl windows. The lobby area has aluminum-framed, double pane windows. The front doors are double swing doors with glazing, and the rear entry point is a single hollow metal door with glazing.

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. At the very least, we recommend double-glazed windows in thermally broken frames to meet current code standards.

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.

- **Glazed Entry Doors:** Should be triple-glazed and thermally broken as part of the curtain wall/window improvements.

Project cost estimate

Table 43: Project cost estimate (Windows and doors to high performance)

Category	Line item	Unit	Value
Construction	Window and door replacement	[$]	76,000
	General requirements (25%)	[$]	19,000
Contingency	Subtotal after Construction	[$]	95,000
	Design Contingency (25%)	[$]	23,800
	Construction Contingency (10%)	[$]	9,500
Design, Contractors, PM	Subtotal after Contingency	[$]	128,300
	Engineering Design and Field Review (10%)	[$]	12,800
	Contractor Fee (7%)	[$]	9,000
Total	Total	[$]	150,100

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 0.476 BTU/hr.ft2.F and 0.701 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 44: Windows and doors to high performance analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	72,966	72,949	16.6	0.02
	Natural gas use	[m3/yr]	10,931	10,557	375	3.4
	Carbon offset use	[tCO2e/yr]	0	0	0	–
Equivalent energy use	Electricity energy	[kWh/yr]	72,966	72,949	16.6	0.02
	Natural gas energy	[kWh/yr]	115,397	111,443	3,954	3.4
	Total energy	[kWh/yr]	188,363	184,392	3,971	2.1
GHG emissions	Electricity GHGs	[tCO2e/yr]	1.7	1.7	0.00	0.02
	Natural gas GHGs	[tCO2e/yr]	21.1	20.4	0.72	3.4
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	–
	Total GHGs	[tCO2e/yr]	22.9	22.1	0.72	3.2
Utility cost	Electricity utility cost	[$/yr]	7,238	7,237	1.6	0.02
	Natural gas utility cost	[$/yr]	2,842	2,745	97.4	3.4
	Carbon offsets utility cost	[$/yr]	0	0	0	–
	Federal carbon charge	[$/yr]	1,056	1,020	36.2	3.4
	Total utility cost	[$/yr]	11,136	11,001	135	1.2
Financial	Assumed life	[yrs]	15	40	–	–
	Project cost	[$]	0	150,100	–	–
	Incentive amount	[$]	0	30,020	–	–
	Incremental project cost	[$]	0	120,080	–	–
	Life cycle cost	[$]	286,753	357,805	–	–
	Net present value	[$]	0	-71,051	–	–
	Project cost per GHG reduction	[$yr/tCO2e]	–	165,807	–	–
	Simple payback period	[yr]	–	>20	–	–

5.15 Measure risk analysis

Utility use sensitivity

Figure 100 indicates how sensitive cumulative electricity and natural gas use are to variations in each risk parameter.

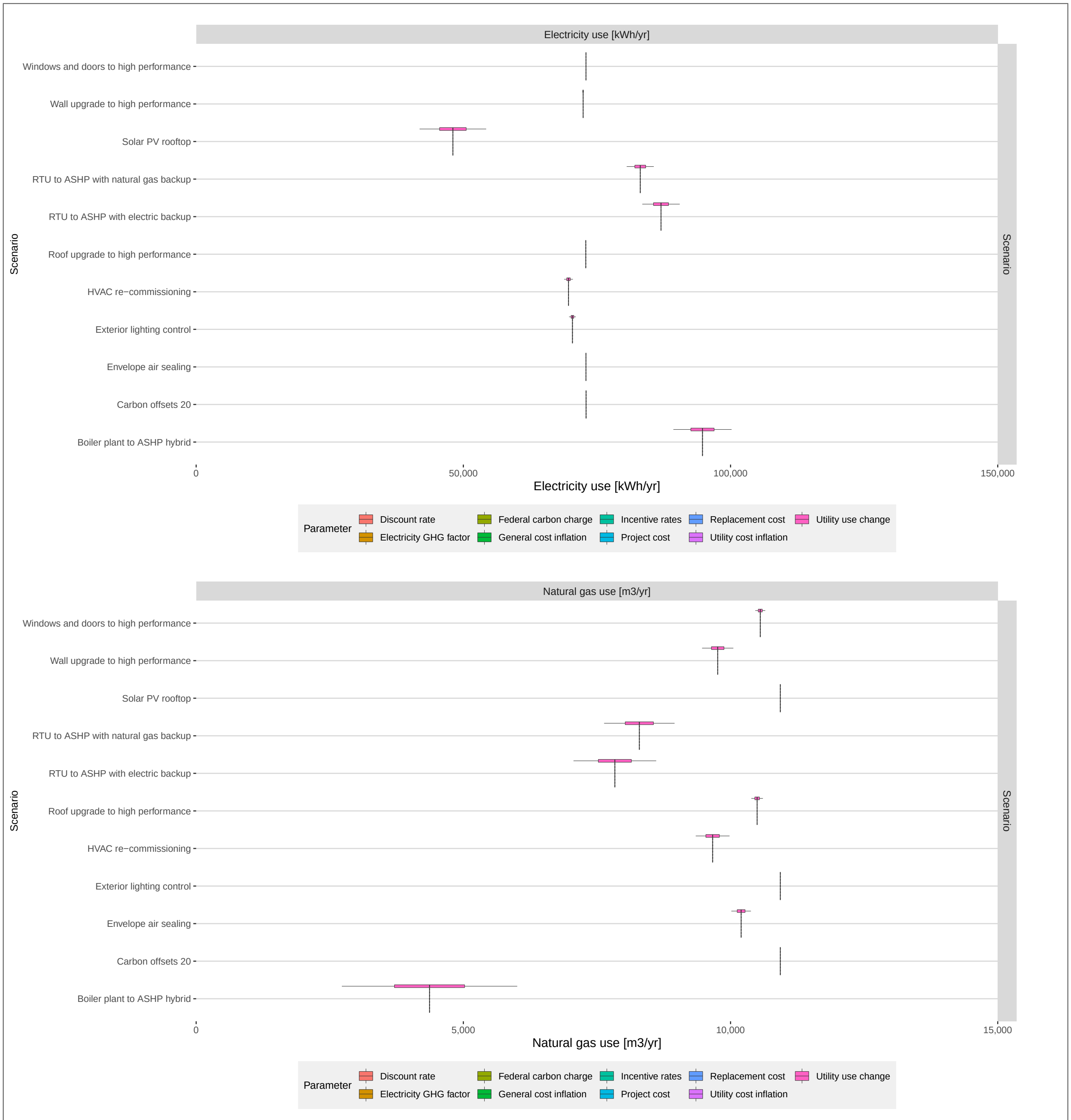


Figure 100: Utility cumulative use sensitivity analysis

GHG emissions and life cycle cost sensitivity

Figure 101 indicates how sensitive cumulative GHG emissions and life cycle costs are to variations in each risk parameter.

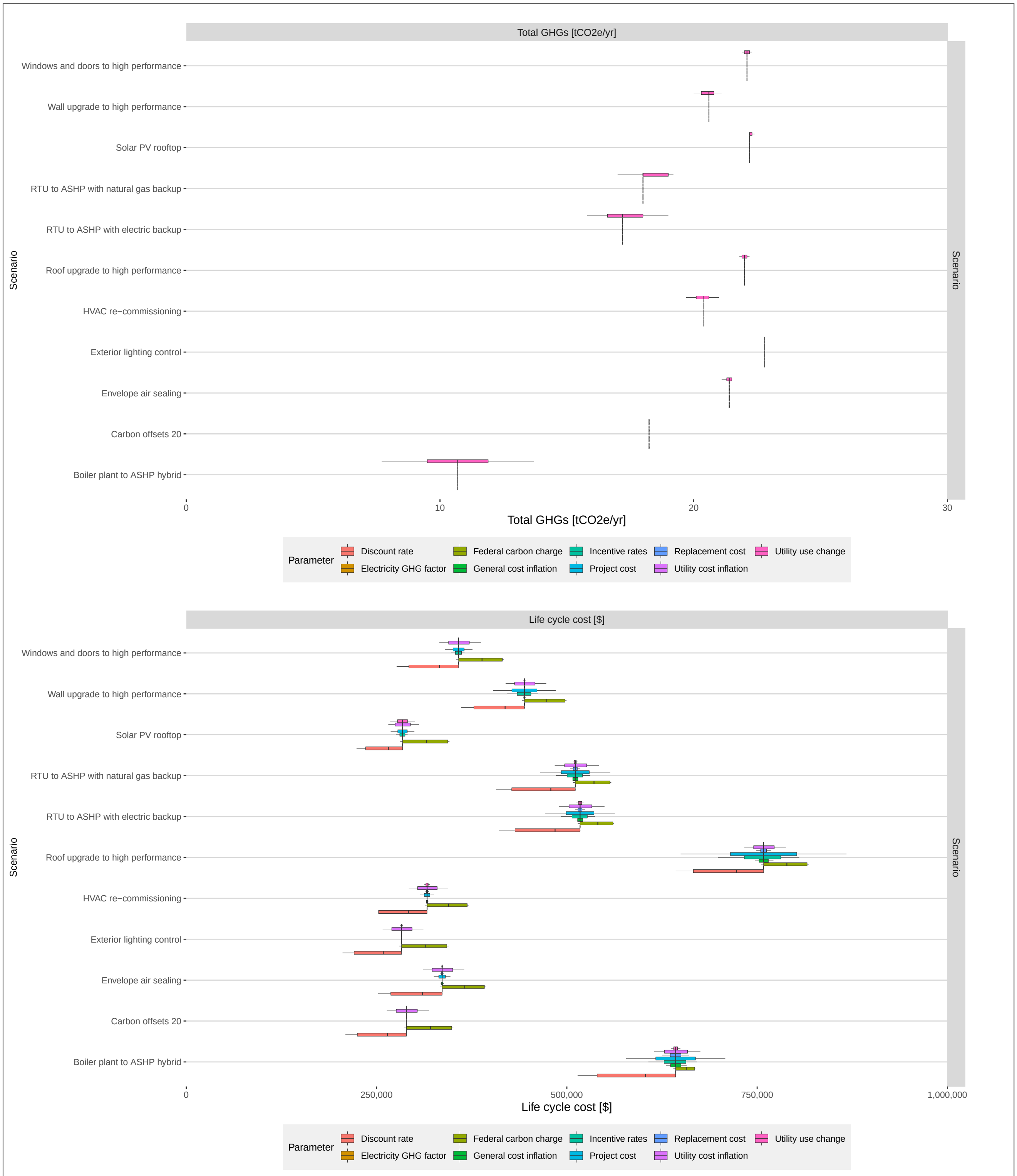


Figure 101: GHG cumulative emissions and life cycle cost sensitivity analysis

5.16 Measure analysis summary

For each analyzed measure, the analysis results are summarized in Table 45.

Table 45: 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	72,966	100.0	10,931	100.0	188,363	100.0	23	100.0	11,136	100.0	15	0	0	0	286,753	0	-	-
Boiler plant to ASHP hybrid	-21,783	-29.9	6,564	60.0	47,511	25.2	12	53.2	180	1.6	15	335,600	67,120	268,480	642,917	-356,164	22,073	1,492
Carbon offsets 20	0	0.0	0	0.0	0	0.0	5	20.0	-137	-1.2	20	-	0	-	289,255	-2,502	-	-
Envelope air sealing	21	0.0	733	6.7	7,758	4.1	1	6.2	263	2.4	15	45,000	183	44,817	336,125	-49,372	31,633	170
Exterior lighting control	2,551	3.5	0	0.0	2,551	1.4	0	0.3	253	2.3	15	2,300	0	2,300	282,825	3,928	37,726	9
HVAC re-commissioning	3,286	4.5	1,266	11.6	16,652	8.8	3	11.0	777	7.0	15	37,500	0	37,500	316,361	-29,608	14,851	48
Roof upgrade to high performance	56	0.1	434	4.0	4,636	2.5	1	3.7	160	1.4	20	560,800	112,160	448,640	758,468	-471,715	534,361	2,799
RTU to ASHP with electric backup	-14,023	-19.2	3,096	28.3	18,659	9.9	6	24.7	-287	-2.6	18	235,100	47,020	188,080	517,374	-230,620	33,305	-655
RTU to ASHP with natural gas backup	-10,138	-13.9	2,638	24.1	17,710	9.4	5	21.2	-65	-0.6	18	236,900	47,380	189,520	511,069	-224,315	39,035	-2,916
Solar PV rooftop	24,924	34.2	0	0.0	24,924	13.2	1	2.6	2,472	22.2	30	96,200	19,240	76,960	284,130	2,623	129,198	31
Wall upgrade to high performance	552	0.8	1,171	10.7	12,918	6.9	2	10.0	473	4.2	75	635,600	127,120	508,480	444,301	-157,548	223,345	1,076
Windows and doors to high performance	17	0.0	375	3.4	3,971	2.1	1	3.2	135	1.2	40	150,100	30,020	120,080	357,804	-71,051	165,807	888
Total project cost	-	-	-	-	-	-	-	-	-	-	-	2,335,100	-	-	-	-	-	-
Boiler renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	30	26,000	0	26,000	307,801	-21,048	-	-
DHW renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	15	4,000	0	4,000	291,478	-4,724	-	-
Exterior walls renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	75	5,000	0	5,000	288,372	-1,619	-	-
Roof renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	20	186,000	0	186,000	480,088	-193,335	-	-
RTU renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	96,000	0	96,000	390,772	-104,019	-	-
Windows and doors renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	40	24,000	0	24,000	301,325	-14,571	-	-
BAU measure totals	-	-	-	-	-	-	-	-	-	-	-	341,000	-	-	-	-	-	-

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 46.
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 46.

Table 46: 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 102 and Table 47 present the results of this exercise, indicating which measures were assigned to which scenario.

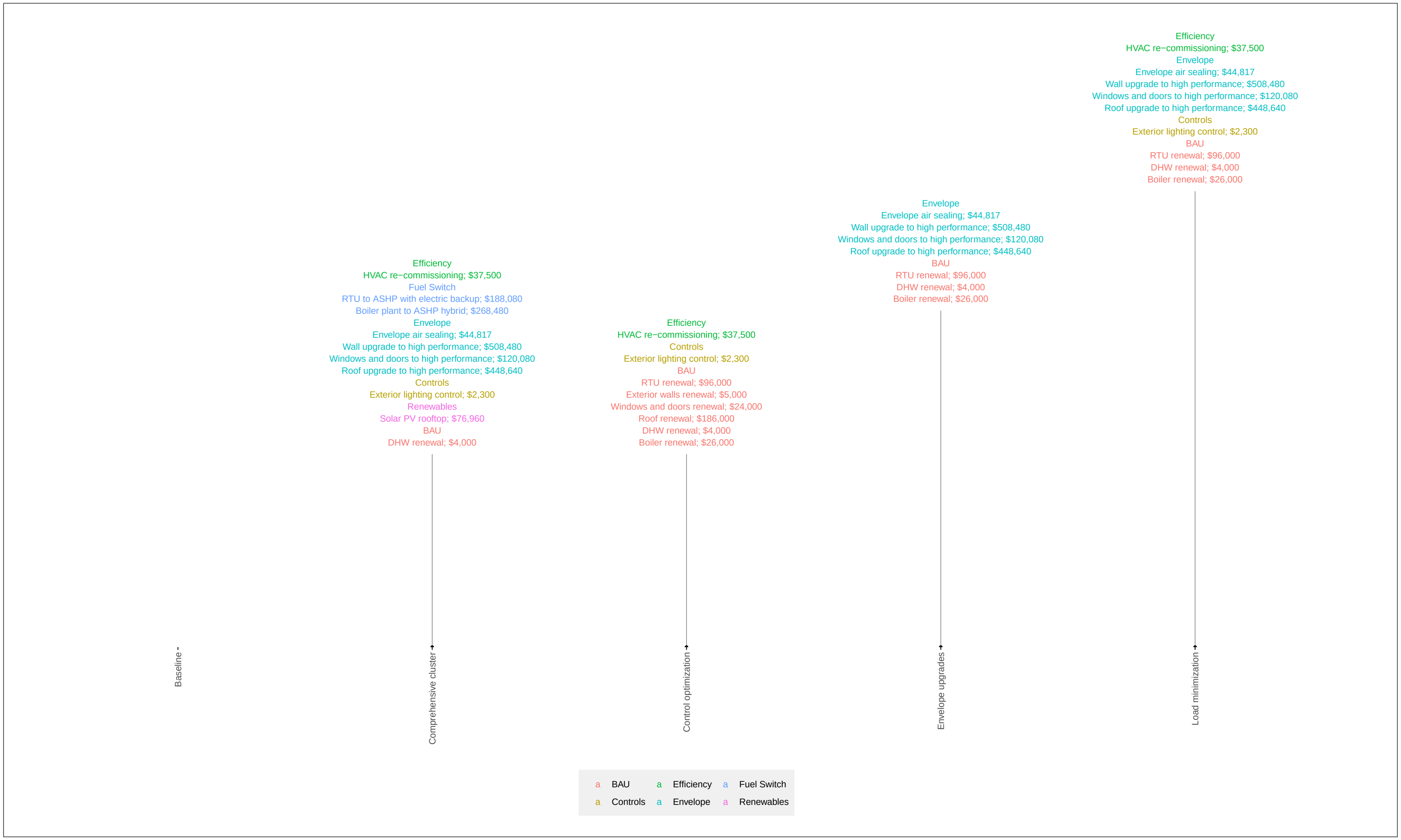


Figure 102: Scenario composition

Table 47: Cluster composition

Measure	Control optimization	Envelope upgrades	Load minimization	Comprehensive cluster
Boiler plant to ASHP hybrid	✖	✖	✖	✔
Carbon offsets 20	✖	✖	✖	✖
Envelope air sealing	✖	✔	✔	✔
Exterior lighting control	✔	✖	✔	✔
HVAC re-commissioning	✔	✖	✔	✔
Roof upgrade to high performance	✖	✔	✔	✔
RTU to ASHP with electric backup	✖	✖	✖	✔
RTU to ASHP with natural gas backup	✖	✖	✖	✖
Solar PV rooftop	✖	✖	✖	✔
Wall upgrade to high performance	✖	✔	✔	✔
Windows and doors to high performance	✖	✔	✔	✔
Boiler renewal	✔	✔	✔	✖
DHW renewal	✔	✔	✔	✔
Exterior walls renewal	✔	✖	✖	✖
Roof renewal	✔	✖	✖	✖
RTU 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 48, 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 48: 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	7,719	10.6	9,590	87.7	108,960	57.8	19	81.8	4,186	37.6	-	2,102,200	402,863	1,699,337	1,570,800	-1,284,047	90,795	406
Comprehensive cluster	HVAC re-commissioning	3,286	4.5	1,266	11.6	16,652	8.8	3	11.0	777	7.0	15	37,500	0	37,500	316,361	-29,608	14,851	48
Comprehensive cluster	RTU to ASHP with electric backup	-14,023	-19.2	3,096	28.3	18,659	9.9	6	24.7	-287	-2.6	18	235,100	47,020	188,080	517,374	-230,620	33,305	-655
Comprehensive cluster	Envelope air sealing	21	0.0	733	6.7	7,758	4.1	1	6.2	263	2.4	15	45,000	183	44,817	336,125	-49,372	31,633	170
Comprehensive cluster	Wall upgrade to high performance	552	0.8	1,171	10.7	12,918	6.9	2	10.0	473	4.2	75	635,600	127,120	508,480	444,301	-157,548	223,345	1,076
Comprehensive cluster	Windows and doors to high performance	17	0.0	375	3.4	3,971	2.1	1	3.2	135	1.2	40	150,100	30,020	120,080	357,804	-71,051	165,807	888
Comprehensive cluster	Roof upgrade to high performance	56	0.1	434	4.0	4,636	2.5	1	3.7	160	1.4	20	560,800	112,160	448,640	758,468	-471,715	534,361	2,799
Comprehensive cluster	Exterior lighting control	2,551	3.5	0	0.0	2,551	1.4	0	0.3	253	2.3	15	2,300	0	2,300	282,825	3,928	37,726	9
Comprehensive cluster	Boiler plant to ASHP hybrid	-21,783	-29.9	6,564	60.0	47,511	25.2	12	53.2	180	1.6	15	335,600	67,120	268,480	642,917	-356,164	22,073	1,492
Comprehensive cluster	Solar PV rooftop	24,924	34.2	0	0.0	24,924	13.2	1	2.6	2,472	22.2	30	96,200	19,240	76,960	284,130	2,623	129,198	31
Comprehensive cluster	DHW renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	15	4,000	0	4,000	291,478	-4,724	-	-
Control optimization	Combined	5,837	8.0	1,266	11.6	19,203	10.2	3	11.3	1,031	9.3	-	380,800	0	380,800	635,603	-348,849	147,249	370
Control optimization	HVAC re-commissioning	3,286	4.5	1,266	11.6	16,652	8.8	3	11.0	777	7.0	15	37,500	0	37,500	316,361	-29,608	14,851	48
Control optimization	Exterior lighting control	2,551	3.5	0	0.0	2,551	1.4	0	0.3	253	2.3	15	2,300	0	2,300	282,825	3,928	37,726	9
Control optimization	RTU renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	96,000	0	96,000	390,772	-104,019	-	-
Control optimization	Exterior walls renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	75	5,000	0	5,000	288,372	-1,619	-	-
Control optimization	Windows and doors renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	40	24,000	0	24,000	301,325	-14,571	-	-
Control optimization	Roof renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	20	186,000	0	186,000	480,088	-193,335	-	-
Control optimization	DHW renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	15	4,000	0	4,000	291,478	-4,724	-	-
Control optimization	Boiler renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	30	26,000	0	26,000	307,801	-21,048	-	-
Envelope upgrades	Combined	544	0.7	1,542	14.1	16,827	8.9	3	13.1	604	5.4	-	1,517,500	269,483	1,248,017	1,127,144	-840,391	416,912	2,066
Envelope upgrades	Envelope air sealing	21	0.0	733	6.7	7,758	4.1	1	6.2	263	2.4	15	45,000	183	44,817	336,125	-49,372	31,633	170
Envelope upgrades	Wall upgrade to high performance	552	0.8	1,171	10.7	12,918	6.9	2	10.0	473	4.2	75	635,600	127,120	508,480	444,301	-157,548	223,345	1,076
Envelope upgrades	Windows and doors to high performance	17	0.0	375	3.4	3,971	2.1	1	3.2	135	1.2	40	150,100	30,020	120,080	357,804	-71,051	165,807	888
Envelope upgrades	Roof upgrade to high performance	56	0.1	434	4.0	4,636	2.5	1	3.7	160	1.4	20	560,800	112,160	448,640	758,468	-471,715	534,361	2,799
Envelope upgrades	RTU renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	96,000	0	96,000	390,772	-104,019	-	-
Envelope upgrades	DHW renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	15	4,000	0	4,000	291,478	-4,724	-	-
Envelope upgrades	Boiler renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	30	26,000	0	26,000	307,801	-21,048	-	-
Load minimization	Combined	6,397	8.8	2,553	23.4	33,344	17.7	5	22.2	1,545	13.9	-	1,557,300	269,483	1,287,817	1,152,982	-866,229	253,232	834
Load minimization	HVAC re-commissioning	3,286	4.5	1,266	11.6	16,652	8.8	3	11.0	777	7.0	15	37,500	0	37,500	316,361	-29,608	14,851	48
Load minimization	Envelope air sealing	21	0.0	733	6.7	7,758	4.1	1	6.2	263	2.4	15	45,000	183	44,817	336,125	-49,372	31,633	170
Load minimization	Wall upgrade to high performance	552	0.8	1,171	10.7	12,918	6.9	2	10.0	473	4.2	75	635,600	127,120	508,480	444,301	-157,548	223,345	1,076
Load minimization	Windows and doors to high performance	17	0.0	375	3.4	3,971	2.1	1	3.2	135	1.2	40	150,100	30,020	120,080	357,804	-71,051	165,807	888
Load minimization	Roof upgrade to high performance	56	0.1	434	4.0	4,636	2.5	1	3.7	160	1.4	20	560,800	112,160	448,640	758,468	-471,715	534,361	2,799
Load minimization	Exterior lighting control	2,551	3.5	0	0.0	2,551	1.4	0	0.3	253	2.3	15	2,300	0	2,300	282,825	3,928	37,726	9
Load minimization	RTU renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	96,000	0	96,000	390,772	-104,019	-	-
Load minimization	DHW renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	15	4,000	0	4,000	291,478	-4,724	-	-
Load minimization	Boiler renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	30	26,000	0	26,000	307,801	-21,048	-	-

Utility use comparison

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

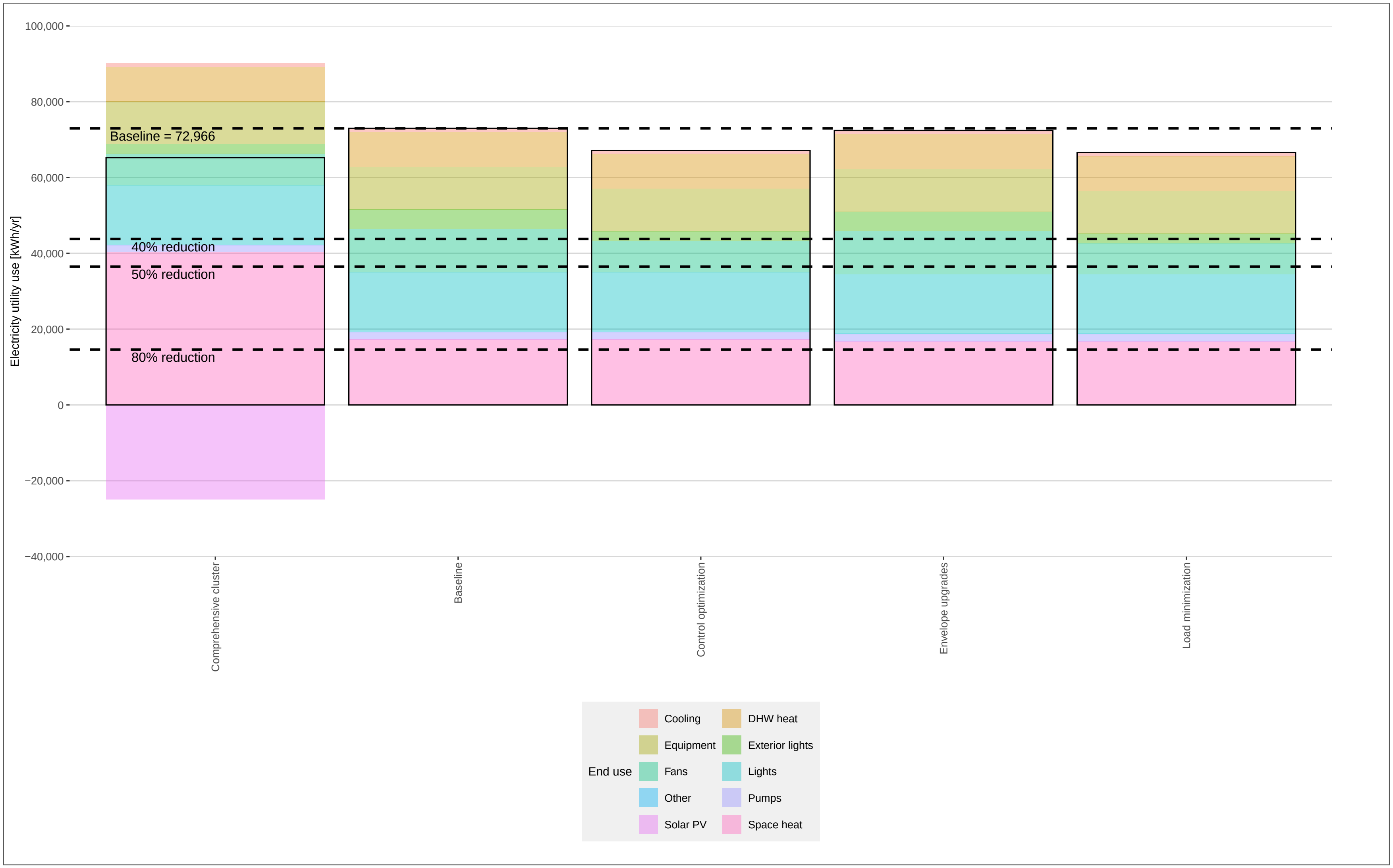


Figure 103: Electricity utility use expected yearly for each scenario by end use

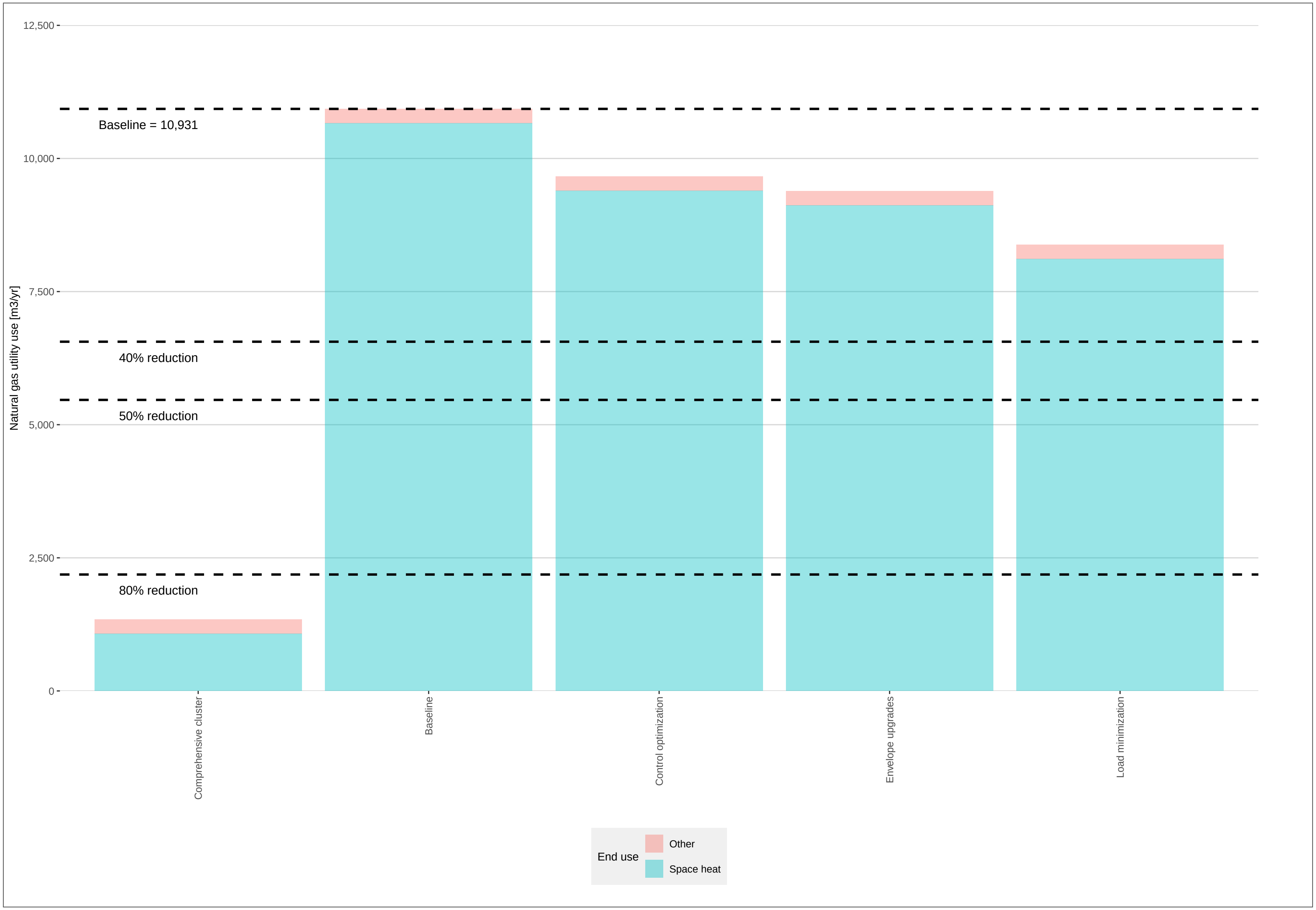


Figure 104: Natural gas utility use expected yearly for each scenario by end use

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.

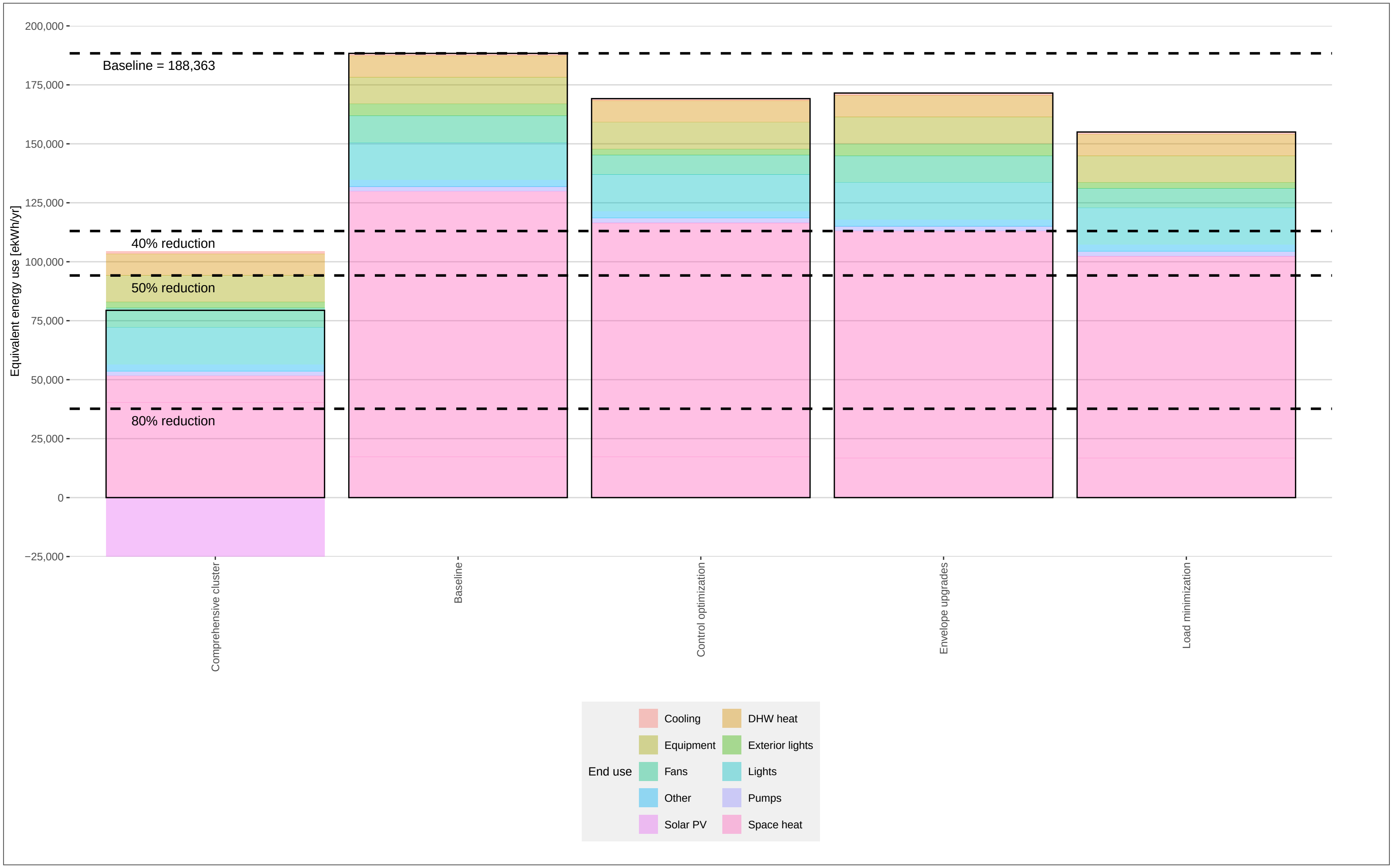


Figure 105: Equivalent energy use expected yearly for each scenario by end use

Figure 106: GHG emissions expected yearly for each scenario by end use

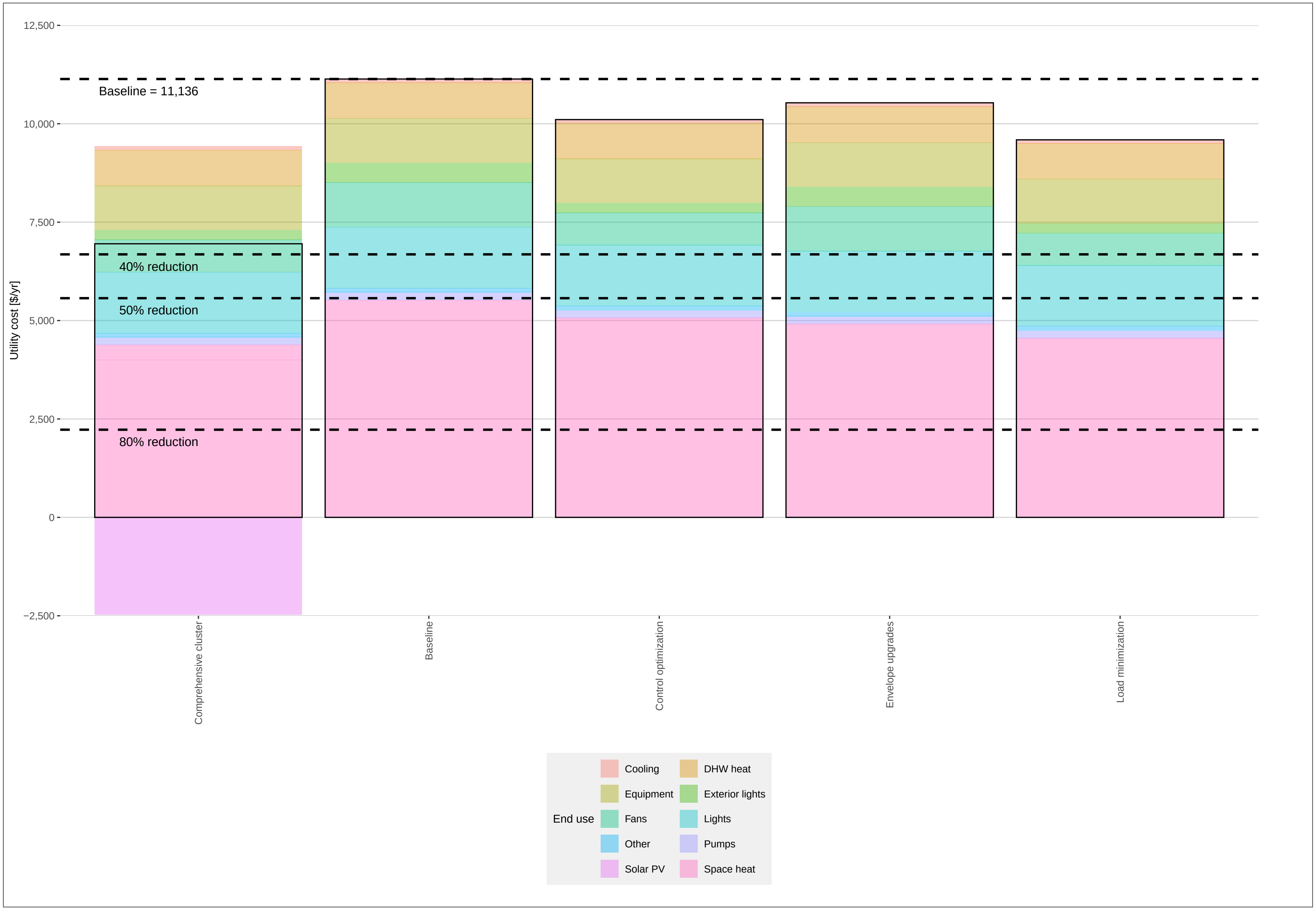


Figure 107: Utility costs expected yearly for each scenario by end use

Financial performance comparison

The following figures compare the financial performance between each scenario.

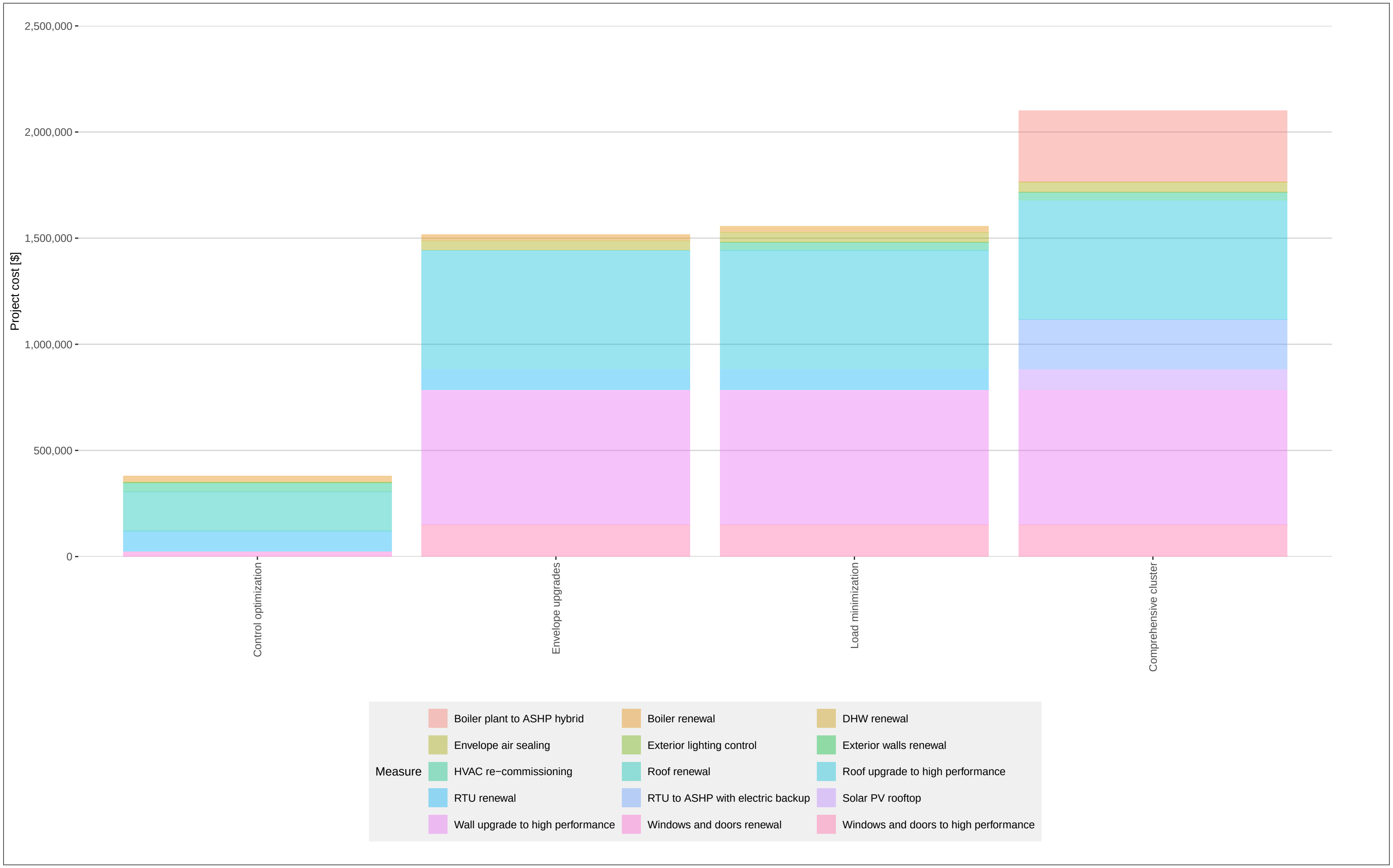


Figure 108: Project cost expected for each scenario by measure

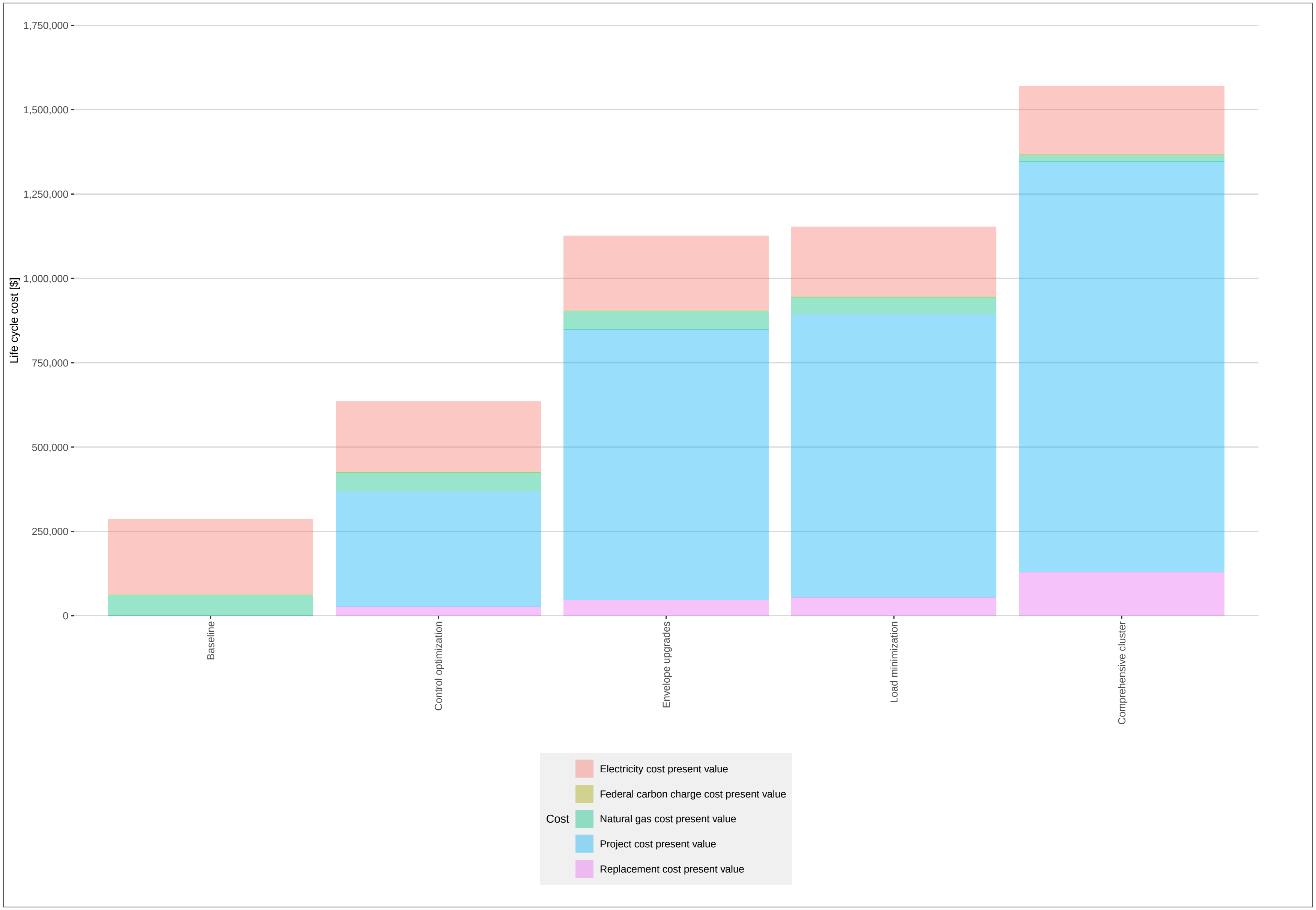


Figure 109: Life cycle cost expected for each scenario by cost item

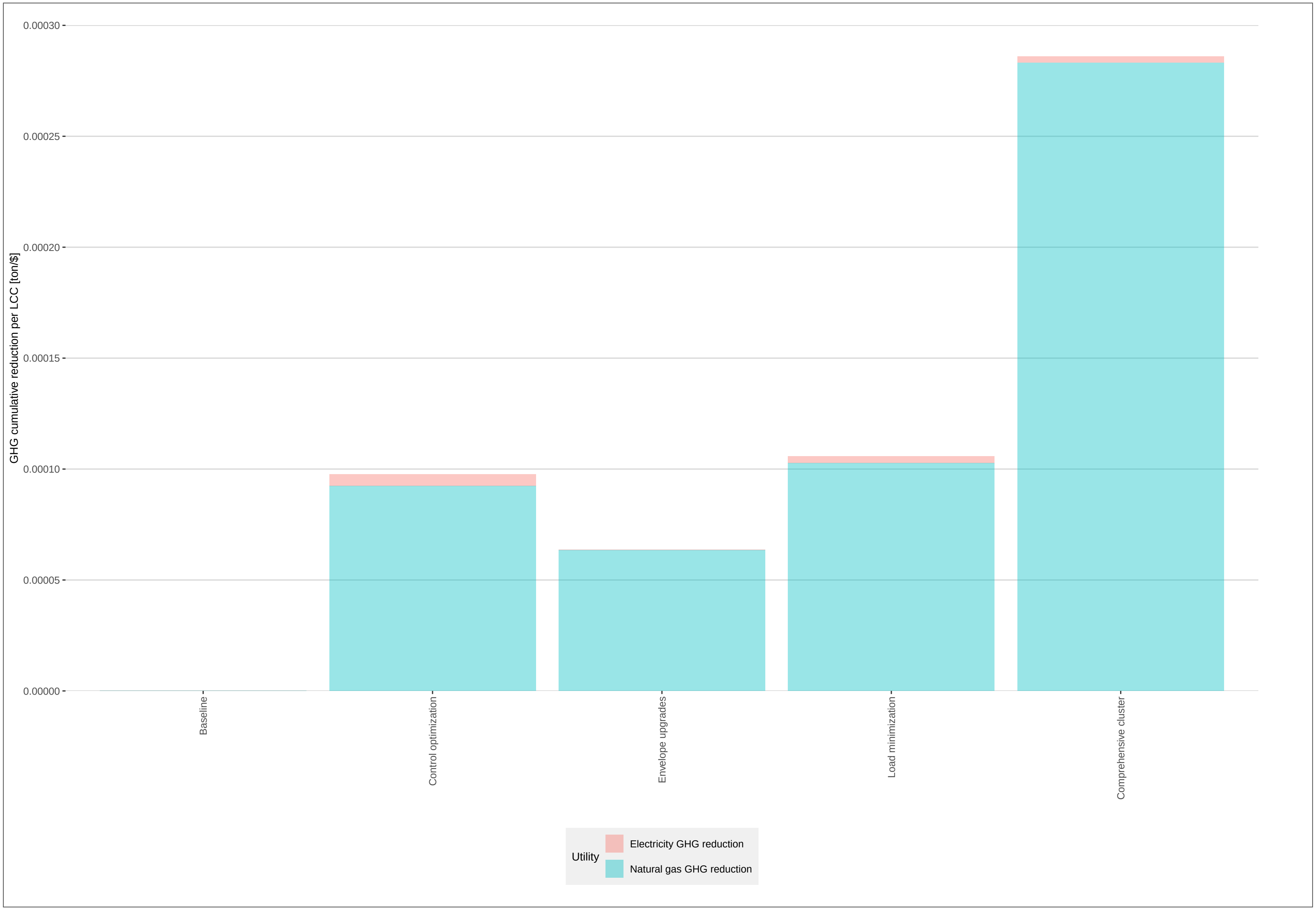


Figure 110: GHG cumulative reduction per life cycle cost (LCC) dollar expected for each scenario by utility

6.5 Plan scenario development

Plan scenario identification and objectives

The plan scenarios that were analyzed and their objectives are summarized in Table 49.

Table 49: 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 49. Results of the plan scenario composition are presented in Figure 111, 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 50 to 55.

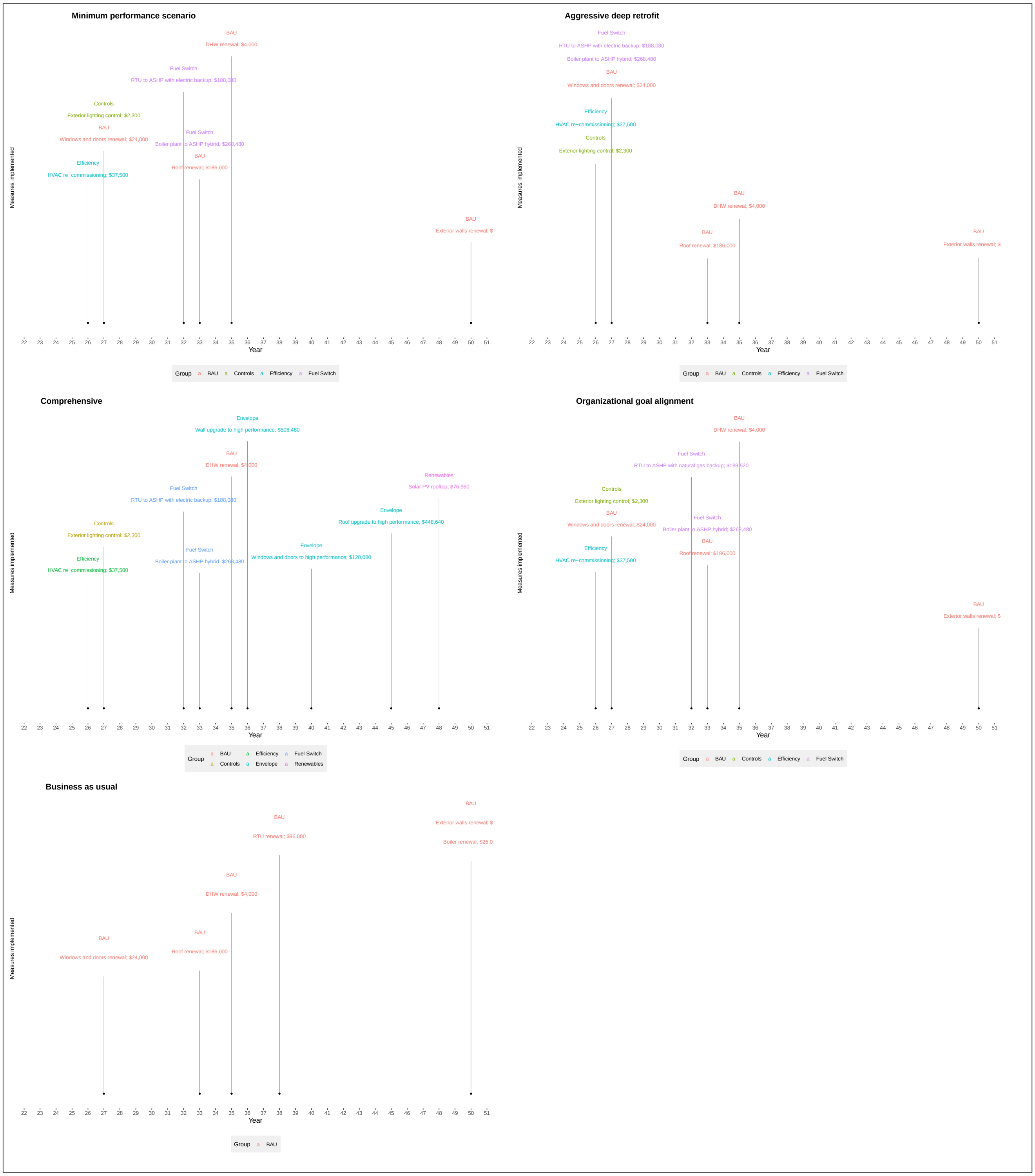


Figure 111: Plan scenario composition, indicating which measures are implemented when and at what cost in each plan scenario

Table 50: Scenario composition summary

Measure	Minimum performance scenario	Aggressive deep retrofit	Comprehensive	Organizational goal alignment
Boiler plant to ASHP hybrid	✔	✔	✔	✔
Carbon offsets 20	✖	✖	✖	✖
Envelope air sealing	✖	✖	✖	✖
Exterior lighting control	✔	✔	✔	✔
HVAC re-commissioning	✔	✔	✔	✔
Roof upgrade to high performance	✖	✖	✔	✖
RTU to ASHP with electric backup	✔	✔	✔	✖
RTU to ASHP with natural gas backup	✖	✖	✖	✔
Solar PV rooftop	✖	✖	✔	✖
Wall upgrade to high performance	✖	✖	✔	✖
Windows and doors to high performance	✖	✖	✔	✖
Boiler renewal	✖	✖	✖	✖
DHW renewal	✔	✔	✔	✔
Exterior walls renewal	✔	✔	✖	✔
Roof renewal	✔	✔	✖	✔
RTU renewal	✖	✖	✖	✖
Windows and doors renewal	✔	✔	✖	✔

Table 51: Minimum performance scenario measure implementation timeline

Measure	Year
HVAC re-commissioning	2026
Exterior lighting control	2027
Windows and doors renewal	2027
RTU to ASHP with electric backup	2032
Boiler plant to ASHP hybrid	2033
Roof renewal	2033
DHW renewal	2035
Exterior walls renewal	2050

Table 52: Aggressive deep retrofit measure implementation timeline

Measure	Year
Exterior lighting control	2026
HVAC re-commissioning	2026
Boiler plant to ASHP hybrid	2027
RTU to ASHP with electric backup	2027
Windows and doors renewal	2027
Roof renewal	2033
DHW renewal	2035
Exterior walls renewal	2050

Table 53: Comprehensive measure implementation timeline

Measure	Year
HVAC re-commissioning	2026
Exterior lighting control	2027
RTU to ASHP with electric backup	2032
Boiler plant to ASHP hybrid	2033
DHW renewal	2035
Wall upgrade to high performance	2036
Windows and doors to high performance	2040
Roof upgrade to high performance	2045
Solar PV rooftop	2048

Table 54: Organizational goal alignment measure implementation timeline

Measure	Year
HVAC re-commissioning	2026
Exterior lighting control	2027
Windows and doors renewal	2027
RTU to ASHP with natural gas backup	2032
Boiler plant to ASHP hybrid	2033
Roof renewal	2033
DHW renewal	2035
Exterior walls renewal	2050

Table 55: Business as usual measure implementation timeline

Measure	Year
Windows and doors renewal	2027
Roof renewal	2033
DHW renewal	2035
RTU renewal	2038
Boiler renewal	2050
Exterior walls renewal	2050

6.6 Plan performance analysis

Figures 112 through 115 present the projected yearly electricity use, natural gas use, GHG emissions and life cycle costs associated with each plan scenario.

Figure 112: Electricity yearly utility use projection for each scenario

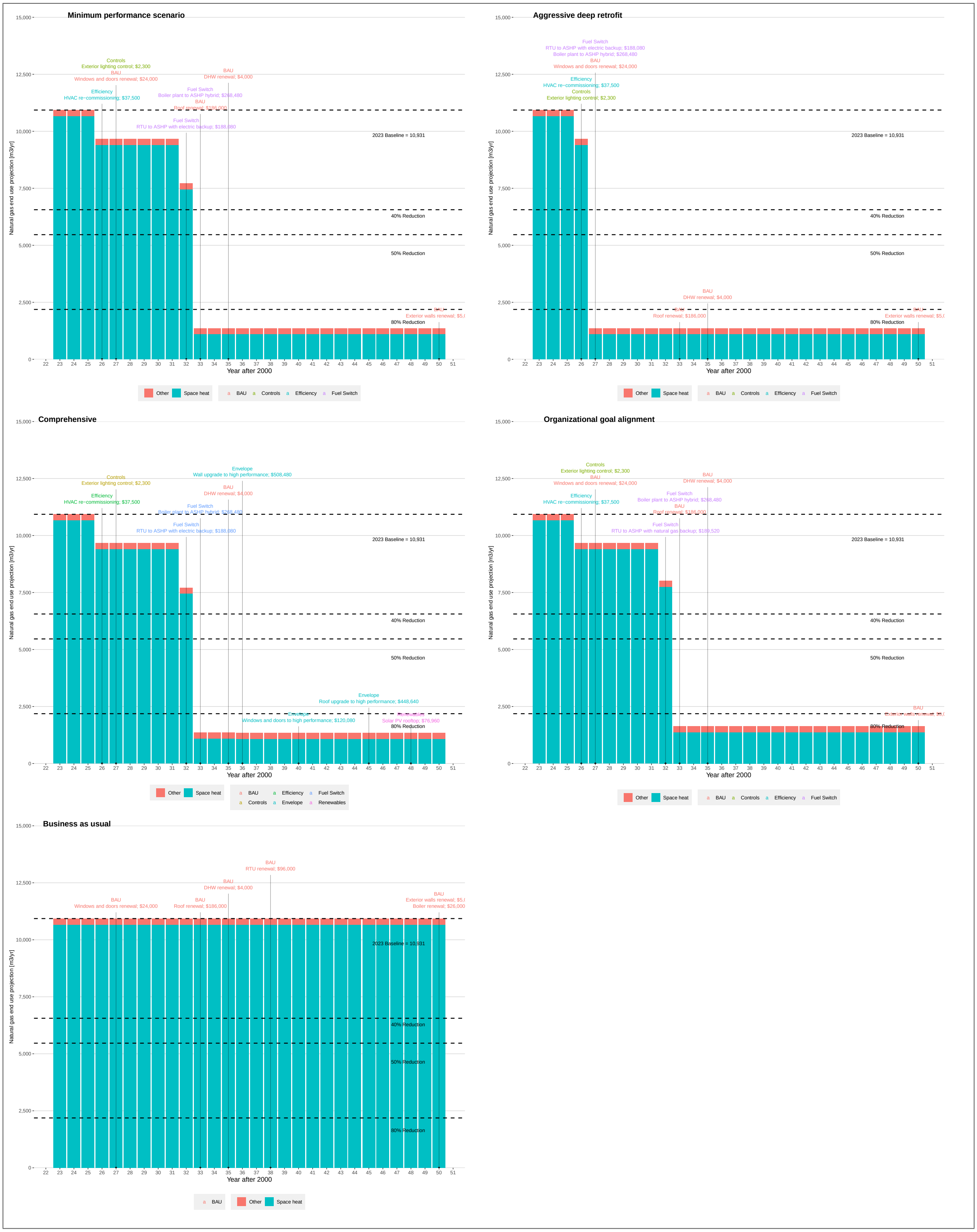


Figure 113: Natural gas yearly utility use projection for each scenario

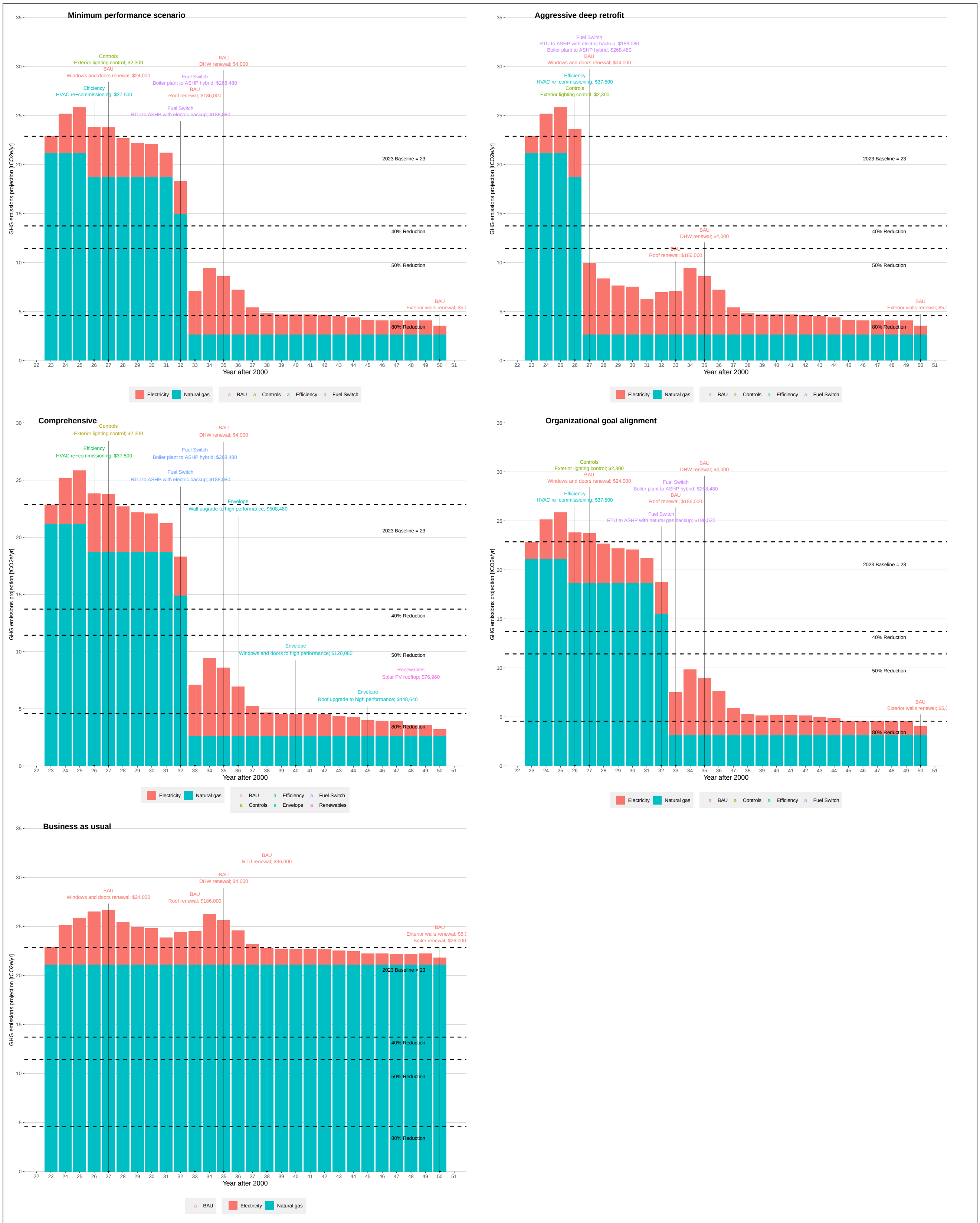


Figure 114: GHG yearly emissions projection for each scenario

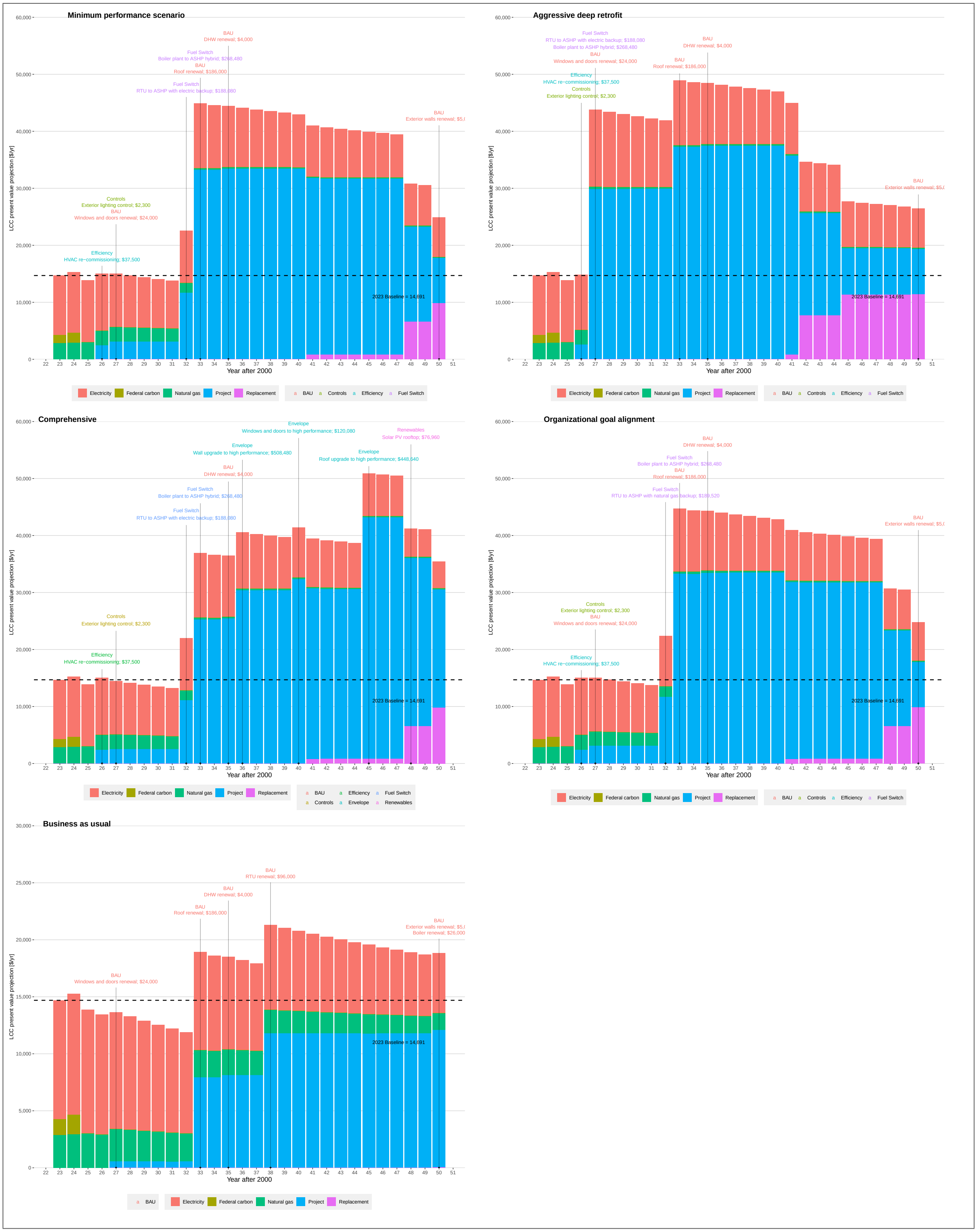


Figure 115: Life cycle yearly cost (after discounting to present value) projection for each scenario

6.7 Plan performance summary

Plan performance summary

Table 56 summarizes the performance of each plan scenario with respect to utility use, GHG emissions, utility cost, and financial metrics. The first half of Table 56 represents the estimated performance in the final year (2050) of the evaluation period. The second half of Table 56 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 56 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 115).

Table 56: 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]	96,367	96,367	65,247	94,067	72,966
	Electricity monthly peak (av)	[kW]	24.2	24.2	20.1	24.1	17.8
	Electricity yearly peak (max)	[kW]	35.7	35.7	30.1	35.3	19.8
	Natural gas use	[m3/yr]	1,358	1,358	1,341	1,633	10,931
GHG emissions final	Electricity GHGs	[tCO2e/yr]	0.92	0.92	0.62	0.89	0.69
	Natural gas GHGs	[tCO2e/yr]	2.6	2.6	2.6	3.2	21.1
	Carbon offsets GHGs	[tCO2e/yr]	0.00	0.00	0.00	0.00	0.00
	Total GHGs	[tCO2e/yr]	3.5	3.5	3.2	4.0	21.8
Utility cost final	Electricity utility cost	[$/yr]	23,494	23,494	15,907	22,933	17,789
	Natural gas utility cost	[$/yr]	614	614	607	739	4,947
	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	[$/yr]	24,109	24,109	16,514	23,672	22,736
Utility use cumulative	Electricity use	[kWh]	2,434,369	2,598,844	2,277,316	2,390,435	2,043,039
	Natural gas use	[m3]	122,934	75,042	122,702	128,183	306,072
GHG emissions cumulative	Electricity GHGs	[tCO2e]	84.5	93.4	81.9	83.3	74.9
	Natural gas GHGs	[tCO2e]	238	145	237	248	591
	Carbon offsets GHGs	[tCO2e]	0.00	0.00	0.00	0.00	0.00
	Total GHGs	[tCO2e]	322	238	319	331	666
Utility cost cumulative	Electricity utility cost	[$]	468,656	495,353	433,119	459,648	386,164
	Natural gas utility cost	[$]	37,868	23,446	37,775	39,866	107,393
	Carbon offsets utility cost	[$]	0.00	0.00	0.00	0.00	0.00
	Federal carbon charge	[$]	3,063	3,063	3,063	3,063	3,063
	Total utility cost	[$]	509,586	521,862	473,957	502,576	496,619
Financial cumulative	Project cost	[$]	959,885	890,330	2,686,104	961,953	422,819
	Replacement cost	[$]	488,088	440,233	488,088	489,565	3,281
	Life cycle cost	[$]	872,703	1,010,159	888,152	870,662	484,169

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. Heating system electrification would be required.

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 achieve the organizational goal alignment of 80% reduction in GHG emissions without carbon offsets, the heating systems must be electrified, although natural gas can be used as a backup heating source.

Comprehensive

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

7 END