

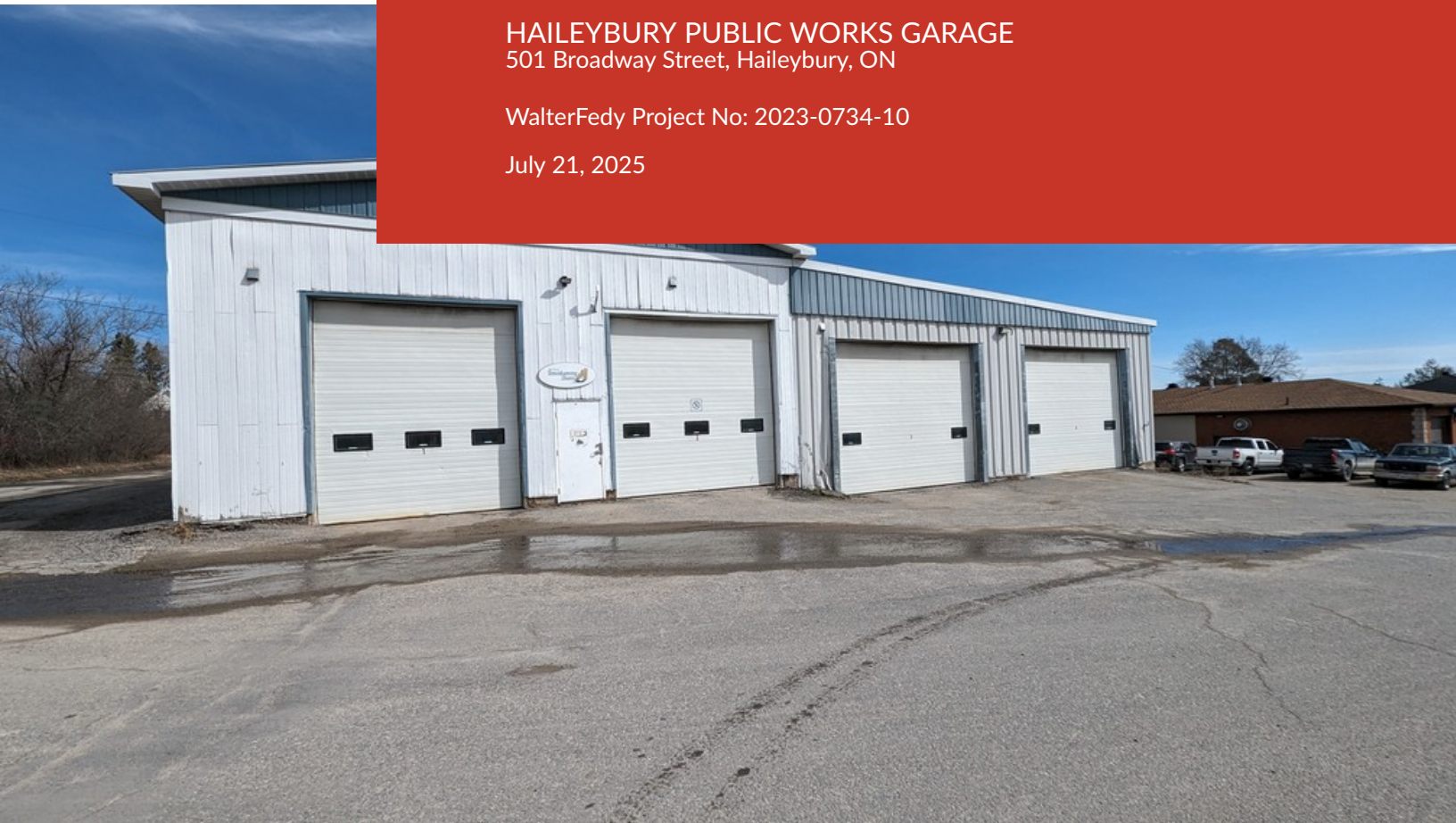
PATHWAY TO DECARBONIZATION FEASIBILITY STUDY

CITY OF TEMISKAMING SHORES

HAILEYBURY PUBLIC WORKS GARAGE
501 Broadway Street, Haileybury, ON

WalterFedy Project No: 2023-0734-10

July 21, 2025



DISCLAIMER AND LIMITATION OF LIABILITY

This document was prepared by WalterFedy for the above stated client ("Client") for the specific purpose and use by the client, as described in the report and subsequent scope of work agreement. This report was completed based on the information that was available at the time of the report preparation and completion, and is subject to all limitations, assumptions and qualifications contained herein. Any events or circumstances that have occurred since the date on which the report was prepared, are the responsibility of the client, and WalterFedy accepts no responsibility to update the report to reflect these changes.

WalterFedy agrees that this report represents its professional judgement and any estimates or opinions regarding probable costs, schedules, or technical estimates provided represent the professional judgement in light of WalterFedy's experience as well as the information available at the time of report preparation. In addition, WalterFedy accepts no responsibilities for changes in market or economic conditions, price fluctuations for labour and material costs, and therefore makes no representations, guarantees or warranties for the estimates in this report. Persons relying on such estimates or opinions do so at their own risk.

Reported utility company incentive amounts are estimated based on information that was available at the time of report preparation. Actual incentive amounts are to be determined and provided by the utility company. The utility company must be contacted prior to beginning any work for which an incentive will be applied for.

This report may not be disclosed or referred to in any public document without the prior formal written consent of WalterFedy. Any use which a third party makes of the report is at the sole responsibility and risk of the third party.

WalterFedy agrees with the Client that it will provide under this Agreement the standards of care, skill and diligence normally provided in the performance of services in respect of work similar to that contemplated by this Agreement. WalterFedy at its own expense carries professional liability insurance to the extent that it deems prudent and WalterFedy's liability under this Agreement to the Client for any claim in contract or in tort related to the services provided under this Agreement howsoever arising shall be limited to the extent that such liability is covered by such professional liability insurance from time to time in effect including the deductible therein, and which is available to indemnify WalterFedy and in any event WalterFedy's liability under this Agreement shall be limited to loss or damage directly attributable to the negligent acts of WalterFedy, its officers, servants or agents, or its failure to provide the standards of care, skill and diligence aforesaid. In no event shall WalterFedy be liable for loss or damage caused by delays beyond WalterFedy's control, or for loss of earnings or for other consequential damage howsoever caused.

The errors and omissions policies are available for inspection by the Client at all times upon request. If the Client, because of its particular circumstances or otherwise, desires to obtain further insurance to protect it against any risk beyond the coverage provided by such policies, WalterFedy will co-operate with the Client to obtain such insurance at the Client's expense.

The Client, in consideration of the provision by WalterFedy of the services set forth in this Agreement, agrees to the limitations of the liability of WalterFedy aforesaid. The Client shall have no right of set-off against any billings of WalterFedy under this Agreement.

COPYRIGHT

© 2025, City of Temiskaming Shores. All Rights Reserved.

This project was carried out with assistance from the Green Municipal Fund, a Fund financed by the Government of Canada and administered by the Federation of Canadian Municipalities. Notwithstanding this support, the views expressed are the personal views of the authors, and the Federation of Canadian Municipalities and the Government of Canada accept no responsibility for them.

Project Number: 2023-0734-10

July 21, 2025

Mathew Bahm
Director of Recreation
City of Temiskaming Shores
325 Farr Drive
Haileybury, ON POJ 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 Haileybury Public Works Garage, which is located at 501 Broadway Street in Haileybury, 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

Contents

	Page
EXECUTIVE SUMMARY	1
1 INTRODUCTION	5
1.1 Overview	5
1.2 Background	5
1.2.1 Corporate Greenhouse Gas Reduction Plan	5
1.2.2 Asset Management Plan	5
1.3 Contact information	6
2 FACILITY DESCRIPTION	7
2.1 Facility description methodology	7
2.2 Facility overview	7
2.3 Building information	9
2.4 Space use	10
2.5 Building Envelope	11
2.6 HVAC	14
2.7 Domestic hot water	17
2.8 Lighting	18
2.9 Process and plug loads	20
2.10 Water fixtures	21
2.11 Utility services	23
2.12 Onsite energy sources	24
2.13 Electrical infrastructure	25
3 UTILITY USE ANALYSIS	26
3.1 Utility analysis methodology	26
3.2 Utility analysis assumptions	28
3.3 Electricity metered utility use	29
3.4 Natural gas metered utility use	31
3.5 Utility use baseline	32
3.6 Benchmarking analysis	33
3.7 ENERGY STAR Portfolio Manager benchmarking analysis	35
3.8 Utility use analysis discussion	36
4 ENERGY MODEL DEVELOPMENT	37
4.1 Energy model development methodology	37
4.2 Hourly utility use profiles	38
4.3 Monthly utility use profiles	41
4.4 Calibration analysis	42
4.5 End use analysis	46
5 MEASURE ANALYSIS	47
5.1 Measure analysis methodology	47
5.2 Measure analysis assumptions	49
5.3 Measure identification	52
5.4 Carbon offsets 20	53
5.5 Install a mini split system in the lunchroom	55
5.6 Interior LED lighting upgrade	57
5.7 Radiant heaters to electric	59
5.8 Roof upgrade to high performance	61
5.9 Wall upgrade to high performance	63

5.10 Windows and doors to high performance	66
5.11 Measure risk analysis	68
5.12 Measure analysis summary	70
6 SCENARIO ANALYSIS	71
6.1 Cluster scenario analysis methodology	71
6.2 Cluster scenario objectives	71
6.3 Cluster scenario composition	72
6.4 Cluster scenario performance analysis	73
6.5 Plan scenario development	83
6.6 Plan performance analysis	87
6.7 Plan performance summary	91
6.8 Scenario analysis discussion	92
7 END	93

List of Figures

1 Recommended plan scenario composition, indicating which measures are implemented when and at what cost in each plan scenario	2
2 Recommended scenario performance	3
3 Haileybury Public Works Garage aerial view	8
4 Aluminum framed window	12
5 Batt insulation has mould on it	12
6 Damage to wall west elevation	12
7 Damaged insulation in the mechanic bay	12
8 More damaged insulation	12
9 Eavestrough is missing	12
10 Gap at bottom of exterior door in lunch room	12
11 Gap in floor to the outside in the electric room	12
12 Hollow metal door on north elevation	12
13 Hollow metal door	12
14 Metal siding on gable end	12
15 Metal siding on the east elevation	12
16 North elevation	12
17 Overhead doors	12
18 West elevation	12
19 Window frame in poor condition	13
20 Windows appear original to the building	13
21 Windows from mechanic shop	13
22 Wood siding deteriorating	13
23 Ceiling fan	15
24 EF1 nameplate	15
25 EF1	15
26 EF2	15
27 Electric cabinet heater in lunch room nameplate	15
28 Electric cabinet heater in lunch room	15
29 Electric cabinet heater in washroom	15
30 Exhaust fan control	15
31 Exhaust port	15
32 IH1	15
33 IH2	15
34 IH3 nameplate	15

35	IH4	16
36	Nameplate of UH1	16
37	Thermostat for IH1	16
38	Thermostat for IH2	16
39	Thermostat for IH3	16
40	Thermostat for IH4	16
41	Thermostat for UH1	16
42	Unitary air conditioner	16
43	WH1 nameplate	17
44	WH1	17
45	Old exterior fixture assumed to not be working	19
46	Type A	19
47	Type B	19
48	Type C lamp	19
49	Type C	19
50	Type D	19
51	Type E - close up	19
52	Type E	19
53	Type F	19
54	Type G	19
55	Type H	19
56	Type I	19
57	Type J	19
58	Air compressor	20
59	Chop saw and drill press	20
60	Grinder	20
61	Microwave	20
62	Portable generator in storage	20
63	Refrigerator	20
64	Faucet in upstairs washroom	21
65	Faucet	21
66	Handwashing fountain	21
67	Hose bibs with hot and cold water supply	21
68	Kitchen sink	21
69	Showerhead	21
70	Toilet in upstairs washroom	22
71	Toilet	22
72	Urinal	22
73	Electricity meter	23
74	Natural gas meter	23
75	Panel A	25
76	Hourly electricity use	29
77	Hourly electricity use hairball plot	29
78	Monthly electricity use	30
79	Monthly natural gas use	31
80	Electricity use intensity benchmarking analysis comparison	33
81	Natural gas use intensity benchmarking analysis comparison	33
82	Total energy use intensity benchmarking analysis comparison	34
83	GHG emissions intensity benchmarking analysis comparison	34
84	Energy Star energy performance scorecard.	35
85	Hourly electricity utility use by end use (made by calibrated energy model)	39
86	Hourly natural gas utility use by end use (made by calibrated energy model)	40
87	Monthly utility use profiles for each modelled utility	41
88	Electricity calibration analysis (metered vs modelled utility use)	42

89	Natural gas calibration analysis (metered vs modelled utility use)	43
90	Electricity end use breakdown (calculated by calibrated energy model)	46
91	Natural gas end use breakdown (calculated by calibrated energy model)	46
92	Utility cumulative use sensitivity analysis	68
93	GHG cumulative emissions and life cycle cost sensitivity analysis	69
94	Scenario composition	72
95	Electricity utility use expected yearly for each scenario by end use	75
96	Natural gas utility use expected yearly for each scenario by end use	76
97	Equivalent energy use expected yearly for each scenario by end use	77
98	GHG emissions expected yearly for each scenario by end use	78
99	Utility costs expected yearly for each scenario by end use	79
100	Project cost expected for each scenario by measure	80
101	Life cycle cost expected for each scenario by cost item	81
102	GHG cumulative reduction per life cycle cost (LCC) dollar expected for each scenario by utility	82
103	Plan scenario composition, indicating which measures are implemented when and at what cost in each plan scenario	84
104	Electricity yearly utility use projection for each scenario	87
105	Natural gas yearly utility use projection for each scenario	88
106	GHG yearly emissions projection for each scenario	89
107	Life cycle yearly cost (after discounting to present value) projection for each scenario	90

List of Tables

1	Recommended plan scenario performance summary	4
2	Asset management summary for this facility	6
3	Contact information	6
4	Facility overview	7
5	Space use summary	10
6	Building envelope summary	11
7	Air distribution systems summary	14
8	Heating systems summary	14
9	Cooling systems summary	14
10	Lighting systems summary	18
11	Water fixture summary	21
12	Baseline performance data source for each utility	26
13	GHG emissions factor assumptions	28
14	Utility cost rate assumptions for the baseline year (2022)	28
15	Baseline utility use performance	32
16	Utility and end use summary and definitions	37
17	Statistical calibration analysis summary	44
18	Utility cost rate future assumptions	49
19	Financial incentive assumptions	50
20	Life cycle cost analysis assumptions	50
21	Risk parameter and case definitions	50
22	Measure identification and triaging summary	52
23	Carbon offsets 20 analysis results summary	54
24	Project cost estimate (Install a mini split system in the lunchroom)	56
25	Install a mini split system in the lunchroom analysis results summary	56
26	Project cost estimate (Interior LED lighting upgrade)	58
27	Interior LED lighting upgrade analysis results summary	58
28	Project cost estimate (Radiant heaters to electric)	60
29	Radiant heaters to electric analysis results summary	60
30	Project cost estimate (Roof upgrade to high performance)	61

31	Roof upgrade to high performance analysis results summary	62
32	Project cost estimate (Wall upgrade to high performance)	64
33	Wall upgrade to high performance analysis results summary	65
34	Project cost estimate (Windows and doors to high performance)	67
35	Windows and doors to high performance analysis results summary	67
36	Measure analysis summary	70
37	Scenario objectives	71
38	Cluster composition	73
39	Scenario analysis summary	74
40	Plan scenario identification and objectives	83
41	Scenario composition summary	85
42	Minimum performance scenario measure implementation timeline	85
43	Aggressive deep retrofit measure implementation timeline	85
44	Comprehensive measure implementation timeline	85
45	Organizational goal alignment measure implementation timeline	86
46	Business as usual measure implementation timeline	86
47	Plan performance summary	91

EXECUTIVE SUMMARY

WalterFedy was engaged by the City of Temiskaming Shores to complete a Pathway to Decarbonization Feasibility Study for the Haileybury Public Works Garage. The objective of this engagement is to identify and analyze measures that reduce utility use, GHG emissions, and utility costs at the Haileybury Public Works Garage, 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 2024-04-17 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 Haileybury Public Works Garage. 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 Haileybury Public Works Garage 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.

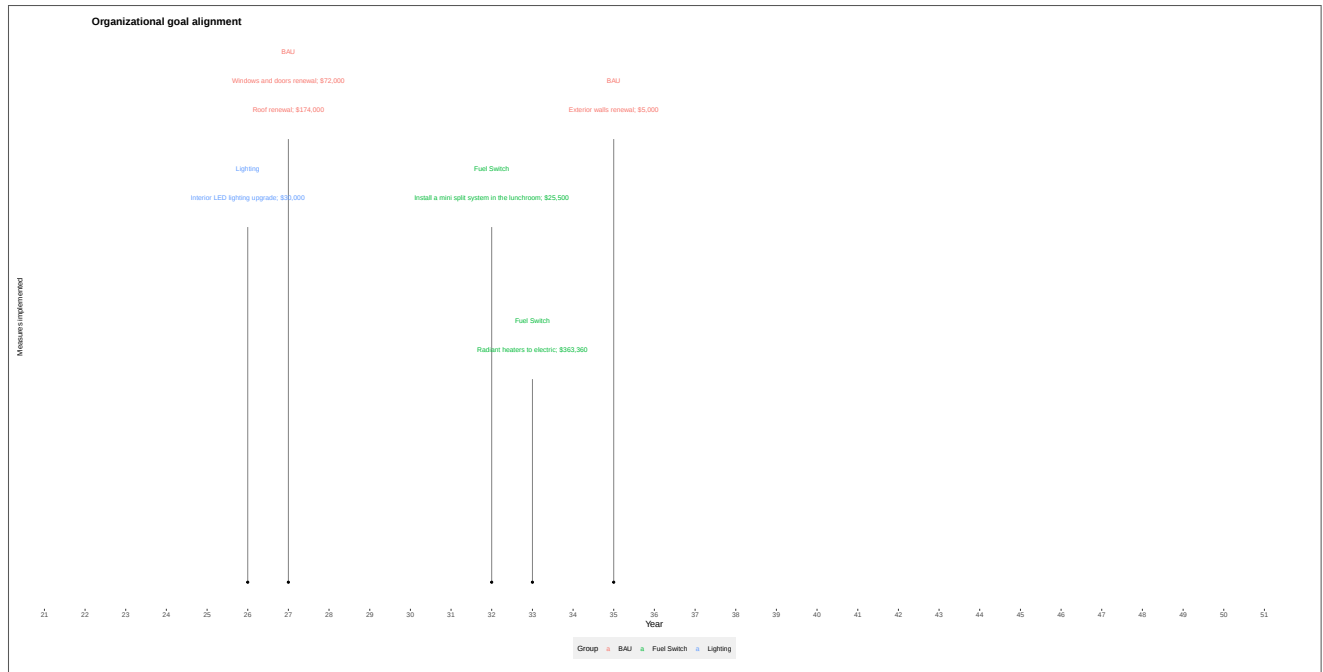


Figure 1: Recommended plan scenario composition, indicating which measures are implemented when and at what cost in each plan scenario

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

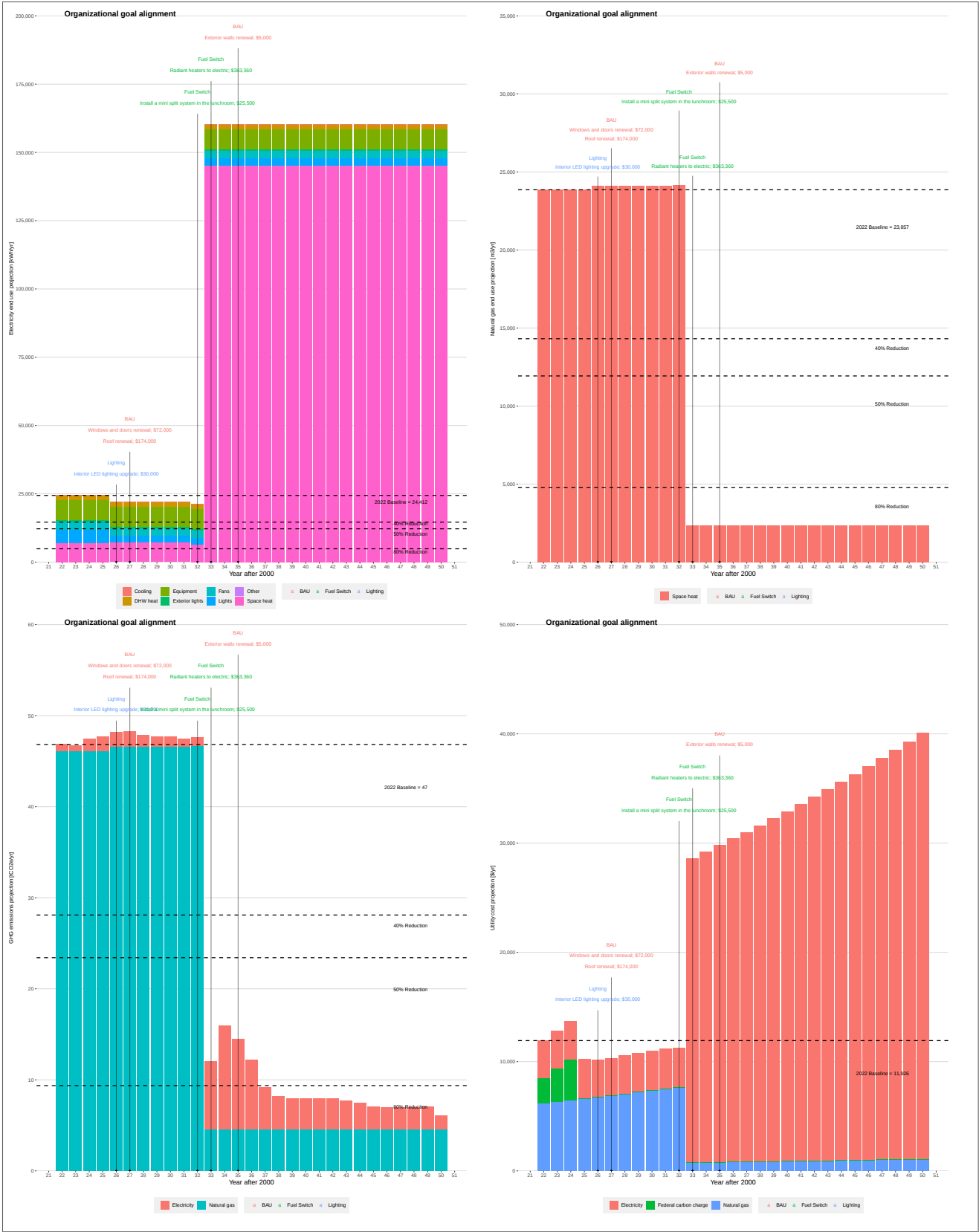


Figure 2: Recommended scenario performance

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]	133,046	133,046	121,191	160,134	24,412
	Electricity monthly peak (av)	[kW]	25.8	25.8	23.9	29.4	6.4
	Electricity yearly peak (max)	[kW]	44.4	44.4	44.0	45.0	8.1
	Natural gas use	[m3/yr]	405	405	108	2,354	23,857
GHG emissions final	Electricity GHGs	[tCO2e/yr]	1.3	1.3	1.2	1.5	0.2
	Natural gas GHGs	[tCO2e/yr]	0.8	0.8	0.2	4.5	46.1
	Carbon offsets GHGs	[tCO2e/yr]	0.00	0.00	0.00	0.00	0.00
	Total GHGs	[tCO2e/yr]	2.0	2.0	1.4	6.1	46.3
Utility cost final	Electricity utility cost	[\$/yr]	32,437	32,437	29,546	39,041	5,952
	Natural gas utility cost	[\$/yr]	183	183	49	1,066	10,798
	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]	32,620	32,620	29,595	40,106	16,749
Utility use cumulative	Electricity use	[kWh]	2,893,453	3,355,306	2,834,178	3,133,446	707,954
	Natural gas use	[m3]	288,838	132,084	287,350	306,579	691,851
GHG emissions cumulative	Electricity GHGs	[tCO2e]	87	116	86	91	26
	Natural gas GHGs	[tCO2e]	558	255	555	592	1,337
	Carbon offsets GHGs	[tCO2e]	0.00	0.00	0.00	0.00	0.00
	Total GHGs	[tCO2e]	645	372	641	683	1,363
Utility cost cumulative	Electricity utility cost	[\$]	581,661	649,858	567,767	635,803	132,617
	Natural gas utility cost	[\$]	84,884	36,703	84,237	92,297	240,585
	Carbon offsets utility cost	[\$]	0.00	0.00	0.00	0.00	0.00
	Federal carbon charge	[\$]	8,990	8,990	8,990	8,990	8,990
	Total utility cost	[\$]	675,534	695,550	660,993	737,090	382,192
Financial cumulative	Project cost	[\$]	2,382,815	1,951,920	2,890,201	854,093	307,202
	Replacement cost	[\$]	535,060	493,083	400,560	535,060	158,576
	Life cycle cost	[\$]	985,242	1,340,343	856,531	966,603	479,330

1 INTRODUCTION

1.1 Overview

WalterFedy was engaged by the City of Temiskaming Shores to complete a Pathway to Decarbonization Feasibility Study for the Haileybury Public Works Garage. 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 Haileybury Public Works Garage 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 Haileybury Public Works Garage represented 18 tCO₂e in 2019, or 0.94% 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 Haileybury Public Works Garage.

Table 2: Asset management summary for this facility

Group	Metric	Unit	Value
Financial	Content Value Estimated	[\$]	147,757
	Building Land Tank	[\$]	1,043,818
	Replacement Cost	[\$]	1,191,575
Information	Install Date	[yr]	1960
	Age	[yrs]	65
Condition Rating	Structure Condition Score	[-]	3.7
	Final Condition Score	[-]	3.7
Risk	Probability of Failure	[-]	2
	Consequence of Failure	[-]	5
	Risk Score	[-]	2.6

1.3 Contact information

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

Table 3: Contact information

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

2 FACILITY DESCRIPTION

2.1 Facility description methodology

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

1. **Facility document review.** Facility documents from the following list were reviewed, if available. Further information on available documentation are available in Section 2.3.
 - Building drawings.
 - Building automation system graphics and points lists.
 - Previously completed Engineering studies, including Energy Audits, Feasibility Studies, and Building Condition Assessments.
 - Historical utility use data.
 - Other documentation made available by the City of Temiskaming Shores.
2. **Site survey.** A site survey was completed on 2024-04-17 to review the energy systems applicable to the desired retrofit scenario.

2.2 Facility overview

An overview of the Haileybury Public Works Garage is provided in Table 4.

Table 4: Facility overview

Description	Unit	Value
Name	[-]	Haileybury Public Works Garage
Address	[-]	501 Broadway Street
Location	[-]	Haileybury, ON
Type	[-]	Public works
Construction year	[-]	1960
Gross floor area	[m2]	690
Gross floor area	[ft2]	7,430

An aerial view of the Haileybury Public Works Garage is provided in Figure 3.



Figure 3: Haileybury Public Works Garage aerial view

2.3 Building information

Renovations

There are no known renovations to this building.

Additions

It is assumed that 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.

Previous studies

The following is a summary of known previous studies:

- Energy audits: None
- Engineering studies: None
- Building condition assessments: None

Documentation availability

Only one document was available, which a CAD drawing showing the floor plans of the facility.

2.4 Space use

Type summary

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

- Bay areas
- Lunch room
- Washroom
- Electrical room
- Storage
- Mechanic shop
- Tool room
- Office

The lunch room is listed as a changeroom on the CAD drawings provided.

Occupancy scheduling

The facility operation hours is assumed as follows:

- 07:00-15:30 Monday to Friday

There are seldom staff in this building. It will be assumed a peak occupancy load of five 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]	-	-
Truck storage days	259	IH1 and IH2	Drawings.
Mechanic bays	401	UH1, IH3, and IH4	Drawings.
Lunchroom	13	Electric heating	Drawings.
Changeroom	17	Electric heating	Drawings.

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]
668	896	800	12.2	83.6

Overview

No architectural drawings were available, and therefore there is no detailed information on building assemblies. All overall R-Values are based on the requirements listed in the Model National Energy Code of Canada for Buildings, 1997.

Roof

- The roof exterior layer appears to be metal. There appears to be minimal insulation.
- The overall R-Value is assumed to be R16.
- The roof condition could not be assessed.

Opaque Walls (above ground)

- The exterior walls had an outer layer of wood or metal siding.
- The overall R-Value is assumed to be R14 as there is missing insulation in multiple areas.
- The wall condition was extremely poor condition, specifically from the inside. There were numerous areas of mould growth on the insulation.

Fenestration

Windows

- The facility has aluminum-framed, double-pane slider windows and single-pane windows at the west elevation.
- The original windows are in poor condition, and the double-pane sliders appear to be in fair condition. However, mould growth was spotted on the double-pane windows.
- The overall U-Value is assumed to be 0.45 Btu/hr.ft².F for the window system with a SHGC of 0.35.

Doors

- The facility has hollow metal and overhead doors.
- The overall fenestration-to-wall ratio is estimated to be 11%, 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 4: Aluminum framed window



Figure 5: Batt insulation has mould on it



Figure 6: Damage to wall west elevation



Figure 7: Damaged insulation in the mechanic bay



Figure 8: More damaged insulation



Figure 9: Eavestrough is missing

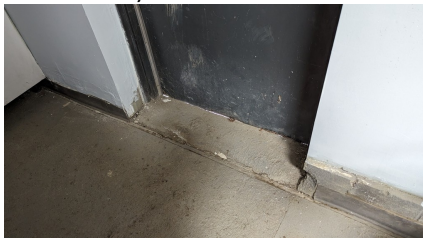


Figure 10: Gap at bottom of exterior door in lunch room



Figure 11: Gap in floor to the outside in the electric room



Figure 12: Hollow metal door on north elevation



Figure 13: Hollow metal door



Figure 14: Metal siding on gable end



Figure 15: Metal siding on the east elevation



Figure 16: North elevation



Figure 17: Overhead doors



Figure 18: West elevation



Figure 19: Window frame in poor condition



Figure 20: Windows appear original to the building



Figure 21: Windows from mechanic shop



Figure 22: Wood siding deteriorating

2.6 HVAC

HVAC equipment summary

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

Table 7: Air distribution systems summary

Tag	Make	Model	Serves	Design flow	Motor output	Data source
-	-	-	-	[cfm]	[hp]	-
EF1	GEC	BC2514.TE	Mechanical bay	800	1	Nameplate.

Table 8: Heating systems summary

Tag	Serves	Utility	Efficiency	Output	Data source
-	-	-	[decimal]	[btuh]	-
IH1	Truck storage bays	Natural gas	0.60	90,000	Nameplate.
IH2	Truck storage bays	Natural gas	0.60	90,000	Nameplate.
IH3	Mechanic bays	Natural gas	0.60	90,000	Nameplate.
IH4	Mechanic bays	Natural gas	0.60	90,000	Nameplate.
UH1	Mechanic shop space	Natural gas	0.83	166,000	Nameplate.
H_ELEC	Changeroom and lunch room	Electricity	1.00	11,912	Assumption.

Table 9: Cooling systems summary

Tag	Serves	Efficiency	Output	Data source
-	-	[decimal]	[ton]	-
AC1	Lunchroom	3	0.50	Assumption.

System type

The facility utilizes the following equipment:

- IH1 and IH2 are infrared heaters serving the truck storage bays on the west side. IH1 and IH2 were controlled by non-programmable thermostats that were both set to 20C.
- IH3 and IH4 are infrared heaters serving the mechanic bays on the east side. IH3 and IH4 were controlled by non-programmable thermostats that were set to 20C and 15C, respectively.
- One natural gas-fired unit heater (UH1) serves the mechanic shop space with IH3 and IH4. This unit is controlled by a non-programmable thermostat. The temperature setpoint is assumed to be 20C.
- EF1 provides general exhaust for the mechanic bay, including, fume and hood extraction. It is assumed that this fan is manually controlled via a switch.
- Electric heating is provided in the changeroom and lunchroom.
- The lunchroom has one unitary air conditioner with the condenser side interfacing with the bay area.

Central Plant

There is no central plant at this facility.

Distribution system

There are no pumps or ductwork present at this site.

Controls

- No BAS is present at this site.

HVAC system documentation

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

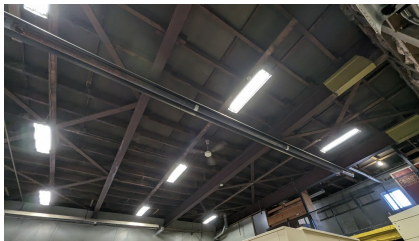


Figure 23: Ceiling fan



Figure 24: EF1 nameplate



Figure 25: EF1

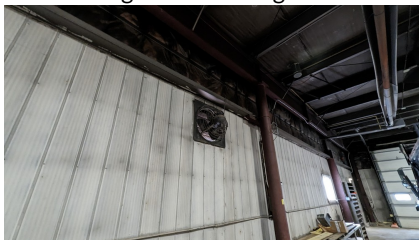


Figure 26: EF2



Figure 27: Electric cabinet heater in lunch room nameplate



Figure 28: Electric cabinet heater in lunch room

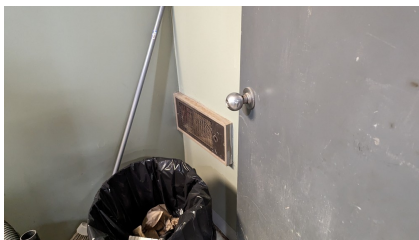


Figure 29: Electric cabinet heater in washroom



Figure 30: Exhaust fan control



Figure 31: Exhaust port

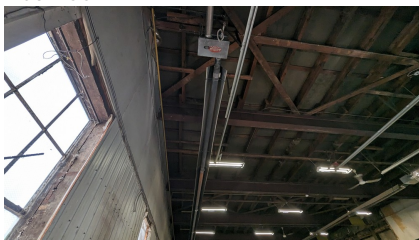


Figure 32: IH1

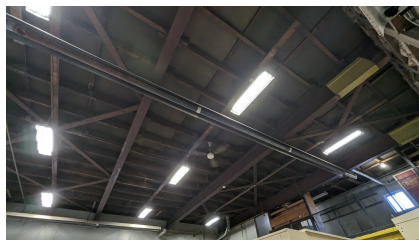


Figure 33: IH2

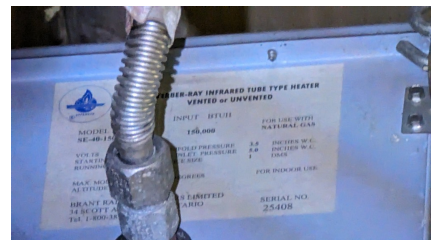


Figure 34: IH3 nameplate



Figure 35: IH4

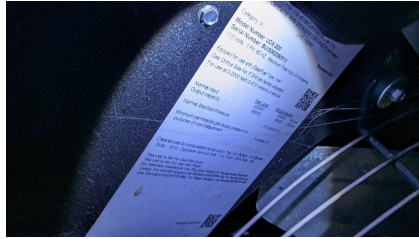


Figure 36: Nameplate of UH1



Figure 37: Thermostat for IH1



Figure 38: Thermostat for IH2



Figure 39: Thermostat for IH3



Figure 40: Thermostat for IH4

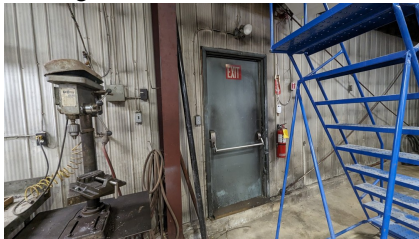


Figure 41: Thermostat for UH1

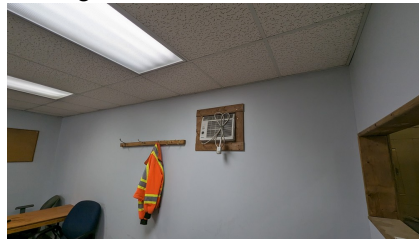


Figure 42: Unitary air conditioner

2.7 Domestic hot water

Overview

One electric DHW heater serves the washroom and lunchroom with a tank capacity of 40 USG.

Domestic Hot Water documentation

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



Figure 43: WH1 nameplate



Figure 44: WH1

2.8 Lighting

Lighting system summary

Lighting systems are summarized in Table 10.

Table 10: Lighting systems summary

Space name	Floor area of space	Light power density	Light power input	Data source
-	[m2]	[W/m2]	[W]	-
Truck storage days	259	3.2	829	Assumed based on ASHRAE 2004 standard for storage garages.
Mechanic bays	401	3.2	1,283	Assumed based on ASHRAE 2004 standard for storage garages.
Lunchroom	13	3.2	42	Assumed based on ASHRAE 2004 standard for storage garages.
Changeroom	17	3.2	54	Assumed based on ASHRAE 2004 standard for storage garages.

Interior lighting

Fixtures

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

- Type C: 2'x4' suspended, 2 lamp, T5, 94 W (assumed)
- Type D: 1'x4' suspended, 2 lamp, T12, 68W (assumed)
- Type E: Recessed downlight, 1 lamp, LED, 9 W (assumed)
- Type F: 2'x4' recessed, 2 lamp, T12, 68W (assumed)
- Type G: 2'x4' recessed, 2 lamp, T8, 56W (assumed)
- Type H: surface mounted, 1 lamp, LED, 9 W (assumed)
- Type I: 1'x4', 2 lamp, T8, 56 W (assumed)
- Type J: 1'x4', 2 lamp, T8, 56 W (assumed)

Controls

Interior lighting control is done through manual switches.

Exterior lighting

Fixtures

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

- Type A: Wall pack, LED, 30 W (assumed)

- Type B: Wall pack, LED, 50 W (assumed)

Controls

It's assumed that the exterior lights are controlled by a photocell.

Lighting system documentation

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



Figure 45: Old exterior fixture assumed to not be working



Figure 46: Type A



Figure 47: Type B



Figure 48: Type C lamp

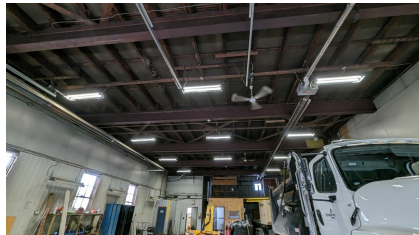


Figure 49: Type C



Figure 50: Type D



Figure 51: Type E - close up



Figure 52: Type E



Figure 53: Type F

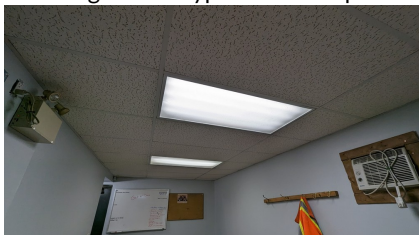


Figure 54: Type G



Figure 55: Type H



Figure 56: Type I



Figure 57: Type J

2.9 Process and plug loads

Process

Various process loads are present at the facility, including:

- Air compressor
- Overhead door openers
- Shop equipment (e.g., drill press, chop saw, grinder, etc.)

Plug loads

Various plug loads are present at the facility, including:

- Appliances (e.g., microwave)

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 58: Air compressor



Figure 59: Chop saw and drill press



Figure 60: Grinder



Figure 61: Microwave



Figure 62: Portable generator in storage

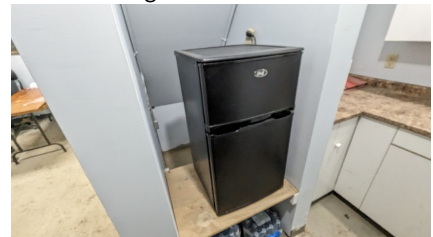


Figure 63: Refrigerator

2.10 Water fixtures

Water fixture summary

Water fixtures at Haileybury Public Works Garage are summarized in Table 11.

Table 11: Water fixture summary

Serves	Unit count	Flow	Volume	Data source
-	-	[gpm]	[gpc]	-
Kitchen faucets	1	2.20	-	Assumption.
Washroom faucets	2	0.50	-	Assumption.
Toilets	1	-	1.6	Assumption.
Urinals	1	-	1.0	Assumption.
Showers	1	1.25	-	Assumption.

Overview

A summary of water fixtures is as follows:

- Two handwashing faucets.
- One kitchen sink.
- One toilet.
- One urinal.
- One shower.

Water fixture documentation

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



Figure 64: Faucet in upstairs washroom



Figure 65: Faucet



Figure 66: Handwashing fountain



Figure 67: Hose bibs with hot and cold water supply



Figure 68: Kitchen sink



Figure 69: Showerhead



Figure 70: Toilet in upstairs washroom



Figure 71: Toilet



Figure 72: Urinal

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 73: Electricity meter



Figure 74: Natural gas meter

2.12 Onsite energy sources

Overview

There are no emergency generators or renewable energy systems present at this facility. It should be noted that there is a portable generator present at this facility. However, it is only stored there.

2.13 Electrical infrastructure

Overview

The existing system appears to have an incoming service with a 200A disconnect at 240V running at a maximum load of 8 kW, which is approximately 21% of the full load of 38.4 kW of the building. The incoming service appears to be a main disconnect to a splitter, with a disconnect to Panel A. Panel A appears to only have one space available for breaker space.

Electrical infrastructure documentation

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



Figure 75: Panel A

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 Haileybury Public Works Garage.
 - 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 12 summarizes the data source of the baseline performance for each utility.

Table 12: 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 Haileybury Public Works Garage 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 Haileybury Public Works Garage.
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 13.

Table 13: GHG emissions factor assumptions

Utility	Unit	Value	Source
Electricity	[tCO ₂ e/kWh]	0.0000302	Environment and Climate Change Canada Data Catalogue, Electricity Grid Intensities-1
Natural gas	[tCO ₂ e/m ³]	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 2022 were assumed as per Table 14. 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 14: Utility cost rate assumptions for the baseline year (2022)

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)	[\$/m ³]	0.2600
GHG emissions	Federal carbon charge	[\$/tCO ₂ e]	50.0000

3.3 Electricity metered utility use

Hourly electricity use is plotted in Figure 76.

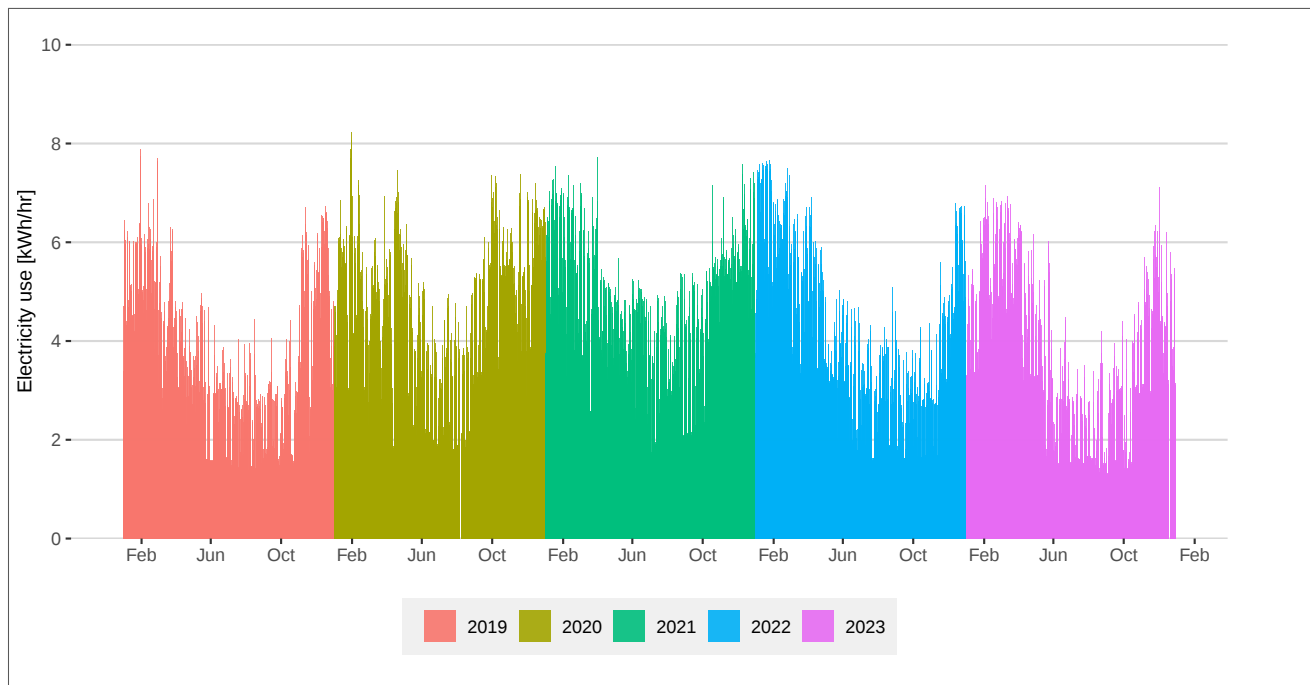


Figure 76: Hourly electricity use

The same hourly electricity use data is plotted in Figure 77, which highlights how electricity use is influenced by year, season, day of week and hour of day. The vertical axis on Figure 77 may be rescaled relative to in Figure 76 for greater resolution.

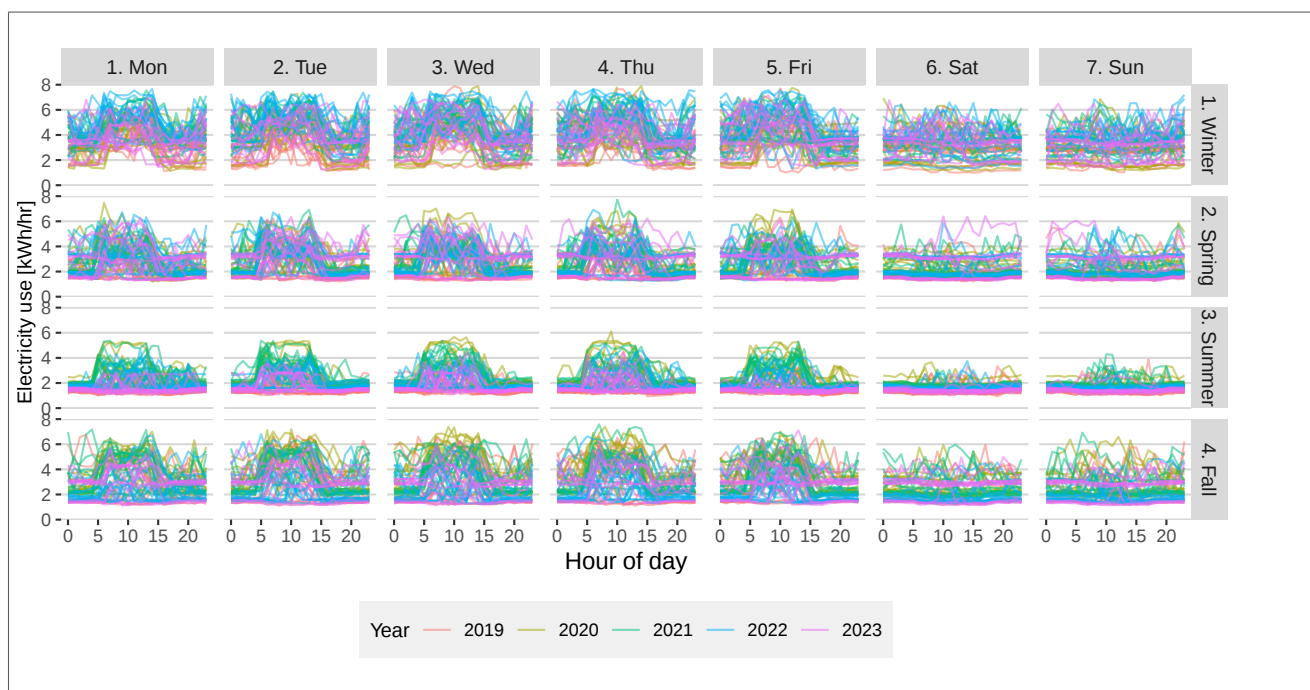


Figure 77: Hourly electricity use hairball plot

Monthly electricity use is plotted in Figure 78.

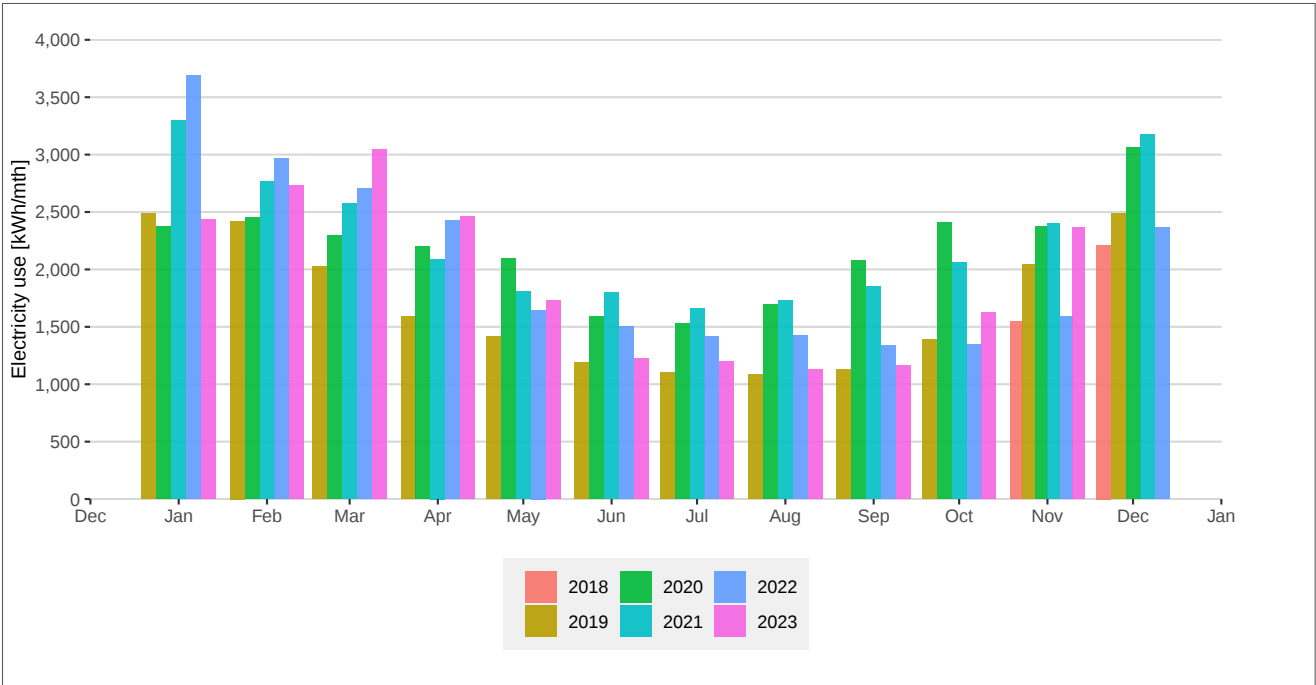


Figure 78: Monthly electricity use

3.4 Natural gas metered utility use

Monthly natural gas use is plotted in Figure 79.

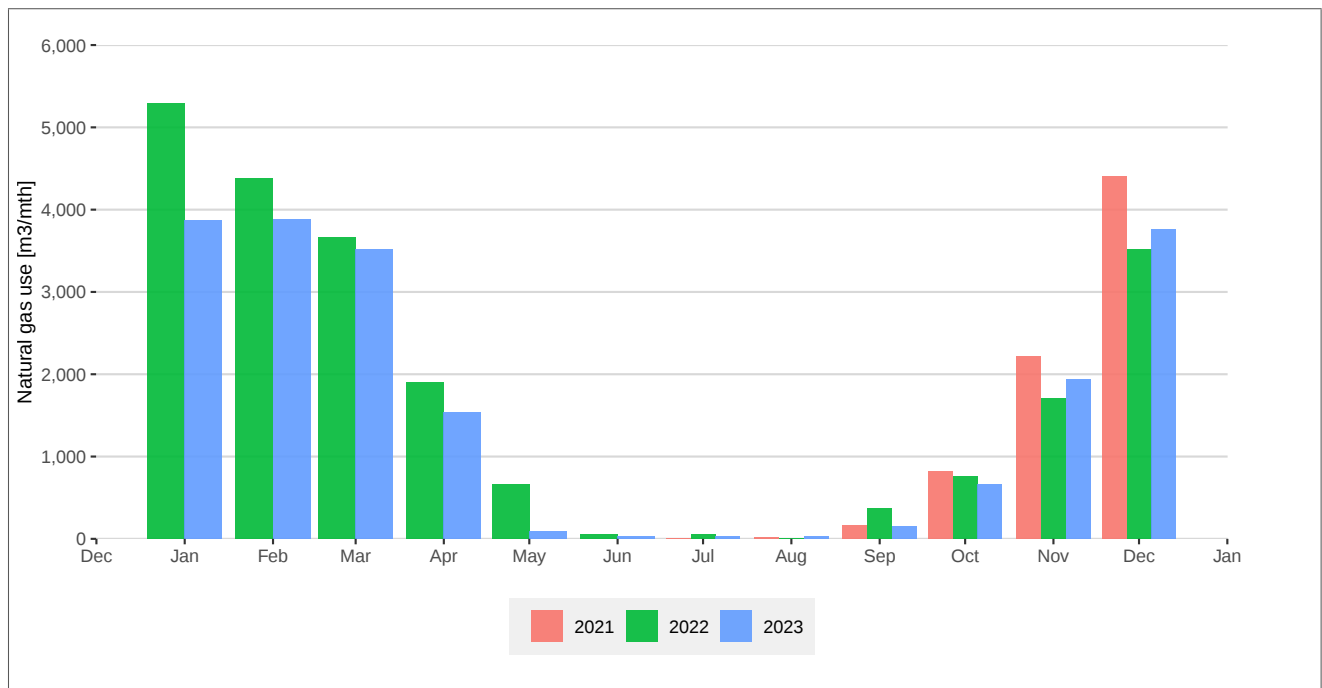


Figure 79: Monthly natural gas use

3.5 Utility use baseline

Baseline year

The baseline year for Haileybury Public Works Garage, which is used to establish the baseline performance through the metered utility use data from that year, is as follows.

- **Baseline year:** 2022.

Baseline performance

Baseline utility use performance for the baseline year of 2022 is summarized in Table 15.

Table 15: Baseline utility use performance

Category	Utility	Unit	Value
Utility use	Electricity use	[kWh/yr]	24,412
	Natural gas use	[m3/yr]	23,857
	Carbon offset use	[tCO2e/yr]	0
Equivalent energy use	Electricity energy	[kWh/yr]	24,412
	Natural gas energy	[kWh/yr]	251,851
	Total energy	[kWh/yr]	276,263
GHG emissions	Electricity GHGs	[tCO2e/yr]	1
	Natural gas GHGs	[tCO2e/yr]	46
	Carbon offsets GHGs	[tCO2e/yr]	0
	Total GHGs	[tCO2e/yr]	47
Utility cost	Electricity utility cost	[\$/yr]	2,422
	Natural gas utility cost	[\$/yr]	6,203
	Carbon offsets utility cost	[\$/yr]	0
	Federal carbon charge	[\$/yr]	2,305
	Total utility cost	[\$/yr]	10,930

3.6 Benchmarking analysis

Benchmarking analysis results are presented in the following figures.

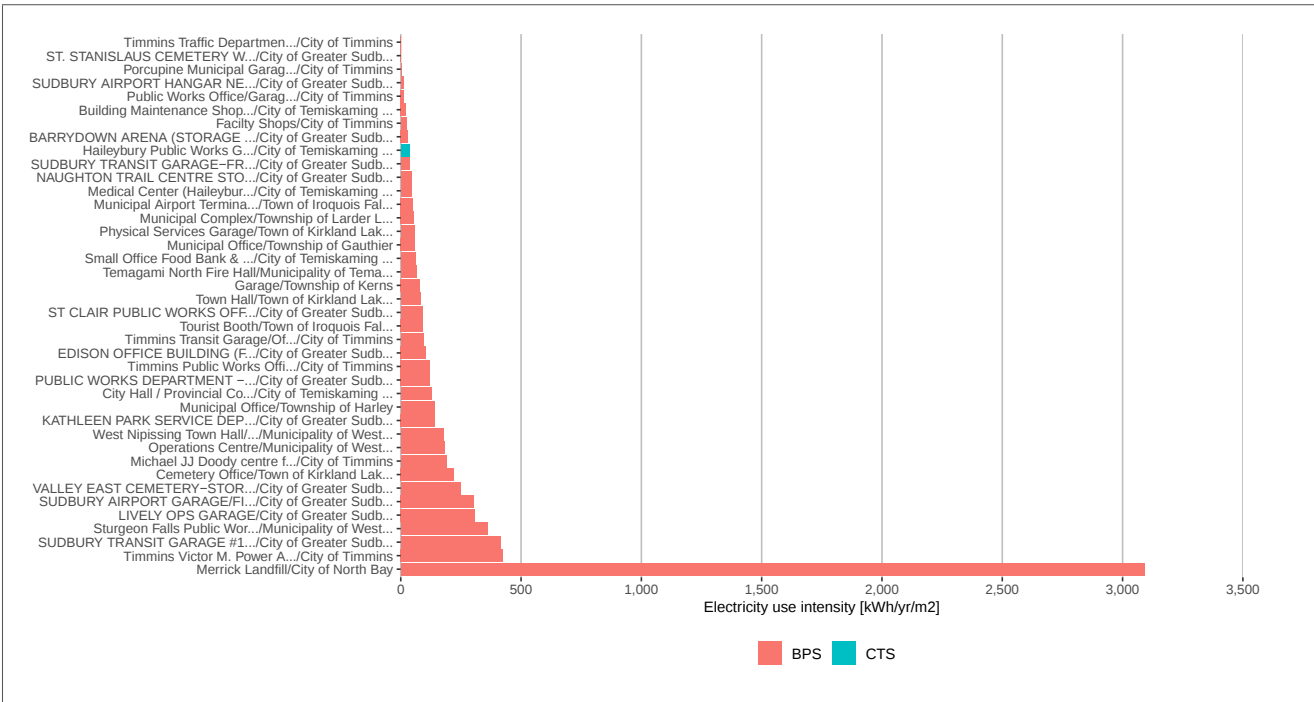


Figure 80: Electricity use intensity benchmarking analysis comparison

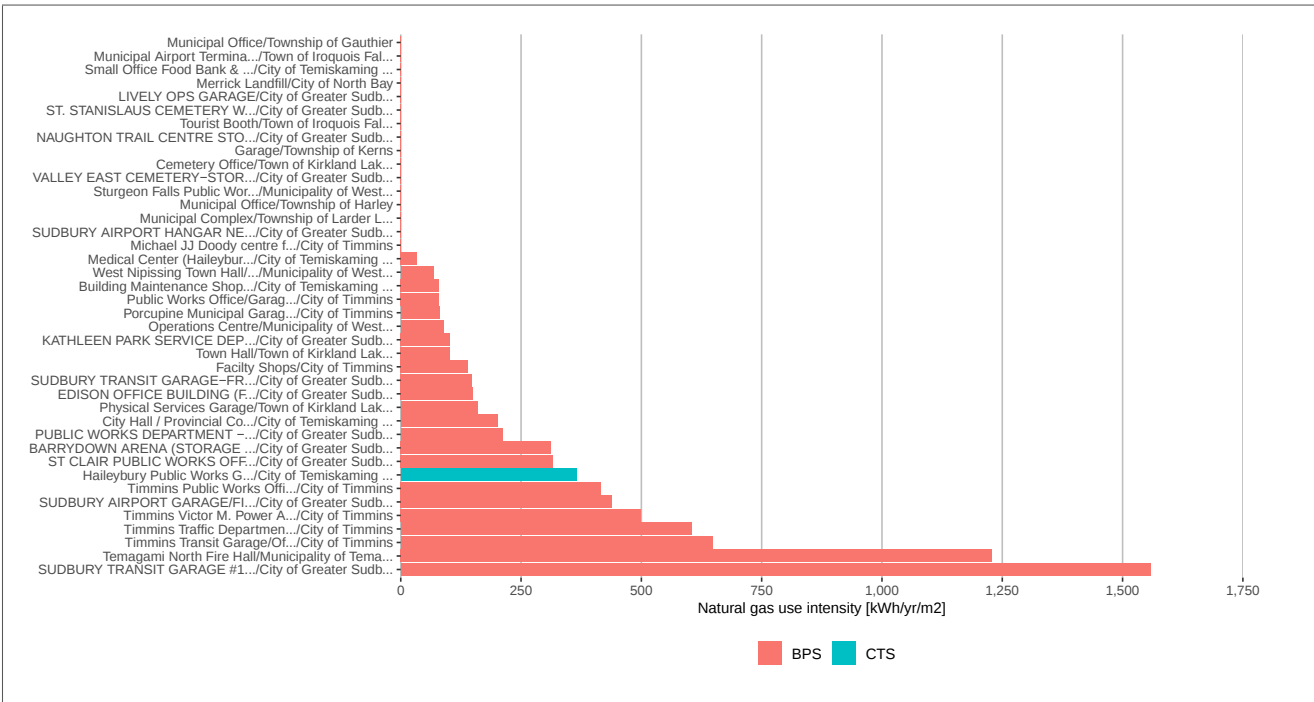


Figure 81: Natural gas use intensity benchmarking analysis comparison

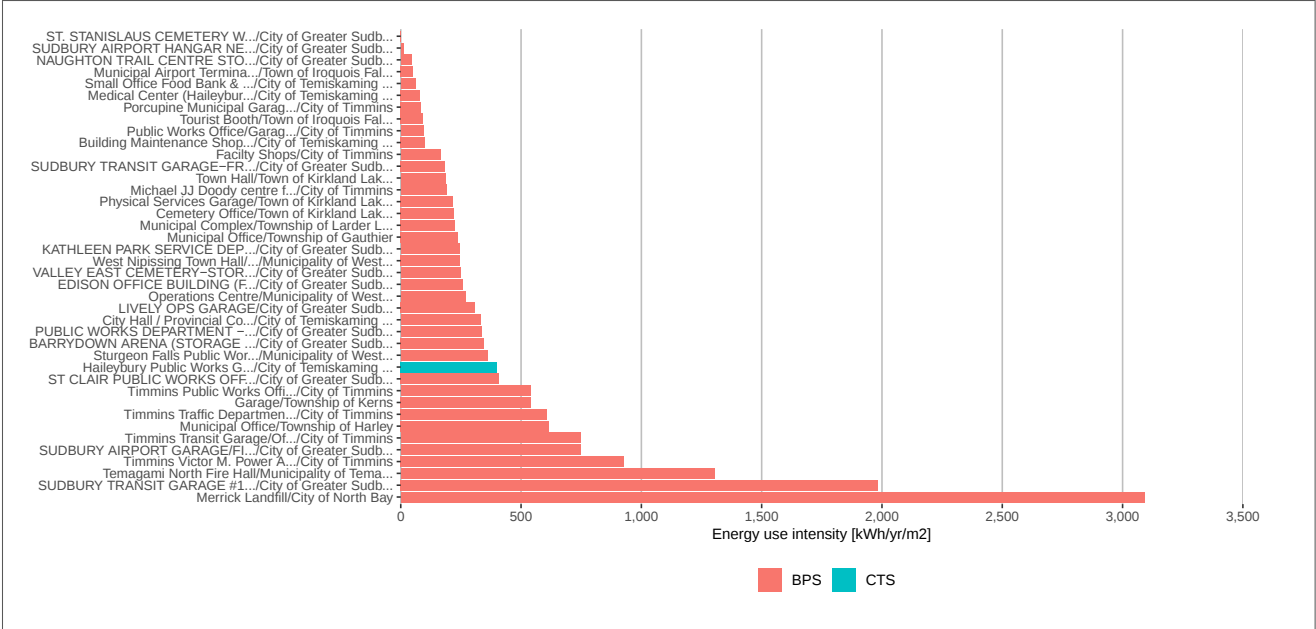


Figure 82: Total energy use intensity benchmarking analysis comparison

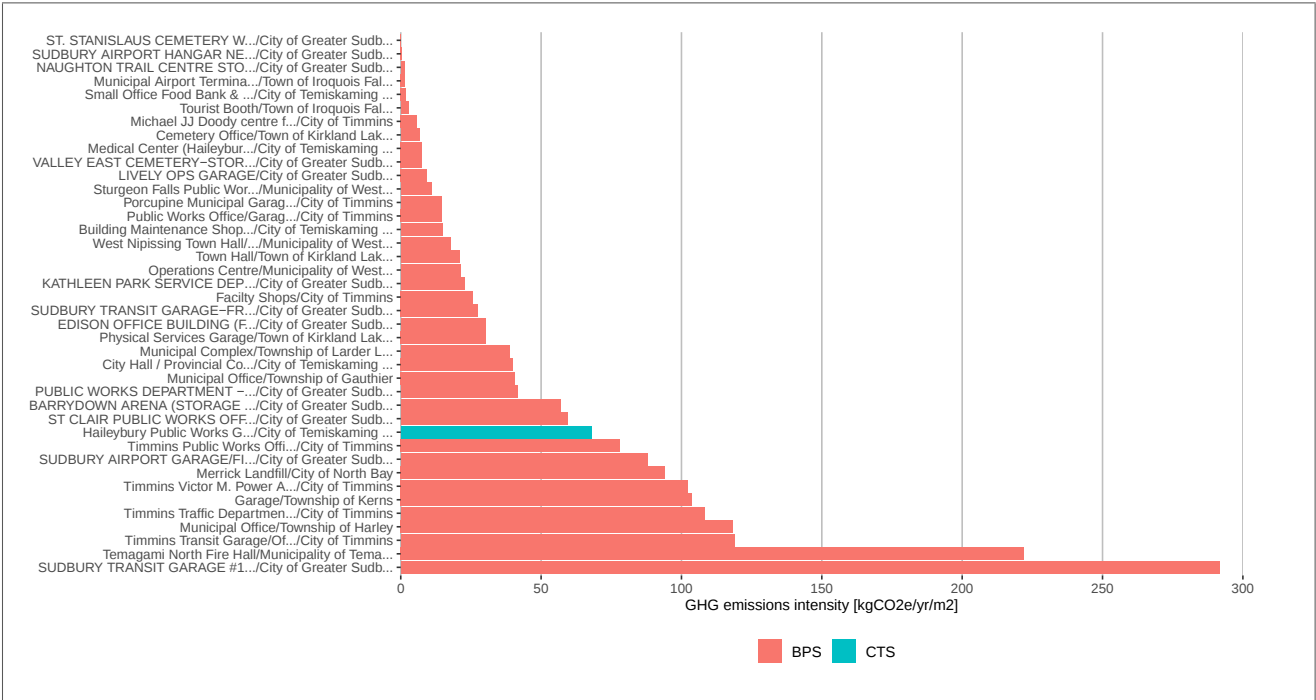


Figure 83: GHG emissions intensity benchmarking analysis comparison

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 Section 2.

Electricity - Hourly

- Hourly electricity consumption typically peaks during the winter, most likely due to heating.
- Hourly consumption is typically under 8 kWh and above 1 kWh.

Electricity - Monthly

- **2019:** Peak consumption in January and December and low overall consumption compared to future years.
- **2020:** There is higher than normal electricity consumption in September and October, compared to the seasonal average from other years.
- **2021:** Similar electrical consumption to 2020, with higher consumption in January and December.
- **2022:** Similar electricity consumption to 2021, with higher than average consumption in January.
- **2023:** Exhibits an annual electricity peak from February to April, but otherwise follows a similar trend to other years.

Natural gas

- Natural gas consumption has maintained a consistent profile year over year. It is highest during the heating season and very low during the cooling season.
- Natural gas in this building is used for space heating, which is why there is next to no natural gas consumption during the summer months.
- Of the 29 data points available for monthly natural gas consumption, only 11 were actual readings, not estimates. This observation can lead to calibration issues, as the model may not meet 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 16.

Table 16: 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.
	Space heat	Space heating energy use.
Natural gas	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 85. See Table 16 for end use definitions.

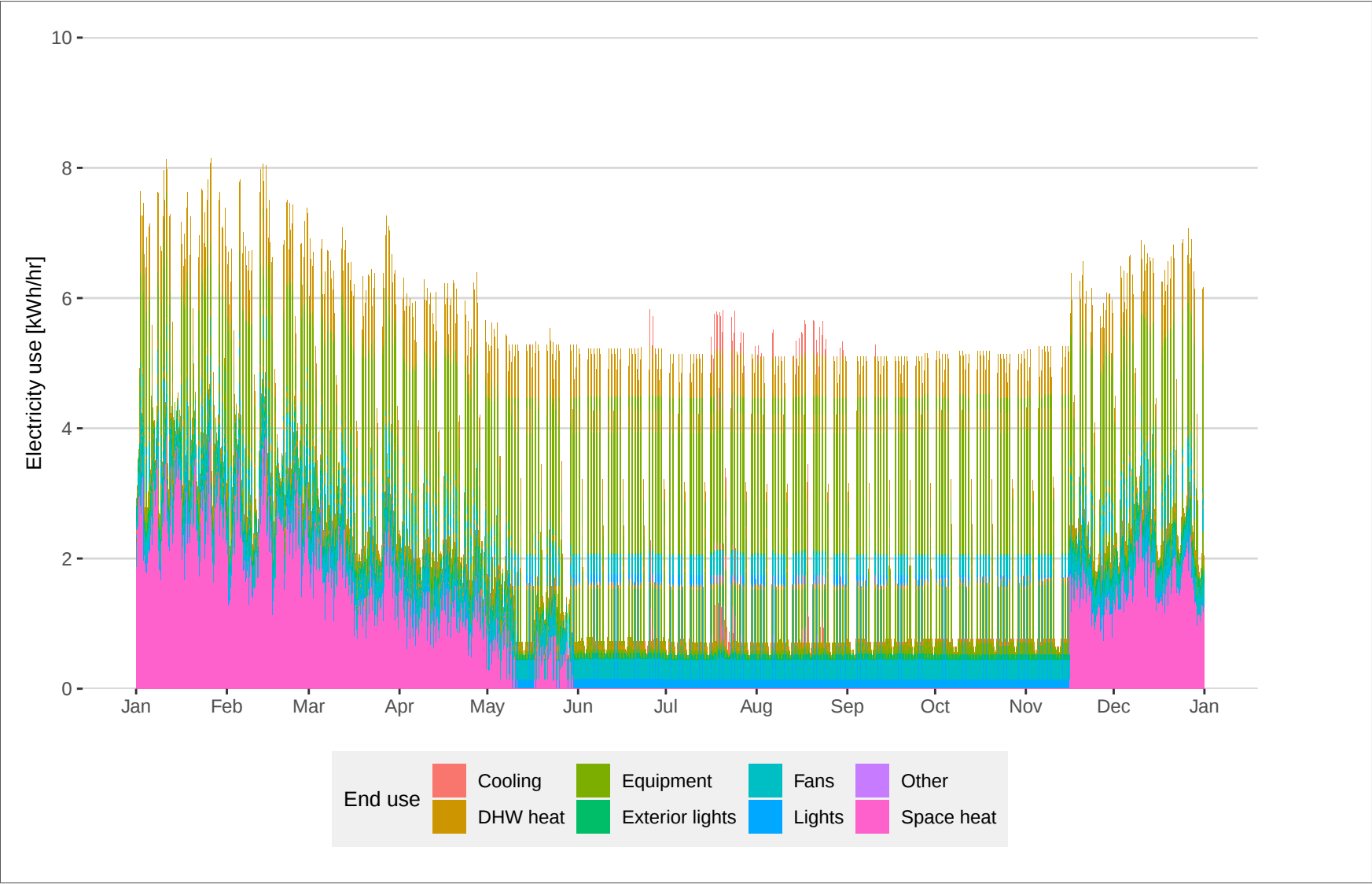


Figure 85: Hourly electricity utility use by end use (made by calibrated energy model)

Natural gas

The hourly natural gas utility use profile by end use made by the energy model is plotted in Figure 86. See Table 16 for end use definitions.

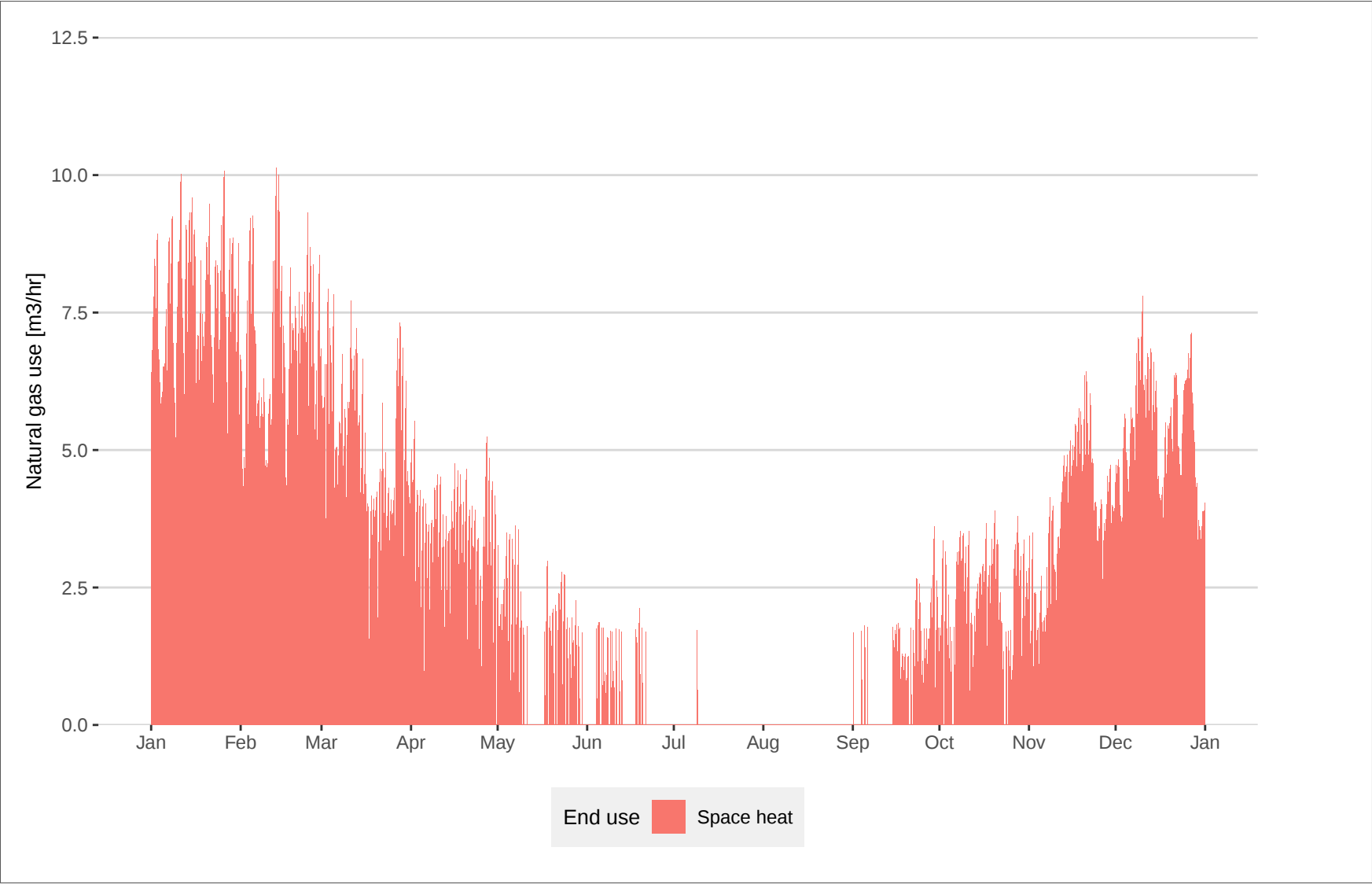


Figure 86: Hourly natural gas utility use by end use (made by calibrated energy model)

4.3 Monthly utility use profiles

Monthly utility use profiles for each modelled utility are presented in Figure 87.

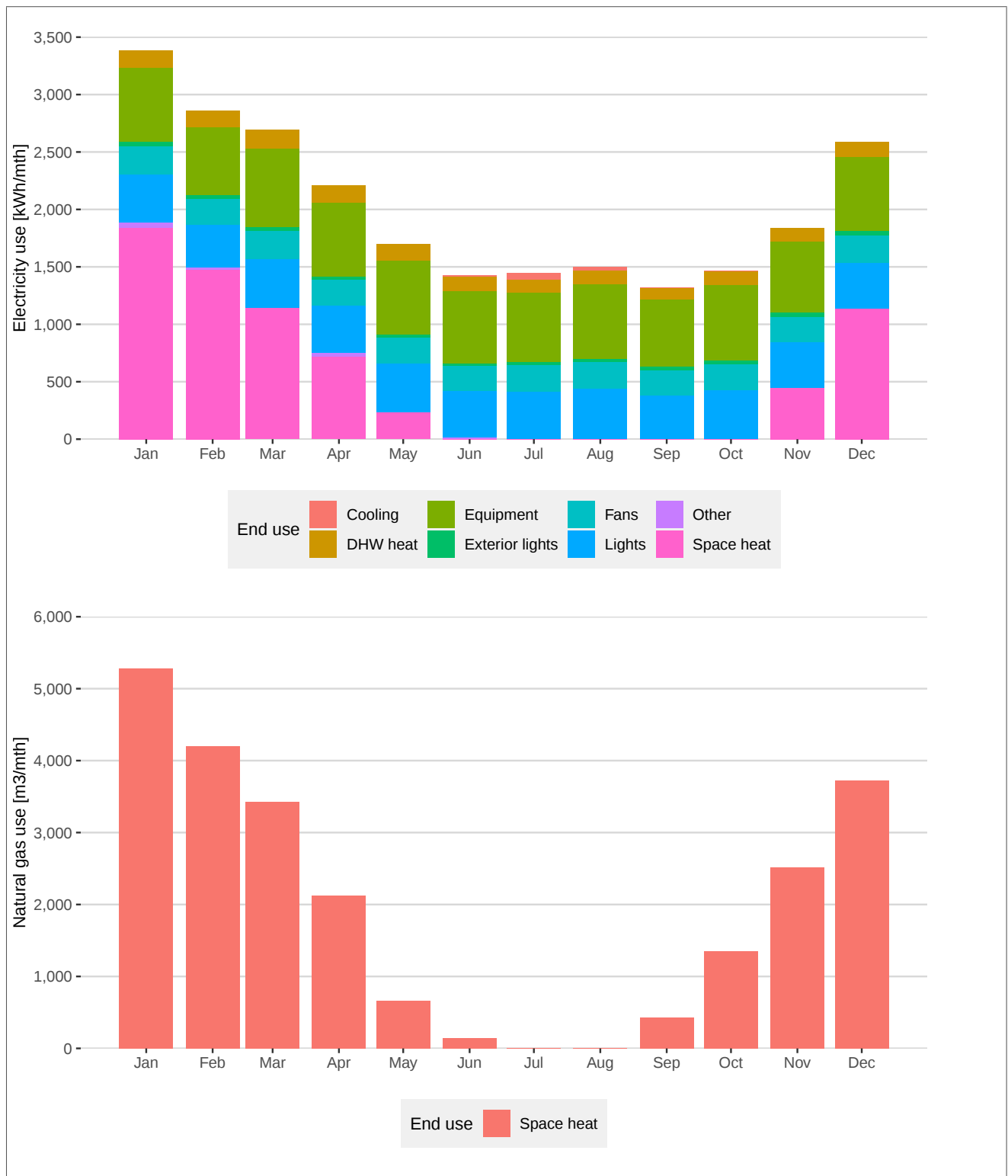


Figure 87: Monthly utility use profiles for each modelled utility

4.4 Calibration analysis

Electricity

Figure 88 compares the metered utility use with the modelled use to check how well the model is calibrated.

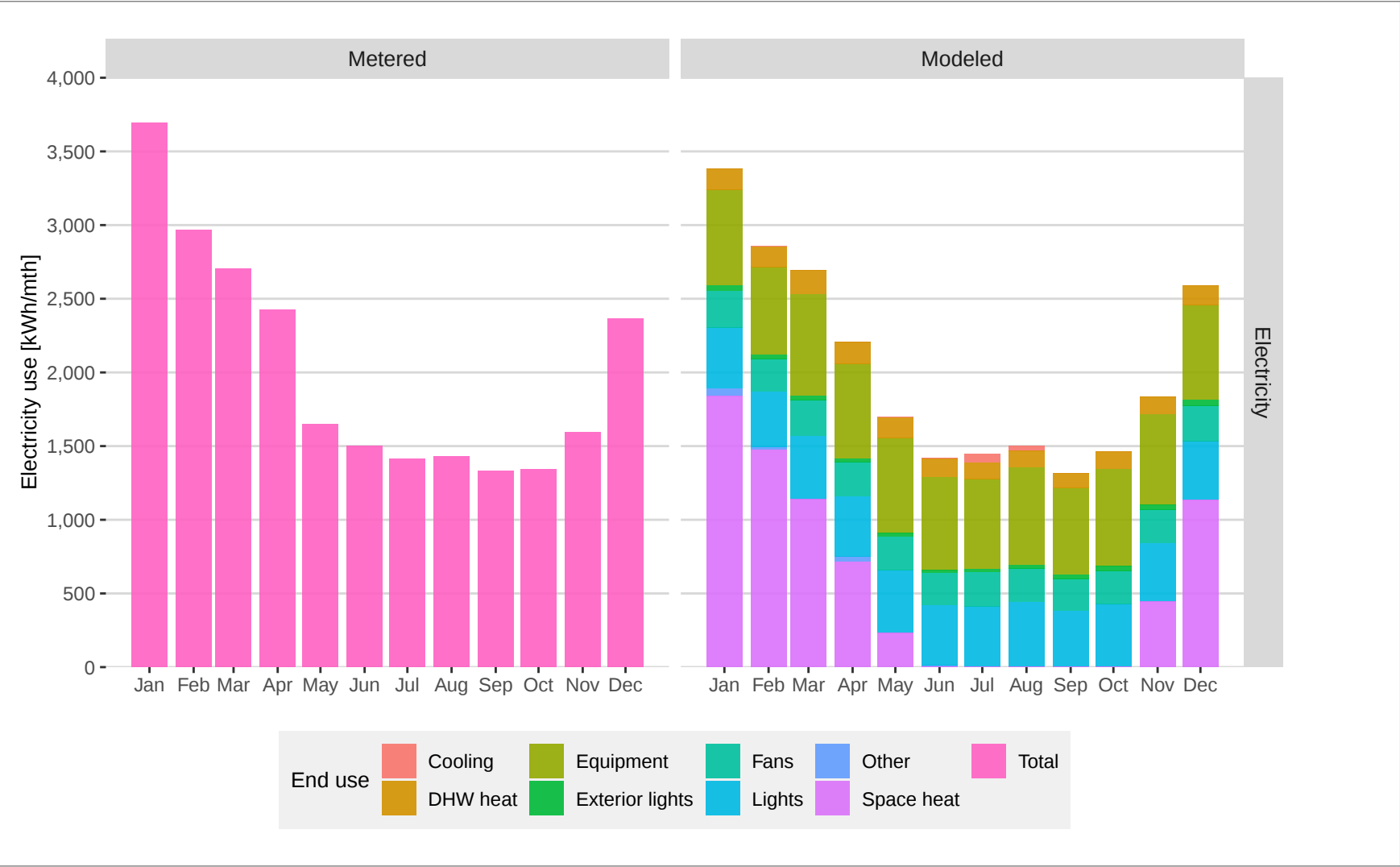


Figure 88: Electricity calibration analysis (metered vs modelled utility use)

Natural gas

Figure 89 compares the metered utility use with the modelled use to check how well the model is calibrated.

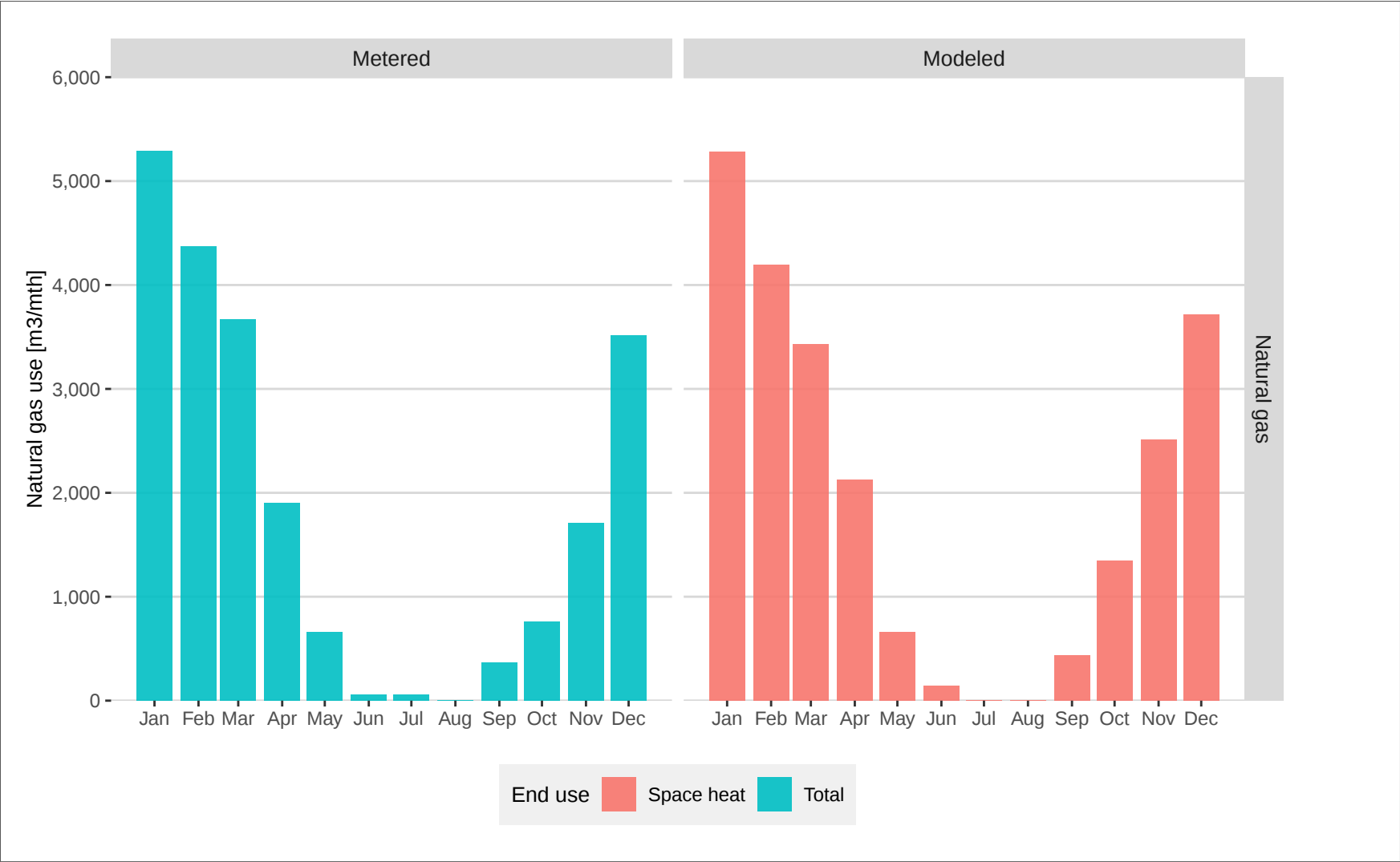


Figure 89: Natural gas calibration analysis (metered vs modelled utility use)

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 (RMSE).** 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 17.

Table 17: 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	8.0	Pass
Natural gas	Mean bias error	[%]	< +/- 5	-7.3	Fail
	Root mean square error	[%]	< 15	17.7	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.

- Figure 88 demonstrates a strong agreement between monthly trends observed in the metered utility use data and the monthly utility use predicted by the calibrated energy model. Figure 89 demonstrates a similar trend in the monthly utility use, although the modelled natural gas consumption is higher than the metered utility use.
- Electricity use was successfully calibrated according to the standards of ASHRAE Guideline 14. Note that the mean bias error is zero for electricity because the Other end-use ensures that the yearly modelled utility use matches the yearly metered utility use. This process also maintains consistency between the baseline utility use derived from the metered utility data and all measure and scenario analyses.
- Natural gas consumption fails to follow Guideline 14 on the mean bias error and the root mean square error. Some notable issues are that consumption is higher in the model. Another note is that only 5 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 from information gained during the site survey, so that these systems could be explicitly modelled one-to-one, precisely reflecting the unique operations associated with each system. The methodology also integrates the Other end-use category, which reflects the exact difference

between metered and modelled utility use in a top-down calculation after all systems have been modelled from the bottom-up.

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

Electricity

- Figure 88 indicates strong agreement between modelled and metered data.
- The peak and trough hourly consumption align with the metered interval data.

Natural gas

- Figure 89 indicates higher modelled natural gas use than the metered natural gas consumption.
- To achieve better alignment between the modelled and metered natural gas use, a relatively low infiltration rate was assumed for the building (0.25 lps/m² envelope). In addition, although most infrared heater temperatures were observed to have a setpoint of 20 C during the site survey, it was assumed that this temperature is varied and kept at an average of 18 C throughout the year.
- The largest discrepancies between the metered and modelled data occur in October and November. Based on the actual consumption in these months, it is thought that the IH heaters in one of the garages might have been turned off for the summer and remained off until late November or December, which would be consistent with the metered consumption.

4.5 End use analysis

Electricity

The yearly electricity end use breakdown calculated by the energy model is plotted in Figure 90. See Table 16 for end use definitions.

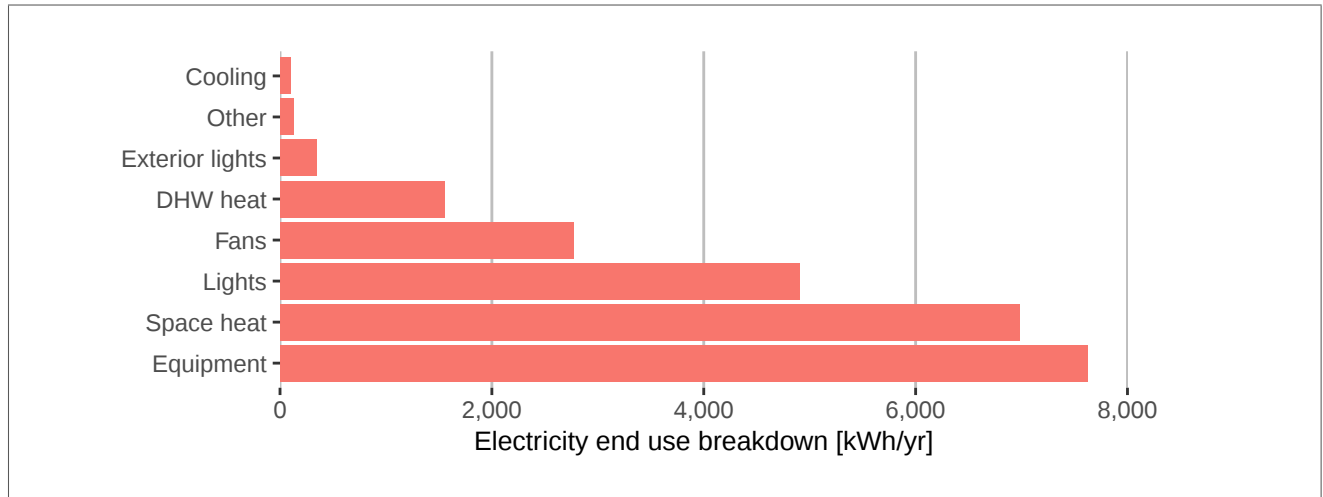


Figure 90: Electricity end use breakdown (calculated by calibrated energy model)

Natural gas

The yearly natural gas end use breakdown calculated by the energy model is plotted in Figure 91. See Table 16 for end use definitions.

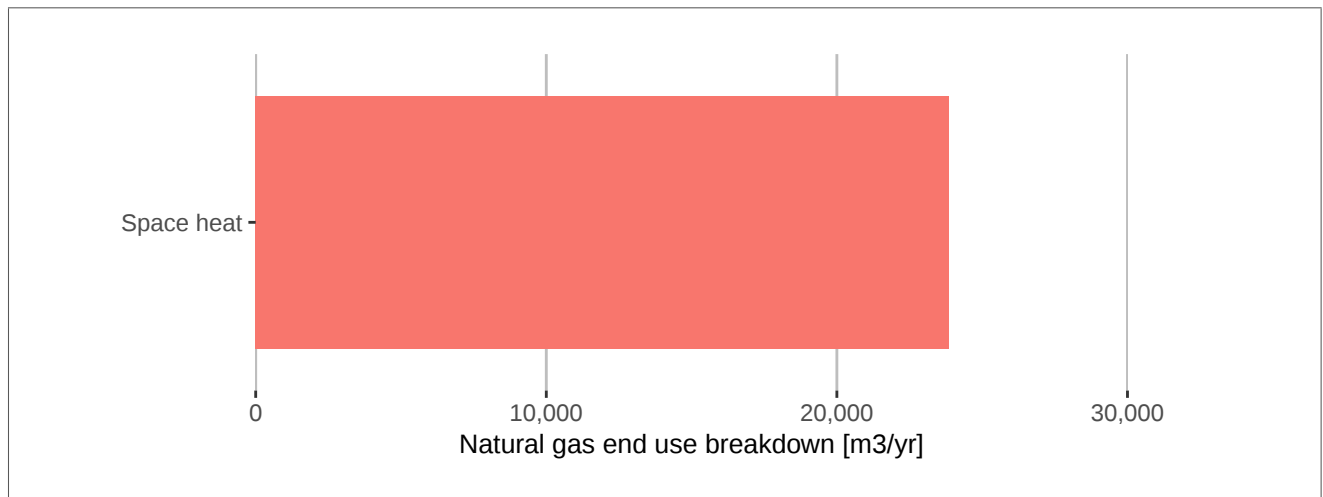


Figure 91: Natural gas end use breakdown (calculated by calibrated energy model)

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 5.10). 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 14 and 20 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 20, 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 20. 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 20. 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 18 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 21 was tested under each risk case also defined in Table 21 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 5.11.

4. **Measure analysis summary.** Measure analysis results for all measures were summarized in table format in Section 5.12.

5.2 Measure analysis assumptions

Assumptions general to all measures are as follows.

- GHG emissions factor assumptions are summarized in Table 13, in Section 3.2.
- Utility cost rate assumptions applied to quantify yearly utility cost impacts relative to the baseline are summarized in Table 14, in Section 3.2. Utility cost rate future assumptions applied in the life cycle analysis for each measure are summarized in Table 18. 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 18: 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]
2022	0.26	50	30	0.02	0.0735	0.0057
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 19.

Table 19: 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 20.

Table 20: 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 21.

Table 21: 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 0.9 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 0.9 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 0.9 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 0.9 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 0.9 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 22.

Table 22: Measure identification and triaging summary

Measure name	Triage for analysis
Baseline	
Carbon offsets 20	Analyzed.
Install a mini split system in the lunchroom	Analyzed.
Interior LED lighting upgrade	Analyzed.
Radiant heaters to electric	Analyzed.
Roof upgrade to high performance	Analyzed.
Wall upgrade to high performance	Analyzed.
Windows and doors to high performance	Analyzed.
Exterior lighting renewal	Business as usual.
Exterior walls renewal	Business as usual.
Infrared renewal	Business as usual.
Interior lighting renewal	Business as usual.
Roof renewal	Business as usual.
Unit heaters renewal	Business as usual.
Windows and doors renewal	Business as usual.
Infrared temperature setpoint reduction	Not analyzed.
Programmable thermostats for infrared heaters and UH1	Not analyzed.
Exterior LED lighting upgrade	Not analyzed: all exterior lights already LED.
Mould remediation	Not analyzed: no energy savings anticipated.

5.4 Carbon offsets 20

Measure description

Existing condition

The facility is currently purchasing no carbon offsets.

Opportunity

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

Utility-savings mechanism

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

Design description

Net zero definition

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

$$\text{Net emissions} = \text{Embodied carbon} + \text{Operational carbon} - \text{Avoided emissions}$$

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 m³ 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 23: Carbon offsets 20 analysis results summary

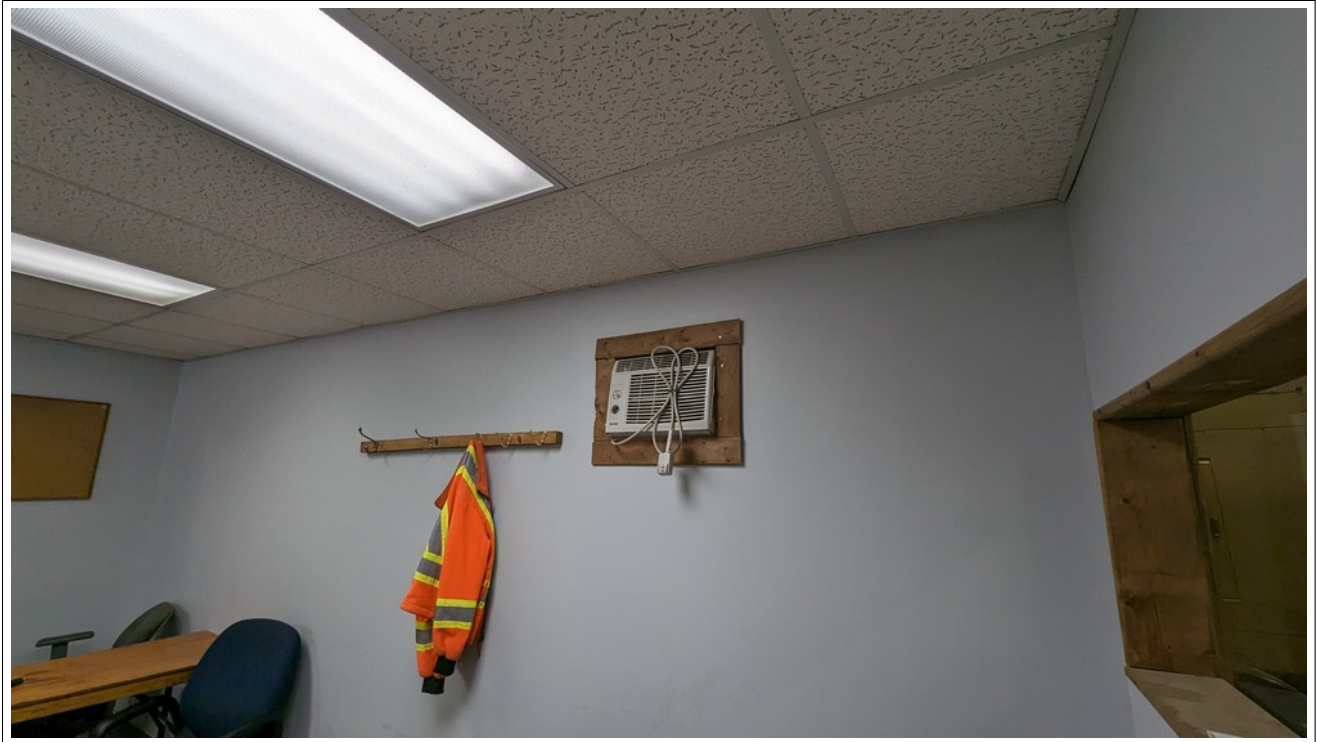
Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	24,412	24,412	0	0
	Natural gas use	[m3/yr]	23,857	23,857	0	0
	Carbon offset use	[tCO ₂ e/yr]	0	9.4	-9.4	—
Equivalent energy use	Electricity energy	[kWh/yr]	24,412	24,412	0	0
	Natural gas energy	[kWh/yr]	251,851	251,851	0	0
	Total energy	[kWh/yr]	276,263	276,263	0	0
GHG emissions	Electricity GHGs	[tCO ₂ e/yr]	0.74	0.74	0	0
	Natural gas GHGs	[tCO ₂ e/yr]	46.1	46.1	0	0
	Carbon offsets GHGs	[tCO ₂ e/yr]	0	-9.4	9.4	—
	Total GHGs	[tCO ₂ e/yr]	46.8	37.5	9.4	20.0
Utility cost	Electricity utility cost	[\$/yr]	2,422	2,422	0	0
	Natural gas utility cost	[\$/yr]	6,203	6,203	0	0
	Carbon offsets utility cost	[\$/yr]	0	281	-281	—
	Federal carbon charge	[\$/yr]	2,305	2,305	0	0
	Total utility cost	[\$/yr]	10,930	11,211	-281	-2.6
Financial	Assumed life	[yrs]	15	20	—	—
	Project cost	[\$]	0	—	—	—
	Incentive amount	[\$]	0	0	—	—
	Incremental project cost	[\$]	0	—	—	—
	Life cycle cost	[\$]	227,592	232,717	—	—
	Net present value	[\$]	0	-5,125	—	—
	Project cost per GHG reduction	[\$/tCO ₂ e]	—	—	—	—
	Simple payback period	[yr]	—	—	—	—

5.5 Install a mini split system in the lunchroom

Measure description

Existing condition

The lunchroom is heated via electric heating. The lunchroom has one unitary air conditioner with the condenser side interfacing with the bay area.



Opportunity

Replace the electric heater and unitary AC with a mini split.

Utility-savings mechanism

Reduced energy use due to improved efficiency of heating and cooling.

Design description

Overview

Replace the window AC unit with a ductless mini-split. The unit shall be similar to a Moovair 1T unit. The portable resistance heating elements are to remain as backup for the coldest days.

Electrical

The radiant heaters will add approximately 1.5 kW of power to the existing system, which will put the system at 9.5 kW, which is approximately 25% of the full load of the electrical capacity of the building. The panel does not have enough physical capacity for the breaker, so the unit will need to be powered from the main incoming splitter.

Project cost estimate

Table 24: Project cost estimate (Install a mini split system in the lunchroom)

Category	Line item	Unit	Value
Construction	Supply	[\$]	4,000
	Installation	[\$]	4,000
	Electrical	[\$]	5,000
	General requirements (25%)	[\$]	3,200
Contingency	Subtotal after Construction	[\$]	16,200
	Design Contingency (25%)	[\$]	4,000
	Construction Contingency (10%)	[\$]	1,600
Design, Contractors, PM	Subtotal after Contingency	[\$]	21,800
	Engineering Design and Field Review (10%)	[\$]	2,200
	Contractor Fee (7%)	[\$]	1,500
Total	Total	[\$]	25,500

Utility analysis

Utility analysis methodology

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

- **Baseline.** The lunchroom is heated by an electric space heater, with an efficiency of 100%. The lunchroom is cooled by a unitary air conditioner with a COP of 3.
- **Proposed.** Primary heating and cooling is provided from a mini-split with heating and cooling COPs of 2.8 and 4.1 (14 EER), respectively. Backup heating is provided by electric resistance, with an efficiency of 100%.

Utility analysis results

Table 25: Install a mini split system in the lunchroom analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	24,412	23,645	767	3.1
	Natural gas use	[m3/yr]	23,857	23,901	-44.0	-0.18
	Carbon offset use	[tCO2e/yr]	0	0	0	—
Equivalent energy use	Electricity energy	[kWh/yr]	24,412	23,645	767	3.1
	Natural gas energy	[kWh/yr]	251,851	252,316	-465	-0.18
	Total energy	[kWh/yr]	276,263	275,961	302	0.11
GHG emissions	Electricity GHGs	[tCO2e/yr]	0.74	0.71	0.02	3.1
	Natural gas GHGs	[tCO2e/yr]	46.1	46.2	-0.09	-0.18
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	—
	Total GHGs	[tCO2e/yr]	46.8	46.9	-0.06	-0.13
Utility cost	Electricity utility cost	[\$/yr]	2,422	2,346	76.1	3.1
	Natural gas utility cost	[\$/yr]	6,203	6,214	-11.4	-0.18
	Carbon offsets utility cost	[\$/yr]	0	0	0	—
	Federal carbon charge	[\$/yr]	2,305	2,309	-4.3	-0.18
	Total utility cost	[\$/yr]	10,930	10,869	60.4	0.55
Financial	Assumed life	[yrs]	15	15	—	—
	Project cost	[\$]	0	25,500	—	—
	Incentive amount	[\$]	0	0	—	—
	Incremental project cost	[\$]	0	25,500	—	—
	Life cycle cost	[\$]	227,592	255,925	—	—
	Net present value	[\$]	0	-28,333	—	—
	Project cost per GHG reduction	[\$/tCO2e]	—	-411,781	—	—
	Simple payback period	[yr]	—	>20	—	—

5.6 Interior LED lighting upgrade

Measure description

Existing condition

Some areas of the building currently operate with LED fixtures (e.g. some washrooms). The remaining areas of the building primarily utilize T5, T8, or T12 lighting.



Opportunity

Replace remaining fixtures containing T5, T8, and T12 lamps with new LED fixtures.

Utility-savings mechanism

Reduced interior lighting energy use with higher efficiency LED fixtures. However, heating energy use will increase to offset the reduction in internal heat gain from the fixtures, while cooling energy use will decrease.

Design description

Overview

The lighting system shall be designed to meet the latest ASHRAE 90.1 energy codes, IESNA standards, the Haileybury Public Works Garage standards and other applicable regulations and standards.

The existing site has gone through some recent LED upgrades. It will be proposed that all the remaining fluorescent fixtures will be replaced with new LED fixtures.

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

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

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

Type C, D, F, G, I, and J fixtures should be replaced.

Project cost estimate

Table 26: Project cost estimate (Interior LED lighting upgrade)

Category	Line item	Unit	Value
Materials and labour	Interior LED lighting upgrade	[\$]	20,000
Contingency	Subtotal after Materials and labour	[\$]	20,000
	General Contingency (50%)	[\$]	10,000
Total	Total	[\$]	30,000

Utility analysis

Utility analysis methodology

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

- **Baseline:** The average lighting power density is assumed to be 3.2 W/m².
- **Proposed:** The average lighting power density is assumed to be 1.6 W/m². Operation schedules are maintained.

Utility analysis results

Table 27: Interior LED lighting upgrade analysis results summary

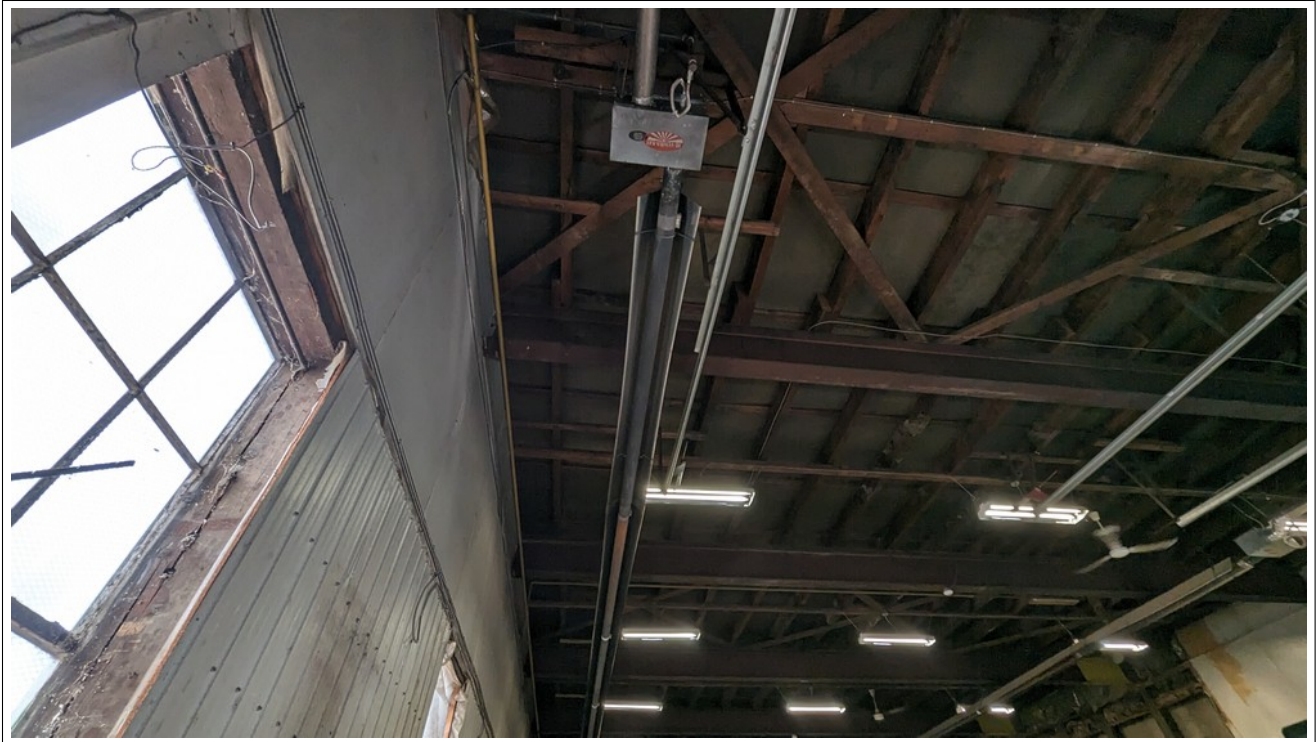
Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	24,412	22,026	2,386	9.8
	Natural gas use	[m ³ /yr]	23,857	24,104	-247	-1.0
	Carbon offset use	[tCO ₂ e/yr]	0	0	0	—
Equivalent energy use	Electricity energy	[kWh/yr]	24,412	22,026	2,386	9.8
	Natural gas energy	[kWh/yr]	251,851	254,457	-2,606	-1.0
	Total energy	[kWh/yr]	276,263	276,483	-220	-0.08
GHG emissions	Electricity GHGs	[tCO ₂ e/yr]	0.74	0.67	0.07	9.8
	Natural gas GHGs	[tCO ₂ e/yr]	46.1	46.6	-0.48	-1.0
	Carbon offsets GHGs	[tCO ₂ e/yr]	0	0	0	—
	Total GHGs	[tCO ₂ e/yr]	46.8	47.2	-0.41	-0.86
Utility cost	Electricity utility cost	[\$/yr]	2,422	2,185	237	9.8
	Natural gas utility cost	[\$/yr]	6,203	6,267	-64.2	-1.0
	Carbon offsets utility cost	[\$/yr]	0	0	0	—
	Federal carbon charge	[\$/yr]	2,305	2,329	-23.9	-1.0
	Total utility cost	[\$/yr]	10,930	10,781	149	1.4
Financial	Assumed life	[yrs]	15	20	—	—
	Project cost	[\$]	0	30,000	—	—
	Incentive amount	[\$]	0	0	—	—
	Incremental project cost	[\$]	0	30,000	—	—
	Life cycle cost	[\$]	227,592	253,752	—	—
	Net present value	[\$]	0	-26,160	—	—
	Project cost per GHG reduction	[\$/tCO ₂ e]	—	-74,070	—	—
	Simple payback period	[yr]	—	>20	—	—

5.7 Radiant heaters to electric

Measure description

Existing condition

IH1 and IH2 are natural gas-fired infrared heaters serving the truck storage bays on the west side. IH3 and IH4 are natural gas-fired infrared heaters serving the mechanic bays on the east side.



Opportunity

Replace the gas-fired heaters with electric resistance equivalents.

Utility-savings mechanism

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

Design description

Overview

Remove the ceiling-hung, gas-fired radiant tube heaters currently serving the Public Works Garage. To match the existing service area of the gas-fired units, eight ceiling-hung 4.5 kW electric units will be required and located accordingly. The new unit controls are to implemented with a combination of occupancy/motion detection and manual enable. Electrical upgrades may be required to accommodate the new units.

Electrical

The radiant heaters will add approximately 36 kW of power to the existing system, which will put the system at 44 kW, which is approximately 115% of the full load of the electrical capacity of the building. A system upgrade would be required to at least a 75 kVA transformer, with a 400A 208V-3P panel. The existing 200A service can

be powered from the new 400A panel. The existing service could accommodate approximately 6 electric radiant heaters.

Project cost estimate

Table 28: Project cost estimate (Radiant heaters to electric)

Category	Line item	Unit	Value
Construction	Supply and install	[\$]	24,000
	Electrical	[\$]	206,000
	General requirements (25%)	[\$]	57,500
Contingency	Subtotal after Construction	[\$]	287,500
	Design Contingency (25%)	[\$]	71,900
	Construction Contingency (10%)	[\$]	28,800
Design, Contractors, PM	Subtotal after Contingency	[\$]	388,200
	Engineering Design and Field Review (10%)	[\$]	38,800
	Contractor Fee (7%)	[\$]	27,200
Total	Total	[\$]	454,200

Utility analysis

Utility analysis methodology

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

- **Baseline.** The infrared heaters are gas-fired with an average thermal efficiency of 70%.
- **Proposed.** The infrared heaters are electric, with an efficiency of 100%.

Utility analysis results

Table 29: Radiant heaters to electric analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	24,412	162,137	-137,725	-564
	Natural gas use	[m3/yr]	23,857	2,276	21,581	90.5
	Carbon offset use	[tCO2e/yr]	0	0	0	—
Equivalent energy use	Electricity energy	[kWh/yr]	24,412	162,137	-137,725	-564
	Natural gas energy	[kWh/yr]	251,851	24,023	227,828	90.5
	Total energy	[kWh/yr]	276,263	186,160	90,103	32.6
GHG emissions	Electricity GHGs	[tCO2e/yr]	0.74	4.9	-4.2	-564
	Natural gas GHGs	[tCO2e/yr]	46.1	4.4	41.7	90.5
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	—
	Total GHGs	[tCO2e/yr]	46.8	9.3	37.5	80.2
Utility cost	Electricity utility cost	[\$/yr]	2,422	16,084	-13,662	-564
	Natural gas utility cost	[\$/yr]	6,203	592	5,611	90.5
	Carbon offsets utility cost	[\$/yr]	0	0	0	—
	Federal carbon charge	[\$/yr]	2,305	220	2,085	90.5
	Total utility cost	[\$/yr]	10,930	16,895	-5,966	-54.6
Financial	Assumed life	[yrs]	15	15	—	—
	Project cost	[\$]	0	454,200	—	—
	Incentive amount	[\$]	0	90,840	—	—
	Incremental project cost	[\$]	0	363,360	—	—
	Life cycle cost	[\$]	227,592	930,190	—	—
	Net present value	[\$]	0	-702,598	—	—
	Project cost per GHG reduction	[\$/tCO2e]	—	9,678	—	—
	Simple payback period	[yr]	—	—	—	—

5.8 Roof upgrade to high performance

Measure description

Existing condition

The roofs appear to be corrugated metal on sheathing and wood strapping on a steel structure, with little or no insulation.

Opportunity

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

Utility-savings mechanism

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

Design description

Overview

The roof appears to be constructed of corrugated metal on sheathing and wood strapping, supported by a steel structure, with little to no insulation present. We recommend removing the metal roofing and installing new sheathing along with an air barrier that is connected to the air barrier on the wall. Additionally, we suggest adding 10-12 inches of rigid insulation on top of the air barrier, finished with a PVC or TPO membrane. This will ensure a thermal performance of at least R40, which is the minimum requirement according to current building codes.

Project cost estimate

Table 30: Project cost estimate (Roof upgrade to high performance)

Category	Line item	Unit	Value
Construction	Roof replacement	[\$]	230,000
	General requirements (25%)	[\$]	57,500
Contingency	Subtotal after Construction	[\$]	287,500
	Design Contingency (25%)	[\$]	71,900
	Construction Contingency (10%)	[\$]	28,800
Design, Contractors, PM	Subtotal after Contingency	[\$]	388,200
	Engineering Design and Field Review (10%)	[\$]	38,800
	Contractor Fee (7%)	[\$]	27,200
Total	Total	[\$]	454,200

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 0.0625 BTU/hr.ft².F (R16) was assumed.
- **Proposed.** An average roof U-value of 0.025 BTU/hr.ft².F (R40) was assumed.

Utility analysis results

Table 31: Roof upgrade to high performance analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	24,412	24,474	-61.8	-0.25
	Natural gas use	[m3/yr]	23,857	21,926	1,931	8.1
	Carbon offset use	[tCO2e/yr]	0	0	0	—
Equivalent energy use	Electricity energy	[kWh/yr]	24,412	24,474	-61.8	-0.25
	Natural gas energy	[kWh/yr]	251,851	231,464	20,387	8.1
	Total energy	[kWh/yr]	276,263	255,937	20,326	7.4
GHG emissions	Electricity GHGs	[tCO2e/yr]	0.74	0.74	-0.00	-0.25
	Natural gas GHGs	[tCO2e/yr]	46.1	42.4	3.7	8.1
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	—
	Total GHGs	[tCO2e/yr]	46.8	43.1	3.7	8.0
Utility cost	Electricity utility cost	[\$/yr]	2,422	2,428	-6.1	-0.25
	Natural gas utility cost	[\$/yr]	6,203	5,701	502	8.1
	Carbon offsets utility cost	[\$/yr]	0	0	0	—
	Federal carbon charge	[\$/yr]	2,305	2,118	187	8.1
	Total utility cost	[\$/yr]	10,930	10,247	683	6.2
Financial	Assumed life	[yrs]	15	20	—	—
	Project cost	[\$]	0	454,200	—	—
	Incentive amount	[\$]	0	90,840	—	—
	Incremental project cost	[\$]	0	363,360	—	—
	Life cycle cost	[\$]	227,592	602,281	—	—
	Net present value	[\$]	0	-374,689	—	—
	Project cost per GHG reduction	[\$/tCO2e]	—	97,417	—	—
	Simple payback period	[yr]	—	>20	—	—

5.9 Wall upgrade to high performance

Measure description

Existing condition

The walls appear to be constructed with wood studs or 6x6 beams and are partially finished with fibreglass batt insulation, at least near the roof. The interior is lined with either metal panels or gypsum board, while the exterior consists of corrugated metal siding or wood fibre and cement panels. The steel beams supporting the roof seem to be held up by timber framing or steel columns embedded in the exterior walls, with batt insulation placed between horizontal wooden girts.

The condition of the exterior finish is poor, with numerous areas showing signs of water damage and deterioration in the siding or sheathing. Overall, the walls are in extremely poor condition, particularly from the interior side. Several areas of mould growth were observed on the insulation.



Opportunity

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

Utility-savings mechanism

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

Design description

Overview

The wall insulation is significantly compromised by thermal bridging, resulting in an R-Value that is believed to be much lower than what is required by current building codes. The office areas of the building appear to have gypsum board or plywood sheathing on the interior, which may or may not include additional insulation within the stud cavities.

Thermal bridging caused by secondary metal building connections and air leakage through gaps at the foundation and the top of the walls are major factors that reduce the thermal performance of the walls. This issue can be effectively addressed by installing an air barrier beneath a layer of exterior insulation on the walls, which should then connect to a new air barrier on the roof along with new insulation. This approach will create a continuous enclosure to prevent air leakage, while also protecting the steel structure from the effects of thermal bridging.

We recommend removing the existing siding, applying sheathing and an air barrier to the current wood structure (adding secondary members if necessary to support the sheathing), and then installing either thermally broken girts with semi-rigid batt insulation and new metal siding on the exterior, or using rigid insulation applied directly to the sheathing with an EIFS (acrylic stucco) finish. In either scenario, the goal is to improve the thermal performance of the walls to at least R-30, as the minimum code requirement is R-25. Moreover, working from the exterior allows all interior services and accessories to remain in place.

Project cost estimate

Table 32: Project cost estimate (Wall upgrade to high performance)

Category	Line item	Unit	Value
Construction	Wall upgrade	[\$]	517,000
	General requirements (25%)	[\$]	129,200
Contingency	Subtotal after Construction	[\$]	646,200
	Design Contingency (25%)	[\$]	161,600
	Construction Contingency (10%)	[\$]	64,600
Design, Contractors, PM	Subtotal after Contingency	[\$]	872,400
	Engineering Design and Field Review (10%)	[\$]	87,200
	Contractor Fee (7%)	[\$]	61,100
Total	Total	[\$]	1,020,700

Utility analysis

Utility analysis methodology

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

- **Baseline.** An average wall U-value of 0.0714 BTU/hr.ft².F (R14) was assumed.
- **Proposed.** An average wall U-value of 0.0333 BTU/hr.ft².F (R30) was assumed. Infiltration flow was assumed to be reduced by 10% in total relative to the Baseline for affected spaces.

Utility analysis results

Table 33: Wall upgrade to high performance analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	24,412	23,663	750	3.1
	Natural gas use	[m3/yr]	23,857	21,091	2,766	11.6
	Carbon offset use	[tCO2e/yr]	0	0	0	—
Equivalent energy use	Electricity energy	[kWh/yr]	24,412	23,663	750	3.1
	Natural gas energy	[kWh/yr]	251,851	222,656	29,195	11.6
	Total energy	[kWh/yr]	276,263	246,319	29,944	10.8
GHG emissions	Electricity GHGs	[tCO2e/yr]	0.74	0.71	0.02	3.1
	Natural gas GHGs	[tCO2e/yr]	46.1	40.8	5.3	11.6
	Carbon offsets GHGs	[tCO2e/yr]	0	0	0	—
	Total GHGs	[tCO2e/yr]	46.8	41.5	5.4	11.5
Utility cost	Electricity utility cost	[\$/yr]	2,422	2,347	74.4	3.1
	Natural gas utility cost	[\$/yr]	6,203	5,484	719	11.6
	Carbon offsets utility cost	[\$/yr]	0	0	0	—
	Federal carbon charge	[\$/yr]	2,305	2,038	267	11.6
	Total utility cost	[\$/yr]	10,929	9,869	1,061	9.7
Financial	Assumed life	[yrs]	15	75	—	—
	Project cost	[\$]	0	1,020,700	—	—
	Incentive amount	[\$]	0	204,140	—	—
	Incremental project cost	[\$]	0	816,560	—	—
	Life cycle cost	[\$]	227,592	476,677	—	—
	Net present value	[\$]	0	-249,085	—	—
	Project cost per GHG reduction	[\$/tCO2e]	—	152,155	—	—
	Simple payback period	[yr]	—	>20	—	—

5.10 Windows and doors to high performance

Measure description

Existing condition

The facility has aluminum-framed, double-pane slider windows and single-pane windows at the west elevation. The facility has hollow metal and overhead doors.



Opportunity

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

Utility-savings mechanism

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

Design description

Windows

We recommend replacing all windows with Passive House Certified Triple-glazed, thermally broken windows. These could be framed in aluminum, vinyl or fiberglass. At the very least we would recommend double-glazed windows in thermally broken frames to bring them up to 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.
- **Overhead Doors:** Replace the existing overhead doors with high-performance sectional insulated roll-up doors that use systems with polyurethane cores and a full perimeter seal.

Project cost estimate

Table 34: Project cost estimate (Windows and doors to high performance)

Category	Line item	Unit	Value
Construction	Window and door replacement	[\$]	74,000
	General requirements (25%)	[\$]	18,500
Contingency	Subtotal after Construction	[\$]	92,500
	Design Contingency (25%)	[\$]	23,100
	Construction Contingency (10%)	[\$]	9,200
Design, Contractors, PM	Subtotal after Contingency	[\$]	124,800
	Engineering Design and Field Review (10%)	[\$]	12,500
	Contractor Fee (7%)	[\$]	8,700
Total	Total	[\$]	146,000

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 0.45 and 0.8806 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 35: Windows and doors to high performance analysis results summary

Category	Description	Unit	Baseline	Proposed	Reduction	Reduction [%]
Utility use	Electricity use	[kWh/yr]	24,412	23,432	980	4.0
	Natural gas use	[m3/yr]	23,857	20,190	3,667	15.4
	Carbon offset use	[tCO ₂ e/yr]	0	0	0	—
Equivalent energy use	Electricity energy	[kWh/yr]	24,412	23,432	980	4.0
	Natural gas energy	[kWh/yr]	251,851	213,143	38,708	15.4
	Total energy	[kWh/yr]	276,263	236,575	39,688	14.4
GHG emissions	Electricity GHGs	[tCO ₂ e/yr]	0.74	0.71	0.03	4.0
	Natural gas GHGs	[tCO ₂ e/yr]	46.1	39.0	7.1	15.4
	Carbon offsets GHGs	[tCO ₂ e/yr]	0	0	0	—
	Total GHGs	[tCO ₂ e/yr]	46.8	39.7	7.1	15.2
Utility cost	Electricity utility cost	[\$/yr]	2,422	2,324	97.2	4.0
	Natural gas utility cost	[\$/yr]	6,203	5,249	953	15.4
	Carbon offsets utility cost	[\$/yr]	0	0	0	—
	Federal carbon charge	[\$/yr]	2,305	1,951	354	15.4
	Total utility cost	[\$/yr]	10,929	9,525	1,405	12.9
Financial	Assumed life	[yrs]	15	40	—	—
	Project cost	[\$]	0	146,000	—	—
	Incentive amount	[\$]	0	29,200	—	—
	Incremental project cost	[\$]	0	116,800	—	—
	Life cycle cost	[\$]	227,592	278,224	—	—
	Net present value	[\$]	0	-50,632	—	—
	Project cost per GHG reduction	[\$/tCO ₂ e]	—	16,416	—	—
	Simple payback period	[yr]	—	>20	—	—

5.11 Measure risk analysis

Utility use sensitivity

Figure 92 indicates how sensitive cumulative electricity and natural gas use are to variations in each risk parameter.

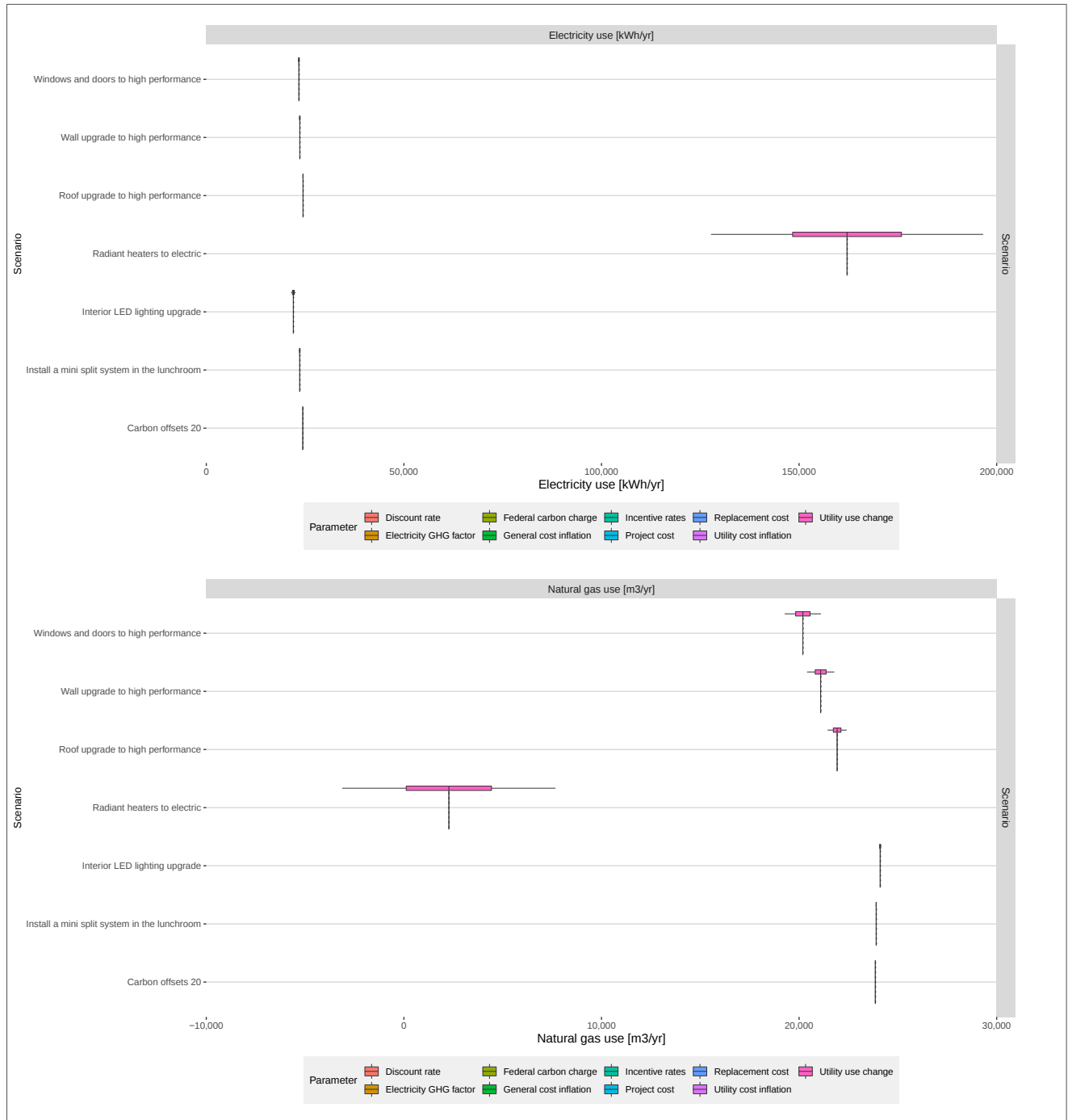


Figure 92: Utility cumulative use sensitivity analysis

GHG emissions and life cycle cost sensitivity

Figure 93 indicates how sensitive cumulative GHG emissions and life cycle costs are to variations in each risk parameter.

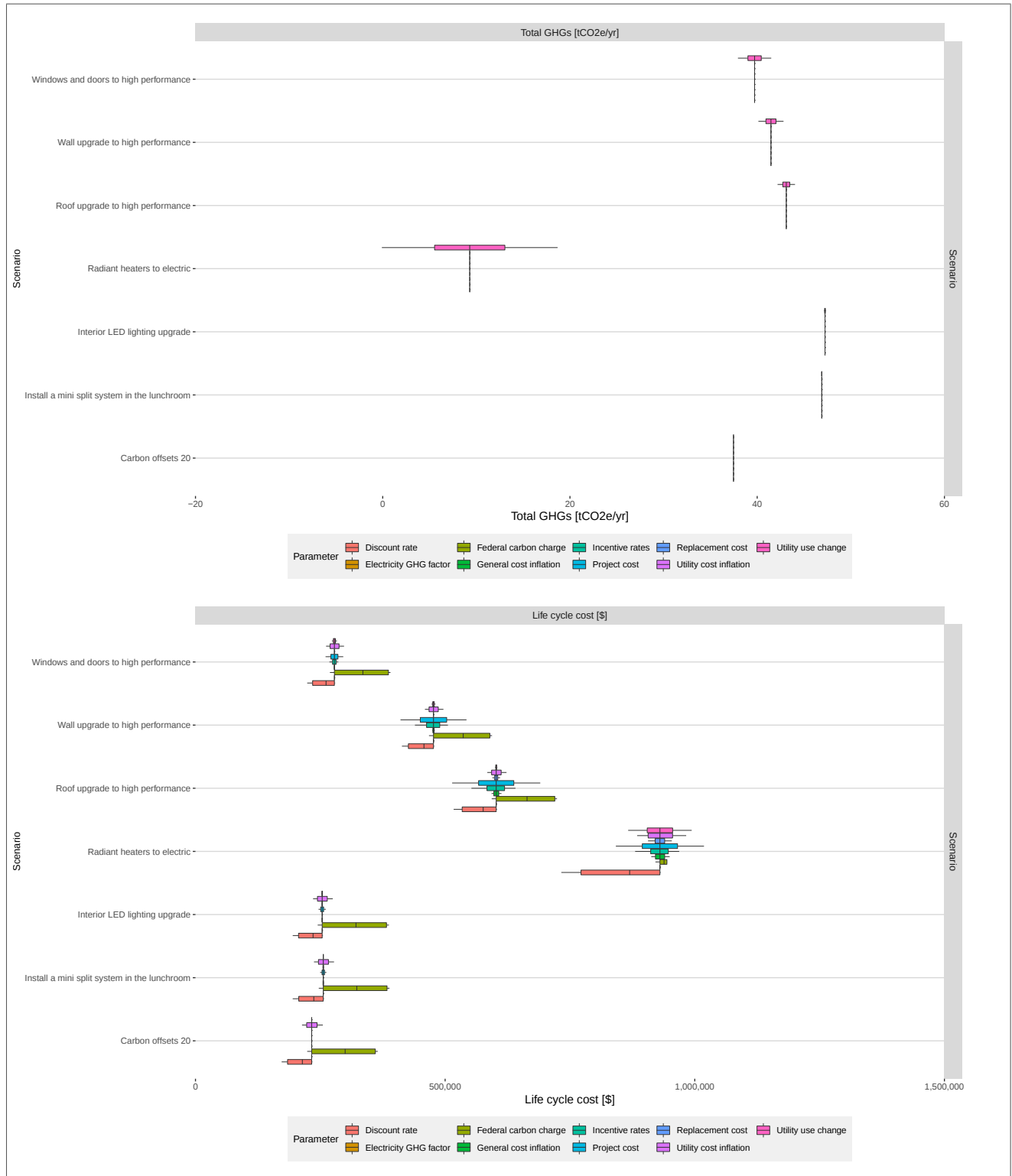


Figure 93: GHG cumulative emissions and life cycle cost sensitivity analysis

5.12 Measure analysis summary

For each analyzed measure, the analysis results are summarized in Table 36.

Table 36: 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]	[\$]	[\$]	[\$]	[\$]	[\$]	[\$/tCO2e]	[yr]
Baseline	24,412	100.0	23,857	100.0	276,263	100.0	47	100.0	10,929	100.0	15	0	0	0	227,592	0	-	-
Carbon offsets 20	0	0.0	0	0.0	0	0.0	9	20.0	-281	-2.6	20	-	0	-	232,717	-5,125	-	-
Install a mini split system in the lunchroom	767	3.1	-44	-0.2	302	0.1	-0	-0.1	60	0.6	15	25,500	0	25,500	255,925	-28,333	-411,781	422
Interior LED lighting upgrade	2,386	9.8	-247	-1.0	-220	-0.1	-0	-0.9	149	1.4	20	30,000	0	30,000	253,752	-26,160	-74,070	202
Radiant heaters to electric	-137,724	-564.2	21,581	90.5	90,103	32.6	38	80.2	-5,966	-54.6	15	454,200	90,840	363,360	930,190	-702,598	9,678	-61
Roof upgrade to high performance	-62	-0.3	1,931	8.1	20,326	7.4	4	8.0	683	6.2	20	454,200	90,840	363,360	602,281	-374,689	97,417	532
Wall upgrade to high performance	750	3.1	2,766	11.6	29,945	10.8	5	11.5	1,061	9.7	75	1,020,700	204,140	816,560	476,677	-249,085	152,155	770
Windows and doors to high performance	980	4.0	3,667	15.4	39,688	14.4	7	15.2	1,405	12.9	40	146,000	29,200	116,800	278,224	-50,632	16,416	83
Total project cost	-	-	-	-	-	-	-	-	-	-	-	2,130,600	-	-	-	-	-	-
Exterior lighting renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	20	1,000	0	1,000	228,632	-1,039	-	-
Exterior walls renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	75	5,000	0	5,000	229,211	-1,619	-	-
Infrared renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	22,000	0	22,000	251,430	-23,838	-	-
Interior lighting renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	20	10,000	0	10,000	237,987	-10,394	-	-
Roof renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	20	174,000	0	174,000	408,454	-180,861	-	-
Unit heaters renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	9,000	0	9,000	237,344	-9,752	-	-
Windows and doors renewal	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	40	72,000	0	72,000	271,306	-43,714	-	-
BAU measure totals	-	-	-	-	-	-	-	-	-	-	-	293,000	-	-	-	-	-	-

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 37.
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 37.

Table 37: 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 94 and Table 38 present the results of this exercise, indicating which measures were assigned to which scenario.

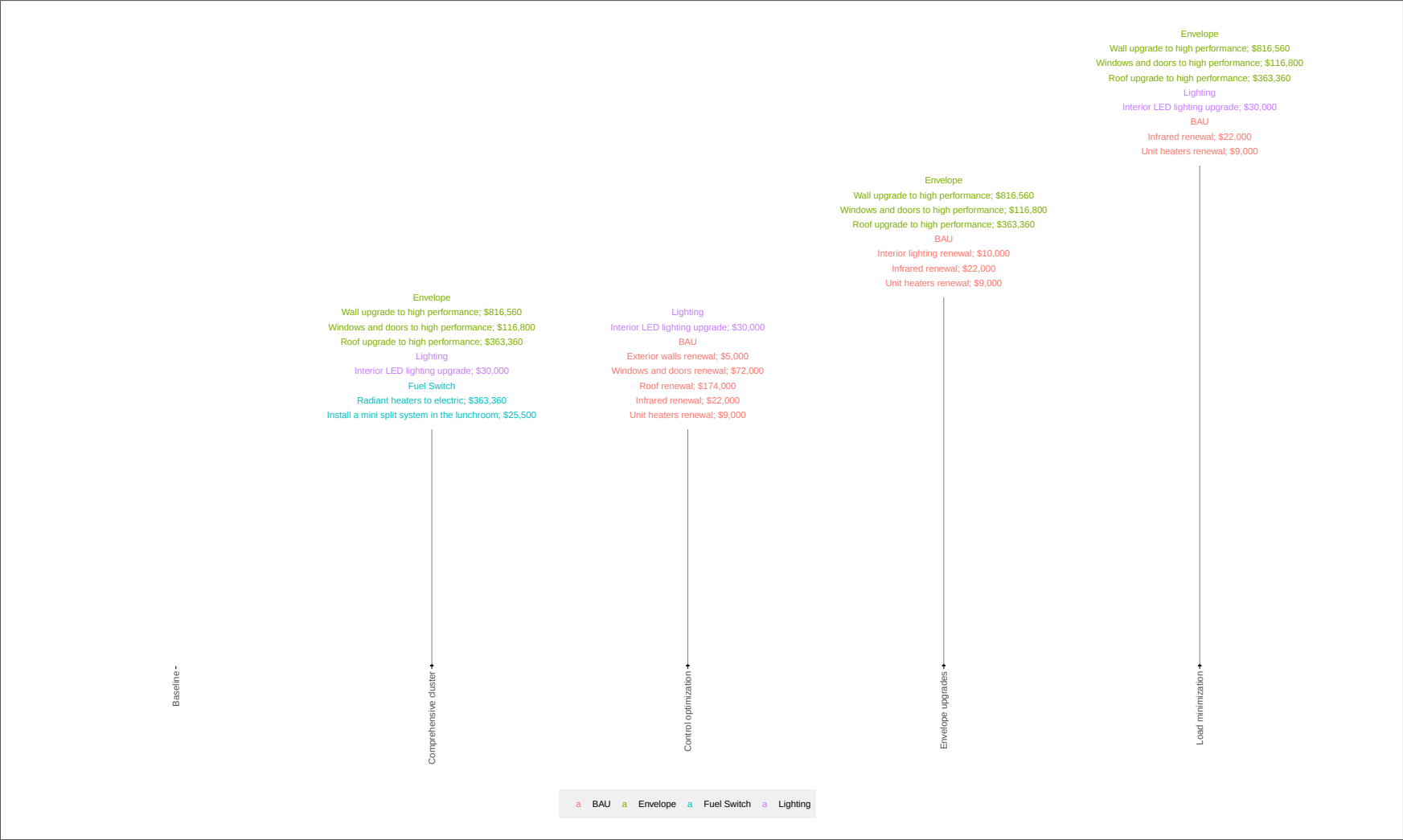


Figure 94: Scenario composition

Table 38: Cluster composition

Measure	Control optimization	Envelope upgrades	Load minimization	Comprehensive cluster
Carbon offsets 20	✗	✗	✗	✗
Install a mini split system in the lunchroom	✗	✗	✗	✓
Interior LED lighting upgrade	✓	✗	✓	✓
Radiant heaters to electric	✗	✗	✗	✓
Roof upgrade to high performance	✗	✓	✓	✓
Wall upgrade to high performance	✗	✓	✓	✓
Windows and doors to high performance	✗	✓	✓	✓
Exterior lighting renewal	✗	✗	✗	✗
Exterior walls renewal	✓	✗	✗	✗
Infrared renewal	✓	✓	✓	✗
Interior lighting renewal	✗	✓	✗	✗
Roof renewal	✓	✗	✗	✗
Unit heaters 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 39, 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 39: Scenario analysis summary

Measure ID	Scenario	Measure name	Utility use				Equivalent energy use		GHG emissions		Utility cost		Financial							
			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		-96,779	-396.4	23,749	99.5	153,935	55.7	43	91.7	-1,131	-10.3	-	2,130,600	415,020	1,715,580	1,521,628	-1,294,036	39,926	-1,517
Comprehensive cluster	Wall upgrade to high performance		750	3.1	2,766	11.6	29,945	10.8	5	11.5	1,061	9.7	75	1,020,700	204,140	816,560	476,677	-249,085	152,155	770
Comprehensive cluster	Windows and doors to high performance		980	4.0	3,667	15.4	39,688	14.4	7	15.2	1,405	12.9	40	146,000	29,200	116,800	278,224	-50,632	16,416	83
Comprehensive cluster	Roof upgrade to high performance		-62	-0.3	1,931	8.1	20,326	7.4	4	8.0	683	6.2	20	454,200	90,840	363,360	602,281	-374,689	97,417	532
Comprehensive cluster	Interior LED lighting upgrade		2,386	9.8	-247	-1.0	-220	-0.1	-0	-0.9	149	1.4	20	30,000	0	30,000	253,752	-26,160	-74,070	202
Comprehensive cluster	Radiant heaters to electric		-137,724	-564.2	21,581	90.5	90,103	32.6	38	80.2	-5,966	-54.6	15	454,200	90,840	363,360	930,190	-702,598	9,678	-61
Comprehensive cluster	Install a mini split system in the lunchroom		767	3.1	-44	-0.2	302	0.1	-0	-0.1	60	0.6	15	25,500	0	25,500	255,925	-28,333	-411,781	422
Control optimization	Combined		2,386	9.8	-247	-1.0	-220	-0.1	-0	-0.9	149	1.4	-	312,000	0	312,000	500,562	-272,970	-770,331	2,098
Control optimization	Interior LED lighting upgrade		2,386	9.8	-247	-1.0	-220	-0.1	-0	-0.9	149	1.4	20	30,000	0	30,000	253,752	-26,160	-74,070	202
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	229,211	-1,619	-	-
Control optimization	Windows and doors renewal		0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	40	72,000	0	72,000	271,306	-43,714	-	-
Control optimization	Roof renewal		0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	20	174,000	0	174,000	408,454	-180,861	-	-
Control optimization	Infrared renewal		0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	22,000	0	22,000	251,430	-23,838	-	-
Control optimization	Unit heaters renewal		0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	9,000	0	9,000	237,344	-9,752	-	-
Envelope upgrades	Combined		1,492	6.1	7,755	32.5	83,359	30.2	15	32.1	2,914	26.7	-	1,661,900	324,180	1,337,720	910,225	-682,633	89,001	459
Envelope upgrades	Wall upgrade to high performance		750	3.1	2,766	11.6	29,945	10.8	5	11.5	1,061	9.7	75	1,020,700	204,140	816,560	476,677	-249,085	152,155	770
Envelope upgrades	Windows and doors to high performance		980	4.0	3,667	15.4	39,688	14.4	7	15.2	1,405	12.9	40	146,000	29,200	116,800	278,224	-50,632	16,416	83
Envelope upgrades	Roof upgrade to high performance		-62	-0.3	1,931	8.1	20,326	7.4	4	8.0	683	6.2	20	454,200	90,840	363,360	602,281	-374,689	97,417	532
Envelope upgrades	Interior lighting renewal		0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	20	10,000	0	10,000	237,987	-10,394	-	-
Envelope upgrades	Infrared renewal		0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	22,000	0	22,000	251,430	-23,838	-	-
Envelope upgrades	Unit heaters renewal		0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	9,000	0	9,000	237,344	-9,752	-	-
Load minimization	Combined		3,894	16.0	7,488	31.4	82,939	30.0	15	31.1	3,057	28.0	-	1,661,900	324,180	1,337,720	925,466	-697,873	93,081	444
Load minimization	Wall upgrade to high performance		750	3.1	2,766	11.6	29,945	10.8	5	11.5	1,061	9.7	75	1,020,700	204,140	816,560	476,677	-249,085	152,155	770
Load minimization	Windows and doors to high performance		980	4.0	3,667	15.4	39,688	14.4	7	15.2	1,405	12.9	40	146,000	29,200	116,800	278,224	-50,632	16,416	83
Load minimization	Roof upgrade to high performance		-62	-0.3	1,931	8.1	20,326	7.4	4	8.0	683	6.2	20	454,200	90,840	363,360	602,281	-374,689	97,417	532
Load minimization	Interior LED lighting upgrade		2,386	9.8	-247	-1.0	-220	-0.1	-0	-0.9	149	1.4	20	30,000	0	30,000	253,752	-26,160	-74,070	202
Load minimization	Infrared renewal		0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	22,000	0	22,000	251,430	-23,838	-	-
Load minimization	Unit heaters renewal		0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	18	9,000	0	9,000	237,344	-9,752	-	-

Utility use comparison

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

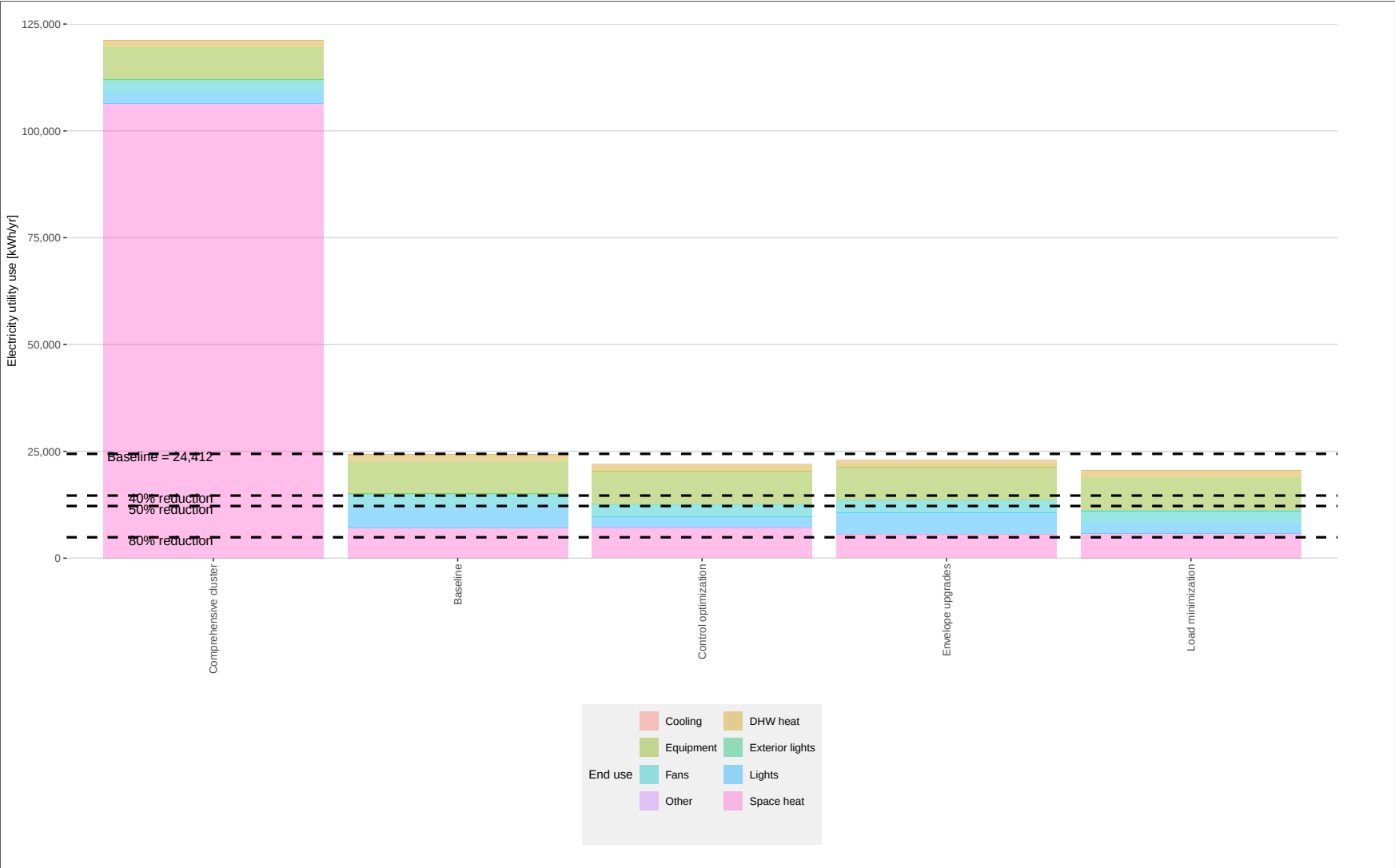


Figure 95: Electricity utility use expected yearly for each scenario by end use

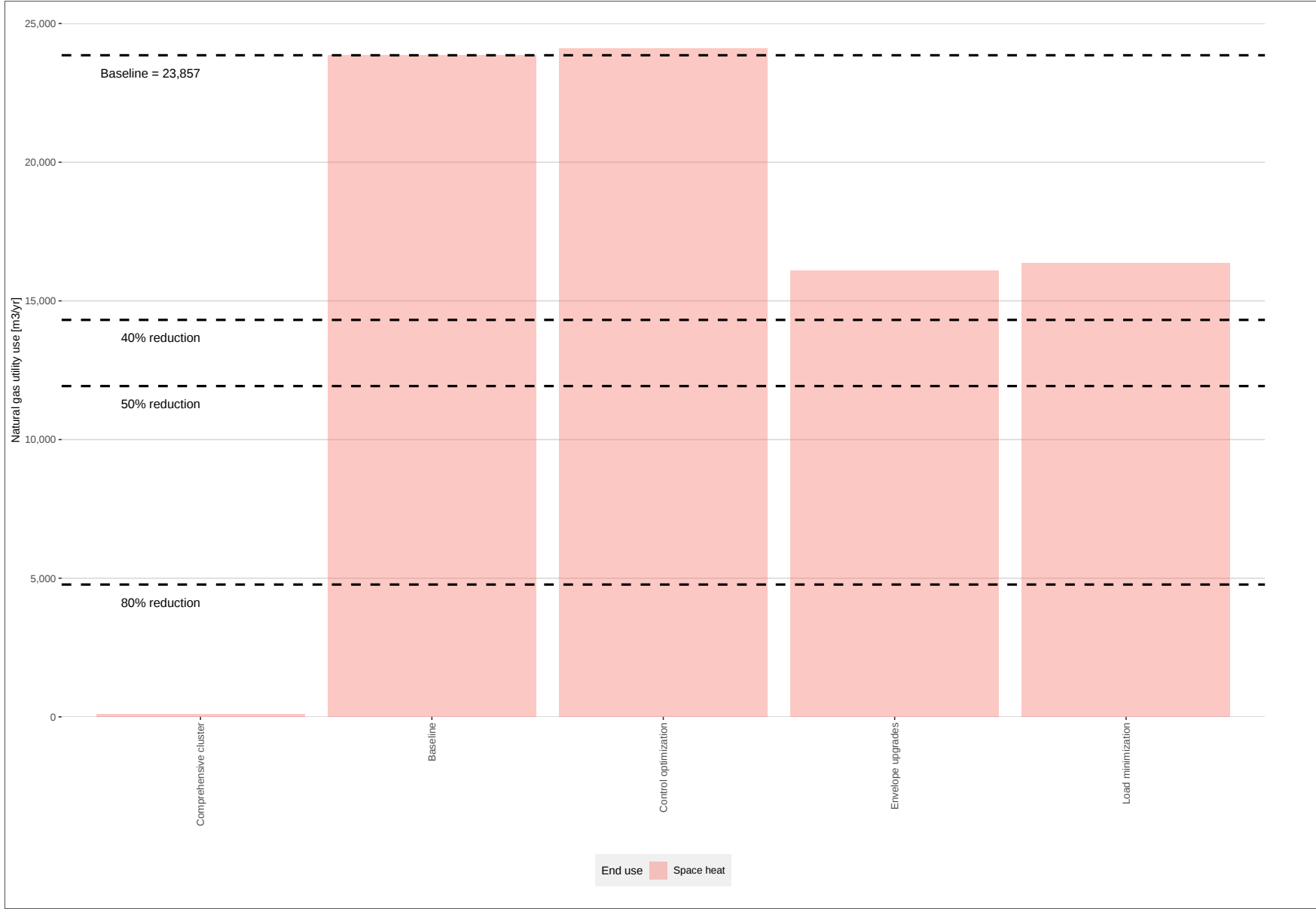


Figure 96: Natural gas utility use expected yearly for each scenario by end use

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.

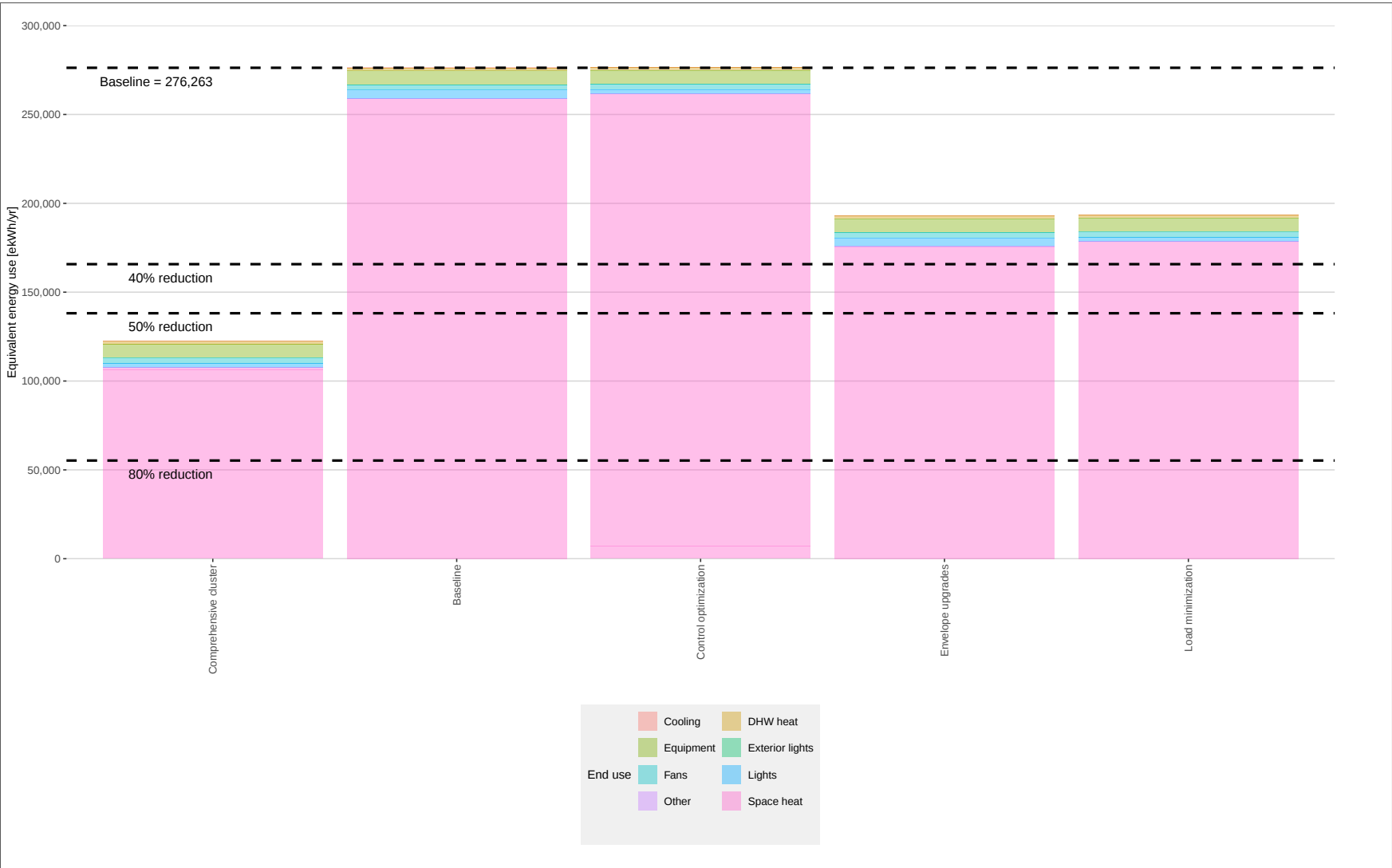


Figure 97: Equivalent energy use expected yearly for each scenario by end use

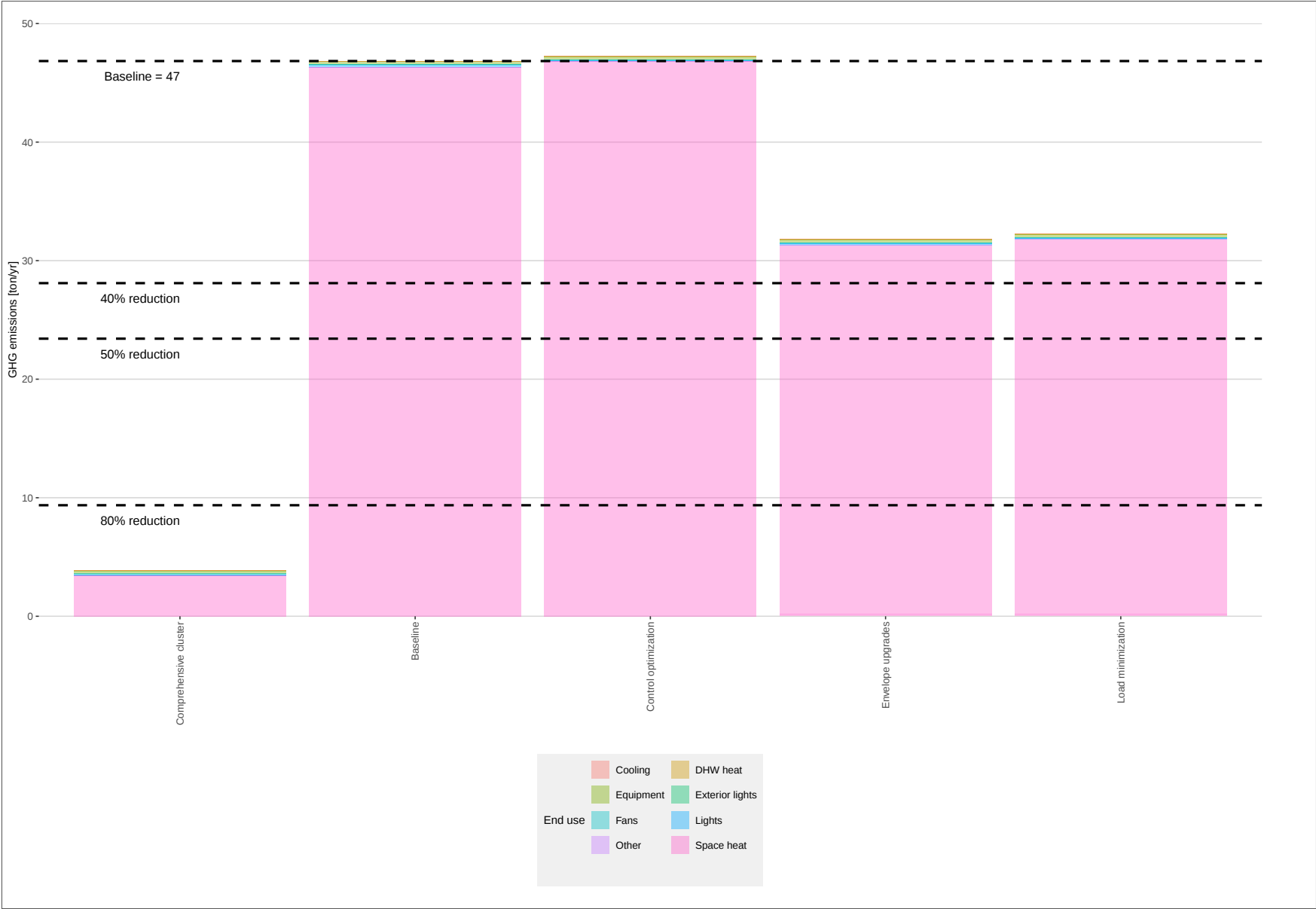


Figure 98: GHG emissions expected yearly for each scenario by end use

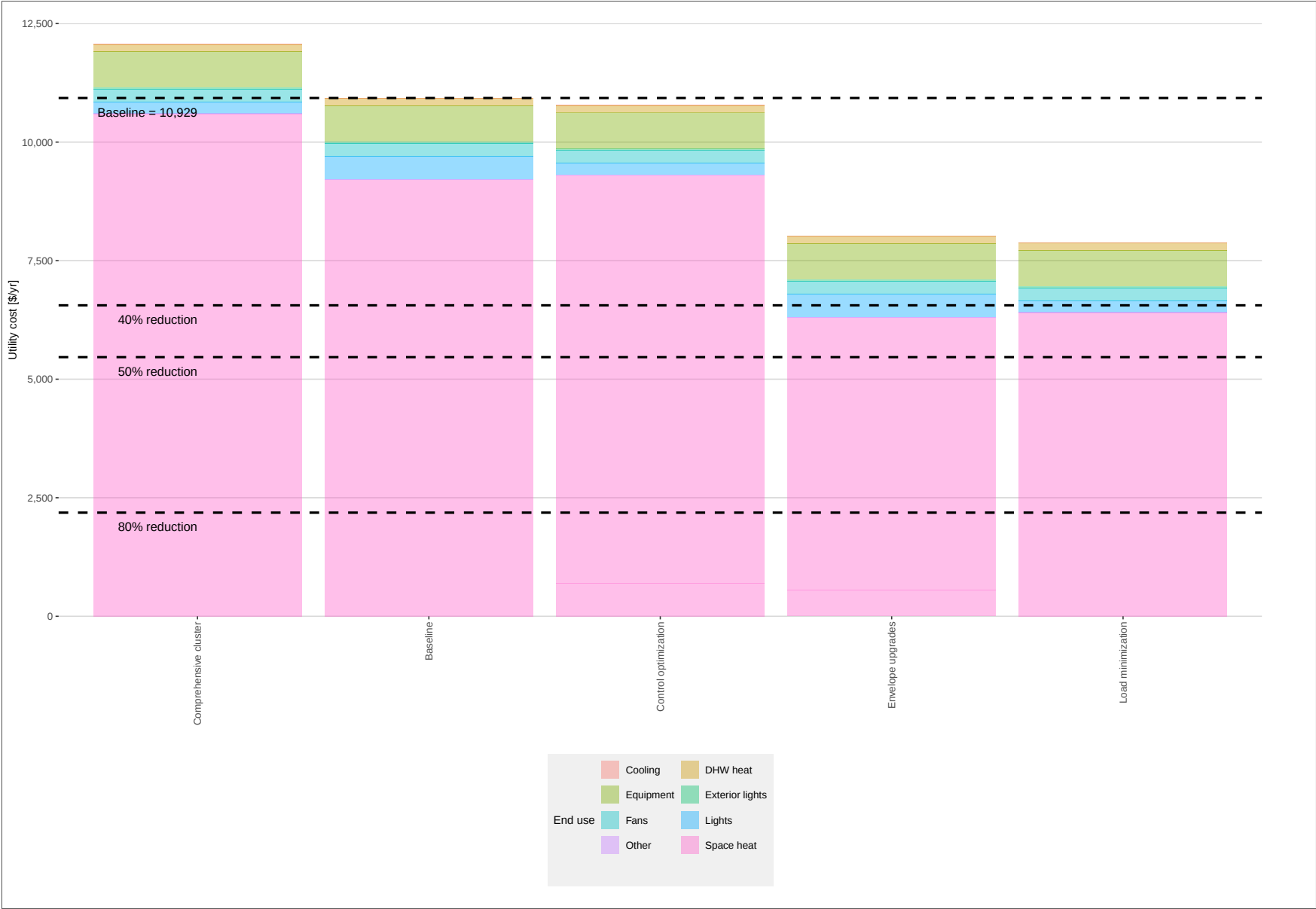


Figure 99: Utility costs expected yearly for each scenario by end use

Financial performance comparison

The following figures compare the financial performance between each scenario.

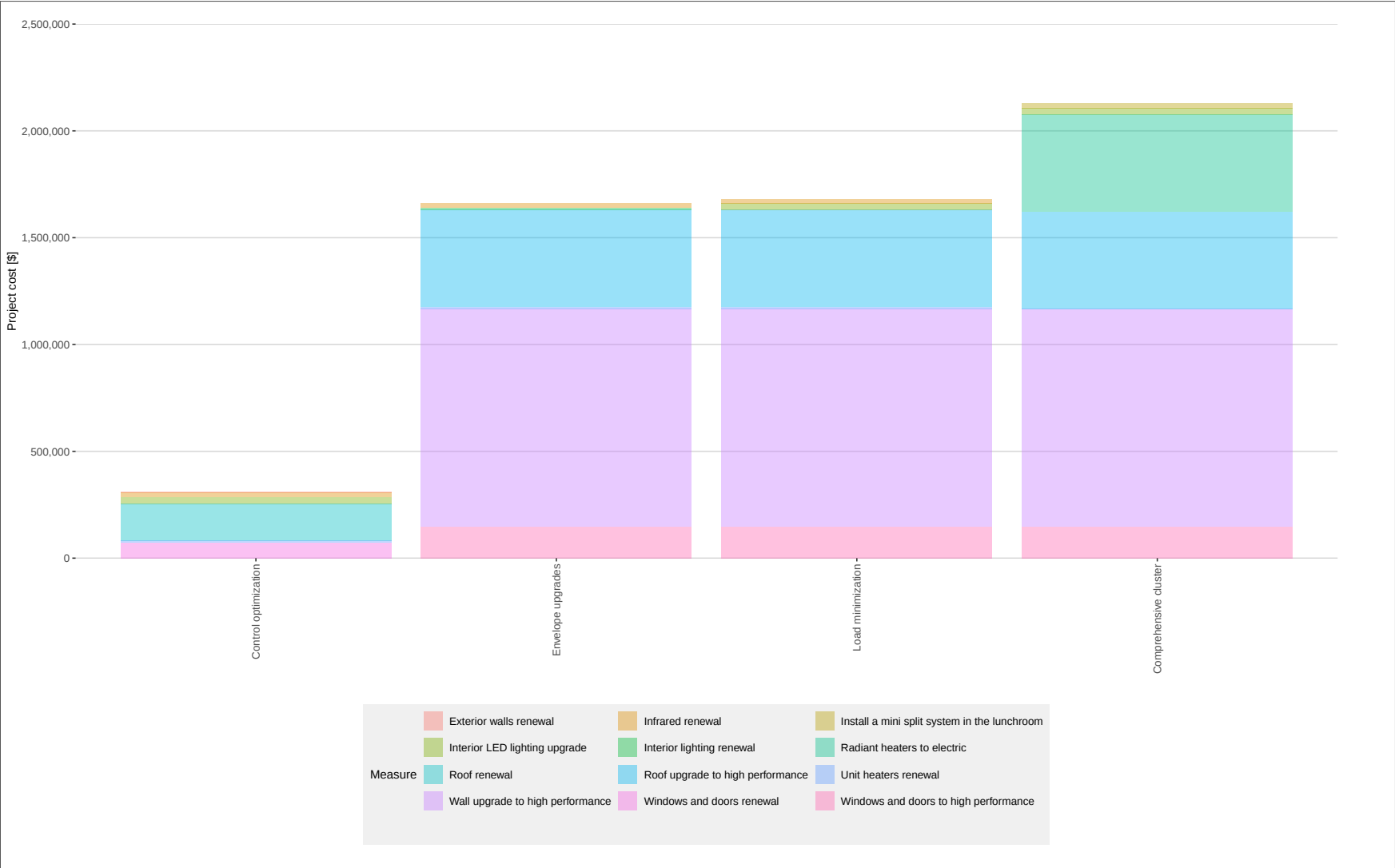


Figure 100: Project cost expected for each scenario by measure

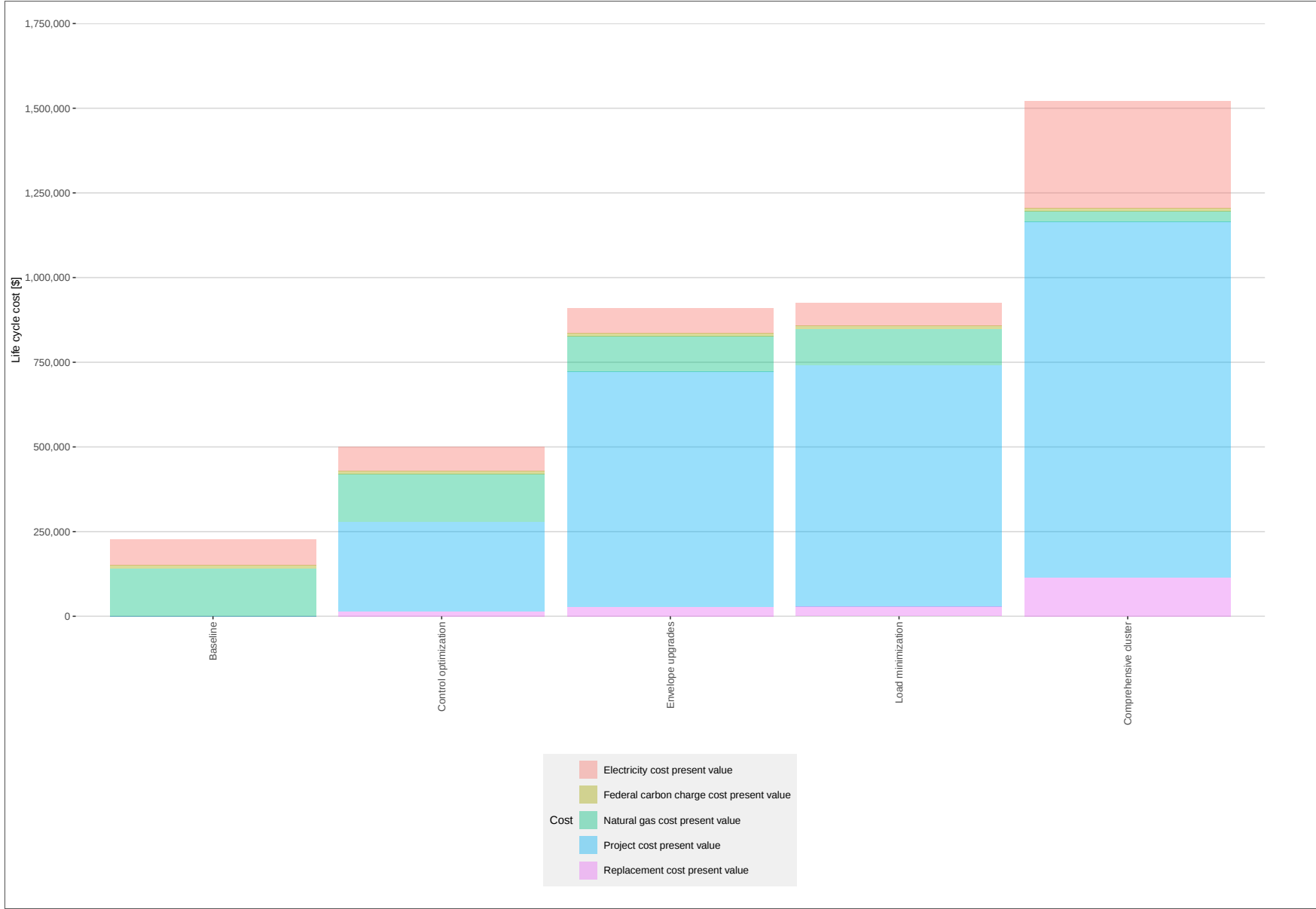


Figure 101: Life cycle cost expected for each scenario by cost item

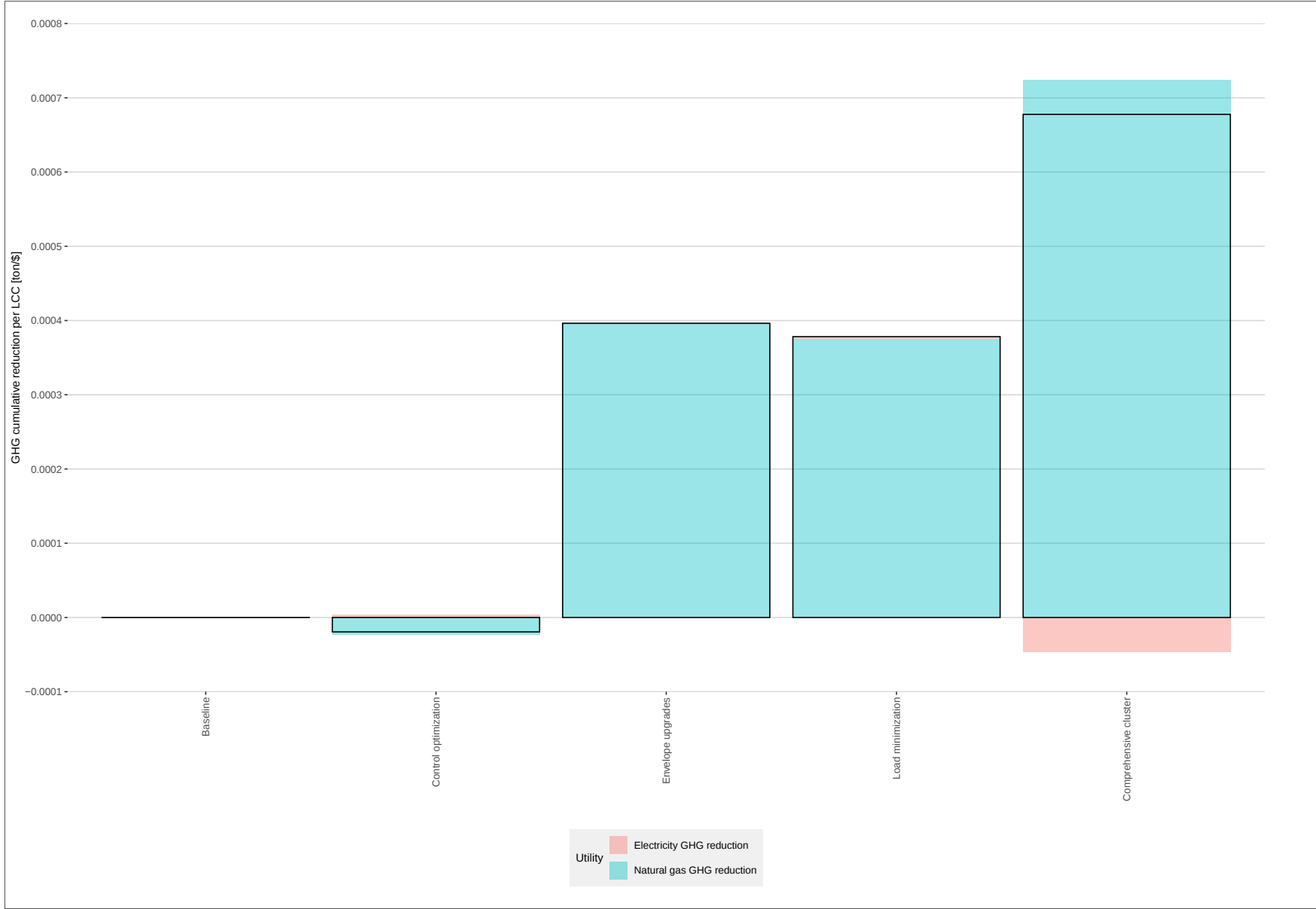


Figure 102: GHG cumulative reduction per life cycle cost (LCC) dollar expected for each scenario by utility

6.5 Plan scenario development

Plan scenario identification and objectives

The plan scenarios that were analyzed and their objectives are summarized in Table 40.

Table 40: 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 40. Results of the plan scenario composition are presented in Figure 103, 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 41 to 46.

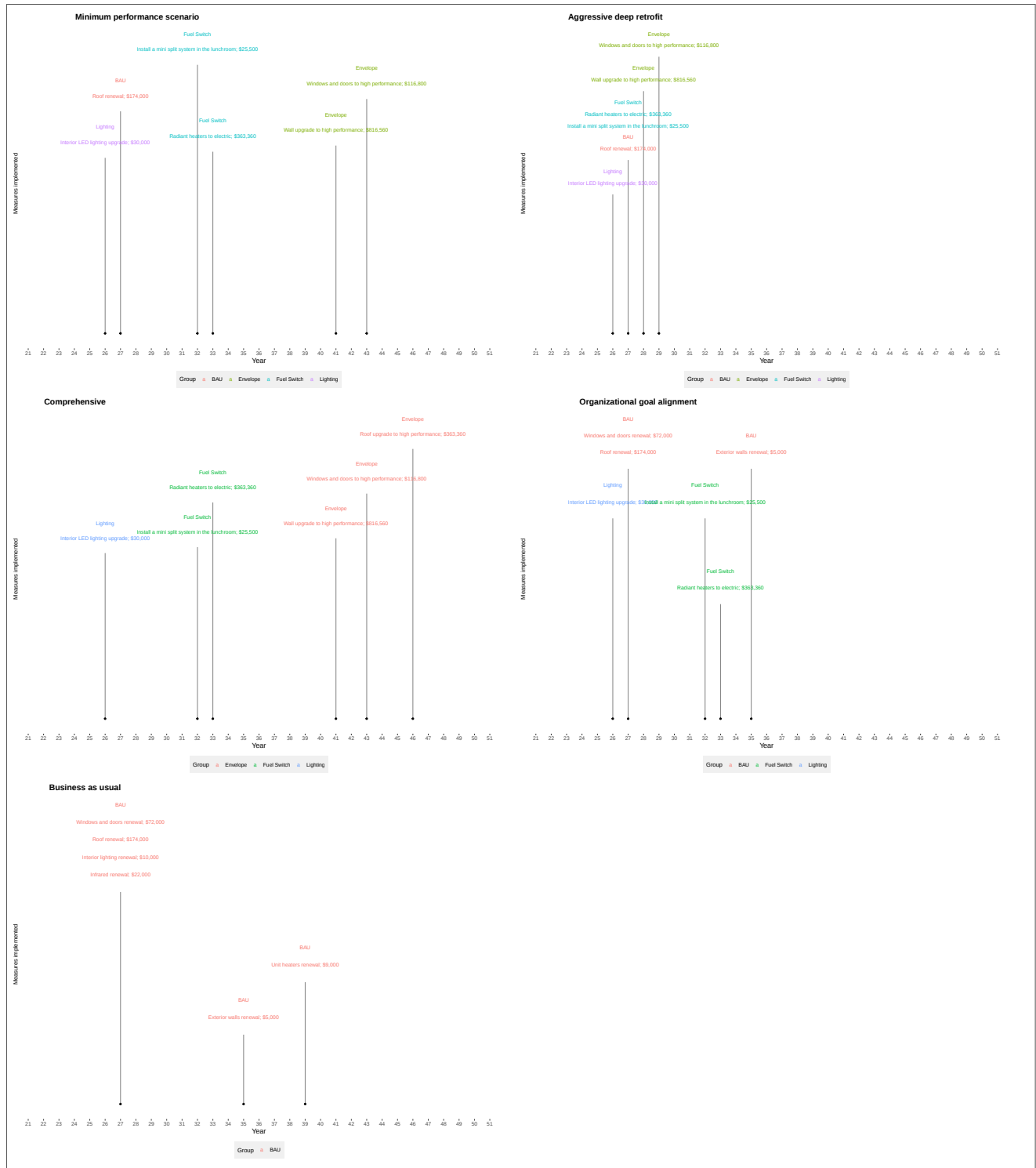


Figure 103: Plan scenario composition, indicating which measures are implemented when and at what cost in each plan scenario

Table 41: Scenario composition summary

Measure	Minimum performance scenario	Aggressive deep retrofit	Comprehensive	Organizational goal alignment
Carbon offsets 20	✗	✗	✗	✗
Install a mini split system in the lunchroom	✓	✓	✓	✓
Interior LED lighting upgrade	✓	✓	✓	✓
Radiant heaters to electric	✓	✓	✓	✓
Roof upgrade to high performance	✗	✗	✓	✗
Wall upgrade to high performance	✓	✓	✓	✗
Windows and doors to high performance	✓	✓	✓	✗
Exterior lighting renewal	✗	✗	✗	✗
Exterior walls renewal	✗	✗	✗	✓
Infrared renewal	✗	✗	✗	✗
Interior lighting renewal	✗	✗	✗	✗
Roof renewal	✓	✓	✗	✓
Unit heaters renewal	✗	✗	✗	✗
Windows and doors renewal	✗	✗	✗	✓

Table 42: Minimum performance scenario measure implementation timeline

Measure	Year
Interior LED lighting upgrade	2026
Roof renewal	2027
Install a mini split system in the lunchroom	2032
Radiant heaters to electric	2033
Wall upgrade to high performance	2041
Windows and doors to high performance	2043

Table 43: Aggressive deep retrofit measure implementation timeline

Measure	Year
Interior LED lighting upgrade	2026
Install a mini split system in the lunchroom	2027
Radiant heaters to electric	2027
Roof renewal	2027
Wall upgrade to high performance	2028
Windows and doors to high performance	2029

Table 44: Comprehensive measure implementation timeline

Measure	Year
Interior LED lighting upgrade	2026
Install a mini split system in the lunchroom	2032
Radiant heaters to electric	2033
Wall upgrade to high performance	2041
Windows and doors to high performance	2043
Roof upgrade to high performance	2046

Table 45: Organizational goal alignment measure implementation timeline

Measure	Year
Interior LED lighting upgrade	2026
Roof renewal	2027
Windows and doors renewal	2027
Install a mini split system in the lunchroom	2032
Radiant heaters to electric	2033
Exterior walls renewal	2035

Table 46: Business as usual measure implementation timeline

Measure	Year
Infrared renewal	2027
Interior lighting renewal	2027
Roof renewal	2027
Windows and doors renewal	2027
Exterior walls renewal	2035
Unit heaters renewal	2039

6.6 Plan performance analysis

Figures 104 through 107 present the projected yearly electricity use, natural gas use, GHG emissions and life cycle costs associated with each plan scenario.



Figure 104: Electricity yearly utility use projection for each scenario



Figure 105: Natural gas yearly utility use projection for each scenario



Figure 106: GHG yearly emissions projection for each scenario

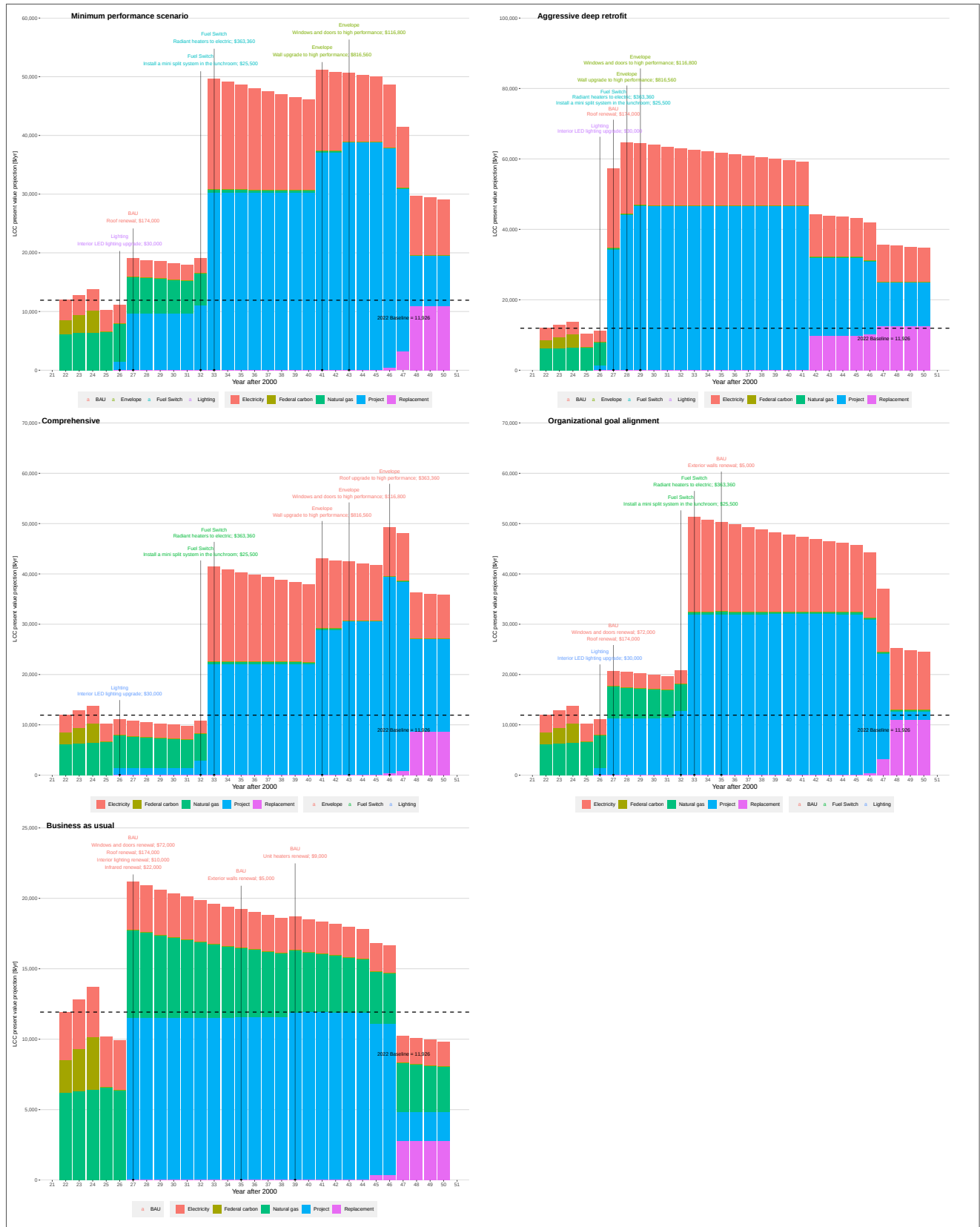


Figure 107: Life cycle yearly cost (after discounting to present value) projection for each scenario

6.7 Plan performance summary

Plan performance summary

Table 47 summarizes the performance of each plan scenario with respect to utility use, GHG emissions, utility cost, and financial metrics. The first half of Table 47 represents the estimated performance in the final year (2050) of the evaluation period. The second half of Table 47 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 47 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 107).

Table 47: 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]	133,046	133,046	121,191	160,134	24,412
	Electricity monthly peak (av)	[kW]	25.8	25.8	23.9	29.4	6.4
	Electricity yearly peak (max)	[kW]	44.4	44.4	44.0	45.0	8.1
	Natural gas use	[m3/yr]	405	405	108	2,354	23,857
GHG emissions final	Electricity GHGs	[tCO2e/yr]	1.3	1.3	1.2	1.5	0.2
	Natural gas GHGs	[tCO2e/yr]	0.8	0.8	0.2	4.5	46.1
	Carbon offsets GHGs	[tCO2e/yr]	0.00	0.00	0.00	0.00	0.00
	Total GHGs	[tCO2e/yr]	2.0	2.0	1.4	6.1	46.3
Utility cost final	Electricity utility cost	[\$/yr]	32,437	32,437	29,546	39,041	5,952
	Natural gas utility cost	[\$/yr]	183	183	49	1,066	10,798
	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]	32,620	32,620	29,595	40,106	16,749
Utility use cumulative	Electricity use	[kWh]	2,893,453	3,355,306	2,834,178	3,133,446	707,954
	Natural gas use	[m3]	288,838	132,084	287,350	306,579	691,851
GHG emissions cumulative	Electricity GHGs	[tCO2e]	87	116	86	91	26
	Natural gas GHGs	[tCO2e]	558	255	555	592	1,337
	Carbon offsets GHGs	[tCO2e]	0.00	0.00	0.00	0.00	0.00
	Total GHGs	[tCO2e]	645	372	641	683	1,363
Utility cost cumulative	Electricity utility cost	[\$]	581,661	649,858	567,767	635,803	132,617
	Natural gas utility cost	[\$]	84,884	36,703	84,237	92,297	240,585
	Carbon offsets utility cost	[\$]	0.00	0.00	0.00	0.00	0.00
	Federal carbon charge	[\$]	8,990	8,990	8,990	8,990	8,990
	Total utility cost	[\$]	675,534	695,550	660,993	737,090	382,192
Financial cumulative	Project cost	[\$]	2,382,815	1,951,920	2,890,201	854,093	307,202
	Replacement cost	[\$]	535,060	493,083	400,560	535,060	158,576
	Life cycle cost	[\$]	985,242	1,340,343	856,531	966,603	479,330

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, and wall, window, and door upgrades are highly recommended.

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.

Comprehensive

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

7 END