Energy Efficiency Assessment
Sacred Heart Cathedral

Project No.: C20-805
Issued: June 29, 2020

ReNü ENGINEERING

Sacred Heart Cathedral

Energy Efficiency Assessment

Energy Auditor

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1 Executive Summary

ReNü Engineering was contracted by Northern Climate Engineering to perform an ASHRAE level 2 energy audit of Sacred Heart Cathedral as part of the design process for planned envelope and mechanical upgrades. The intent of this audit is to review the building's current energy use, operating cost, and greenhouse gas (GHG) emissions, then propose a number of upgrades. The effect of these upgrades on the expected energy use, costs, and GHGs will be calculated, and weighing in the estimated capital cost will determine whether or not upgrades are recommended.

Based on a year with historically average weather and taking into account the planned new mechanical systems, this building is expected to have an annual energy consumption of 164 MWh/y, operating cost of $18,236, and GHG emissions of 36 tCO_2e.

After analysis using energy modeling software, a number of potential energy conservation measures (ECMs) were identified. The recommended ECMs are as follows:

- ECM-1: Add Wall Insulation
- ECM-2: Add Roof Insulation
- ECM-3: Window Upgrade
- ECM-5b: Heat Recovery Ventilator (with DCV)
- ECM-6: Install Solar PV System

Implementing the recommended ECMs results in an energy consumption reduction of 81 MWh/y, saving $8,903 annually. The total estimated capital cost is $206,000 (including Energy Solutions Centre rebates) and provides a simple payback of 23.1 y. The proposed upgrades result in an annual GHG reduction of 19 tCO_2e.

1.1 ECM Summary

Table 1: Energy, GHG, and financial savings summary

ECM	Annual Grid Electricity Savings	Annual Fuel Oil Savings	Annual GHG Reductions	Capital Cost	Annual Cost Savings	Simple Payback
ECM-1: Add Wall Insulation	1338 kWh	2157 L	6 tCO_2e	$90,000	$2,571	35 y
ECM-2: Add Roof Insulation	405 kWh	326 L	0.9 tCO_2e	$15,000	$429	35 y
ECM-3: Window Upgrade	1473 kWh	1827 L	5.1 tCO_2e	$60,000	$2,245	26.7 y
ECM-4: Electric Heating	-122082 kWh	12806 L	30.6 tCO_2e	$0	-$11,310	Never
ECM-5a: Heat Recovery Ventilator (without DCV)[A]	-2373 kWh	1809 L	4.9 tCO_2e	$27,000	$1,472	18.3 y
ECM-5b: Heat Recovery Ventilator (with DCV)	885 kWh	2463 L	6.8 tCO_2e	$30,000	$2,810	10.7 y
ECM-6: Solar PV	4082 kWh	0 L	0.2 tCO_2e	$11,000	$977	11.3 y
Proposed Upgrades[B]	8568 kWh	6565 L	18.5 tCO_2e	$206,000	$8,903	23.1 y

[A] ECMs shown in grey are not recommended for implementation.

[B] The proposed upgrades do not necessarily add up to the sum of the individual ECMs due to interactions between building systems.

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2 Introduction

2.1 Scope of Study

ReNü Engineering was contracted by Northern Climate Engineering to perform an ASHRAE level 2 energy audit of Sacred Heart Cathedral as part of the design process for planned envelope and mechanical upgrades. The level of effort for this assessment is described in the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) publication *Procedures for Commercial Building Energy Audits, Second Edition*. The objective of this assessment is to suggest recommended upgrades to be completed as part of the planned renovations, and to assist in the selection of new mechanical systems.

2.2 Information Received

We have been provided with the following documentation:

- Original 1959 drawings by Dupuis & Dunn Architects (12 sheets total)
- 1998 addition drawings by Charles A McLaren Architects Ltd (9 sheets total)
- Compiled utility bill summary for 2017 and 2018
- Schematic design report by Northern Climate Engineering dated April 2020
- Photographs supplied by Northern Climate Engineering and Doug MacLean

2.3 Site Walkthrough

Due to the inter-territorial travel restrictions imposed in response to the COVID-19 pandemic, an in-person site walkthrough has not been completed. For this reason, some aspects of the building that are not relevant to the planned envelope and mechanical upgrades have been assumed in the energy model.

3 Building Description

Figure 1: Sacred Heart Cathedral viewed from the southeast

Sacred Heart Cathedral is a 1037 m² church located at 406 Steele Street in Whitehorse, YT that was constructed in 1959. The main floor features the large nave and the sanctuary, sacristy, crying room, and a choir loft that opens into the nave. The basement has a large hall, washrooms, commercial kitchen, storage, and the mechanical room. In 1998 an addition was constructed that added office storage, a washroom, and a lift for barrier-free access to the main floor and basement. The basement kitchen was also expanded.

3.1 Building Use & Occupancy

The main floor cathedral spaces are used by staff 8h per day on weekdays, and there are church services twice on weekends for an approximate duration of 4h. The basement hall is used approximately once per month for a duration of about 4h and the kitchen is used once weekly for a similar duration.

3.2 Architectural & Building Envelope

3.2.1 Walls

The building's wall assemblies were obtained from the original construction and addition drawings.

Table 2: Modeled wall U-values

Assembly		Assembly Details
Above-grade wall	1959 Wall	25 mm stucco 25 mm wood sheathing 76 mm fiberglass insulation in 2x6 wood studs @ 400 mm OC 25 mm wood sheathing 13 mm gypsum board U-value: 0.401 (R-14.2)
	1959 Basement Wall	305 mm reinforced concrete 38 mm fiberglass insulation in 2x2 wood furring @ 400 mm OC 13 mm gypsum board U-value: 0.835 (R-6.8)
	1998 Wall	25 mm stucco 13 mm sheathing 140 mm fiberglass insulation in 2x6 wood studs @ 400 mm OC 38 mm fiberglass insulation in 2x2 wood furring @ 400 mm OC 13 mm gypsum board U-value: 0.231 (R-24.6)
	1998 Basement Wall	13 mm plywood sheathing 38 mm XPS insulation in 2x4 wood furring @ 600 mm OC 254 mm reinforced concrete 38 mm fiberglass insulation in 2x2 wood furring @ 400 mm OC 13 mm gypsum board U-value: 0.430 (R-13.2)
Below-grade wall[C]	1959 Basement Wall	Same as shown above Modeled U-value: 0.368
	1998 Basement Wall	Same as shown above Modeled U-value: 0.228

For comparison, in this climate zone the National Energy Code of Canada for Buildings 2015 (NECB 2015) requires a wall insulating value of RSI-4.8 (R-27.0) for new buildings.

[C] Modeled U-value for below-grade walls takes into account the insulating value of the ground.

3.2.2 Roof

Figure 2: View of retrofit fiberglass insulation on the roof. Photo provided by Doug MacLean.

The building's roof insulating values were also obtained from the construction drawings. The original building has no attic spaces, with all insulation installed above the roof decking. The addition instead has a ventilated attic space between the insulated ceiling and the sloped roof.

The church has lifted a portion of the metal roof and found that there is 9.5" of fiberglass insulation installed above what appears to be the original roof membrane. It's assumed that the original fiberboard insulation is below this membrane. The new metal roof is suspended above and fastened to the roof by metal girts that penetrate through the fiberglass insulation.

Table 3: Modeled roof U-values

Assembly		Assembly Details
Roof	1959 Nave Roof	Metal roof 241 mm (9.5") fiberglass batt with metal girts (estimated to reduce insulating value of batts by 20%) 51 mm fiberboard insulation 89 mm cedar U-value: 0.132 (R-43.0)
	1959 Lower Roof	51 mm fiberboard insulation 25 mm sheathing Unventilated cavity 13 mm gypsum U-value: 0.492 (R-11.5)
	1959 Tower Vestibule Roof	25 mm sheathing 76 mm fiberglass insulation in 2x8 wood joists @ 400 mm OC 13 mm gypsum U-value: 0.441 (R-12.9)
	1998 Roof	Ventilated attic space 235 mm fiberglass insulation in 2x10 wood joists @ 400 mm OC 13 mm drywall U-value: 0.177 (R-32.1)

For comparison, NECB 2015 requires a roof insulating value of RSI-6.2 (R-35.1) for new buildings.

3.2.3 Floor

The floors are uninsulated concrete slabs.

For comparison, NECB 2015 requires that concrete slabs have RSI-1.3 (R-7.5) insulation below the slab around the perimeter of the building.

3.2.4 Windows

Figure 3: View of windows on south side of building. Note the newer white awning windows within the original coloured glass cathedral window assemblies. Photo supplied by Northern Climate Engineering.

The drawings indicate that the basement windows are double-pane glazing in aluminum insulated frames. The coloured cathedral glass is noted to be in an aluminum sash without indicating the type of glazing. The original sliding windows within the coloured cathedral glass have been replaced by what appears to be vinyl or fiberglass-framed awning windows, which are assumed to be double-pane.

For simplicity, all windows have been modeled as double-pane, air-fill windows in aluminum-clad wood frames, which represents a middle value between aluminum framing and insulated vinyl framing. These windows have a U-value of 2.84 (R-2.0).

For comparison, NECB 2015 requires that windows have a U-value less than or equal to 2.2, which equals R-2.6.

3.2.5 Doors

All entrance doors are assumed to be insulated steel doors in steel frames, typical of commercial building construction. These doors have a U-value of 2.1 (R-2.7).

For comparison, NECB 2015 requires that doors have a U-value less than or equal to 2.2, which equals R-2.6.

3.3 Mechanical

3.3.1 Heating

3.3.1.1 Furnaces

The original building is heated by two Jackson & Church oil-fired furnaces, with furnace F-1 supplying the basement spaces and F-2 heating the main floor spaces and church loft. These furnaces have a rated efficiency of 80%. The furnaces are at end-of-life and are planned for immediate replacement.

Table 4: Furnace summary

Tag	Type	Heating Capacity	Motor Power
F-1	Jackson & Church OL-350	103 kW (350 MBH)	0.6 kW[D]
F-2	Jackson & Church SDF-45	132 kW (450 MBH)	1.1 kW (1.5 hp)

3.3.1.2 Electric Baseboards

The addition is heated by 100% efficient electric baseboard heaters.

[D] The motor power for this furnace was not listed on the nameplate so it is calculated by reducing the power proportionally to flow compared to furnace F-2.

3.3.3 Ventilation

The building has no dedicated ventilation system. Fresh air is provided via the furnaces' outdoor air ducts when the exhaust fans are operating.

3.3.3.1 Original EF-1

The original building is fit with an exhaust fans for the basement washrooms. This fan is not used so it is not included in the energy model.

3.3.3.2 Kitchen Exhaust Fans

The kitchen is fit with two range hoods. These are assumed to be used infrequently so they are not included in the energy model.

3.3.3.3 Addition EF-1

The addition's washroom, archives room, and storage room are ventilated by an exhaust fan with a capacity of 94 L/s (200 cfm). This fun runs for approximately one hour per week.

3.3.4 Cooling

The building is not fit with mechanical cooling systems. Cooling is provided through the use of operable windows.

3.3.5 Domestic Hot Water

Water heating is provided by an electric hot water heater with an assumed efficiency of 100%.

3.5 Electrical

3.5.1 Interior Lighting, Exterior Lighting, and Plug Loads

Because lighting is not part of the planned upgrades and a site walkthrough has not been conducted, a load has been applied in the energy model to represent lighting and plug loads so that the model's energy consumption matches the building's actual electricity consumption. This load is held constant so that the effect of different fan power for new furnaces/air handlers can be accurately estimated.

3.6 Controls

The furnaces are controlled by thermostats, with the temperature normally held at 17°C constantly.

Exhaust fans are assumed to be controlled by local switches.

4 Energy Use, Cost, and GHG Analysis

4.1 Historical Energy Consumption

4.1.1 Energy Use

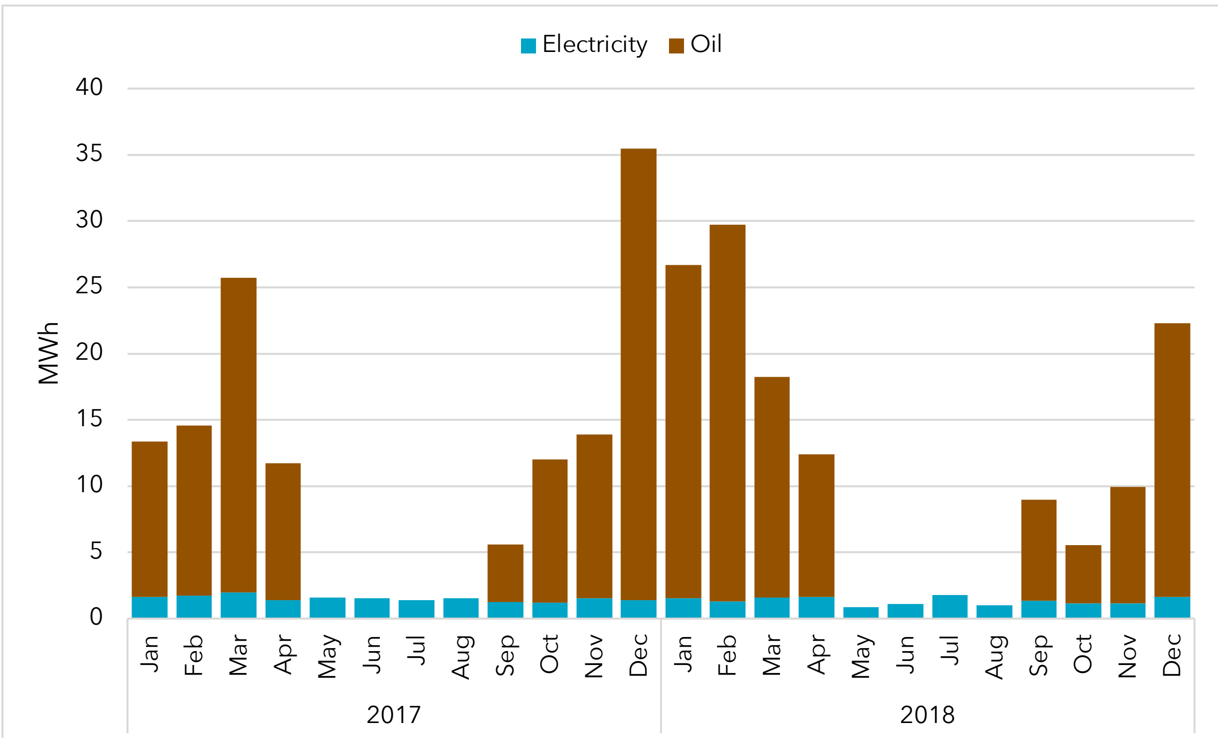

Figure 4: Building total energy consumption broken down by energy source

A summary of electricity and fuel oil use for 2017 and 2018 was provided.

Electricity consumption is fairly constant through the year, with some increase in the winter months for electrical space heating and the furnaces' fans.

Fuel oil consumption follows the normal pattern for buildings in the north, with consumption increasing during the cold winter months when the heating load on the building is highest.

The conversion factors for each form of energy are included in Table 5.

4.1.2 Energy Cost

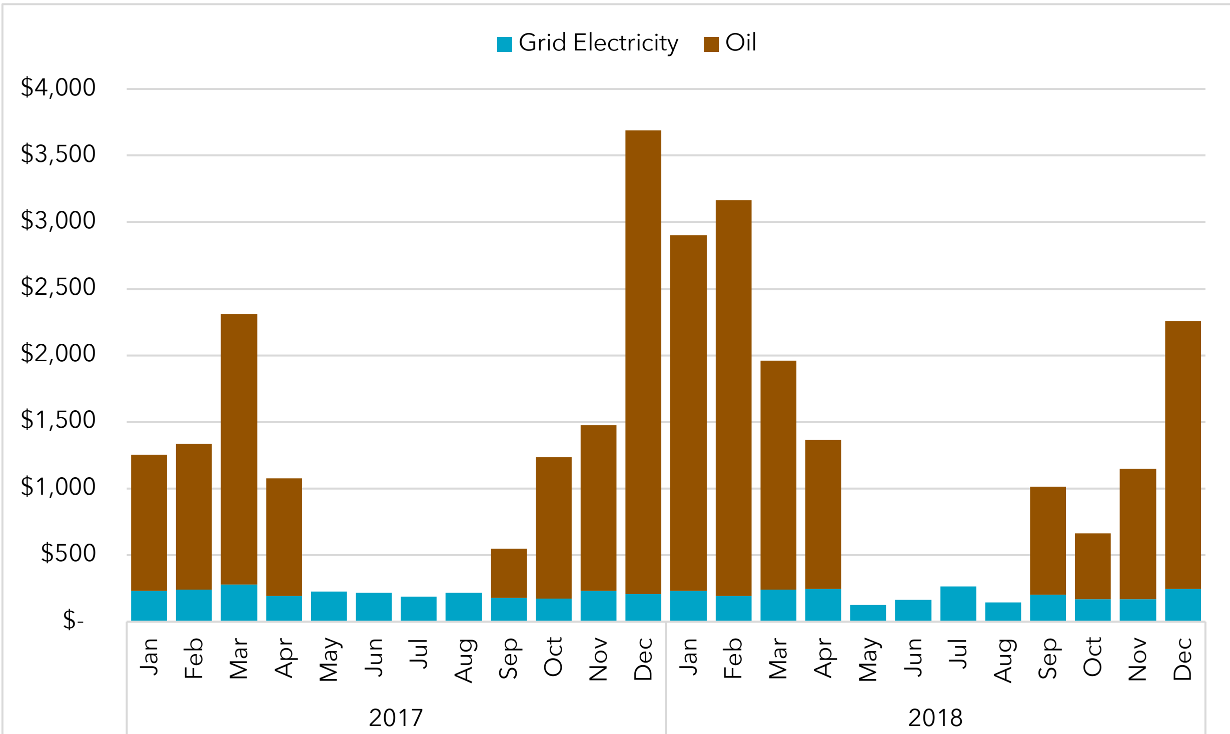

Figure 5: Building total energy cost broken down by energy source

Heating oil represents the majority of the building's utility costs, but electricity costs more per unit of energy than fuel oil as shown below in Table 5.

Sacred Heart Cathedral is on ATCO Electric Yukon's Hydro-1160 rate plan, which has varying $/kWh rates depending on monthly electricity consumption. Their online bill calculator[E] shows the applicable electrical costs and associated fees. This rate plan is a residential rate plan and so has no charge for electrical demand (kW).

Fuel oil is delivered in bulk and through 2017-2018 averaged $1.07/L. This is the rate that is assumed for future use.

Table 5: Energy content and cost of energy for fuels used at this building

Energy Source	Energy Content	Unit Cost	Energy Cost
Grid Electricity	0.001 MWh/kWh	$0.153/kWh[F]	$153.12/MWh
Fuel Oil	0.011 MWh/L	$1.07/L	$98.86/MWh

[E] https://www.atcoelectricyukon.com/en-ca/customer-billing-rates/bill-calculator.html

[F] This is the average unit cost per kWh over the 2017-2018 period. For predicting future energy costs, the actual rate structure as shown on the ATCO Electric Yukon bill calculator is used.

4.1.3 GHG Emissions

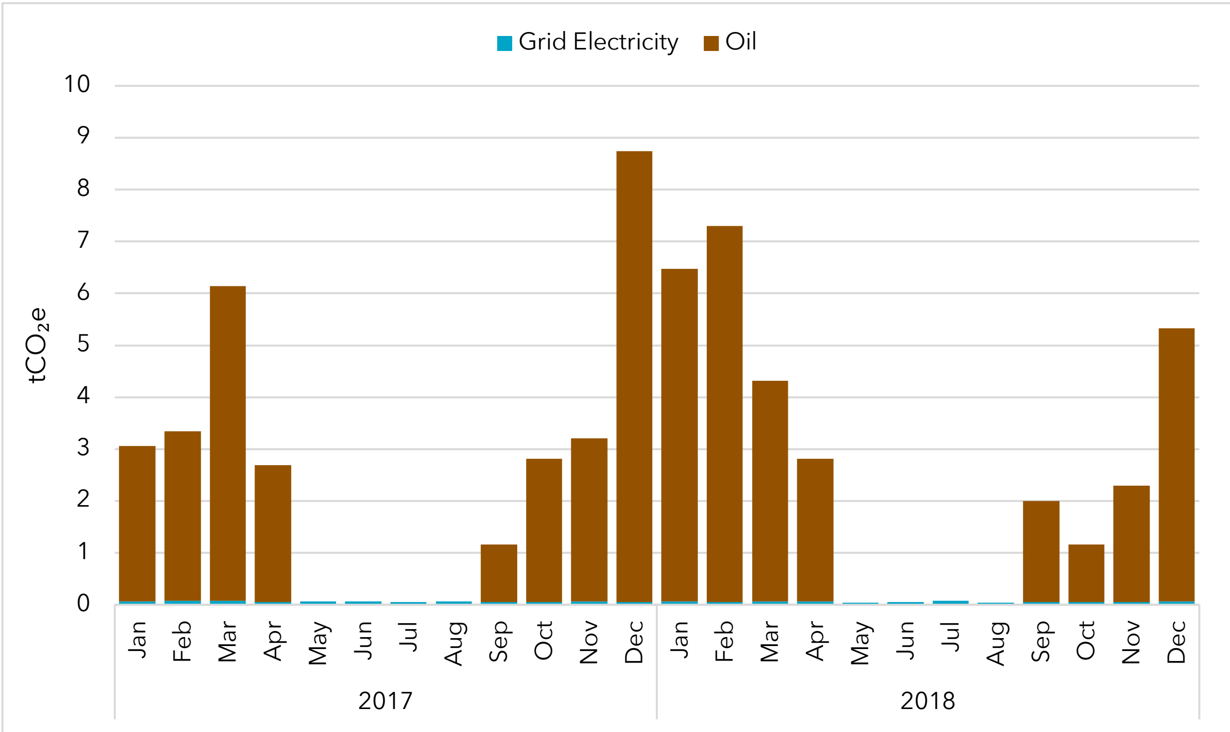

Figure 6: Building GHG emissions broken down by energy source

Whitehorse is on Yukon's hydro grid. The majority (~95%) of electricity is produced by hydroelectricity which has negligible carbon emissions associated with it. The remaining ~5% is provided by diesel or liquified natural gas (LNG) generators. For this reason, the majority of this building's emissions are caused by the on-site burning of fuel oil.

Table 6: GHG emissions attributed to each energy source

Energy Source	Unit GHG Emissions	Energy GHG Emissions
Grid Electricity	0.00004 tCO_2e[G]/kWh	0.039 tCO_2e/MWh
Fuel Oil	0.00276 tCO_2e/L	0.255 tCO_2e/MWh

[G] tCO_2e represents tonnes of carbon dioxide equivalent. It converts other common combustion products with different global warming potentials (such as nitrogen oxides) into an equivalent amount of carbon dioxide.

4.2 Average Annual Consumption

To perform the energy modeling and determine projected future energy use and savings, the historical data is condensed into a yearly average energy consumption. This average is also multiplied by a correction factor to account for the fact that the weather during the billing period may be different from the historical average. Weather data for the location is from the closest weather station (Whitehorse) and is shown in the table below, along with the calculation of a weather adjustment factor.

Table 7: Weather normalization adjustment factor calculation

Period	HDD
Actual Average (HDDb)	6500
IES VE Whitehorse Weather File (HDDr)	6490
Adjustment Factor	0.998

The actual energy use is multiplied by the adjustment factor to find the expected energy use for a year with average weather. In this building, fuel oil consumption is certainly affected by weather. Weather will have a limited effect on electricity consumption as well (via the electric baseboards and furnace fans) but this effect is assumed to be negligible. The adjustment factor is only applied to the fuel oil consumption.

Table 8: Calculation of adjusted baseline energy use

	Grid Electricity	Fuel Oil
	MWh	MWh
Average 2017-2018	17.2	121.3
Adjustment Factor	1.000	0.998
Adjusted Consumption	17.2	121.0

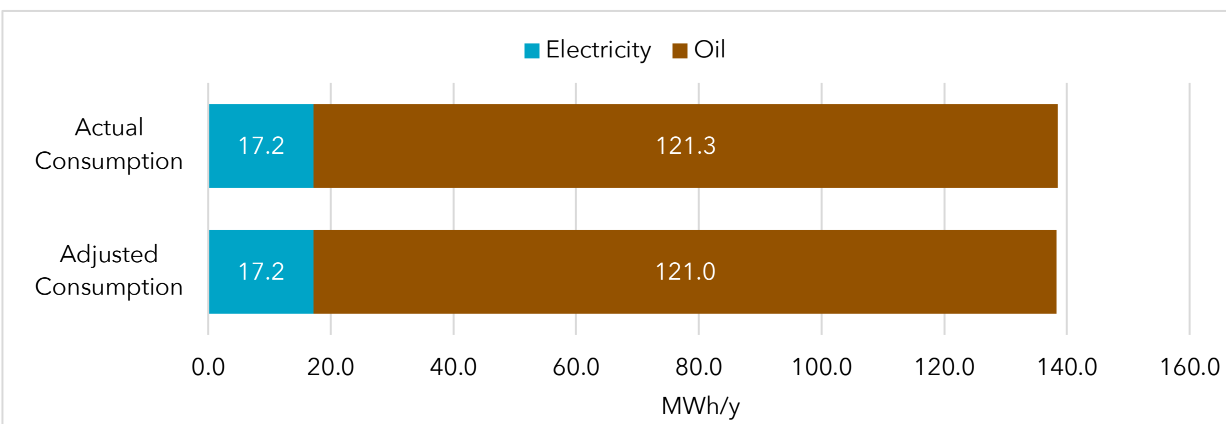

Figure 7: Actual average and weather-adjusted baseline energy consumption

4.3 Energy Benchmarking

In order to get an understanding of this building's performance relative to other buildings, we divide the total energy used in an average year by the building's floor area to find the Energy Use Intensity (EUI), expressed in MWh/m². Energy management and tracking organizations publish reports that summarize building EUI figures for different building categories, comparison to these published figures[H] is shown below.

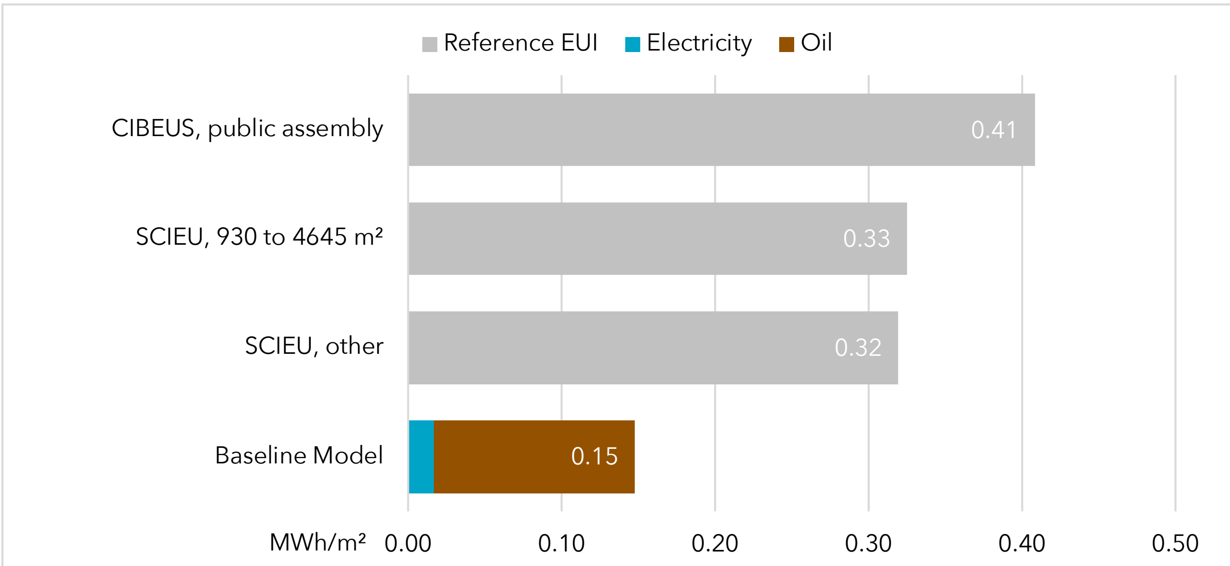

Figure 8: EUI comparison between Sacred Heart Cathedral and similar buildings

The building appears to have lower energy consumption than similar buildings, but it is important to remember that the building is used much less frequently than an average building, has minimal ventilation currently provided, and is heated to a low temperature of 17°C.

[H] The figure for "CIBEUS" is from the Natural Resources Canada *Commercial and Institutional Building Energy Use Detailed Statistical Report – December 2002*. The figures for "SCIEU" are from the Natural Resources Canada *Survey of Commercial and Institutional Energy Use – Buildings 2009,* using the "Other" climate zone entry in tables 2.1 and 2.4.

5 Building Energy Model

5.1 Energy Modeling Method

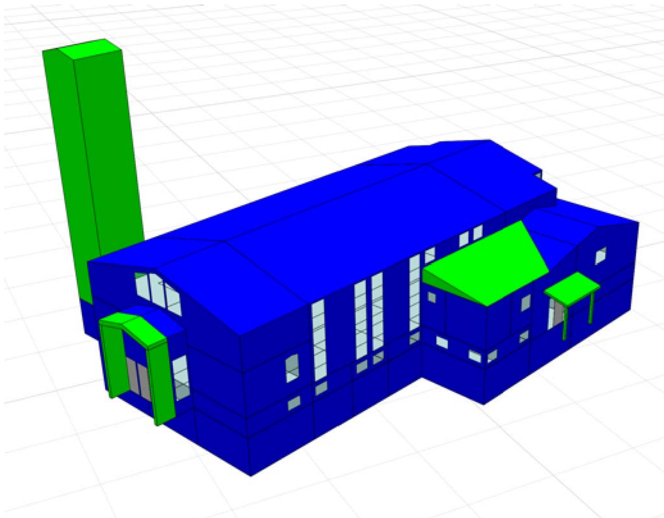

Figure 9: View of the energy model as input into IES VE 2019.

Because the building does not have sub-metering on every piece of equipment, energy modeling software is used to break the building's energy consumption down into end uses and to quantify the savings from proposed upgrades. For this analysis, IES VE 2019 was used to create the energy model. The building location, use patterns, envelope assemblies and geometry, mechanical systems, and electrical systems are input into the software.

The energy consumption of the building energy model as compared to the adjusted actual energy consumption is shown below.

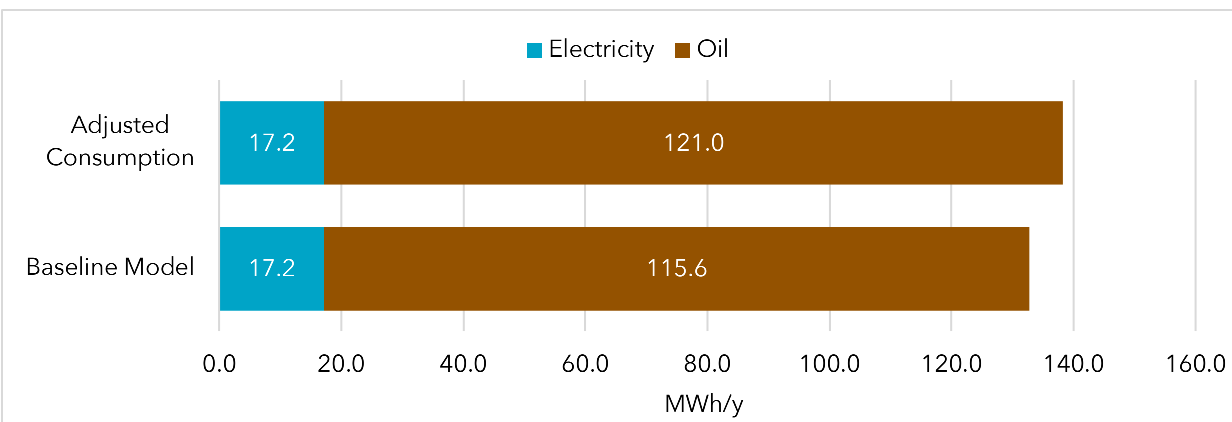

Figure 10: Building energy model energy consumption compared to weather-adjusted actual consumption.

As previously noted, the electrical consumption of interior lighting and plugs is set to match the actual utility bills. The oil consumption in the energy model is slightly (4%) lower than that of the real building. The most likely cause is that the actual building's airtightness is slightly worse than used in the energy model (the default NECB 2015 value of 0.25 $L/s{\cdot}m^2$ wall and roof area). The energy model is sufficiently accurate to be used to estimate savings from proposed upgrades.

The energy model provides a breakdown of energy uses as shown in the next section.

5.2 Energy End Use Breakdown

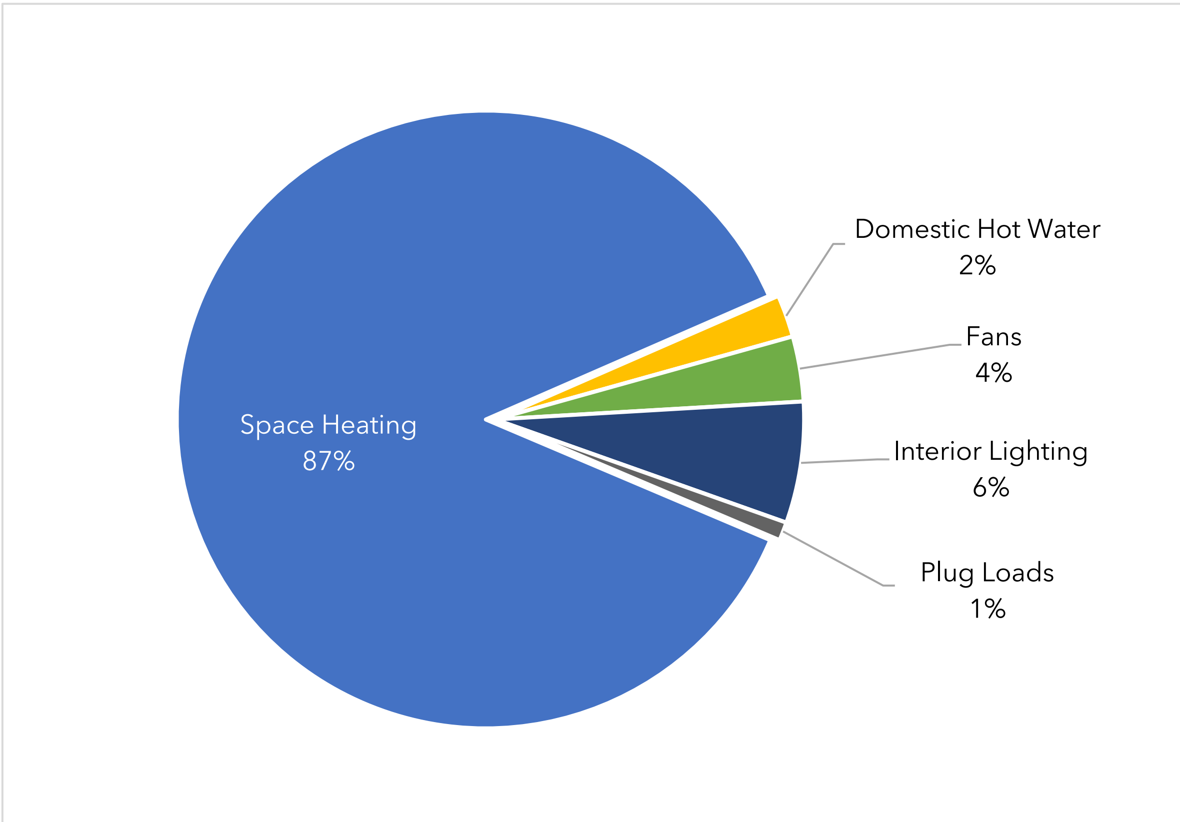

Figure 11: Energy end use breakdown for the building as currently operated

As expected for a building in a northern climate, space heating uses the largest amount of energy. Note that the categories for "interior lighting" and "plug loads" are approximations and are set to match the energy model's electricity use to the actual bills. The furnace fans' energy consumption is accurately estimated by inputting their motor power into the model.

5.4 Adjustment for New Mechanical Systems

Northern Climate Engineering is currently in the process of designing mechanical system upgrades for the church. These upgrades will replace the failing furnaces with new air handlers, which will be designed to provide the proper amount of fresh air to the church's spaces as specified in ASHRAE 62.1. These upgrades will improve occupant comfort and health, but the extra ventilation will increase energy use as well.

The energy model has been adjusted to account for the new ventilation requirements so that the effect of potential modifications to the planned mechanical system can be assessed.

Each furnace will be removed and replaced with a new air handler. The minimum and maximum outdoor air rates for each are shown below. The minimum is set to correspond to the amount of air required per unit of floor area (0.30 L/s·m²) for public assembly spaces. The maximum is set closely to the values in the schematic design report. The ventilation rate will be controlled by carbon dioxide sensors to allow ventilation to increase when the spaces are heavily occupied. The ventilation system is assumed to be in the occupied mode (providing fresh air) for 8h/day.

Table 9: Assigned ventilation rates for air handlers

System	Min Air Flow	Max Air Flow
AHU-1 (Replaces F-1)	187 L/s (396 cfm)	421 L/s (892 cfm)
AHU-2 (Replaces F-2)	202 L/s (428 cfm)	890 L/s (1886 cfm)

The 80% efficient furnaces will be replaced with 88% efficient De Dietrich GT-335A boilers.

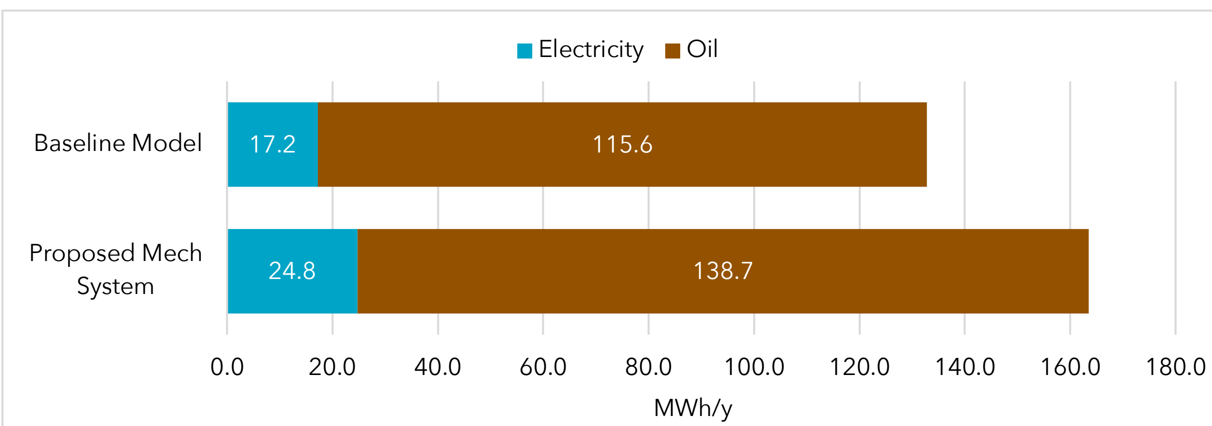

Figure 12: Effect of new mechanical systems on building energy consumption.

The building's electrical consumption will increase due to increased fan run time. Fuel oil consumption will increase due to the extra energy needed to heat cold fresh air to be distributed throughout the building. This extra energy use will increase the building's operating costs to about $18,200 per year (from about $14,500 per year).

The energy consumption of the building with the new mechanical system described in the schematic design report will be used as the basis of comparison for energy conservation measures.

6 Energy Conservation Measures

6.1 ECM-1: Add Wall Insulation

6.1.1 Description

The existing walls have fairly low insulating values. This analysis assumes that a Larsen truss or TJI with a depth of 241 mm (9½”) is installed outboard of the existing wall assemblies at spacing of 400 mm (16”) OC with a cavity filled with mineral wool insulation. Such an assembly would have an effective insulating value of RSI-6.1 (R-34.5). This would increase the wall assemblies as noted below.

Assembly	Existing Insulating Value	Upgraded Insulating Value
1959 Wall	RSI-2.5 (R-14.2)	RSI-8.5 (R-48.5)
1959 Basement Wall	RSI-1.2 (R-6.8)	RSI-7.3 (R-41.3)
1998 Wall	RSI-4.3 (R-24.6)	RSI-10.4 (R-59.2)
1998 Basement Wall	RSI-2.3 (R-13.2)	RSI-8.4 (R-47.7)

6.1.2 Energy Analysis

Table 10: Annual fuel, energy, and GHG emission reductions

	Total	Electricity	Fuel Oil
Baseline Energy Use	163 MWh	24758 kWh	12806 L
ECM Energy Use	139 MWh	23420 kWh	10649 L
Energy Savings	25 MWh	1338 kWh	2157 L
Energy Cost Savings	$2,571	$260	$2,310
GHG Reduction	6 tCO_2e	0.1 tCO_2e	6 tCO_2e

6.1.3 Financial Analysis

Table 11: Simple payback calculation

	Without Incentive	With Incentive
Capital Cost	$150,000	$90,000
Annual Energy Cost Savings	$2,571	$2,571
Simple Payback	58.4 y	35 y

6.1.4 Recommendation

Upgrading the wall assemblies as part of a whole-building envelope upgrade is recommended.

6.2 ECM-2: Add Roof Insulation

6.2.1 Description

The lower sloped roof has an insulating value of RSI-2.0 (R-11.5). This analysis assumes 254 mm (10”) of EPS rigid foam with an insulating value of RSI-7.0 (R-40) is added to the sloped roof. As previously noted, the upper main roof has already had fiberglass batt added, bringing its insulating value up to R-43.

The insulation above the 1998 addition has an insulating value RSI-5.6 (R-32). This analysis assumes an additional 152 mm (6”) of fiberglass batt is added with an insulating value of RSI-3.8 (R-21.6).

6.2.2 Energy Analysis

Table 12: Annual fuel, energy, and GHG emission reductions

	Total	Grid Electricity	Fuel Oil
Baseline Energy Use	163 MWh	24758 kWh	12806 L
ECM Energy Use	160 MWh	24352 kWh	12479 L
Energy Savings	4 MWh	405 kWh	326 L
Energy Cost Savings	$429	$80	$350
GHG Reduction	0.9 tCO_2e	0 tCO_2e	0.9 tCO_2e

6.2.3 Financial Analysis

Table 13: Simple payback calculation

	Without Incentive	With Incentive
Capital Cost	$25,000	$15,000
Annual Energy Cost Savings	$429	$429
Simple Payback	58.3 y	35 y

6.2.4 Recommendation

We do not recommend further insulating the main portion of the roof that has already had fiberglass batt added as the metal roof is in good condition and further upgrade will provide incrementally lower cost savings.

Upgrading the rest of the roof as part of a whole-building envelope upgrade is recommended. A structural engineer should be consulted to confirm that the existing roof structure can safely accommodate the extra weight from more insulation.

6.3 ECM-3: Window Upgrade

6.3.1 Description

Most of the existing windows are aluminum-framed with some insulated fiberglass/vinyl windows. They are estimated to have an average thermal transmittance of U-2.84 (R-2.0). These could be replaced with new Northerm 3800 Series triple-pane argon-fill windows having a low-emissivity coating. These new windows would have a U-value of 1.16 (R-4.9).

6.3.2 Energy Analysis

Table 14: Annual fuel, energy, and GHG emission reductions

	Total	Grid Electricity	Fuel Oil
Baseline Energy Use	163 MWh	24758 kWh	12806 L
ECM Energy Use	142 MWh	23285 kWh	10979 L
Energy Savings	21 MWh	1473 kWh	1827 L
Energy Cost Savings	$2,245	$289	$1,957
GHG Reduction	5.1 tCO_2e	0.1 tCO_2e	5 tCO_2e

6.3.3 Financial Analysis

Table 15: Simple payback calculation

	Without Incentive	With Incentive
Capital Cost	$100,000	$60,000
Annual Energy Cost Savings	$2,245	$2,245
Simple Payback	44.5 y	26.7 y

6.3.4 Recommendation

Replacing the windows as part of a whole-building envelope upgrade is recommended. New windows could have coloured glass used or coloured films applied to replicate the current windows' stained glass appearance.

6.4 ECM-4: Electric Heating

6.4.1 Description

The planned mechanical system will use fuel oil boilers to provide heat to the air handlers. The use of electric boilers has been discussed as an alternative. This analysis assumes the fuel oil boilers are substituted with 100% efficient electric boilers.

6.4.2 Energy Analysis

Table 16: Annual fuel, energy, and GHG emission reductions

	Total	Grid Electricity	Fuel Oil
Baseline Energy Use	163 MWh	24758 kWh	12806 L
ECM Energy Use	147 MWh	146840 kWh	0 L
Energy Savings	17 MWh	-122082 kWh	12806 L
Energy Cost Savings	-$11,310	-$25,025	$13,715
GHG Reduction	30.6 tCO_2e	-4.8 tCO_2e	35.4 tCO_2e

6.4.3 Financial Analysis

Table 17: Simple payback calculation

	Without Incentive
Capital Cost	TBD
Annual Energy Cost Savings	None
Simple Payback	Never

6.4.4 Recommendation

Switching from fuel oil to electric heating is not recommended.

Note that this analysis doesn't take into account that switching to electric heat would likely require increasing the building's electrical service and demand charges would be added to the church's bills. The energy model shows a peak demand of 90 kW with electric heat, which would result in an annual demand cost of $12,000 in addition to the extra $11,000 in energy costs shown above.

6.5 ECM-5a: Heat Recovery Ventilator (without DCV)

6.5.1 Description

The planned design does not include heat recovery but will use carbon dioxide sensors to decrease the ventilation flow rates when the building is lightly occupied. The minimum ventilation air flow is approximately 30% of the peak ventilation requirement.

As an alternative, a heat recovery ventilator could be installed which has a heat exchanger that uses warm air leaving the building to preheat incoming cold air. For this analysis, it's assumed an 85% sensible, 70% latent effective dual-core energy recovery ventilator is used (Tempeff RGSP or similar). This would be instead of the demand-control ventilation system, so it would provide full air flow at all times.

6.5.2 Energy Analysis

Table 18: Annual fuel, energy, and GHG emission reductions

	Total	Grid Electricity	Fuel Oil
Baseline Energy Use	163 MWh	24758 kWh	12806 L
ECM Energy Use	146 MWh	27130 kWh	10997 L
Energy Savings	17 MWh	-2373 kWh	1809 L
Energy Cost Savings	$1,472	-$465	$1,937
GHG Reduction	4.9 tCO_2e	-0.1 tCO_2e	5 tCO_2e

6.5.3 Financial Analysis

Table 19: Simple payback calculation

	Without Incentive	With Incentive
Capital Cost	$45,000	$27,000
Annual Energy Cost Savings	$1,472	$1,472
Simple Payback	30.6 y	18.3 y

6.5.4 Recommendation

Including a heat recovery system is recommended, but including demand-control ventilation is preferable as shown in the next section.

6.6 ECM-5b: Heat Recovery Ventilator (with DCV)

6.6.1 Description

This analysis assumes the heat recovery system is installed as in ECM-5a, but the demand-control ventilation is also installed as originally planned.

6.6.2 Energy Analysis

Table 20: Annual fuel, energy, and GHG emission reductions

	Total	Grid Electricity	Fuel Oil
Baseline Energy Use	163 MWh	24758 kWh	12806 L
ECM Energy Use	136 MWh	23873 kWh	10342 L
Energy Savings	28 MWh	885 kWh	2463 L
Energy Cost Savings	$2,810	$171	$2,638
GHG Reduction	6.8 tCO_2e	0 tCO_2e	6.8 tCO_2e

6.6.3 Financial Analysis

Table 21: Simple payback calculation

	Without Incentive	With Incentive
Capital Cost	$50,000	$30,000
Annual Energy Cost Savings	$2,810	$2,810
Simple Payback	17.8 y	10.7 y

6.6.4 Recommendation

Including a heat recovery along with demand-control ventilation has a short payback period and so is recommended.

6.7 ECM-6: Install Solar PV System

6.7.1 Description

The south-facing sloped roof of the cathedral would be a good location for a solar photovoltaic (PV) installation on the building. Since the church is on a residential electrical meter, 5 kW is likely the maximum system allowable, which would have an area of 32.5 m². Net excess electrical production is credited to the producer at $0.21/kWh according to the Yukon Microgeneration Regulation.

This system would be net-metered, meaning that in the summer when the system is producing excess energy, that excess would be fed into the power grid and the society would receive a credit on its bill. In the winter or at night when production is low, the building would draw power from the grid as it does now.

6.7.2 Energy Analysis

Table 22: Annual fuel, energy, and GHG emission reductions

	Total	Grid Electricity	Solar Electricity	Fuel Oil
Baseline Energy Use	163 MWh	24758 kWh	0 kWh	12806 L
ECM Energy Use	158 MWh	20676 kWh	-1087 kWh	12806 L
Energy Savings	5 MWh	4082 kWh	1087 kWh	0 L
Energy Cost Savings	$977	$749	$228	$0
GHG Reduction	0.2 tCO_2e	0.2 tCO_2e	0 tCO_2e	0 tCO_2e

6.7.3 Financial Analysis

Table 23: Simple payback calculation

	Without Incentive	With Incentive
Capital Cost	$15,000	$11,000
Annual Energy Cost Savings	$977	$977
Simple Payback	15.3 y	11.3 y

6.7.4 Recommendation

A solar PV system has a reasonable payback period and is an energy efficiency measure that is visible to the public. To install such a system, we recommend working with a specialist solar contractor who will be able to review the building's electrical service and roof structure. Solar contractors are able to provide a full "turn-key" installation that requires little work on the part of the church.

7 Proposed Upgrades Summary

In the previous sections, a number of ECMs were analyzed, with estimated reductions in fuel use, operating cost, and greenhouse gas emissions calculated for each. If ECMs are implemented at the same time, they interact in ways that either diminish or enhance each other's effects. This section takes all of the proposed ECMs and calculates what the combined effect would be if they were implemented together.

7.1 Recommended ECMs

The ECMs that are recommended for implementation are:

- ECM-1: Add Wall Insulation
- ECM-2: Add Roof Insulation
- ECM-3: Window Upgrade
- ECM-5b: Heat Recovery Ventilator (with DCV)
- ECM-6: Install Solar PV System

We recommend that an architect is retained to advise on how best to implement the wall, roof, and window upgrades in an integrated manner that will result in the most efficient, safe, and aesthetically pleasing building envelope. As an example, if the walls are upgraded then the new windows should be placed correctly in the new wall assembly to ensure continuity of the thermal and vapour barriers.

The figures on the following pages represent the projected energy savings if all ECMs are implemented at the same time and take into account the interactive effects between the different ECMs using the whole-building energy model.

7.1.1 Energy Analysis

Table 24: Annual fuel, energy, and GHG emission reductions

	Total	Grid Electricity	Solar Electricity	Fuel Oil
Baseline Energy Use	163 MWh	24758 kWh	0 kWh	12806 L
ECM Energy Use	82 MWh	16189 kWh	-1313 kWh	6241 L
Energy Savings	81 MWh	8568 kWh	1313 kWh	6565 L
Energy Cost Savings	$8,903	$1,596	$276	$7,031
GHG Reduction	18.5 tCO_2e	0.3 tCO_2e	0 tCO_2e	18.1 tCO_2e

7.1.2 Financial Analysis

Table 25: Simple payback calculation

	Without Incentive	With Incentive
Capital Cost	$340,000	$206,000
Annual Energy Cost Savings	$8,903	$8,903
Simple Payback	38.2 y	23.1 y

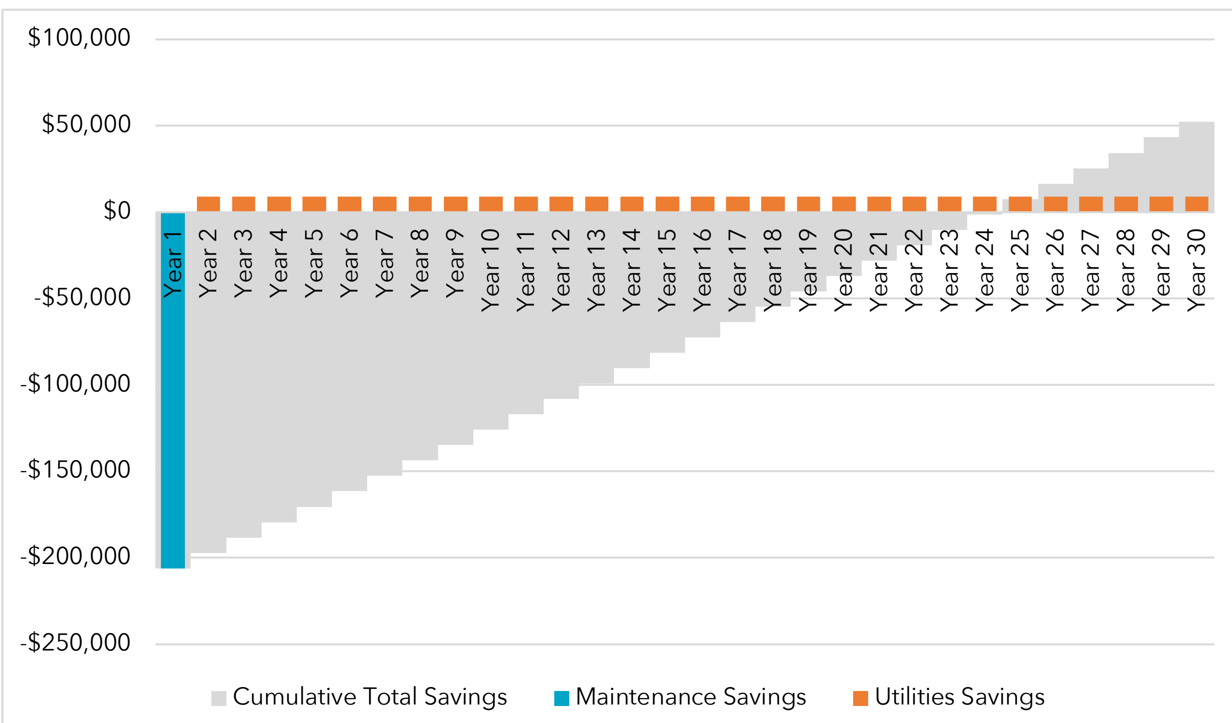

Figure 13: Annual maintenance savings, utilities savings, and cumulative total cost savings

7.2 Projected Annual Energy Consumption, Cost, and GHG Emissions

The graphs below show the expected annual energy use, operating cost, and GHG emissions for the building if no changes were made, with the proposed mechanical systems, and with the upgrade case outlined in section 7.1.

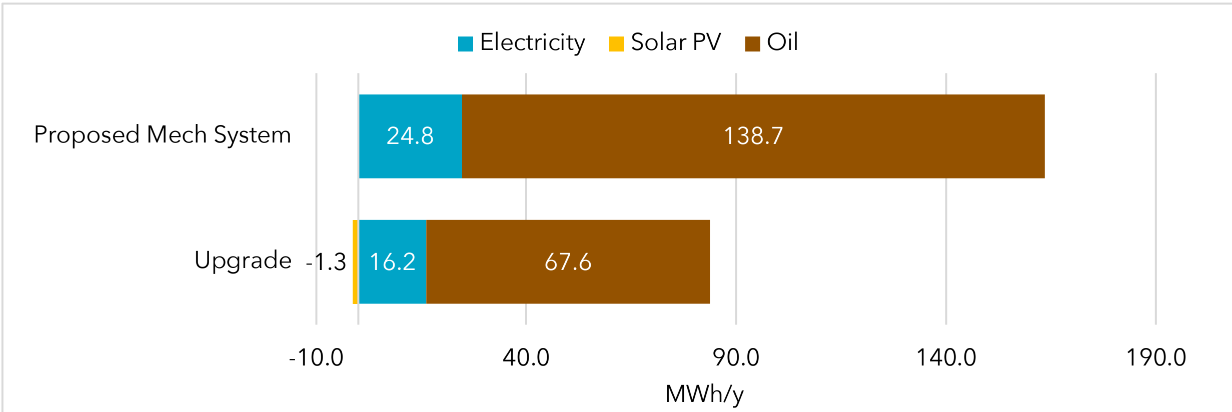

Figure 14: Projected energy use for the building with new mechanical systems and with proposed upgrades

Overall electricity and oil use would be reduced, and a small amount of electricity would be exported to the grid by the solar PV system.

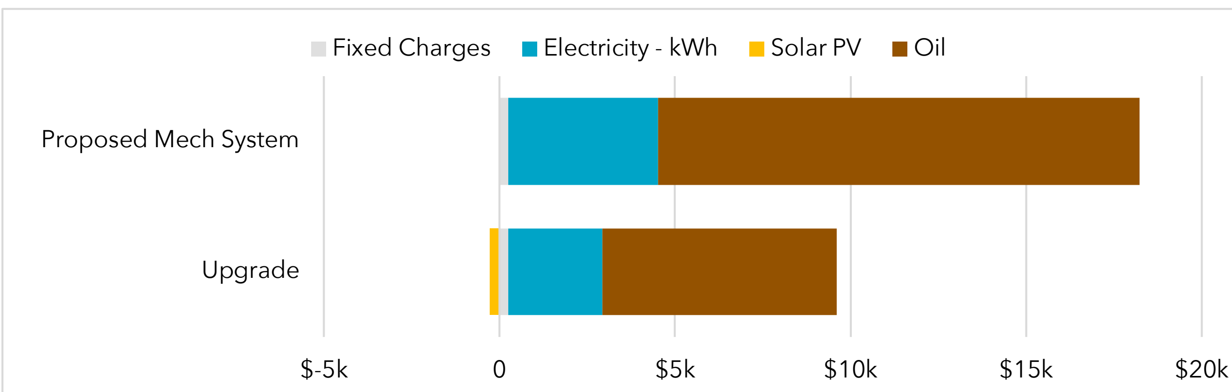

Figure 15: Projected energy cost for the building with new mechanical systems and with proposed upgrades

The building's energy costs would be reduced from $18,236 annually to $9,333, a reduction of 49%.

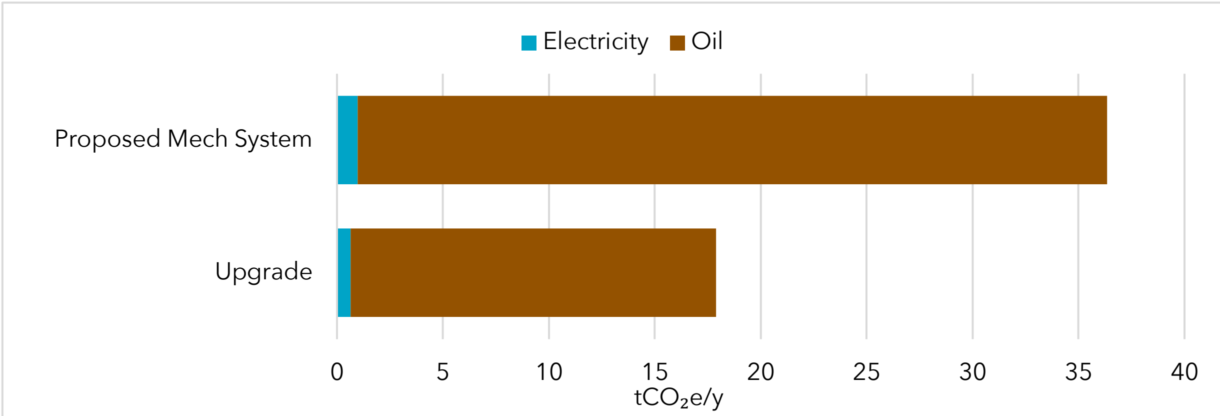

Figure 16: Projected GHG emissions for the building with new mechanical systems and with proposed upgrades

Greenhouse gas emissions would be reduced from 36 tCO_2e to 18 tCO_2e, which is a 51% reduction.

7.3 Projected Energy Benchmarking

In section 4.3, a comparison was provided of this building's energy consumption with other buildings of similar type and size. The proposed upgrade case is added to this comparison below.

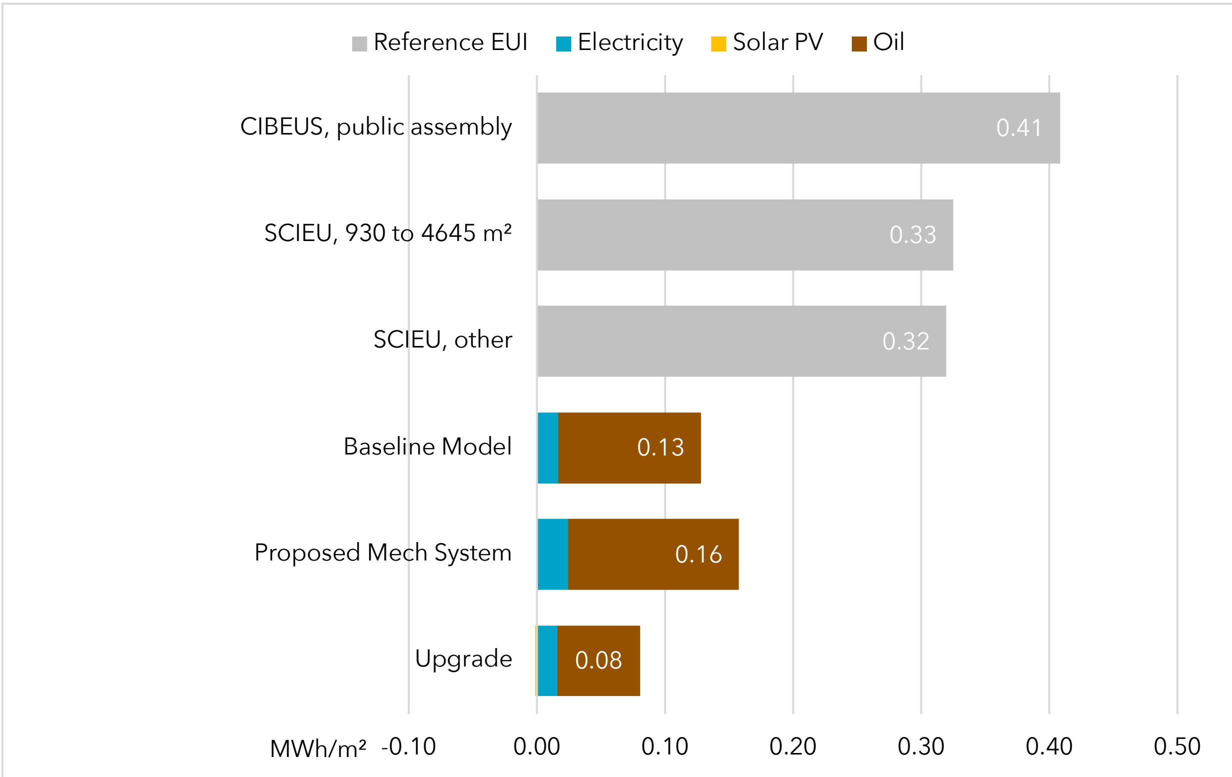

Figure 17: Projected EUI for the building with new mechanical systems and with proposed upgrades relative to similar buildings

7.5 Alternative Fuel Sources

The church has expressed a desire to switch from fuel oil to alternative heating fuels. The following options were not analyzed in detail:

- Biomass systems require wood chip handling facilities that take up more room than is available on site.
- Ground-source heat pumps (commonly referred to as geothermal) are not an option as there is no room on site for the ground-loop piping field or wells.

Propane and air-source heat pumps are considered below.

7.5.1 Propane

Propane tanks have legal limitations regarding distance from buildings and the property line depending on size. If the recommended building upgrades are completed then the required tank size may be small enough to be located on site.

The analysis below assumes that 95% efficient propane boilers are installed instead of the 88% efficient fuel oil boilers that are planned. Superior Propane's Whitehorse office was contacted and it was found that their floating propane rate is currently $0.80/L, with a lower rate possible if a fixed rate contract is signed. The analysis assumes a rate of $0.75/L.

Table 26: Annual fuel, energy, and GHG emission reductions

	Total	Grid Electricity	Solar Electricity	Propane	Fuel Oil
Baseline Energy Use	82 MWh	16189 kWh	-1313 kWh	0 L	6241 L
ECM Energy Use	78 MWh	16189 kWh	-1313 kWh	8841 L	0 L
Energy Savings	5 MWh	0 kWh	0 kWh	-8841 L	6241 L
Energy Cost Savings	$53	$0	$0	-$6,631	$6,684
GHG Reduction	3.6 tCO_2e	0 tCO_2e	0 tCO_2e	-13.6 tCO_2e	17.2 tCO_2e

The cost of propane would be slightly cheaper than fuel oil, assuming a rate of $0.75/L can be obtained. However, propane tanks have annual rental fees and the heaters to prevent freezing in extreme cold weather will use some electricity. Both of these factors will offset the savings in the cost of the fuel. For this reason, switching to propane is not recommended.

7.5.3 Air-Source Heat Pumps

Air-source heat pumps use electricity to move heat from the outdoors to the interior of the building. In cold weather their efficiency drops, and a backup source of heat is required, usually electric resistance heating for packaged heat pump furnaces.

Switching to heat pumps without performing building upgrades is not recommended for the same reason as switching to electric boilers: it will result in a very large peak electrical demand that may require electrical service upsizing and high demand charges.

An analysis was performed to compare the use of air-source heat pumps assuming that all building upgrades noted in the "Proposed Upgrades" case are performed, which will reduce the size of the heating system needed. The energy model shows that if the recommended envelope upgrades are performed, four Mitsubishi Zuba-Central PVA-A42AA7 units with 15 kW electric backup may be sufficient to handle the building's heating load (to be confirmed by the mechanical engineer).

Using these units to provide heating results in the following predicted energy and cost savings (compared to the baseline of 88% efficient fuel oil boilers with other building upgrades completed).

Table 27: Annual fuel, energy, and GHG emission reductions

	Total	Grid Electricity	Solar Electricity	Fuel Oil
Baseline Energy Use	82 MWh	16189 kWh	-1313 kWh	6241 L
ECM Energy Use	52 MWh	53593 kWh	-1239 kWh	0 L
Energy Savings	30 MWh	-37403 kWh	-74 kWh	6241 L
Energy Cost Savings	-$905	-$7,573	-$16	$6,684
GHG Reduction	15.8 tCO_2e	-1.5 tCO_2e	0 tCO_2e	17.2 tCO_2e

Heat with air-source heat pumps is more expensive due to the higher cost of electricity compared to fuel oil per unit of energy (negative savings indicates in increase in cost). Additionally, the increased electrical demand may require increasing the size of the building's electrical service and the church may then be required to pay demand charges. For these reasons, heating with air-source heat pumps is not recommended.

7.6 Summary of ECMs

7.6.1 Energy and GHG Savings

Table 28: Energy, GHG, and financial savings summary

ECM	Annual Grid Electricity Savings	Annual Fuel Oil Savings	Annual GHG Reductions	Capital Cost	Annual Cost Savings	Simple Payback
ECM-1: Add Wall Insulation	1338 kWh	2157 L	6 tCO_2e	$90,000	$2,571	35 y
ECM-2: Add Roof Insulation	405 kWh	326 L	0.9 tCO_2e	$15,000	$429	35 y
ECM-3: Window Upgrade	1473 kWh	1827 L	5.1 tCO_2e	$60,000	$2,245	26.7 y
ECM-4: Electric Heating	-122082 kWh	12806 L	30.6 tCO_2e	$0	-$11,310	Never
ECM-5a: Heat Recovery Ventilator (without DCV)	-2373 kWh	1809 L	4.9 tCO_2e	$27,000	$1,472	18.3 y
ECM-5b: Heat Recovery Ventilator (with DCV)	885 kWh	2463 L	6.8 tCO_2e	$30,000	$2,810	10.7 y
ECM-6: Solar PV	4082 kWh	0 L	0.2 tCO_2e	$11,000	$977	11.3 y
Proposed Upgrades	8568 kWh	6565 L	18.5 tCO_2e	$206,000	$8,903	23.1 y

8 Appendices

8.1 Appendix A: Historical Billing and Weather Data

Historical energy consumption was provided in the form of a summary of consumption for 2017 and 2018. Weather data is downloaded from Environment Canada's historical data archive.

Table 29: Historical utility billing and weather data

Billing Period		Grid Electricity					Fuel Oil	
		kWh	kWh $	kW $	Fixed $	Total $	L	$
Jan	2017	1640	$242.91	$-	$(12.56)	$230.35	1084.0	$1,024.38
Feb	2017	1720	$254.99	$-	$(12.56)	$242.43	1184.9	$1,094.85
Mar	2017	1960	$291.32	$-	$(12.56)	$278.76	2192.4	$2,029.81
Apr	2017	1400	$206.59	$-	$(12.56)	$194.03	951.7	$884.55
May	2017	1600	$236.85	$-	$(12.56)	$224.29	0.0	$-
Jun	2017	1560	$230.78	$-	$(12.56)	$218.22	0.0	$-
Jul	2017	1400	$200.76	$-	$(12.56)	$188.20	0.0	$-
Aug	2017	1560	$229.07	$-	$(12.56)	$216.51	0.0	$-
Sep	2017	1240	$189.54	$-	$(12.56)	$176.98	400.0	$369.60
Oct	2017	1200	$185.86	$-	$(12.56)	$173.30	1000.1	$1,060.61
Nov	2017	1560	$243.16	$-	$(12.56)	$230.60	1138.9	$1,243.68
Dec	2017	1400	$217.71	$-	$(12.56)	$205.15	3142.9	$3,485.91
Jan	2018	1560	$244.00	$-	$(12.56)	$231.44	2320.7	$2,668.86
Feb	2018	1320	$206.12	$-	$(12.56)	$193.56	2620.1	$2,971.20
Mar	2018	1600	$250.94	$-	$(12.56)	$238.38	1536.2	$1,719.53
Apr	2018	1640	$257.36	$-	$(12.56)	$244.80	992.1	$1,120.30
May	2018	880	$136.77	$-	$(9.21)	$127.56	0.0	$-
Jun	2018	1120	$174.11	$-	$(12.56)	$161.55	0.0	$-
Jul	2018	1760	$276.56	$-	$(12.56)	$264.00	0.0	$-
Aug	2018	1000	$155.68	$-	$(12.56)	$143.13	0.0	$-
Sep	2018	1360	$214.10	$-	$(12.56)	$201.54	704.7	$813.93
Oct	2018	1160	$181.86	$-	$(12.56)	$169.30	404.0	$496.31
Nov	2018	1160	$181.86	$-	$(12.56)	$169.30	812.0	$980.73
Dec	2018	1640	$257.11	$-	$(12.56)	$244.55	1905.1	$2,015.18