

ENERGY MODELING REPORT

Huston House

Edna Curren Memorial Fund (ECMF)



ReNü
ENGINEERING

Huston House

Energy Modeling Report

Energy Modeler

ReNü Engineering Inc.
#200, 10039 80 Ave NW
Edmonton, AB T6E 1T4

Clients

Edna Curren Memorial Fund (ECMF)

Analysis & Report By

Sarah Mattar, EIT
smattar@renu.engineering

Client Contact

Stephen Weiss
stephen.weiss@sasktel.net

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1 Energy Model Inputs

1.1 Scope of Analysis

ReNü Engineering was requested to perform energy modeling and retrofit study of the existing Huston House in Regina, SK, based on information and drawings provided by Stephen Weiss. The intent of this study is to review the existing building's estimated envelope and energy usage, and develop building envelope scenarios and heating, ventilation, and air conditioning system scenarios to determine the annual building energy consumption, greenhouse gas emissions, and annual utility costs for each envelope scenario.

1.2 Site and Climate Data

The nearest weather station site and climate data used for the energy model is shown below.

Table 1: IES and ASHRAE Location and Climate Information

IES VE	Location	Regina, SK
	Weather File	Regina Intl Airport
ASHRAE	Heating Load Temp	-36°C
	Cooling Load Temp	31°C
NECB 2017	Location	Regina
	Heating Degree Days (HDD)	5600
	Climate Zone	7A

2 Envelope and HVAC System Analysis

2.1 Envelope Scenarios

Three building envelope scenarios were developed and analyzed as described below. These envelope scenarios were developed to demonstrate the different building energy demands associated with different building envelope scenario targets such as envelope thermal resistance and airtightness.

- 1) Existing envelope scenario; estimated existing envelope
- 2) National Building Code 2015 (NBC 2015) envelope scenario; retrofit of existing Huston House envelope to NBC 2015 effective thermal resistance R-values.
- 3) Mid-Performance (MP) envelope scenario; retrofit of existing Huston House envelope to mid-performance target thermal resistance R-values.
- 4) High-Performance (HP) envelope scenario; retrofit of existing Huston House envelope to high performance target thermal resistance R-values.

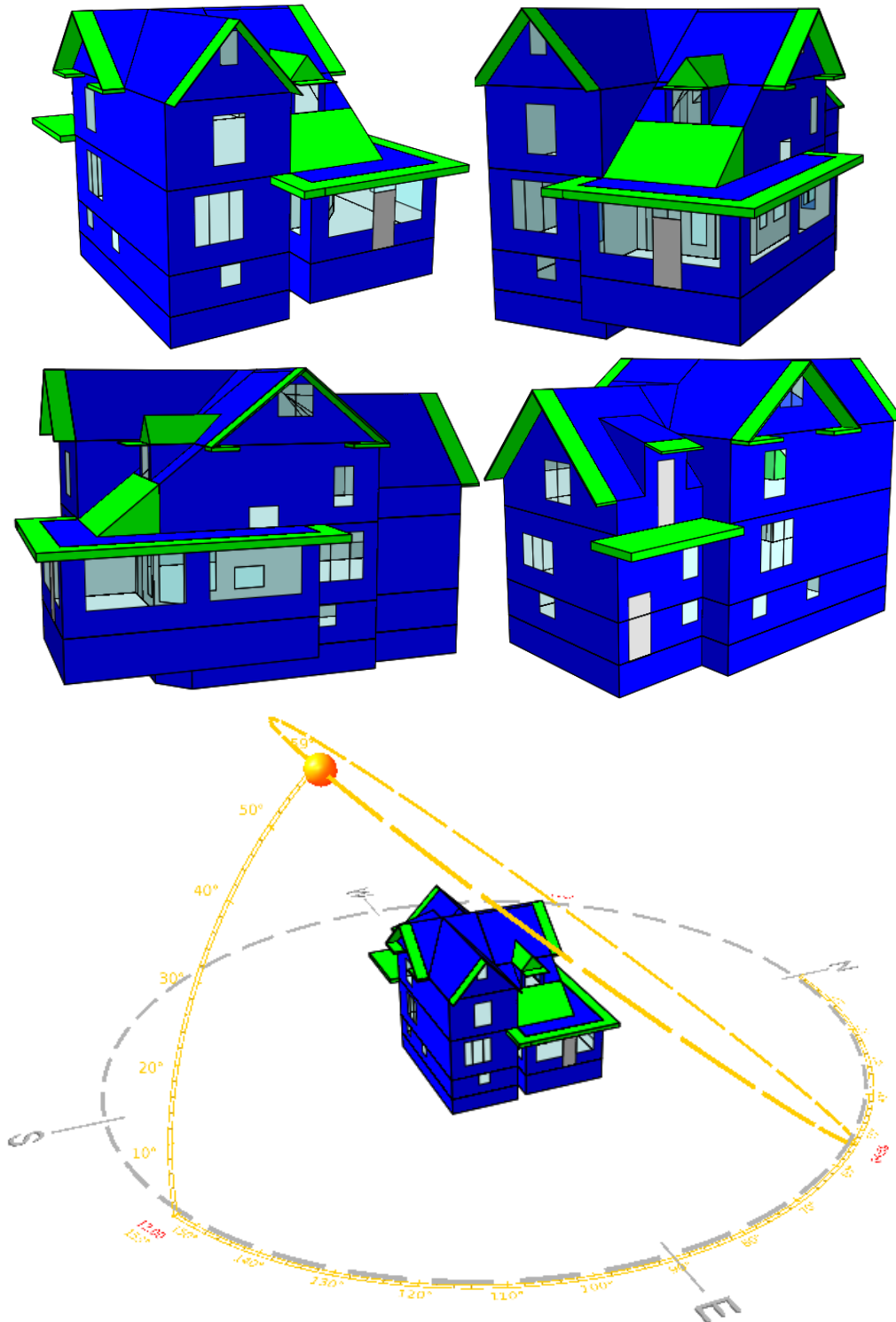
The envelope upgrades and associated insulating values, airtightness, and additional upgrades (ventilation) for the four (4) levels of envelope scenarios are provide in Table 2.

Table 2: Building Envelope Scenarios Summary.

	Existing	National Building Code 2015 (NBC 2015)	Mid Performance (MP)	High Performance (HP)
Building Assembly	R-Value	R-Value	R-Value	R-Value
Above Ground External Wall	R6	R17	R30	R40
Below Grade External Wall	R6	R17	R30	R40
Ground Contact Floor	Uninsulated	Uninsulated	R20	R20
Roof	R10	R29	R40	R60
External Windows	Single and double pane, R1 & R3	Double pane, U=2.8, SHGC=0.5	Triple pane, U=0.15, SHGC=0.35	Triple pane, U=0.15, SHGC=0.35
Airtightness	5ACH50Pa	2ACH50Pa	1ACH50Pa	1ACH50Pa
ERV	N/A	60% @ 0C	75% @ 0C	75% @ 0C

Analysis of the of the four (4) envelope scenarios was completed using dynamic energy modeling software IES with geometry based on the information received. The IES model is shown in Figure 1.

Figure 1: Huston House geometry as modelled in IESVE.



2.2 HVAC Scenarios

In addition to the different envelope scenarios, three (3) different heating, ventilation, and air conditioning (HVAC) scenarios were also developed and analyzed as described below. These HVAC scenarios, in combination with the different building envelope scenarios, are modeled to calculate the approximate the annual energy consumption, greenhouse gases, and utility costs for the building.

1) Natural gas (NG) HVAC scenario

Natural gas furnace for space heating, electric air conditioning for space cooling and mechanical ventilation as per Table 2.

2) Air source heat pump (ASHP) HVAC scenario

Electric air source heat pump (ASHP) for space heating and space cooling and mechanical ventilation as per Table 2.

3) Ground source heat pump (GSHP) HVAC scenario

Geothermal ground loop (whole building), electric ground source heat pump (ASHP) for space heating and space cooling and mechanical ventilation as per Table 2.

The HVAC system scenarios are summarized in Table 3, including the assumed seasonal coefficient of performance (COP) for the space heating and space cooling.

Table 3: Huston House HVAC scenarios – heating, cooling, and ventilation details.

	HVAC System Scenarios		
	NG System	ASHP System	GSHP System
Heating	NG Furnace, COP 0.9	Electric ASHP, COP 2.0	Geothermal ground loop, Electric GSHP, COP 3.5
Cooling	Electric Cooling, COP 3.8	Electric ASHP, COP 4.0	Geothermal ground loop, Electric GSHP, COP 4.0
Ventilation	ERV, 60% @ 0C	ERV, 75% @ 0C	ERV, 75% @ 0C

3 Energy Analysis Details

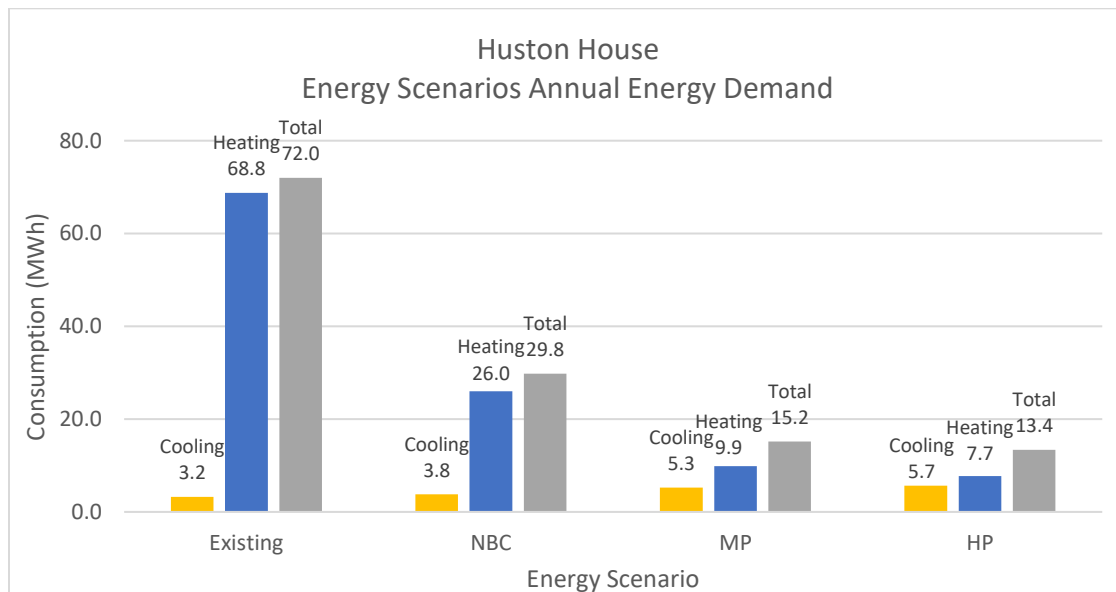
3.1 Annual Energy Demand

The calculated annual energy demand for space heating and space cooling for each envelope scenario are provided in Table 4 and Figure 2. As shown, the HP and MP envelope scenario significantly reduce annual energy demand by 56.8 and 58.6 MWh respectively (79-81%) relative to the Existing envelope scenario. A deeper breakdown of the energy demand for Huston House, highlighting the demand for the basement suite and the main house is shown in Table 4.

Table 4: Huston House envelope scenarios annual energy demand for space heating and space cooling.

Energy Scenarios Annual Energy Demand (MWh)			
Envelope Scenario	Space Heating	Space Cooling	Total
Existing	68.8	3.2	72.0
NBC 2015	26.0	3.8	29.8
MP	9.9	5.3	15.2
HP	7.7	5.7	13.4

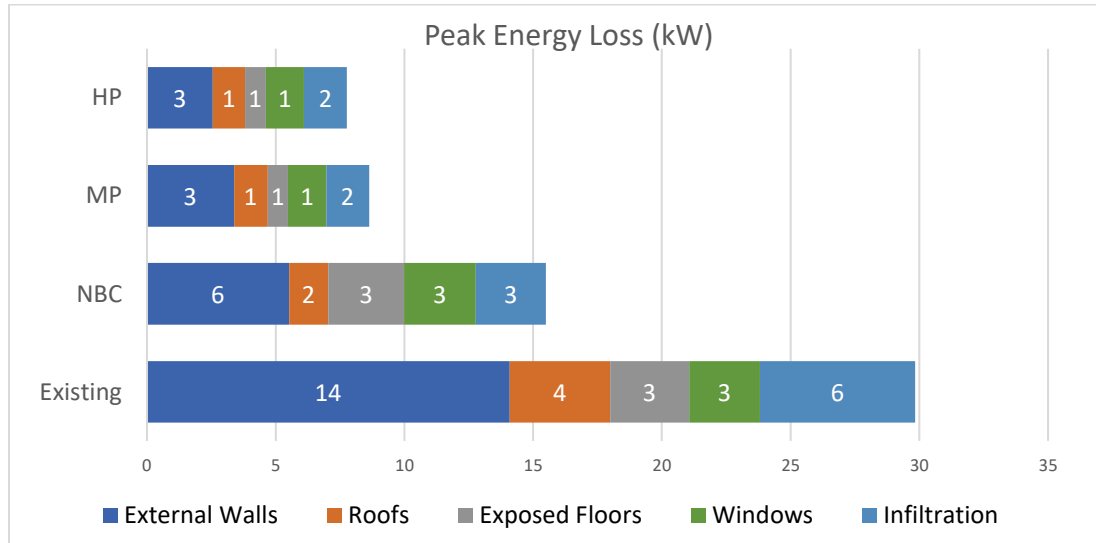
Figure 2: Huston House envelope scenarios annual energy demand for space heating and space cooling.



3.2 Peak Energy Losses

The calculated peak energy losses for each envelope scenario Huston House are provided in Figure 3. As shown, the peak energy losses for the MP and HP envelope scenarios are 71% and 74% less than the peak energy losses for the Existing envelope scenario, respectively. Relative to the Existing and NBC envelope scenarios, the largest reduction in peaks energy losses for the MP and HP envelope scenarios are associated with increased insulation in the exterior walls and roof, insulated triple pane windows and reducing infiltration through increased building airtightness.

Figure 3: Huston House envelope scenarios peak energy losses.



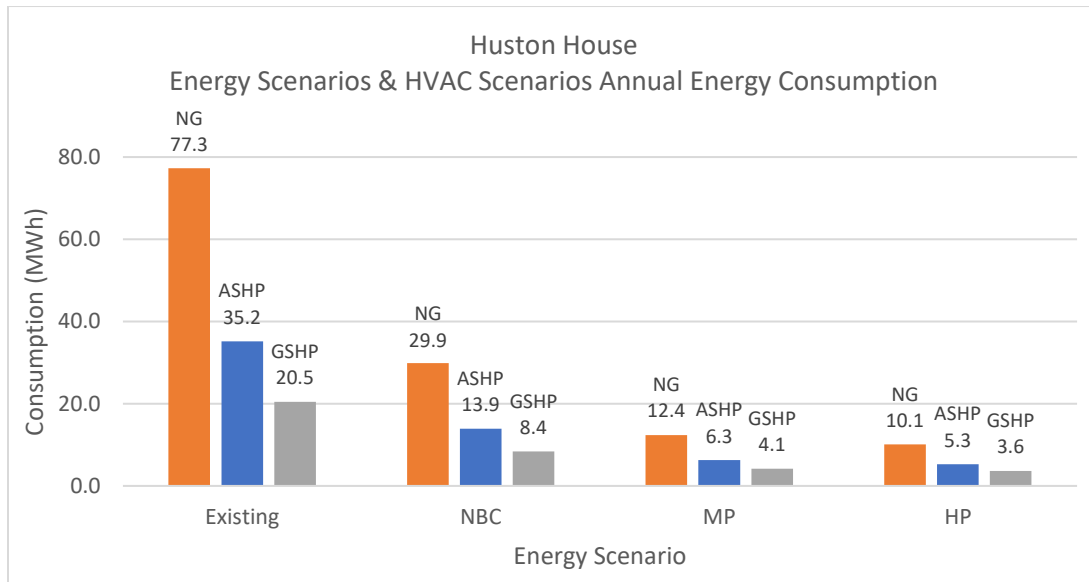
3.3 Annual Energy Consumption

The calculated annual energy consumption for space heating and space cooling for each envelope and HVAC scenario are provided in Table 6.

Table 5: Huston House envelope scenarios and HVAC scenarios annual energy consumption for space heating and space cooling.

Energy & HVAC Scenarios Annual Energy Consumption (MWh)			
Envelope Scenario	HVAC Scenario		
	NG Heating & Electric Cooling	ASHP Heating & Cooling	GSHP Heating & Cooling
Existing	77.3	35.2	20.5
NBC 2015	29.9	13.9	8.4
MP	12.4	6.3	4.1
HP	10.1	5.3	3.6

Figure 4: Huston House envelope scenarios and HVAC scenarios annual energy consumption for space heating and space cooling.



As shown, the HP and MP envelope scenarios significantly reduce annual energy consumption for all HVAC scenarios, by approximately 80-87% relative to the Existing envelope scenario. The lowest annual energy consumption for both the HP and MP envelope scenarios is associated with the GSHP HVAC scenario, which is approximately 6.5 - 8.2 MWh (52-64%) less than the natural gas HVAC scenario. A breakdown of the Huston House energy consumption is shown in Table 6 below, including the assumed seasonal COPs of the various HVAC scenarios.

Table 6: Huston House envelope scenarios and HVAC scenarios annual energy consumption for space heating and space cooling with HVAC COPs.

						Envelope Scenario (MWh)			
	HVAC Scenario	Heating/Cooling	Heating COP	Cooling COP		Existing	NBC	MP	HP
Annual Energy Consumption	1	NG Heating, Electric Cooling	0.9	3.8	Heating	76.4	28.9	11.0	8.6
					Cooling	0.9	1.0	1.4	1.5
		Total				Total	77.3	29.9	12.4
	2	Heating and Cooling with ASHP	2	4	Heating	34.4	13.0	4.9	3.9
					Cooling	0.8	0.9	1.3	1.4
		Total				Total	35.2	13.9	6.3
	3	Heating and Cooling with GSHP	3.5	4	Heating	19.6	7.4	2.8	2.2
					Cooling	0.8	0.9	1.3	1.4
		Total				Total	20.5	8.4	4.1

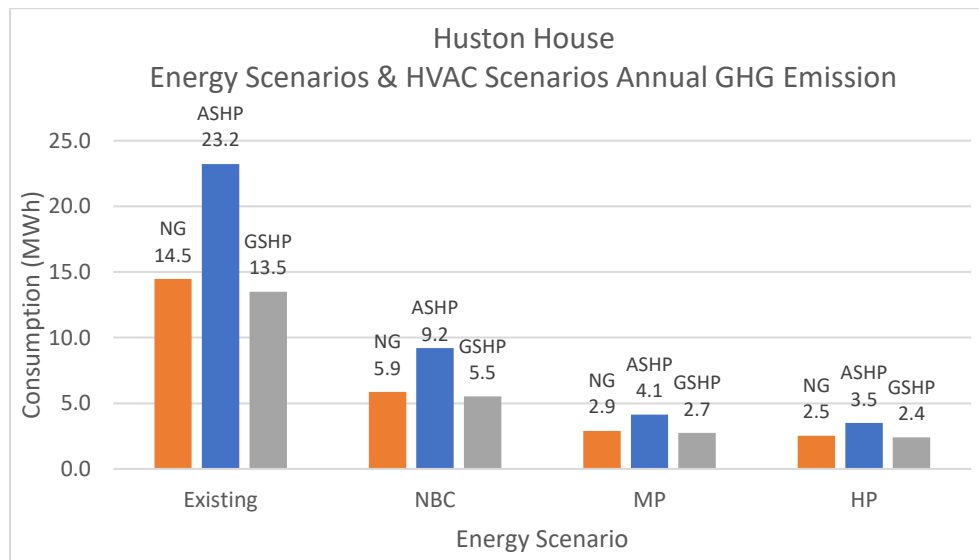
3.4 Annual Greenhouse Gas Emissions

The calculated annual greenhouse gas (GHG) emissions for space heating and space cooling for each envelope scenario and HVAC scenario for Huston House are provided in Table 7 and Figure 5. As shown, the HP and MP envelope scenarios significantly reduce annual GHG emissions for all HVAC scenarios, by approximately 80% relative to the Existing envelope scenario. The natural gas HVAC scenario and the GSHP HVAC scenario result in the lowest annual GHG emissions for both the HP and MP envelope scenarios. The annual GHG emissions for the ASHP HVAC scenario are approximately 1 tCO₂e (27-30%) greater than the annual GHG emissions for the natural gas and GSHP HVAC scenarios for both the MP and HP envelope scenarios. As the electrical grid in Saskatchewan transitions towards less carbon intense electricity generation sources, the annual carbon emissions for a fully electric building will decrease, whereas gas heating will always have the same carbon intensity.

Table 7: Huston House envelope scenario and HVAC scenario annual greenhouse gas (GHG) emissions for space heating and space cooling. Carbon emissions 0.660 tCO₂e/MWh for electricity from Canada Energy Regulator Provincial and Territorial Energy Profiles – Saskatchewan, 0.18 tCO₂e/MWh for NG.

Energy & HVAC Scenarios Annual GHG Emissions (tCO ₂ e)			
Envelope Scenario	HVAC Scenario		
	NG Heating & Electric Cooling	ASHP Heating & Cooling	GSHP Heating & Cooling
Existing	14.5	23.2	13.5
NBC 2015	5.9	9.2	5.5
MP	2.9	4.1	2.7
HP	2.5	3.5	2.4

Figure 5: Huston House envelope scenario and HVAC scenario annual greenhouse gas (GHG) emissions for space heating and space cooling.



3.5 Annual Energy Costs

The estimated annual energy costs for each envelope scenario for Huston House are provided in Tables 8 and 9. Table 9 shows calculated energy costs including projected carbon tax cost increases, for each envelope scenario. As shown, the annual utility costs are greatest for the Existing and NBC 2015 envelope scenarios, and without extensive building envelope improvements, electric space heating and cooling with an ASHP is less cost effective than NG.

Table 8: Huston House envelope scenario breakdown of annual energy costs. Energy rates constant at natural gas: variable fees \$0.030/kWh, fixed fees \$500/year; electricity variable fees \$0.14/kW.

Energy & HVAC Scenarios Annual Utility Costs			
Envelope Scenario	HVAC Scenario		
	NG Heating & Electric Cooling	ASHP Heating & Cooling	GSHP Heating & Cooling
Existing	\$2,944	\$4,927	\$2,864
NBC 2015	\$1,513	\$1,952	\$1,173
MP	\$1,031	\$877	\$580
HP	\$973	\$740	\$508

Table 9: Huston House envelope scenario breakdown of annual energy costs. Energy rates constant at natural gas: variable fees \$0.048/kWh, fixed fees \$500/year; electricity variable fees \$0.14/kW. Natural gas variable fee calculated based on current variable fees and carbon tax averaged over 30 years based on reaching \$170/ton by 2030.

Energy & HVAC Scenarios Annual Space Heating and Cooling Costs			
Envelope Scenario	HVAC Scenario		
	NG Heating & Electric Cooling	ASHP Heating & Cooling	GSHP Heating & Cooling
Existing	\$4,335	\$4,927	\$3,170
NBC 2015	\$2,033	\$1,952	\$1,173
MP	\$1,229	\$877	\$580
HP	\$1,128	\$740	\$508

A comparison and breakdown of the annual costs and energy consumption including estimated annual miscellaneous electricity consumption and cost for all HVAC options for the MP and HP building envelope scenarios is shown in Tables 10-13 below.

Table 10: Comparative energy consumption and life cycle operational cost estimation for three different HVAC strategies based on Mid-Performance (MP) building envelope. Energy rates constant at natural gas: variable fees \$0.030/kWh, fixed fees \$500/year; electricity variable fees \$0.14/kWh. No inflation nor escalation over time has been included. Carbon emissions 0.660 tCO₂e/MWh for electricity from Canada Energy Regulator Provincial and Territorial Energy Profiles – Saskatchewan.

	HVAC Scenario		
	NG Heating & Electric Cooling	ASHP	GSHP
Envelope & Ventilation Scenario	MP	MP	MP
Space Heating	Gas Furnace (Forced Air)	Air Source Heat Pump (Forced Air)	Ground Source Heat Pump (Forced Air)
Space Cooling	A/C (Forced Air)	Air Source Heat Pump (Forced Air)	Ground Source Heat Pump (Forced Air)
Annual Space Heating Demand	9,896 kWh	9,896 kWh	9,896 kWh
Space Heating COP	0.9	2.0	3.5
Annual Space Heating Consumption	10,996 kWh	4,948 kWh	2,827 kWh
Annual Cooling Demand	5,270 kWh	5,270 kWh	5,270 kWh
Space Cooling COP	3.8	4.0	4.0
Annual Cooling Consumption	1,387 kWh	1,318 kWh	1,318 kWh
Annual Heating and Cooling Consumption	12,383 kWh	6,266 kWh	4,145 kWh
Annual ERV Fan Electricity Consumption	1,175 kWh	1,175 kWh	1,175 kWh
Annual Domestic Electricity Consumption	18,787 kWh	18,787 kWh	18,787 kWh
Total Annual Energy Consumption	32,344 kWh	26,227 kWh	24,106 kWh
Annual Utility Costs			
Annual NG Consumption (Space Heating)	10,997 kWh	0 kWh	0 kWh
Annual NG Cost (Space Heating)	\$830	\$0	\$0
Annual Electricity Consumption	21,348 kWh	26,227 kWh	24,106 kWh
Annual Electricity Cost	\$3,053	\$3,750	\$3,447
Total Annual Utilities Cost	\$3,883	\$3,750	\$3,447
Carbon Emissions from Annual Electricity and Natural Gas Use	16.07 tCO₂e	17.31 tCO₂e	15.91 tCO₂e

Table 11: Comparative energy consumption and life cycle operational cost estimation for three different HVAC strategies based on Mid-Performance (MP) building envelope. Energy rates constant at natural gas: variable fees \$0.048/kWh, fixed fees \$500/year; electricity variable fees \$0.14/kWh. Natural gas variable fee calculated based on current variable fees and carbon tax averaged over 30 years based on reaching \$170/ton by 2030. No inflation nor escalation over time has been included. Carbon emissions 0.660 tCO₂e/MWh for electricity from Canada Energy Regulator Provincial and Territorial Energy Profiles – Saskatchewan.

	HVAC Scenario		
	NG Heating & Electric Cooling	ASHP	GSHP
Envelope & Ventilation Scenario	MP	MP	MP
Space Heating	Gas Furnace (Forced Air)	Air Source Heat Pump (Forced Air)	Ground Source Heat Pump (Forced Air)
Space Cooling	A/C (Forced Air)	Air Source Heat Pump (Forced Air)	Ground Source Heat Pump (Forced Air)
Annual Space Heating Demand	9,896 kWh	9,896 kWh	9,896 kWh
Space Heating COP	0.9	2.0	3.5
Annual Space Heating Consumption	10,996 kWh	4,948 kWh	2,827 kWh
Annual Cooling Demand	5,270 kWh	5,270 kWh	5,270 kWh
Space Cooling COP	3.8	4.0	4.0
Annual Cooling Consumption	1,387 kWh	1,318 kWh	1,318 kWh
Annual Heating and Cooling Consumption	12,383 kWh	6,266 kWh	4,145 kWh
Annual ERV Fan Electricity Consumption	1,175 kWh	1,175 kWh	1,175 kWh
Annual Domestic Electricity Consumption	18,787 kWh	18,787 kWh	18,787 kWh
Total Annual Energy Consumption	32,344 kWh	26,227 kWh	24,106 kWh
Annual Utility Costs			
Annual NG Consumption (Space Heating)	10,997 kWh	0 kWh	0 kWh
Annual NG Cost (Space Heating)	\$1,028	\$0	\$0
Annual Electricity Consumption	21,348 kWh	26,227 kWh	24,106 kWh
Annual Electricity Cost	\$3,053	\$3,750	\$3,447
Total Annual Utilities Cost	\$4,081	\$3,750	\$3,447
Carbon Emissions from Annual Electricity and Natural Gas Use	16.07 tCO₂e	17.31 tCO₂e	15.91 tCO₂e

Table 12: Comparative energy consumption and life cycle operational cost estimation for three different HVAC strategies based on High-Performance (HP) building envelope. Energy rates constant at natural gas: variable fees \$0.030/kWh, fixed fees \$500/year; electricity variable fees \$0.14/kWh. No inflation nor escalation over time has been included. Carbon emissions 0.660 tCO₂e/MWh for electricity from Canada Energy Regulator Provincial and Territorial Energy Profiles – Saskatchewan.

	HVAC Scenario		
	NG Heating + Electric Cooling	ASHP	GSHP
Envelope & Ventilation Scenario	HP	HP	HP
Space Heating	Gas Furnace (Forced Air)	Air Source Heat Pump (Forced Air)	Ground Source Heat Pump (Forced Air)
Space Cooling	A/C (Forced Air)	Air Source Heat Pump (Forced Air)	Ground Source Heat Pump (Forced Air)
Annual Space Heating Demand	7,750 kWh	7,750 kWh	7,750 kWh
Space Heating COP	0.9	2.0	3.5
Annual Space Heating Consumption	8,611 kWh	3,875 kWh	2,214 kWh
Annual Cooling Demand	5,653 kWh	5,653 kWh	5,653 kWh
Space Cooling COP	3.8	4.0	4.0
Annual Cooling Consumption	1,488 kWh	1,413 kWh	1,413 kWh
Annual Heating and Cooling Consumption	10,098 kWh	5,288 kWh	3,627 kWh
Annual ERV Fan Electricity Consumption	1,175 kWh	1,175 kWh	1,175 kWh
Annual Domestic Electricity Consumption	18,787 kWh	18,787 kWh	18,787 kWh
Total Annual Energy Consumption	30,060 kWh	25,249 kWh	23,589 kWh
Annual Utility Costs			
Annual NG Consumption	8,612 kWh	0 kWh	0 kWh
Annual NG Cost	\$758	\$0	\$0
Annual Electricity Consumption	21,449 kWh	25,249 kWh	23,589 kWh
Annual Electricity Cost	\$3,067	\$3,611	\$3,373
Total Annual Utilities Cost	\$3,826	\$3,611	\$3,373
Carbon Emissions from Annual Electricity and Natural Gas Use	15.71 tCO₂e	16.66 tCO₂e	15.57 tCO₂e

Table 13: Comparative energy consumption and life cycle operational cost estimation for three different HVAC strategies based on High-Performance (HP) building envelope. Energy rates constant at natural gas: variable fees \$0.048/kWh, fixed fees \$500/year; electricity variable fees \$0.14/kWh. Natural gas variable fee calculated based on current variable fees and carbon tax averaged over 30 years based on reaching \$170/ton by 2030. No inflation nor escalation over time has been included. Carbon emissions 0.660 tCO₂e/MWh for electricity from Canada Energy Regulator Provincial and Territorial Energy Profiles – Saskatchewan.

	HVAC Scenario		
	NG Heating + Electric Cooling	ASHP	GSHP
Envelope & Ventilation Scenario	HP	HP	HP
Space Heating	Gas Furnace (Forced Air)	Air Source Heat Pump (Forced Air)	Ground Source Heat Pump (Forced Air)
Space Cooling	A/C (Forced Air)	Air Source Heat Pump (Forced Air)	Ground Source Heat Pump (Forced Air)
Annual Space Heating Demand	7,750 kWh	7,750 kWh	7,750 kWh
Space Heating COP	0.9	2.0	3.5
Annual Space Heating Consumption	8,611 kWh	3,875 kWh	2,214 kWh
Annual Cooling Demand	5,653 kWh	5,653 kWh	5,653 kWh
Space Cooling COP	3.8	4.0	4.0
Annual Cooling Consumption	1,488 kWh	1,413 kWh	1,413 kWh
Annual Heating and Cooling Consumption	10,098 kWh	5,288 kWh	3,627 kWh
Annual ERV Fan Electricity Consumption	1,175 kWh	1,175 kWh	1,175 kWh
Annual Misc. Electricity Consumption	18,787 kWh	18,787 kWh	18,787 kWh
Total Annual Energy Consumption	30,060 kWh	25,249 kWh	23,589 kWh
	Annual Utility Costs		
Annual NG Consumption (Space Heating)	8,612 kWh	0 kWh	0 kWh
Annual NG Cost (Space Heating)	\$913	\$0	\$0
Annual Electricity Consumption	21,449 kWh	25,249 kWh	23,589 kWh
Annual Electricity Cost	\$3,067	\$3,611	\$3,373
Total Annual Utilities Cost	\$3,981	\$3,611	\$3,373
Carbon Emissions from Annual Electricity and Natural Gas Use	15.71 tCO₂e	16.66 tCO₂e	15.57 tCO₂e

4 Conclusions

Our analysis indicates that upfront investment into a mid-performance (MP) or high-performance (HP) envelope results in a significant decrease in annual space cooling and space heating energy demand, consumption, and the associated greenhouse gases. As summarized in Table 4, the MP and HP envelope scenarios result in roughly an 80% decrease in annual space heating and space cooling energy demand relative to the Existing and National Building Code (NBC) 2015 envelope scenarios. The reduction in annual space heating and space cooling energy demand is largely associated with incorporating an energy recovery ventilator (ERV) for ventilation in the building, reduced infiltration as a result of increased airtightness through advanced construction techniques, and increased building envelope and window thermal resistance. Additional energy savings could be achieved through incorporating cavity insulation into the existing building assemblies in Huston House. Annual energy consumption analysis indicates that the GSHP HVAC scenario provides an approximately 70% and decrease in annual energy consumption relative to the NG HVAC scenario. The carbon intensity of the electrical grid in Saskatchewan is greater than that of natural gas, therefore the annual greenhouse gas (GHG) emissions for the GSHP HVAC scenario are comparable to the NG HVAC scenario despite the significant difference in annual energy consumption.

Reviewing the HVAC and building envelope scenarios, the GSHP HVAC scenario provides the lowest annual utility fees, closely followed by the ASHP HVAC Scenario for both the MP and HP envelopes. However, as capital costs of equipment would vary greatly depending on the HVAC scenario selected, with the GSHP HVAC scenario having the highest capital costs and the NG HVAC scenario have the lowest, the ASHP HVAC scenario with the MP envelope option offers comparable consumption and utility fees as the higher envelope, and electrification can provide stability in utility costs as compared to the NG HVAC option when considering the rising costs of the carbon tax, which is currently set to increase to \$170/ton by 2030, despite having a higher upfront capital cost.