Appendix 4.6
Home Heating Retrofit
Business Case Study

YUKON ENERGY

Home Heating Retrofit Business Case Study

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With support from Yukon Government Energy Branch

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Executive Summary

Home heating represents a significant potential growth market for Yukon Energy and the electrification of heating also offers a means to significantly reduce greenhouse gas emissions in the Yukon. The number of homes in Yukon using electric heat is also a significant factor in how much electricity Yukon Energy needs to generate, particularly during peak periods.

To help understand the home heating market, Yukon Energy, with support from the Yukon Government Energy Branch, completed this study to analyze the business case for home owners to switch heating systems from fossil fuels to electric heat. This report also looks at the non-economic drivers that may affect the choice of home heating system and importance of economics as compared to other drivers. Finally, the report quantifies the reduction in GHG emissions from the switch to electric heat.

To complete the analysis for this report, the energy use of an archetype Yukon home was modelled at four thermal enclosure (insulation) levels which correspond to significant changes in insulation and air sealing practices. The energy model results were used to calculate the total fuel load for each level of insulation and heating system, which in turn were used to calculate annual fuel costs and GHG emissions. The upfront costs of completing the retrofit, maintaining and insuring each system, as well as the annual fuel costs were analyzed to understand the business case for a Yukon homeowner to retrofit their home with electric heat. Other non-economic drivers such as GHG emissions, safety and ease of maintenance are also discussed.

The economic analysis indicates that, at current prices, a retrofit from a functional oil or propane furnace to electric heating would increase homeowners' annual fuel costs with the exception of heat pumps. These increased fuel costs are partially offset by a small reduction in maintenance costs. Comprehensive home insurance costs were found to be relatively uniform across home heating types. The retrofit to a cold climate heat pump offers fuel savings and the payback period may be acceptable for some home owners.

The results of this cost analysis indicate that at current fuel pricing, there is no business case for home owners to switch from fossil fuel heat to electric heat for economic reasons. Consequently, it is not expected that many existing oil or propane heated homes will switch to electric heat in the near future as a cost saving measure.

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1 Introduction

Home heating represents a significant potential growth market for Yukon Energy and the electrification of heating also offers a means to significantly reduce greenhouse gas emissions in the Yukon. The number of homes in Yukon using electric heat is also a significant factor in how much electricity Yukon Energy needs to generate, particularly during peak periods.

To help understand the home heating market, Yukon Energy, with support from the Yukon Government Energy Branch, completed this study in analyze the business case for home owners switching heating fuels from fossil fuels to electric heat. Most existing homes in the Yukon are heated primarily with oil or propane. However, analysis of the energy labelling requirements in the City of Whitehorse and energy assessment data show that the majority of newly constructed homes are heated electrically. This report also looks at the non-economic drivers that may affect the choice of home heating system and importance of economics as compared to other drivers. Finally, the report quantifies the reduction in GHG emissions from the switch to electric heat.

2 Methodology

2.1 Home Energy Use

The energy use of an archetype Yukon home was modelled at four thermal enclosure (insulation) levels. The enclosure levels selected corresponded to significant changes in insulation and air sealing practices, and included:

- Older Home (pre-1980s) – 2x4 walls (R11), uninsulated slab, ceiling (R40), 7 air changes per hour (ACH) (@50Pa)
- Newer Home (1980s and newer) – 2x6 walls (R21), 2ft perimeter slab insulation (R5), ceiling (R40), 5 ACH (@50Pa)
- Energy Efficient Home (Whitehorse Green Building Standard) – 2x6 walls (R28), whole slab (R10), ceiling (R60), 1.5 ACH (@50Pa)
- Super-Insulated Home – Double stud wall (R60), whole slab (R10), ceiling (R80), 1.5 ACH (@50Pa)

It is not expected that there are a large number of super-insulated homes currently heated with fossil fuels. However, this insulation level was modelled to evaluate the effects of increased insulation values as well as to allow the model to be used for a follow-up economic analysis on increasing thermal envelope performance. The layout for the archetype home can be found in Appendix A. Energy use modelling of the archetype home was completed using BEOpt, a free modelling software package developed by the National Renewable Energy Laboratory of the US Department of Energy's Office of Energy Efficiency. This software was chosen for its ease of use and availability to anyone wanting to recreate the model and adapt it to their requirements. The BEOpt model estimated the total energy needs of the home, reported by end-use including heating. These results were used to calculate total fuel loads for each insulation level and heating system, which in turn was used to calculate annual fuel cost and GHG emissions.

2.2 Heating System Retrofit Costs

Cost estimates for both the labor and materials to remove an existing oil or propane furnace and replace it with an electrical heating system in the archetype house were obtained from local contractors and previous reports[1]. The study examined switching from both oil and propane forced air furnaces to the following range of electric heating systems:

- electric baseboard
- electric forced air furnace
- cold climate heat pump with electric back-up
- electro-thermal storage with forced air circulation

In each case an assumption was made that the home was upgraded from a 100 amp to 200 amp service to meet the additional load from the electrical heating system, but would not require an upgrade to the neighborhood transformer. For the electric forced air systems, it was assumed that no upgrades were needed to the ducting and for the electric baseboard installation it was assumed that the ducting was left in the home.

2.3 Heating System Operating Costs

2.3.1 Fuel Costs

The amount of energy required to maintain the archetype home at 19 °C was estimated using the BEOpt model. This was used to calculate the quantities of oil, propane or electricity to heat the archetype home, which was then used to calculate the associated fuel costs. The price of electricity was based on the 2015 electrical rates including rate riders[2], and an assumption was made that the cost of heating is incremental to the existing base electrical use of the home. The costs of heating with oil and propane were calculated using Yukon Government posted prices for furnace oil and propane (500 gallon tank) delivered to a residence of Whitehorse on December 9, 2015. The efficiency of the oil furnace was assumed to be a 90% and the efficiency of the propane furnace was assumed to be 95%. These efficiencies are a conservative assumption and more fuel would be used for less efficient furnaces.

In order to understand how future potential carbon pricing might impact the costs of fossil fuels and thereby impact the business case for conversion to electrical heating, a carbon tax of $30 and $100/tonne of CO_2 equivalent (CO_2e) was included in the operating costs of the fossil fuel heating systems as a scenario.

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[1] *Draft Shifting Demand: Yukon Home Heating Trends,* Yukon Government Energy Branch, November 17, 2015, Yukon Housing Website, Energy Efficient Heating http://www.housing.yk.ca/eeh.html accessed December 2015

[2] Riders R and J at a net increase of 18.21% and Riders E and F for a net decrease of $0.0124/kWh

2.3.2 Maintenance Costs

The costs of maintaining a home heating system can change depending on the type heating system. Both oil and propane furnaces as well as heat pumps require annual maintenance, while electrical heating systems do not. All forced air systems require the home owner to check and change filters periodically. Estimated annual maintenance costs of each heating system were obtained from local contractors and previous reports.

2.3.3 Insurance Costs

Home insurance costs may depend on the type of heating system in the home and annual insurance costs for each system were obtained from local insurance agents. Some insurance companies require oil tanks to be replaced periodically. The cost for tank replacement was not considered in this study.

2.4 Business Case

The costs of completing the retrofit, annual fuel costs as well as maintenance and insurance costs of each system were analyzed to understand whether Yukon homeowners have an economic business case to retrofit their fossil fuel based heating system with electric heating. In cases where the annual operating costs of electric heating systems are lower than the corresponding operating costs of fossil-fuel based heating systems, the simple payback period on the upfront costs of the electric heating system was estimated.

In cases where the annual operating costs of electric heating systems are higher than the corresponding operating costs of fossil-fuel based heating systems at current fuel prices, the break-even fossil fuel prices required to provide homeowners with a 5 year simple payback on the retrofit investment were also calculated for each electrical heating option.

2.5 Non-Financial Considerations

Currently 24% of the GHG emissions in the Yukon are a result of space heating with oil or propane[3]. Electricity produced on the Yukon Integrated Grid is generated by over 99% renewable (hydro and wind) with only a small amount generated from burning diesel or natural gas. Home owners may choose to switch to electric heat in order to reduce the GHG emissions from their homes. A home in the Yukon that is serviced by an isolated diesel grid (e.g. Watson Lake) may only be heated electrically if written permission is obtained from their service provider as per the Yukon Utilities Board Terms of Reference. The GHG emissions for electricity supplied from an isolated diesel grid would be higher that calculated in this report due to the fact that all electricity is generated by diesel instead of majority hydro. This report assumes that the archetype home is in Whitehorse.

Other non-economic drivers such as safety and ease of maintenance are also documented, based on comments from homeowners shared by contractors.

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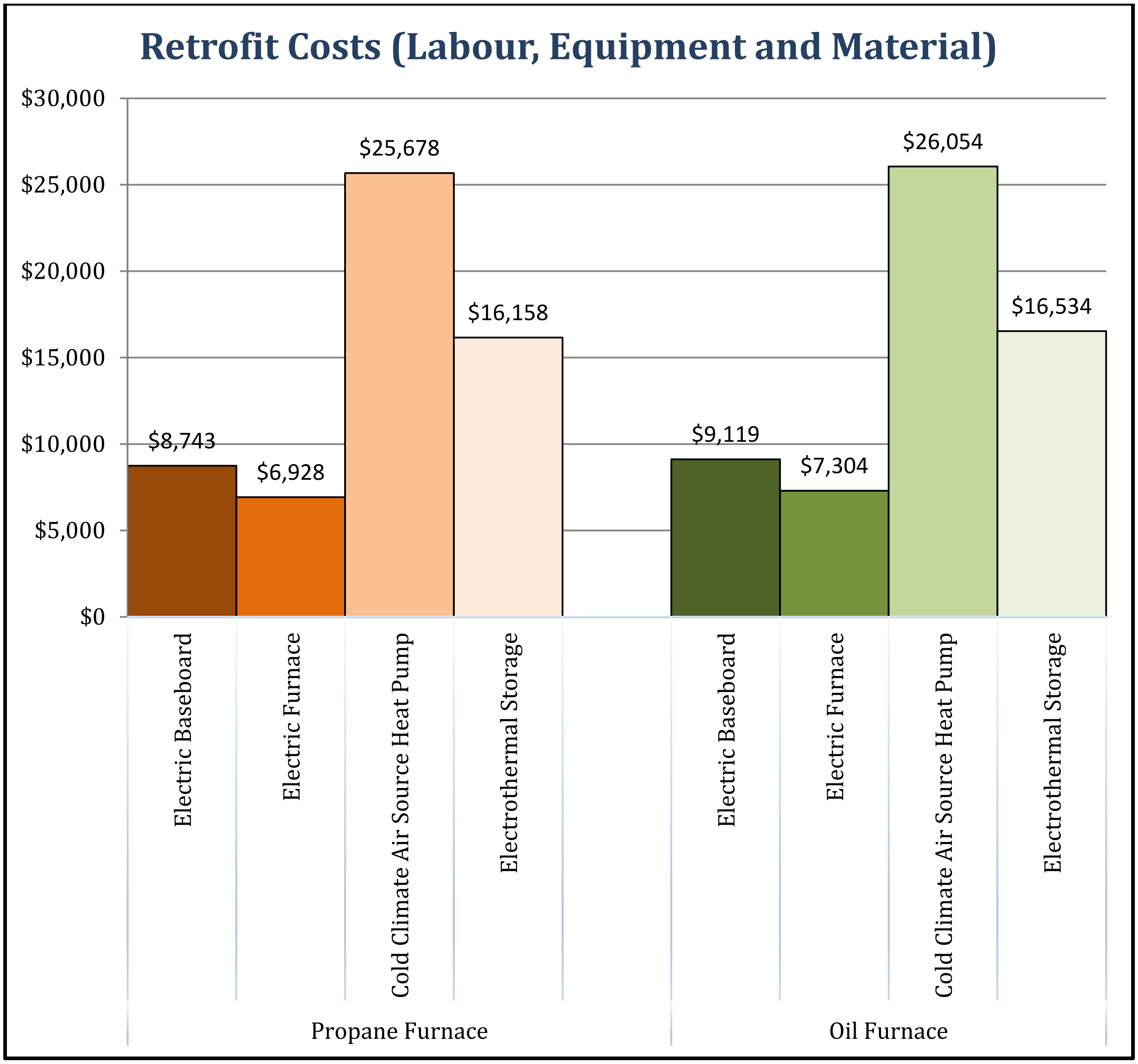
[3] *Yukon Greenhouse Gas Emissions: The Transportation Sector, Updated Report 2015*, prepared by Malcolm Taggart in association with Forest Pearson for the Yukon Government Climate Change Secretariat, March 23, 2015. Calculations assuming year is 2012.

3 Results

3.1 Retrofit Costs

A summary of the total labor, equipment and material costs involved in retrofitting existing fuel oil and propane based heating systems to electrical heating is presented in Figure 1 below.

Figure 1: Retrofit Costs (Labour, Equipment and Material)



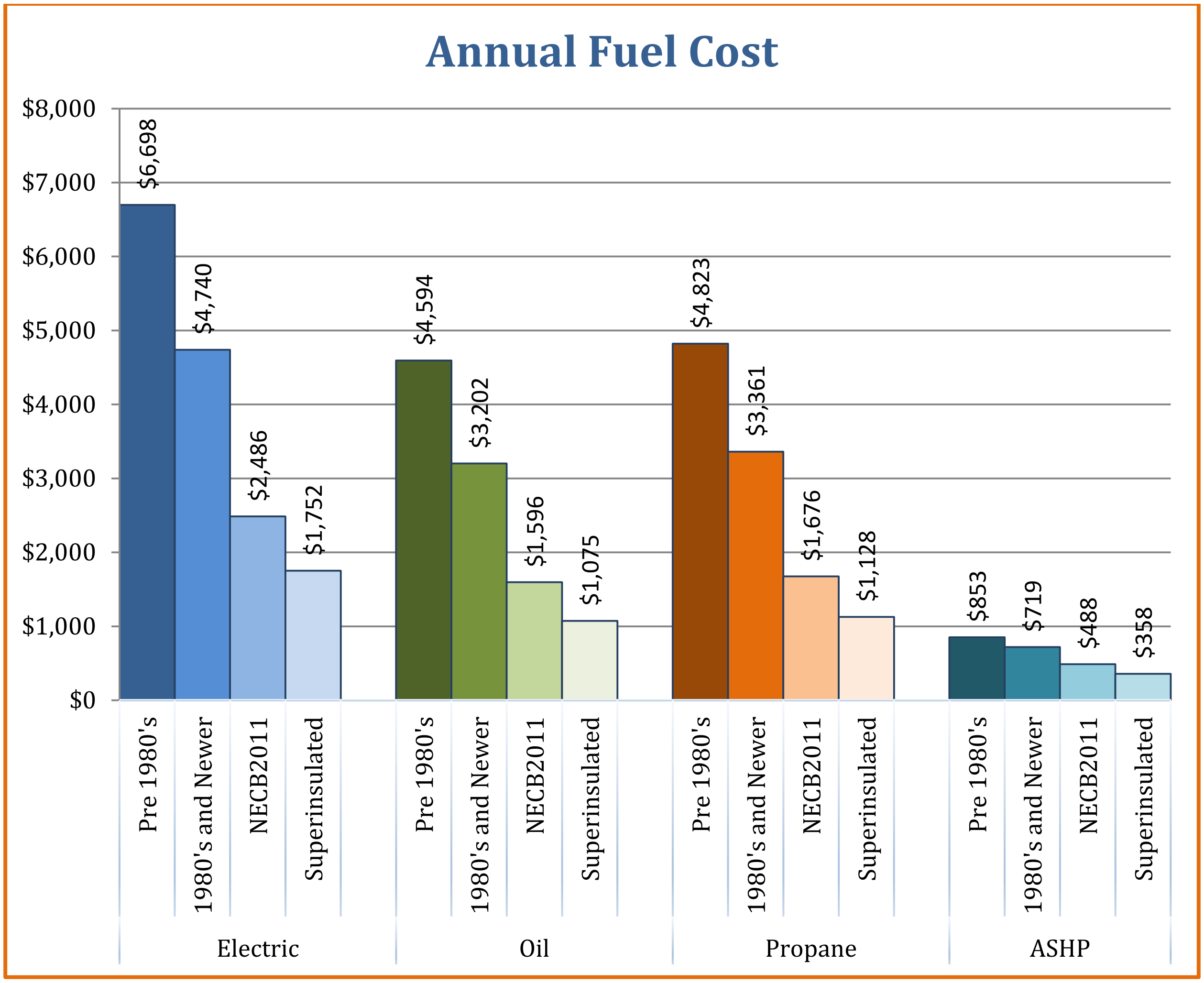
In general, the retrofit costs in the case of an oil furnace are slightly higher than in the case of a propane furnace due to the additional time required to remove the oil tank. The retrofit costs of the air source heat pumps and electrothermal storage are both higher due to the higher costs of the heating units (equipment) when compared to baseboard heaters or an electric furnace. The costs of an electrical service upgrade is included for all of the retrofit options.

3.2 Operating Costs

3.2.1 Cost of Fuels

The annual fuel costs for each heating system and building enclosure level are summarized in Figure 2 below.

Figure 2: Annual Fuel Cost



The data in illustrates the significantly higher heating requirements and heating costs of an older home when compared to a modern home. The older homes require nearly three times as much heat as homes built to meet the current code, and the four times more than a super-insulated home. The data also shows that the annual fuel costs for the electric baseboards, electric furnaces and electrothermal heating systems are higher than the corresponding fuel costs for the propane and oil heating systems.

This result is consistent for all building envelope types. The exception is the cold climate air source heat pump (ASHP), which offers lowest annual fuel costs of all heating types. These heat pumps use a refrigerant system involving a compressor and a condenser to bring heat from the outdoors into the home. Cold climate heat pumps can function down to an outdoor air temperature of around -25°C before it is more efficient to switch to an electric resistance heat back-up. Heat pumps use much less electricity than conventional resistance electric heaters.

3.2.2 Maintenance and Insurance Cost

Estimated annual maintenance and insurance costs for each heating system are provided in Table 1 below.

Table 1: Annual Heating System Maintenance and Insurance Cost

	Annual Maintenance	Annual Insurance
Oil Furnace	$220	$1,424
Propane Furnace	$158	$1,424
Electric Baseboard	$0	$1,395
Electric Furnace	$0	$1,424
Electrothermal Storage	$0	$1,424
Cold Climate Heat Pump	$250	$1,424

Oil and propane furnaces have burners that require annual inspection and maintenance, while electric systems do not require the same level of annual maintenance. All forced air systems require a small amount of work by the owner to check and replace air filters as required. The cost of filters, and the time to check the filters, were not considered. Heat pumps required an annual maintenance by a specially trained professional.

The estimates received for insurance on the archetype home did not show a significant cost difference between a home with an oil or propane heating system and a home with an electric heating system. One insurance provider did offer a discount for electric baseboard heat.

The total annual operating cost for each system, including fuel, maintenance and insurance is shown in Table 2 below. The data show that the total operating costs of the electric baseboards, electric furnaces and electrothermal heating systems are higher than the fossil fuel heating systems for all enclosure levels. Cold climate air source heat pumps offer the lowers annual operating costs of all heating systems.

Table 2: Total Annual Operating Costs by Heating System

	Annual Operating Cost			
Heating System	Pre 1980s	1980s and Newer	NECB 2011	Super-Insulated
Oil Furnace	$5,983	$4,669	$3,153	$2,660
Propane Furnace	$5,864	$4,566	$3,070	$2,583
Electric Baseboard	$8,082	$6,032	$3,666	$2,903
Electric Furnace	$8,111	$6,061	$3,695	$2,932
Electrothermal Storage	$8,111	$6,061	$3,695	$2,932
Cold Climate Air Source Heat Pump	$2,887	$2,469	$2,072	$1,939

3.3 Economic Modeling Results

3.3.1 Annual Operating Costs

The change in annual operating costs, including cost of fuel, maintenance and insurance, of each retrofit scenario, are presented in Table 3 below.

Table 3: Change in Total Annual Costs

	Change in Annual Fuel, Maintenance & Insurance Cost from Oil Furnace			
Heating System	Pre 1980s	1980s and Newer	NECB 2011	Super-Insulated
Electric Baseboard	$2,099	$1,363	$514	$243
Electric Furnace	$2,128	$1,392	$543	$272
Electrothermal Storage	$2,128	$1,392	$543	$272
Cold Climate Heat Pump	-$3,097	-$2,199	-$1,081	-$720
Heating System	Change in Annual Fuel, Maintenance & Insurance Cost from Propane Furnace			
Electric Baseboard	$2,219	$1,465	$597	$319
Electric Furnace	$2,248	$1,494	$626	$348
Electrothermal Storage	$2,248	$1,494	$626	$348
Cold Climate Heat Pump	-$2,977	-$2,097	-$998	-$644

The results shown in indicate that a retrofit from a functional oil or propane furnace to an electric baseboard, electric furnace or electro-thermal storage system would result in an increase in annual operating costs at current fuel prices.

A retrofit to a cold climate air source heat pump would deliver savings to the homeowner from reduced annual operating costs. The simple payback period for the investment in a retrofit to a cold climate air source heat pump is presented in Table 4 below.

Table 4: Simple Payback of Cold Climate Air Source Heat Pump Retrofit

	Simple Payback of Cold Climate Air Source Heat Pump Retrofit - Years			
Heating System	Pre 1980s	1980s and Newer	NECB 2011	Super-Insulated
Furnace Oil	8.4	11.8	24.1	36.2
Propane	8.6	12.2	25.7	39.9

The data in Table 4 show that the operating costs savings from heat pumps may offer an acceptable payback period for some homeowners of just over 8 years for older building envelopes. However, the payback period becomes progressively longer and less acceptable for newer building envelopes with lower overall heating requirements. It should also be noted that heat pumps are a relatively rare in the Yukon and thus far the market uptake has been modest.

3.3.2 Break-Even Fuel Pricing

Five years is generally considered a reasonable payback period for homeowners to invest in home upgrades which deliver savings in operating costs. The break-even fuel prices that would deliver a 5 year payback on retrofits from an oil or propane furnace to electric systems are presented in Tables 5 and 6. These fuel prices were calculated to help understand the price points at which home owners may start to switch heating systems for as a cost saving measures. It should be noted that current oil and propane prices are $1.005/L and $0.713/L respectively, and the pricing of these fuels peaked at $1.36 and $1.18 in November 2011 and February 2014 respectively.

The data in Tables 5 and 6 illustrate that fossil fuel prices need to reach levels significantly higher than recent peak pricing in order for electric baseboard, electric furnace or electro-thermal storage system to deliver an economic payback in a reasonable timeframe (5 years).

Table 5: Oil Pricing for a 5 Year Retrofit Payback

	Oil prices required for 5 year retrofit payback			
	Pre 1980s	1980s and Newer	NECB 2011	Super-Insulated
Electric Baseboard	$1.81	$1.96	$2.44	$2.91
Electric Furnace	$1.73	$1.84	$2.21	$2.57
Electrothermal Storage	$2.14	$2.42	$3.37	$4.30

Table 6: Propane Pricing for a 5 Year Retrofit Payback

	Propane prices required for 5 year retrofit payback			
	Pre 1980s	1980s and Newer	NECB 2011	Super-Insulated
Electric Baseboard	$1.25	$1.34	$1.66	$1.97
Electric Furnace	$1.20	$1.28	$1.53	$1.77
Electrothermal Storage	$1.48	$1.68	$2.33	$2.97

3.3.3 Impact of Carbon Pricing

Home heating is a large emitter of greenhouse gases in the Yukon. Table 7 below shows the annual CO2e emissions for the study home at each insulation level.

Table 7: Annual CO2e Emissions

	Annual GHG Emissions (CO2e) by Home Insulation Level			
Heating System	Pre 1980s	1980s and Newer	NECB 2011	Super-Insulated
Furnace Oil	11.88	8.29	4.13	2.78
Propane	9.67	6.74	3.36	2.26

The addition of a carbon tax on oil or propane would increase the cost of these fuels, thus improving the business case for a retrofit to electric heating. To understand the impacts a future carbon tax could have on the business case of retrofits, a carbon tax of $30 and $100/tonne of CO^2e was applied to the annual operating costs of oil and propane heating systems. The incremental annual carbon tax costs at both prices are shown in Table 8 below.

Table 8: Annual Carbon Tax

	Annual Carbon Tax at $30/ Tonne			
Heating System	Pre 1980s	1980s and Newer	NECB 2011	Super-Insulated
Furnace Oil	$356	$249	$124	$83
Propane	$290	$202	$101	$68
	Annual Carbon Tax at $100/ Tonne			
Furnace Oil	$1,188	$829	$413	$278
Propane	$967	$674	$336	$226

Figures 3 and 4 below show the annual fuel costs for each heating system and insulation level, with carbon taxes applied at $30 and $100/tonne of CO_2e. This data show that even with a carbon tax as high as $100, electricity is still a more expensive heating fuel choice than oil or propane.

Figure 3: Annual Fuel Costs with $30/tonne Carbon Tax

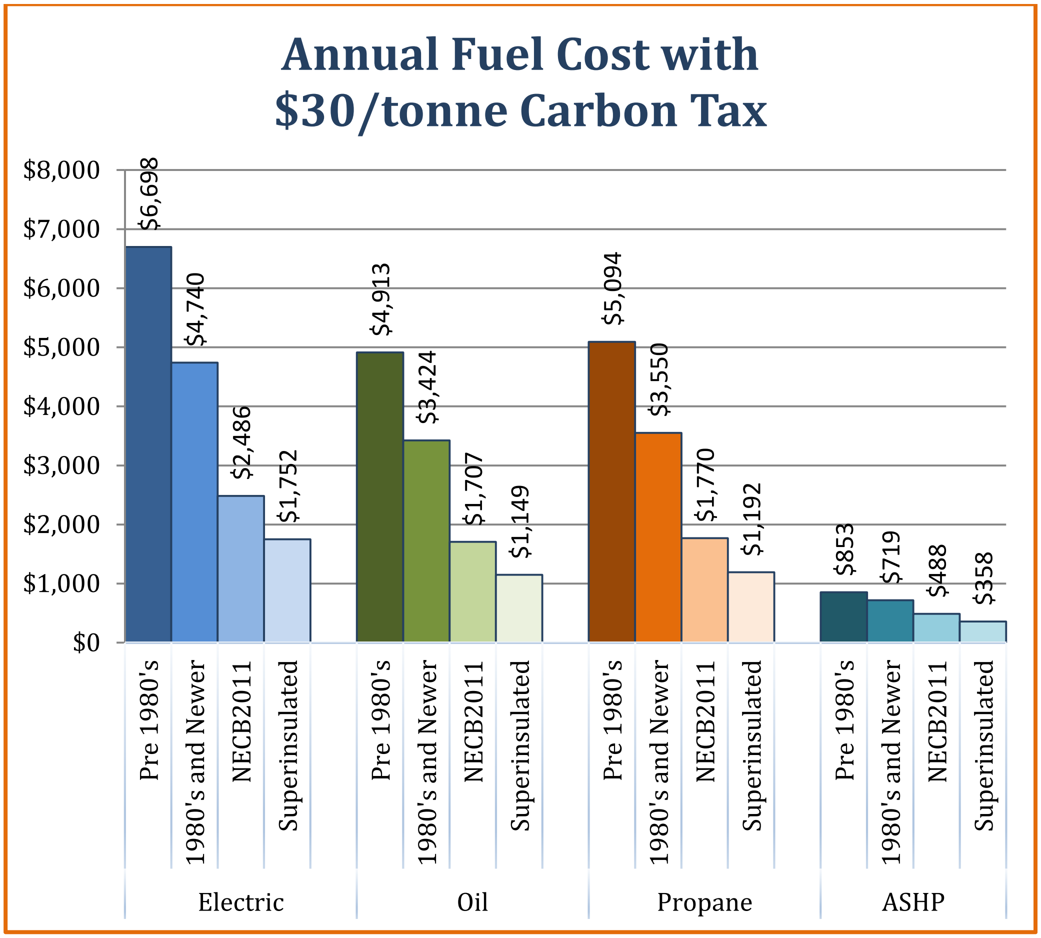
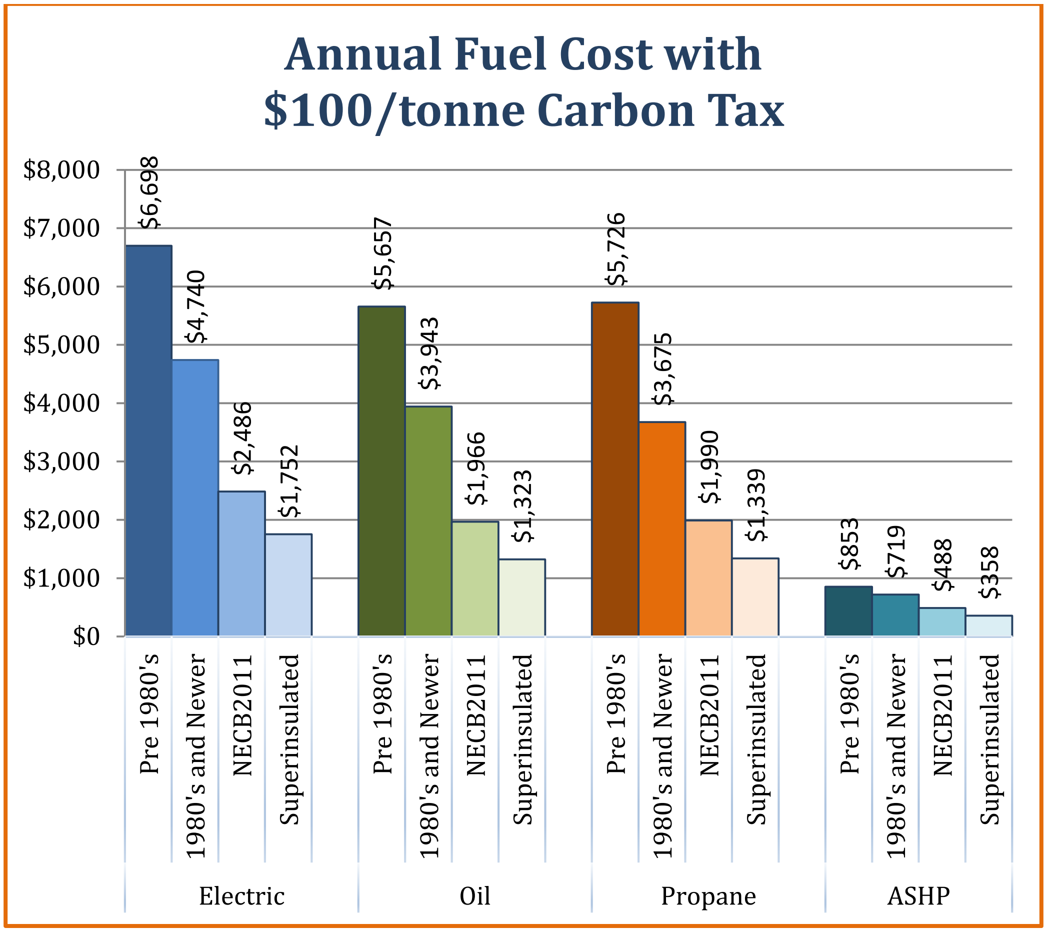


Figure 4: Annual Fuel Costs with $100/tonne Carbon Tax



The payback period for the Cold Climate Air Source Heat Pump with the $30 and $100/tonne of CO_2e carbon tax applied can be seen in Tables 10 and 11 below. The data in Tables 9 and 10 show that the inclusion of a carbon tax reduces the payback period of cold climate air source heat pumps to 6-8 years for older building envelopes. However, the payback period remains long for newer building envelopes with lower overall heating requirements.

Table 9: Simple Payback for a Cold Climate Air Source Heat Pump with $30/tonne Carbon Tax

Simple Payback of Cold Climate Air Source Heat Pump Retrofit - $30/tonne carbon tax				
Heating System	Pre 1980s	1980s and Newer	NECB 2011	Super-Insulated
Furnace Oil	7.5	10.6	21.6	32.4
Propane	8.0	11.3	23.7	36.6

Table 10: Simple Payback for a Cold Climate Air Source Heat Pump with $100/tonne Carbon Tax

Simple Payback of Cold Climate Air Source Heat Pump Retrofit - $100/tonne carbon tax				
Heating System	Pre 1980s	1980s and Newer	NECB 2011	Super-Insulated
Furnace Oil	6.1	8.6	17.4	26.1
Propane	6.6	9.4	19.5	29.9

A carbon tax would also affect the break-even fossil fuel prices which would deliver a 5 year payback on a retrofit to electrically heated systems. Appendix B show the prices that oil and propane would have to reach to give a five year retrofit payback with a $30 and $100/tonne of CO_2e carbon tax applied.

It was found that for a $30/tonne tax, oil prices would need to be between $1.74/L and $4.22/L while propane would need to cost between $1.21/L and $2.92/L to achieve a five year payback on a heating system retrofit. At a $100/tonne tax, oil prices would need to be between $1.55/L to $4.04/L and propane prices between $1.11/L and $2.83/L for a five year payback on a heating system retrofit.

3.4 Non-Financial Considerations

3.4.1 Greenhouse Gas (GHG) Emissions

As shown in Table 7, the electrification of a home heating system from oil or propane could reduce the GHG emissions. Given the growing concern about climate change, some homeowners may choose to change their heating system in order to reduce their personal GHG emissions footprints.

3.4.2 Other

When choosing a heating system for a home, homeowners may take other considerations into account in addition to cost and GHG emissions. These non-economic considerations were noted from discussions with contractors and homeowners. These considerations include:

- Safety: Burning fossil fuels could result in carbon monoxide being released into the home, which is dangerous and potentially fatal.
- Environmental Liability: The cost of remediating a hydrocarbon spill from an oil tank can be very high and a liability that homeowners and insurance companies are becoming less comfortable assuming.
- Commercial Convenience: The convenience offered by a monthly electrical bill instead of large fuel bills after a fill-up is attractive to many homeowners.
- Maintenance: Not having to remember to arrange an annual furnace service is also a convenience offered by electric heating systems.

4 Conclusions and Next Steps

The results of this study indicate that with current fuel and electricity pricing, home owners are unlikely to switch from fossil fuel heat to electric heat for economic reasons. The payback for a retrofit to a cold climate heat pump in an older home may be acceptable to some homeowners. The introduction of a carbon tax, even as high as $100/tonne CO_2e would not change the business case for home heating retrofits, also with the exception of bringing the payback period for Air Source Heat Pumps retrofits in older home to six years. Research from the Oak Ridge National Laboratory[4] shows that consumers

[4] D Greene. How Consumers Value Fuel Economy: A Literature Review, EPA-420-R-10-008, March 2010. Available online: http://www3epa.gov/otaq/climate/regulations/420r10008.pdf

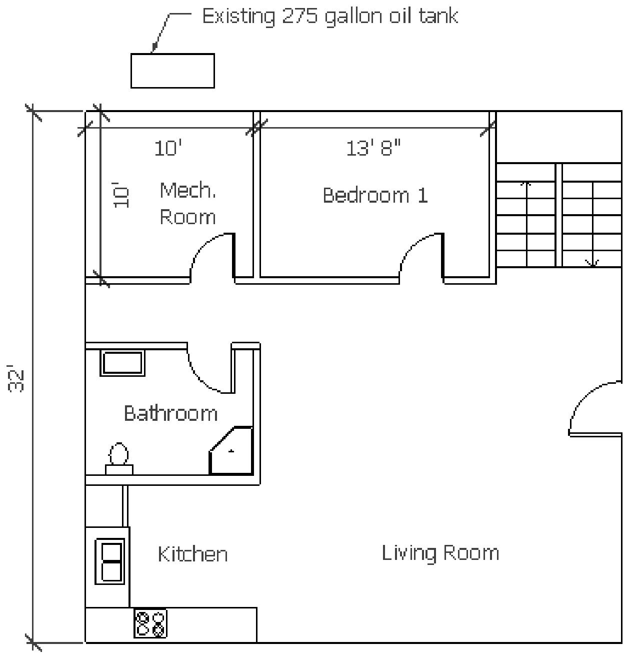
heavily discount future fuel savings in comparison to upfront cost due to the high uncertainty of fuel prices.

Additional areas of study to build on the findings of this report could be:

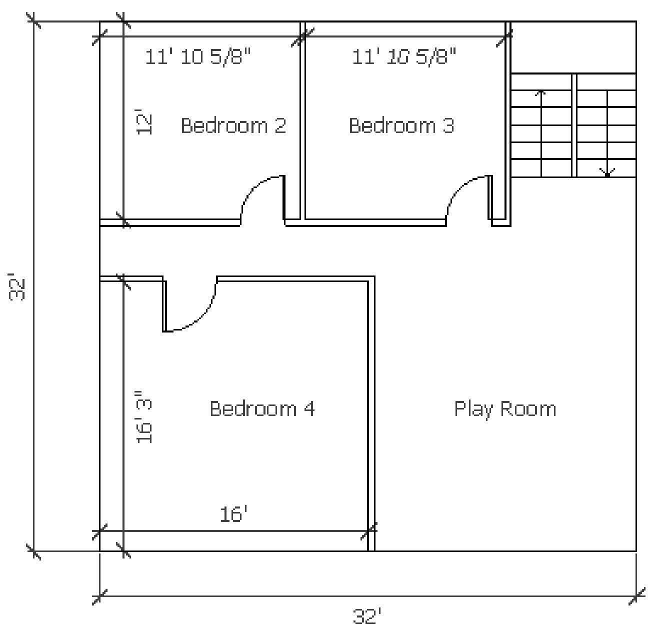
- A survey to confirm the primary drivers of homeowners' choice of home heating system.
- Further analysis to assess the impact of secondary biomass heating on the net heating needs of a home, and resulting changes to the economics of electric retrofits.
- Economics of the retrofit for a homeowner interested in installing solar panels and participating in the governments microgeneration program
- Further investigation into the insurance costs for home heated by different heating options. For example, requirements to replace oil tanks periodically were not addressed in the insurance estimates received.
- Confirmation of the retrofit costs by sourcing quotations for additional contractors, as well as homeowners themselves increasing the number of pricing quotations, either directly or from homeowners that have actually completed a heating system retrofit, would be helpful to refine the cost estimates used in the study.

Appendices

Appendix A: Description of Archetype Home[5]



Ground Floor



Second Floor

[5] Plans based off Cold Climate Housing Research Center's "Southwest Prototype Home," http://www.cchrc.org/sites/default/files/docs/spruce_plans_final.pdf.

Appendix B: Oil Prices and Carbon Tax Required for a Five Year Payback

Table 11: Oil prices required for a 5 year retrofit payback - $30/tonne carbon tax

	Oil prices required for a 5 year retrofit payback - $30/tonne carbon tax			
Heating System	**Pre 1980s**	**1980s and Newer**	**NECB 2011**	**Super-Insulated**
Electric Baseboard	$1.74	$1.88	$2.36	$2.83
Electric Furnace	$1.66	$1.77	$2.13	$2.49
Electrothermal Storage	$2.06	$2.35	$3.29	$4.22

Table 12: Propane prices required for a 5 year retrofit payback - $30/tonne carbon tax

	Propane prices required for a 5 year retrofit payback - $30/tonne carbon tax			
Heating System	**Pre 1980s**	**1980s and Newer**	**NECB 2011**	**Super-Insulated**
Electric Baseboard	$1.21	$1.31	$1.64	$1.96
Electric Furnace	$1.16	$1.23	$1.48	$1.73
Electrothermal Storage	$1.44	$1.63	$2.29	$2.92

Table 13: Oil prices required for a 5 year retrofit payback - $100/tonne carbon tax

	Oil prices required for a 5 year retrofit payback - $100/tonne carbon tax			
Heating System	**Pre 1980s**	**1980s and Newer**	**NECB 2011**	**Super-Insulated**
Electric Baseboard	$1.55	$1.70	$2.18	$2.65
Electric Furnace	$1.47	$1.58	$1.95	$2.31
Electrothermal Storage	$1.88	$2.16	$3.11	$4.04

Table 14: Propane prices required for a 5 year retrofit payback - $100/tonne carbon tax

	Propane prices required for a 5 year retrofit payback - $100/tonne carbon tax			
Heating System	**Pre 1980s**	**1980s and Newer**	**NECB 2011**	**Super-Insulated**
Electric Baseboard	$1.11	$1.21	$1.54	$1.87
Electric Furnace	$1.06	$1.13	$1.38	$1.63
Electrothermal Storage	$1.33	$1.53	$2.19	$2.83