Energy Transition Strategy
1.5 Degree Update

Role of Geothermal Energy

Prepared by City of Edmonton

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ISSUE IDENTIFICATION

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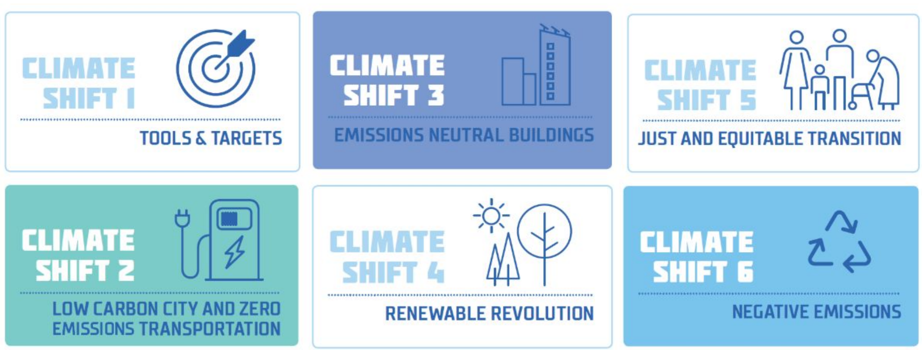
On August 26th, 2019, Edmonton City Council Declared a Climate Emergency and requested that Administration take steps to develop a revised Community Energy Transition Strategy by the end of third Quarter 2020 that aligns the emissions targets and actions with the local carbon budget for City Council's approval.

Council's motion was informed by Administration's report contextualizing Edmonton's current Community Energy Transition Strategy with a local carbon budget that was developed to assess whether or not the 35% below 2005 levels by 2035 greenhouse gas reduction goal was aligned with a global average temperature increase of 1.5 degrees scenario.

The conclusions was that Edmonton was not on track to limit its contribution to global climate change at a level aligned with 1.5 degrees. The report provided to City Council also provided an illustrative pathway to achieve a level of emissions reductions aligned with the 1.5 scenario. The results were summarized within six climate shifts:



The shifts include 23 modelled actions that would facilitate approximately the emissions reductions required to stay within the local carbon budget and achieve 3 tonnes of emissions per capita by 2030 and carbon neutrality by 2050.

One key action that is the focus of this policy brief is the installation of geothermal heat pumps in 25 percent of dwellings by 2050, complementing the transition to emissions neutral buildings.

GEOTHERMAL APPROACH TO NET ZERO

Revolve Engineering Inc. was engaged to perform an analysis of the potential of utilizing geothermal (GeoExchange) technology in reducing GHG emissions in Edmonton. In particular, this analysis compared using GeoExchange technology to a more passive approach (with Air Source Heat Pump (ASHP)) to achieve Net Zero energy in a home. The two approaches were compared in terms of energy use, capital and operating costs, complexity, and installation time.

Technical Assumptions

For the analysis a typical detached home built in the last 10 years was modelled using the IES Virtual Environment energy modelling software. A visual representation of the modelled home can be seen in Figure 1. Since home construction has not changed significantly in the last 20 years, this home was chosen as a representation of homes built in the last 10-15 years. To capture newer homes, the analysis assumed that the main furnace has been replaced or upgraded to a modern 95% efficient furnace.

This analysis compared using GeoExchange technology to a more passive approach with an Air Source Heat Pump to achieve Net Zero energy in a home

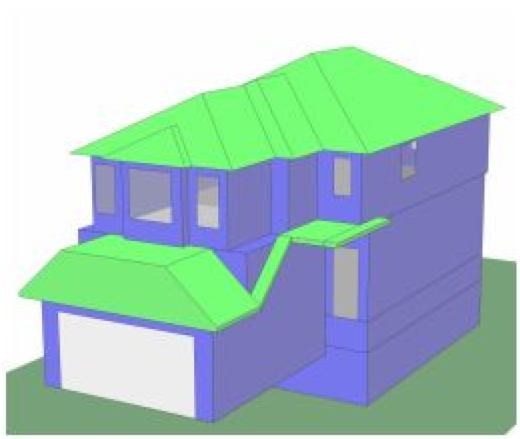


Figure 1: Image of the home modelled in the IES Virtual Environment

The following assumptions were used for the analysis:

<u>Typical "Newer" Alberta House</u>

House layout

- Single detached
- 2 storeys with undeveloped basement
- Floor area of 194 m2 (2083 ft2)
- Unheated garage (not included in analysis)

Building Envelope

- Typical 2 x 6 Wall with R20 Batt (R-16 Effective)
- Typical Basement Wall 2 x 4 with R20 (R-18 Effective)
- R40 Roof
- Dual Pane Windows (U-value 1.6)
- Air tightness of 2.5 ACH (air changes per hour)

Lighting/Plug Loads/Internal Gains

- 5150 kWh/ year modeled, using residential schedule from Section 9.36 of the Alberta Building Code

Mechanical

- 95% Efficient Furnace
- No HRV
- Hot Water Tank with Energy Factor (EF)=0.67

Energy Analysis

The following assumptions were made in regards to energy prices, escalation, carbon taxes.

- Only the energy rates of natural gas and electricity were used in the analysis, fixed fees were ignored for both. Rates were taken from Enmax – 5 year Fixed plan.
- Fixed Natural gas rate of $4.09 per GJ ($0.0147/kWh)
- Capped electricity rate of $0.066/kWh.

Net Zero Budget

The following assumptions were used to estimate the Solar PV generating capacity, to determine the energy budget for Net Zero energy. Based on the available 146m2 of roof area, the following assumptions were made:

- Assume half of roof is available for PV
- 18% efficient PV panels
- 13 kW can fit on the roof
- Conservative estimate of 1000 kWh/kW production Based on the above, the Energy Budget is 13,000 kWh.

Energy Demand

An energy demand chart was developed for a typical house built in the past 10 years in Alberta, shown in Figure 2. It should be noted that electricity represents approximately 15% of total energy consumption.

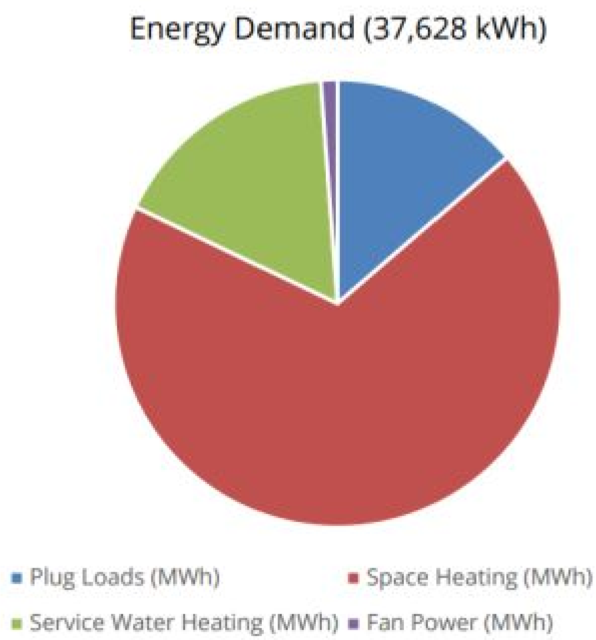


Figure 2: Energy Demand

For comparison, Figure 3 below shows the total energy consumption of the “average” Alberta home, and a “newer” built home (built in the past 10 years). The average numbers are based on Natural Resources Canada data, and the Figure shows that a newer built home uses a similar amount of energy.

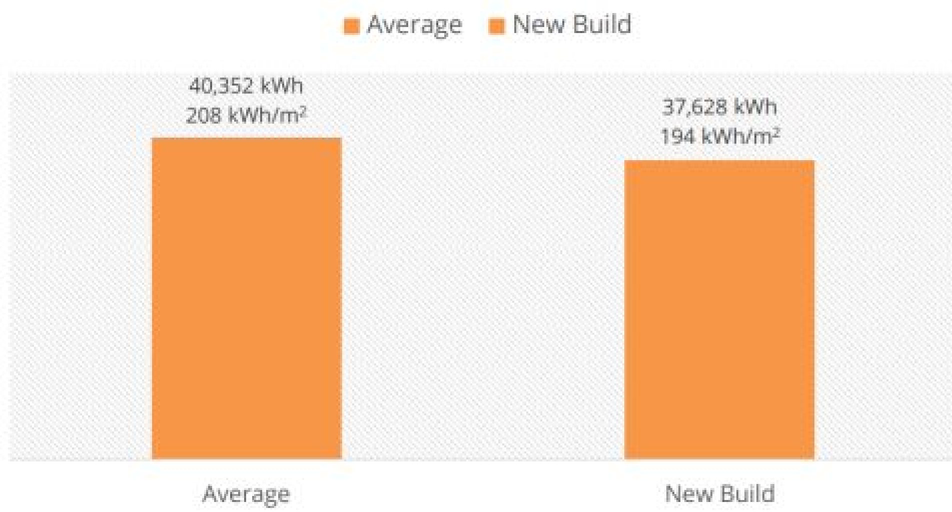


Figure 3: Energy Usage for the current average Alberta home compared to the energy usage for new construction.

Passive Approach (Option 1 - Standard Approach)

The analysis below shows a typical approach to achieving Net Zero in a newly built home using standard passive approaches. Upgrades were made incrementally until the energy consumption was below our 13,000 kWh energy budget. The following represents the energy uses that were compared in the analysis:

- Space heating
- Space cooling
- Interior Local Fans, Pumps and Exhaust Fans
- Service Water Heating
- Interior Lighting and Receptacle Equipment

As shown in Figure 4, the home's energy consumption was reduced to below 13,000 kWh to approximately 11,600 kWh. This energy load represents a demand that can be supplied through an on-site solar PV system, and therefore reach the net zero energy objective and Table 1 provides a summary of the upgrades that are needed to an existing or new home to reach the net zero energy target.

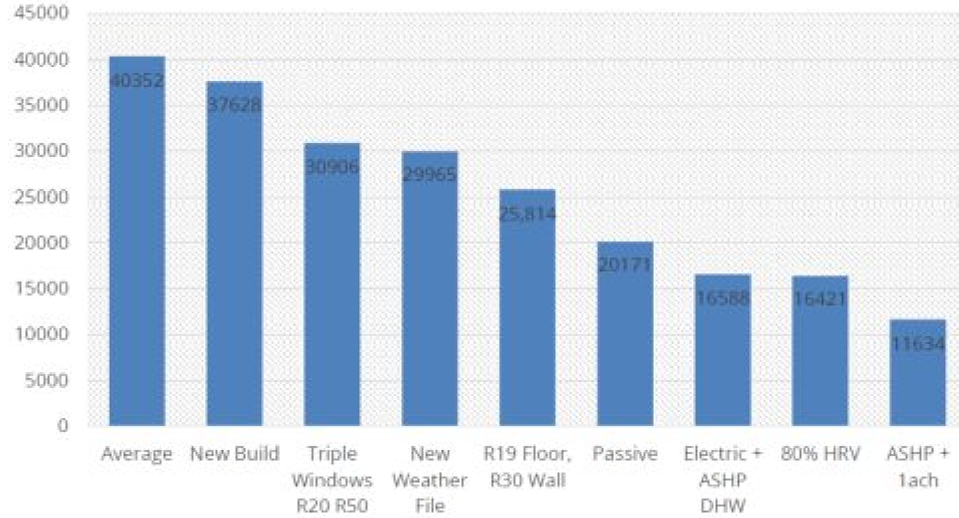


Figure 4: Improvements made to reduce energy consumption to align with energy neutrality using standard passive design features.

Table 1: Summary of upgrades to meet net zero energy target

Step #	Upgrades Required
1	Upgrading Envelope - Roof / Windows / Wall ● Roof insulation upgraded to R50 ● Double pane windows replaced with triple pane (All Weather HS2-C180, High SHGC, U-Value of 1.3) ● Walls upgraded to R-20 effective (1" of exterior rigid insulation)
2	Updating Weather File ● Updated weather file: instead of typical 30 year CWEC file used a more recent 15 year file (TMY-15).
3	Further Upgrades to Envelop - Walls / Floor ● Wall upgraded to R30 effective ● Floor upgraded to R19 effective (insulation under slab)
4	Full Passive House Envelope - Walls / Roof / Windows / Foundation ● Wall upgraded to R50 effective ● R40 foundation ● Roof upgraded to R80 ● Windows upgraded to fiberglass triple (U-0.7)
5	Mechanical Upgrades - DHW served by ASHP ● Electric resistance heating added ● Service water served by air sourced heat pump (ASHP)

6	Mechanical - HRV ● 80% efficient HRV installed
7	Air Tightness and ASHP ● Heating served by ASHP (average efficiency of 200% but requires 100% efficient electric backup heat below -15 to -20 degrees Celsius ● Infiltration lowered to 1 ACH

Active Approach (Option 2 - GeoExchange)

As an alternative approach, the same home was modelled and upgrades made incrementally but with GeoExchange replaced as the main heating source (designated as 'Active Step 1').

As shown in Figure 5, following the installation of a GeoExchange system (Active Step 1) the resulting energy use is within approximately 15% of the "Passive" option in terms of energy usage. It is also only 670 kWh over the 13,000 kWh energy budget to meet net zero energy from onsite solar PV and uses 64% less energy than a typical new build.

To fall within the energy use performance of the Passive Approach, replacement of dual pane windows with triple pane windows was included (designated as 'Active Step 2'). While this step was necessary to reduce energy use below the 13,000 kWh energy budget to meet net zero energy, financially these upgrades would likely not be justified since the high efficiency of the GeoExchange system makes the impact of envelope upgrades minimal.

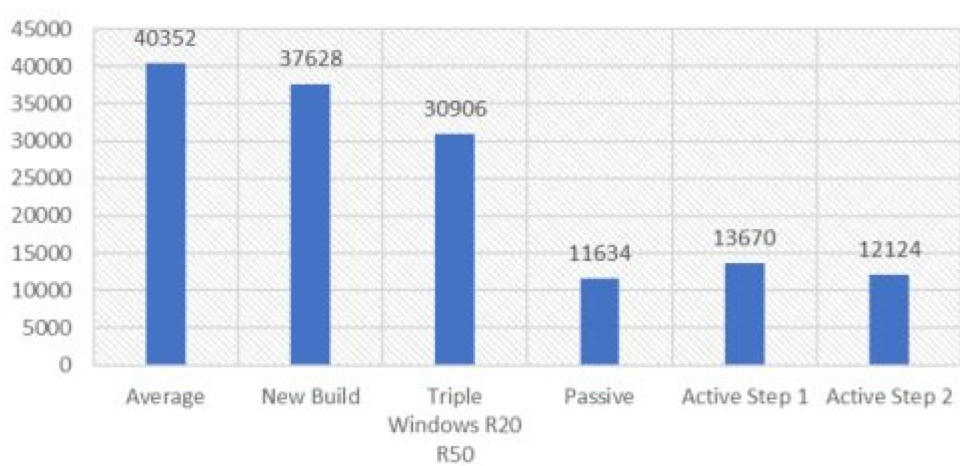


Figure 5: Improvements made to reduce energy consumption to align with energy neutrality within a home heated by GeoExchange.

Comparison of Active and Passive Approach

Table 2 shows a comparison of the upgrades required to retrofit homes for the passive and active options discussed.

Table 2: Comparison of upgrades required for Passive and Active options to meet net zero energy objectives.

	Typical Home	"Passive" Home	"Active" Home
Floor	Concrete	R19 Floor	None
Foundation	R18 Foundation	R40 Foundation	None
Walls	R16 Walls	R50 Walls	None
Roof	R40 Roof	R80 Roof	None
Glazing	Dual Pane Windows	Duxton Fibreglass Triple	PVC Triple
HRV	No HRV	HRV 80%	No HRV
DHW	NG Hot Water Tank	ASHP for Service Water	ASHP for Service Water
Heating	Furnace	ASHP for heating and back up heating	Ground Source Heat Pump
Infiltration	2.5 ACH	1 ACH	None

Figure 6 below shows the comparison of the approach between the passive and active options (compared to a typical home; labeled "original"). The blue lines show the heating demand, and the orange lines show the heating energy consumption. You can see that in the passive option, the heating demand is reduced by approximately 70%, whereas in the active option, the heating demand is only lowered by 15-20%. However, using the high efficiency of the GeoExchange system, the active option can achieve almost the same energy consumption.

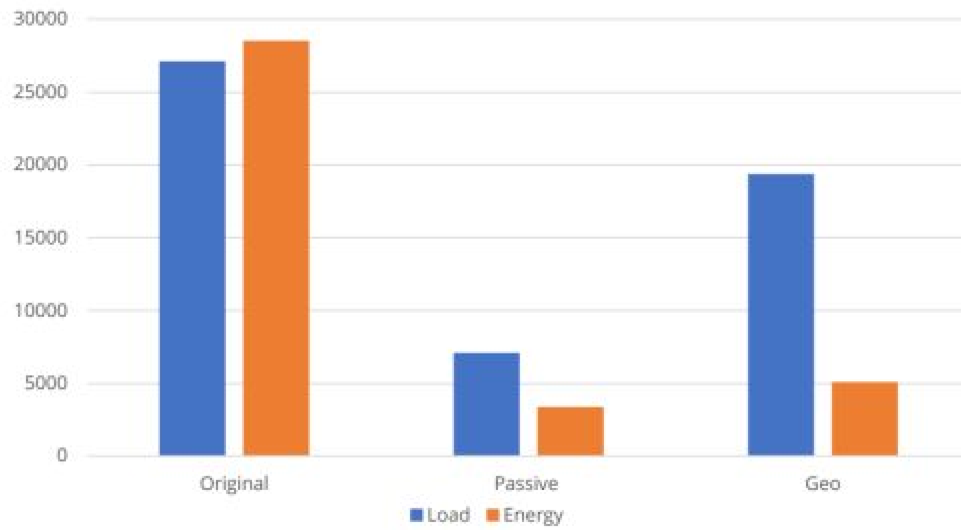


Figure 6: Comparison of the passive and active options to achieve net zero energy compared to the typical Albertan home.

EMISSIONS REDUCTIONS

Analytical Assumptions

The emissions reductions analysis is based on the following assumptions:

- Scenarios include 25%, 50% and 100% of all residential buildings upgraded to have a GeoExchange system installed for heating. An ASHP is assumed to handle domestic hot water.
- Implementing GeoExchange would achieve a 74% energy reduction per home.
- Plug loads are assumed to be equal in each scenario and are not included in the comparison.
- Alberta Grid Intensity Factors are as per Table 3. Grid intensities are reduced by 10% per year after 2030.

Table 3: Assumed future grid intensity factors

Year	GHG Intensity of Electricity (tonnes CO_2e/MWh)
2018	0.64
2019	0.61
2020	0.58

2021	**0.55**
2022	**0.52**
2023	**0.49**
2024	**0.46**
2025	**0.43**
2026	**0.40**
2027	**0.37**
2028	**0.34**
2029	**0.31**
2030 onwards	**0.28**

Residential Energy and Emissions Savings

Based on the information provided by the City of Edmonton, in 2018 there were approximately 368,000 houses or apartment buildings in Edmonton and these buildings collectively used 31.7 million GJ of natural gas. This averages to approximately 23,928 kWh per house, per year, of natural gas and approximately 4400 kgs of CO2 emissions per year. Note that these GHG emissions ignore emissions associated with plug loads and fugitive methane emissions.

The analytical results indicate that by installing a GeoExchange system as described in the previous section, each home can reduce its energy use by 74% and eliminate NG use entirely. By moving to an electric system based on GeoExchange, the average home can reduce its total heating energy use to approximately 6,221 kWh. Based on a grid emissions factor of 0.64 kg/kWh, this equates to 3,982 kg CO2 (a reduction of approximately 10%). Over 30 years (based on the reducing grid emissions intensity), the emissions are reduced by 66.8%, or 94.2 tonnes of CO2. For comparison, if the grid intensity stayed the same over 30 years, the emissions reductions would be 9.6% or 13.4 tonnes of CO_2.

For the city wide GHG analysis, these results are extrapolated based on the following scenarios:

- GeoExchange installed in 25% of homes
- GeoExchange installed in 50% of homes

- GeoExchange installed in all homes

The summary of the energy and GHG savings potential for city wide GeoExchange implementation are shown in Table 4. Please note that the analysis assumes that GeoExchange is implemented without solar PV in tandem, which would reduce the GHG emissions further (potentially to zero depending on the size of the solar PV system). The GHG reduction amounts are estimates based on grid electricity as the only electricity source.

As Table 4 shows, installing GeoExchange in only 25% of dwellings reduces CO_2 emissions by 2050 by only 17%. This is because 75% of homes are still assumed to use natural gas which obscures the GHG savings from individual GeoExchange homes (each home reduces it's GHG emissions by 67% over the same period). However, as the adoption is increased to 50% and 100%, the GHG emissions savings increase to 33.4% and 66.8% respectively.

Table 4: Energy and GHG savings from City-wide deployment of GeoExchange systems on different proportions of homes.

Measure Type	GeoExchange Adoption			
	0% of Dwellings (Base)	25% of Dwellings	50% of Dwellings	100% of Dwellings
Energy Usage (million GJ)	31.7	25.8	20.0	8.2
Energy Savings	-	19%	37%	74%
2019 Emissions (Mt)	1.62	1.58	1.54	1.47
2050 Emissions (Mt)	1.62	1.23	0.85	0.08
Total Emissions 2019 - 2050 (Mt)	51.8	43.2	34.5	17.2
Total Emissions Savings 2019-2050 (Mt)	-	8.7	17.3	34.7
Total Emissions Savings 2019-2050	-	16.7%	33.4%	66.8%

Pairing GeoExchange with Solar PV

It should be noted again that the above analysis does not include the synergies between GeoExchange and solar PV. Table 5 illustrates the results of the analysis if Solar PV were implemented to cover 50% of the heating electricity portion of the system. As can be seen from the results, pairing solar PV with GeoExchange can significantly improve the GHG savings, especially in the early years (when the grid is still relatively dirty). As the grid gets cleaner, the impact is lessened.

Table 5: Energy and GHG savings from City-wide deployment of GeoExchange systems paired with solar PV on different proportions of homes.

Measure Type	GeoExchange Adoption			
	0% of Dwellings (Base)	25% of Dwellings	50% of Dwellings	100% of Dwellings
Energy Usage (million GJ)	31.7	25.8	20.0	8.2
Energy Savings	-	19%	37%	74%
2019 Emissions (Mt)	1.62	1.40	1.18	0.73
2050 Emissions (Mt)	1.62	1.22	0.83	0.04
Total Emissions 2019 - 2050 (Mt)	51.8	41.0	30.2	8.6
Total Emissions Savings 2019-2050 (Mt)	-	10.8	21.6	43.3
Total Emissions Savings 2019-2050	-	20.9%	41.7%	83.4%

Commercial Energy and Emissions Savings

Based on the information provided by the City of Edmonton, 42.7 million GJ of natural gas was used in commercial and institutional buildings. The GHG emissions associated with this natural gas usage is approximately 2.18 million tonnes of CO2. By moving to GeoExchange, based on the experience of Revolve Engineering, commercial buildings can reduce their heating energy usage by approximately 70-80%. Assuming 50% of buildings were retrofitted to GeoExchange, and using a 70% heating energy savings, the energy savings would be 14.9 million GJ or 35%. The GHG savings would actually be negligible if the change occurred today (because of the current grid intensity factor). As the grid gets cleaner, the savings will go up proportionately. If the conversion happened immediately, the 30 year accumulated GHG savings would be 21,559,892 tonnes of CO2.

It should be noted that these numbers only account for heating energy savings, but since GeoExchange systems are 2-3 times as efficient in cooling as traditional systems, there could be significant GHG savings associated with cooling electricity as well (most larger commercial buildings are cooling dominant).

COST ANALYSIS

Single House Capital Costs

Table 6 shows the estimated costs of the upgrades associated with the passive and active approaches to achieve net zero energy. It is important to note that these costs are based on a retrofit scenario, whereas the costs of both options would change for a new home. These costs are estimates only (class 4) and should be refined further through contractors and cost consultants. Also note that Solar PV generation costs are not accounted for but would be the same for both options.

As shown in Table 6, the costs for the active option are almost half the cost of the passive option. However, an important consideration is the practicality of the upgrades for a homeowner. For example, in a retrofit, it is not always possible or practical to add insulation under the basement slab. Furthermore, building a R50 wall will require gutting the entire envelope, moving all residents out of the house, and rebuilding a much thicker wall.

Table 6: Single home cost comparison of passive and active options to achieve net zero energy.

Passive		Active	
Upgrade Required	Cost of Upgrade	Upgrade Required	Cost of Upgrade
R19 Floor	$10,000	Concrete Floor	$0
R40 Foundation	$10,000	R18 Foundation	$0
R50 Walls	$30,000	R16 Walls	$0
R80 Roof	$10,000	R40 Roof	$0
Duxton Fibreglass Windows	$25,000	PVC Triple Pane	$15,000
HRV 80%	$1,000	No HRV	$0
ASHP Hot Water	$1,000	ASHP DHW	$1,000
ASHP Heating	$12,000	GSHP	$30,000
1 ACH Infiltration	$1,000	2.5 ACH Infiltration	$0
Landscaping	$0	Landscaping	$10,000
Total Cost of Upgrades Required	$100,000		$56,000

City-Wide Capital Cost

Based on information provided by the City of Edmonton, in 2018 there was approximately 368,000 houses or apartment buildings within City limits. Table 7 identifies the capital cost necessary to achieve the retrofit of the specified percentage of Edmonton homes with GeoExchange. It should be noted that the average cost of a GSHP installed in a home is approximately $30,000 excluding the other upgrades that were identified in the "active" option analysis to take the home to Net Zero. The analysis in Table 7 only includes the installation of a GSHP retrofit and does not consider the timing and phasing for installation completion. A stand alone GSHP upgrade would achieve a 60-70% energy reduction on a typical home.

Table 7: Estimated City-wide capital cost for installation of GeoExchange heating systems at different adoption rates.

Percentage of Homes Retrofitted	Total Number of Homes	Estimated Capital Costs
25%	**92,000**	**$2.76 Billion**
50%	**184,000**	**$5.52 Billion**

Single House Operating Cost

Based on energy usage determined in the analysis for each option, the comparison of yearly energy cost is provided in Table 8. Plug loads including lighting and equipment has been excluded in this analysis since it is assumed to be the same between all options. Also, because the passive and active options do not require a natural gas connection, the fixed natural gas costs have been removed. The yearly fixed fees for the natural gas connection have been conservatively estimated at $700 per year. For the increase in electricity fixed fees, an increase of $0.03/kWh has been added to the comparison. While this is just an estimate (the fixed fees won't go up linearly because the fixed fees are mostly already paid for the plug loads), it serves as an indicator or placeholder for future analysis. Rates for operating cost comparison have been taken from Enmax's 5-year plan rates in October 2019, defined as a fixed natural gas rate of $4.09 per GJ ($0.0147/kWh) and a capped electricity rate of $0.066/kWh.

Table 8: Comparison of operating cost of passive and active options

	Base Case Typical New Build House	Passive Option	Active Option
Energy Usage (kWh)	32,481	6,480	8,524
Electricity	454	6,480	8,524
Gas	32,027	-	-
Energy Cost ($) / Year	501	428	527
Electricity Cost	30	428	563

Gas Cost	471	-	-
Natural Gas Connection Cost ($)	700	-	-
Increase in Electricity Fixed Fees ($)	-	194	256
Total Cost ($)	1,201	622	782
Comparison to Base Case			
Cost compared to base case ($)	-	-579	-419
Cost compared to base case (%)	-	-48	-35
Total Investment	-	$100,000	$56,000
Savings per $1,000 Invested	-	5.79	7.47
kWh Saved per $1000 Invested	-	260	428

Please note that the costs in Table 8 are only first year costs and do not include energy price escalation, levies or carbon taxes. The two electric options will have slightly higher fixed fees because of the increased electrical usage.

FEASIBILITY ANALYSIS

Irregardless of the analysis performed above, the energy savings calculated can only be achieved if the retrofits can be performed. If some of the upgrades are too complicated or expensive, or create other installation challenges, they are not likely to happen. This is where the active and passive approaches have vastly different feasibilities.

Retrofit Feasibility of the Passive Approach to Net Zero

Since the passive approach requires significant upgrades to the building envelope, in a retrofit scenario, the tenants would have to move out of the home until the upgrades are completed. This is a major practical hurdle and cost (which has not been accounted for in the analysis). Having to rent a home for however long the upgrades take, could incur large moving and renting costs. This should also consider the disruption to a homeowner's life which in many cases would make this option impractical. The following is a list of homeowner challenges with the passive approach:

- The passive upgrades represent an almost complete "gut" of the building. For some (especially older homes), a teardown might make more financial sense.
- Home upgrades require the home to be vacated for the entire construction period.
- R50 wall system will require much thicker wall, reducing interior floor space
- R40 wall in basement will reduce interior floor space.
- It is practically impossible to install insulation below an existing slab, the energy savings associated with the insulated floor would not be realized; other upgrades would need to be made to compensate, or the energy savings would not be as calculated.
- Achieving 1 ACH air tightness in an existing home would be a challenge, although because most of the wall and roof systems would be rebuilt anyway, this could be achieved with good air barrier details and attention to detail.
- The air source heat pump can only operate down to a certain temperature at which point backup heat is required. This presents a challenge during really cold months (such as the polar vortex in February 2019) where the home would be operating at 100% efficiency (heat pump would not be used). If demand charges are added to electricity rates (like in BC or many parts of Alberta), an ASHP would become financially impractical.
- Installing such high R-value envelopes and reducing air penetration to below 1 ACH will require significant expertise which is currently lacking in the construction world.

Retrofit Feasibility of the Active Approach to Net Zero

While fundamentally much more practical from an installation standpoint, the active approach does provide its own challenges. Like in the passive approach, window upgrades need to be made, but this is the only envelope upgrade and does not require tenants to move out of the home. The main challenge with installing a GSHP is the drilling operations that would typically require partial demolition/trenching of the front or back lawn. Once the boreholes are drilled, they are either connected into a header or run individually back to the basement mechanical room/area. The heat pump replaces the furnace and reuses the existing ductwork so there is very minimal if any disturbance inside. However, the outdoor work means that the landscaping will need to be redone following drilling operations. The following are some challenges to the active approach:

- Outdoor work is "destructive" so landscaping will need to be redone; this can pose challenges depending on type and quality of landscaping, presence of trees etc..
- Some homes might not have enough space to drill sufficient boreholes. This will be true of higher density lots and or large homes on small lots (to be discussed later in this report).
- There is a lack of geothermal installers in the City and Province currently, the industry needs to grow.

Space Limitations with Geothermal Systems

While most homes in the province will have sufficient space for the installation of a geothermal system there will be many that won't have the physical space to install sufficient boreholes (boreholes need to be spaced at a minimum 4.5m - 6.1m (15-20 ft) grid). This will be true of homes with small front or backyards (or no access to backyards), and newer homes that tend to be very large compared to the small amount of front/back yard space. Newer neighbourhoods tend to fall into this category and will pose a challenge as the homes tend to be much larger than older homes, and are on very small lots. For some homes, a simple solution will be to rely on the backup electric heat that can be installed in any heat pump for the few days of the year that they are needed. This is essentially a "hybrid" system where the backup heat "shaves off" the peak loads on the coldest days. This is actually very effective at reducing the ground heat exchanger size, while maintaining ground loop operability for over 95-99% of the year. The colder Edmonton climate requires a larger ground loop to ensure heat supply during the 5-10 coldest days throughout a typical year. Another solution would be to reduce the heating load of the home by adding insulation (1-2" of rigid to the outside), in many cases, this could be enough. This would obviously increase the cost of the installation.

For homes where this is not practical or sufficient, community or “district” systems could be implemented at scale. In fact, this will likely be the most cost effective and practical solution to implement these systems on a large scale. Utilities could install community based, shared systems that provide heating to dozens or even hundreds of homes. The heat would be distributed through low temperature uninsulated piping (similar to the system installed at Blatchford). Each home could get a supply and return stub out from the main system running in the road, as an example.

One of the exciting opportunities with district systems is that buildings can share energy on a neighbourhood scale, and cooling dominant buildings such as commercial buildings, grocery stores and hockey arenas can act as “heating plants” for the residential homes. This reduces the number of boreholes needed. In addition, other waste sources of heat can be used in the same system, including sewer heat recovery (similar to Blatchford). In particular, hockey arenas, cannabis facilities, data centres and other buildings where cooling is a constant process load, can become hubs of heat that can be shared on a district level. Each hockey arena (per ice sheet) can heat 50-100 homes, each cannabis or data centre 500-1000 homes for an entire year. Using this existing heat loads to provide heating could be a massive opportunity for these businesses.

Other advantages of Active over Passive

- Ground source heat pumps will last longer (average of 23 years) than air source heat pumps (average 15-18) years. Partly because of the extreme temperatures that ASHPs must withstand and use as a source of heat. Cold climate ASHPs have not been around for very long and the operational life is still to be determined.
- The ground loop lasts hundreds of years and will never need to be replaced within the remaining life of the retrofitted home.
- GSHPs aren’t sensitive to outdoor temperature swings and can operate without backup, ASHPs are less efficient and have less capacity as the temperature drops. This means that ASHPs must eventually rely on 100% efficient heat during the coldest days, potentially spiking energy bills during the colder months. Furthermore, if demand charges are brought in, this would make them financially unsustainable.
- GSHPs can be implemented at the community level.

CONCLUSIONS AND RECOMMENDATIONS

The use of GeoExchange systems is an important pathway for reducing emissions from building heating. Specifically, the analysis demonstrates that in instances where buildings must be retrofitted a GeoExchange system that achieves similar performance levels to passive approaches can be deployed with significant cost savings. These savings can be enhanced through the deployment of district GeoExchange systems to serve multiple buildings or through strategic partnerships with cooling dominate buildings (such as grocery stores or arenas) that can serve as “heating plants”.

Although costs are lower, there are some important limitations and personal considerations that would impact the ability and desire for an owner to install a GeoExchange system. The most important consideration is whether a site has the available space required to install a system with sufficient capacity to provide year-round heat. This would be a significant challenge in areas that have a high density or are increasing in density, but can be overcome through coordination with multiple owners to establish district GeoExchange systems. The drilling of the GeoExchange wells is also destructive to outdoor landscaping and yards, and owners may not want to pursue this approach to preserve their current landscaping. Lastly, there is currently a lack of geothermal installers in the City of Edmonton and the Province more broadly. This is an important consideration since the successful installation of a GeoExchange system requires significant upfront design and engineering, for which current capacity is lacking.

Following the Market Transformation Approach to becoming an energy sustainable city, the lack of capacity for professional and trades people to incorporate GeoExchange systems in buildings means that the technology is at the Capacity Building (stage 2) step of the process. To advance this technology further the following steps are recommended:

1. Further assess and define the technical capacity necessary for broader deployment through the Low Carbon Cities Canada, Edmonton centre.

2. Evaluate available education and training programs for GeoExchange system design and installation, and fill any key education gaps necessary.
3. Provide business and project development resources for new start ups specializing in GeoExchange system design and installation.
4. Identify and pursue opportunities for installation of GeoExchange systems to reduce energy use and emissions from City-owned buildings.
5. Maintain the current application for GeoExchange installations, and evaluate for any barriers for successful adoption.