GLOBAL WARMING IMPACTS OF GROUND-SOURCE HEAT PUMPS COMPARED TO OTHER HEATING AND COOLING SYSTEMS

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Abstract: Heat pumps can significantly reduce primary energy use for building heating and cooling. Geoexchange or ground source heat pumps (GSHP) utilize renewable energy stored in the ground near the surface. The renewable component, as high as 65 percent (ground-source) depending on location (climate), displaces the need for primary fuels, which when burned, produce greenhouse gases and contribute to global warming. The energy simulation program DOE 2.1E was employed to model the energy use of a single family residence and office building in six locations across Canada. Utilities provided up-to-date emission factor data associated with new (marginal) generation plants in each area.

Significant emission reductions resulted through the application of ground-source heat pumps in both the residential and small office buildings. For the examples presented here, residential high efficiency natural gas heating systems produced anywhere from 1.05 to 30 times the equivalent CO_2 emissions of ground-source heat pumps. In the small office building example, CO_2 emission reductions from 10% to 75 % were achieved through the use of ground-source heat pumps. Even under the assumption of new incremental generation capacity which in most cases examined here is natural gas plants, greenhouse gas emissions are significantly lower in buildings with ground source heat pumps.

Key Words: heat pump, ground source, greenhouse gas, global warming

1 INTRODUCTION

Heat pumps can significantly reduce primary energy use for building heating and cooling. Geoexchange or ground source heat pumps utilize renewable energy stored in the ground near the surface. The renewable component, as high as 65 percent (ground-source) depending on location (climate), displaces the need for primary fuels, which when burned, produce greenhouse gases and contribute to global warming.

This analysis was undertaken on behalf of the Renewable and Electrical Energy Division of Natural Resources Canada to update and refine earlier estimates provided by Caneta of the greenhouse gas impact of geoexchange systems in both residential and commercial/institutional buildings across Canada. The modelling results show emission reductions in major cities in Canadian Geoexchange Coalition (CGC) member regions. Heating and cooling impacts here are examined in a single family residential and small office building.

2 BACKGROUND

In 1998, Caneta Research [Caneta Research Inc.1999] prepared a paper for the Climate Change Buildings Table that provided estimates of the greenhouse gas reduction benefits of geoexchange systems compared to other residential and commercial/institutional systems. The paper analysed a single-family house, multi-unit residential building and a primary school with different systems in five locations - Vancouver, Regina, Toronto, Montreal and Halifax. The results showed that greenhouse gas emissions were generally very much lower with geoexchange systems in all regions.

The earlier results are now recognized to have two significant shortcomings as follows:

- average electrical generation mix rather than electrical generation on the margin was assumed for all locations. Critics have pointed out that generation on the margin must be the basis for the comparison;
- only space heating was analysed in the residential cases , whereas geoexchange systems provide both space and domestic water heating and space cooling. All these features need to be analysed.

Since 1998, the formation of a Canadian Geoexchange Coalition of electric utilities has been gradually coming together. These utilities needed a more complete, updated and refined estimate of the GHG impact attributable to geoexchange technology applied to buildings in their territories as a means of raising awareness of the benefits of geoexchange and of measuring the impact of their activities. This project will provide a methodology and basis for future calculations.

2.1 Scope and Methodology

Caneta identified and spoke with contacts, knowledgeable of power plant emissions, within each of the existing CGC utility organizations. The CGC utilities at present are BC Hydro, Yukon Development Corporation, SaskPower, Manitoba Hydro and Hydro Quebec. Locations for the purposes of the modelling and analysis were Vancouver, Whitehorse, Regina, Winnipeg and Montreal. As there was possible interest in CGC from Alberta, analysis was undertaken for Edmonton as well. Telephone contact was made with CGC member utilities to obtain the most up-to-date emission factor data associated with new (marginal) generation plants in each area. This data was used in this analysis rather than "average mix" emission factors. This should result in a more credible result, which all stakeholders are more likely to embrace.

The energy simulation program DOE 2.1E was employed to model the energy use of a single family residence and office building in each of the locations. Both heating and cooling energy were accounted for in the single-family analysis, unlike before. DOE 2.1E provided a more credible basis for the energy use estimates. The same systems were modelled as before in the single-family house. The office building utilized a central, variable-air-volume cooling system with gas-fired boiler. Insulation and equipment characteristics for both building types were as per local building codes. The single family residence and office buildings were models of actual buildings used by Caneta in previous studies for other clients. The residence was a two-storey 186 m^2 house while the office building was a five-storey 4180 m^2 building typical of modern suburban commercial developments. Total building energy use was estimated by running energy simulations of the two model buildings in each of the six locales. Emission results were obtained by applying the emission factors obtained from the utilities for new generation plants to the predicted electricity use. Natural Resources Canada sources were relied on for emission factors for the natural gas used by each system in each of the cities.

3 GREENHOUSE GAS EMISSION ANALYSIS

Greenhouse Gas Emission analysis can determine the overall contribution to global warming from energy using equipment over its operating lifetime. The electrical energy required by the equipment can result in releases of carbon dioxide and other greenhouse gases at the power plant. Fossil fuels, burned for building heating purposes, release carbon monoxide, carbon dioxide and NO_x, which also contribute to global warming. The leakage of refrigerants, greenhouse gases in themselves, used in both chillers and all heat pumps and air conditioners contribute to global warming, as well.

The greenhouse gases released from fossil-fuel electricity production and burner combustion are referred to as the **indirect** effect. The leakage of refrigerants into the atmosphere is referred to as the **direct** effect. The global warming potential of released or leaked refrigerants and natural gas is much greater than that of carbon dioxide.

The fuel used for electricity generation determines whether the electricity production results in large emissions of CO_2. As recently as 1996 [Statistics Canada 1997], in Canada, hydro power plants produced 64 percent of the total electricity generated with another 16 percent from nuclear. Generation from combustion and fossil-fuel steam plants accounted for only 20 percent of the total electricity generated. The latter are large producers of CO_2, while the former produce none. However, new generation in many jurisdictions in Canada will burn or alternatively displace natural gas and this is the generation, on the margin, which is assumed to meet all new consumption.

3.1 Emission Analysis Data and Assumptions

The atmospheric emission factors for electricity generation were obtained from the CGC member utilities. The electric utility transmission and distribution losses were from the National Energy Board [National Energy Board 1991] and updated where needed based on CGC member utility contacts. The emission factors for natural gas combustion were from Natural Resources Canada [Combs, A.1990]. A natural gas transmission and distribution loss of 0.33 percent has been assumed for all end use distribution. Refrigerant charges (R-22), for calculating the direct effect, reflect those of currently available equipment. Refrigerant leakage rates reflect current practice and were from the Residential and Commercial reports of Environment Canada's Expert Panel on Alternative Refrigerants [Snelson, Linton,Cane,Smale 1999-1],[Snelson,Linton,Cane,Smale 1999-2].

3.2 Energy Modelling

The residential house model had 186 m^2 of floor area above grade with a window area of 29.6 m^2. The energy consumption of the competing heating and cooling systems was determined using either the HVAC Advisor computer program (for air source heat pumps) or DOE 2.1E for all other systems. The ground-source heat pump was closed-loop and was modelled using DOE 2.1E. The ground source heat pump was equipped with a desuperheater for domestic water heating. Household electricity for appliances and lights was included in all cases as was energy for domestic water heating. Cases with electric resistance heating and heat pumps used electric water heating. Cases with gas heating used natural gas water heating. It was considered appropriate to use the total energy at the billing meters in all cases because this is understood by customers.

A small office building model was analyzed here. The total energy use of the office building was also determined using the DOE 2.1E energy analysis program. As in the residential case, electricity and natural gas use for lights, office equipment, fans, pumps, water heating were also included. The ground source heat pumps in the small office building did not provide water heating.

The energy efficiency criteria for the residential heating and cooling equipment, ground-source heat pump, chiller and boiler used in the models are summarized in Tables 3 through 6. The residential heating equipment, with the exception of the central air conditioner, is high efficiency. The air source heat pump meets Energy Star energy criteria. The ground-source heat pump used in both the residential and small office buildings is a high efficiency model, exceeding EPA Energy Star ratings. This was done in this case because ground-source heat pumps are not regulated the United States and the current EPA Energy Star rating is not that stringent. The air source and ground source heat pump efficiency ratings used here are considered by the authors to be equally stringent.

4. RESULTS OF EMISSION ANALYSIS

4.1 Residential Systems

The results of the residential emission analysis are presented in Table 1.

The **ground-source heat pump** has the lowest GHG emissions or total equivalent mass of CO_2 over the twenty year lifetime, in all the cities examined.

The **high efficiency air-source** heat pump has the second lowest GHG emissions in Vancouver. In Montreal, because of the hydropower electricity generation, the electric furnace has the same emissions as the air-source heat pump. This is due to the direct effect of refrigerant leakage, which is the same for the central air conditioner (electric furnace case) as for the air-source heat pump. In Winnipeg, the gas furnace has slightly smaller GHG emissions than the high efficiency air-source heat pump.

The **electric furnace** has the highest GHG emissions in all cities but Whitehorse and Montreal. The low emissions in these locales are again due to the hydro electricity generation.

In Vancouver and Winnipeg the **high efficiency natural gas furnace** produces about 25 % more greenhouse gas emissions than the high efficiency ground-source heat pump. In Regina, this is reduced to about 12 % more GHG emissions over the 20 year life.

4.2 Small Office

The results of the small office building GHG emission analysis are presented in Table 2. Once again, total building energy use is included in the GHG emissions total.

The GSHP building has the lowest total equivalent mass of CO_2 in all cities.

The magnitude of the reduction depends on the location and the electrical generation on the margin. It varies from a high of 85 % in Whitehorse to only 10 % in Edmonton, where fossil-fuel steam plants largely produce electricity on the margin.

5. CONCLUSIONS

Significant emission reductions are available through the application of ground-source heat pumps in both residential and small office buildings. For the examples presented here, residential high efficiency natural gas heating systems produced anywhere from 1.05 to 30 times the equivalent CO_2 emissions of ground-source heat pumps. In the small office building example, CO_2 emission reductions from 10% to 75 % were achieved through the use of ground-source heat pumps. In Whitehorse the CO_2 reduction compared to oil heating is 85%. In all locations the buildings energy criteria, both envelope and systems, were designed in accord with local building codes.

Ground-source heat pump equipment is widely available throughout Canada. The equipment is competitive on a life cycle cost basis with those systems examined here, particularly in those markets where air-conditioning is desired.

Even under the assumption of new incremental generation capacity which in most cases examined here is natural gas plants, greenhouse gas emissions are significantly lower in buildings with ground source heat pumps.

6. REFERENCES

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Table 1: Energy Use and Emissions - Residential

City	System	Total Building Energy Use		Heating Energy Use		Cooling Energy Use		GHG Emissions CO_2 Equivalent
		(kWh/yr)	(m^3/yr)	(kWh/yr)*	(m^3/yr)**	(kWh/yr)	(m^3/yr)	(kg)
Vancouver	Electric Furnace	20,132	0	5,694	0	1,586	0	157,756
	Hi Eff. Air-source HP	15,561	0	1,851	0	1,220	0	122,744
	Ground Source	14,283	0	2,318	0	777	0	112,632
	Natural Gas Furnace	9,383	1,621	0	608	1,586	0	140,230
Regina	Electric Furnace	80,279	0	63,954	0	1,467	0	843,153
	Hi Eff. Air-source HP	60,736	0	46,428	0	1,128	0	639,037
	Ground Source	36,585	0	24,114	0	769	0	386,309
	Natural Gas Furnace	10,580	8,000	0	6,832	1,467	0	435,013
Montreal	Electric Furnace	26,919	0	111,78	0	2,269	0	3,553
	Hi Eff. Air-source HP	19,775	0	5,154	0	1,745	0	3,553
	Ground Source	17,130	0	4,543	0	1,112	0	3,230
	Natural Gas Furnace	10,300	2,298	0	1,194	2,269	0	95,426
Edmonton	Electric Furnace	33,629	0	19,001	0	913	0	380,836
	Hi Eff. Air-source HP	24,525	0	10,628	0	702	0	278,699
	Ground Source	19,380	0	7,159	0	509	0	220,654
	Natural Gas Furnace	8,868	3,194	0	2,030	913	0	230,738
Whitehorse	Electric Furnace	87,470	0	72,060	0	266	0	3,553
	Hi Eff. Air-source HP	63,953	0	50,177	0	205	0	3,553
	Ground Source	39,292	0	27,166	0	135	0	3,230
	Oil Furnace	9,273	8,734 ***	0	7,519 ***	266	0	498,603
Winnipeg	Electric Furnace	33,133	0	17,344	0	1,868	0	274,641
	Hi Eff. Air-source HP	25,585	0	10,959	0	1,437	0	212,885
	Ground Source	19,530	0	6,889	0	934	0	163,021
	Natural Gas Furnace	10,035	3,024	0	1,853	1,868	0	206,547

* Space heating only - excludes pumps and circulation fans
**Space heating only - excludes domestic hot water heater
***Oil consumption in litres / year of light distillate oil

Table 2: Energy Use and Emissions - Small Office

City	System	Total Building Energy Use		Heating Energy Use		Cooling Energy Use		GHG Emissions CO_2 Equivalent
		(kWh/yr)	(m^3/yr)	(kWh/yr)*	(m^3/yr)**	(kWh/yr)	(m^3/yr)	(kg)
Vancouver	Hydronic VAV	524,496	21,841	399	16,443	58,903	0	4,930,896
	Ground Source	526,524	5,397	45,516	0	61,002	0	4,335,759
Regina	Hydronic VAV	560,367	56,252	1,207	50,077	72,147	0	8,150,913
	Ground Source	613,023	6,175	117,608	0	57,235	0	6,751,780
Montreal	Hydronic VAV	561,421	33,496	676	27,653	85,612	0	1,395,251
	Ground Source	553,664	5,843	67,382	0	59,436	0	345,510
Edmonton	Hydronic VAV	532,235	52,475	1,122	46,301	56,202	0	8,111,907
	Ground Source	615,640	6,174	116,150	0	51,145	0	7,217,796
Whitehorse	Hydronic VAV	499,130	56,372 ***	1,245	49,937 ***	30,887	0	3,227,300
	Ground Source	598,677	6,436 ***	122,670	0	38,164	0	435,194
Winnipeg	Hydronic VAV	522,531	55,698	1,191	49,509	60,851	0	6,543,872
	Ground Source	594,926	6,189	115,978	0	44,950	0	5,193,489

* Space heating only - excludes pumps and ventilation fans
**Space heating only - excludes domestic hot water heater
***Oil consumption in litres / year of light distillate oil

Table 3: Single-Family Residence

Description

- Two-storey, single detached house.
- Above grade floor area of 186 m^2 (2,000 ft^2).
- Furnished basement area of 93 m^2 (1,000 ft^2).
- Total volume of house is 700 m^3 (24,680 ft^3).
- Total window area of 29.6 m^2 (319 ft^2).
- Gross exterior wall area of 232 m^2 (2,498 ft^2).
- Walls constructed of face brick on wood frame.
- Attic style roof.
- Amount of insulation as per local building codes.

Occupancy and Use

- Family of four - two adults and two children.
- Assumed 0.25 air changes per hour for ventilation and infiltration.
- Total daily DHW consumption of 236 litres (62 gallons).
- Lighting and appliance - 1306 kWh and 6,129 kWh per year, respectively.

Temperature Set Points

- Heating set point is 21.1 8C (70 8F).
- Cooling set point is 22.8 8C (73 8F).

Table 4: Small Office

Description

- Five-storey, 4,180 m^2 (45,000 ft^2) floor area.
- Floor plate of 45 m by 18 m (150 ft by 60 ft).
- The building is served by a hydronic variable-air-volume heating and cooling system in the base case.
- Enthalpy based economizers are used in jurisdictions where they are required by local Code.
- Air handling units serve each of north, east, south and west perimeter and one serves the building interior.
- External walls are 40% fenestration.
- External walls have face brick, air space, rigid insulation on masonry block wall with gypsum board interior.
- The roof has 2 inches of gravel, rigid insulation, steel deck with steel beams/joist.
- Amount of insulation selected as per local building code requirements.

Occupancy and Use

- Peak occupancy of 269 ft^2/person.
- Outdoor air provided at rate of 21 CFM/person.
- Peak DHW consumption of 0.4 GPH/person.
- Peak equipment loads are assumed to be 0.7 W/ft^2.
- Lighting power density is 1.65 W/ft^2.

Temperature Set Points

- Heating set point is 22 8C (71.6 8F) occupied; 18 8C (64.4 8F) unoccupied.
- Cooling set point is 24 8C (75.2 8F) occupied; off during unoccupied period.

Table 5: Heating and Cooling Equipment Efficiency Criteria

Residential Heating/Cooling Equipment	Energy Efficiency Rating / Value
Electric furnace	AFUE / 100%
Hi efficiency air-source heat pump	COP @ 47°F / 3.34
	COP @ 17°F / 2.38
	SEER / 13.0
Ground-source heat pump[1]	COP / 3.5
	EER / 15.0
Natural gas furnace	AFUE / 90%
Oil furnace	AFUE / 82%
Oil boiler	AFUE / 82%
Residential air conditioner[2]	SEER / 10.0

1. equipped with desuperheater for DHW heating
2. used in both electric furnace and natural gas furnace systems

Small Office Heating/Cooling Equipment	Energy Efficiency Rating / Value
Natural gas boiler	Ec / 80%
Reciprocating chiller	COP / 4.2
Ground-source heat pump	COP / 3.5
	EER / 15.0
Oil boiler	AFUE / 82%

Table 6: Energy Efficiency Rating Definitions

AFUE - Annual fuel utilization efficiency, defined as ratio of annual output energy to annual input energy including off-cycle loss and cycling effects.

HSPF(Region V) - heating seasonal performance factor, total heating output of an air-source heat pump during its normal annual usage period for heating (Btu) divided by the total electric energy input during the same period (Watt-hrs), for a given climate.

SEER - Seasonal energy efficiency ratio, total cooling output during normal annual usage period for cooling (Btu) divided by the total electric energy input during same period (Watt-hrs).

COP - Coefficient of performance, ratio of heating or cooling delivered to energy input, for compressor, fans, pumps, if any, at a given operating condition.

EER - Energy efficiency ratio, ratio of net cooling capacity (Btu/h) divided by the electric input in watts, under standard rating conditions.

Ec - Combustion efficiency, defined as 100% less flue losses

Table 7: Utility Assumptions

Electric Utility Generation Emission Factors (Generation on Margin - New Plants)

City	Utility	Emission Factor
Vancouver	BC Hydro	360 tonnes/GWh
Edmonton	EPCOR	520 tonnes/GWh
Regina	SaskPower	470 tonnes/GWh
Winnipeg	Manitoba Hydro	360 tonnes/GWh
Montreal	Hydro Quebec	0 tonnes/GWh
Whitehorse	Yukon Development Corp.	0 tonnes/GWh

Electrical Transmission / Distribution Losses

City	Transmission / Distribution Loss
Vancouver	6.0 %
Edmonton	7.3 %
Regina	10.0 %
Winnipeg	12.0 %
Montreal	8.5 %
Whitehorse	10.0 %

Natural Gas Transmission / Distribution Losses (End-Use Distribution Only)

All cities (losses are methane)	0.33 % of end-use

Sources: Personal communication with John Duffy, BC Hydro
Personal communication with Oliver Bussler, SaskPower
Personal communication with Bill Hamlin, Manitoba Hydro
Personal communication with Kathy Cottrell-Tribe, Yukon Development Corporation

Table 8: Other Results

Seasonal COP for Ground Source Heat Pumps

The ground-source heat pump chosen is very efficient. The EPA Energy Star Program for ground loop heat pumps sets COP and EER requirements of 3.3 and 14.1. Only 53 % of current models exceed these Energy Star requirements. The model chosen here exceeds EPA Energy Star requirements - COP of 3.5 and EER of 15. Seasonal COP calculated from DOE 2.1E energy simulation results includes part-load, cyclic losses, auxiliary heat and pumping energy. The values of seasonal COP and SEER for the ground source heat pumps are:

	Seasonal COP		SEER	
City	**Residential**	**Small Office**	**Residential**	**Small Office**
Vancouver	2.64	2.99	13.5	12.8
Edmonton	2.87	3.11	13.6	12.3
Regina	2.61	3.31	13.8	13.5
Winnipeg	2.69	3.34	13.8	12.8
Montreal	2.67	3.22	13.6	14.1
Whitehorse	2.61	3.28	13.5	11.5

Seasonal COP for High Efficiency Air-Source Heat Pumps

The seasonal COP for the air-source heat pumps was calculated using HVAC Advisor Software. Steady state efficiencies (COP) used in HVAC Advisor were taken from manufacturer data. The air-source heat pump modelled has a COP at 47F of 3.34 and a COP at 17F of 2.38. The values calculated for seasonal COP for the air-source heat pumps are:

City	Seasonal COP
Vancouver	2.61
Edmonton	1.79
Regina	1.38
Winnipeg	1.58
Montreal	2.17
Whitehorse	1.44

Refrigerant Choice

The leakage of refrigerants, which are greenhouse gases, contribute to global warming, as well. All air conditioning systems modelled here were assumed to use HCFC-22 - the residential air conditioner, the ground and air source heat pumps and the reciprocating chiller. The leakage of refrigerant into the atmosphere is referred to as the direct effect. The reciprocating chiller was assumed to leak 1.5 % of its initial charge annually, while the air conditioner and heat pumps were assumed to leak 4 %. In all cases an end of life leakage of 15 % of initial charge was assumed. Under current federal regulations, HCFC-22 will be phased out by 2020. Alternative refrigerants HFC-407C and HFC-410A have global warming potentials of 1530 and 1730 respectively, not much different than HCFC-22 at 1700. Alternatives to HFCs are under investigation for the very long term.

Table 9: Environmental Analysis (Small Office - Marginal Electrical Generation)

City	System	Lifetime [yrs]	Electrical Energy [kWh]	Gas Consumed [m³/yr]	INDIRECT EFFECT: Electricity Gen./Trans. [kg equiv. CO_2]	INDIRECT EFFECT: Natural Gas Burner [kg equiv. CO_2]	INDIRECT EFFECT: Natural Gas Transmission [kg equiv. CO_2]	INDIRECT EFFECT: Total Indirect [kg equiv. CO_2]	DIRECT EFFECT: Refrigerant Mass of CO_2 [kg]	DIRECT EFFECT: Total Direct [kg equiv. CO_2]	Total Equiv. Mass of CO_2 [kg]
Vancouver											
	Hydronic VAV	20	524,496	21,841	4,017,416	850,700	22,460	4,890,580	40,316	40,316	4,930,896
	Ground Source	20	526,524	5,397	4,032,950	210,210	5,550	4,248,710	87,049	87,049	4,335,759
Regina											
	Hydronic VAV	20	560,367	56,252	5,852,722	2,191,000	57,850	8,101,570	49,343	49,343	8,150,913
	Ground Source	20	613,023	6,175	6,402,685	240,510	6,350	6,649,550	102,230	102,230	6,751,780
Montreal											
	Hydronic VAV	20	561,421	33,496	0	1,304,660	34,450	1,339,100	56,151	56,151	1,395,251
	Ground Source	20	553,664	5,843	0	227,580	6,010	233,590	111,920	111,920	345,510
Edmonton											
	Hydronic VAV	20	532,235	52,475	5,971,137	2,043,880	53,970	8,068,990	42,917	42,917	8,111,907
	Ground Source	20	615,640	6,174	6,906,857	240,480	6,350	7,153,680	64,116	64,116	7,217,796
Whitehorse											
	Hydronic VAV	20	499,130	56,372 *	0	3,195,170	-	3,195,170	32,130	32,130	3,227,300
	Ground Source	20	598,677	6,436 *	0	364,780	-	364,780	70,414	70,414	435,194
Winnipeg											
	Hydronic VAV	20	522,531	55,698	4,275,254	2,169,420	57,280	6,501,950	41,922	41,922	6,543,872
	Ground Source	20	594,926	6,189	4,867,576	241,060	6,360	5,115,000	78,489	78,489	5,193,489

*Oil consumption in litre/year of light distillate oil

Table 10: Environmental Analysis (Residential - Marginal Electrical Generation)

Cit	Syste	Lifetime [yrs]	Electrica Energ [kWh/yr	Ga Consumed [^{3}/yr]	INDIRECT Electricit Gen./Trans [kg equiv. CO_2]	Oil or Burne [kg equiv. CO_2]	Natural Transmissio [kg equiv. CO_2]	Tota Indirec [kg equiv. CO_2]	DIRECT Refrigeran Mass of 2 [kg	Tota Direc [kg equiv. CO_2]	Total Mass of 2 [kg
Vancouver	Electric	20	20,132	-	154,203	-	-	154,203	3,553	3,553	157,756
	Hi. Eff. air-source HP	20	15,561	-	119,191	-	-	119,191	3,553	3,553	122,744
	Ground Source	20	14,283	-	109,402	-	-	109,402	3,230	3,230	112,632
	Natural Gas Furnace	20	9,383	1,621	71,870	63,140	1,667	136,677	3,553	3,553	140,230
Regin	Electric	20	80,279	-	838,470	-	-	838,470	4,684	4,684	843,153
	Hi. Eff. air-source HP	20	60,736	-	634,354	-	-	634,354	4,684	4,684	639,037
	Ground Source	20	36,585	-	382,110	-	-	382,110	4,199	4,199	386,309
	Natural Gas Furnace	20	10,580	8,000	110,502	311,600	8,227	430,330	4,684	4,684	435,013
Montreal	Electric	20	26,919	-	0	-	-	0	3,553	3,553	3,553
	Hi. Eff. air-source HP	20	19,775	-	0	-	-	0	3,553	3,553	3,553
	Ground Source	20	17,130	-	0	-	-	0	3,230	3,230	3,230
	Natural Gas Furnace	20	10,300	2,298	0	89,510	2,363	91,873	3,553	3,553	95,426
Edmonto	Electric	20	33,629	-	377,283	-	-	377,283	3,553	3,553	380,836
	Hi. Eff. air-source HP	20	24,525	-	275,146	-	-	275,146	3,553	3,553	278,699
	Ground Source	20	19,380	-	217,424	-	-	217,424	3,230	3,230	220,654
	Natural Gas Furnace	20	8,868	3,194	99,490	124,410	3,285	227,185	3,553	3,553	230,738
Whitehorse	Electric	20	87,470	-	0	-	-	0	3,553	3,553	3,553
	Hi. Eff. air-source HP	20	63,953	-	0	-	-	0	3,553	3,553	3,553
	Ground Source	20	39,292	-	0	-	-	0	3,230	3,230	3,230
	Oil	20	9,273	8734	0	495,050	-	495,050	3,553	3,553	498,603
Winnipeg	Electric	20	33,133	-	271,088	-	-	271,088	3,553	3,553	274,641
	Hi. Eff. air-source HP	20	25,585	-	209,332	-	-	209,332	3,553	3,553	212,885
	Ground Source	20	19,530	-	159,791	-	-	159,791	3,230	3,230	163,021
	Natural Gas Furnace	20	10,035	3,024	82,105	117,780	3,110	202,994	3,553	3,553	206,547

*Oil consumption in litre / year of light distillate oil