Canadian GeoExchange Coalition

Coalition canadienne de l'énergie géothermique

Comparative Analysis of Greenhouse Gas Emissions of Various Residential Heating Systems in the Canadian Provinces

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Canadian GeoExchange Coalition
1030, Cherrier St, Suite 405
Montréal, Québec, H2L 1H9

www.geoexchange.ca

Summary

The Canadian GeoExchange Coalition (CGC) has been asked over the past few years to provide those in political and environmental circles with data and analysis to enable better positioning of geoexchange technology in the ongoing debates on climate change. Several studies on the subject have been published by various groups in recent years. However, in these studies we frequently note the absence of clear research protocols or the formulation of nebulous and unrealistic hypotheses based on limited data sources or even hearsay. The often fragmentary focus of these studies has created a great deal of confusion, and has contributed little to advance the debate. The lack of coherence in the data published to date, has been a solid argument for CGC to complete an exhaustive study based on clear hypotheses and recognized environmental protocols.

This study uses data that are both precise and specific to each of the capitals of the Canadian provinces in order to compare the GHG emissions of various heating systems. The study limits itself exclusively to heating analysis because heating represents almost 60% of total energy consumption in single-family homes (OEE 2006b). Although water heating is usually in second place with regard to residential energy consumption, we chose not to take it into account for purposes of this study. The use of desuperheaters is not generalized in geoexchange systems and thus would tend, in a comparative analysis, to give a favourable bias to geoexchange systems.

Besides, as the use of air conditioning is variable and disparate in most regions of the country, we also chose to exclude this component from the analysis in order to make interprovincial comparisons more uniform and consistent, even though air conditioning using geoexchange systems represents a significant source of energy savings compared to conventional systems, and therefore a potential source of GHG reductions or increases.

The analysis presented in the text itself concerns a reference building of 2,000 ft^2 (185 m^2) with average insulation. The various heating systems are compared to a geoexchange system operating at a coefficient of performance of 2.8 (considered low by most industry stakeholders). This measurement reflects the performance of the entire system, and not just the theoretical coefficient of performance of the heat pump. The reasons justifying such an approach are presented in the section *Methodology*.

This approach, which represents the most pessimistic scenario, nevertheless produces results favourable to geoexchange systems for the entire Canadian territory. Any performance above this coefficient leads to a greater reduction in energy consumption, further reduces GHG emissions and improves the comparative advantages of geoexchange systems as compared to other residential heating systems.

The proportion of single-family homes using the various types of heating systems has been used in order to make this analysis realistic. The calculations of market penetration and their associated reductions are based on the number of homes having a specific system, and not on the total number of single-family homes in each province.

This report demonstrates that geoexchange systems do offer both an interesting GHG solution in most contexts and significant potential for reduction of greenhouse gas emissions nationally. The results of the study confirm the recurring advantages in greenhouse gas emission reductions generally when converting a conventional heating system to a geoexchange system. For example, if only 2% of Canadian single-family homes used a geoexchange system for their heating needs, a potential country-wide reduction in emissions of 376 000 tons of CO_2 eq. would be possible, which is equivalent to removing nearly 112,000 automobiles from Canadian roads.

The study establishes that potential reductions vary from province to province because the climatic factors and the sources of energy used for heating, and for electricity production, differ from region to region. However, the results of the study demonstrate that geoexchange systems in the residential sector are advantageous in every province, especially when they replace electric baseboards or oil furnaces.

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Introduction

Since the signing of the Kyoto Protocol in 1998, climate change has become an important scientific issue, both on the national and the international scene. The Kyoto Protocol is a complement to the United Nations Framework Convention on Climate Change, the objective of which is to compel signatory countries to reduce their greenhouse gas emissions (GHGs)[1] by at least 5% as compared to the 1990 level. The period of the agreement extends from 2008 to 2012 (UNFCCC 1998).

To date, almost 180 countries have ratified the Protocol. Canada joined the ranks of signatory countries in 2002, becoming the 99th country to sign the agreement. The United States, one of the largest emitters of GHGs in the world (OECD 2008), has not yet ratified the Protocol, judging it to be too constraining. With the implementation of the Kyoto Protocol in 2005, the initially scientific discussions were moved into the political arena. Tumultuous debates have occurred at the international level. Although divergent policies created tensions, the debates have nevertheless led to a certain progress and encouraged the adoption of many emerging and new technologies.

In 2006, world energy consumption stood at 11,730 million tons of oil equivalent annually, or an increase of 23% between 1990 and 2006 (IEA 2008). This increase in energy demand translates into environmental impacts, in particular into greenhouse gas (GHG) emissions, or even into more intensive use of land resulting from the increased use of resources and the construction of new energy production units.

On a worldwide scale, the most recent data indicate that direct emissions from the building sector (including electricity consumption) have been in the magnitude of 10.6 Gt of CO_2 eq. annually, or almost one-quarter of the 49 Gt of CO_2 equivalents emitted in the world in 2004 (IPCC 2007).

In Canada, 5.9% of GHG emissions come from the residential sector, or the equivalent of 44 Mt of CO_2 eq. (Environment Canada 2007). The proportion of emissions from buildings varies from one region to another (see Appendix C), but still, a large part of the human impact on GHG increases in our atmosphere comes from the energy consumption of our buildings.

Energy production and use are at the heart of many of these environmental concerns. In Canada, we have seen marked divergence with regard to plans to reduce environmental impacts. However, a consensus is gradually forming on the need to adopt measures to enable a reduction in the greenhouse gas (GHG) emissions resulting from the exploitation of energy resources.

Mitigating measures, in particular better management of energy consumption thanks to energy efficiency, or energy production from alternative or renewable sources, are gaining in popularity, and are being increasingly integrated by governments and energy distributors into plans to fight climate change.

The increase in energy demand has had a favourable effect on the emergence of new and renewable sources of energy, not only in the developed economies of the European Union or North America, but also in certain emerging countries like China, India and Brazil. This interest in these forms of energy has also been observed in geoexchange systems. The total number of geoexchange systems installed throughout the world stood at 1.3 million in 2005, which represents almost double the number of units installed in 2000 (World Energy Council 2007). However, this increase is very uneven at the worldwide level. In Canada, the market penetration of geoexchange systems also varies by province and by region.

[1] Greenhouse gases are gases that imprison solar energy in the atmosphere, and are essential to life on Earth. However, the sustained increase in their concentration in the atmosphere is worrisome because they lead to an increase in the Earth's temperature as well as undesirable effects on our climate. Note that GHGs often make reference to carbon dioxide (CO_2), but they include several gases, such as methane, nitrous oxide, fluorocarbons, etc.

This study suggests that programs and promotional tools must be adapted according to market characteristics.

Despite the increasing popularity of geoexchange systems, questions around GHG effects are often cited as a barrier to more general adoption of geoexchange systems, at least in certain provinces. This debate turns mainly on the generation sources for a province`s electricity. More and more studies, attempt to demonstrate that this argument cannot be maintained uniformly due to energy system variation by province.

The results presented in this document are intended to compare, on a common basis, the GHG emissions of the various residential heating systems used in the Canadian provinces. These comparisons are performed *strictly* from the environmental perspective, and exclude the exergy and economic aspect, or any other related issues.

Despite the attributes and differences specific to each of the provinces, in particular with respect to electricity production or to the composition of the existing stock of heating equipment, the hypotheses and the calculations used are the same for the entire country. The reader is invited to take into account the limitations of these hypotheses and to use or interpret the results with caution.

Methodology

This study uses data that are both precise and specific to each of the capitols of the Canadian provinces in order to compare the GHG emissions of various heating systems. The study limits itself exclusively to heating analysis because heating represents almost 60% of total energy consumption in single-family homes (OEE 2006b). Although water heating is usually in second place with regard to residential energy consumption, we chose not to take it into account for purposes of this study. The use of desuperheaters is not generalized in geoexchange systems and thus would tend, in a comparative analysis, to give a favourable bias to geoexchange systems.

Furthermore, as the use of air conditioning is variable and disparate in most regions of the country, we also chose to exclude this component from the analysis in order to make interprovincial comparisons more uniform and consistent, even though air conditioning using geoexchange systems represents a significant source of energy savings compared to conventional systems, and therefore a potential source of GHG reductions or increases.

It is widely accepted the best oil heating systems have an efficiency of almost 85%, those using natural gas have an efficiency of 90%, and that electric systems have an efficiency of close to 100%. Most analysts rely on these simple hypotheses in order to compare the performance of different heating systems to each other. We have judged these hypotheses too simplistic for purposes of this study.

The efficiency of systems varies considerably. We have therefore opted to use an efficiency interval in order to better illustrate GHG emissions. Hypotheses focusing on various efficiency values for buildings have also been retained in order to provide a portrait that is both fairer and more representative of the markets and the existing building stock. These assumptions enable us to broaden the scope of study.

For purposes of this study, we have used an efficiency of 95% for electric furnaces. For natural gas and oil heating, different types of systems are found in the market. The Office of Energy Efficiency (2009) classifies heating system efficiency according to three categories:

> **Normal efficiency heating system:** This classification indicates the energy efficiency of natural gas and oil furnaces. The normal efficiency classification refers to a heating system for which the average annual energy yield is less than 78%.
>
> **Medium efficiency heating system:** This classification indicates the energy efficiency of natural gas and oil furnaces. The medium efficiency classification refers to a heating system for which the average annual energy yield is 78% to 89%.
>
> **High efficiency heating system:** This classification indicates the energy efficiency of natural gas and oil furnaces. The high efficiency classification refers to a heating system for which the average annual energy yield is 90% or higher.

Therefore, a system with an efficiency corresponding to each of the previous categories was selected for this analysis: 0.75, 0.84 and 0.95. In this manner, the study will target actual heating systems in each province likely to be substituted by a geoexchange system. In order to reflect current technology available on the market, our research on oil heating systems has led us to choose 90% as a maximum efficiency for this type of technology. (NRCan 2010)

The efficiency of geoexchange systems must also be worked out carefully. Although it is not uncommon that geoexchange systems present coefficients of performance (COPs[2]) of 4 or higher, it is wiser, in our

[2] The coefficient of performance represents the energy performance of a heat pump. It corresponds to the energy produced by the system compared to the electrical energy consumed by the heat pump. For purposes of this analysis, the suggested coefficient of performance is that of the entire system and not just that of the heat pump.

opinion, to posit the hypothesis that a lower COP is much more realistic when you consider seasonal factors as well as real heat losses.

This hypothesis relies on the important distinction to be made between the theoretical COP of the heat pump, which reflects laboratory tests under predetermined conditions, and the system COP, which reflects the real functional conditions of the entire system (i.e. ground loop, appliance, and distribution in the home), and not just that of the heat pump. For purposes of this analysis, when the COP is mentioned, we understand it to mean the system COP, since it reflects the real and annual performance of the entire system – rather than the exclusive theoretical performance of the heat pump.

For purposes of comparison with other types of heating systems, three coefficients of performance have been used: 2.8, 3.2 and 3.6. For the detailed analysis by province, the comparison is based on a COP of 2.8; this is our minimum comparative threshold. Any performance of geoexchange systems above 2.8 would therefore improve the GHG performances for geoexchange which we are presenting here.

Furthermore, with the goal of increasing the precision of this analysis, and to better consider the energy performance of buildings, three different building sizes were used. This was done to more effectively represent a wide proportion of the Canadian residential sector. The average size of single-family residences in Canada is 1,475 ft^2 ($135m^2$), but we have noted a constant increase in the size of new residences (NRCan 2006a). Based on this fact, GHG emissions were calculated for homes of 1,500 ft^2 ($140m^2$), 2,000 ft^2 ($185m^2$) and 2,500 ft^2 ($230m^2$) in order to better reflect the characteristics of the future building stock rather than the existing stock. The analysis presented in the text itself concerns a reference building of 2,000 ft^2 (185 m^2) with average insulation.

To best frame these comparisons on the basis of equivalent data, the GHG emissions of the various heating systems are represented as equivalent tons of CO_2. To arrive at this unit, the coefficients of emissions suggested by Environment Canada (2009a), as well as the global heating power of the various emitted gases (UNFCCC 1995), were used in the final calculation of emissions. For accuracy purposes, CO_2 emission factors for natural gas adjusted by province were used in this study, as provided by Environment Canada's *National Inventory Report 1990-2007: Greenhouse Gas Sources and Sinks in Canada*. Tables 1 and 2 below summarize these equivalences.

Table 1

Emission factors

Source	***CO_2***	***CH_4***	***N_2O***
Natural Gas (g/m^3)			
Québec	1878	0.037	0.035
Ontario	1879	0.037	0.035
Manitoba	1877	0.037	0.035
Saskatchewan	1820	0.037	0.035
Alberta	1918	0.037	0.035
British Columbia	1916	0.037	0.035
Territories	2454	0.037	0.035
Other provinces	1891	0.037	0.035
Oil (g/L)	2830	0.026	0.006

Source: Environment Canada 2009a

Table 2 Global warming potential	
Gas	***CO_2 equivalent***
Methane (CH_4)	21
Nitrous oxide (N_2O)	310

Source: UNFCCC 1995

In addition, out of concern for a fair comparison with electricity, indirect emissions related to natural gas distribution have been included in our calculations. These fugitive emissions, mainly composed of methane (CH_4), have a coefficient of emission allocated per kilometer of natural gas distribution network. As defined by Environment Canada (2009a), this leakage rate is evaluated at 0.0007 kt of CH_4/km. By adding this correction factor, we limit the scope of the natural gas efficiency coefficients which are determined on a theoretical basis and do not necessarily reflect their true operational efficiency, contrary to those used for geoexchange systems. Line losses for electricity are reflected in electricity efficiency factor of 95 % retained in the study.

Moreover, in its *National Inventory Report – Greenhouse Gas Sources and Sinks in Canada 1990-2007*, Environment Canada presents data on the intensity of greenhouse gas emissions for the electricity sector of each province. Although these data are essential to our analysis, it is important to note that they reflect only the GHG emissions arising from the production of electricity in each province, and do not take into account the provinces' electricity imports and exports.

For certain provinces, the difference between the GHG emissions from electricity produced in the province and the GHG emissions from imported electricity is considerable and sufficient to make any comparison between the various forms of energy pointless. Interprovincial – and international – trade in electricity cannot be ignored, and we have taken this into account in our study. For example, Prince Edward Island, which imports almost 95% of its electricity from New Brunswick, sees its GHG emission intensity vary significantly by including interprovincial electricity transfers. This is also the case for other provinces.

In a thesis submitted at the University of British Columbia, Jana Hanova (2007) suggested including the electricity imports of each province in order to more precisely reflect the sources of production of the electricity consumed. Our study retains this idea, but adds further depth to the concept by integrating interprovincial transfers and international trade, and by establishing an average over 5 years. This average enables us to avoid, at least partly, having the analysis biased by exceptional annual statistical data – the electricity imports and exports of a province may vary considerably from year to year. Since 2008 data are not yet available in Canada nor in the United States, we have used the average for the period between 2003 and 2007.

Table 3 therefore presents the revised GHG emission intensity by province for the electricity sector, including imports, exports and interprovincial transfers. For more details on this data, please refer to Appendix A on the GHG intensity of the electricity sector by province.

Table3 Electric sector GHG emission intensities		
Provinces	***Electricity generation only (tons CO_2 eq./GWh) 5-year average***	***Electricity consumption including imports / exports / transfers (tons CO_2 eq./GWh) 5-year average***
British Columbia	18	53
Territories	84	84
Alberta	878	872
Saskatchewan	796	782
Manitoba	16	105
Ontario	216	228
Quebec	7	28
New Brunswick	440	428
Prince Edward Island	336	434
Nova Scotia	756	752
Newfoundland/Labrador	30	30

Our comparative analysis also takes into account significant differences in temperature between the Canadian reference cities used for purposes of this study. We have therefore adjusted the energy consumption of typical buildings by taking into account degree-days of heating. [3]

To better demonstrate the annual GHG reductions in tons for a single-family home, the various tables presented in this document illustrate the possible GHG reductions at the provincial level with varying market penetration rates. We have extended the analysis to buildings of different sizes with variable energy performances.

Another way to illustrate the importance of these potential reductions is to estimate an equivalent number of cars that would be taken off Canada's roads every year if the reductions had in fact taken place. Note that this equivalence uses the volume of GHGs emitted by the average of the vehicles on the road in Canada according to data published by Natural Resources Canada. The average emission for vehicles in Canada is 3,360 kg of CO_2 eq. annually (NRCan 2009). These emissions are equivalent to the annual emissions of a wagon-type car like the Jetta Wagon (Éco Action, 2009).

Our study also considers the marginal introduction of greener electricity as base load power. There is no substitution – or replacement of an electricity production unit – but rather a marginal diversification.

Finally, reference cities selected are the provincial capitals. This choice is purely elective, and has no real impact on the study's general conclusions. In reality, it is clear that none of the capitals reveals all the geological and meteorological conditions of its province. So extrapolation to the provincial level of the results obtained for a specific city as part of this study – without prior adjustments for climatic conditions – is not advised.

[3] The concept of degree-days of heating is used to estimate building heating needs. For every degree for which the daily average temperature is below 18℃ (it is considered that below this threshold, heating must be used to maintain a temperature in the comfort zone), we count a degree-day of heating. Therefore, if the daily average for a day is 15℃, three (3) degree-days of heating will be accounted for. However, if no heating is necessary, that is, if the temperature is above 18℃, the number of degree-days will be zero. With this method, calculations concerning the use of heating systems are more exact and take into consideration the meteorological particularities of each city.

To illustrate the importance of geoexchange systems in the process of GHG reduction, we propose an analysis that relies on a certain number of scenarios, providing evidence of the recurring advantages of geoexchange systems.

Table 4 summarizes the Canadian potential for GHG reduction for various geoexchange system penetration rates. The data show the potential for GHG reduction for all single-family homes of 2,000 ft^2 (185m^2) in Canada using various forms of heating, compared to a geoexchange system with a COP of 2.8, which is the reference used throughout this document for provincial analyses.

Table 4
GHG savings potential in Canada compared with different Geoexchange market penetration scenarios, considering replacement of actual heating systems

Market penetration*	***2%***	***4%***	***8%***	***16%***
Electric baseboard				
GHG savings (tons CO_2 eq.)	115 350	230 701	461 402	922 804
Natural gas				
GHG savings (tons CO_2 eq.)	201 589	403 178	806 356	1 612 713
Oil				
GHG savings (tons CO_2 eq.)	59 315	118 630	237 261	474 521
Total				
GHG savings (tons CO_2 eq.)	376 255	752 510	1 505 019	3 010 038
Equivalent number of cars	111 981	223 961	447 922	895 845

*There are 7 181 000 single detached houses in Canada (OEE 2006b)

It is useful, and important, to note here that replacement of oil heating systems represents the greatest potential for GHG reduction at the level of a single-family home. On the other hand, Canada-wide, the replacement of natural gas heating systems with geoexchange systems represents the greatest global potential, since natural gas is used for space heating in almost half the single-family homes in the country (OEE 2006a).

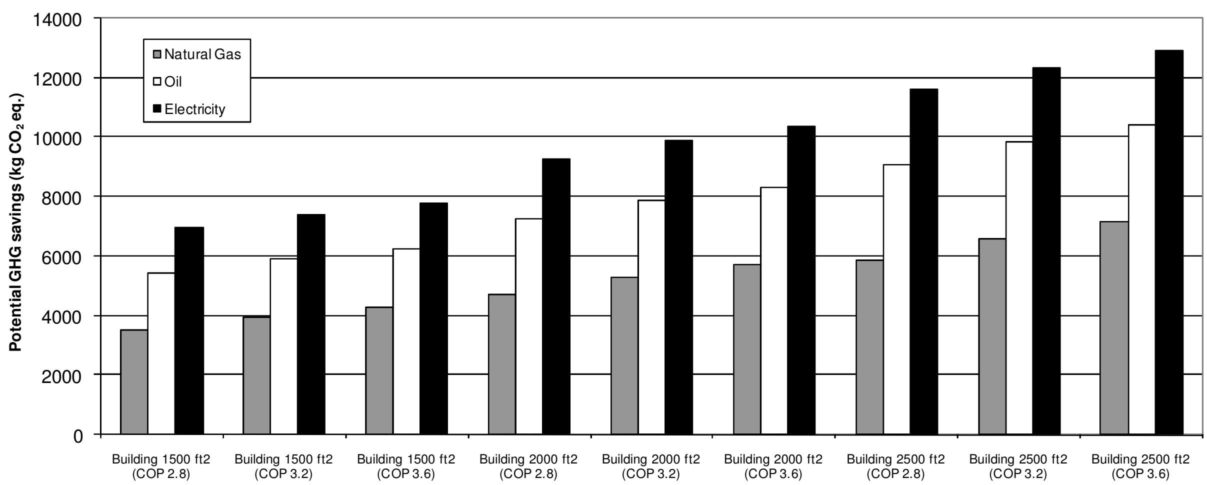
Note also that the data presented in Table 4 reflect only the potential reductions in GHGs from single-family homes in Canada, and do not take the commercial, institutional and industrial sectors into account at all. So it is clear that geoexchange systems possess a potential for GHG emission reductions that is much higher than the partial potential shown here.

Furthermore, Figure 1 illustrates the progression of GHG reductions enabled by an increase in performance (COP) of geoexchange systems. The figure also clearly gives evidence of the direct relationship between increasing the building area and the total volume of GHGs avoided. With regard to system performance, three theoretical COPs were used for purposes of this study: 2.8, 3.2 and 3.6.

It is clear that the progression of the COP from 2.8 to 3.2 and from 3.2 to 3.6 enables additional reductions in GHGs of 6.4% and 4.7% in the case of electric systems substitutions. In addition, it should be noted that these reductions are cumulative. Stated differently, an increase in the COP from 2.8 to 3.6 represents a reduction of 11.1%. In the case of replacing natural gas and heating oil, we obtain supplementary reductions on the order of 12,5% and 8,6% for natural gas and 8,2% and 5,9% for heating oil.

If we look at the potential for GHG reductions from the point of view of building size, the results are consistent with the logic: higher gross energy consumption in large buildings will result in a higher potential GHG reduction if geoexchange systems are adopted. The results demonstrate that, all other things being equal, buildings of 2,000 ft^2 (185m^2) have a reduction potential that is 33% higher than that of buildings with an area of 1,500 ft^2 (140m^2). For a building of 2,500 ft^2 (230m^2), this increase in potential is 67% compared to the potential of buildings of 1,500 ft^2 (140m^2).

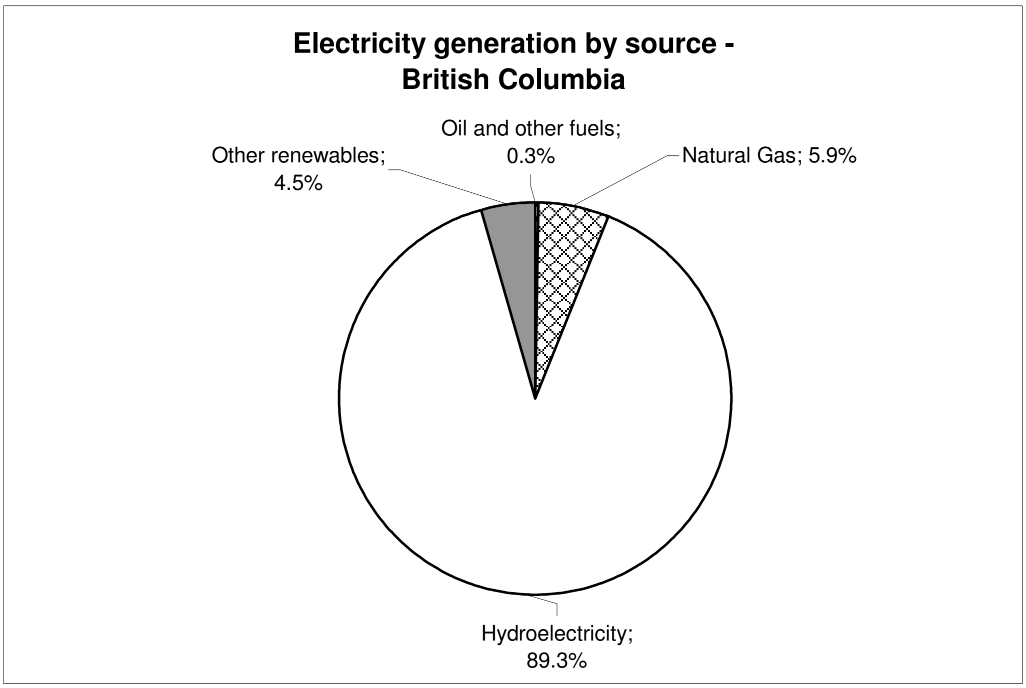
Figure 1 - Potential GHG reductions for a single-detached house in Canada



British Columbia

As illustrated in Figure 2, the majority of the electricity produced in British Columbia comes from hydroelectric power stations. Since hydroelectricity is considered to be a low emitter of GHGs, and since 86% of the emissions in this province resulted from the use of other forms of energy in 2007 (Environment Canada 2009a), British Columbia occupies second place for the lowest emitters of GHGs per capita in Canada, just slightly ahead of Quebec. In addition, even though its population represents 13% of the Canadian population, the province contributes only 8.5% of the country's GHG emissions, or a total volume of 63.1 Mt of GHGs emitted annually (see Appendix C). However, British Columbia has nevertheless seen its GHG emissions increase by 28% since 1990 (Environment Canada 2008). This increase comes essentially from the sub-sectors of mining operations and fossil fuel industries.

Figure 2



Source : Statistics Canada 2007b

With sometimes unfavourable hydraulic conditions, the province, to satisfy internal demand, must at times import its electricity from the United States, where there exists a significant exchange market with California. In addition, the electricity produced in British Columbia is frequently transmitted to Alberta during peak hours, and the reverse is true outside of peak hours. Therefore, if we include electricity imports and exports in calculating the GHG emissions in the electricity sector, we observe an increase in emission intensity, as illustrated in Table 3. With this new calculation, it is estimated that the intensity of GHG emissions is 53 tons of CO_2 eq./GWh, which remains relatively low compared to the other Canadian provinces. In 2003, more than one-quarter (27.4%) of the electricity demand came from the residential sector (ONE 2006). Despite the strong contribution of hydroelectricity, natural gas dominates as the heating method in single-family homes in British Columbia (see Table 5).

Table 5 Residential heating system shares in British Columbia								
	Oil			***Natural Gas***			***Electric baseboard***	***Other***
Efficiency	**Normal**	**Mid**	**High**	**Normal**	**Mid**	**High**		
Share (%)	1,4	0,8	0	31,5	12,4	10,2	26,4	17,3

Source: OEE 2006b

Table 7, which appears at the end of this section on British Columbia, shows that considerable reductions in GHGs are possible with increased use of geoexchange systems. Note that the reductions are even more significant if we compare a geoexchange system to an oil heating system. The reductions remain considerable if we compare them to the conventional natural gas system, with a reduction of almost 5 tons annually.

To properly illustrate what a reduction of 5 tons represents annually for a single-family home, Table 6 presents the possible reductions at the provincial level with various market penetration rates for geoexchange systems. As mentioned in the *Methodology* section, the data used are those corresponding to a building of 2,000 ft^2 ($185m^2$) with average insulation while conventional heating systems are compared to geoexchange systems with a COP of 2.8. In addition, the proportion of the number of single-family homes using the various types of systems has been used in order to make the analysis realistic. Thus the calculations of market penetration and the resulting reductions are based on the number of homes that have a specific system, and not on the total number of single-family homes in British Columbia. To clarify, in order to increase the precision of our analysis, we have used the data from Table 4 without taking into account the proportion of homes that use other types of heating systems (17.3%).

Table 6
GHG savings potential in British Columbia compared with different Geoexchange market penetration scenarios, considering replacement of actual heating systems

Market penetration*	***2%***	***4%***	***8%***	***16%***
Electric baseboard				
GHG savings (tons CO_2 eq.)	4 383	8 765	17 531	35 062
Natural gas				
GHG savings (tons CO_2 eq.)	54 376	108 752	217 504	435 008
Oil				
GHG savings (tons CO_2 eq.)	3 202	6 404	12 807	25 614
Total				
GHG savings (tons CO_2 eq.)	61 961	123 921	247 842	495 684
Equivalent number of cars	18 441	36 881	73 763	147 525

*There are 970 000 single detached houses in British Columbia (OEE 2006b)

In summary, from a perspective of GHG emission reductions, British Columbia would derive great benefit from promoting the increased use of geoexchange systems. For every percentage point of penetration of geoexchange systems in the province's residential sector, a reduction of about 31,000 tons of CO_2 eq. would be observed.

Victoria, BC

Table 7: Annual GHG emissions (kg CO_2 eq.) - Heating only

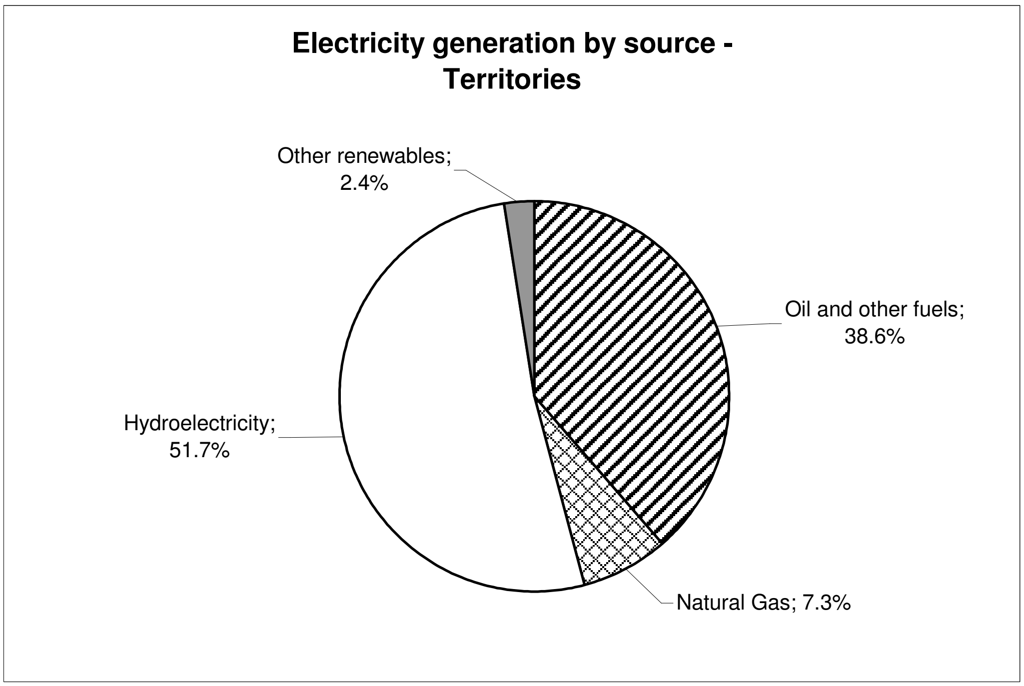
Degree-Days			**Building 1500 ft² (140 m²)**			**Building 2000 ft² (185 m²)**			**Building 2500 ft² (230 m²)**		
3041			Low	Mid	High	Low	Mid	High	Low	Mid	High
		Btu/h	24339	18722	14402	32451	24962	19202	40563	31202	24002
	COP										
Electricity											
Conventional	0,95		1263	971	747	1684	1295	996	2105	1619	1245
Geoexchange - HP	2,8		428	330	254	571	439	338	714	549	423
Geoexchange - HP	3,2		375	288	222	500	385	296	625	481	370
Geoexchange - HP	3,6		333	256	197	444	342	263	555	427	329
Natural gas											
Normal efficiency	0,75		5856	4505	3465	7808	6006	4620	9760	7508	5775
Medium efficiency	0,84		5229	4022	3094	6972	5363	4125	8714	6703	5156
High efficiency	0,95		4623	3556	2736	6164	4742	3648	7705	5927	4559
Oil											
Normal efficiency	0,75		8057	6198	4767	10742	8263	6356	13428	10329	7945
Medium efficiency	0,84		7194	5534	4257	9591	7378	5675	11989	9222	7094
High efficiency	0,9		6714	5165	3973	8952	6886	5297	11190	8607	6621

Data provided by CGC

The Territories

The territories (Yukon, Northwest Territories and Nunavut) represent almost 40% of Canada's land area. However, the territories have a very low population density. Based on this fact, a considerable proportion of the electricity production capacity is decentralized and relies on the use of heating oil (ONE 2006). Beyond this generalization, each of the territories has characteristics specific to itself. In the Yukon, hydroelectricity largely dominates, while in the Northwest Territories the production is divided between hydroelectricity and diesel. Nunavut is the only place in the country that depends entirely on diesel fuel for electricity. However, despite these notable differences, the data concerning the three territories are often grouped together for statistical purposes. In addition, data collected before 1999 for establishing the distinction between the Northwest Territories and Nunavut are not available. The analysis of the three territories is, while imperfect, a good reflection of the available statistics.

Figure 3



Source : Statistics Canada 2007b

Together, the three territories represent 0.3% of the Canadian population, and each contributes as much as the others to the country's GHG emissions. Note that the territories are among the rare regions in Canada where total GHG emissions have decreased since 1990. Despite the fact that the natural gas, mining and oil industries are omnipresent in this region, the Yukon, for example, has seen its GHG emissions decrease by 24.6% since 1990. This decrease is primarily attributable to a reduction in emissions from fossil fuels for electricity production, gasoline automobiles and a decrease in emissions in the commercial and institutional sub-sectors.

However, this considerable decrease has been attenuated at the level of the three territories by an increase in GHG emissions on the order of 21.5% compared to 1990 in the Northwest Territories and Nunavut (Environment Canada 2009a). So if the Yukon were the subject of a distinct analysis, its emissions per capita would place it in 2nd position for lowest emitters in the country, just after Quebec.

However, the three territories combined emit on average 21.4 tons of CO_2 per inhabitant per year, which places them slightly above the median for the Canadian provinces. The intensity of GHG emissions is 84 tons of CO_2 eq./GWh, which is similar to that of Manitoba. This comparison is not surprising, since more than half of the electricity produced in the territories comes from hydroelectric sources (see Figure 3). In addition, in these far-flung regions, heating oil largely dominates as the method for heating buildings, a situation that leads to greater potential reductions of GHGs (see Table 8).

Table 8

Residential heating system shares in the Territories

	Oil			***Natural Gas***			***Electric baseboard***	***Other***
Efficiency	**Normal**	**Mid**	**High**	**Normal**	**Mid**	**High**		
Share (%)	47,5	19,5	0	2,5	7,6	6,3	2,8	13,8

Source: OEE 2006b

Table 9

GHG savings potential in the Territories compared with different Geoexchange market penetration scenarios, considering replacement of actual heating systems

Market penetration*	***2%***	***4%***	***8%***	***16%***
Electric baseboard				
GHG savings (tons CO_2 eq.)	36	71	143	286
Natural gas				
GHG savings (tons CO_2 eq.)	875	1 750	3 500	7 000
Oil				
GHG savings (tons CO_2 eq.)	4 607	9 213	18 426	36 853
Total				
GHG savings (tons CO_2 eq.)	5 517	11 035	22 069	44 139
Equivalent number of cars	1 642	3 284	6 568	13 137

*There are 21 000 single detached houses in the Territories (OEE 2006b)

Although additional variables must be taken into consideration in these regions when installing a geoexchange system (e.g.: presence of permafrost), the territories represent an interesting market for the geoexchange industry. An increase in the penetration rate would reflect favourably in a reduction in the consumption of fossil fuels (in particular heating oil) and in reduced GHG emissions.

Whitehorse, YT

Table 10: Annual GHG emissions (kg CO_2 eq.) - Heating only

Degree-Days			**Building 1500 ft² (140 m²)**			**Building 2000 ft² (185 m²)**			**Building 2500 ft² (230 m²)**		
6811			Low	Mid	High	Low	Mid	High	Low	Mid	High
		Btu/h	62434	48026	36943	83243	64033	49256	104052	80040	61569
	COP										
Electricity											
Conventional	0,95		4483	3448	2652	5977	4597	3537	7471	5747	4421
Geoexchange - HP	2,8		1521	1170	900	2028	1560	1200	2535	1950	1500
Geoexchange - HP	3,2		1331	1024	787	1774	1365	1050	2218	1706	1312
Geoexchange - HP	3,6		1183	910	700	1577	1213	933	1971	1517	1167
Natural gas											
Normal efficiency	0,75		15995	12304	9464	21326	16405	12619	26657	20505	15773
Medium efficiency	0,84		14281	10985	8450	19041	14647	11267	23801	18308	14083
High efficiency	0,95		12627	9713	7472	16836	12951	9962	21045	16188	12453
Oil											
Normal efficiency	0,75		18045	13881	10678	24060	18507	14236	30074	23134	17795
Medium efficiency	0,84		16112	12394	9534	21482	16524	12711	26852	20655	15889
High efficiency	0,9		15038	11567	8898	20050	15423	11864	25062	19278	14829

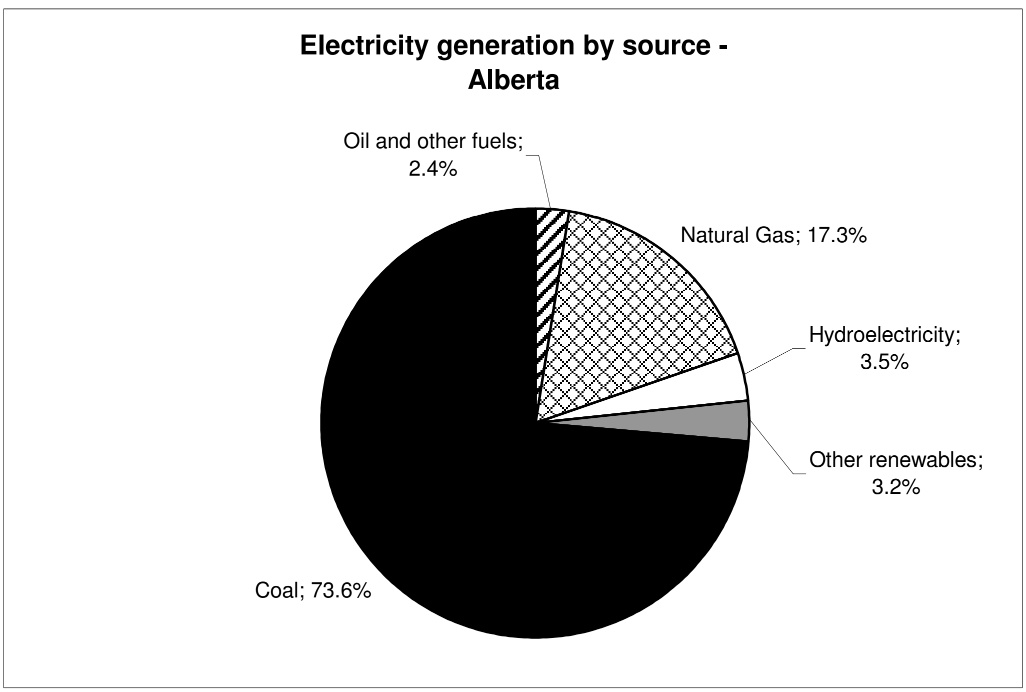
Data provided by CGC

Alberta

The high intensity of the use of fossil fuels for electricity production in Alberta means that we observe high levels of GHG emissions, at 872 tons CO_2 eq./GWh. Alberta stands in 2nd place for the highest emitters per inhabitant, closely following Saskatchewan. In absolute numbers, Alberta is the largest emitter of GHGs in the country, contributing 33.2% of the total volume of GHGs emitted in Canada. With an impressive participation in primary energy production in Canada (64%), sustained demographic growth (38%), a high and rapidly-growing electricity demand and an increased use of road transportation (primarily as a consequence of activities relating to the exploitation of oil sands), it is not surprising to note that GHG emissions in Alberta have increased by 43.7% since 1990 (Environment Canada 2009a).

With regard to electricity production, almost three-quarters come from coal, which can be explained by the abundance of coal resources in the province and its low potential with regard to hydroelectric resources. Natural gas occupies second place for sources of electricity production, with 17% of Alberta's production capacity. As mentioned previously, Alberta imports significant quantities of electricity from British Columbia during peak hours, and, to a lesser extent, from Saskatchewan and the United States.

Figure 4



Source : Statistics Canada 2007b

The industrial sector largely dominates the province's energy consumption. With regard to heating, natural gas is mainly used for its low cost (thanks to subsidies awarded by the provincial government) and for its environmental impact, which is less than that of electricity produced from coal (see Table 11).

Table 11 Residential heating system shares in Alberta								
	Oil			Natural Gas			Electric baseboard	Other
Efficiency	**Normal**	**Mid**	**High**	**Normal**	**Mid**	**High**		
Share (%)	0	0,8	0	44,7	47,4	0	2,6	4,5

Source: OEE 2006b

Table 13 shows us that geoexchange systems and natural gas present similar situations with regard to GHG emissions for the province's residential sector. According to the hypotheses used in this study, which are aimed at establishing both interprovincial and intraprovincial comparisons, we note a marginal minimal advantage for natural gas, since the electricity used by the heat pump of a geoexchange system comes essentially from coal sources and thus emits a large amount of GHGs.[4] It should be noted that a geoexchange system with a high COP compared to a high efficiency gas furnace whose theoretical performance is reduced by a lack of maintenance will make geoexchange more attractive from a GHG emissions perspective.

In comparison to heating oil, although this source of energy is relatively little used for residential heating in the province, geoexchange systems are evidently advantageous from an environmental perspective. What draws attention in the detailed analysis of Table 13 is the net environmental advantage of geoexchange systems compared to electric furnaces. As mentioned above, this major gap can be explained by the source of the electricity in Alberta. Table 13 clearly demonstrates that the direct use of electricity as a source of heating is not the best heating option in Alberta. Once again, the table that follows takes into account the proportions of use of the various heating systems in the province.

Table 12 GHG savings potential in Alberta compared with different Geoexchange market penetration scenarios, considering replacement of actual heating systems				
Market penetration*	***2%***	***4%***	***8%***	***16%***
Electric baseboard				
GHG savings (tons CO_2 eq.)	11 763	23 526	47 052	94 105
Natural gas				
GHG savings (tons CO_2 eq.)	(43 276)	(86 553)	(173 105)	(346 210)
Oil				
GHG savings (tons CO_2 eq.)	38	76	152	304
Total				
GHG savings (tons CO_2 eq.)	(31 475)	(62 950)	(125 900)	(251 801)
Equivalent number of cars	-	-	-	-

*There are 856 000 single detached houses in Alberta (OEE 2006b)

In Alberta, as in all provinces of Canada, and from a perspective of GHG emission reductions, geoexchange systems are advantageous compared to electric heating. Still from this perspective of GHG emissions, and taking into account the hypotheses used in this study, natural gas heating presents a slim advantage, primarily because of the sources of electricity production.

[4] Considering the relative position of geoexchange systems and natural gas for residential heating in Alberta with regard to GHG emissions, which reflects the current state of electricity markets and does not at all take into account the life cycle, we invite readers to interpret the results presented here with the greatest prudence. Note also that these results should in no way be extrapolated to the commercial sector. In that sector, one might think that the addition of the air conditioning load into the comparative analysis would likely favour geoexchange systems.

However, this situation could change following any increased introduction of electricity production units from renewable sources (e.g.: wind power), which would contribute to favourably improving the environmental competitiveness of geoexchange systems.

In addition, it is important to repeat that the scenarios used are "conservative" and that better coefficients of performance are easily attainable as long as the geoexchange system has been adequately designed and installed.

Furthermore, recall that the *Office of Energy Efficiency* (2009) defined a heating system of normal efficiency as a system having an average annual energy yield lower than 78 p. 100. Also note that, according to the data supplied by the *Office of Energy Efficiency* presented in Table 11, almost half of natural gas heating systems in Alberta are of normal efficiency. Thus the potential for conversion of these systems to geoexchange systems is enormous.

Edmonton, AB

Table 13: Annual GHG emissions (kg CO_2 eq.) - Heating only

Degree-Days			Building 1500 ft² (140 m²)			Building 2000 ft² (185 m²)			Building 2500 ft² (230 m²)		
5708			Low	Mid	High	Low	Mid	High	Low	Mid	High
		Btu/h	52910	40700	31308	70545	54265	41743	88180	67831	52177
	COP										
Electricity											
Conventional	0,95		38998	29999	23076	51997	39997	30767	64995	49996	38458
Geoexchange - HP	2,8		13232	10178	7829	17642	13571	10439	22052	16963	13048
Geoexchange - HP	3,2		11578	8906	6851	15436	11874	9134	19295	14843	11417
Geoexchange - HP	3,6		10291	7916	6089	13721	10555	8119	17151	13193	10149
Natural gas											
Normal efficiency	0,75		11172	8593	6610	14895	11458	8814	18618	14322	11017
Medium efficiency	0,84		9975	7673	5902	13299	10230	7869	16624	12787	9836
High efficiency	0,95		8820	6784	5219	11759	9046	6958	14699	11307	8698
Oil											
Normal efficiency	0,75		15123	11633	8948	20163	15510	11931	25204	19387	14913
Medium efficiency	0,84		13503	10387	7990	18003	13848	10653	22503	17310	13316
High efficiency	0,9		12602	9694	7457	16803	12925	9942	21003	16156	12428

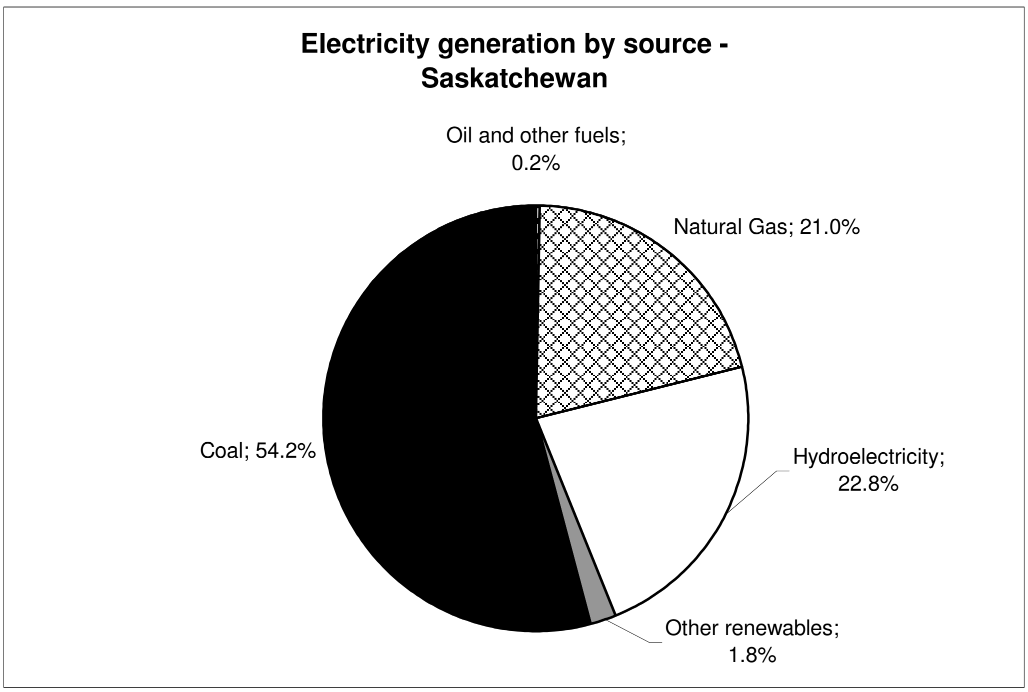
Data provided by CGC

Saskatchewan

With an increase in GHG emissions of 66% since 1990 (the national average being 26.2%) and a GHG emission intensity in the electricity sector standing at 782 tons CO_2 eq./GWh (placing Saskatchewan in 2nd place at this level, just after Alberta), Saskatchewan is among the most polluting provinces in Canada. In addition, with an economy centered on natural resources and a small population size (see Appendix B), the GHG emission intensity in the province is 72.2 tons per inhabitant, which is the highest ratio in the country (Environment Canada 2009a).

These statistics reflect the high proportion of electricity production capacity from coal, the proportion being 54.2%. In addition, almost 80% of GHG emission sources in Saskatchewan come from sectors associated with energy, thus contributing greatly to the province's increase in GHG emissions (Environment Canada 2009a). Furthermore, the sources of heating for residences in Saskatchewan are similar to those in Alberta, as natural gas heating systems dominate in single-family homes (see Table 14).

Figure 5



Source : Statistics Canada 2007b

Table 14 Residential heating system shares in Saskatchewan								
	Oil			***Natural Gas***			***Electric baseboard***	***Other***
Efficiency	**Normal**	**Mid**	**High**	**Normal**	**Mid**	**High**		
Share (%)	0,6	0,7	0	46,9	20,9	17,7	4,2	9

Source: OEE 2006b

The results presented in Table 16 on annual GHG emissions of the various heating systems suggest once again an environmental benefit for geoexchange systems compared with all other types of heating systems. We note a sizable advantage in reduction of GHG emissions in comparing geoexchange systems to electric furnaces which, once again, can be easily explained by the significant use of coal for electricity production in Saskatchewan (see Table 15).

From a GHG emissions perspective, geoexchange has proven to be the most ecological option compared to other types of heating systems that were studied. Furthermore, the useful lifespan of many coal-fired power plants in Saskatchewan will be reached during the coming decade (ONE 2006). Consequently, one might presume that the province's structure for electricity production will undergo certain changes that will likely modify the intensity of GHG emissions in the province.

In parallel, the introduction of cleaner sources of energy is on the increase in Saskatchewan, as shown by the opening in 2006 of one of the largest wind farms in Canada. Certain new technologies, for example coal-fired power plants that have the ability to capture and store all of the GHGs they emit – the Clean Coal[TM] project – could also have a favourable impact on the reduction of GHG emissions from electricity production in Saskatchewan. Should that be the case, and depending on the speed with which these technologies are introduced, the GHG reductions from geoexchange systems would increase proportionally based on the number of these installations.

Table 15 GHG savings potential in Saskatchewan compared with different Geoexchange market penetration scenarios, considering replacement of actual heating systems				
Market penetration*	***2%***	***4%***	***8%***	***16%***
Electric baseboard				
GHG savings (tons CO_2 eq.)	5 824	11 649	23 297	46 595
Natural gas				
GHG savings (tons CO_2 eq.)	1 925	3 850	7 701	15 401
Oil				
GHG savings (tons CO_2 eq.)	186	372	744	1 488
Total				
GHG savings (tons CO_2 eq.)	7 936	15 871	31 742	63 484
Equivalent number of cars	-	-	-	-

*There are 295 000 single detached houses in Saskatchewan (OEE 2006b)

As suggested by the *GHG Protocol* of the World Resource Institute (WRI 2007), it would also be interesting to analyze the markets from the perspective of integrating marginal electricity sources into the network, that is, sources for which usage would be reduced following a decrease in the demand for electricity or, inversely, the production method avoided if there is an increase in demand.

Appendix D presents such a marginal analysis for Saskatchewan. Looking at the scenario of a 2,000 ft^2 (185 m^2) residence with superior insulation as well as a high-performance heating system (efficiency of 95% for a natural gas furnace and a COP of 3.6 for a geoexchange system), we obtain optimal results for the two technologies. So in these conditions, installation of a geoexchange system would reduce the GHG emissions by almost 6 tons.

Regina, SK

Table 16: Annual GHG emissions (kg CO_2 eq.) - Heating only

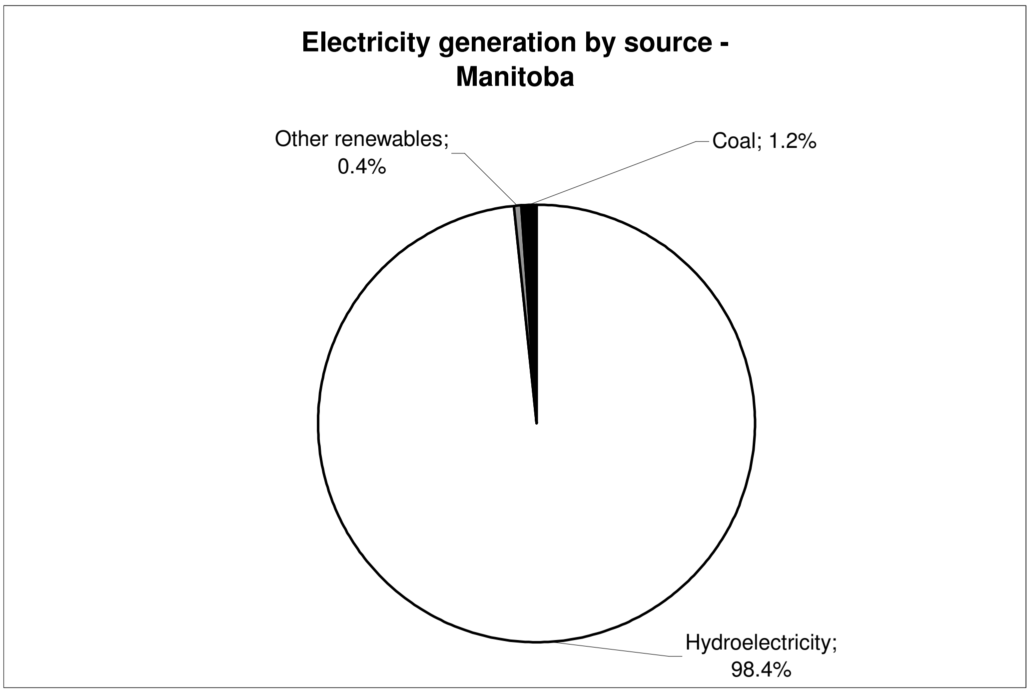
Degree-Days			**Building 1500 ft² (140 m²)**			**Building 2000 ft² (185 m²)**			**Building 2500 ft² (230 m²)**		
5661			Low	Mid	High	Low	Mid	High	Low	Mid	High
		Btu/h	55026	42328	32560	73367	56436	43412	91707	70544	54264
	COP										
Electricity											
Conventional	0,95		34685	26681	20524	46246	35574	27364	57807	44467	34205
Geoexchange - HP	2,8		11768	9052	6963	15691	12070	9284	19613	15087	11605
Geoexchange - HP	3,2		10297	7921	6093	13729	10561	8124	17161	13201	10155
Geoexchange - HP	3,6		9153	7041	5416	12204	9388	7221	15255	11734	9026
Natural gas											
Normal efficiency	0,75		13051	10039	7722	17401	13385	10296	21751	16731	12870
Medium efficiency	0,84		11653	8964	6895	15536	11951	9193	19420	14939	11491
High efficiency	0,95		10303	7926	6097	13738	10567	8129	17172	13209	10161
Oil											
Normal efficiency	0,75		14998	11537	8875	19997	15382	11833	24996	19228	14791
Medium efficiency	0,84		13391	10301	7924	17855	13734	10565	22318	17168	13206
High efficiency	0,9		12499	9614	7396	16664	12819	9861	20830	16023	12326

Data provided by CGC

Manitoba

In Manitoba, almost all of the electricity production comes from hydroelectric power plants. During dry periods, Manitoba sometimes imports electricity from the United States, but, generally speaking, the province is a net exporter of electricity (ONE 2006). Despite the importance of its hydroelectric capacity, Manitoba's GHG emissions have risen by 14.5% since 1990. This increase is noteworthy in that it is largely attributable to the agricultural sector and not the energy sector, which is responsible for only a low percentage of the province's emissions, a particularity specific to Manitoba (Environment Canada 2009a).

Figure 6



Source : Statistics Canada 2007b

Electrical heating is fairly popular in Manitoba, representing almost 30% of residential heating systems. However, natural gas prevails as the method of heating in the majority of single-family homes (see Table 17). Note that since 1990, GHG emissions from the residential sector have fallen considerably, a drop primarily attributable to the replacement of oil heating systems with electrical heating systems.

Furthermore, the electricity rates in the province are among the lowest in North America. The use of electrical heating systems constitutes an economic advantage for customers. The low intensity of GHG emissions from the province's electricity sector (105 tons CO_2 eq./GWh) means that increased use of geoexchange systems would lead to significant reductions in GHG emissions compared to natural gas or oil heating systems (see Table 18).

Table 17 Residential heating system shares in Manitoba								
	Oil			*Natural Gas*			*Electric baseboard*	*Other*
Efficiency	**Normal**	**Mid**	**High**	**Normal**	**Mid**	**High**		
Share (%)	0,1	1,2	0	23,1	19,1	15,7	29,9	10,9

Source: OEE 2006b

Table 18 GHG savings potential in Manitoba compared with different Geoexchange market penetration scenarios, considering replacement of actual heating systems				
Market penetration*	***2%***	***4%***	***8%***	***16%***
Electric baseboard				
GHG savings (tons CO_2 eq.)	6 259	12 518	25 037	50 074
Natural gas				
GHG savings (tons CO_2 eq.)	31 577	63 154	126 308	252 615
Oil				
GHG savings (tons CO_2 eq.)	1 056	2 111	4 222	8 444
Total				
GHG savings (tons CO_2 eq.)	38 892	77 783	155 567	311 133
Equivalent number of cars	11 575	23 150	46 300	92 599

*There are 325 000 single detached houses in Manitoba (OEE 2006b)

Since hydroelectric resources represent a major portion of the electricity production in Manitoba, geoexchange systems are the preferred solution for replacing natural gas, oil and electric baseboard heaters in order to reduce the GHGs emitted by residential buildings. The same logic applies to new residential buildings.

Winnipeg, MB

Table 19: Annual GHG emissions (kg CO_2 eq.) - Heating only

Degree-Days			**Building 1500 ft² (140 m²)**			**Building 2000 ft² (185 m²)**			**Building 2500 ft² (230 m²)**		
5777			Low	Mid	High	Low	Mid	High	Low	Mid	High
		Btu/h	53968	41514	31934	71956	55351	42577	89943	69187	53221
	COP										
Electricity											
Conventional	0,95		4753	3656	2812	6337	4874	3750	7921	6093	4687
Geoexchange - HP	2,8		1613	1240	954	2150	1654	1272	2687	2067	1590
Geoexchange - HP	3,2		1411	1085	835	1881	1447	1113	2351	1809	1391
Geoexchange - HP	3,6		1254	965	742	1672	1286	989	2090	1608	1237
Natural gas											
Normal efficiency	0,75		10791	8300	6385	14387	11067	8513	17984	13834	10641
Medium efficiency	0,84		9634	7411	5701	12846	9881	7601	16057	12351	9501
High efficiency	0,95		8519	6553	5041	11358	8737	6721	14198	10921	8401
Oil											
Normal efficiency	0,75		15306	11774	9057	20407	15698	12075	25508	19622	15094
Medium efficiency	0,84		13666	10512	8086	18221	14016	10781	22775	17519	13477
High efficiency	0,9		12755	9811	7547	17006	13081	10063	21257	16352	12578

Data provided by CGC

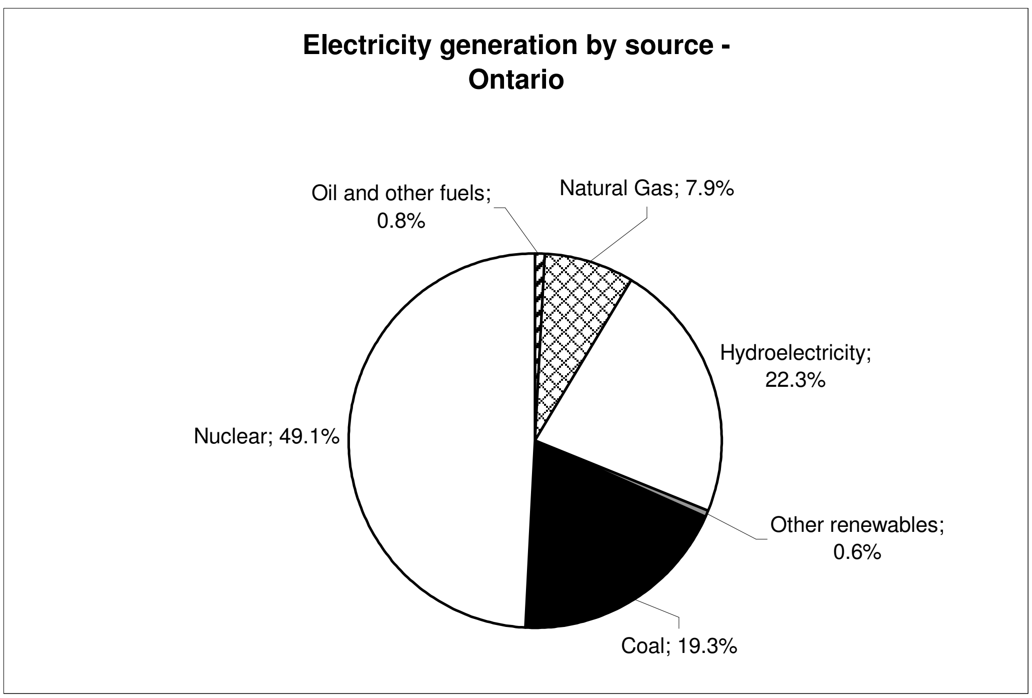
Ontario

Like the majority of the Canadian provinces, Ontario has seen its GHG emissions climb (by 13%) since 1990 (Environment Canada 2009a). With almost 40% of the Canadian population, it is evident that a significant proportion of the emissions come from road transportation, although the emissions from the residential, commercial and institutional sectors also contribute partly to this increase.

However, the province is in third place for the lowest GHG emissions per inhabitant. Its economy is dominated by manufacturing industries, a sector with low energy intensity. From the perspective of electricity production, Ontario has the most nuclear power in Canada, with hydroelectric resources and coal following in almost equal parts.

Electricity imports come mainly from the United States, and to a lesser extent from Quebec. These also play a significant role with regard to the electricity supply structure of the province. With this variety of energy sources, the intensity of GHG emissions is 228 tons CO_2 eq./GWh, situating it slightly below the Canadian average.

Figure 7



Source : Statistics Canada 2007b

Table 20 Residential heating system shares in Ontario								
	Oil			*Natural Gas*			*Electric baseboard*	*Other*
Efficiency	**Normal**	**Mid**	**High**	**Normal**	**Mid**	**High**		
Share (%)	1,0	2,9	0	27,3	21,6	18,5	11,3	17,4

Source: OEE 2006b

Natural gas is the fuel of choice for heating of single-family homes in Ontario. Greater penetration of geoexchange systems into the market for single-family homes that have a natural gas heating system would enable significant GHG reductions, as indicated in Table 21.

Table 21 GHG savings potential in Ontario compared with different Geoexchange market penetration scenarios, considering replacement of actual heating systems				
Market penetration*	***2%***	***4%***	***8%***	***16%***
Electric baseboard				
GHG savings (tons CO_2 eq.)	27 455	54 909	109 819	219 638
Natural gas				
GHG savings (tons CO_2 eq.)	143 554	287 108	574 216	1 148 431
Oil				
GHG savings (tons CO_2 eq.)	14 709	29 418	58 837	117 673
Total				
GHG savings (tons CO_2 eq.)	185 718	371 435	742 871	1 485 742
Equivalent number of cars	55 273	110 546	221 093	442 185

*There are 2 811 000 single detached houses in Ontario (OEE 2006b)

Toronto, ON

Table 22: Annual GHG emissions (kg CO_2 eq.) - Heating only

Degree-Days			**Building 1500 ft² (140 m²)**			**Building 2000 ft² (185 m²)**			**Building 2500 ft² (230 m²)**		
3570			Low	Mid	High	Low	Mid	High	Low	Mid	High
		Btu/h	38095	29304	22542	50792	39071	30055	63489	48838	37568
	COP										
Electricity											
Conventional	0,95		6377	4906	3774	8503	6541	5031	10629	8176	6289
Geoexchange - HP	2,8		2164	1664	1280	2885	2219	1707	3606	2774	2134
Geoexchange - HP	3,2		1893	1456	1120	2524	1942	1494	3155	2427	1867
Geoexchange - HP	3,6		1683	1295	996	2244	1726	1328	2805	2158	1660
Natural gas											
Normal efficiency	0,75		6452	4963	3818	8602	6617	5090	10753	8271	6363
Medium efficiency	0,84		5761	4431	3409	7681	5908	4545	9601	7385	5681
High efficiency	0,95		5094	3918	3014	6791	5224	4019	8489	6530	5023
Oil											
Normal efficiency	0,75		9458	7276	5597	12611	9701	7462	15763	12126	9327
Medium efficiency	0,84		8445	6496	4997	11260	8661	6663	14074	10826	8328
High efficiency	0,9		7882	6063	4664	10509	8084	6218	13136	10105	7773

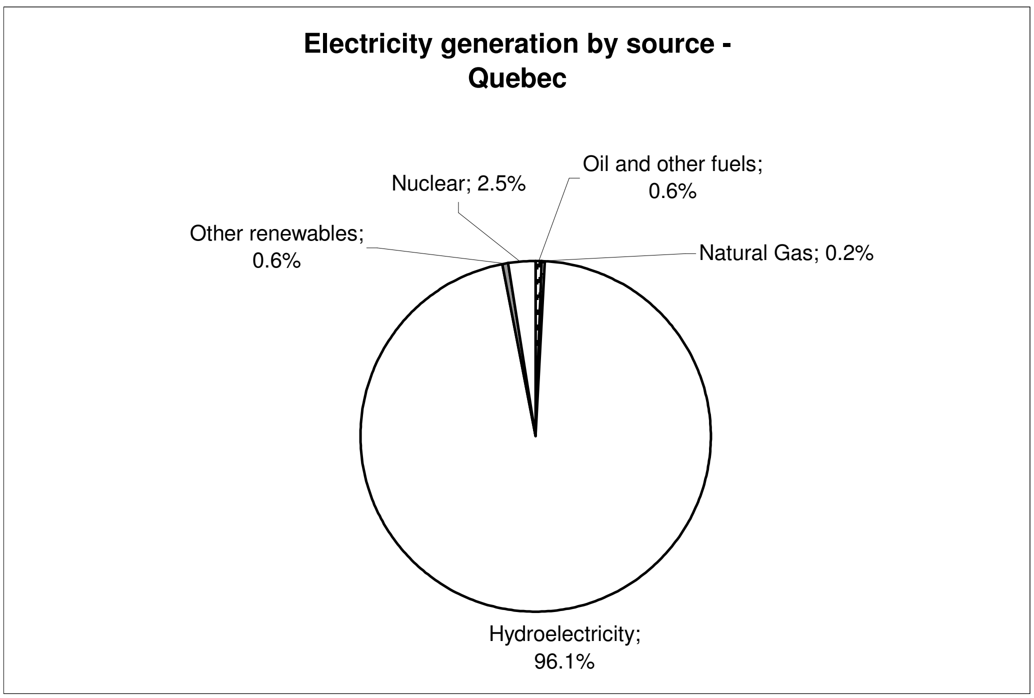
Data provided by CGC

Quebec

Quebec is the largest electricity market in Canada, accounting for 27% of total electricity production in the country, taking all sources together (Environment Canada 2009a). Given the importance of electricity in Quebec's economic structure, and considering that 95% of this comes from hydroelectric sources, Quebec posts the lowest rate of GHG emissions per inhabitant in the country.

Quebec also has the lowest GHG emission intensity per electricity unit (28 tons CO_2 eq./GWh) and is among the rare regions in Canada that have succeeded in decreasing their GHG emissions since 1990. Note however that since 2006, the opening of the Becancour gas co-generation power plant has contributed to increasing the province's GHG emissions (Environment Canada 2009a). Although this power plant is currently not operational, the data used for this study include the emissions from this power plant for the years 2006 and 2007. On the other hand, it is fair to add that the increase in road transportation also contributes strongly to increasing the province's GHG emissions.

Figure 8



Source : Statistics Canada 2007b

The industrial sector, mainly the aluminum and metal transformation industries, account for half of Quebec's electricity consumption (OEE 2006). The low cost of electricity, as well as its accessibility, make electric heating a solution of choice for the majority of Quebec's single-family homes. Note that firewood is still being used as a source of back-up heating; however, this study does not take this type of system into account because many cities are already subject to restrictions with regard to the use of wood stoves.

Table 23 Residential heating system shares in Quebec								
	Oil			Natural Gas			Electric baseboard	Other
Efficiency	**Normal**	**Mid**	**High**	**Normal**	**Mid**	**High**		
Share (%)	0,1	2,1	0	2,0	1,2	1,1	48,9	44,6

Source: OEE 2006b

** The high percentage of this category arises from dual-energy heating systems, which are popular in Quebec. These are mainly a combination of firewood and electricity. In addition, heat pumps occupy 9.6% of the market for heating systems.*

Evidently with the share of electric heating systems so high, the transition from electricity to geoexchange systems as a source of heating represents an immense potential for GHG reductions in Quebec. However, although natural gas represents only 4.3% of residential heating systems in the province, it is interesting to highlight that the possible reductions are equivalent to the potential for baseboard heater reductions, even though these occupy 50% of the market. This equivalence can be explained by the low GHG emissions from the electricity used by the geoexchange heat pump.

Table 24
GHG savings potential in Quebec compared with different Geoexchange market penetration scenarios, considering replacement of actual heating systems

Market penetration*	*2%*	*4%*	*8%*	*16%*
Electric baseboard				
GHG savings (tons CO_2 eq.)	12 464	24 929	49 857	99 715
Natural gas				
GHG savings (tons CO_2 eq.)	12 544	25 087	50 175	100 349
Oil				
GHG savings (tons CO_2 eq.)	8 914	17 827	35 654	71 308
Total				
GHG savings (tons CO_2 eq.)	33 922	67 843	135 686	271 372
Equivalent number of cars	10 096	20 191	40 383	80 766

*There are 1 648 000 single detached houses in Quebec (OEE 2006b)

Note that 5.6% of single-family homes use a combination of firewood and heating oil for space heating, which represents a total of 128,544 homes using heating oil, including those in which heating oil constitutes the only heating source. So the potential reductions from replacing this source with geoexchange systems are immense and easily accessible.

Finally, recall that the figures presented in Table 24 underestimate the real potential of the province, since dual-energy heating systems were excluded from the analysis.

Québec, QC

Table 25: Annual GHG emissions (kg CO_2 eq.) - Heating only

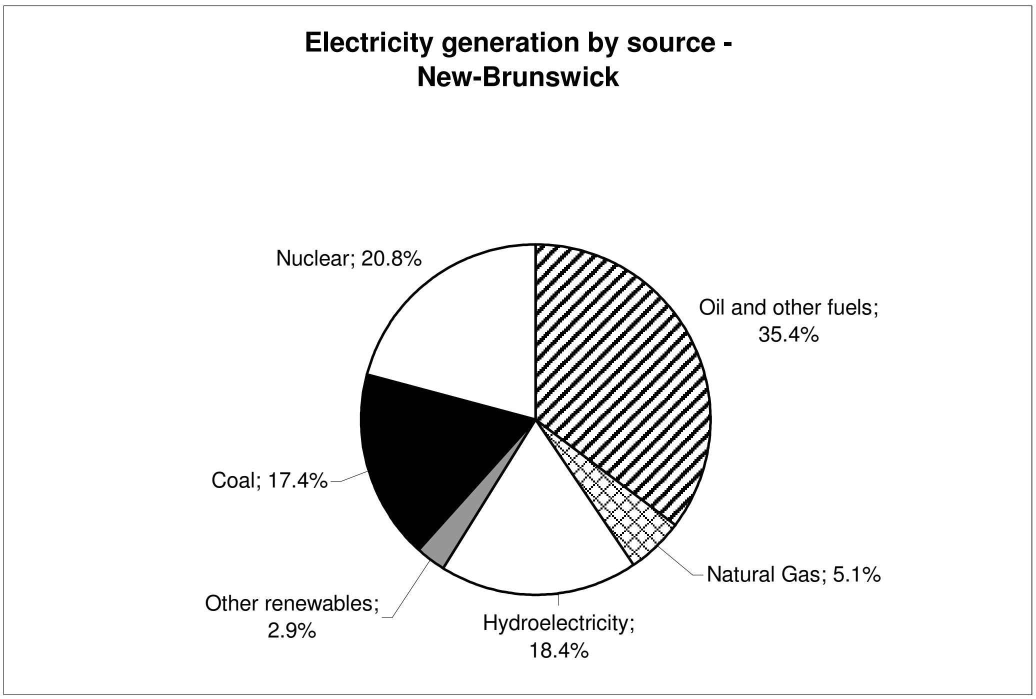
Degree-Days			**Building 1500 ft² (140 m²)**			**Building 2000 ft² (185 m²)**			**Building 2500 ft² (230 m²)**		
5202			Low	Mid	High	Low	Mid	High	Low	Mid	High
		Btu/h	45503	35002	26925	60669	46668	35899	75835	58334	44873
	COP										
Electricity											
Conventional	0,95		1141	878	675	1522	1170	900	1902	1463	1125
Geoexchange - HP	2,8		387	298	229	516	397	305	645	496	382
Geoexchange - HP	3,2		339	261	200	452	347	267	565	434	334
Geoexchange - HP	3,6		301	232	178	402	309	238	502	386	297
Natural gas											
Normal efficiency	0,75		9841	7570	5823	13121	10093	7764	16401	12616	9705
Medium efficiency	0,84		8787	6759	5199	11715	9012	6932	14644	11264	8665
High efficiency	0,95		7769	5976	4597	10359	7968	6129	12948	9960	7662
Oil											
Normal efficiency	0,75		13782	10602	8155	18376	14135	10873	22969	17669	13591
Medium efficiency	0,84		12306	9466	7281	16407	12621	9708	20508	15776	12135
High efficiency	0,9		11485	8835	6796	15313	11779	9061	19141	14724	11326

Data provided by CGC

New Brunswick

New Brunswick displays a diversified use of the various forms of energy, but heating oil dominates slightly. This situation, combined with the non-negligible use of coal, ranks the province in third place among the most polluting provinces per capita, with emissions of 24.9 tons of GHG per inhabitant. With regard to its GHG emission intensity from the electricity sector, New Brunswick ranks slightly above the Canadian average, at 428 tons CO_2 eq./GWh. With regard to total GHG emissions, the province has experienced an increase of 17.4% in its GHG emissions since 1990, the mining, fossil fuel and road transportation sectors having largely contributed to this increase (Environment Canada 2009a). Furthermore, New Brunswick provides 95% of the electrical energy to Prince Edward Island. The impacts relating to these transfers are discussed in detail later in this document.

Figure 9



Source : Statistics Canada 2007b

Like Quebec, electric baseboard heaters dominate for residential heating in New Brunswick and are often combined with firewood (14.8%). However, unlike Quebec, the penetration rate of heating oil in New Brunswick is much higher, accounting for 17.2% of heating systems in the single-family home sector.

Table 26 Residential heating system shares in New-Brunswick								
	Oil			Natural Gas			Electric baseboard	Other
Efficiency	Normal	Mid	High	Normal	Mid	High		
Share (%)	11,5	5,7	0	0,1	0	0	52	30,7

Source: OEE 2006b

Natural gas being rare in New Brunswick, it does not represent a market segment with massive potential for GHG reductions. However, since a large proportion of the electricity comes from heating oil, and since electric baseboard heaters represent more than half the heating systems in the province, this segment becomes a potentially interesting market for geoexchange systems from the perspective of GHG reductions.

Table 27 GHG savings potential in New Brunswick compared with different Geoexchange market penetration scenarios, considering replacement of actual heating systems				
Market penetration*	2%	4%	8%	16%
Electric baseboard				
GHG savings (tons CO_2 eq.)	25 151	50 302	100 604	201 208
Natural gas				
GHG savings (tons CO_2 eq.)	15	29	59	118
Oil				
GHG savings (tons CO_2 eq.)	5 323	10 645	21 290	42 580
Total				
GHG savings (tons CO_2 eq.)	30 488	60 976	121 953	243 906
Equivalent number of cars	9 074	18 148	36 296	72 591

*There are 224 000 single detached houses in New Brunswick (OEE 2006b)

Fredericton, NB

Table 28: Annual GHG emissions (kg CO_2 eq.) - Heating only

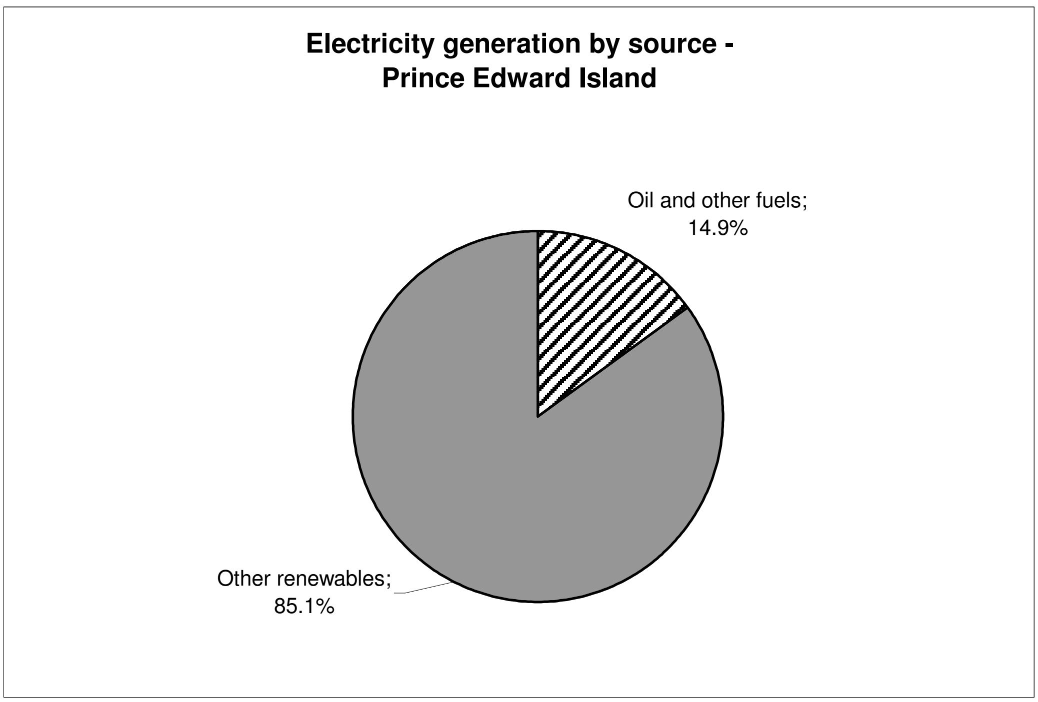
Degree-Days			**Building 1500 ft² (140 m²)**			**Building 2000 ft² (185 m²)**			**Building 2500 ft² (230 m²)**		
4751			Low	Mid	High	Low	Mid	High	Low	Mid	High
		Btu/h	44444	34188	26298	59258	45583	35064	74071	56978	43829
	COP										
Electricity											
Conventional	0,95		15932	12256	9427	21242	16340	12569	26553	20425	15712
Geoexchange - HP	2,8		5406	4158	3199	7207	5544	4265	9009	6930	5331
Geoexchange - HP	3,2		4730	3638	2799	6306	4851	3732	7883	6064	4664
Geoexchange - HP	3,6		4204	3234	2488	5606	4312	3317	7007	5390	4146
Natural gas											
Normal efficiency	0,75		8610	6623	5094	11479	8830	6792	14349	11037	8490
Medium efficiency	0,84		7687	5913	4549	10249	7884	6065	12811	9855	7581
High efficiency	0,95		6797	5228	4022	9062	6971	5362	11328	8714	6703
Oil											
Normal efficiency	0,75		12587	9683	7448	16783	12910	9931	20978	16137	12413
Medium efficiency	0,84		11239	8645	6650	14985	11527	8867	18730	14408	11083
High efficiency	0,9		10489	8069	6207	13986	10758	8275	17482	13447	10344

Data provided by CGC

Prince Edward Island

Prince Edward Island (PEI) is a typical example of the importance of considering electricity transfers in the calculation of GHG emission intensity. Since the majority of the electrical energy produced on the island comes from the wind farm network, and since the use of thermal power plants is becoming less frequent, the intensity of GHG emissions from electricity consumption is greatly influenced by the relatively more polluting electricity production of New Brunswick, which provides almost 95% of PEI's electricity through undersea transmission cables. Using the full calculation including electricity transfers, the intensity of GHG emissions is 434 tons CO_2 eq./GWh. Although there has been growth in electricity production from wind farms and biomass, GHG emissions have nevertheless increased by 5.6% since 1990 (Environment Canada 2009a). However, according to recent data from Environment Canada (2009a), Prince Edward Island's GHG emissions decreased by 8% between 2004 and 2007. The strength of the wind farm sector, which has quintupled since 2004, has procured favourable environmental impacts for the province.

Figure 10



Source : Statistics Canada 2007b

PEI's economy is primarily focused on services and manufacturing industries. The residential and commercial sectors consume almost 80% of the province's electricity (ONE 2006). In PEI natural gas is not used as a heating source. Heating oil is the primary source, sometimes in combination with firewood (27.3%). So although the number of single-family homes is small, the heating of buildings still constitutes a considerable source of GHG emissions for the province, considering that the industrial sector consumes only 20% of the available energy and that heating oil is widely used for residential heating.

Table 29 Residential heating system shares in Prince-Edward-Island								
	Oil			Natural Gas			Electric baseboard	Other
Efficiency	**Normal**	**Mid**	**High**	**Normal**	**Mid**	**High**		
Share (%)	46,2	20,1	0	0	0	0	2,5	31,2

Source: OEE 2006b

Table 30 GHG savings potential in Prince Edward Island compared with different Geoexchange market penetration scenarios, considering replacement of actual heating systems				
Market penetration*	***2%***	***4%***	***8%***	***16%***
Electric baseboard				
GHG savings (tons CO_2 eq.)	212	424	847	1 695
Oil				
GHG savings (tons CO_2 eq.)	3 525	7 050	14 101	28 201
Total				
GHG savings (tons CO_2 eq.)	3 737	7 474	14 948	29 896
Equivalent number of cars	1 112	2 224	4 449	8 898

*There are 39 000 single detached houses in Prince Edward Island (OEE 2006b)

With this massive use of heating oil for space heating, Table 30 clearly indicates that geoexchange systems are a prime solution for reducing GHG emissions from buildings.

Charlottetown, PEI

Table 31: Annual GHG emissions (kg CO_2 eq.) - Heating only

Degree-Days			**Building 1500 ft² (140 m²)**			**Building 2000 ft² (185 m²)**			**Building 2500 ft² (230 m²)**		
4715			Low	Mid	High	Low	Mid	High	Low	Mid	High
		Btu/h	40212	30932	23794	53614	41242	31724	67017	51551	39655
	COP										
Electricity											
Conventional	0,95		16033	12333	9487	21377	16444	12649	26721	20554	15811
Geoexchange - HP	2,8		5440	4184	3219	7253	5579	4292	9066	6974	5364
Geoexchange - HP	3,2		4760	3661	2816	6346	4882	3755	7933	6102	4694
Geoexchange - HP	3,6		4231	3255	2504	5641	4339	3338	7051	5424	4172
Natural gas											
Normal efficiency	0,75		8544	6573	5056	11392	8763	6741	14240	10954	8426
Medium efficiency	0,84		7629	5868	4514	10172	7824	6019	12714	9780	7523
High efficiency	0,95		6745	5189	3991	8994	6918	5322	11242	8648	6652
Oil											
Normal efficiency	0,75		12492	9609	7392	16656	12812	9855	20819	16015	12319
Medium efficiency	0,84		11154	8580	6600	14871	11439	8799	18588	14299	10999
High efficiency	0,9		10410	8008	6160	13880	10677	8213	17349	13346	10266

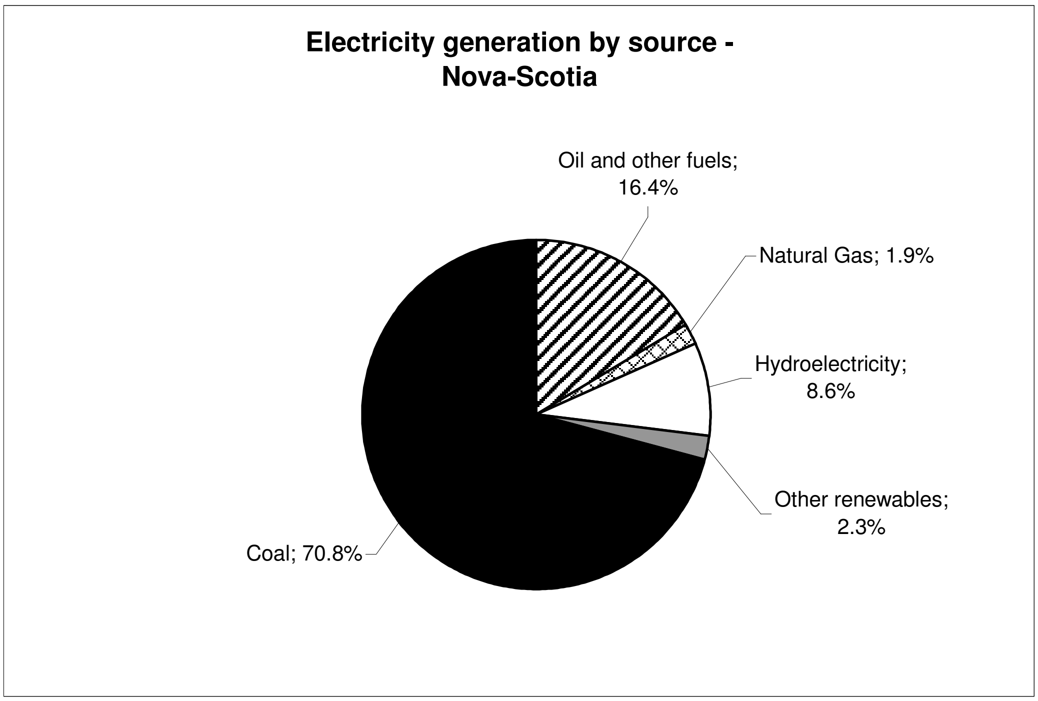
Data provided by CGC

Nova Scotia

Although a significant proportion of Nova Scotia's electricity production relies on coal-fired power plants, the province is distinguished from other Canadian provinces by its use of a tidal power plant. The plant at Annapolis is the only one of its kind in the Western hemisphere (Environment Canada 2009a).

Across the province, the heavy use of fossil fuels in the energy sector leads to a high intensity of GHG emissions, amounting to 752 tons CO_2 eq./GWh, placing it clearly above the Canadian average. Furthermore, GHG emissions have increased by 8.7% since 1990, but decreased by 9.1% during the period 2004-2007, this decrease arising mainly from the electricity production sector (Environment Canada 2009a). Nova Scotia's emissions are proportional to its representation in the Canadian population, at slightly less than 3%.

Figure 11



Source : Statistics Canada 2007b

Energy consumption in the province is shared almost equally among the industrial, commercial and residential sectors (ONE 2006). Like Prince Edward Island, Nova Scotia does not use natural gas as a source of residential heating. The use of heating oil is dominant. However, electric heating also plays an important role in the province.

Table 32 Residential heating system shares in Nova-Scotia								
	Oil			*Natural Gas*			*Electric baseboard*	*Other*
Efficiency	**Normal**	**Mid**	**High**	**Normal**	**Mid**	**High**		
Share (%)	39,0	10,5	0	0	0	0	21,9	28,6

Source: OEE 2006b

With a proportion of use of almost 50%, oil heating systems represent a considerable volume of potential GHG reductions. Electricity, although it accounts for only 22% of residential heating systems, also presents a significant potential for GHG reductions since the electricity that feeds electric baseboard heaters comes mostly from coal, which emits a great deal of GHGs.

Table 33 GHG savings potential in Nova Scotia compared with different Geoexchange market penetration scenarios, considering replacement of actual heating systems				
Market penetration*	***2%***	***4%***	***8%***	***16%***
Electric baseboard				
GHG savings (tons CO_2 eq.)	20 467	40 934	81 868	163 736
Oil				
GHG savings (tons CO_2 eq.)	7 013	14 025	28 050	56 100
Total				
GHG savings (tons CO_2 eq.)	27 480	54 959	109 918	219 836
Equivalent number of cars	8 178	16 357	32 714	65 428

*There are 268 000 single detached houses in Nova Scotia (OEE 2006b)

Halifax, NS

Table 34: Annual GHG emissions (kg CO_2 eq.) - Heating only

Degree-Days			Building 1500 ft² (140 m²)			Building 2000 ft² (185 m²)			Building 2500 ft² (230 m²)		
4367			Low	Mid	High	Low	Mid	High	Low	Mid	High
		Btu/h	35979	27676	21289	47971	36900	28385	59962	46125	35481
	COP										
Electricity											
Conventional	0,95		25730	19793	15225	34306	26390	20300	42882	32986	25374
Geoexchange - HP	2,8		8730	6715	5166	11640	8954	6887	14549	11192	8609
Geoexchange - HP	3,2		7639	5876	4520	10185	7834	6026	12731	9793	7533
Geoexchange - HP	3,6		6790	5223	4018	9053	6964	5357	11316	8705	6696
Natural gas											
Normal efficiency	0,75		7914	6087	4683	10551	8116	6243	13189	10145	7804
Medium efficiency	0,84		7066	5435	4181	9421	7247	5574	11776	9058	6968
High efficiency	0,95		6248	4806	3697	8330	6408	4929	10412	8009	6161
Oil											
Normal efficiency	0,75		11570	8900	6846	15426	11866	9128	19283	14833	11410
Medium efficiency	0,84		10330	7946	6113	13773	10595	8150	17217	13243	10187
High efficiency	0,9		9642	7417	5705	12855	9889	7607	16069	12361	9508

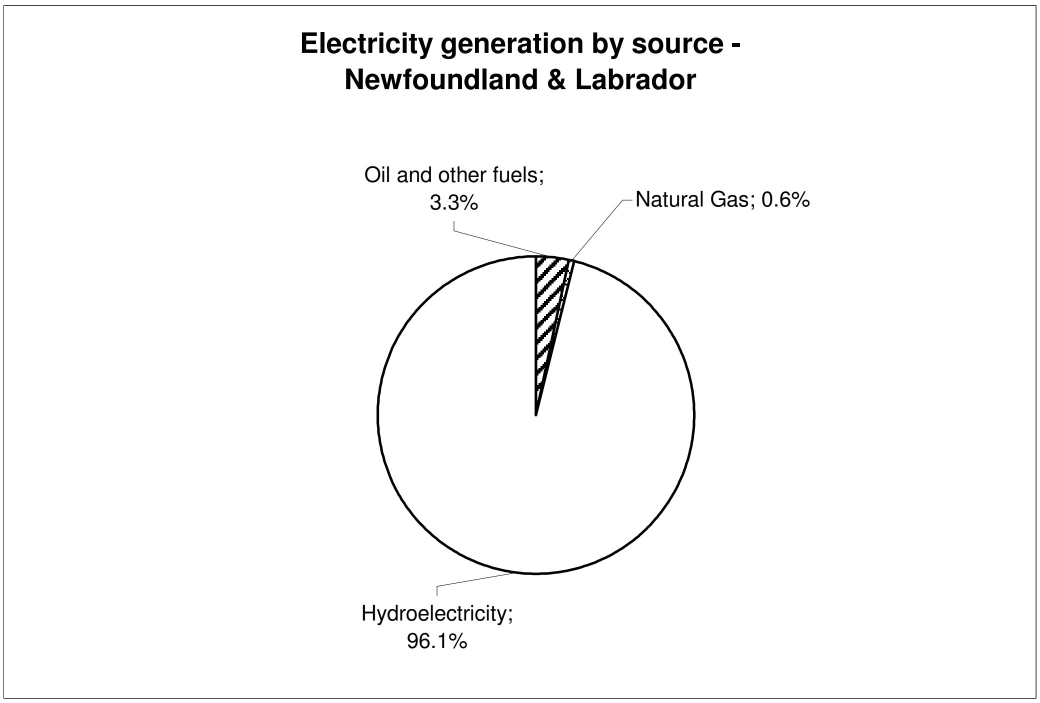
Data provided by CGC

Newfoundland and Labrador

Newfoundland and Labrador's electrical energy production sector falls in second place among the provinces for low levels of GHG emission intensity, with an average of 30 tons CO_2 eq./GWh for the period 2003-2007. This situation reflects the fact that the majority of Newfoundland and Labrador's electrical energy comes from hydroelectric power.

Despite this, considering its small population size and its economy based on resources, the province is the fifth-largest emitter of GHGs per capita in Canada, with emissions of 20.8 tons of GHG per inhabitant. Also, GHG emissions have increased by 11.4% since 1990 (Environment Canada 2008).

Figure 12



Source : Statistics Canada 2007b

Electric heating is very popular. Almost 80% of new buildings use this heating method (ONE 2006). On the other hand, like the majority of the Atlantic provinces, single-family homes in Newfoundland and Labrador do not use natural gas for their heating (see Table 35).

Table 35

Residential heating system shares in Newfoundland/Labrador

	Oil			***Natural Gas***			***Electric baseboard***	***Other***
Efficiency	**Normal**	**Mid**	**High**	**Normal**	**Mid**	**High**		
Share (%)	20,3	5,8	0	0	0	0	52,4	21,5

Source: OEE 2006b

Potential reductions in GHGs therefore depend on the possibility of replacing oil heating, which constitutes 26% of installations, with geoexchange systems.

Table 36
GHG savings potential in Newfoundland/Labrador compared with different Geoexchange market penetration scenarios, considering replacement of actual heating systems

Market penetration*	***2%***	***4%***	***8%***	***16%***
Electric baseboard				
GHG savings (tons CO_2 eq.)	1 336	2 673	5 346	10 692
Oil				
GHG savings (tons CO_2 eq.)	10 744	21 489	42 977	85 954
Total				
GHG savings (tons CO_2 eq.)	12 081	24 162	48 323	96 646
Equivalent number of cars	3 595	7 191	14 382	28 764

*There are 164 000 single detached houses in Newfoundland/Labrador (OEE 2006b)

St-John's, NL

Table 37: Annual GHG emissions (kg CO_2 eq.) - Heating only

Degree-Days			**Building 1500 ft² (140 m²)**			**Building 2000 ft² (185 m²)**			**Building 2500 ft² (230 m²)**		
4882			Low	Mid	High	Low	Mid	High	Low	Mid	High
		Btu/h	33862	26048	20037	45149	34730	26715	56435	43412	33394
	COP										
Electricity											
Conventional	0,95		1148	883	679	1530	1177	905	1912	1471	1132
Geoexchange - HP	2,8		389	299	230	519	399	307	649	499	384
Geoexchange - HP	3,2		341	262	202	454	349	269	568	437	336
Geoexchange - HP	3,6		303	233	179	404	311	239	505	388	299
Natural gas											
Normal efficiency	0,75		8847	6805	5235	11796	9074	6980	14744	11342	8724
Medium efficiency	0,84		7899	6076	4674	10532	8101	6232	13165	10127	7790
High efficiency	0,95		6984	5373	4133	9312	7163	5510	11640	8954	6888
Oil											
Normal efficiency	0,75		12934	9950	7653	17245	13266	10204	21556	16582	12755
Medium efficiency	0,84		11549	8884	6833	15398	11844	9111	19247	14805	11389
High efficiency	0,9		10779	8291	6378	14371	11055	8504	17964	13818	10629

Data provided by CGC

Conclusions

According to the hypotheses used for purposes of this study, geoexchange systems offer a solution for GHG reduction in all of the analyzed scenarios, with few exceptions and for a specific scenario. However in that specific case, the narrowing of certain hypotheses could lead to different results that are favourable to geoexchange systems. For example, a more exhaustive analysis that took marginal production of electricity from renewable sources of energy into account would make geoexchange systems the solution of choice.

Generally speaking, the hypotheses that we have used are somewhat conservative in terms of the COP. We also based our analysis on hypotheses that are factual, realistic and verifiable with regard to GHG emission factors, and with regard to the production of electricity in each of the provinces. The interprovincial and international trade in electricity also adds a touch of realism to our analysis.

Although this study includes maximum details for each of the markets, it must be remembered that there are significant disparities between the provinces, and between various regions in the same province. Based on this fact, we believe that it is risky to try to extrapolate the results without taking these limitations into account, since they correspond to the specific characteristics of the cities that were studied. In addition, the study does not take into account the characteristics of the soils, which are often specific to each city, each region or each province, and which sometimes limit the potential for penetration of geoexchange systems.

Nevertheless, in keeping with the spirit and the hypotheses used for this study, we can affirm without hesitation that the potential GHG reductions measured here indicate that the installation of geoexchange systems leads to a real reduction in GHG emissions, but that the magnitude of these reductions can vary from region to region. Furthermore, there is a direct relationship between an increase in the COPs of geoexchange systems, the size of single-family homes, and the total volume of GHG reductions. On a Canada-wide level, a 4% penetration rate of geoexchange systems into the single-family home residential sector would enable annual reductions of 750,000 tons of CO_2 eq.

Remember also that this study considers only the GHG emissions involved in the heating of single-family homes. It is evident that geoexchange systems are also used for air conditioning and for water heating. These two uses represent a further 2.6% and 16.3% respectively of the energy consumption of single-family homes in Canada (OEE 2006b). These data were not used in this analysis, partly because the installation of desuperheaters is not common practice everywhere in the country, and partly because the use of air conditioning is somewhat variable from province to province. In many regions of Canada, however, we believe that the addition of these variables to the analysis would enhance the environmental advantages of geoexchange systems.

The analysis presented in this document focuses primarily on direct GHG reductions (replacement of heating oil and natural gas at the point of consumption) and indirect reductions (sources of energy used for electricity production in existing power plants, methane leakage on the distribution network) that lead to increased market penetration potential for geoexchange systems. A more exhaustive analysis of future energy supplies, particularly in the case of increased penetration of green electricity production facilities (wind, hydroelectric, etc.), would enable us to highlight the important role that geoexchange systems could potentially play in the future in terms of a clear reduction in energy requirements for space heating, but also in terms of the global demand for electricity.

As suggested by the *GHG Protocol* of the World Resource Institute (WRI 2007), it would also be interesting to analyze the markets from the perspective of integrating marginal electricity sources into the network, that is, sources for which usage would be reduced following a decrease in the demand for electricity or, inversely, the production method avoided if there is an increase in demand. Please see Appendix D for an analysis of this type performed for Saskatchewan.

Furthermore, this approach by marginal analysis would also enable us to calculate the impacts of supplementary electricity production required following the conversion of fossil-fuel systems to geoexchange heat pumps.

These considerations, however, greatly exceed the framework of this study.

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Appendix A: GHG intensity – Electric sector[5]

British Columbia

	2003	2004	2005	2006	2007	Average
Electricity Generation						
Total production (GWh)	49 500	48 000	53 400	47 200	57 700	51 160
GHG intensity (tons eq. CO_2/GWh)	10	20	20	20	20	18
Inter-provincial transfers						
Alberta						
Imports (GWh)	955	1 017	1 042	394	738	829
Exports (GWh)	862	1 246	907	1 051	850	983
GHG intensity (tons eq. CO_2/GWh)	960	900	840	870	820	878
Imports						
Arizona						
Imports (GWh)	-	20,303	106,049	233,181	144,689	100,844
GHG intensity (tons eq. CO_2/GWh)	494	500	506	511	492	501
California						
Imports (GWh)	-	-	-	66,424	76,240	28,533
GHG intensity (tons eq. CO_2/GWh)	290	307	273	274	298	288
Colorado						
Imports (GWh)	-	-	0,194	-	1,679	0,375
GHG intensity (tons eq. CO_2/GWh)	871	848	823	825	798	833
Idaho						
Imports (GWh)	-	-	-	-	56,263	11,253
GHG intensity (tons eq. CO_2/GWh)	106	119	124	65	111	105
Indiana						
Imports (GWh)	-	-	-	-	5,899	1,180
GHG intensity (tons eq. CO_2/GWh)	933	933	936	934	932	934
Iowa						
Imports (GWh)	-	0,471	0,220	0,073	0,009	0,155
GHG intensity (tons eq. CO_2/GWh)	965	954	910	892	881	920
Massachusets						
Imports (GWh)	-	-	0,130	-	-	0,026
GHG intensity (tons eq. CO_2/GWh)	562	548	565	520	542	547
Montana						
Imports (GWh)	-	74,784	98,289	299,130	148,774	124,195
GHG intensity (tons eq. CO_2/GWh)	710	720	701	677	692	700
Nebraska						
Imports (GWh)	-	2,533	4,443	1,288	0,611	1,775
GHG intensity (tons eq. CO_2/GWh)	701	656	701	703	637	680

5 http://www.neb-one.gc.ca/clf-nsi/rpblctn/rprt/nnlrprt/2003/nnlrprt2003-fra.pdf
http://www.neb-one.gc.ca/clf-nsi/rpblctn/rprt/nnlrprt/2004/nnlrprt2004_f.pdf
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http://www.eia.doe.gov/cneaf/electricity/epa/backissues.html

British Columbia

	2003	2004	2005	2006	2007	Average
Nevada						
Imports (GWh)	-	14,948	42,720	66,846	43,112	33,525
GHG intensity (tons eq. CO_2/GWh)	692	662	646	521	513	607
New Mexico						
Imports (GWh)	-	22,224	97,762	64,851	61,555	49,278
GHG intensity (tons eq. CO_2/GWh)	953	950	933	886	874	919
Oregon						
Imports (GWh)	0,015	77,434	445,386	468,481	207,157	239,695
GHG intensity (tons eq. CO_2/GWh)	179	178	182	133	192	173
Pennsylvania						
Imports (GWh)	-	-	-	-	0,824	0,165
GHG intensity (tons eq. CO_2/GWh)	577	567	581	575	566	573
South Dakota						
Imports (GWh)	-	-	-	-	0,035	0,007
GHG intensity (tons eq. CO_2/GWh)	462	517	508	497	495	496
Texas						
Imports (GWh)	-	-	-	0,800	-	0,160
GHG intensity (tons eq. CO_2/GWh)	673	658	652	643	629	651
Utah						
Imports (GWh)	-	-	0,824	0,814	37,666	7,861
GHG intensity (tons eq. CO_2/GWh)	905	919	940	882	848	899
Washington						
Imports (GWh)	5 087,174	6 711,824	5 094,226	10 899,079	6 330,248	6 824,510
GHG intensity (tons eq. CO_2/GWh)	150	147	146	96	118	131
Wyoming						
Imports (GWh)	-	75,296	145,487	74,760	86,976	76,504
GHG intensity (tons eq. CO_2/GWh)	1 040	1 027	996	996	1 002	1 012
Total Imports (GWh)	5 087	7 000	6 036	12 176	7 202	7 500
GHG intensity (tons eq. CO_2/GWh)	150	167	201	133	166	165
Exports (GWh)	7 166	5 393	7 848	5 175	10 312	7 179
Total consumption (GWh) (Generation - Exports + Imports)	47 514	49 378	51 722	53 544	54 478	51 327
GHG intensity including imports, exports and inter-provincial transfers (tons eq. CO_2/GWh)	44	59	58	52	50	53

Territories

	2003	2004	2005	2006	2007	Average
Electricity Generation						
Total production (GWh)	780	830	820	830	840	820
GHG intensity (tons eq. CO_2/GWh)	110	80	80	80	70	84
GHG intensity including imports, exports and inter-provincial transfers (tons eq. CO_2/GWh)	110	80	80	80	70	84

Appendix A: GHG intensity – Electric sector

Alberta

	2003	2004	2005	2006	2007	Average
Electricity Generation						
Total production (GWh)	53 800	56 400	57 300	56 100	60 700	56 860
GHG intensity (tons eq. CO_2/GWh)	960	900	840	870	820	878
Inter-provincial transfers						
British Columbia						
Imports (GWh)	862	1 246	907	1 051	850	983
Exports (GWh)	955	1 017	1 042	394	738	829
GHG intensity (tons eq. CO_2/GWh)	960	900	840	870	820	878
Saskatchewan						
Imports (GWh)	518	639	529	765	568	604
Exports (GWh)	46	303	272	252	67	188
GHG intensity (tons eq. CO_2/GWh)	840	880	790	760	710	796
Total Inter-provincial imports (GWh)	1 380	1 885	1 436	1 816	1 418	1 587
Total Inter-provincial exports (GWh)	1 001	1 320	1 314	646	805	1 017
Weighted GHG intensity (tons eq. CO_2/GWh)	915	893	822	824	776	847
Imports						
Indiana						
Imports (GWh)	-	-	-	-	11,917	2,383
GHG intensity (tons eq. CO_2/GWh)	933	933	936	934	932	934
Minnesota						
Imports (GWh)	9,567	0,025	7,266	17,340	16,735	10,187
GHG intensity (tons eq. CO_2/GWh)	720	731	734	706	692	717
Montana						
Imports (GWh)	1,001	1,463	1,318	-	-	0,756
GHG intensity (tons eq. CO_2/GWh)	710	720	701	677	692	700
New York						
Imports (GWh)	-	-	-	0,050	3,690	0,748
GHG intensity (tons eq. CO_2/GWh)	414	417	411	358	365	393
North Dakota						
Imports (GWh)	-	-	-	140,885	62,615	40,700
GHG intensity (tons eq. CO_2/GWh)	1 015	1 016	1 029	1 012	1 025	1 019
Oregon						
Imports (GWh)	6,130	-	-	1,592	-	1,544
GHG intensity (tons eq. CO_2/GWh)	179	178	182	133	192	173
Pennsylvania						
Imports (GWh)	-	-	-	-	0,211	0,042
GHG intensity (tons eq. CO_2/GWh)	577	567	581	575	566	573
Washington						
Imports (GWh)	314,461	365,123	443,143	433,012	550,674	421,283
GHG intensity (tons eq. CO_2/GWh)	150	147	146	96	118	131
Total Imports (GWh)	331	367	452	593	646	478
GHG intensity (tons eq. CO_2/GWh)	169	149	157	331	238	209
Exports (GWh)	74	131	86	88	241	124
Total consumption (GWh) (Generation - Exports + Imports)	54 437	57 201	57 788	57 775	61 718	57 784
GHG intensity including imports, exports and inter-provincial transfers (tons eq. CO_2/GWh)	954	895	834	863	813	872

Saskatchewan

	2003	2004	2005	2006	2007	Average
Electricity Generation						
Total production (GWh)	19 200	18 800	19 500	19 400	20 900	19 560
GHG intensity (tons eq. CO_2/GWh)	840	880	790	760	710	796
Inter-provincial transfers						
Alberta						
Imports (GWh)	46	303	272	252	67	188
Exports (GWh)	518	639	529	765	568	604
GHG intensity (tons eq. CO_2/GWh)	960	900	840	870	820	878
Manitoba						
Imports (GWh)	117	278	443	629	1 232	540
Exports (GWh)	320	290	108	210	996	385
GHG intensity (tons eq. CO_2/GWh)	40	10	10	10	10	16
Total Inter-provincial imports (GWh)	163	581	715	881	1 299	728
Total Inter-provincial exports (GWh)	838	929	637	975	1 564	989
Weighted GHG intensity (tons eq. CO_2/GWh)	300	474	326	256	52	239
Imports						
Indiana						
Imports (GWh)	-	-	-	-	3,147	0,629
GHG intensity (tons eq. CO_2/GWh)	933	933	936	934	932	934
North Dakota						
Imports (GWh)	908	1 083	427	371	198	597
GHG intensity (tons eq. CO_2/GWh)	1 015	1 016	1 029	1 012	1 025	1 019
Pennsylvania						
Imports (GWh)	-	-	-	-	0,095	0,019
GHG intensity (tons eq. CO_2/GWh)	577	567	581	575	566	573
Washington						
Imports (GWh)	0,156	-	-	-	-	0,031
GHG intensity (tons eq. CO_2/GWh)	150	147	146	96	118	131
Total Imports (GWh)	908	1 083	427	371	201	598
GHG intensity (tons eq. CO_2/GWh)	1 014	1 016	1 029	1 012	1 023	1 019
Exports (GWh)	708	686	691	262	386	547
Total consumption (GWh) (Generation - Exports + Imports)	18 725	18 849	19 314	19 414	20 450	19 350
GHG intensity including imports, exports and inter-provincial transfers (tons eq. CO_2/GWh)	844	875	778	742	671	782

Manitoba

	2003	2004	2005	2006	2007	Average
Electricity Generation						
Total production (GWh)	21 100	27 600	36 900	34 400	34 600	30 920
GHG intensity (tons eq. CO_2/GWh)	40	10	10	10	10	16
Inter-provincial transfers						
Ontario						
Imports (GWh)	108	163	45	93	181	
Exports (GWh)	1 651	1 295	2 749	1 547	550	1 558
GHG intensity (tons eq. CO_2/GWh)	270	200	210	180	220	216
Saskatchewan						
Imports (GWh)	320	290	108	210	996	385
Exports (GWh)	117	278	443	629	1 232	540
GHG intensity (tons eq. CO_2/GWh)	840	880	790	760	710	796
Total Inter-provincial imports (GWh)	428	453	153	303	1 177	385
Total Inter-provincial exports (GWh)	1 768	1 573	3 192	2 176	1 782	2 098
Weighted GHG intensity (tons eq. CO_2/GWh)	696	635	619	582	635	796
Imports						
Indiana						
Imports (GWh)	-	-	-	-	0,114	0,023
GHG intensity (tons eq. CO_2/GWh)	933	933	936	934	932	934
Michigan						
Imports (GWh)	-	-	-	-	0,371	0,074
GHG intensity (tons eq. CO_2/GWh)	658	654	647	672	663	659
ND/Minn						
Imports (GWh)	5 906,405	2 554,588	246,565	821,052	527,281	2 011,178
GHG intensity (tons eq. CO_2/GWh)	867	874	881	859	859	868
Total Imports (GWh)	5 906	2 555	247	821	528	2 011
GHG intensity (tons eq. CO_2/GWh)	867	874	881	859	858	868
Exports (GWh)	4 242	6 484	11 481	10 334	9 861	8 480
Total consumption (GWh) (Generation - Exports + Imports)	21 424	22 551	22 627	23 014	24 662	22 738
GHG intensity including imports, exports and inter-provincial transfers (tons eq. CO_2/GWh)	281	120	24	48	58	105

Appendix A: GHG intensity – Electric sector

Ontario

	2003	2004	2005	2006	2007	Average
Electricity Generation						
Total production (GWh)	145 200	152 000	155 300	155 000	155 100	152 520
GHG intensity (tons eq. CO_2/GWh)	270	200	210	180	220	216
Inter-provincial transfers						
Manitoba						
Imports (GWh)	1 651	1 295	2 749	1 547	550	1 558
Exports (GWh)	108	163	45	93	181	118
GHG intensity (tons eq. CO_2/GWh)	40	10	10	10	10	16
Québec						
Imports (GWh)	2 716	2 716	4 758	4 009	4 566	3 753
Exports (GWh)	5 326	5 326	7 218	8 811	5 143	6 365
GHG intensity (tons eq. CO_2/GWh)	10	9	3	4	11	7
Total Inter-provincial imports (GWh)	4 367	4 011	7 507	5 556	5 116	5 311
Total Inter-provincial exports (GWh)	5 434	5 489	7 263	8 904	5 324	6 483
Weighted GHG intensity (tons eq. CO_2/GWh)	21	9	6	6	11	10
Imports						
Connecticut						
Imports (GWh)	-	-	-	0,886	-	0,177
GHG intensity (tons eq. CO_2/GWh)	323	316	345	319	312	323
Illinois						
Imports (GWh)	160,185	18,123	19,136	0,150	6,192	40,757
GHG intensity (tons eq. CO_2/GWh)	502	527	519	517	522	518
Indiana						
Imports (GWh)	-	-	0,887	72,808	73,522	29,443
GHG intensity (tons eq. CO_2/GWh)	933	933	936	934	932	934
Iowa						
Imports (GWh)	1,319	0,150	0,600	-	-	0,414
GHG intensity (tons eq. CO_2/GWh)	965	954	910	892	881	920
Kansas						
Imports (GWh)	-	0,206	0,253	-	-	0,092
GHG intensity (tons eq. CO_2/GWh)	826	806	820	783	777	802
Kentucky						
Imports (GWh)	-	-	0,250	-	-	0,050
GHG intensity (tons eq. CO_2/GWh)	932	923	924	943	950	934
Massachusetts						
Imports (GWh)	2,537	0,035	4,623	3,571	12,452	4,644
GHG intensity (tons eq. CO_2/GWh)	562	548	565	520	542	547
Michigan						
Imports (GWh)	4 817,768	5 258,329	4 411,246	2 609,021	2 887,447	3 996,762
GHG intensity (tons eq. CO_2/GWh)	658	654	647	672	663	659
Minnesota						
Imports (GWh)	1 203,893	1 079,673	2 106,102	1 433,517	1 609,911	1 486,619
GHG intensity (tons eq. CO_2/GWh)	720	731	734	706	692	717
Missouri						
Imports (GWh)	-	6,276	2,087	0,010	0,300	1,735
GHG intensity (tons eq. CO_2/GWh)	868	877	879	863	846	866

Appendix A: GHG intensity – Electric sector

Ontario

	2003	2004	2005	2006	2007	Average
Montana						
Imports (GWh)	0,208	-	-	-	-	0,042
GHG intensity (tons eq. CO_2/GWh)	710	720	701	677	692	700
ND/Minn						
Imports (GWh)	-	0,062	-	-	-	0,012
GHG intensity (tons eq. CO_2/GWh)	867	874	881	859	859	868
Nebraska						
Imports (GWh)	-	0,042	-	-	-	0,008
GHG intensity (tons eq. CO_2/GWh)	701	656	701	703	637	680
New Jersey						
Imports (GWh)	-	0,400	-	-	-	0,080
GHG intensity (tons eq. CO_2/GWh)	352	381	349	327	328	347
New York						
Imports (GWh)	1 052,483	1 045,094	926,918	635,158	1 005,494	933,029
GHG intensity (tons eq. CO_2/GWh)	414	417	411	358	365	393
North Dakota						
Imports (GWh)	-	0,011	1,026	-	-	0,207
GHG intensity (tons eq. CO_2/GWh)	1 015	1 016	1 029	1 012	1 025	1 019
Ohio						
Imports (GWh)	13,740	67,940	396,514	225,034	55,197	151,685
GHG intensity (tons eq. CO_2/GWh)	870	831	840	830	840	842
Oklahoma						
Imports (GWh)	-	0,450	0,342	-	-	0,158
GHG intensity (tons eq. CO_2/GWh)	801	774	750	740	706	754
Pennsylvania						
Imports (GWh)	101,590	222,653	247,241	24,694	27,991	124,834
GHG intensity (tons eq. CO_2/GWh)	577	567	581	575	566	573
South Dakota						
Imports (GWh)	-	0,841	0,150	-	-	0,198
GHG intensity (tons eq. CO_2/GWh)	462	517	508	497	495	496
Texas						
Imports (GWh)	-	0,250	3,379	-	111,310	22,988
GHG intensity (tons eq. CO_2/GWh)	673	658	652	643	629	651
Vermont						
Imports (GWh)	-	-	-	1,574	1,013	0,517
GHG intensity (tons eq. CO_2/GWh)	4	4	2	1	2	3
Total Imports (GWh)	7 354	7 701	8 121	5 006	5 791	6 794
GHG intensity (tons eq. CO_2/GWh)	629	631	650	652	623	637
Exports (GWh)	4 294	8 182	8 582	9 752	10 489	8 260
Total consumption (GWh) (Generation - Exports + Imports)	147 193	150 041	155 083	146 907	150 194	149 883
GHG intensity including imports, exports and inter-provincial transfers (tons eq. CO_2/GWh)	281	217	223	189	228	228

Appendix A: GHG intensity – Electric sector

Québec

	2003	2004	2005	2006	2007	Average
Electricity Generation						
Total production (GWh)	159 000	153 800	161 000	159 000	171 900	160 940
GHG intensity (tons eq. CO_2/GWh)	10	9	3	4	11	7
Inter-provincial transfers						
Ontario						
Imports (GWh)	5 326	5 326	7 218	8 811	5 143	6 365
Exports (GWh)	2 716	2 716	4 758	4 009	4 566	3 753
GHG intensity (tons eq. CO_2/GWh)	270	200	210	180	220	216
New Brunswick						
Imports (GWh)	1 266	1 462	1 963	777	221	1 138
Exports (GWh)	335	58	63	104	1 727	457
GHG intensity (tons eq. CO_2/GWh)	450	480	460	390	420	440
Newfoundland/Labrador						
Imports (GWh)	31 791	28 217	30 420	31 284	29 752	30 293
Exports (GWh)	15	15	14	16	26	17
GHG intensity (tons eq. CO_2/GWh)	40	30	30	20	30	30
Total Inter-provincial imports (GWh)	38 383	35 005	39 601	40 872	35 116	37 795
Total Inter-provincial exports (GWh)	3 066	2 789	4 835	4 129	6 319	4 228
Weighted GHG intensity (tons eq. CO_2/GWh)	85	75	84	62	60	74
Imports						
Maine						
Imports (GWh)	425,962	240,484	97,295	82,178	2,084	169,601
GHG intensity (tons eq. CO_2/GWh)	406	384	375	335	346	369
Massachusetts						
Imports (GWh)	40,800	-	-	-	0,084	8,177
GHG intensity (tons eq. CO_2/GWh)	562	548	565	520	542	547
New York						
Imports (GWh)	3 458,210	3 219,328	2 509,586	1 888,298	2 149,560	2 644,996
GHG intensity (tons eq. CO_2/GWh)	414	417	411	358	365	393
New England						
Imports (GWh)	-	-	686,036	564,457	1 202,946	490,688
GHG intensity (tons eq. CO_2/GWh)	484	466	470	428	444	458
Pennsylvania						
Imports (GWh)	-	-	-	-	3,569	0,714
GHG intensity (tons eq. CO_2/GWh)	577	567	581	575	566	573
Vermont						
Imports (GWh)	-	-	-	-	0,511	0,102
GHG intensity (tons eq. CO_2/GWh)	4	4	2	1	2	3
Total Imports (GWh)	3 925	3 460	3 293	2 535	3 359	3 314
GHG intensity (tons eq. CO_2/GWh)	415	415	423	373	393	404
Exports (GWh)	10 038	9 478	10 565	11 713	16 101	11 579
Total consumption (GWh) (Generation - Exports + Imports)	188 204	179 998	188 494	186 565	187 955	186 243
GHG intensity including imports, exports and inter-provincial transfers (tons eq. CO_2/GWh)	34	30	27	22	27	28

New Brunswick

	2003	2004	2005	2006	2007	Average
Electricity Generation						
Total production (GWh)	18 200	19 600	20 300	17 500	16 300	18 380
GHG intensity (tons eq. CO_2/GWh)	450	480	460	390	420	440
Inter-provincial transfers						
Nova Scotia						
Imports (GWh)	331	178	86	41	14	130
Exports (GWh)	131	287	217	85	16	147
GHG intensity (tons eq. CO_2/GWh)	670	790	750	760	810	756
Prince Edward Island						
Imports (GWh)	-	-	-	-	-	-
Exports (GWh)	1 087	1 119	1 148	1 139	1 059	1 110
GHG intensity (tons eq. CO_2/GWh)[6]	680	380	260	180	180	336
Québec						
Imports (GWh)	335	58	63	104	1 727	457
Exports (GWh)	1 266	1 462	1 963	777	221	1 138
GHG intensity (tons eq. CO_2/GWh)	10	9	3	4	11	7
Total Inter-provincial imports (GWh)	666	236	149	145	1 741	587
Total Inter-provincial exports (GWh)	2 484	2 868	3 328	2 001	1 296	2 395
Weighted GHG intensity (tons eq. CO_2/GWh)	338	598	434	218	17	173
Imports						
Maine						
Imports (GWh)	72,086	44,384	36,334	548,173	637,541	267,704
GHG intensity (tons eq. CO_2/GWh)	406	384	375	335	346	369
New York						
Imports (GWh)	-	-	-	-	4,675	0,935
GHG intensity (tons eq. CO_2/GWh)	414	417	411	358	365	393
Total Imports (GWh)	72	44	36	548	642	269
GHG intensity (tons eq. CO_2/GWh)	406	384	375	335	346	369
Exports (GWh)	2 687	2 306	2 974	2 177	1 911	2 411
Total consumption (GWh) (Generation - Exports + Imports)	13 767	14 707	14 183	14 015	15 476	14 430
GHG intensity including imports, exports and inter-provincial transfers (tons eq. CO_2/GWh)	444	482	460	386	372	428

[6] Data about GHG intensity is not available for 2007 in Prince Edward Island. GHG intensity used comes from previous year (2006).

Prince Edward Island

	2003	2004	2005	2006	2007	Average
Electricity Generation						
Total production (GWh)	60	50	50	40	113	63
GHG intensity (tons eq. CO_2/GWh)[7]	680	380	260	180	180	336
Inter-provincial transfers						
New Brunswick						
Imports (GWh)	1 087	1 119	1 148	1 139	1 059	1 110
Exports (GWh)	-	-	-	-	-	-
GHG intensity (tons eq. CO_2/GWh)	450	480	460	390	420	440
Total consumption (GWh) (Generation - Exports + Imports)	1 147	1 169	1 198	1 179	1 172	1 173
GHG intensity including imports, exports and inter-provincial transfers (tons eq. CO_2/GWh)	462	476	452	383	397	434

[7] Data about GHG intensity is not available for 2007 in Prince Edward Island. GHG intensity used comes from previous year (2006).

Nova Scotia

	2003	2004	2005	2006	2007	Average
Electricity Generation						
Total production (GWh)	12 300	12 500	12 400	11 400	12 500	12 220
GHG intensity (tons eq. CO_2/GWh)	670	790	750	760	810	756
Inter-provincial transfers						
New Brunswick						
Imports (GWh)	131	287	217	85	16	147
Exports (GWh)	331	178	86	41	14	130
GHG intensity (tons eq. CO_2/GWh)	450	480	460	390	420	440
Imports						
Pennsylvania						
Imports (GWh)	1,221	40,146	69,297	24,588	62,917	39,634
GHG intensity (tons eq. CO_2/GWh)	577	567	581	575	566	573
Exports (GWh)	115,746	115,405	104,425	228,598	30,634	118,962
Total consumption (GWh) (Generation - Exports + Imports)	11 985	12 534	12 496	11 240	12 534	12 158
GHG intensity including imports, exports and inter-provincial transfers (tons eq. CO_2/GWh)	668	782	744	757	808	752

New Foundland/Labrador

	2003	2004	2005	2006	2007	Average
Electricity Generation						
Total production (GWh)	40 400	39 800	40 300	40 800	39 800	40 220
GHG intensity (tons eq. CO_2/GWh)	40	30	30	20	30	30
Inter-provincial transfers						
Québec						
Imports (GWh)	15	15	14	16	26	17
Exports (GWh)	31 791	28 217	30 420	31 284	29 752	30 293
GHG intensity (tons eq. CO_2/GWh)	10	9	3	4	11	7
Total consumption (GWh) (Generation - Exports + Imports)	8 624	11 598	9 894	9 532	10 074	9 944
GHG intensity including imports, exports and inter-provincial transfers (tons eq. CO_2/GWh)	40	30	30	20	30	30

Appendix B: Population of Canada by geographic region, 2006

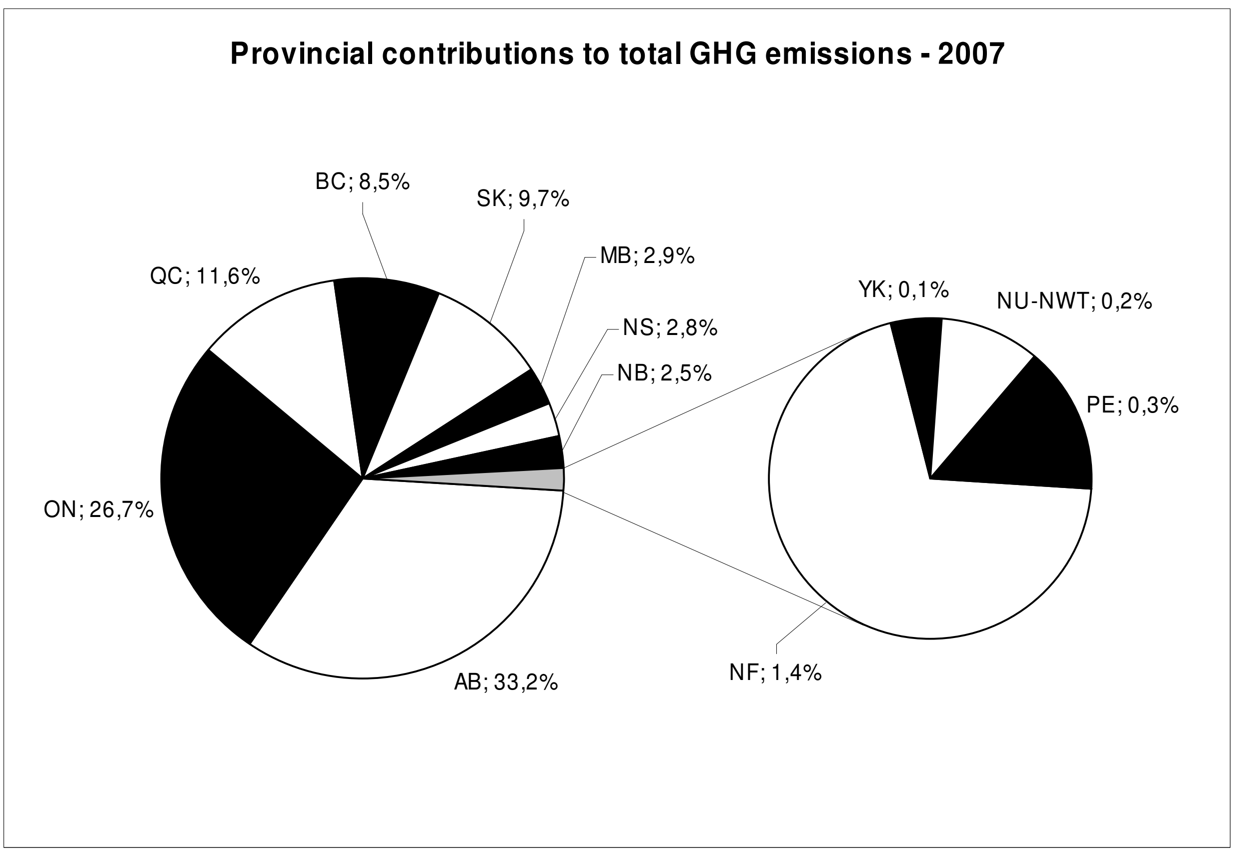
Geographic region	Inhabitants (in thousands)	Percentage	Rank (Decreasing order)
Canada	31 613	100%	-
Alberta	3 290	10.4%	4
British Columbia	4 114	13.0%	3
Prince Edward Island	136	0.4%	10
Manitoba	1 148	3.6%	5
New Brunswick	730	2.3%	8
Nova Scotia	914	2.9%	7
Ontario	12 160	38.5%	1
Québec	7 546	23.9%	2
Saskatchewan	968	3.1%	6
Newfoundland/Labrador	506	1.6%	9
Territories	101	0.3%	11

Source: Statistics Canada 2008

Appendix C: Data on GHG emissions by province, 2007

Province/Territory	*GHG emissions (Mt eq. CO_2)*	*GHG emissions per capita (tons / inhab.)*	*GHG share from residential sector (%)*	*Total GHG contribution over Canada's emissions (%)*
Canada	747	22.7	5.9	100
Alberta	245.7	70.7	3.7	33.2
British Columbia	63.1	14.4	7.0	8.5
Prince Edward Island	2.1	15.1	15.3	0.3
Manitoba	21.3	18	5.2	2.9
New Brunswick	18.7	24.9	3.9	2.5
Nova Scotia	20.6	22.1	5.8	2.8
Ontario	197.4	15.4	10.2	26.7
Québec	85.7	11.1	5.7	11.6
Saskatchewan	72	72.2	2.2	9.7
Newfoundland/Labrador	10.5	20.8	4.7	1.4
Territories	2.2	21.4	6.2	0.3

Source: Environment Canada 2009a



Source: Environment Canada 2009a

Appendix D: Marginal Analysis - Saskatchewan

There are different approaches to analyzing, first of all, the impact due to a greater penetration of geoexchange systems into the markets and, secondly, the consequent increase in electricity consumption. In the report, we have used an average of the GHG emissions from the stock of existing electricity production facilities and taken into account the interprovincial and the international electricity trade. On the other hand, marginal analysis, such as suggested by the *GHG Protocol* of the *World Resource Institute* (WRI 2007), enables identification, on one hand, of existing electricity production installations for which usage would be reduced following a reduction in demand for electricity or, on the other hand, the means of production used if there had been an increase in demand. Using marginal analysis, it is possible to calculate the consequences of additional production on GHG emissions.

We have chosen to apply this approach to Saskatchewan due to the characteristics of its stock of existing electricity production facilities. The base load for Saskatchewan comes essentially from coal-fired power stations. However, according to data provided by the Natural Sciences and Engineering Research Council of Canada (NSERC), the intensity of emissions arising from marginal electricity production in Saskatchewan is considerably lower than that generally used in our report. This gap can be explained by the fact that almost all of the marginal production of electricity in the province comes from hydroelectricity and the burning of natural gas, a less polluting fuel than coal.

Using the data from the NSERC, and maintaining the general hypotheses of the study, we calculated the average emission intensity from marginal production of electricity in Saskatchewan for the period 2004-2006 and obtained 0.225 kg CO_2 eq./kWh. Considering this emission coefficient and the same scenarios modeled in this study, but this time using the marginal approach, we note that the GHG emissions arising from the use of a geoexchange system are clearly lower than those from natural gas heating systems.

Marginal Electricity Production Analysis

Régina, SK

Annual GHG emissions (kg CO2 eq.) - Heating only

			Building 1500 ft² (140 m²)			Building 2000 ft² (185 m²)			Building 2500 ft² (230 m²)		
Degree-Days			Low	Mid	High	Low	Mid	High	Low	Mid	High
5661		**Btu/h**	55026	42328	32560	73367	56436	43412	91707	70544	54264
	COP										
Electricity											
Conventional	0,95		9980	7677	5905	13306	10235	7873	16632	12794	9842
Geoexchange - HP	2,8		3386	2605	2004	4515	3473	2671	5643	4341	3339
Geoexchange - HP	3,2		2963	2279	1753	3950	3039	2337	4938	3798	2922
Geoexchange - HP	3,6		2634	2026	1558	3511	2701	2078	4389	3376	2597
Natural gas											
Normal efficiency	0,75		13051	10039	7722	17401	13385	10296	21751	16731	12870
Medium efficiency	0,84		11653	8964	6895	15536	11951	9193	19420	14939	11491
High efficiency	0,95		10303	7926	6097	13738	10567	8129	17172	13209	10161
Oil											
Normal efficiency	0,75		14998	11537	8875	19997	15382	11833	24996	19228	14791
Medium efficiency	0,84		13391	10301	7924	17855	13734	10565	22318	17168	13206
High efficiency	0,9		12499	9614	7396	16664	12819	9861	20830	16023	12326

Data provided by CGC

Looking at the scenario of a 2,000 ft² (185 m²) residence with superior insulation as well as a high-performance heating system (efficiency of 95% for a natural gas furnace and a COP of 3.6 for a geoexchange system), we obtain optimal results for the two technologies. So in these conditions, installation of a geoexchange system would reduce the GHG emissions by almost 6 tons.

