Trends in Retrofit Activity in the EnerGuide for Houses Program

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Executive Summary

Under the EnerGuide for Houses (EGH) Program, homeowners request and pay for an energy audit of their home. The audit results in a report to the homeowner detailing energy consumption with recommendations for upgrades. If the homeowner undertakes sufficient upgrades and has a follow-up energy audit completed that reveals a satisfactory level of energy savings, the homeowner is eligible for a grant to offset some of the costs of the audits and retrofits.

By September 2005, over 188,000 homes had completed the first energy audit, and over 35,000 of these had undertaken the second post-retrofit audit. The purpose of this report is to analyze the data collected in these audits, which includes specifics such as amount of energy loss through basements, windows, doors, main walls, and ceilings, before and after the recommended retrofits take place, as well as a breakdown of energy used for space heating, domestic water heating, and lighting and appliances. In addition, the EGH audit provides estimates of the pre- and post-retrofit efficiency ratings of the homes, which summarize the energy saving potential of the recommended retrofits.

This project involves analyzing this database to determine what types of retrofits homeowners were more likely to implement and what kind of energy and cost savings were realized by taking these actions. One of the conclusions we can draw from the analysis of the EGH data base provided here is that decision to undertake energy retrofit investments, and the intensity of the investment (how many different kinds of upgrades to consider), depends on the characteristics of the homes. Based on these characteristics, it appears that the extent of inefficiencies observed in energy use, and therefore the expected high savings from investing in upgrades, is one of the main

motivating factors for the decision to undertake the investments. Other things remaining equal, homeowners characterized by high energy intensity and hence high cost of energy have a higher propensity to undertake the investment. Furthermore, from among those who decide to undertake the retrofit investment, those with very high expected cost and energy savings tend to have a higher retrofit intensity.

In addition to providing detailed information about residential retrofit behavior and trends, this description lays the groundwork for future modelling of residential energy retrofits. Since the EGH data lack sufficient information on demographic characteristics of the homeowners to investigate the effects of these factors on their decisions, one major task in ongoing research is to supplement the EGH data with relevant demographic and socio-economic information from available sources.

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1. Introduction

According to data from Natural Resource Canada's Office of Energy Efficiency, the residential sector is the third largest both in terms of energy consumption and greenhouse gas (GHG) emissions (Natural Resources Canada, 2005a). The sector's energy consumption grew, on average, by 13 percent during the period 1990 – 2003, notwithstanding a19 percent efficiency improvement. In terms of energy saving from the efficiency improvement, the same source also indicates that GHG emissions from the residential sector would have increased by 15 percent during the same period as opposed to the actual 13 percent. Space heating, ventilation, air conditioning and cooling (HVAC) account for over 60 percent of energy use and 50 percent of GHG emissions by the residential energy sector.

In Canada, residential home retrofitting appears to have great potential for energy saving and hence for the reduction of GHG emissions. According to Jaccard et al (2002), about 46 percent of the emission reductions requirement of the residential sector under Kyoto can be achieved through retrofitting shell and furnace improvements. This is because the stocks of houses built before 1980, when many of the energy conservation programs started, represents 70 percent of the current total housing stocks. Houses built before 1980 are about 25-40% less energy efficient as compared to R2000 (OEE, 2005b) and therefore use 30 percent more energy than homes built to the R2000 standard (Sadler, 2003). Yet, a survey of residential retrofits conducted in 1994 shows that only about one in twenty homeowner households undertook major work (improved insulation and improvements to windows and doors) aimed at improved energy efficiency (Natural Resources Canada, 1997).

Meanwhile, a recent publication by Natural Resources Canada (2005a) on the study of the trends in major appliances and equipments purchases since 1990 shows that significant energy efficiency improvement has been achieved in that respect.[1] The minimum energy performance standards (MEPS) put in place in 1995 and the availability of the Energy Star® products likely resulted in significant energy efficiency improvements in residential appliance energy consumption. However, the vast majority of residential energy consumption is for space heating so that improvements in the energy efficiency of appliances have played a relatively small role in bringing about the required changes.

This suggests that improvements in existing structures through various energy efficiency retrofit upgrades is the single most important activity required to achieve the stipulated goals of reducing GHG emissions in the residential sector. Building energy retrofits are of great significance not only because there are widespread energy efficiency gaps in the buildings sector, but also due to the very low cost requirement to tap them (Jacob, 2004). In addition to their energy saving roles, home retrofits have also ancillary benefits in the form of improved thermal comfort (Clinch and Healy, 2003). Conservation through retrofitting does not involve major adjustments to consumers' lifestyles, and it offers potential economic returns to the consumer (Deutscher and Munro, 1980). Various policies and policy incentives aimed at improving residential energy efficiency and thereby reducing GHG emissions in Canada attest to the importance of residential retrofit programs.

The general policy stance is reflected in the fact that Canada signed an agreement with the United Nations Framework on Climate Change (UNFCC) in 1992 to reduce the volume of greenhouse gas

[1] The major appliances and equipments include Refrigerators, Freezers, Dishwashers, Electric Ranges, Clothes Washers, and Electric Clothes Dryers.

emissions to their 1990 levels by the year 2010 (Jaccard et al, 2004). Canada's Efficiency Act was passed by Parliament in 1992 and the first Energy Efficiency regulations came into effect in February 1995 (Natural Resources Canada, 2005b). Following the November 1997 UNFCC Kyoto conference, Canada created the National Climate Change Process (NCCP) in Spring 1998, a body that is responsible for assessing the social, economic and environmental implication of policies and programs adopted to meet the Kyoto commitment (Jaccard, et al 2002). As part of this commitment the federal government at the time started a program asking all citizens to be part of a Canadian effort to reduce GHG emissions by one tonne per year, on average, assisted by incentives, improved information, and product availability.[2]

The financial incentive program was reflected in the year 2003 federal budget which allocated subsidies in the amount of $131 million for residential building shell and heating system improvements; $250 million for research and development of energy efficient technologies; $303 million for industrial energy-efficiency actions; and $321 million for improvements to federal government buildings, vehicles and infrastructure (Ministry of Finance, cited in Jaccard et al, 2004, p. 10).

For the residential sector, it is clearly indicated in the climate change action plan that the government will attempt to achieve the targets by creating conditions for more informed choices through cost-shared home audit programs for homeowners and providing information to encourage consumers to purchase cost-efficient appliances and equipment (Government of Canada, 2003). More specifically, the plan stipulates energy efficiency retrofits of 20 percent of existing low-rise housing and building all new houses to R2000 standards by 2010. This focus is in line with the

[2] The new Conservative government announced cessation of funding for local challenge programs on April 1, 2006.

observation that there exists untapped large energy saving potentials that could be harnessed through the retrofit programs. According to Jaccard et al (2002), about 46 percent of the emission reductions requirement of the residential sector under Kyoto can be achieved through retrofitting shell and furnace improvements.

The EnerGuide for Houses (EGH) program is one of the methods that has been used to achieve these stipulated goals. The program developed by the OEE in cooperation with Canada Mortgage and Housing Corporation (CMHC) provides evaluation service to homeowners with information on energy-efficiency improvements for their homes (OEE, 2005d). In simple terms, it is a home energy audit program with an incentive package. The Government of Canada allocated $73.4 million dollars in Fall 2003 to the EGH retrofit incentive. The EGH home retrofit has proven to be so effective that the 2005 federal budget increased this investment by $225 million over five years to encourage up to half a million homeowners to increase the energy efficiency of their homes (OEE, 2005).[3]

There are a number of qualified energy efficiency experts involved in the EGH program who are capable of providing Canadian homeowners with expert advice on the status of energy-efficiency of their homes and improvement options. An EGH evaluation costs between $300 and $350, although the effective cost varies across the regions because some provinces subsidize this service. Generally, homeowners obtain the service for a lower cost because of support from the Government of Canada and the CMHC. If requested by the homeowner, the EGH experts make an assessment of how the houses use energy and where energy is being lost through a "blower door" test to identify air leakage points, as well as a comprehensive walk-through of the house to collect

[3] The new federal Government discontinued the EGH program as of May 12, 2006. Property owners who have had a pre-retrofit evaluation performed prior to May 13, 2006 can have a post-retrofit evaluation and still qualify for a grant until March 31, 2007.

data. The information collected during the audit includes construction characteristics and thermal properties of the houses, as well as details of their space and domestic hot water heating equipment. The collected data are used for modeling home energy use, which generates estimates of home energy consumption and costs as well as EGH energy-efficiency ratings, and is used to determine energy-efficiency upgrade options. Based on the information that is compiled, a list of improvement recommendations is provided and reported.

The Government of Canada provides grants to homeowners who complete energy efficiency retrofits based on EGH advisor recommendations as an incentive for undertaking the recommended retrofit actions even though it is believed that the retrofit costs are recoverable through energy savings. This grant amount is determined based on the difference between the pre- and post-retrofit EGH ratings of the houses. Only homes that have been evaluated using the EGH service are eligible for the government grants. Thus, homeowners have to request the EGH auditors to conduct a second round assessment and determine that the minimum energy efficiency improvements have been achieved in order to qualify for government grants. There is also a time limit in terms of the gap between the first audit and time when the homeowners implement the recommendations and have their second audit review in order to qualify for the grant. Homeowners whose first EGH audit was conducted prior to August 12, 2003 had until October 15, 2004 to complete their second evaluation and have their application received. Homeowners who had their first evaluation after August 12, 2003, have 18 months from the date of this first evaluation to complete their second evaluation and submit their application in order to qualify for the grant.

For homeowners demonstrating a minimum improvement in the energy efficiency of their homes, the amount of the grant ranges between $116 and $3,348. The actual amount paid to each homeowner depends on the difference between pre- and post-retrofit EGH ratings. Another incentive package is offered by CMHC as a 10 percent refund on the mortgage loan insurance premium for homeowners who borrow money to build or buy an energy–efficient home or renovate an existing one. Beginning January 1, 2005, homebuyers also have the flexibility of extending the amount of time required to repay their mortgage from 25 years to a maximum of 35 years.

The EGH audit reports have resulted in a very rich data set which contains the information compiled during both the first and the second audits. During the initial assessment, the report provides estimates of pre and post-retrofit energy consumption and costs by energy type. It also provides details of the actual thermal properties of the buildings and HVAC system along with the recommended upgrades. During the second audit, the EGH auditors estimate the actual post-retrofit energy consumption and energy efficiency properties which can be compared to the pre-retrofit and upgrade case counterparts.

An earlier analysis of the data by Aydinalp et al (2001) indicates that the number of houses audited by end of year 2000 was only 20,000. This figure had increased to 122,723 as of July, 2004 (Zyzniewski and Mistry, 2005**)**. This shows that the EGH program has become increasingly popular among Canadian homeowners during the past few years. The number of homeowners who had ordered a second evaluation as of December 2005 is about 35,000. This number has shown a significant increase compared to the figures observed a year earlier. The figure as of July 2004 was only 8,869 (less than 8% of the houses that had undergone the first evaluation). Thus, the percentage of homeowners who have had their homes evaluated for the second time – those who undertook the recommended retrofits – has also increased significantly. This is perhaps due to the fact that the incentive package aspect of the EGH program was introduced in October 2003.

The purpose of this study is to describe homeowners' retrofit behavior and trends in retrofit activities using the latest available EGH data. In addition to providing detailed information about residential retrofit behaviors and trends, this description lays the groundwork for subsequent modelling of residential energy retrofits.

2. The Effectiveness of the EGH Program

We consider three criteria to evaluate the effectiveness of the EGH program. First, the extent to which homeowners are induced to undertake retrofits upgrades. Second, the magnitudes of energy saved and GHG emissions reduced. Lastly, at what costs are these goals achieved, or how cost effective are the programs?

Generally, home energy audits are very important mechanisms for informing homeowners about their current energy usage and wastage, as well as available energy-savings options. Deutscher and Munro (1980) argue that home energy auditing is a vital tool to help homeowners decide to undertake the required retrofit decisions since the most important barrier to making such decisions is lack of information and uncertainties surrounding the alternatives and the resulting cost savings.

The available evidence on the effectiveness of similar programs suggests that such programs can generally lead to energy savings although the savings may not be cost effective. Loughran and Kulick (2004) provide evidence on the effectiveness of the utility-sponsored Demand Side Management (DSM) programs in the US that have been in place since the 1970s. These programs are similar in nature to the EGH program in that they include the provision of general and technical information to consumers about how they can better manage their energy consumption. They also involve incentives in the form of low-interest loans and other subsidies for the installation of energy-efficient technologies (Loughran and Kulick, 2004:20). The authors find that DSM programs did result in a reduction in energy consumption. However, when compared to the expense required to achieve the savings, the effect is small. Hartman (1988) concludes that, after correcting for self selection bias in estimation, the amount of energy saved through such programs is less than is traditionally believed.

Hirst (1987) studied the Bonneville Power Administration Interim Residential Weatherization Program, a program that ran for three years providing free audit services and zero interest loans for the installation of measures recommended in the audit. His finding is that the energy savings achieved through these programs were sufficient to cover the costs of the retrofits. A similar study by Hartman and Doane (1987) considers the Portland General Electric Companies audit program while Sebold and Fox (1985) provide evidence on the San Diego Gas and Electric Company's audit program. Their findings are that even though consumption dropped, the realized saving is below the level predicted by the energy auditors.

More generally, Jaccard et al (2004) argue that there is mounting evidence indicating that voluntary participation programs with modest subsidies are ineffective and inefficient. Voluntary participation is ineffective because participation will be optional and hence the retrofit investments may not be undertaken to the required extent, particularly when there are no significant incentive payments. The EGH data tend to be supportive of this suggestion, with only 18.7% of the homeowners that ordered the first audit services actually completing the second round audit, although it must be noted that some of these homeowners may still be eligible for the second audit, and some energy audits may have indicated the need for a relatively small amount of retrofitting which did not warrant the cost of a second audit. OEE (2005b) estimates that if all of the homes in the first round audit had implemented the recommended upgrades, they would have achieved the 1-tonne challenge (that is, it is estimated that each household would have reduced GHG emission by 4 tonnes).

While failure to induce retrofit decisions to the required extent is one issue, it is equally important to consider the cost effectiveness of the investments if undertaken. Using 1994 residential energy retrofit survey data, Guler et al (1999) evaluate the cost effectiveness of energy savings through retrofits in Canada. Using investment cost estimates of each upgrade scenario, the study calculates the energy saving per dollar investment by dividing the estimated annual household energy savings by the retrofit investment cost. According to the study, upgrading a space heater to high efficiency is the best in terms *of energy saving potential* as compared to all the retrofit options available to homeowners (it results in an energy saving of 8% per year). However, in terms of *cost effectiveness*, upgrading the space heater to the medium efficiency level is the most effective option, suggesting that some retrofit upgrades might be highly costly even if they are characterized by significant energy saving potential. Among the insulation retrofit options, a basement ceiling upgrade was found to be the most feasible, while insulating the main walls to achieve an RSI value of 3.3 was the least feasible. The study shows that there is no significant energy saving potential from appliance upgrade scenarios, mainly because few houses that are eligible for such upgrades.

3. The EGH Program

As noted in the introduction, the EnerGuide for Houses (EGH) program is essentially a home energy audit program with an incentive package that was developed by the OEE in cooperation with Canada Mortgage and Housing Corporation (CMHC) to provide an evaluation service to homeowners with information on energy-efficiency improvements for their homes (Natural Resources Canada, 2005c). Homeowners request and pay for an energy audit of their home. The audit results in a report to the homeowner detailing energy consumption with recommendations for upgrades. If the homeowner undertakes sufficient upgrades they pay for a follow-up energy audit and if this reveals sufficient energy savings, the homeowner is eligible for a grant to offset some of the costs of the retrofit.

The report that is provided to the homeowner includes specifics such as amount of energy loss through basements, windows, doors, main walls, and ceilings, before and after the recommended retrofits take place.[4] The report also provides a breakdown of energy used for space heating, domestic hot water heating (DWH), and lighting and appliances. Most importantly, the EGH auditor provides estimates of the pre- and post-retrofit efficiency ratings of the homes, which summarize the energy saving potential of the recommended retrofits. A general guide to the EGH ratings is provided in Table 1. The rating is used for assessing the eligibility of homeowners for a grant, with the grant calculation based solely on the difference between pre- and post-retrofit EGH ratings. The grant itself is only meant to partially defray some of the costs as OEE argues that the initial investment for the EGH expert service as well as the retrofit costs are easily recovered in energy savings if the home improvements outlined in the evaluator's EGH report are implemented (Natural Resources Canada, 2005c).

[4] http://oee.nrcan.gc.ca/residential/personal/home-improvement/service/report.cfm?attr=4

Table 1: A Guide to EGH Ratings

House Characteristics	Typical Rating
Older house not upgraded	0 to 50
Upgraded older house	51 to 65
Energy-efficient upgraded older house or typical new house	66 to 74
Energy-efficient new house	75 to 79
Highly energy-efficient new house	80 to 90
House requiring little or no purchased energy	91 to 100

Source: OEE, NRCan[5]

The EGH data set contains the information compiled during both the first and the second audits. This information includes estimates of pre- and post-retrofit energy consumption and costs by energy type, details of the actual thermal properties of the buildings and HVAC system, the recommended upgrades, and the EGH pre- and post-retrofit ratings. A comparison of the pre-retrofit and post-retrofit energy consumption and costs provides information concerning energy consumption and cost savings emanating from the undertaken retrofit activities and how much of the estimated (upgrade case) post-retrofit levels were actually achieved after undertaking the retrofit activities.

The EGH dataset that is used in the analysis here (as at September 2005) includes 188,368 houses from across Canada that have undergone the first EGH evaluation. As shown in Table 2, approximately 32% of the houses that underwent the first EGH evaluation are in Ontario; 19% are in Alberta, and 17% are in British Columbia. The fourth largest location for the initial audits is in Quebec (12%), with all other provinces and regions totalling 20%. An earlier analysis of the data available at the end of the year 2000 by Aydinalp et al (2001) shows that the number of houses

[5] http://oee.nrcan.gc.ca/residential/personal/home-improvement/service/rating.cfm?attr=4

audited at that time was only 20,000, although this had grown to 122,723 by July 2004 (Zyzniewski and Mistry, 2005).

Table 2. Number of Homes undertaking the First and Second EGH Audits (Sept 2005)

House Region	No. Homes in 1st audit	Percent of total	No. of Homes in 2nd Audit	Homes in the 2nd Audit as a % of No. in 1st audit	Homes in the 2nd Audit as a % of No. in the 2nd Audit
Alberta	34798	18.5	7927	22.8	22.5
British Columbia	32647	17.3	6461	19.8	18.3
Manitoba	12668	6.7	2782	22.0	7.9
New Brunswick	1781	0.9	334	18.8	0.9
Newfoundland	2089	1.1	187	9.0	0.5
North West Territory	364	0.2	30	8.2	0.1
Nova Scotia	5326	2.8	696	13.1	2.0
Nunavut	64	0.0	0	0.0	0.0
Ontario	60448	32.1	11344	18.8	32.1
Prince Edward Island	533	0.3	41	7.7	0.1
Quebec	22114	11.7	1580	27.2	4.5
Saskatchewan	13823	7.3	3756	10.6	10.6
Yukon Territory	1713	0.9	151	8.8	0.4
Total	188368	100.0	35289	18.7	100.0

As Table 2 shows, less than 20% of homeowners who undertook the first audit also completed the second evaluation, although this still totals over 35,000 houses. This number has grown substantially from the corresponding figure observed a year earlier – as of July 2004 only 8,869 homeowners had completed both evaluations, which is less than 8% of the houses that had undergone the first evaluation). This growth in the percentage of homeowners who have had their homes evaluated for the second time – that is, those who undertook sufficient of the recommended retrofits – may be partially due to the introduction of the incentive package for the EGH program in October 2003.

As the last two columns of Table 2 show, there is again quite marked variation across the regions in terms of the percentage of homes participating in the second phase (undertaking retrofits). The largest proportions of houses undertaking the second audits are again in Ontario, Alberta, and British Columbia, which together account for 73% of the second audits. However, there is a quite different pattern across provinces and regions in terms of the proportion of houses from the first audit that also undertook the second evaluation. Quebec has the highest proportion at 27.2%, while Alberta and Manitoba have around 22% each, followed by British Columbia with 19.8% and Ontario and New Brunswick both having 18.8% of homeowners who undertook the first audit also undertaking the second evaluation.

A number of reasons can be listed as factors behind the relatively low participation in the second audit for those houses that underwent the first audit. First, it must be kept in mind that at the time of the sample many of the homeowners were planning to have a second audit but had not undergone it by that time. Apart from this possibility, the most obvious explanation is that for a variety of reasons, most of the homeowners didn't implement the recommended retrofits at all. It is also possible that they did not see the importance of the second audit even though they undertook the recommended retrofits. This could occur because the second phase EGH auditor's service involves service charges as well, and homeowners may not consider a second audit to be worthwhile if the expected grant amount is very small. This is perhaps more likely for newer houses where the efficiency rating may not significantly increase after upgrades. Alternately, homeowners may have followed only some of the upgrade recommendations, in which case they may have anticipated that the grant would not offset the cost of the second audit. Another possible reason is that the grants were available for a specific time period – retrofits and the second audit generally had to be completed within 18 months of the first audit – and this may have proven too short a period for some homeowners, or the 18 month period may not yet have expired for many homeowners. Finally, another possibility is that the EGH auditors may not have offered retrofit recommendations of any sort. Clearly, in order to determine an accurate explanation of non-participation in the second audit it is necessary to explore the EGH data in some detail.

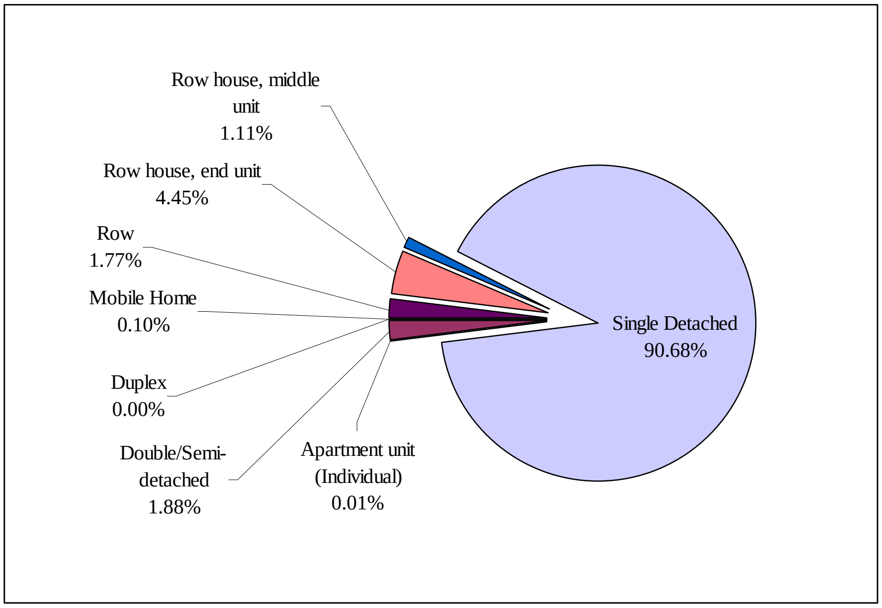
4. Characteristics of Houses in the EGH Program

The characteristics of the homes are very important in determining residential energy efficiency. Part of the variation in retrofit decisions across the provinces could be attributed to variation in house characteristics. Table 3 below shows that the large majority of the homes in the EGH program are quite old. In general, about 94% of the houses were built in 1990 or before. Houses built before 1971 alone account for 55 % of the participants. As Figure 1 shows, over 90 percent of the houses in the sample are single detached houses. About 46 percent of these are one storey while 46 percent are two storey buildings. Only 3 percent of the houses are three storey buildings owing to the fact that the focus in the EGH program is on low-rise homes. Also, over 90 percent of the houses do not have a ventilation system of any sort.

Table 3: Age Distribution of the Houses Participating in the EGH Program

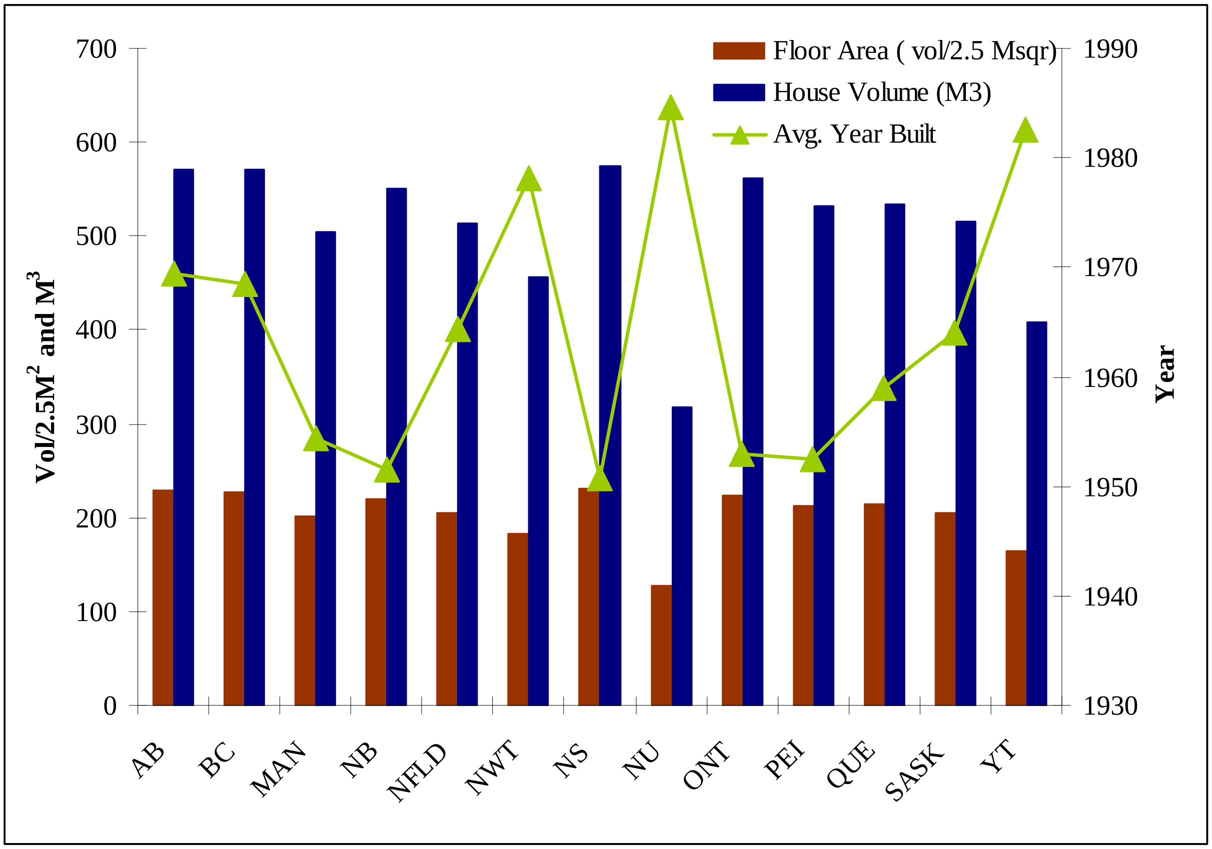
Vintage	Frequency	Percent	Cumulative Percent
1945 or before	37563	19.9	19.9
1946 - 1960	35575	18.9	38.8
1961 - 1970	30409	16.1	55.0
1971 - 1980	46561	24.7	79.7
1981 - 1990	26369	14.0	93.7
1991 to 2005	11891	6.3	100.0
Total	188368	100.0	

Figure 1: Types of Houses



There is marked variation in the average ages of the homes across the provinces (Figure 2). On average, the most recent buildings are from Nunavut, Yukon and North Western Territories while the oldest are from Nova Scotia and New Brunswick. While there are no significant variations across the rest of the provinces in the average sizes of the buildings as described by the floor area and house volume, we observe that the provinces characterized by newer buildings are also characterized by small home sizes. This feature is very important to note since home heating which is directly dependent upon the house volume is the most important component of residential energy consumption. The fact that older houses tend to have larger floor areas would tend to make energy consumption by old homes much higher than that for newer homes. To the extent that this is the case, there would be great potential for the (predominately older) houses involved in the initial assessment to increase their energy efficiency by undertaking the recommended retrofits. Of course this assumes that other factors such as heating-degree days are the same. Despite being newer and having smaller floor areas, energy consumption could be higher in typical houses in Nunavut, Yukon, and the Northwestern Territories as they experience more heating-degree days.

Figure 2: House Floor Area, Volume, and Average Year of Construction by Province



4.1 Thermal Envelope

The variation in the average ages of the houses across provinces implies that the thermal conditions of the buildings, and hence their energy intensity, are also likely to vary. This is because thermal conditions are highly dependent upon the ages of the buildings. Figure 3 shows that newer buildings have better average levels of ceiling and wall insulation, although this relationship is not as marked for foundation wall insulation. Figure 4 presents the distribution of the estimated heat loss through house ceilings, main walls and foundation walls. This figure shows that the heat loss through the ceilings is not as significant as the losses through main walls and foundation walls. While all types of heat losses are higher (worse) for older buildings, this relationship is particularly evident for heat losses through main walls. .

Figure 3: Conditions of Thermal Envelope by House Age

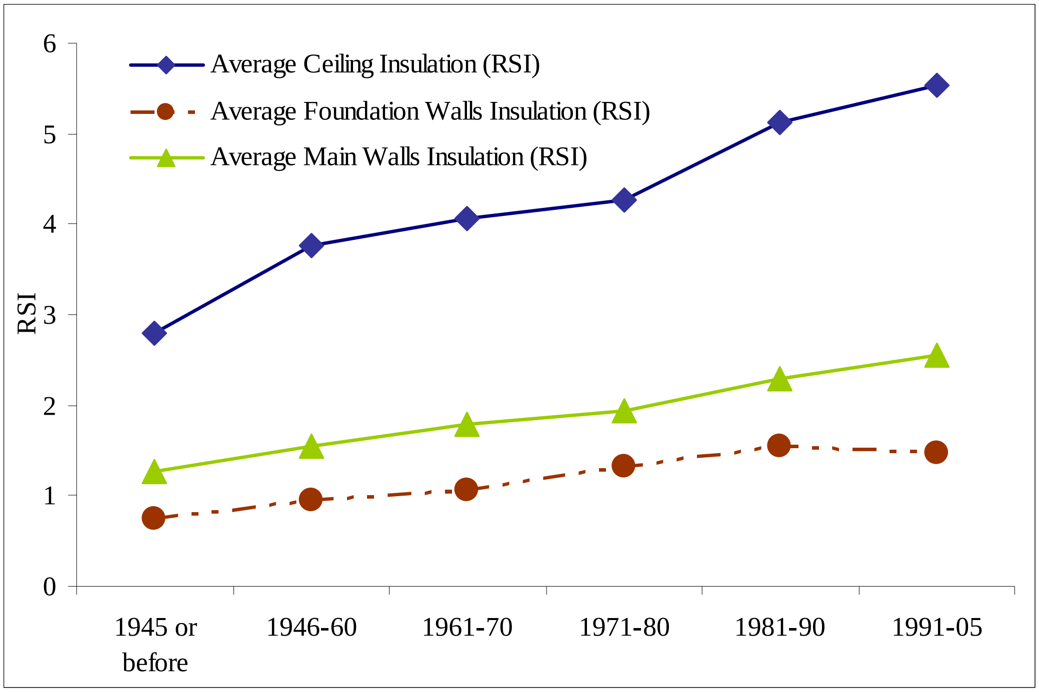
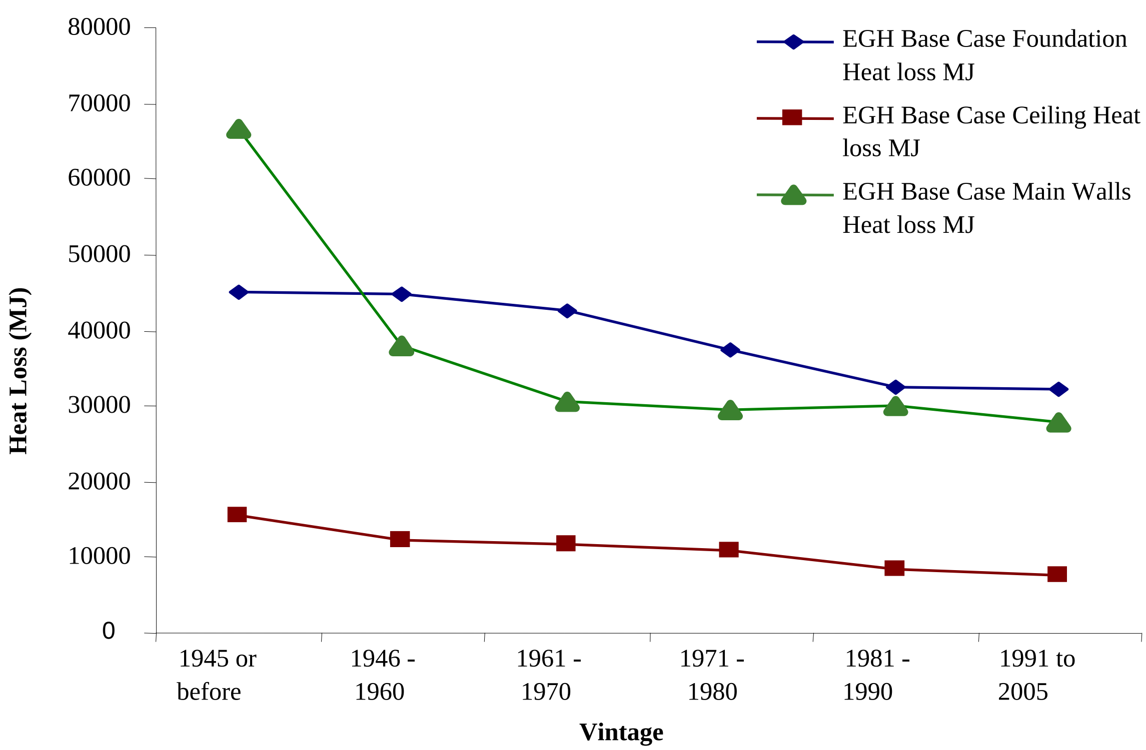
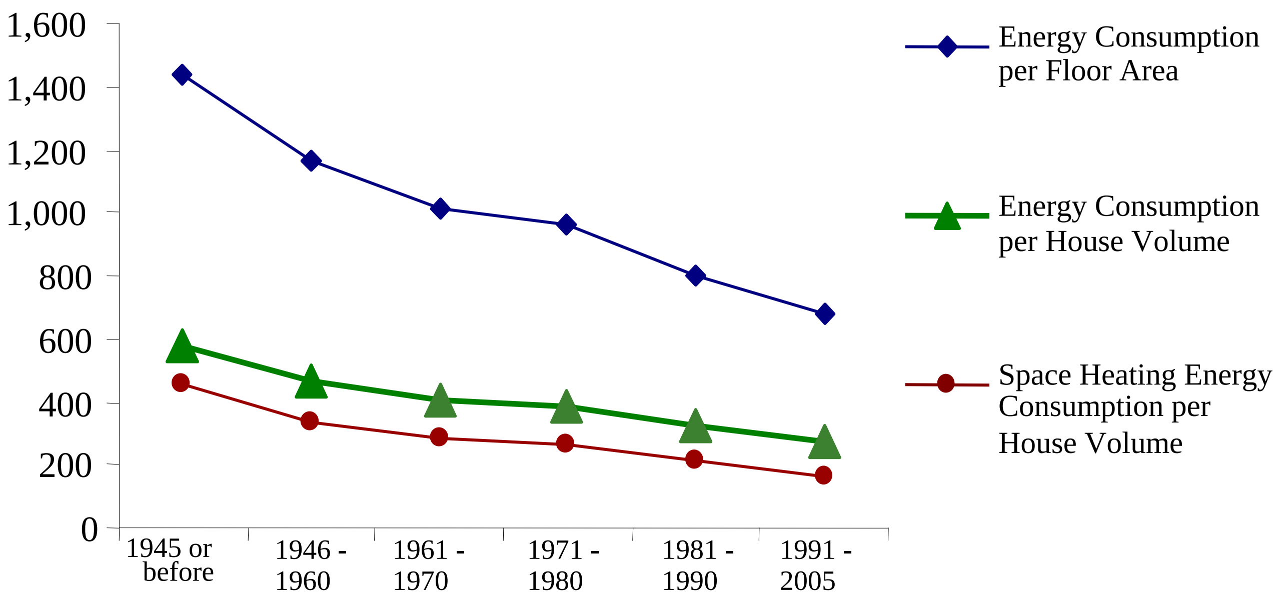


Figure 4: Heat Loss for Building Envelope Components by Vintage



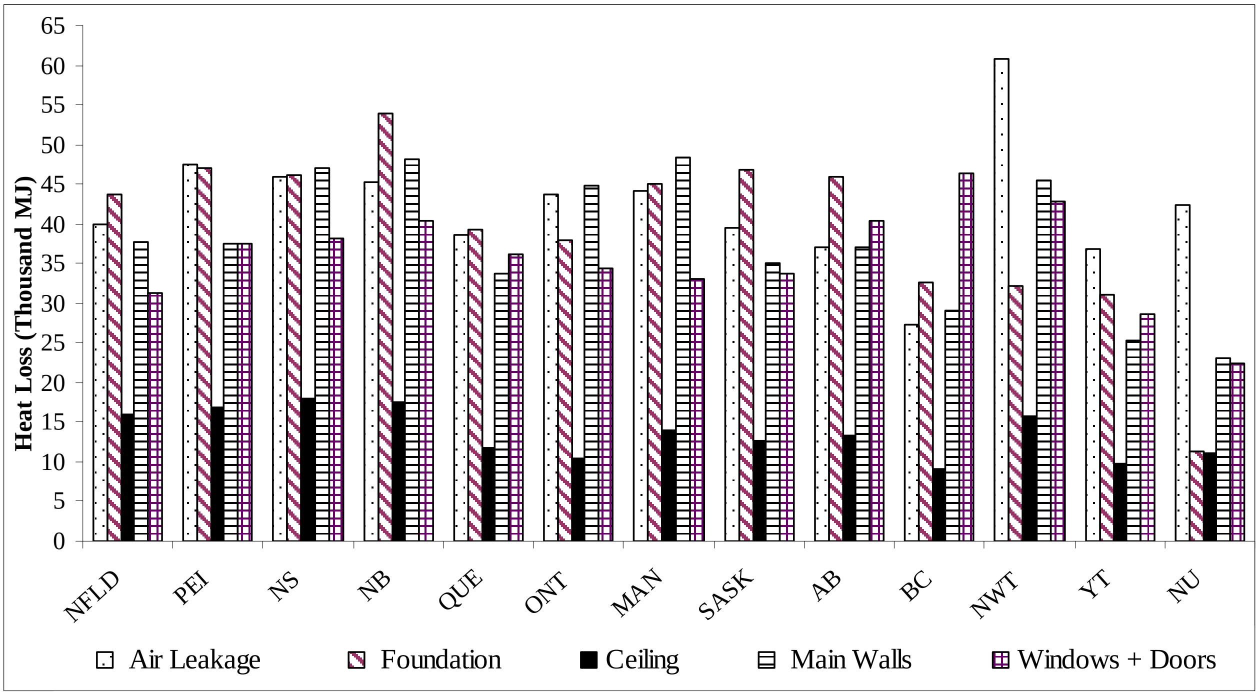
Of course, poorer insulation properties and higher heat losses in older buildings translate into lower levels of energy intensity (higher energy efficiency) for newer houses, as shown in Figure 5.

Figure 5: Energy Consumption by House Age



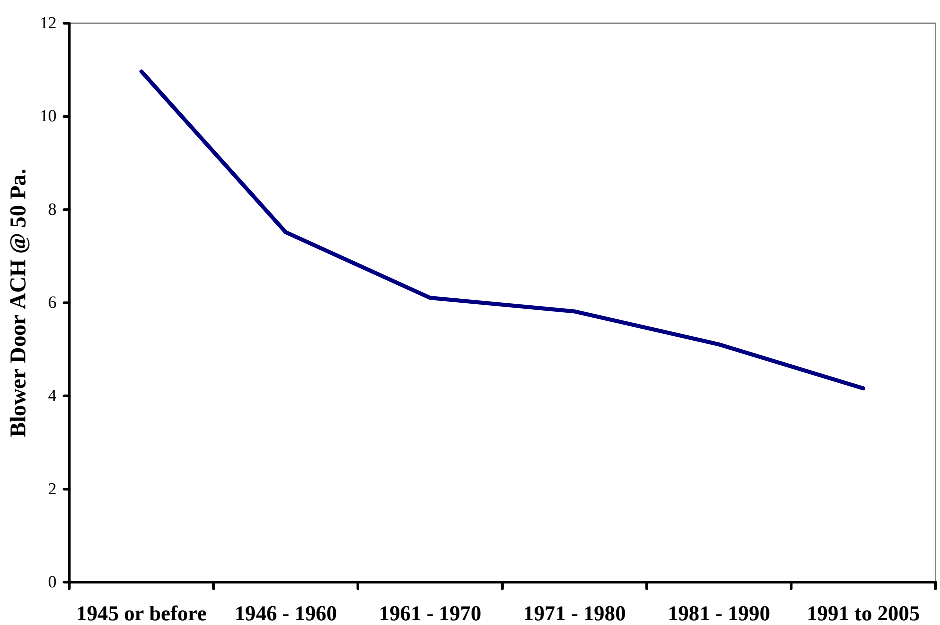
Given the differences across provinces and regions in average house age, as depicted in Figure 2, and the finding that the thermal envelope and heat loss are worse in older buildings (Figures 3 and 4), it would be expected that heat losses due to different causes would also vary across regions. This is found to be the case, as shown in Figure 6. Heat losses through foundations appear to be worst in New Brunswick while air leakage is much higher in the Northwest Territories than elsewhere. Heat losses through ceilings are lowest in British Columbia and Ontario, while heat losses through main walls are highest in Nova Scotia, New Brunswick, Manitoba, Ontario and the Northwest Territories. Of course, it must be noted that the sample contains houses that had at least one energy audit, and these may not necessarily be representative of all houses in each region.

Figure 6: Estimates of Base Case Heat Loss



Finally, the blower door measure of the air-tightness of the building also shows a clear pattern that newer buildings are superior in terms of the thermal envelope (Figure 7).

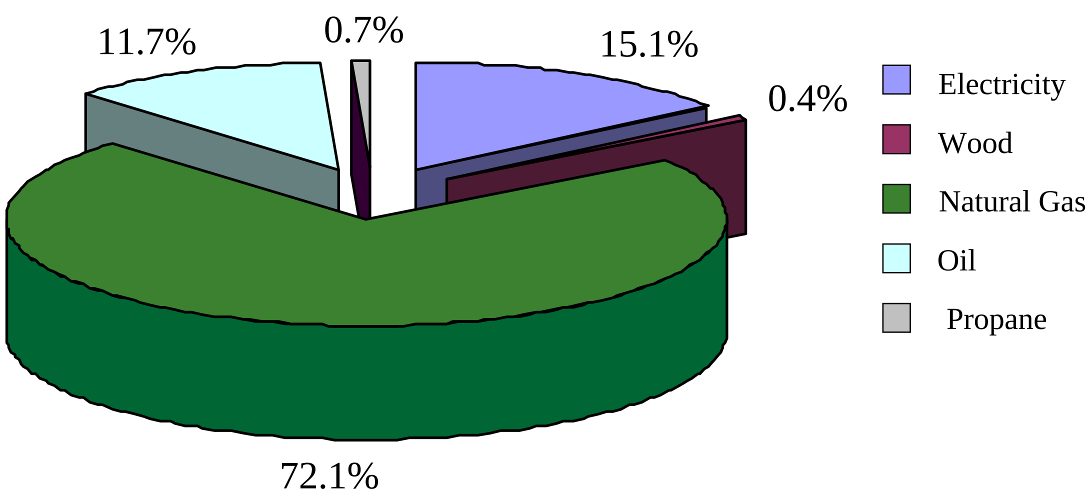
Figure 7: Blower Door ACH by Vintage



4.2 Furnace and Domestic Water Heating (DWH) System and Fuel Types

Energy consumption patterns naturally depend on the types of equipment used. In the EGH database, furnaces with continuous pilots are used in more than 45 percent of the cases. This shows that natural gas is the most widely used energy for space heating. Electric baseboards /hydronic heaters are used in 12 percent of the cases (mainly in Quebec). This suggests that electricity is the second most widely used form of energy for space heating, and is foremost in Quebec. This is revealed from the furnace fuel type data. As Figure 8 shows, natural gas is the furnace fuel used in more than 72 percent of the cases, followed by electricity (15%) and oil (12%). Propane and wood together are used only for 1% of the cases.

Figure 8: Distribution of Furnace Fuel Type



The DWH system type is predominantly conventional tank and conventional tank (pilot). The conventional tank and conventional tank (pilot) together account for more than 90 percent of the DWH system type (Figure 9). As Figure 10 shows, the conventional tank (pilot) is widely used in Alberta, British Columbia, Ontario and Saskatchewan.

Figure 9: Domestic Hot Water Equipment type (pre-upgrade)

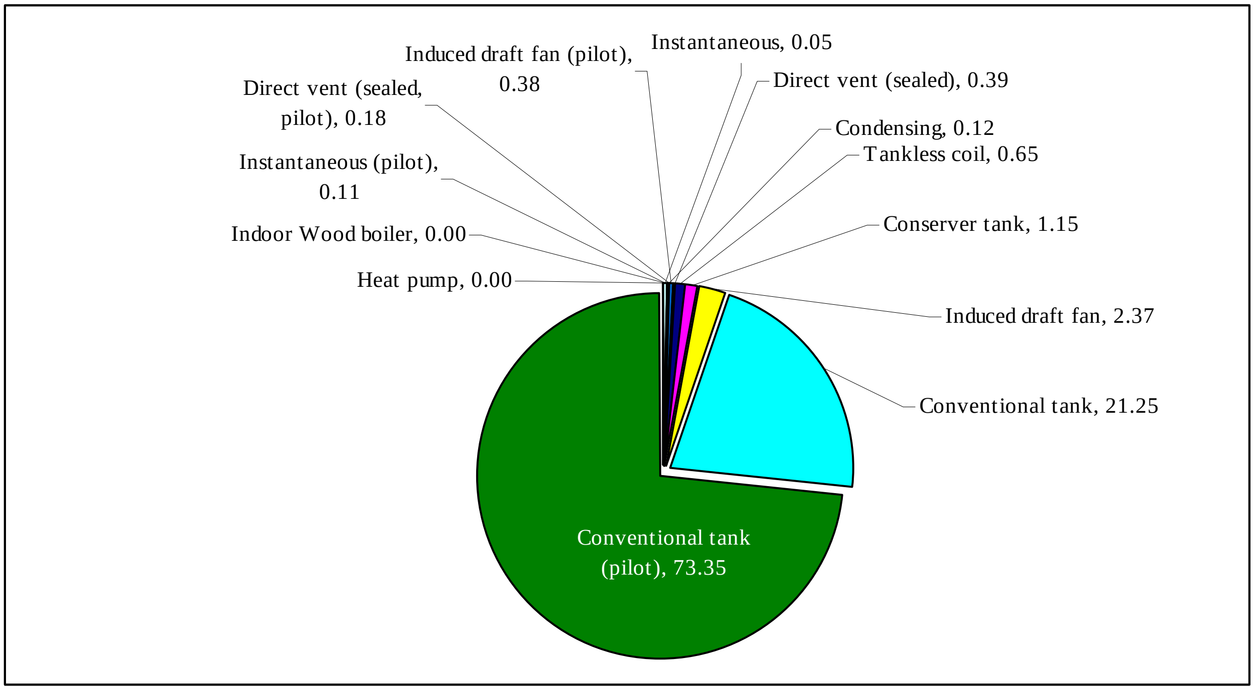
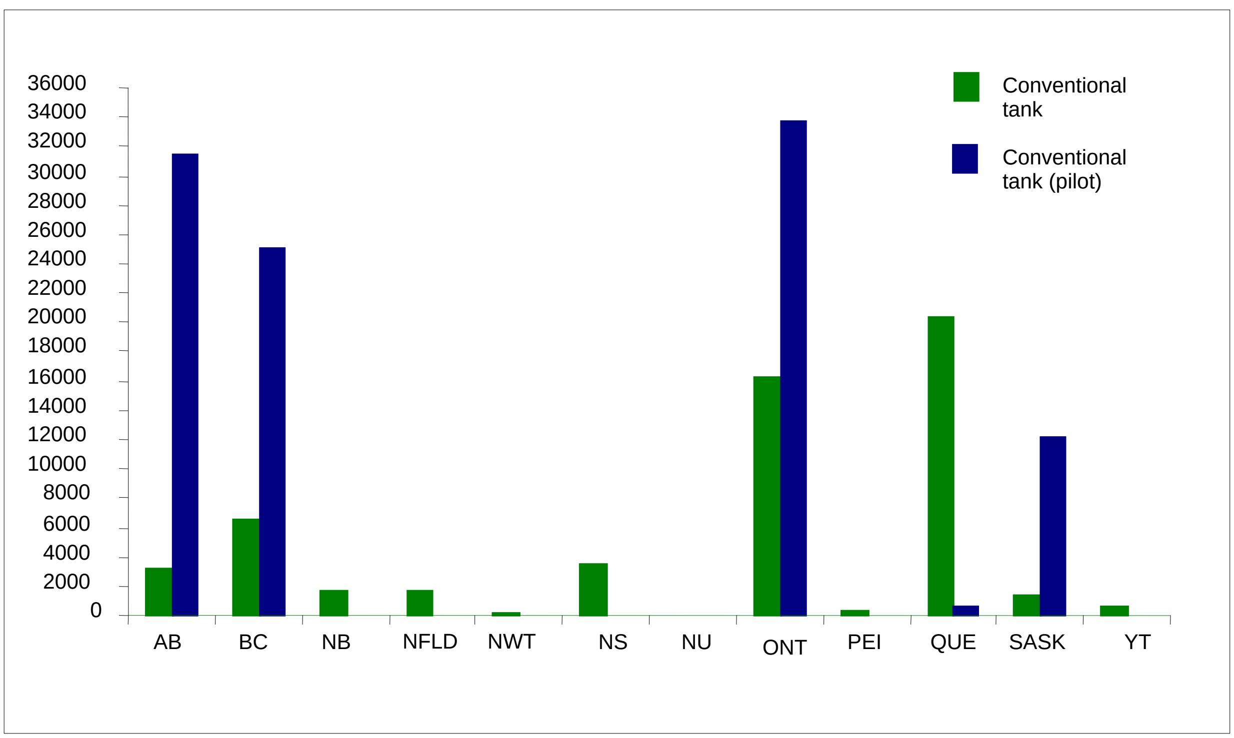
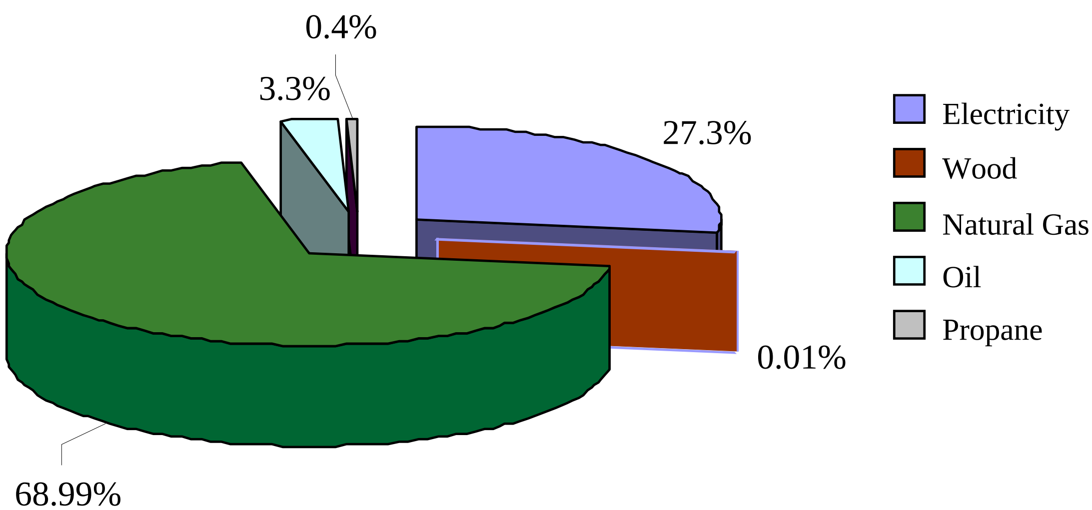


Figure 10: Conventional and Conventional Pilot tank, by Region



The DWH fuel type is also dominated by the use of natural gas (about 69%). However, there is more widespread use of electricity for domestic water heating compared to home heating, while there is less widespread use of oil for this purpose compared to the home heating (Figure 11).

Figure 11: Distribution of Domestic Water Heating Fuel Type



There is a marked difference in the distribution of furnace and DWH fuel types used by Canadian residences in different provinces. For example, although it is used only in about 12% of the residences countrywide, oil is most dominant space heating/furnace fuel in the Northwest Territories, Nova Scotia, Nunavut, Prince Edward Island and the Yukon Territory (Figure 12). This kind of variation is also observed when comparing the DWH fuel types across provinces and regions (Figure 13).

Figure 12: Distribution of Furnace Fuel Type by Province

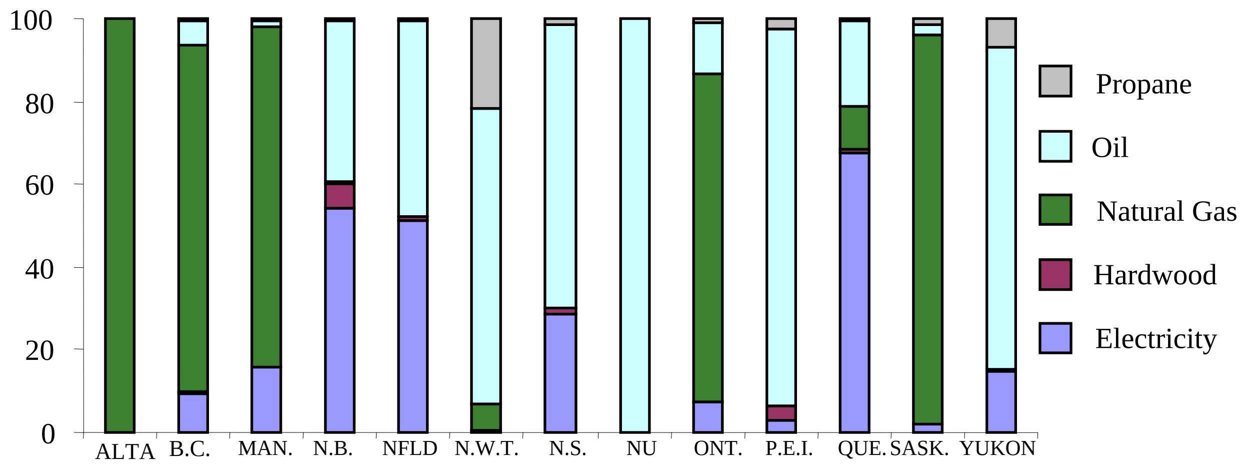
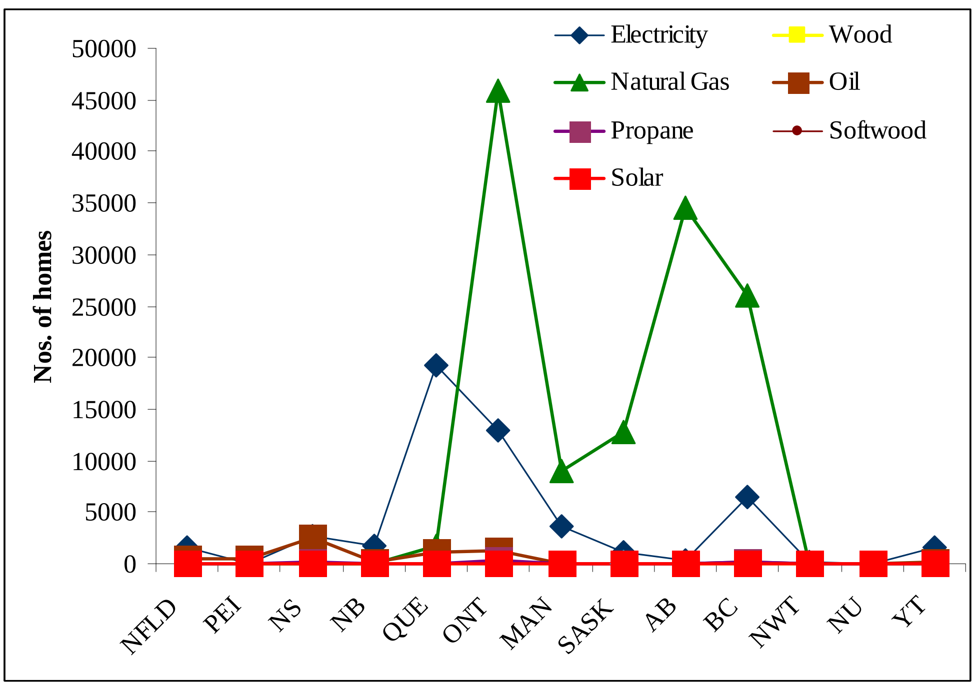


Figure 13: DWH Fuel Type by Province – Base Case



Variation in furnace types across the provinces can contribute to variation in energy efficiency. High efficiency baseboards, forced air furnaces, radiant ceiling panels and radiant floor panels are 100 percent efficient while wood furnaces, and conventional furnaces and boilers are highly inefficient (see Appendix 1). This shows that home heating energy efficiency varies depending on the type of heating system in place. Furthermore, it suggests that there are potentially significant gains from upgrading the heating system from less efficient to the most efficient specifications. Figure 14 shows the furnace efficiency that could be achieved (upgrade case) against the actual efficiency level by house age. As expected the gains are less for newer houses that presumably also have newer furnaces. Figure 15 shows similar information by province. Both these figures show that furnace efficiency could be increased by a significant margin if the recommended upgrades take place. The upgrade scenario largely involves replacement of the conventional tank by the conventional tank pilot. By upgrading the furnace/boiler, it is shown that significant energy savings could be achieved in all provinces. Figure 15 also indicates that the extent of the possible savings is larger the larger is the initial furnace/boiler energy consumption.

Figure 14: Pre and Post Upgrade Furnace Steady State Efficiency by Vintage

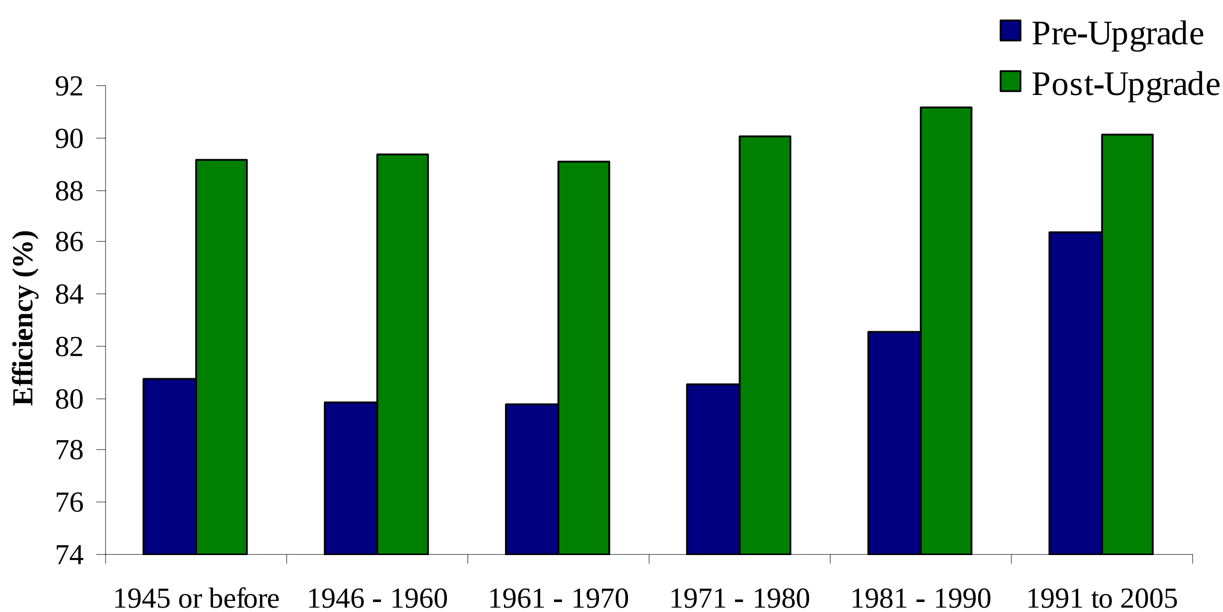
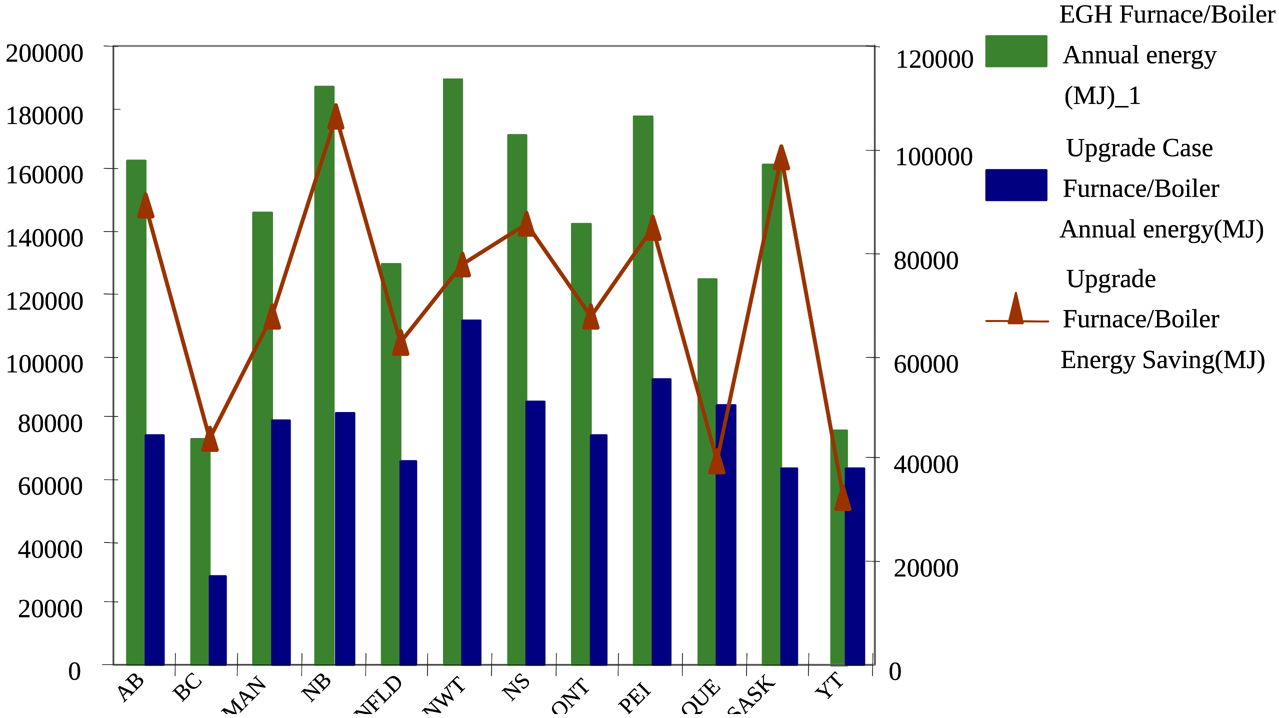
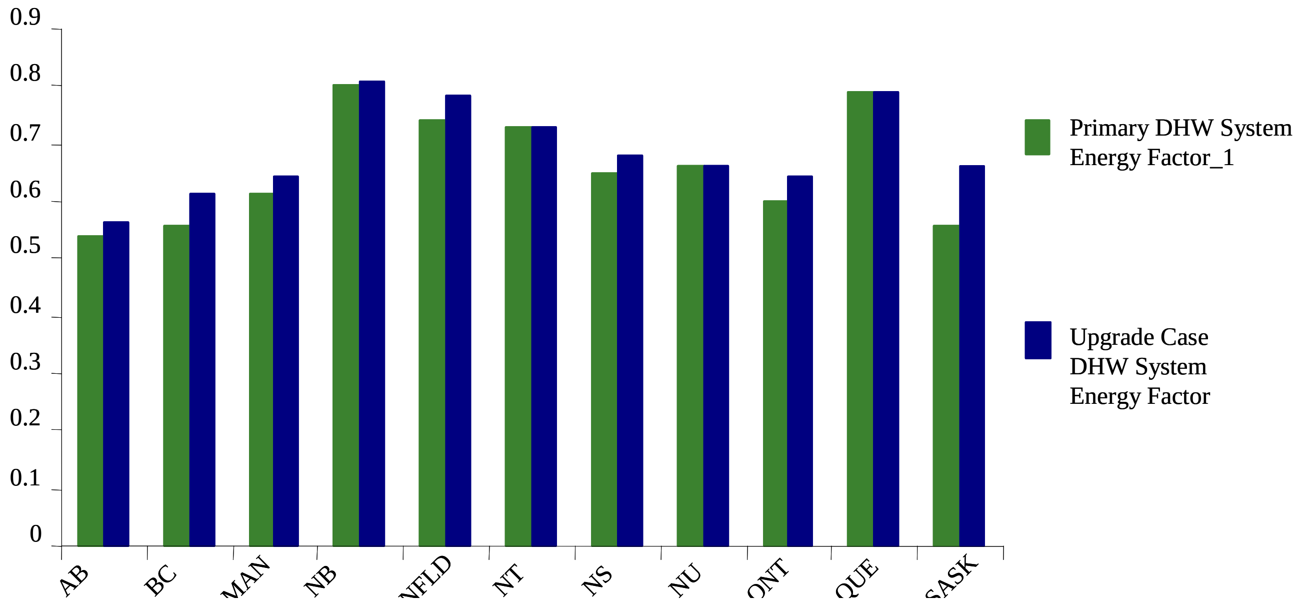


Figure 15: Comparison of Initial and Upgrade Case Furnace/Boiler Average Annual energy consumption with the Implied Savings



DWH system efficiency seems to be unrelated to the type of system originally in place. Only about 10% of the DWH systems are characterized by a heat pump while the remaining 90% are non-heat pump DWH systems. Most interestingly, the DWH system heat factor (efficiency) is not positively related to widespread use of the "Pilot" conventional tank. For example, the region that has the highest DWH system heat factor, New Brunswick, does not use the "pilot" conventional tank at all (Figure 16). Similarly, provinces with the highest number of "pilot" conventional tanks, Alberta and Ontario, are not characterized by the best DWH system energy factors either. The DWH system energy factor might largely depend on the type of energy used.

Figure 16: Comparison of Primary DHW System Efficiency



The DWH fuel type descriptions in the EGH database suggest that natural gas is the most dominant fuel used for domestic hot water heating followed by electricity (69 % and 27%, respectively). However, compared to energy consumption for space heating, the importance of natural gas is less pronounced while electricity's importance is stronger. The dominance of natural gas seems to come mainly from Alberta, British Columbia, Ontario, and Saskatchewan (Figure 13). Figure 16 shows that there is significant variation in primary DWH system efficiency as well. The upgrade scenario shows that there is room for improvement on average in all the regions except for Quebec, Nunavut, and the Northwestern Territories. The highest efficiency (0.8) is recorded in New Brunswick, followed by Quebec. To relate this to the energy use pattern, Quebec mainly relies on electricity while New Brunswick mainly relies on oil and electricity. Hence, it seems that natural gas as the DWH energy type is characterized by lower efficiency (DWH energy factor).

4.3 Energy Consumption Patterns

The frequency distribution of fuel types is a useful indicator of the importance of a particular fuel type. To get the exact consumption pattern, however, we need to examine the quantity consumed of each type of energy. Overall, the energy consumption pattern is such that natural gas accounts for about 64 percent while electricity, propane and oil account for 25%, 10%, and 1%, respectively (Figure 17). This general pattern is not sensitive to the ages of the buildings (Figure 18).

Figure 17: EGH Residential Energy Consumption Pattern in Canada

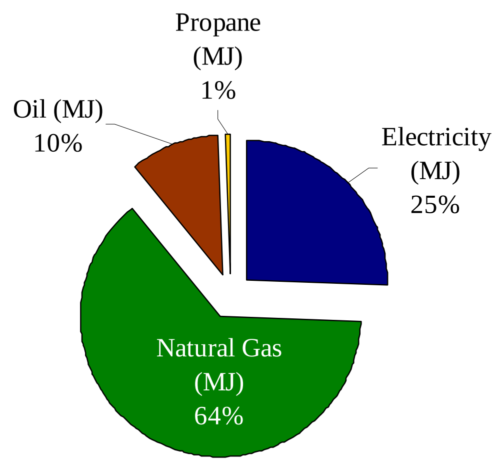


Figure 18: Residential Energy Consumption Pattern by House Age

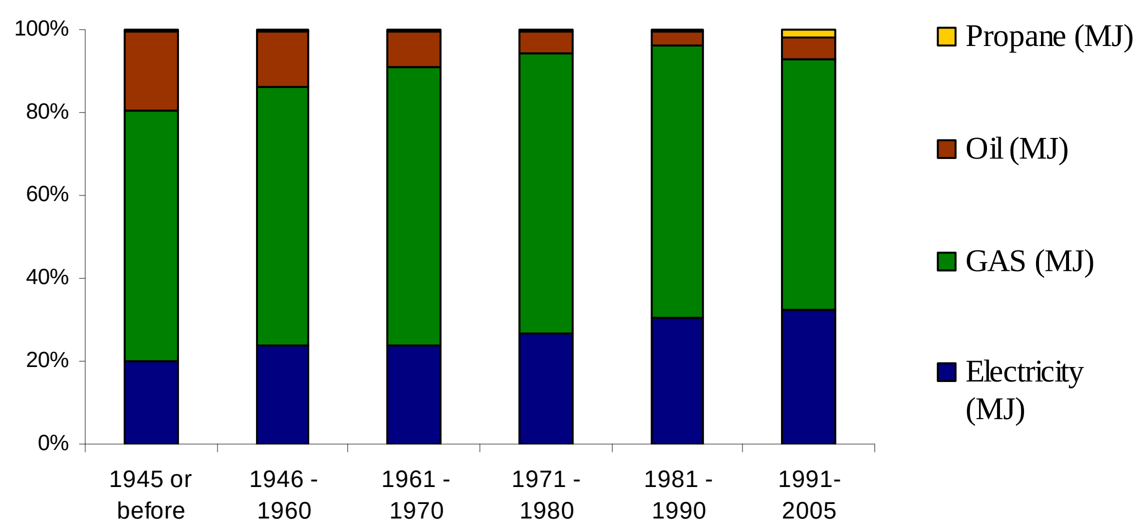
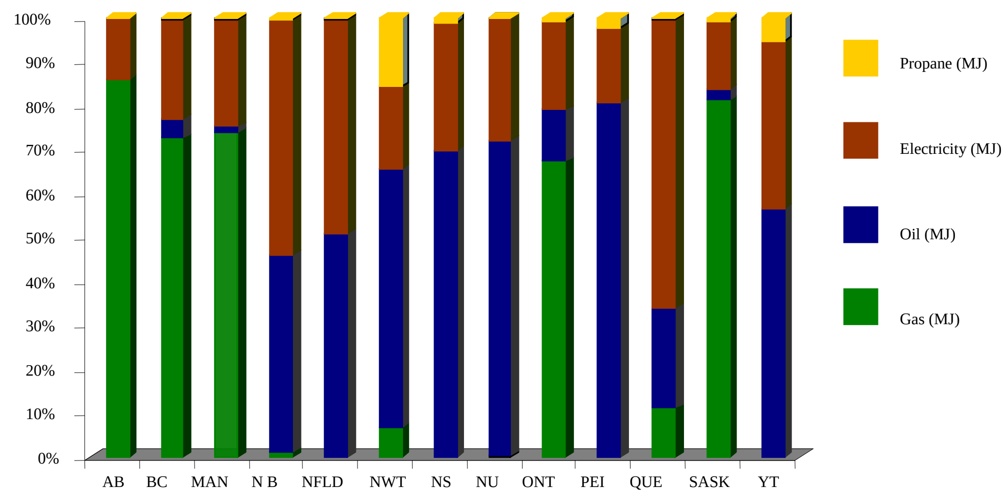


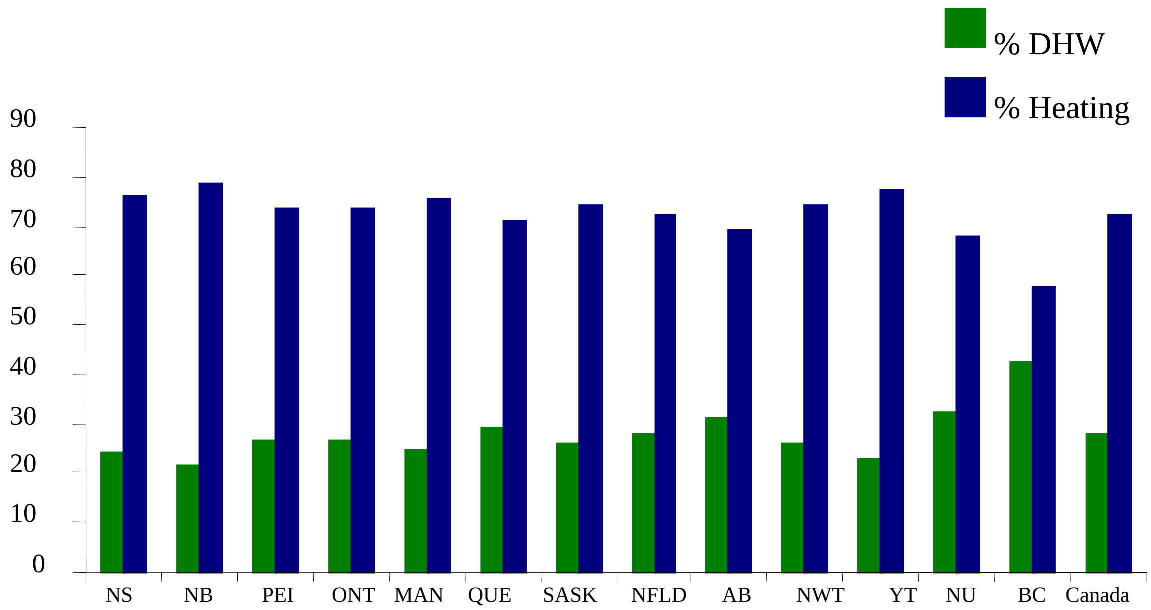
Figure 19: Energy Consumption Patterns by Province



There is, however, significant variation in this pattern across the regions (Figure 19). This figure shows that natural gas is the main energy source in Ontario, Saskatchewan, British Columbia and Alberta. Electricity dominates in New Brunswick, Quebec and Newfoundland, whereas oil is the main fuel in Nova Scotia, PEI, North Western Territory, Nunavut and Yukon. The consumption pattern that is observed generally supports the evidence from the use pattern (frequency distribution) of the energy types described previously.

Comparing the two main fuel uses, Figure 20 shows that about 72 percent of energy consumption is for heating purposes. This proportion is as high as 78 percent in New Brunswick and as low as 58 percent in Nunavut. The proportion grossly classified as DWH energy comprises all energy uses other than for the purposes of heating the homes. Hence, it includes energy consumption for lighting and appliances as well.

Figure 20: Energy Consumption Patterns - DHW and Heating Energy by Province



A classification by construction year shows that the estimates for both overall and space heating energy consumption exhibit a downward trend as we go from older houses to newer ones (Figure 21). Comparison of the actual with the upgrade case energy consumption (Figure 22) shows that the estimated energy saving from undertaking the recommended upgrades (retrofits) is very high for very old houses while little saving is expected from energy retrofits for newer houses.

Figure 21: Total and Space Heating Energy Consumption by House Vintage

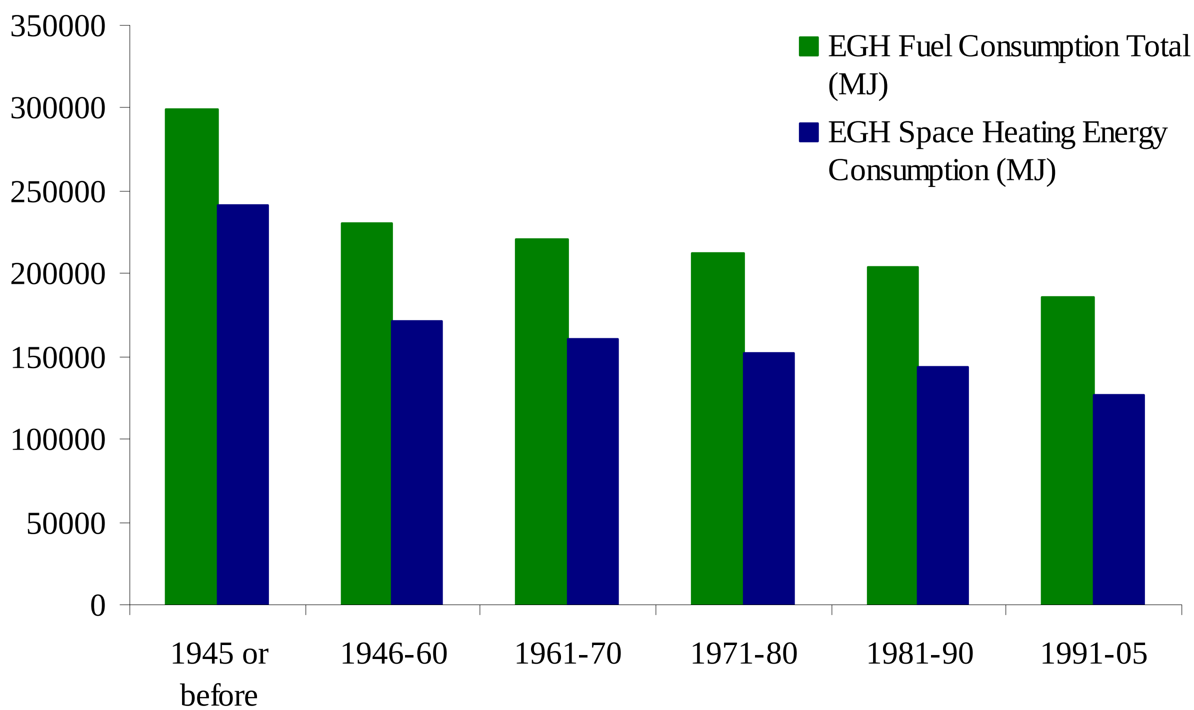
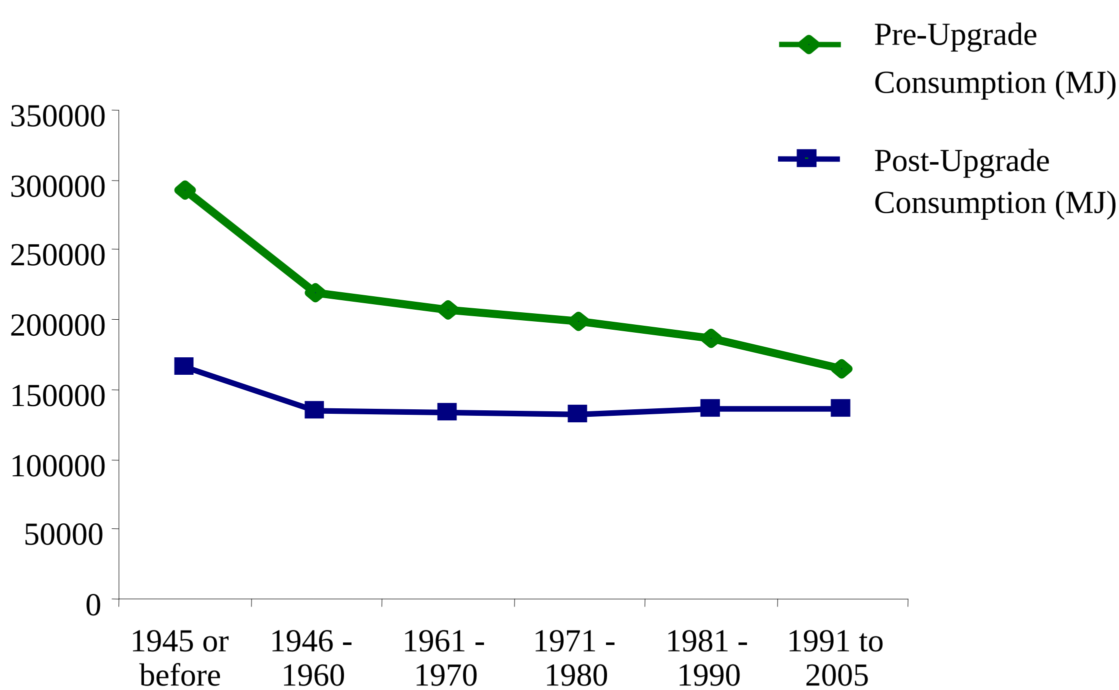


Figure 22: Pre and Post-Upgrade Energy Consumption (MJ) by Vintage



4.4 Second Phase Audit Participants (those who did the retrofitting)

Only about 18 percent of the homeowners in the first phase also undertook the second phase of EGH energy efficiency assessment. Although, as outlined earlier, some households may have undergone the first audit and declined the second audit despite doing some of the recommended retrofits, these households that completed the second audit are those that are known to have undertaken at least some of the recommended retrofit actions. One of the most important questions is, therefore, what specific characteristics these homeowners have compared to the rest.

First, comparison of the regional shares in the first and second phases of the audits (Table 2) reveals that there is regional disparity in the tendency to undertake retrofits (participation rate in the second audit). The shares of houses in the second audit in Alberta, British Columbia, Manitoba and Saskatchewan are higher than their first phase counterparts. On the other hand, smaller shares, as compared to the first audits, were observed in the eastern and Atlantic provinces in general (Figure 23). This disparity can be attributed to a number of factors including the regional variation in the costs of the EGH audit services itself due to presence of provincial subsidies. As we have seen earlier, regional variation in the distribution of house ages could be another factor. Furthermore, variation in the distribution of the heating system and fuel type could be another possible explanation since, as we have seen before, some heating systems are more efficient than others. We have seen that Quebec is characterized more by electric heating systems, that the western provinces and Ontario largely rely on natural gas, while the Atlantic Provinces significantly rely on propane. Generally, it would be expected that energy efficiency conditions would be one of the main factors behind the homeowner’s decision to undertake the recommended upgrades.

Figure 23: Regional Shares in First (Phase A) and Second (Phase B) Audits

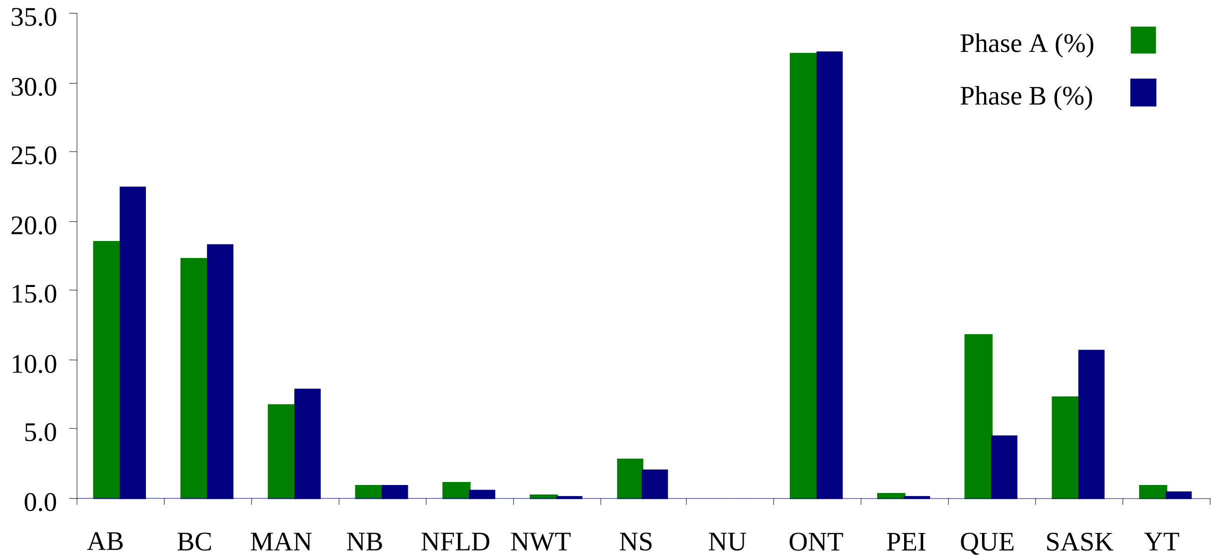
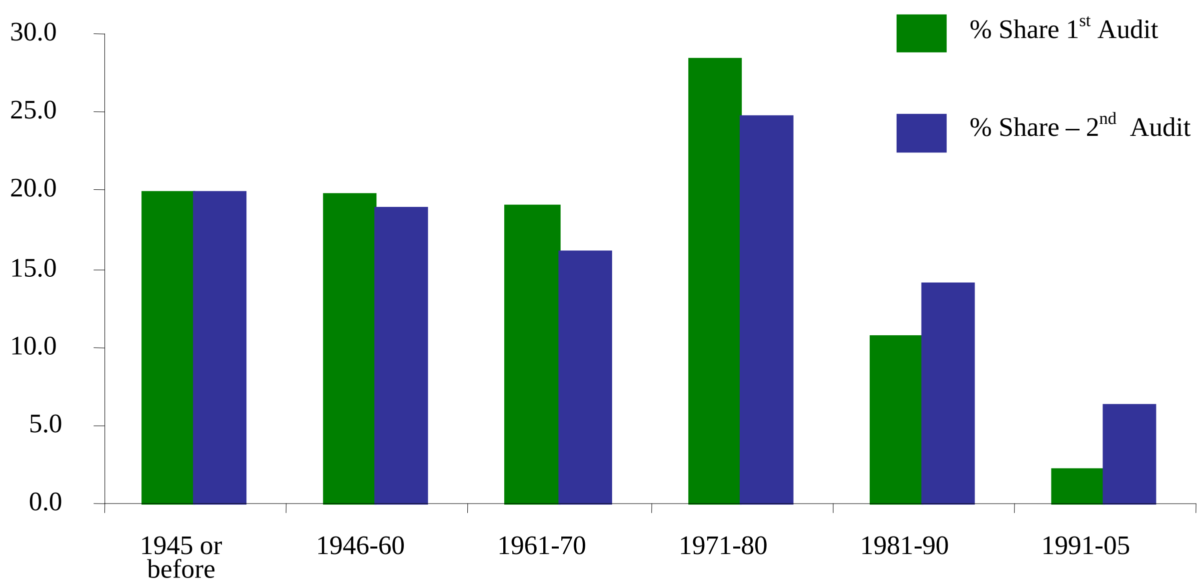


Figure 24 shows that the share of more recent buildings in the second or "phase B" audit is larger than their share in the first or "phase A" audit. However, the share of the oldest age group in "phase B" is similar to their share in "phase A." These two observations suggest that cost of retrofitting and the magnitude of the gains from the upgrades are very important factors in the decision to make the retrofits. The fact that we have observed stronger retrofit participation rate in newer homes is likely because the range of the activities recommended are usually few for new homes and hence it is less costly to retrofit. On the other hand, the strong participation in old homes may be mainly because undertaking retrofits in such homes is more rewarding.

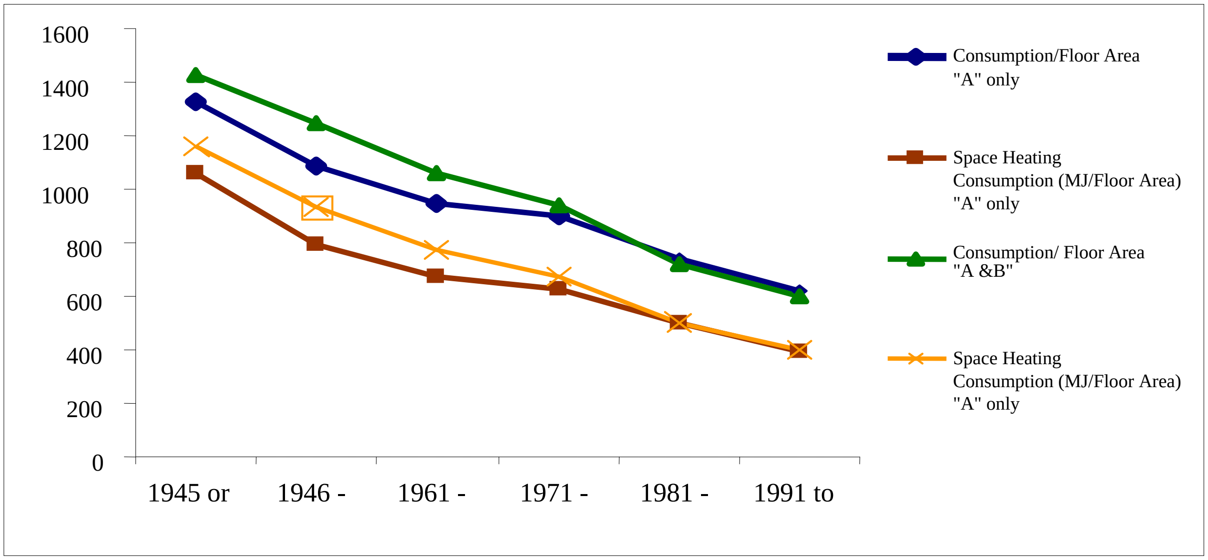
In summary, we observe that homeowners in the western provinces are more likely to undertake the recommended retrofits compared to homeowners in other provinces. Furthermore, homeowners whose buildings are too old likely undertake the recommended retrofits because it is more rewarding while homeowners owning very recently built homes are more likely to undertake the recommended retrofits because the required upgrades are minor and hence less costly.

Figure 24: Comparison of Shares of Building Ages in the Two Phases of EGH Audits



The EGH database does not have information on the demographic characteristics of the homeowners except for the total number of occupants. Hence, our characterization purely focuses on the physical characteristics of the buildings and the energy efficiency of the homes that have undergone the second phase evaluation compared to those that did not. Other things remaining the same, the higher is the expected return from the undertaken retrofit activities, the more likely it is that the households would undergo the retrofit upgrades. This can be identified by comparing the pre-retrofit energy intensity of the homes for the two groups – those that did just the first phase audit versus those that completed both phases of the energy audits. Figure 25 shows plots of both overall and space heating energy intensity (consumption per floor area) for the two groups. We see that for older houses (all cases before 1990), the homeowners who undertook the retrofit actions (both “A” and “B” group) were characterized by higher energy intensity before undertaking the energy retrofit upgrades as compared to the overall average. The group that did not undergo the second phase was characterized by relatively lower energy intensities

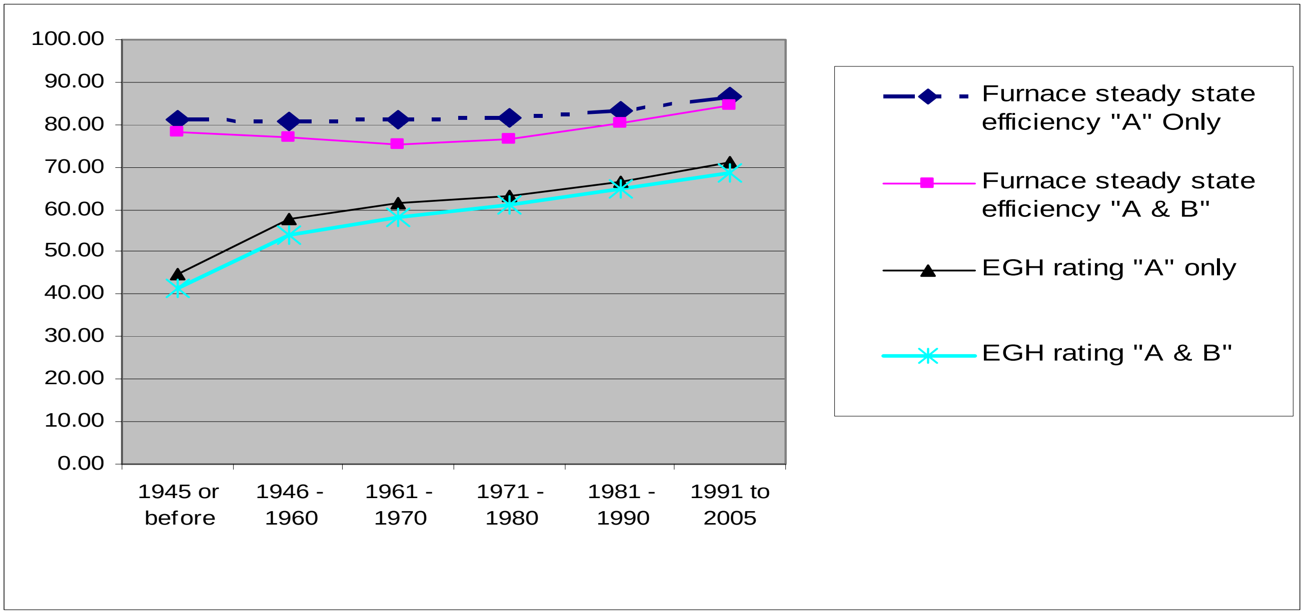
Figure 25: Total and Space Heating Energy Consumption/Floor Area and Vintage



As we have seen earlier, higher energy intensities are related to low efficiencies. As shown in Figure 26, homeowners who did not undergo the second phase audit (did not undertake the recommended energy efficiency upgrades) were generally characterized by higher furnace efficiency and higher EGH rating, which summarizes their overall energy efficiency.

Thus, in general, homeowners who undertook the recommended retrofit actions were those characterized by very high energy intensities and hence higher energy costs, poor thermal conditions and low efficiency of their heating equipment. The decision seems to be largely guided by the energy saving potential of the undertaken retrofits (as seen from the largely older homes group) and the cost of the upgrades (as observed from the recent buildings group).

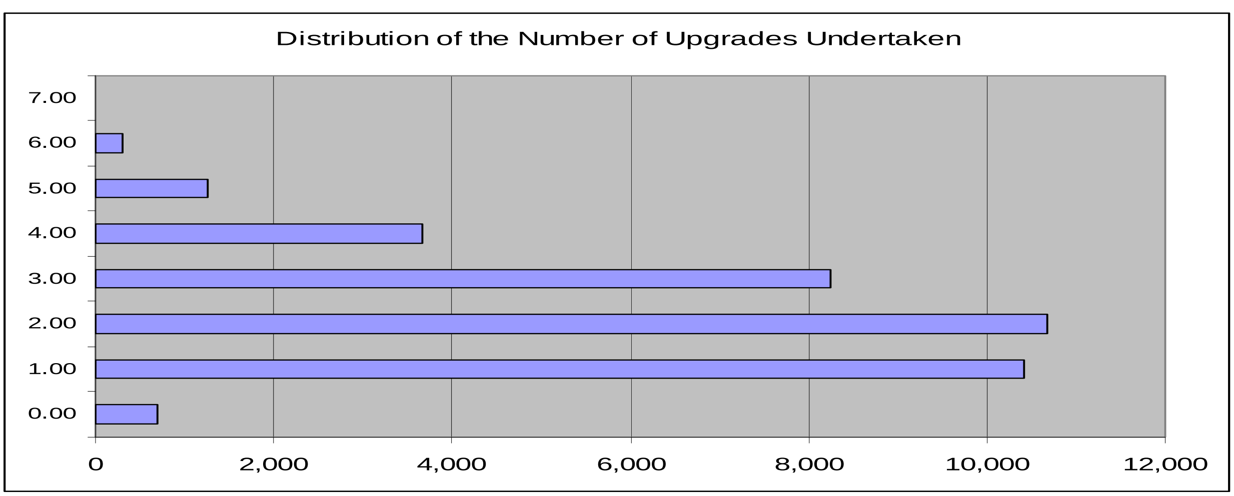
Figure 26: Furnace Efficiency and EGH Rating for the Different Groups



4.5 Summary of the Specific Upgrades Undertaken by Homeowners: Retrofit Intensity

There are about eight categories of energy efficiency upgrades in the data base: RSI upgrades of main walls, foundation walls, ceilings, and exposed floors; efficiency upgrades of heating equipment, and of DWH systems, heat loss reduction through windows and doors, and "others." Figure 27 shows that most homeowners undertook two of the specific upgrades.

Figure 27: Distribution of the Number of Upgrades Undertaken



There is significant variation in retrofit intensity across the provinces. Most importantly, undertaking a combination of two specific upgrades is the most dominant case only in Alberta and Ontario (Figure 28). Like the decision to undertake any retrofits, the intensity (the number of upgrades) is also closely related to energy efficiency. On average, households with lower EGH ratings, more energy intensity – and hence greater energy savings potential – and more energy costs prior to the retrofits tend to undertake a larger number of upgrades (Table 4).

Figure 28: Intensity of Upgrades (number of upgrades) by Province

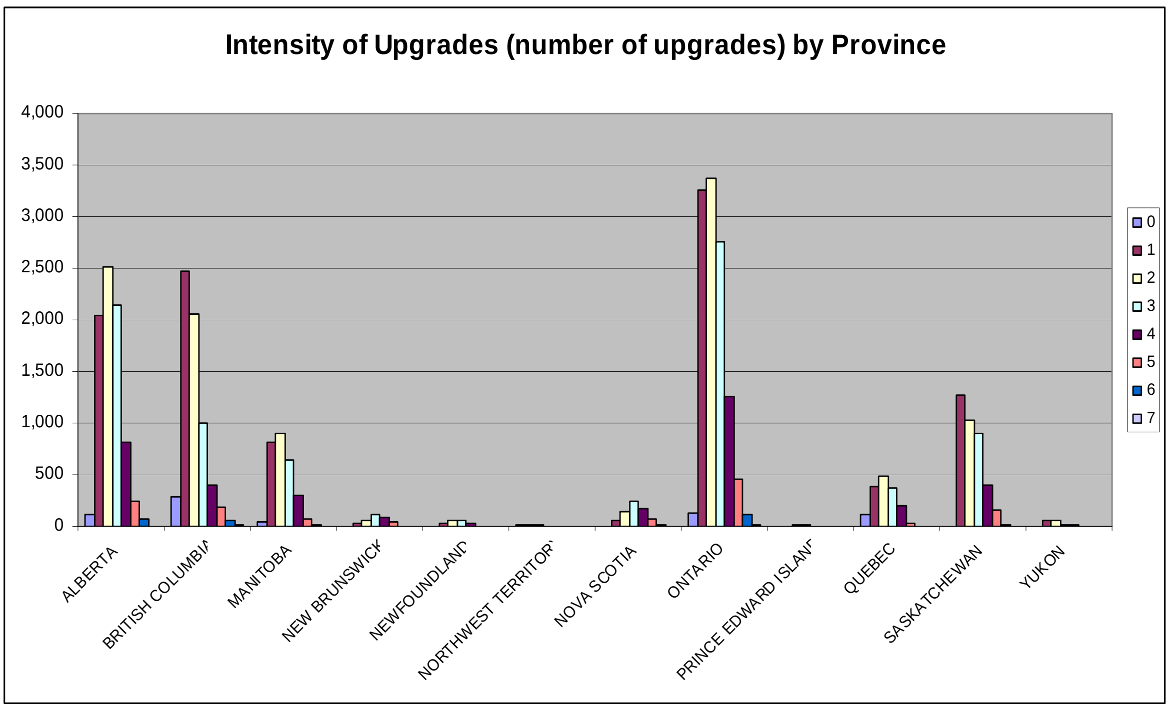


Table 4: Upgrade Intensity and its Determinants

Total Number of Upgrades	EGH Rating	Energy Consumption Ratio (A/B)	Energy cost Ratio (A/B)	Blower Door ACH @ 50Pa Ratio (A/B)
0	61.9	1.15	1.16	1.22
1	59.7	1.26	1.19	1.15
2	57.3	1.32	1.22	1.21
3	54.4	1.44	1.30	1.28
4	50.4	1.60	1.42	1.40
5	45.2	1.87	1.57	1.55
6	39.7	2.19	1.70	1.60
7	32.7	2.49	2.00	2.02

Among the homeowners who undertook a single upgrade, most of them upgraded their furnaces. The second most observed upgrade configuration involves upgrades of windows and doors (Figure 29). However, this pattern is not uniform across the provinces. For example, upgrading the main wall RSI is the most common upgrade in Nova Scotia while in British Columbia, upgrading windows and doors is the most commonly undertaken retrofit activity. Upgrading furnace efficiency is popular in Alberta, Ontario and Saskatchewan (Figure 30). Foundation walls and ceiling insulation upgrades are equally significant.

Figure 29: Number of Homes with Specific Upgrades

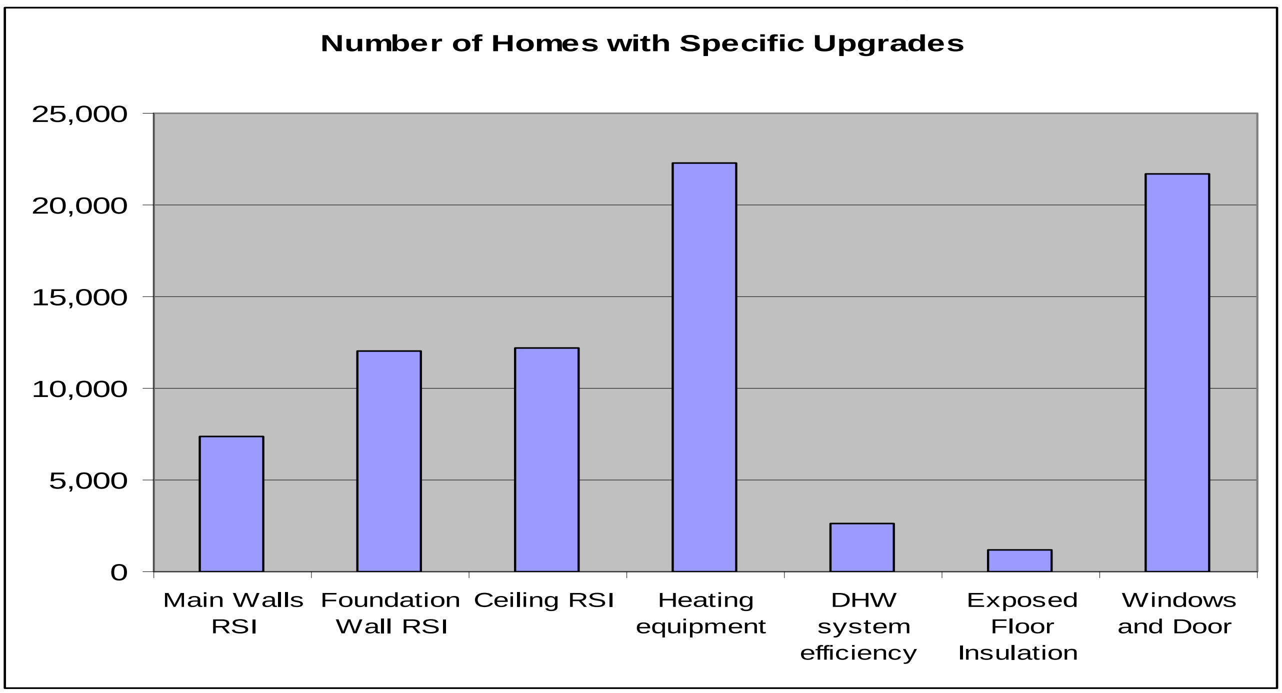
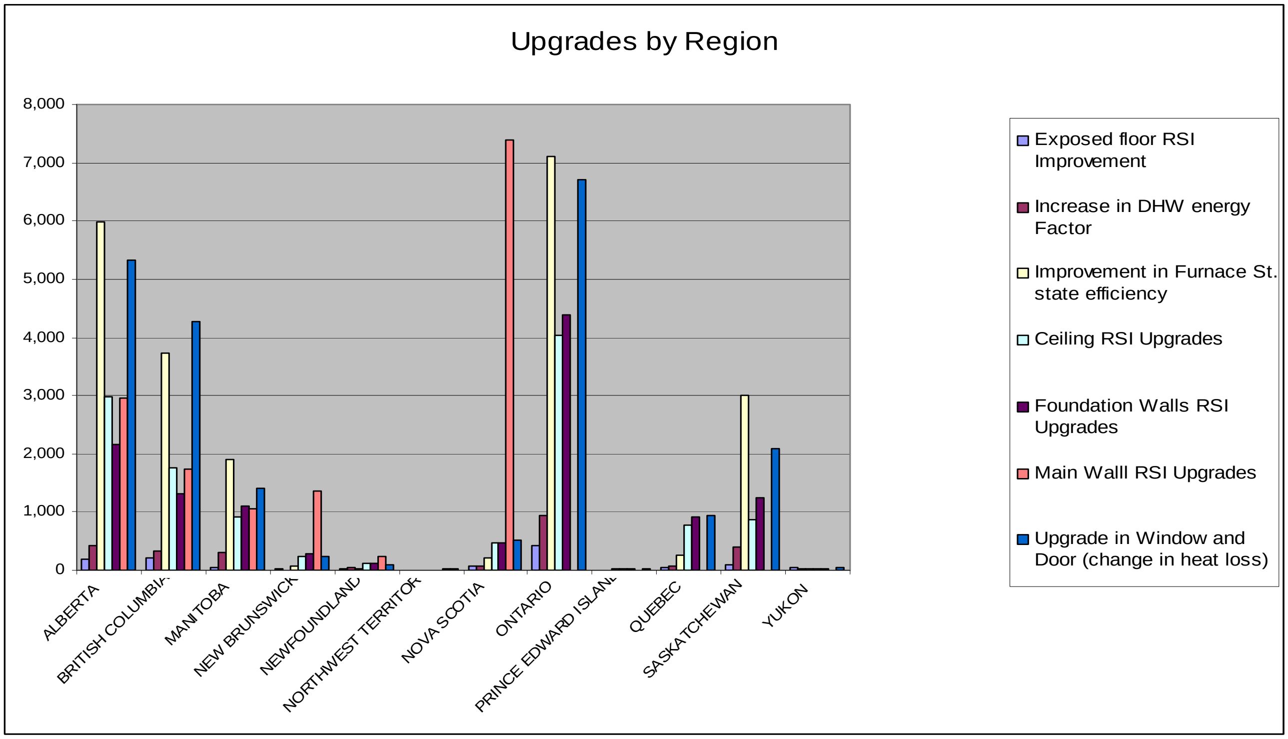


Figure 30: Upgrades by Province



The description of the specific upgrades by regions suggests the importance of the age of the house in determining the specific type of upgrade undertaken. Recall that we have shown that Nova Scotia is the province characterized by old houses. To see this more closely, Figure 31 plots house related upgrades against house age groups. While upgrading the windows and doors generally leads, the relative ranking of ceiling RSI and foundation walls RSI upgrades alternates across the various age groups. Most importantly, we see that the importance of main wall RSI upgrades dwindles as we move from old to the new age group.

From among the cases with two upgrades, the most popular mix is furnace upgrades and windows and door upgrades, followed by the mix of ceiling RSI upgrades and windows and door upgrades. The third most common combination is furnace and foundations walls insulation upgrades (Table 5).

Figure 31: Upgrades in Building Envelopes by Age

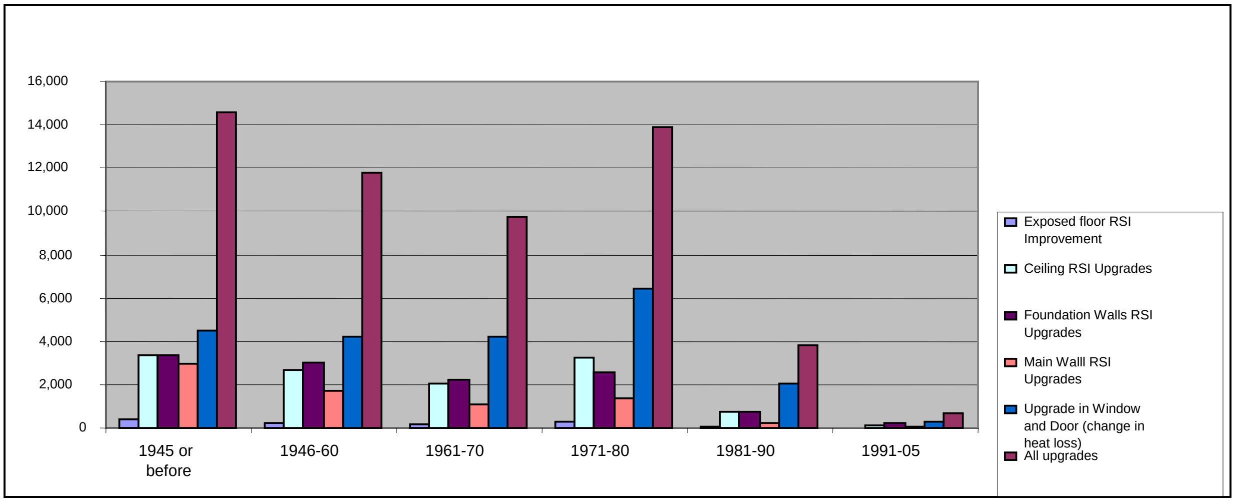


Table 5: Frequency of Retrofit Mixes (2-upgrades)

	Main Wall RSI Upgrade	Foundation Wall RSI Upgrades	Ceiling RSI Upgrades	Improvement in furnace state efficiency	Increase in DHW energy Factor	Exposed floor RSI improvement	Window and Door Upgrades (heat loss change)
Main Wall RSI Upgrade		174	113	90	11	42	591
Foundation Wall RSI Upgrades	174		525	1534	14	24	801
Ceiling RSI Upgrades	113	525		465	3	10	1720
Improvement in furnace St. state efficiency	90	1534	465		151	29	4283
Increase in DHW energy Factor	11	14	3	151		0	60
Exposed floor RSI improvement	42	24	10	29	0		43
Window and Door Upgrades (heat loss change)	591	801	1720	4283	60	43	

4.6 Effects of Residential Energy Retrofits

Energy saving retrofits can have energy switching effects. Figure 32 compares pre-retrofit, upgrade case, and post-retrofit heating energy use patterns. The upgrade case is generally a case for partially moving towards more reliance on natural gas rather than oil and wood. The post-retrofit outcome is also in the same direction.

Figure 32: Distribution of Heating Energy Fuel Type (Initial, Upgrade Case & Post-Retrofit

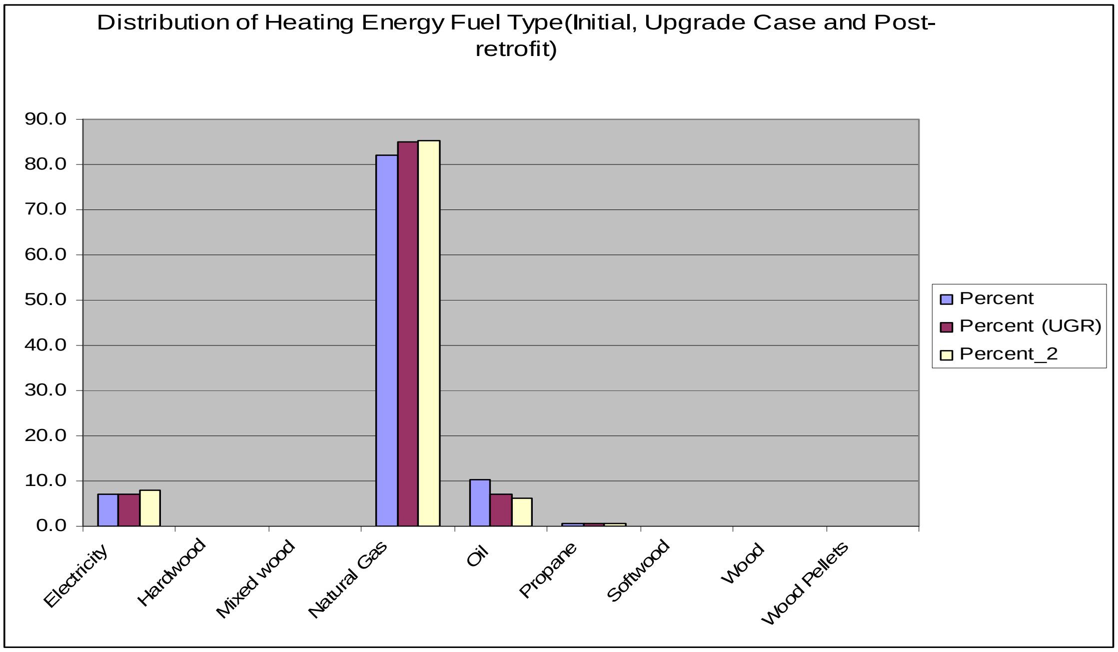
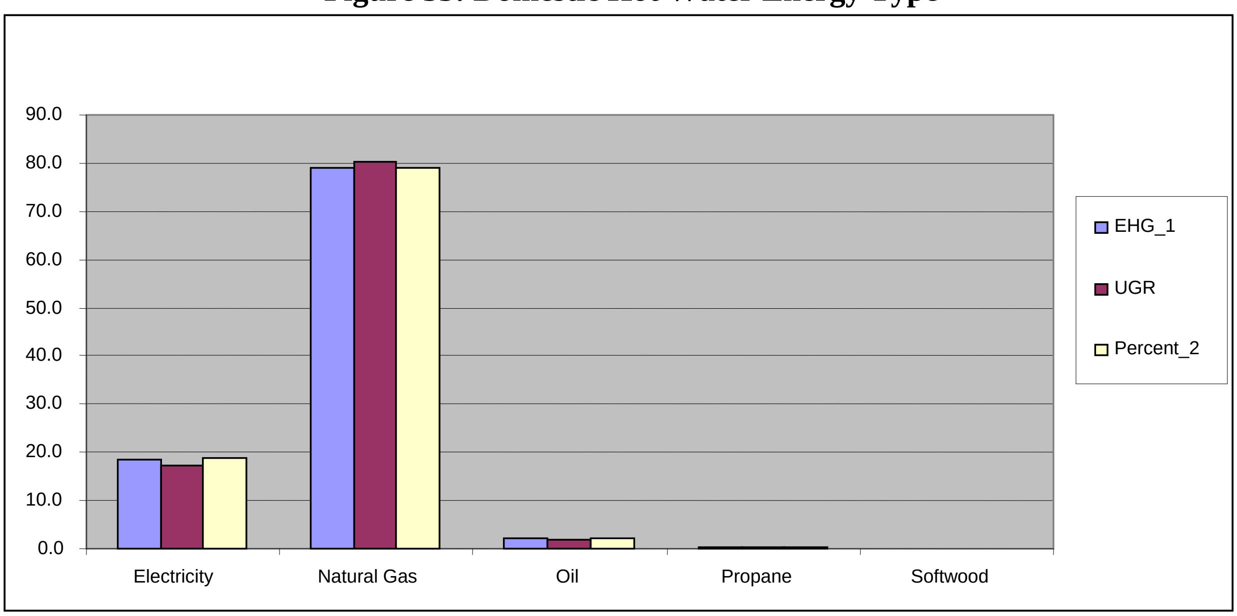


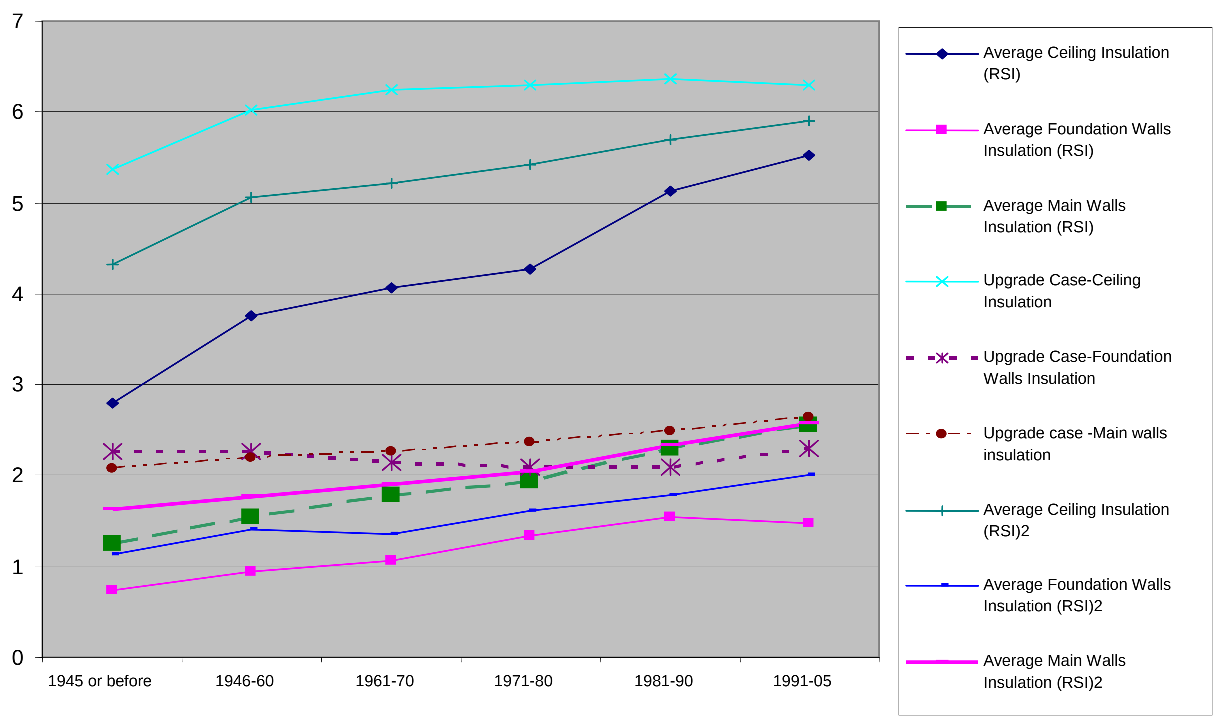
Figure 33: Domestic Hot Water Energy Type



In the case of DWH energy, we see that the shares of electricity and oil show a marginal increase after the efficiency upgrades even though the upgrade case predicts that the shares of both of these fuel types would decrease marginally while the use of natural gas would increase (Figure 33).

After the undertaken retrofits, we observe that thermal efficiency of the homes has generally improved even though the improvement stipulated by the upgrade case estimates is never fully adopted. In fact the only case where we see the post-retrofit measure being the same as the upgrade case measure is for main wall insulation for the recently built homes category, and the reason for this is that there were no upgrades scenarios for this group so that the pre-retrofit, upgrade case and post-retrofit main wall RSI's are equal (Figure 34).

Figure 34: Initial, Upgrade Case & Post-Retrofit Measures of Thermal Efficiency



A similar conclusion can be reached about changes in heating equipment efficiency. Furnace efficiencies have improved in general (Figure 35), wherever there are upgrade cases, except in Nova Scotia and the Northwest Territories where there was no change at all. There are no furnace efficiency upgrade cases for Newfoundland, Quebec, and the Yukon Territory. Whenever the upgrades were undertaken, the efficiency levels increased to the recommended levels in general. This is because the upgrades are generally prescribed in terms of replacing the existing furnace with another and hence, if implemented, the recommended efficiency levels will most likely be achieved. One more interesting observation is that there were furnace efficiency upgrades made in the Yukon even though there no such recommendations.

Figure 35: Comparison of Pre-retrofit, Upgrade Case & Post-retrofit Furnace Steady State Efficiency

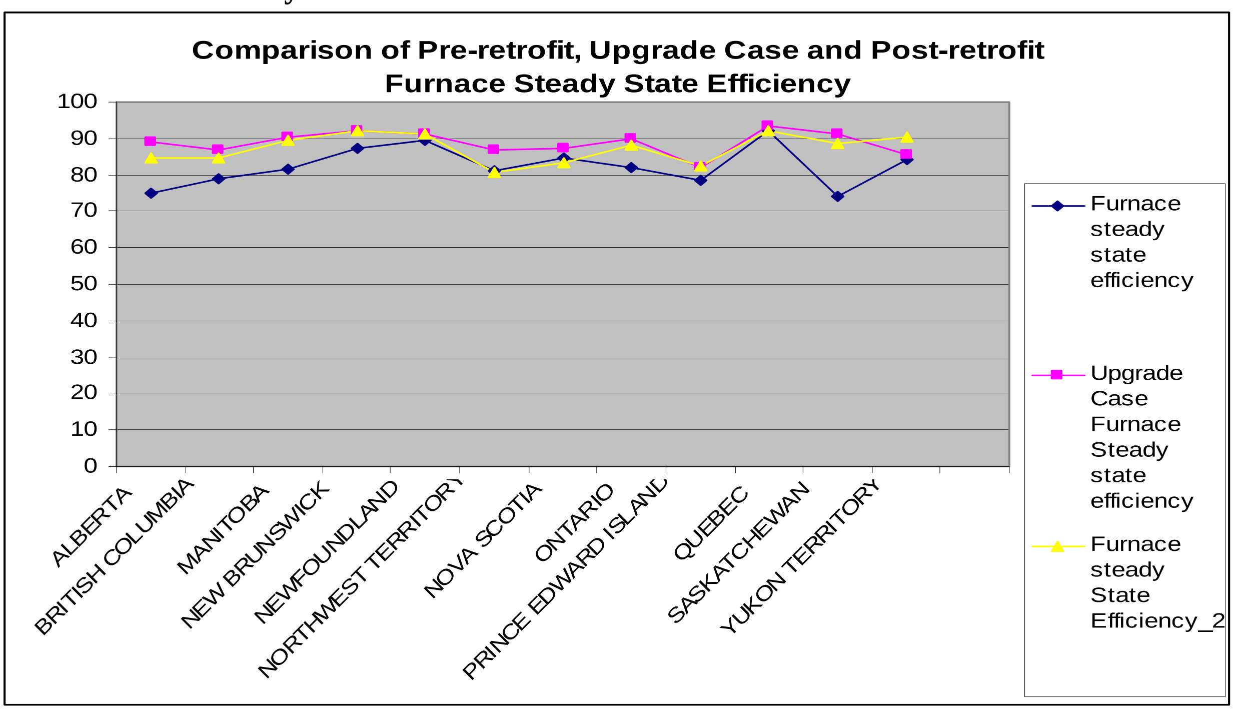
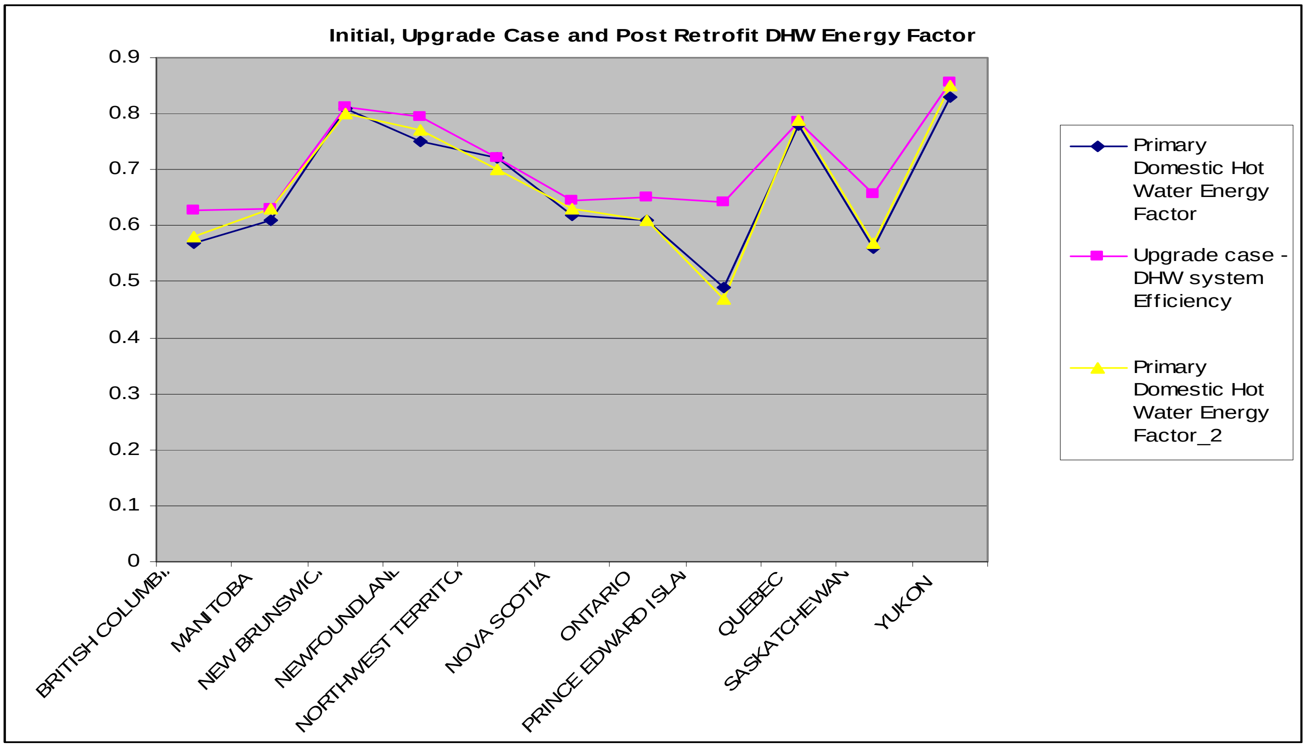


Figure 36 shows that there were no significant changes in DWH efficiency as such. This is mainly because the shares of DWH energy consumption are small and hence homeowners mainly focused on improving heating energy efficacy.

Figure 36: Initial, Upgrade Case and Post Retrofit DHW Energy Factor



Given that thermal conditions and furnace efficiencies have been improved after retrofitting, it is obvious that energy intensity declines and energy cost is saved. The only question is if the retrofit intensity (number of upgrades) has some relationship with the magnitude the decline in energy intensity and the extent of cost saving. In other words, are homeowners who undertook several upgrades better off in terms of energy /cost saving? Figure 36 shows how the post retrofit EGH ratings of the homes relative to the pre-retrofits case increase with the number of upgrades, while the blower door measure of air leakage shows a downward trend with more upgrades. On the other hand, the ratio of the post-retrofit energy intensity relative to the pre-retrofit energy intensity declines with the increase in retrofit intensity. A similar pattern is observed for the cost ratio. Most importantly, we observe in Figure 38 that both the overall and heating energy saving significantly increase as the number of the upgrades that are undertaken increases.

Figure 37: Effects of Energy Saving Retrofits

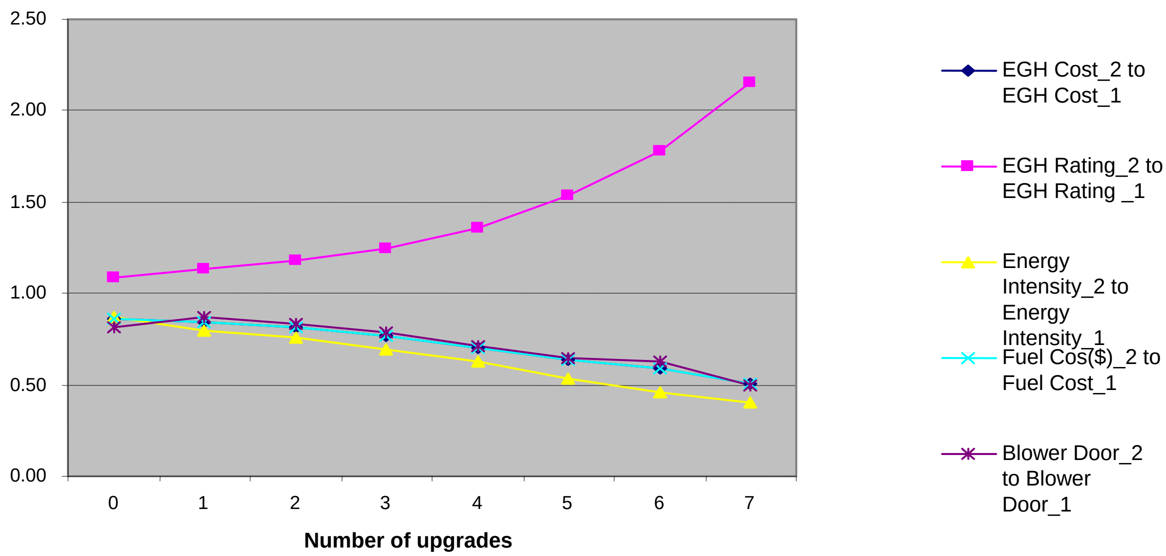
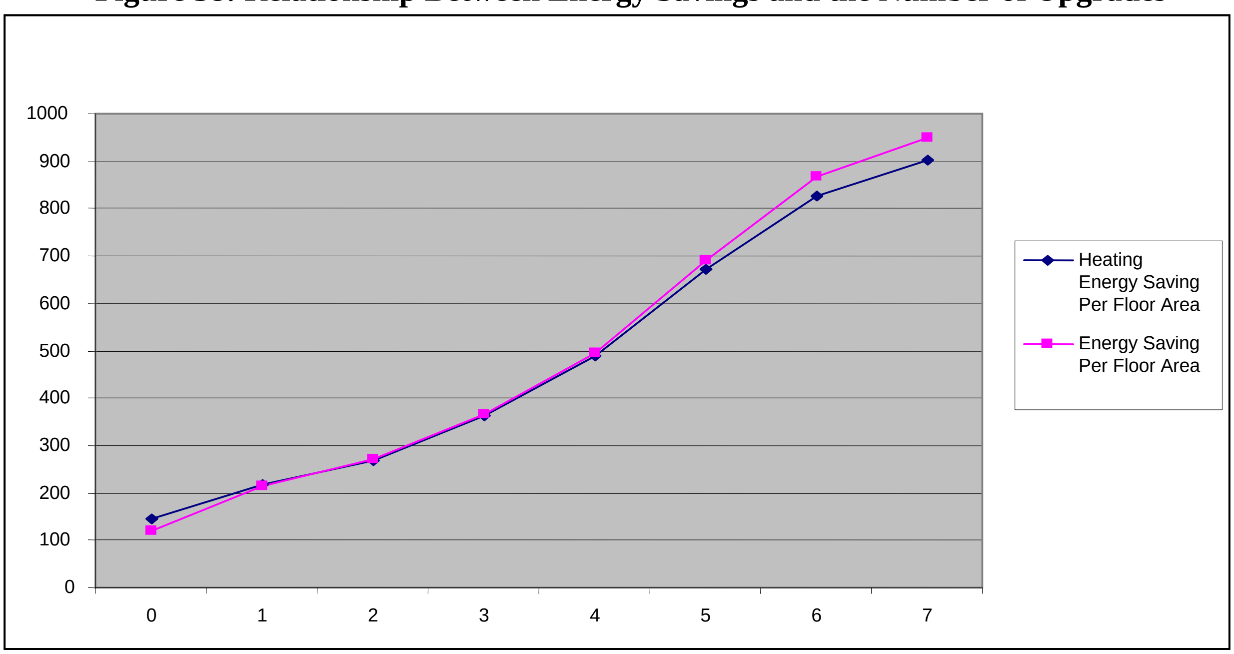


Figure 38: Relationship Between Energy Savings and the Number of Upgrades



5. Conclusion

The conclusion we can draw from the description of the EGH data base is that decision to undertake energy retrofit investments depends on the characteristics of the homes. The extent of inefficiencies observed in energy use, and therefore the expected high saving from investing in upgrades appears to be the main motivator of the decision to undertake the investments. It is not only the decision as to whether to invest, but also the intensity of the investment (how many different kinds upgrades to consider) that depends on the characteristics of the building. Other things remaining equal, homeowners characterized by high energy intensity and hence high cost of energy have a higher propensity to undertake the investment. Furthermore, from among those who decide to undertake the retrofit investment, those with very high expected cost and energy savings tend to undertake several different investments (higher retrofit intensity). It is also evident that the extent of the realized cost and energy savings are directly related to the upgrade intensity.

Unfortunately, the data lack sufficient information on demographic characteristics of the homeowners to investigate the effects of these factors on their decisions. In particular, information on income is a very important variable missing from the data. Another important missing variable is the cost of the conservation investments. The cost of investment is highly important in estimating the rate of return, which is a key to assessing the effectiveness of the investment. Thus, one major task in ongoing research will be to supplement the EGH data with relevant demographic and socio-economic information from available sources.

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Appendix 1: Furnace Steady State Efficiency

Figure A1a: Furnace Steady State Efficiency by Furnace Type for Furnaces with Efficiency < 80%

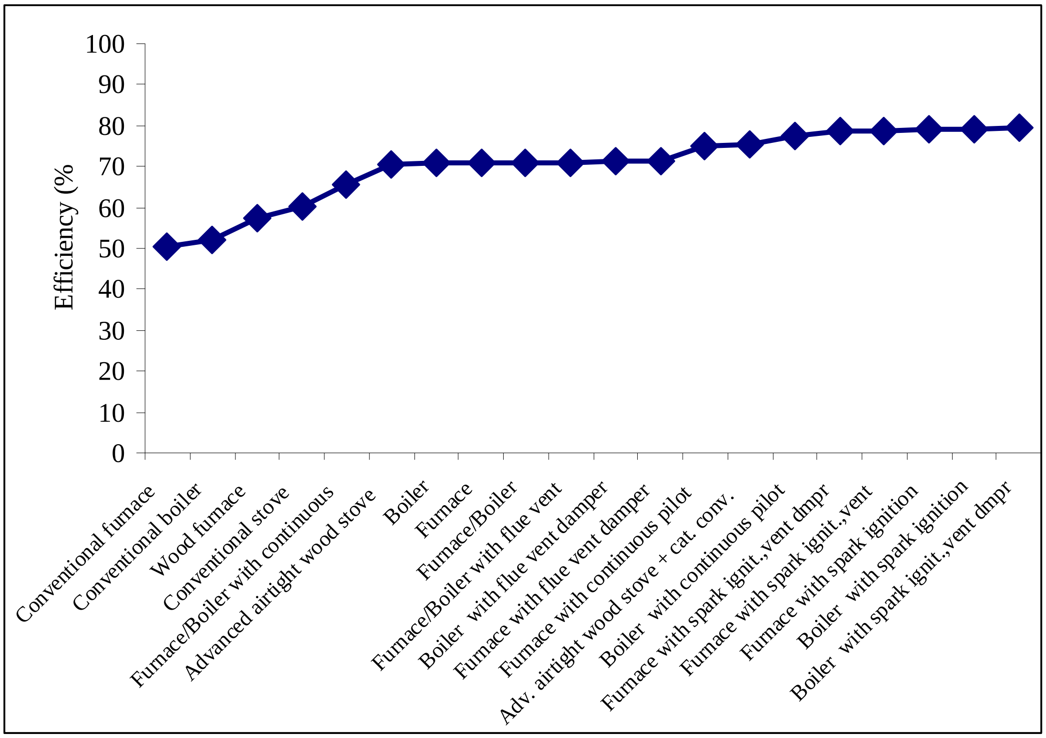

Figure A1b: Furnace Steady State Efficiency by Furnace Type for Furnaces with Efficiency > 80%