The Now House Windsor 5 Project: A Socio-Technical Analysis

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complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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By: Andrea-Marie Pearson

Abstract:

The Canadian housing stock offers an enormous opportunity to retrofit homes to reduce the associated greenhouse gas emissions and reduce consumption of energy. The Now House Windsor 5 Project is a pilot project undertaken by the Windsor Essex Community Housing Corperation (WECHC) and The Now House Team. The goal of this project was to retrofit five war-time homes (one-and-a-half storey homes built in 1940-1975), which are currently used as low-income housing, and make them as energy efficient as possible. This research examined the benefits of not only the technical side, or the retrofit itself, but also the benefits of incorprating educational material given to the occupants, so that they can gain the greatest benefit from the retrofit, also known as a "social-technical study". Significant savings in electricity, natural gas, and water consumption were achieved by the retrofits. This study found that the HOT2000 software used to assess the homes and make predictions as to potential retrofit results has a number of limitations. The estimated greenhouse gas emission reductions and percentage of energy reductions were greatly over predicted by the HOT2000 software. The energy behavior surveys indicated that although the demonstration home was "interesting", the tenants found the residential manual and training sessions to be far more beneficial. Therefore it is recommended that future energy retrofit programs consider including training sessions and user friendly manual(s) to be a part of the retrofit grant process, conducted by qualified personnel within the field.

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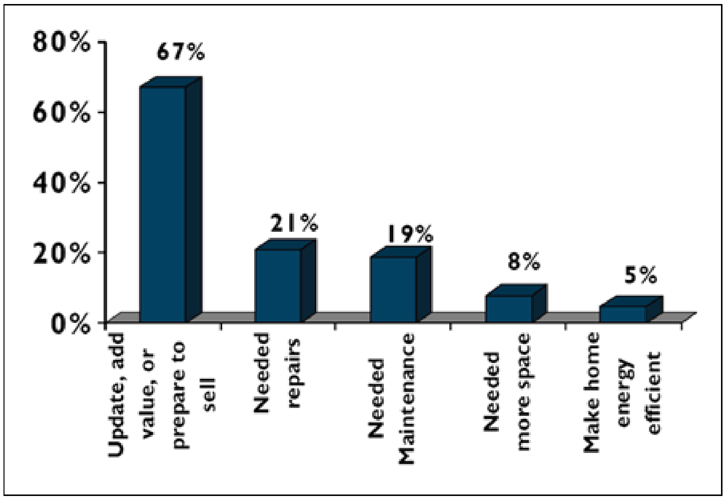
Chapter 1 - Introduction:

Canada's existing housing stock offers enormous opportunities in energy savings through retrofitting across the country. The energy saving potential "has long been recognized by policy makers, energy experts, program implementers, and advocates in the energy efficiency community" (Thorne, 2003, page 1). Unfortunately, capturing this energy saving potential in existing buildings has proven to be a great challenge (ibid). For example, Urea-Formaldehyde foam insulation was used in existing homes in Canada to improve the insulation of the wall cavities and 'difficult to reach' places starting in 1977 and was banned in 1980 due to concerns that health problems may occur from over exposure to formaldehyde (CMHC, 1996). Thus, both homeowners and contractors/developers are faced with a number of obstacles and barriers, which in turn prevents the successful completion of energy efficient retrofits.

The Canadian residential sector is responsible for approximately 16% of the country's greenhouse gas (GHG) emissions (Natural Resources Canada, 2006). It was projected that the Canadian residential sector would be able to reduce its emissions by 12% without any special initiatives (Parker et al, 2004), however GHG emissions from the residential sector continue to increase. Although new structures are built with improved insulation and tighter building envelope, retrofitting existing homes allows for significant opportunities to be made in reducing the associated greenhouse gas emissions within a shorter time frame than that achieved by new construction (Bell & Lowe, 2000).

Despite the previous low success rate of energy efficient retrofits, according to a survey conducted by the Canadian Mortgage and Housing Commission (CMHC) on *Renovation and Home Purchasing*, in Canada, 40% of homeowners reported their intentions to spend $1,000 or more on renovations for 2008 (CMHC, 2009);. However, as seen in Figure 1 below, only 5% of the intended renovations were with the goal to improve energy efficiency (Statistics Canada, 2008 and CMHC, 2009). The survey questions asked how people prioritized spending money on their home. Participants of this study were asked to choose only one of the five categories shown in Figure 1. The survey illustrates that Canadians are willing to spend money to up date their homes, and energy efficiency is not a priority. Identifying what the barriers are that prevent them from considering energy efficient up grades would allow for valuable insight into what can be done to change this general trend.

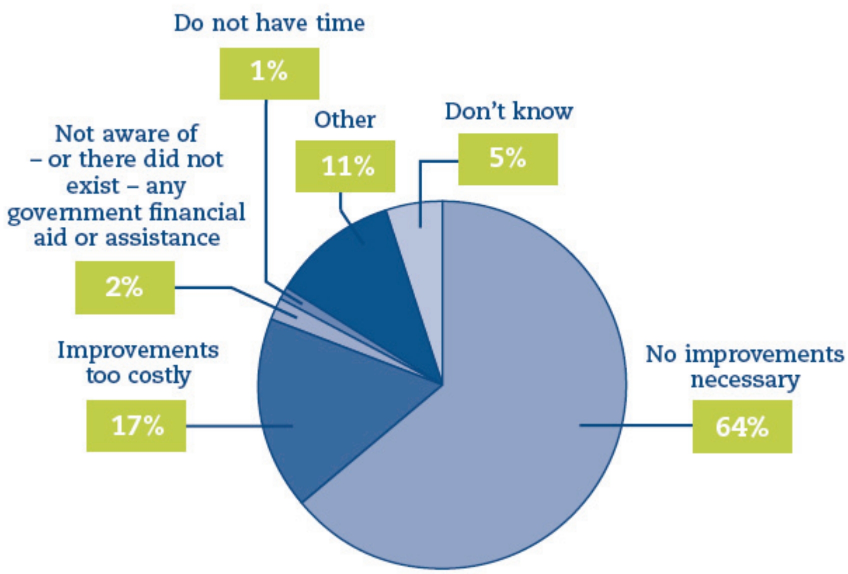
Figure 1: Reasons for intended renovations for Canadian homeowners in 2008



Note: Renovation intentions are only on projects of $1,000 or more
Source: CMHC Renovation and Home Purchase Survey (2009)

It is estimated that 66% of the buildings which currently exist will still be standing in 2050 (Business Council for Sustainable Development, 2006), thus illustrating the importance of energy efficient improvements to be made to existing buildings. A study conducted by the Canadian Federal Government, asked home owners if they felt that home improvements or renovations to their home related to energy conservation were need. The results from this study indicates that only 15% of Canadian citizens recognize that home energy retrofits are desirable (Natural Resources Canada, 2007). The remaining 85% of Canadian citizens (sampled) stated that home energy retrofits were not needed (64%), are too costly (17%), unaware that retrofit grants existed (2%), or other (12%), as seen in Figure 2 below (Natural Resources Canada, 2007).

Figure 2: Natural Resources Canada Survey on Home Retrofits
Sources: Natural Resources Canada, 2007



Both the Canadian Federal Government and the Provincial / Territorial Governments have tried implementing energy retrofit and conservation programs and policies to encourage homeowners to reduce energy consumption (refer to appendix 1 for examples of different programs tried by the different levels of government, and section 2.6 for further explanation of the Federal Governments energy efficiency programs). Unfortunately, most of these programs and policies have been unsuccessful, with only a small number of citizens participating in these programs. An example of a failed residential energy conservation program is the implementation of the R-2000 Homes Program (Parker et al, 2006).

The value of energy efficiency in homes is not restricted to retrofits, but is also undervalued in new homes, as illustrated by the lack of success of the R-2000 program for new structures. In 1982 the R-2000 home program was established in order to promote “the use of cost-effective energy efficient building practices and technology” (OEE 2003, from Parker et. al., 2003, page 5). R-2000 homes were designed in such a way as to increase the amount and quality of insulation within the home, thus reducing the amount of heat loss and air leaks. Despite the improved energy efficiency of an R-2000 home, it is estimated that only “0.7 percent of new houses built [between] 1990-1996” met the R-2000 standard, thus accounting for less than 9,000 homes built across Canada (Parker et al 2003; p. 173). In addition, in 1997 the Conservative Government came into power, and revised the building code requirements, thus resulting in a reduction of wall and basement insulation standards, which further reduced the potential energy efficiency of buildings in Canada (Rowlands et al, 2000).

The failure of the R-2000 home program can be attributed to the public’s lack of awareness of both the benefits of an R-2000 home and the government’s programs in financially supporting homeowners in their purchase. A community-based approach to residential energy conservation may greatly improve the success of an energy conservation project. By allowing the public to participate in the project, enabling the community to identify its needs and concerns, and developing local partnerships, the community’s trust in the proponent and their general awareness of the topic may improve, thus improving the chances for successful energy use reduction programmes. The purpose of this work is to examine an energy retrofit pilot program.

1.1 CMHC EQuilibrium™ initiative and The Now House™ project:

In May 2006 the Canada Mortgage and Housing Corporation (CMHC) began accepting proposals from builders and developers for net-zero energy* building plans, as part of their Net Zero Energy Healthy House competition, known as EQuilibrium™ Housing. The goals of the EQuilibrium™ initiative were to:

1. Develop a clear vision and approach to develop and promote low-environmental impact healthy and energy efficient housing across Canada.
2. Build the capacity of Canada's home builders, developers, architects and engineers to design and build EQuilibrium™ homes and communities across the country;
3. Educate consumers on the benefits of owning an EQuilibrium™ home and achieve market acceptance of EQuilibrium™ houses and sustainable communities; and
4. Enhance Canada's domestic and international leadership and business opportunities in sustainable housing design, construction services and technologies. (CMHC (b), 2009; no page number(s) given)

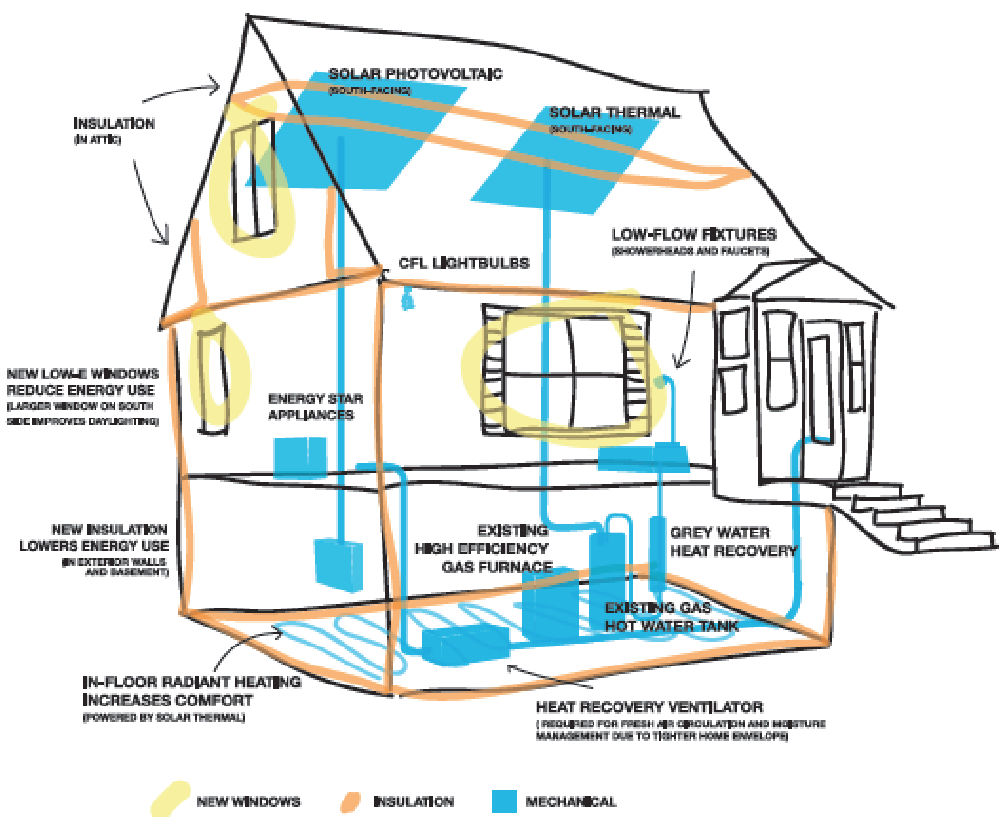
Seventy-two teams entered the EQuilibrium™ competition, and of these twelve were selected, one of which was the Now House™ Project. Out of all the winning teams,

* A net zero energy building is one which produces as much energy as it uses on an annual basis

the Now House™ is the only retrofit. The project is a retrofit of a 60-year-old, 1-1/2 storey wartime home located in Topham Park, East York, Toronto. The home was retrofitted to reach near net zero energy; meaning a house which will produce as much energy as it uses. The design for the retrofit was developed using modeling programs, Hot2000 and RETScreen. Over seventy-five different models were developed before selecting the most appropriate method for retrofitting the demo house, as illustrated in the image below (Appendix 2).

Figure 3: Changes Made to the Now House

Sources: Prepared by Alex Quinto 2007, for the Now House Project◊



◊ This image was produced for display purposes (displayed on a banner) and was not actually published.

The goal of the Now House was to find the most effective energy technologies to implement, in order to reduce the homeowner's operating cost, as well as the ability to do the same other homes. A basic life-cycle assessment (LCA) of the different technologies was conducted, as well as a cost-benefit analysis as a means of selecting the most appropriate changes. The outcome in energy reduction in the Now House is predicted to achieve the following:

- Reduce emissions by 6 tonnes;
- Reduce electrical load by 60%;
- Achieve a net zero energy cost on an annual basis;
- Employ a renewable energy source; and
- Be replicable (Now House Project, 2007)

The Now House Project in Toronto received a great deal of media attention throughout the construction phase. This lead to the City of Windsor commissioning the Now House Team to retrofit five of their low income housing units, which are also the one-and-a-half storey wartime home model, which is the same as the original Now House project in Toronto. The project was given the name 'The Now House Windsor 5 Project'. Each home was planned to be retrofitted at different levels and meters were placed in the homes to measure energy use and production, allowing for a comparative analysis to be conducted. The data collected from the Windsor 5 Project was used to conduct a cost-benefit analysis of the different stages of retrofitting. Details on the five different models can be found in Appendix 3.

The model of a wartime home was selected for the purpose of the Now House Project (the original demo home in Toronto) for many reasons. Firstly, the house is small (1,200 square feet for all three floors), thus making it easier to work with and assess the usefulness and limitations of different energy saving technologies. Secondly, wartime housing communities now tend to have a vast array of socio-economic demographics within the community, thus allowing for the concept of sustainable housing to be available to all economic groups, and not just the wealthy. Third, the history of wartime housing within Canada has strong ties to Canadian culture and heritage, allowing for a great story to be told of the "rebirth" of wartime homes.

1.2 The History of Wartime Homes:

Immediately following World War II, Canada experienced a severe housing shortage, resulting in overcrowding. The housing shortage was by no means a new phenomenon. Beginning in the 1930's, despite the continued population growth within Canadian cities, development of new housing began to lag as there was a lack of skilled labour which initiated the housing shortage (University of Toronto Press, 1948). At the end of World War II, the housing shortage intensified as returning military personnel and their new families needed housing, in addition to the two million European immigrants, who arrived in the 1960's (Harris and Shulist, 2001). As a result, the concept of the one-and-a-half storey, prefabricated wartime home, or 'victory home' as they were often called, was developed. The design allowed the homes to be built quickly, with minimal resources and on a small budget. These homes were built between 1940 and 1975, and have a building footprint between 550 to 1020 square feet.

According to statistics in the 1941 Curtis report, it was estimated that 194,000 units were needed to diminish the housing shortage. Due to the fact that the Canadian government was having difficulty keeping up with the housing demands, local residents took matters into their own hands, by building their own homes. Initially the Canadian Government was not overly supportive of owner-built homes; however this did not stop citizens from doing so. The Veterans' Land Act aided Canadian veterans to acquire or build homes in the urban fringe starting in 1942 (Shulist and Harris, 2002). By 1949, the "Build Your Own Home" (BYOH) program was introduced and ran until 1975. During this time period it is estimated that over 30,000 self-built homes were constructed (Harris and Shulist, 2001).

Originally these homes were built as temporary rental units. However, due to the housing shortage these low-income homes they became permanent housing with the option to purchase, allowing people to own a home who would otherwise be restricted to renting. These small homes were built on large parcels of land, which at that time were inexpensive, allowing for additions to be made later on when a family's financial situation improved. The wartime homes forced people to make efficient use of the small space without reducing the standard of living. Wartime homes can be found in almost every community across Canada. "They offer a material glimpse into the memory of World War II and the socioeconomic challenges associated with that event" (Now House Team (b), 2009); no page number given). Although some of these wartime neighbourhoods have since disappeared, many continue to flourish and currently remain a fixture in Canada's urban areas (Now House Team (b), 2009).

1.3 The current energy status of WWII homes

These victory homes have gone full circle—built during a time of conservation and efficiency, now they are sone of Canada's most energy inefficient homes. Over the last decade, the Canadian government and private home owners have been selling their victory homes, to have them replaced by more modern "monster homes" taking away from the sense of community and loss in Canadian heritage. Rather than demolishing these homes, efforts could be made to increase their energy efficiency. Studies have been conducted which support the notion that it is more sustainable to make improvements to existing homes, rather than build new (Canadian Green Building Council, 2004)

1.4 Purpose of research

The purpose of this research is to go beyond the standard cost-benefit analysis of the energy efficient technologies used in the Now House Windsor 5 Project and conduct a "social-technical" study (Parker et al, 2001,2003, 2004; Rowlands et al, unknown, 2003;Scott et al, 2000). As illustrated in the literature review in Chapter 2, including a social or behavioural analysis in an energy conservation study allows for a more in-depth look at not only how the new energy efficient technology operates but also how the occupant uses and understands the new system. The majority of energy conservation studies focus on the development of new technology, and very little research has been conducted on the social aspects (Herring, 2006). However, Turner et al (2005), Mahlia et al (2005), and Bell and Lowe (2000) have all concluded that the energy conservation studies they examined could have greatly benefitted by including a social element in the study as a means of educating people on new technologies. Thus, the occupants would clearly understand the benefits of the energy saving systems and the way to use the technology properly so that they can achieve the energy saving goals.

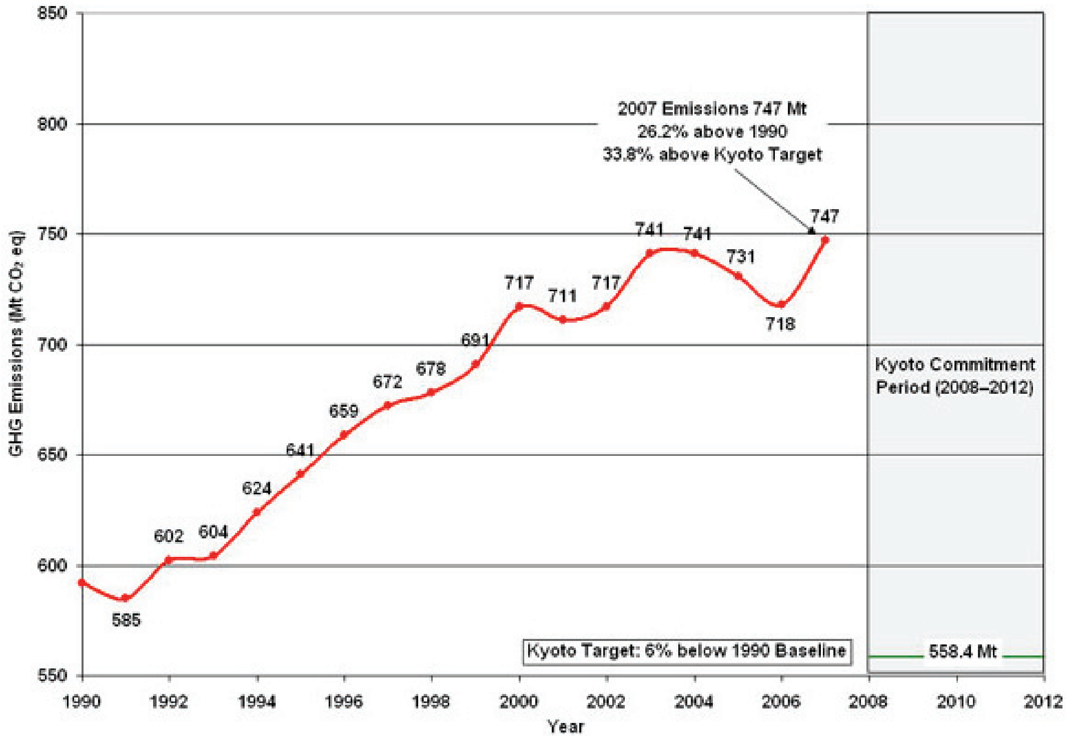
Chapter 2 - Literature Review:

2.1 Why Retrofit?

Canada has been under increasing pressure to reduce its energy consumption and associated carbon dioxide emissions (Farahbakhsh, 1998) and other greenhouse gas emissions (example the Kyoto Protocol). One means of achieving this objective would be to reduce the amount of energy consumed by the residential sector. Building reuse, and retrofitting, is identified as being "one of the most effective strategies for minimizing the environmental impacts of materials" (Canadian Green Building Council, 2004; page 255).

The Kyoto Protocol was signed and then ratified in 1997 to commit Canada to reduce its net greenhouse gas emissions by 6% below 1990 levels by 2012 (Environment Canada, 2009). Canada's greenhouse gas emissions as of 2007 were 33.8% above the Kyoto targets, as seen in the graph below (Figure 4). Although emissions from the residential sector have only increased by 0.2% (or 0.1 Mt) from 1990 levels (Environment Canada (b), 2010), the Canadian residential sector was projected to be able to reduce its emissions by 12%, which would exceed the Kyoto targets without any special initiatives (Parker et al, 2004). The minimal increases seen in emissions in the residential sector are attributed to the improved energy efficiency of ‘new build’ homes, and warmer winter weather, thus greatly reducing heating needs (Environment Canada, 2006). Research has been conducted on how to improve energy efficiency in homes; however, the main focus has been on new buildings (Bell & Lowe, 2000). It is clear though, that energy improvements of new housing stock “will only have a marginal effect in the short to medium term” (Bell & Lowe, 2000, page 267). Improving the energy efficiency of the existing housing stock, allows for significant opportunities to be made in reducing the associate greenhouse gas emissions within a shorter time frame than that achieved by new construction (Bell & Lowe, 2000). According to Parker et al (2003), those homes built from 1940 to the1960’s have the potential to reduce their heat loss by approximately 30 GJ per year as a result of improving the buildings envelop (ibid).

Figure 4: Canadian Greenhouse Gas Emissions 1990-2007



Source: Environment Canada (b): Canada's 2007 Greenhouse Gas Inventory – A Summary of Trends. 2010

In addition to the enormous potential in decreased environmental impact, retrofitting also serves a number of benefits for those occupying these dwellings, such as:

- Improved thermal comfort (Canadian Green Building Council, 2004);
- Improved air quality (Canadian Green Building Council, 2004);
- Superior building quality (based on life cycle assessments) (Voss, 2000);
- Cost effective - reduction in maintenance and utility costs (Voss, 2000; Thorne, 2003; Canadian Green Building Council, 2004)
- Potential for healthier living, as it reduces the likelihood of the occupants developing 'sick building syndrome' (Canadian Green Building Council, 2004);
- Potential for reduced noise (Voss, 2000); and

- Increased value of property (greater resell value) (Voss, 2000)

Despite the health and cost benefits of retrofitting, there are a number of known barriers, which prevent or delay a person's decision to retrofit. These are discussed in the next section.

2.1.1 Challenges of retrofitting:

A homeowner's decision to retrofit can become an overwhelming task, with countless decisions to be made on what home improvements should be given priority (Thorne, 2003). Specialty contractors are needed for features such as windows, insulation, Heating Ventilation Air Conditioning (HVAC) systems and so on. As a result, multiple contractors are needed in order to adapt to the whole house approach (Thorne, 2003). Thorne identifies two main barriers, 'Demand-Side' (consumers), and 'Supply-Side' (contractors) barriers. These barriers are described in the Table 1, below. The main barriers identified within Table 1 for both the 'demand-side' and 'supply side', are cost, knowledge, time, and mistrust. Issues surrounding mistrust are most likely the most difficult to overcome, and articles, such as the Toronto Star investigation report on energy auditing (2007), although valuable information, may lead to increased uncertainty and mistrust in contractors and energy experts (article found in Appendix 4).

Table 1: Market Barriers of Retrofitting as identified by Thorne (2003)

Demand-Side Barriers	Supply-Side Barriers
Cost: - Even when a relatively short payback can be demonstrated, the initial up-front cost often remains a barrier to consumer investments	Cost: - Contractors are expected to have special training in different areas of home improvements (whether to be licensed to install solar cells, insulation, and so on), all of which require expense for acquiring and maintaining their license(s)
Education / Understanding: - Homeowners do not always fully understand the benefits of different retrofits; - Homeowners have a difficult time identifying what improvements should be given priority; and - Homeowners may not fully understand how to use new technology effectively (as seen in UK case study presented by (Bell & Lowe, 2000), refer to section 2.2.2)	Lack of consumer demand: - Consumers unwillingness or inability to make a decision on what renovations to do, there is a lack of demand for energy efficient retrofit projects, thus a lack of incentive for contractors to obtain specialized licenses
Mistrust of contractors: - Contracts will sell the 'products and services' they are able to offer themselves, rather than proposing a plan which would result in the greatest benefit for the homeowner, due to an unwillingness to share profits with a competing contractors; - Independent energy audits are required to be done to assists homeowners in their decision making process, however, these energy audits do not appear to be 'standardized', and a single home can achieve very different scores by different auditors. Please refer to Appendix 4 for an investigative newspaper report written by Catherine Porter, which addresses the inconsistencies of energy audits.	Mistrust amongst competing contractors: - Contractors are reluctant to sub-contract work out, in order to prevent someone else from taking their current or potential future profits
Time costs: - Depending on the type of work being done, this may result in the homeowners being displaced, whether from the home or access to a room while the construction is being done.	Time cost: - In addition to the financial cost of acquiring and maintaining the appropriate licenses, contractors have additional time cost for their training.

In addition to the market barriers identified by Thorne (2003), there are also legislation barriers, as seen in the example of a retrofit of the ‘old land house’ in Finland. The retrofit of the ‘old land house’ (which is a typical architectural type of building in Finland, originally with clay walls and a straw roof) was supposed to start in 1996 (Verbruggen, 2008). However, due to regulatory and government delays renovations on this house did not commence until Christmas 2004 (Verbruggen, 2008). At the ECOprize / ECOventure conference, the EcoDesign panelists identified that the government is always the last to make changes to policies and programs, thus creating an additional barrier in encouraging energy conservation (March 2008). Keith Tufts, a senior environmental designer with Lydon Lynch Architects (based in Halifax, NB), stated that the "municipal [provincial and federal] governments are not caught up with current energy-saving technologies mainly due to the fact they do not know how to adopt [and implement] these new principles" (Tufts, EcoDesign panelist, March 25, 2008). Energy efficient technologies are being developed at a relatively fast pace, making it increasingly more challenging for government officials and consumers to keep up.

2.1.2 Contributing factors of Canada’s residential energy consumption:

The residential sector in Canada consists of four major dwelling types – single-attached, single-detached, apartments, and mobile homes (Farahbakhsh et al 1998, and NRCan, 2008). Table 2 displays the breakdown of the different housing stocks within Canada.

Table 2: Housing stock across Canada

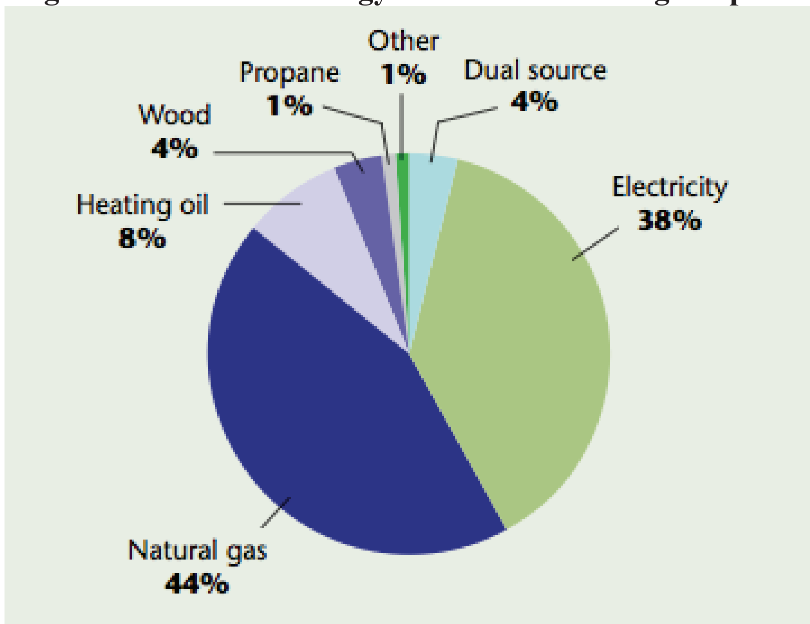
(Based on the 2006 statistics)

Housing Type	Number (in Thousands)	Share
Single-attached	1,428	10.7%
Single-detached	7,622	57.2%
Apartments	4,021	30.1%
Mobile homes	263	2%
Total	13,334	100%

Source: (Natural Resources Canada (b), 2009)

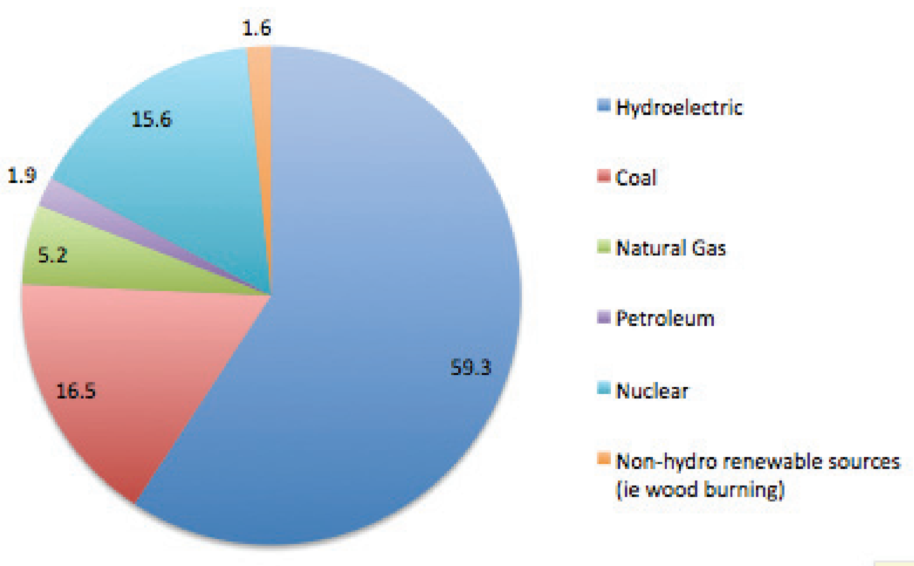
Different energy sources are used across Canada for heating and electricity as seen in Figures 5 through 7. As seen in these figures, the percentage type of resources used for energy sources vary from place to place. Therefore, location plays a large role in the potential emission reduction. Table 3 outlines the amount of energy used and the associated greenhouse gas emissions based on housing types across the country. With over 13 million residential dwellings across the country, this leaves a great potential to reduce emissions from the residential sector. This is significant because, according to Statistics Canada, Canada's residential sector is the third largest emitter of the G8 countries (refer to statistics in Figure 8).

Figure 5: Canadian Energy Sources for Heating Purposes



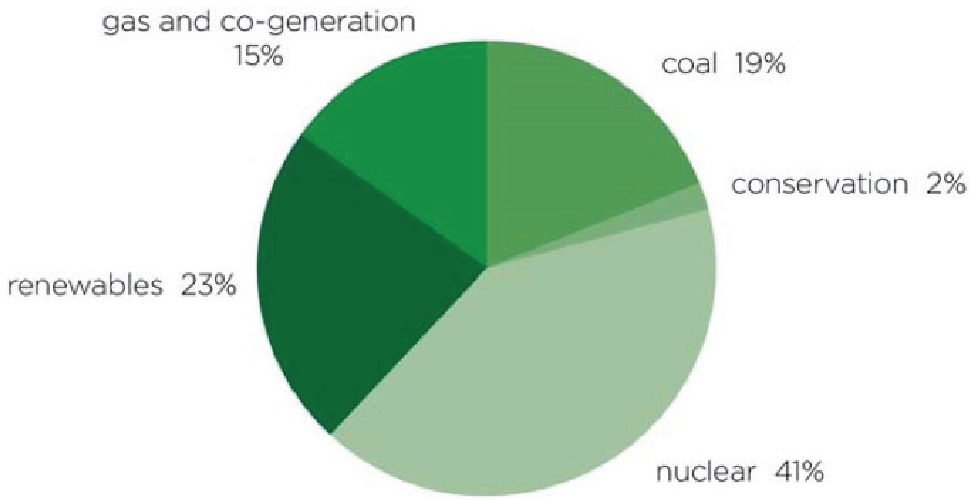
Source: Natural Resources Canada (e), 2010, p 26

Figure 6: Canadian Energy Sources for Electricity Purposes



Source: (Natural Resources Canada (g), 2009)

Figure 7: Ontario Energy Sources for Electricity Purposes



Source: Now House Windsor 5 Project, Case Study Report (Draft), 2010.

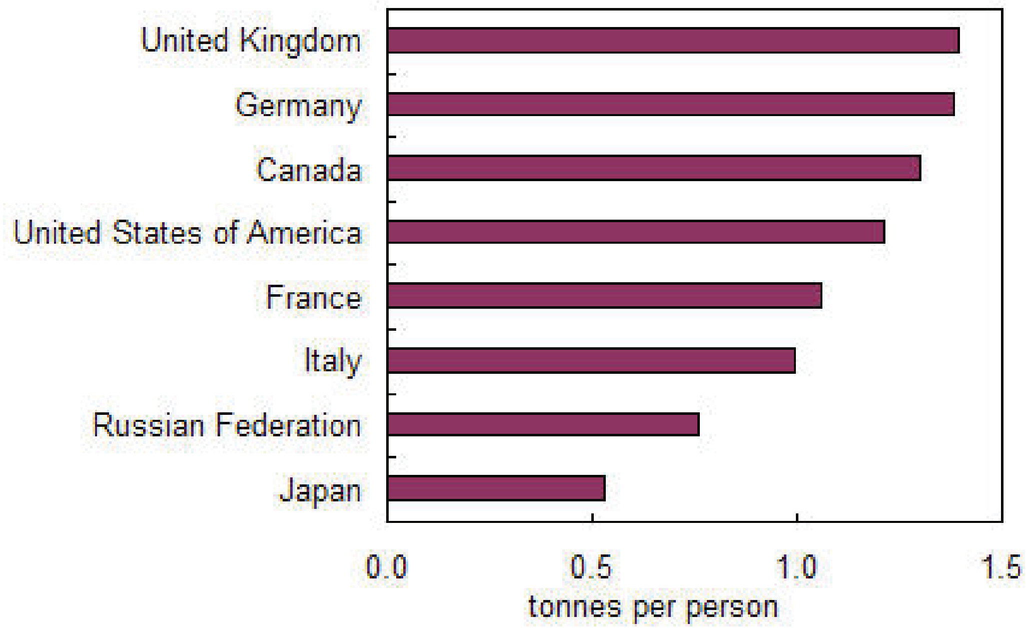
Table 3: Canadian residential energy use and GHG emissions

(Based on the 2006 data sets).

Housing Type	Energy Used (in PJ)*	Emissions (in Mt of CO_2)**
Single-attached	135.53	7.12
Single-detached	937.87	47.86
Apartments	242.79	13.01
Mobile homes	31.07	1.64
Total	1347.26	69.63

Source: (Natural Resources Canada (c), 2009)
http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/analysis_ca.cfm?attr=0
*Table 3(a): Residential Sector - Energy Use Analysis
**Table 4: Residential Sector – GHG Emissions

Figure 8: Canadian GHG emissions for the residential sector: Third largest of all G8 Countries.



Source: Statistics Canada (2008) taken from United Nations (2008)

2.2 Examples of Retrofit Projects Around the World

Retrofitting is by no means a new concept. There was a spike in retrofit studies being published in the early 1970's which correlate with the oil shock (based on examining text such as 'Energy conservation in buildings: A Bibliography' (Vance Bibliographies, 1983); Concordia University Library, CLUES call No. TJ 163.5 B84V36X 1983). Studies have been published on a wide variety of cost-scales, from inexpensive changes (under $500), such as the national lighting retrofitting study conducted in Malaysia, where incandescent lamps and bulbs were replaced with more energy efficient CFL bulbs (Mahlia et al 2005), to high cost projects which aim to achieve net-zero energy, such as the solar demonstration buildings in Europe discussed by Voss (2000).

2.2.1 Inexpensive retrofits:

The initial cost of retrofitting a home is the primary barrier for most homeowners (Thorne, 2003), however as demonstrated within the literature, one does not need to necessarily make large expensive changes to reduce energy consumption and related emissions. Two examples of inexpensive retrofit projects that resulted in a reduction in energy use and emissions are the Malaysia Residential Lighting Retrofit Project (Mahlia et al, 2005), and the modifications made to the United States, National Renewable Energy Laboratory in Golden, Colorado (Voss, 2000). In addition the example of the Australia Residential Demand Project (Turner et al, 2005) illustrates how a retrofit of minimal cost can result in significant conservation of natural resources. Both of the studies conducted in Australia and Malaysia were pilot initiatives, which were carried out on the national level, with initially 3,500 households participating in a water efficiency study in Australia, which later grew to 200,000 participants, and 427 households participating in a lighting efficiency study in Malaysia.

The Malaysia low cost lighting retrofitting study examined the projected outcome of retrofitting homes with 25, 50 or 75% of the lighting within the home, from regular incandescent light bulb to CFL bulbs (Mahlia et al, 2005). The goal of this study was to identify potential electricity savings, emission reductions (of CO_2, SO_2, NO_x, and CO), and conduct a cost-benefit analysis of the changes at the national level (Mahlia et al, 2005). This study was not based on a "real life" project but rather calculations. Surveys were conducted of 427 households to determine the average operating hours of lighting (4.21 hours) and to calculate potential savings and emission reduction (Mahlia et al, 2005). The findings of this study concluded significant monetary savings, ranging between $37 to $111 million USD (for 5000 operating hours) and emission reductions (please refer to table 4 for complete break-down of results). No further articles were found, to be able to establish whether or not the lighting retrofits were ever actually carried out.

Table 4: Break down of projected results for the Malaysia lighting retrofit assessment

(Information taken from (Mahlia et al, 2005) Table 7)

Item*	25% retrofit	50% retrofit	75% retrofit
Savings in RM** (in millions) for 5000 operating hours)	141	282	423
Approximate equitant savings in USD (in millions)	37	74	111
ES (GWh)	774	1548	2322
CO2 (ton)	303481	606962	910443
SO2 (kg)	1791821	3583642	5375463
NOx (kg)	846409	1692818	2539227
CO (kg)	186936	373872	560808

* Calculations used for each item and corresponding graphs can be found in appendix 4
** At the time this article was publish, $1 USD = 3.8 RM (same conversion was used here)

The authors of these studies also stressed the importance of developing a 'consumer awareness campaign', if these initiatives were to be successfully implemented nation wide. In the case of the National Renewable Energy Laboratory, in Colorado, they made use of a demonstration buildings on the grounds of the Institutional Laboratory buildings as a means of educating the public on the benefits and use of alternative energy systems.

The retrofit of the National Renewable Energy Laboratory, in Colorado, consisted of improving the lighting efficiency of the demonstration building (laboratory buildings) by adding mechanical lighting control systems and installing a skylight (Voss, 2000). As a result of these inexpensive lighting retrofits, it was determined that the building lighting consumption was reduced by 86%, and the building's overall energy consumption was reduced by 41% (Voss, 2000).

The initial cost of the water conservation study conducted in Australia, was $130 (AUD) per household, however, the homeowner paid only $22 (AUD) unless they were of a low-income status, in which case there was no charge (Turner et al, 2005). All water leaks inside and outside of the home were repaired and the homes were retrofitted with one of four different water efficient methods listed below:

1. Low flow shower heads;
2. Low flow shower heads, and taps;
3. Low flow shower heads, and toilets; or
4. Low flow shower heads, toilets, and taps (Turner et al, 2005; page 6)

The goals of this study were to identify the annual water demand reduction achieved through the different retrofit measures, assess whether these savings can be maintained over time, and identify how to improve the implementation of these strategies to other target populations (Turner et al, 2005). The water demand of 200,000 retrofitted homes nation-wide were monitored. Scattered throughout, 24,000 randomly selected non-retrofitted homes were also monitored. This allowed for the water demands of these two groups to be compared (Turner et al, 2005). The general findings of this study concluded that there was a water savings of approximately 20.9 +/- 2.5 kL/hh/a (kiloliter/

household/ annually), which equates to a potential savings of 3,344 +/- 400 ML/a (million-litres/ annually) (Turner et al, 2005). The water demands were monitored for a period of 4 years, which allowed researchers to determine that there was "no 'decay' in the average savings" (Turner et al, 2005).

2.2.2 Examples of moderate cost retrofits

Over the last decade it has become more popular for government agencies to develop demonstration buildings as a means of educating the public on energy efficient improvements, as seen in Canada's EQuilibrium initiative. Demonstration buildings, which are retrofitted to different energy efficiencies can be found across Europe. Bell and Lowe (2000) discuss the retrofit of approximately 230 houses within York, United Kingdom, as part of the Greenhouse Programme. In addition to the project associated with the National Renewable Energy Laboratory in Colorado, Voss (2000) examined 13 other retrofit projects located in Germany, Denmark, Netherlands, and Sweden. All of these projects were described by the authors as having moderate costs, ranging roughly between $2,000 (CND) to $24,000 (CND) (individual costs are described below).

In the early to mid 1990's, the UK government funded a series of demonstration buildings in partnership with local housing authorities as a means of implementing energy efficient upgrades as part of their 'modernisation programmes' (Bell & Lowe, 2000). In the City of York, 234 homes were retrofitted as part of three separate schemes which had different energy efficiency plans and monitoring agreements: the 4-house scheme, the 30-house scheme, and the 200-house scheme. The purpose of this study was to identify the benefits of implementing readily available technology with the goal of energy conservation within the context of the housing modernisation programme, and to learn from this project how to improve its implementation in the future (Bell & Lowe, 2000). All of the homes underwent retrofits of the kitchens and bathrooms, and all necessary repairs throughout the home were completed. Table 5, below, outlines all of the energy efficient work and monitoring conducted for each housing scheme.

Table 5: Energy efficient work and monitoring for the three York housing schemes
Source: Bell & Lowe (2000) [information taken from page 269 table 2]

Scheme	Energy efficient work	Monitoring
4-house	**Fabric improvements**: 200 mm loft insulation, cavity wall insulation, 20 mm low emissivity double glazing -- new timber window and door frames with drought proofing. **Heating systems**. Four systems: Gas systems -- condensing boiler central system and gas unit heater system. Electric systems -- off-peak electric boiler system and air -- air heat pump with resistant heating back up. **Ventilation systems:** Gas schemes; intermittent mechanical extract (fan in kitchen and bathroom) with trickle vents in the new window frames Electrical themes; balance the mechanical ventilated heat recovery (MVHR) which, in electric house and "B", was integrated with the heat pump and resistance dock heaters to provide whole house heating	Short-term. Co-heating and pressurization tests before and after improvements Long-term. Internal temperatures and energy consumption -- May 1992 to May 1993. Energy flows disaggregated. Measured values compared with estimates of "before" consumption.
30-house	**Fabric improvements**: 200 mm loft insulation, blown fiber cavity wall insulation, drought proofing to existing windows and doors. **Heating system**: Central heating system with gas condensing boiler and a gas fire (tenant choice) as secondary heat source. **Ventilation system**: Same as 4-House scheme -- gas houses	Internal temperatures and gross energy consumption for the period of November 1992 to March 1994
200-house	**Fabric improvements**: Same as the 4-House scheme **Heating system**: Most houses were fitted with gas boilers (a mix of condensing and non-condensing boilers) and a gas fire (tenant's choice). Some houses had one non-cavity wall, which was not insulated. **Ventilation:** Same as 4-House scheme -- gas houses	Internal temperatures and gross energy consumption were monitored in a sample of 10 houses from April 1993 to March 1995

4-House Scheme:

As seen in table 5, the 4-House scheme entailed the greatest amount of energy efficient work of the three schemes. The average cost per house was approximately £1,000, with an estimated payback period of approximately 5 years, if energy consumption was close to that predicted (Bell & Lowe, 2000). The fabric improvements made to the homes resulted in significant improvements in the air-tightness (2.5-3 fold improvement) and the overall thermal performance of the homes (Bell & Lowe, 2000). Although there was a significant improvement made, the authors note that upon observation, the air-tightness of these homes could have been improved further with modest additional effort, such as better insulation quality (Bell & Lowe, 2000). The heat lost coefficients for both the gas (reduction of 39%) and the electric (reduction of 47%) heating systems were observed (Bell & Lowe, 2000).

The tenants moved back into the homes following the retrofits and the energy consumption was monitored for a period of 12 months. The overall energy consumption of the homes decreased by 49% for gas-heated home 'A', 54% for gas-heated home 'B', and 51% for electric-heated home 'A' (Bell & Lowe, 2000). In the case of the electric-heated home 'B', the energy consumption fell by 50%; however, its energy consumption was 24% greater than that predicted (actual consumption was almost 12,300 kWh/year, and the predicted consumption was under 9,900 kWh/year) (Bell & Lowe, 2000). The discrepancy between the predicted and observed energy consumption was mainly due to problems with the heat pump installation during both the design and operation phases (Bell & Lowe, 2000).

During the course of this study, it was discovered that the energy systems which were familiar to the tenants ran without any problems and the projected energy consumption was achieved. However, in the cases where the tenants were unfamiliar with the system, unexpected results (minor problems) were observed. In the case of the gas-heated home 'B', the heating system was equipped with a central timer control, which the tenants never used, due to their lack of knowledge (Bell & Lowe, 2000). As a result, the tenants would manually turn the heaters on and off, which led to some thermal discomfort within the home (Bell & Lowe, 2000). For the electric heat homes, the mechanical ventilated heat recovery (MVHR) systems were found to be less than optimal (Bell & Lowe, 2000). Although the monitored results were inconclusive, the authors noted that it appeared as though the system was not used on a regular basis (Bell & Lowe, 2000). Therefore, they suggest that more information about the new technology and equipment is an asset and would require considerable attention so that the system could run at its full energy saving potential (Bell & Lowe, 2000).

30-House and 200-House Schemes:

In the case of the 30-House scheme, 21 homes were retrofitted (as described in table 5), and 11 homes were renovated as part of the modernisation program with no energy efficient changes made. The two groups had very similar energy characteristics prior to any changes, with the energy consumption varying by only 2% (Bell & Lowe, 2000). The average cost for the 30-House scheme was approximately £1,400, with an estimated pay-back period of 8 years if the predicted energy consumption was used. Overall the energy performance of the homes clearly illustrated a significant saving, except in the case of one home. Although no social aspects of this study were planned, an open-ended interview was conducted in the case of one home where the actual energy consumption was well over 40% of that predicted (Bell & Lowe, 2000). Upon investigation it was discovered that the occupants used their gas fireplace for prolonged periods of time for heating. As a result, the radiator which was fitted with a thermostat, would turn off and the heating needs were met by the gas fireplace. The gas fireplace energy efficiency ran at about 47%, whereas the condensing boiler feeding the radiators had an energy efficiency between 85-90% (Bell & Lowe, 2000), clearly illustrating the importance of educating the user in order to achieve the energy saving goals. Despite some of the unexpected results pertaining to energy consumption, all three housing schemes did result in meaningful energy savings—total reduction in energy use of approximately 47% for the 4-House scheme, 20% for the 30-House scheme, and 39% for the 200-House scheme (Bell & Lowe, 2000).

Voss (2000) also examined a series of different residential demonstration buildings, analysing 14 different solar buildings located within six countries, which used a combination of three different solar energy technologies (refer to table 6 for details). The total investment of these retrofit projects ranged from €20 (solar collector system added) to €700 per m^2 floor area (Voss, 2000). The analysis of these buildings revealed an energy savings between 3% to 70%, as seen in table 6 (Voss, 2000). Improved insulation of the building envelope was found to be a necessity when retrofitting in order to obtain the greatest benefit, as space heating demand was found to typically decrease by 50% with improved insulation (Voss, 2000). Solar domestic hot water (DHW) systems were found to have the greatest energy efficiency improvement when dealing with multifamily buildings, as anywhere between 60-90% of the energy and thermal factors are lost during delivery and storage of hot water (Voss, 2000). Solar wall heating with transparent insulation* was found to be beneficial only under optimal conditions. Of the four projects which utilized this technology, one did not incorporate shading devices. Not purchasing shading devices resulted in two to three times reduced initial cost. However, it was discovered that the shading devices are necessary to insure summer thermal comfort, because without them air conditioning is required. Therefore not buying shading devices was not found to be overly cost effective overall (Voss, 2000).

* A solar wall heating system with transparent insulation consists of a transparent plaster made of small glass spheres set in a polymer matrix (Voss, 2000). The transparent insulation replaces the typical opaque external insulation, and can be used like a glazing on surfaces such as windows. By doing so, the transparent insulation can be used for both passive and active solar energy uses such as daylighting, solar space heating, solar DHW, and so on.

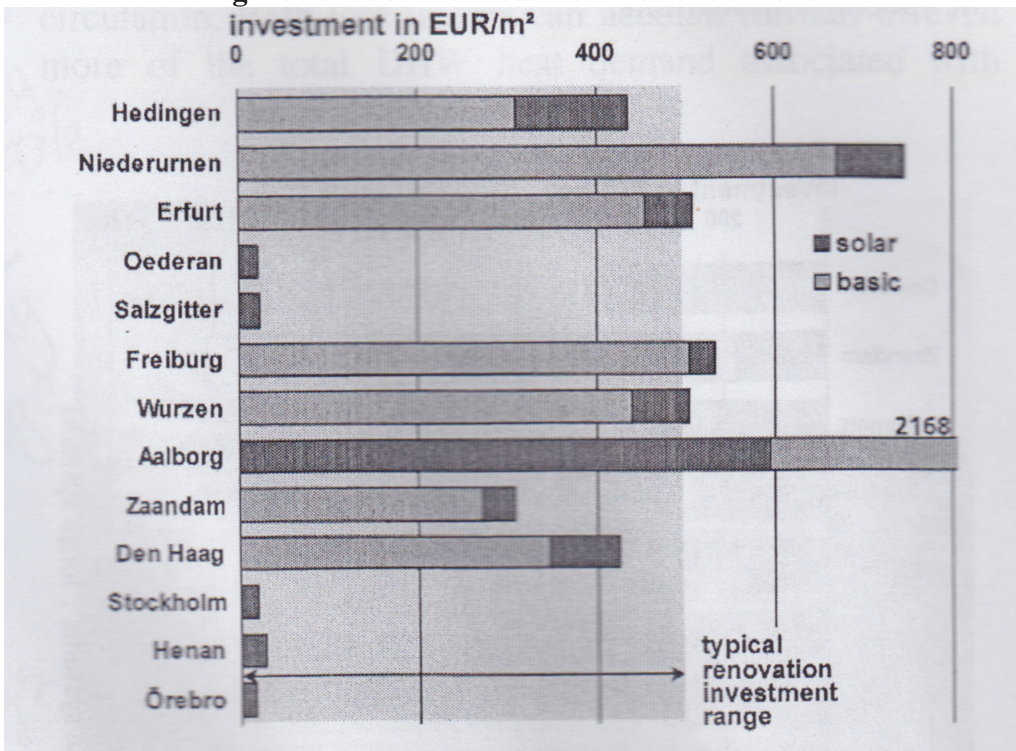
Table 6: List of solar demonstration buildings discussed in Voss (2000)

Location	Country	Type	Built	Size number/floors/floor area (m^2)	Standard renovations and solar retrofit
Niederuren	Switzerland	Multifamily	1971	1/4/966	Improved insulation Solar walls (84 m2) Photovoltaic (11 m2)
Hedingen	Switzerland	Multifamily	1969	1/3/702	Improved insulation HVAC Solar collectors (43 m2) Solar walls (80 m2)
Erfurt	Germany	School	1981	3/3-4/ 3980	Improved insulation HVAC Day lighting
Freuburg	Germany	Residential	1912	1/3/750	Improved insulation HVAC Solar collector (7.5 m2) Solar wall (53 m2)
Oederan	Germany	Multifamily	1983	7/4/2170	Improved insulation HVAC Solar collector (700 m2)
Salzgitter	Germany	Industry hall	1940	1/1/43,000	Improved insulation Day lighting (7500 m2) Table continues on the next page

Location	Country	Type	Built	Size number/floors/floor area (m^2)	Standard renovations and solar retrofit
Wurzen	Germany	School	1978	1/4/4100	Improved insulation HVAC Solar wall (300 m2)
Aalborg	Denmark	Multifamily	1900	1/4/544	Improved insulation HVAC Solar collector (18 m2) Photovoltaic (25 m2) Glazed Balcony
Den Haag	Netherlands	Multifamily	1961	1/4/504	Improved insulation HVAC Solar collector (17 m2) Glazed balcony Photovoltaic (5 m2)
Zaandam	Netherlands	Multifamily	1968	1/14/30,720	Improved insulation HVAC Solar collector (760 m2) Glazed balcony Photovoltaic (90 m2)
Stockholm	Sweden	Multifamily	1961	6/8/40,000	Solar collector (1200 m2)
Henan	Sweden	School	1965	2/1-2/ 10,000	Solar collector (750 m2)
Õrebro	Sweden	Multifamily	1963	1/2/2500	Solar collector (112 m2)
Golden	United States	Exhibition	1994	1/1/560	HVAC Day lighting

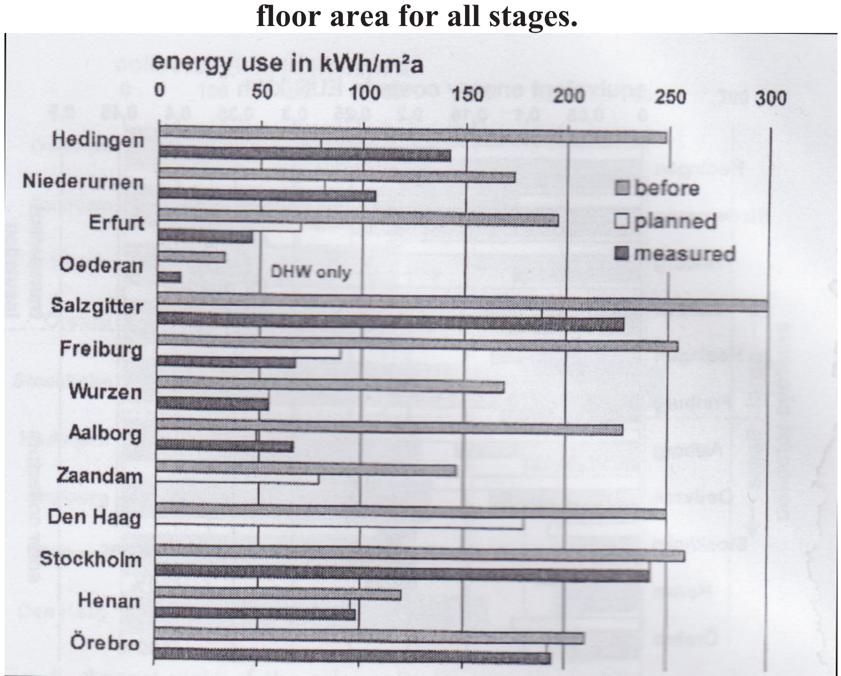
Source: Voss (2000): taken from page 292, Table 1 in article

Figure 9: Investment cost for the renovations



Source: Voss 2000, page 293

Figure 10: Annual final energy use for space heating and DWH in kWh/m2 heated floor area for all stages.



Source: Voss 2000, page 293

2.2.3 High cost retrofit projects:

The concept of net-zero energy buildings–meaning those buildings that produce as much energy as they use on a yearly basis–have also gained momentum over the last 25 years (Charron & Athienitis, 2006). There are a number of examples of net-zero energy buildings around the world. The ‘whole house’ approach, which is required for a net zero energy home, requires significant time spent on planning and design in order to achieve the energy goals without major delays or complications during the construction phase (Verbruggen, 2008). Some examples of high cost retrofits are the “old land-house” project analysed by Verbriggen (2008), The Now House Project, and the net-zero energy chalet retrofit in Egypt.

In the case of the ‘old land-house’, the home retrofit goals were not to necessarily achieve net-zero energy, but rather to greatly improve the energy efficiency of the home and maximize usage of natural ambient energy and resources (Verbruggen, 2008). (Please refer to the points outlined below of the retrofit and energy saving goals). The original home without foundation, was built prior to the 20th century and was constructed with clay walls and a straw roof, which was later replaced with 30 cm thick brick walls (unspecified what was done with the roof) (Verbruggen, 2008). The project was scheduled to commence in 1996, however was delayed by eight years due to regulatory issues (Verbruggen, 2008). The actual cost of the retrofit was not indicated; however, the cost break down was illustrated in percentage (as seen in table 7). The energy saving goals of the Old Land House retrofit were to attain the following, as seen on the next page:

1. High-comfort, superior quality, life-long living space for a household of 1 to 6 persons
2. Energy efficient house: thermal integrity of K20[⊕] or less, application of passive solar concepts, efficient equipment and appliances
3. Maximum use of natural ambient energy and resources
4. Low occupancy and maintenance costs
5. The size, height, external format (roof angle, window and door openings) of the construction had to be maintained. (Verbrugeen 2008; page 403)

Table 7: Break down of costs associated with the renovations of the 'Old Land House'

Renovation Elements	Percentage of Cost
Administration	8%
Construction	70%
Insulation and ventilation	4%
Solar heating and Power	6%
Classic heating system	4%
Rainwater and sanitation	2%
Lighting, electricity, and bathrooms	6%

Source: Verbruggen 2008, page 409

The energy benefits of this retrofit resulted in the following:

- Electricity usage less than 3000 kWh (and produce more than 2000 kWh on site with PV) and a negative net energy bill (due to government subsidies)
- 100% water sanitation done on site
- 50% of water supply collected on site
- food storage (70%)
- laundry (80%) (Verbruggen, 2008)

[⊕] The R-value is a measure of thermal resistance, whereas the K-value is a measure of the thermal conductivity. The K-value is calculated by dividing the insulation thickness by its R-value. Therefore, the higher the R-value is the lower the K-value.

The energy saving outcome of these renovations are quite significant considering the average Canadian household uses approximately 106 GJ of energy per year (Natural Resources Canada (e), 2010) as seen in figure 11. The owner of this particular home had a vested interest in the planned energy efficient retrofit, thus motivating him to continue to pursue the renovation despite the lengthy and costly regulatory delays (Verbruggen, 2008), which is something not everyone would be willing to do.

Figure 11: Average Canadian Household Energy Use for 2007

Source: (Natural Resources Canada (e), 2010)

Energy retrofits are not just about reducing heating costs but also cooling costs. To date there are only two net zero energy retrofit project that were found within the literature; the Now House Project in Canada and a chalet in Egypt.

Based on information found within peer reviewed articles and the internet, it appears as through the Now House Project, in Toronto, Canada, is the worlds first net zero energy retrofit project. (Details about the project can be found in the introduction and Appendix 2). As mentioned previously, the Now House Project utilized both solar electric and solar thermal technologies. It has commonly been believed that solar energy is not a realistic solution for northern world cities which have long winter months due to the short, often grey days; however, this is not the case. As seen in Appendix 4, Canada actually has a significant solar energy potential, ranging between 800-1400 kWh/kW on a yearly average (Natural Resources Canada (d), 2007). In fact, the City of Waterloo, in Ontario, has enough solar energy potential to supply all of its residents with their electricity needs (Parker et al, 2003).

Egypt receives approximately 12.3 kWh/m2 x day on a flat surface during June and July, and approximately 6.7 kWh/m2 x day during the winter (Attia, 2010). The purpose of the net zero energy retrofit of the chalet in Ain-Sukhna, Egypt, was to determine the effectiveness of installing solar thermal systems (STS), solar electric system (SES), and additional wind turbines (Attia, 2010). Details of the retrofit are as follows:

- Reduce heat gains by improving the homes R-value[v] and U-value[ς];
- Reduce internal Loads by using shading devices, energy efficient appliances and light bulbs;
- Passive cooling through the use of natural ventilation;
- Solar thermal system;
- Solar electric system; and
- Wind turbines (Attia, 2010)

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[v] The R-value is a measure of thermal resistance

[ς] The U-value is a rating system for windows which measures how much heat passes through

The changes made to the chalet resulted in significant energy savings, as seen in Table 8 and Table 9 below.

Table 8: Share of each passive solar strategy in the reduction

Passive Design Strategy		Before- After kWh		Reduction%
Reduce Heat Gain	Walls & Insulation	2440	1680	-40%
	Shading Device			-2%
	Windows Glazing			-6%
Reduce Internal Loads	Efficient Lamps	187	85	-6%
	Appliances	432	107	-20%
Total share of reduction		**3486**	**1862**	**-74%**

Source: Attia, 2010 [taken from page 4, table 2 in article]

Table 9: The PV panels and wind turbine generated 2760 kWh/yr

Active Design Strategy		Before- After kWh		Reduction%
STS Thermo.	DHW	427	110	-26%
Total share of reduction		**3486**	**1872**	**-26%**
Active Design Strategy		**After**		**Generation %**
SES	PV panels	+2100		+112%
Wind Turbine	Wind Turbine	+660		+ 35%
Total share of generation		**0**	**2760**	**+147%**

Source: Attia, 2010 [take from page 5, table 3 in article]

Although the retrofit was successful in term of meeting the net zero energy goal, the cost of this retrofit was overly costly and is not a realistic option. One of the reasons is because the cost of electricity from the grid is only 0.01 kWh, making it a cheap electricity source (Attia, 2010). The break down of the costs and the payback period are displayed in Table 10 and Table 11.

Table 10: Break down of retrofit costs

(US $)		Items	Installation	Total
Envelope	Walls	575	175	750
	Insulation	1,200	50	1,250
	Shading Device	120	30	150
	Windows Glazing	320	50	370
Efficient Lamps		60	0	60
Thermosyphon		835	100	935
PV panels incl. Inverter & Batteries		13,120	135	13,255
Wind Turbine*		1,800		
Inverter		1,600	200	3,600

*Not available in the Egyptian market

Total cost = $20,370.00 (USD)

Source: Attia, 2010 [taken from page 6, table 5 in article]

Table 11: Cost analysis for installations and construction

	Total Cost (US $)	Payback years
Walls & Insulation	2000	19
Shading Device	150	
Windows Glazing	370	
Efficient Lamps	60	<1
Thermosyphon	935	2-7
PV panels Inverter	13255	19-28
Wind Turbine Inverter	3600	26-41

Source: Attia, 2010 [taken from page 6, table 4 in article]

2.3 Economics

When examining the economic viability of retrofitting a building, most technical studies express this through the use of payback period and possible CO_2 reduction. However, when addressing economic viability of retrofitting through an environmental economists perspective the approach is very different. Economist believe that improving energy efficiency will ultimately lead to increased consumption since the implicit price decreases, hence becoming more affordable (Herring, 2006). This is referred to as the rebound effect (ibid). Herring (2006) uses the example of the improvements made to light bulbs in the early 1900's, where tungsten filaments bulbs were replaced with carbon ones. This improvement allowed for electricity prices to decrease, leading to an increase in consumption.

This is not to say that investments into energy efficiency should not be made. Energy efficiency improvements allows for consumers to save money, promote a more efficient and prosperous economy, and allows for financing into fossil fuel free solutions for the future (Herring, 2006). "The real question is not 'how much more efficient can we be', but rather, 'how can we ensure the gains from our efficiency strategies are used to deliver real environmental improvements'" (McLaren, Bullock & Yousuf, 1998 from Herring, 2006; p 12).

It has long been advocated that changes in behavior and lifestyle are the key to resource use problems (Herring, 2006). "However, society has generally preferred technical or economic solutions" (Herring, 2006; p 17). One accepted economic solution to reducing CO_2 emissions is a carbon or environmental tax. "The goal should not be taxing energy use so we use less, but raising money to pay for the shift towards CO_2 reductions" (Herring, 2006; page 18). The shift to less carbon intensive fuels, such as solar energy, may allow for continued energy growth while reducing carbon emissions (Herring, 2006).

2.4 Types of energy studies:

Typically energy studies fall within one of the two major categories: technical or social-behavioral studies (Scott et al, 2000). Technical studies consist of a more "engineering approach, with new technologies present and the benefits of their adoption measured" (Parker et al, 2003; page 173). Governments tend to support and promote the development of new technologies, such as the previous example of the R-2000 homes. Social-behavioral studies focus more on a person's decision-making process to determine what a person or community values. Technical and the social-behavioral studies are closely linked and allow for the examination of 'the big picture'. Therefore, in order for new energy programs and policies to be developed and the successful implementation of new technology, energy studies need to examine both the technological and social-behavioral aspects, referred to as socio-technical, in one study, which is the approach adopted by the Now House Windsor 5 Project.

2.5 Example of social-technical study:

The Residential Energy Efficiency Project (REEP), which was undertaken in the Region of Waterloo, case study's overall vision was to encourage "citizen action to contribute to a healthier, more sustainable communit[ies], while simultaneously furthering Canada's international commitment to the Kyoto Protocol" (Parker et al, 2001; page 11). The case study was conducted in the region of Waterloo, Ontario. The region of Waterloo - which is approximately 100 kilometres west of the City of Toronto - has a population of 450,000. The goal of the REEP case study was to "build public awareness and understanding of climate change and to provide technical information and social dialogue about the link to personal energy consumption” (Parker et al, 2001; page 11). In addition REEP aimed to empower behavioral changes of the local community. This was achieved by engaging in personal conversation between the proponent and the community, thus allowing for the identification of energy efficiency benefits and the development of a realistic ‘plan of action’ for homeowners to follow (Parker et al, 2001).

REEP consisted of two different data collection techniques, allowing for technical and social / behavioral studies to be conducted. This was achieved by:

1. A home energy efficiency audit, through the *EnerGuide for Housing* (EGH) program, to identify the potential technical improvements that could be made to ones home to reduce their energy consumption. [Technical study]
2. An energy awareness survey was administered to identify and evaluate a homeowners’ attitude and behavior towards energy use. [Social / behavioral study]

2.5.1 Technical study:

The *EnerGuide for Houses* (EGH) is a government funded grant program, which was established by the Canadian Federal Government in 2003, after being tested from 1999 to 2003. The purpose of this program was to “encourage homeowners, particularly those with older homes in need of energy-efficiency upgrades, to retrofit their homes to make them more energy efficient” (Natural Resources Canada, 2008; no page numbers were given). A part of the EGH program was an energy efficiency audit, including blow-door testing to evaluate areas of air leaks within the home, in order to identify needed /

recommended changes and improvements. The typical cost of an energy audit is $150 CND; however, during the test period of the REEP case study (May 1999 to May 2001), the cost of an energy audit to the homeowner was $25 CND.

Home energy audits within Canada are conducted differently in comparison of other countries, as the Canadian Government allows for a number of different private, non-governmental, and public organizations to conduct the energy audits. (In other countries, such as the United Kingdom, energy audits are conducted by a federal government agency). All certified energy auditors have access to the same tools in order to determine the energy score, referred to as the EGH score. These scores are based on a zero to 100 point system, where zero is no energy efficiency at all (example an open field) to 100 which would be a net-zero energy building (where the building is able to produce all of its own energy). As a reference point, homes which are built to achieve the R-2000 standard (explained within the literature review), are expected to achieve a score of 80. The EGH scores are calculated through a series of tests carried out by a certified energy auditor, who conducted tests such as a blow-door test to check the air-tightness of a buildings envelop, and then inputs the metered data into a computer simulation program called HOT2000 (a Federal Government assessment tool). The HOT2000 software uses a number of different calculations to determine the current energy efficiency of a building including, but not limited to, taking into account such features as the number of exposed walls, type and amount of insulation used, orientation of the building (for passive solar energy potential), and year of construction. HOT2000 also allows energy auditors and people within the building trade to determine what kind an impact the desired changes would have on a building energy efficiency. Due to the fact that not all energy auditors interpret the information the same way has resulted in consumer confusion and increased lack of trust. For example, in a test comparison of energy audit companies, four different companies preformed energy audits on the same home, yielding four very different results (Porter 2007, Appendix 4). This is one of the many reasons why there is a vast lack of trust in the Federal program (EGH), and the minimal participation rate in the program.

Normally when an energy audit is conducted, a worker from a Government certified Energy Audit Company would come into a persons home, conduct a number of different tests and inspections, such as a blow door test for air leaks, and then tell the homeowner(s) what changes and upgrades are needed. The REEP study, on the other hand, took a slightly different approach. Both a certified energy auditor and an intern (a student from the University of Waterloo) would conduct the same tests and inspections as mentioned above. However, rather than just leaving the homeowner(s) with a list of recommended improvements, the representatives would discuss with the homeowner(s) what the recommended changes were, based on the technical aspects, and then discuss what changes the homeowner(s) is realistically able to do (referred to as the socio-technical potential). As a result, the homeowner(s) were able to obtain valuable information on the benefits of the different changes recommended, thus allowing them to make an informed decision while allowing for increased trust and confidence in the people involved with the REEP study. In fact, it was discovered through the energy awareness survey, that the majority of the participants were so pleased with the REEP energy audit process that people would engage in conversation with friends and co-workers about the project, encouraging them to participate.

2.5.2 Social / behavioral study:

The supply of electricity, based on the Canadian Constitution, is primarily the provincial governments' responsibility. In the mid-1990's, new legislation in Ontario, led to the 'privatization' of electricity companies, which came into effect May 1st 2002. The privatization of electricity allowed for consumers to choose to pay a premium for "green" or 'greener' electricity. As a result, the REEP case study analyzed the participant's attitudes and behaviors related to energy use, the likelihood of a homeowner switching to a 'greener' electricity supplier, and their preference for governmental programs and policies related to more sustainable purchasing. This was achieved through the distribution of an energy awareness survey to the 1,390 participants whom had participated and completed a home energy audit. Of the 1,390 survey's distributed, 596 were returned for a response rate of 43% (Rowlands et al, 2003). Rowlands et al (2003) discovered that the demographics of the respondents tended to be older (an average age of 50), have a relatively high level of household income, and have a high level of education in comparison to the average demographic of the Region of Waterloo. In addition, the authors note that the majority of the participants indicated that they frequently engage in conversation about energy issues, which may have contributed to their willingness to pay $25 for a home energy audit (indicating that the participants value the environment and wish to exhibit socially acceptable behavior). Unlike with the energy audit, homeowners filled out the survey independently, to avoid any surveyors influence.

Participants were given a 158-item survey which asked a series of questions related to demographics, perceived consumer effectiveness, liberalism, and ecological concern. The survey revealed that young individuals who have been educated on environmental issues, as well as women, are generally concerned with what their actions will have on the environment, thus making them more environmentally conscious. It was also discovered that "younger, more educated and wealthier, respondents were more likely to be interested in switching electricity suppliers, as well as those who felt they could reduce collective energy use through individual action" (Rowlands et al (date unknown); page 277-278). The survey indicated that 80% of the participants were willing to pay a premium of up to $25 a month for green electricity (Rowlands et al 2003). Unfortunately, when the electricity market was privatized and consumers were given the "opportunity to purchase green electricity in Ontario by paying a premium price ($6.50 on an average monthly bill), only 0.3 percent of the potential customers signed up in the first year" (Goodwin 2002 from Parker et al 2003; p 179). The limited response to switching to a greener electricity supplier was attributed to 'free riders' where a consumer does "not purchase a good, hope others do, and thereby reap the benefits without incurring the cost" (Parker et al, 2003; page 179).

Based on the survey and the respondent's actions following the privatization of the electricity sector, Parker, Scott, and Rowlands indicate that green electricity suppliers need to make more information available to the consumer regarding their percentage of electricity produced through more environmentally friendly methods, why green electricity costs more, as well as the benefits of using green electricity. Participants in the REEP case study also indicated a number of policy options and changes that they would like to see be enforced. Unfortunately, a number of policy options the respondents requested, have been in place through both the Federal Government and Provincial Government for a number of years (please refer to Appendix 1). Based on a conversation with a representative from Natural Resources Canada over the summer of 2007 (when the *ecoACTION* program was first announced), the Federal and Ontario Provincial Governments acknowledge that they have been experiencing difficulties in communicating their energy grant programs to the public and participation has been minimal.

2.6 General Overview of the Canadian Federal Governments Energy Efficiency Programs and Policies:

The Canadian Government has signed and ratified both the United Nations Framework Convention on Climate Change and the Kyoto Protocol. By doing so, Canada has agreed to reduce GHG emissions by 6% based on the 1990 levels by 2008-2012 (Parker et al, 2003). The Energy Research Group developed a plan, which indicated that the Canadian residential sector would be able to reduce its emissions by 12%, thus exceeding the Kyoto target without any special initiatives (Parker et al, 2004). Unfortunately, Canada's GHG emissions have continued to increase; from 612 million tones carbon dioxide (Mt CO_2) to 747 MT CO_2 as of 1998 (Parker et al, 2003; Environment Canada (b), 2010).

The general past trends in Canada has shown that energy demands are growing far faster than gains in energy efficiency, as the residential sector is growing at a phenomenal rate (Parker et al, 2003; Varon,& Aebischer, 2001). In addition Parker et al (2003) highlights the fact that the majority of energy efficiency gains in newer developments are lost, due to the fact that newer homes are typically much larger than past dwellings, and as well, more electricity is being consumed due to the increased use of electronic devices, such as laptops and cell phones.

The Canadian government has developed different programs and policies to help encourage homeowners to reduce their energy consumption – however the Canadian Federal Government only established these policies and programs as of 1992, after a number of provinces (Ontario [May 1987], British Colombia [July 1990], Quebec [June 1991], and Nova Scotia [July 1991]), had already developed and enforced energy-efficient policies in order to allow them to stay economically competitive within the international market (Varon & Aebischer, 2001). One of the major programs offered by the Federal Government was the implementation of the *EnerGuide for Housing* (EGH), which has been updated and now referred to as the EcoAction program.

The EGH (EcoAction) is a government funded grant program, which was established by the Canadian Federal Government in 2003, after being tested from 1999 to 2003. The purpose of this program was to "encourage homeowners, particularly those with older homes in need of energy-efficiency upgrades, to retrofit their homes to make them more energy efficient" (Natural Resources Canada, 2008). A part of the EGH program was an energy efficiency audit, including blow-door testing to evaluate areas of air leaks within the home, in order to identify needed / recommended changes and improvements.

When the EGH program was first established, the energy audits were free. However, very few people who had their homes evaluated made any of the recommended changes. Therefore, changes were made to the EGH program, where the homeowner would be reimbursed for the cost of the energy audit upon the completion of the recommended energy efficient retrofit.

The Federal Government made a commitment to the ECOAction program by investing $7.8 billion through The Canadian Action Plan to further encourage homeowners to renovate and retrofit their homes. This program allows homeowners to include their renovation costs on their income tax claim as well as the opportunity to obtain an interest-free loan for the cost and installation of renewable energies, such as solar. In addition, the government took measures during the economic down turn to increase advertising of the ecoACTION and Canadian Action Plan, thus increasing the awareness of the program to Canadians. The Conservative Government had decided to cancel the program as of March 31 2011, to no longer offer retrofit grants through the ecoACTION program (Government of Canada, 2010), meaning as of April 1st 2011, homeowners would have access to the provincial programs only. However, the ecoACTION program has been extended, as of now, until March 2012 (Natural Resources Canada, 2011).

Chapter 3 – Research Questions and Methodology

3.0 Research Questions – The Now House Windsor 5 Project:

i. Did the Windsor 5 Project achieve its energy conservation goals and greenhouse gas emission reductions? (Refer to appendix 5 for predicted reductions in energy (electricity and natural gas usage) and greenhouse gas emissions for each of the five homes).

ii. What stage of retrofitting is most beneficial and practical when considering both financial and environmental benefits? At what point, if any, are energy efficiency retrofits no longer advantageous?

iii. What environmental educational material and promotion of the Windsor 5 Project was the most effective in encouraging homeowners in making changes to conserve energy (whether physical or behavioural)?

3.1 Methodology

A socio-technical approach will be used for the purpose of this study, similar to that conducted by Parker, Rowlands, and Scott in the REEP study discussed in section 2.4. Therefore collected data of the energy use before and after the retrofits will be used, as well as the administration of an energy awareness survey. The methodology used for addressing each individual question is as follows:

Now House Windsor 5 Project:

i. Did the Windsor 5 Project achieve its energy conservation goals?

Energy data will be obtained through the use of the pre-retrofit utility bills for all 5 homes. This information will give a base-line as to the energy use and related emissions prior to the retrofit. Meters, which will measure the amount of energy being consumed and being produced on site were planned to be installed immediately following the retrofits for a period of 12 months. The pre and post retrofit data will be compared and analysed to determine the impact in reducing energy use and cost. As seen within the literature of technical studies, this information is typically assessed by the following equations:

1. **Energy savings:**

Energy Savings 1 (financial) = Cost Prior to Retrofit – Cost Post Retrofit

Energy Saving 2 (energy use) = kWh Used Prior to Retrofit – kWh Used Post Retrofit

2.**Cost-effectiveness calculation:**

$$\text{Equivalent Energy Cost} = \frac{\text{Capital Cost + Maintenance Cost}}{\text{Annual Energy Savings 2 (kWh)}} * \frac{\text{Dollars}}{\text{kWh}}$$

3.**Emissions following retrofit:**

Energy Source (i) = kWh Used * Emissions Factor (i)

ii. What stage of retrofitting is most beneficial and practical when considering both financial and environmental benefits? At what point, if any, are energy efficiency retrofits no longer advantageous?

A comparative analysis will be conducted of the five different models from the perspective of both the financial and environmental costs and benefits using the calculations listed above. In addition RETScreen software—a free computer program offered by Natural Resources Canada which assess "energy production and savings, costs, emission reductions, financial viability and risk for various types of Renewable-energy and Energy-efficient Technologies (Natural Resources Canada (f), 2010; no page numbers given)—will be used to aid in this evaluation.

iii. What environmental educational material and promotion of the Windsor 5 Project was the most effective in encouraging homeowners in making changes to conserve energy (whether physical or behavioural)?

Two energy awareness surveys will be conducted. The first survey will be given to those individuals who attend the open houses of the 'demonstration home'. Here the goal is to identify what type of educational material on energy savings behavoir and technology was most informative and useful for those visiting the home.

The second survey will be given to the tenants of the homes which were retrofitted. In an attempt to give or provide the tenants with all the necessary tools and knowledge to reduce their energy and water consumption, the following educational materials, events and training were conducted (a full description of these events provided in Appendix 6):

1. The Bridgeview Community Event Now House Launch – on site (November 2008);
2. Opening event for the first retrofitting house (May 2009);
3. Opening event for the Now House Windsor 5 Project (October 2009);
4. 10 open house events (demonstration home of model 3);
5. Residential handbook explaining the energy up-grades mane to each home (copy of the handbook found in Appendix 7); and
6. Participation in the residents training day

Information for the socio-technical study will be collected and assessed through the use of an energy awareness survey, assessing which of the events were most and least beneficial based on the perspective of the tenants occupying the homes retrofitted. Copies of the four different surveys and the corresponding signed consent forms, as required by the university guide lines for social and human research can by found in Appendix 8.

Guided tours of one of the homes were given to anyone who wishes to visit during scheduled open house dates. The guided tours allowed for an explanation of the changes made to the home and the benefits. Participants were be asked to complete a visitor's feedback form before leaving. The information collected here was used to determine what, if anything, they found to be helpful and whether or not this display has an influence on their decision to make any energy efficient up-grades in their home. This feedback form (Appendix 10) was designed and developed by the Now House Team and administrated by volunteers from the University of Windsor. The summary report conducted by the Now House Team can also be found in Appendix 10.

3.2 Anticipated Results:

The information collected from the meters in the houses was compared with the data collected from the utility bills prior to the retrofit to determine whether or not the retrofits achieved the projected energy saving goals.

The results obtained for the social aspect of this study will allow for greater insight into how people make decisions pertaining to retrofits. As discussed earlier, retrofitting an older house offers opportunity for energy savings, and yet often people doing renovations do not prioritize energy efficiencies. Understanding the reasons for this may lead to high rates of retrofitting, and ultimately, may lead to the reduction of greenhouse gas emissions from the residential sector.

It is also important to keep in mind that this case study is working with a low-income housing project. The funds used to pay for these retrofits were paid by the Windsor Essex Community Housing Commission (WECHC). This organization is responsible for approximately 5,000 low income housing units within the district of Essex. Details of the mandate set by the WECHC can be found in appendix 9. As seen in table 12, the average education level within Windsor is completion of high school, and the overall household income over the years has consistently been lower than the Canadian national average (Statistics Canada, 2010: Median Household Income Table). As a result the WECHC plays an important role for this community.

The general demographics for the Windsor area is illustrated in table 12, below:

Table 12: Demographics of Windsor

Basic Demographics	Windsor Area
Population for Windsor	330.9 (thousand)*
Education Level (Average completed)	** High school (please refer to Appendix 13 for breakdown)
Average Household Income (2009 statistics)	$67,220***(this includes those on welfare and unemployment)
Number of People per Household	2.5 persons ****
Percentage of Renters	25.6%*****
Unemployment	54.3%******

* Statistics Canada (2011). Population of census metropolitan area (2010 census). http://www40.statcan.gc.ca/l01/cst01/demo05a-eng.htm
** City of Windsor (2001). Table 12 Highest Level of School. http://www.citywindsor.ca/000503.asp#12
*** Statistics Canada (2010). Median total income, by family type, by census metropolitan area. http://www40.statcan.gc.ca/l01/cst01/famil107a-eng.htm
**** Statistics Canada (2009). Household size, by census metropolitan area (2006 census). http://www40.statcan.gc.ca/l01/cst01/famil122e-eng.htm
***** Statistics Canada (2011). Owner households and tenant households by major payments and gross rent as a percentage of 2005 household income, by census metropolitan area (2006 census). http://www40.statcan.gc.ca/l01/cst01/famil129e-eng.htm
****** Statistics Canada (2008). Employed labour force by place of work, by census metropolitan area (2006 census). http://www40.statcan.gc.ca/l01/cst01/labor70a-eng.htm

It is important to note that Windsor was greatly affected by the recession in 2008, as a large portion of the population worked within the automotive industry. It is likely that the unemployment rate in Windsor is greater than that indicated in the table above, due to the fact that the percentage is base on 2006 census data. The same logic would apply for the average household income – the income is most likely lower than that illustrated in this table (2009 data) – has more individuals loss their jobs following 2009.

Keeping in mind that this project is looking at a social housing project, it also allows for opportunities and constraints of retrofitting lowing income housing from both the renters and proponents perspectives.

Chapter 4: Results

4.0 Results Introduction:

The WECHC collaborated with the Now House Team, to up-grade the energy efficiency of five of their rental properties. The goal was to improve energy efficiency as much as possible while encouraging the tenants to make additional behavioural changes to reduce their energy consumption. Extensive renovations were made to these homes in an attempt to reduced the amount of energy used in each home as much as possible. A summary of the overall results for each home can be found in table 13, below.

Table 13: Summary of energy results from the Now House Windsor Five Project

Model	Electrical Reduction kWh (Percentage %)	Electrical Savings ($)	Photo-Voltaic (PV)*		Gas Reduction (Percentage % - based on annual savings)	Gas Savings ($)	Water Reduction (Percentage %)	GHG Reduction (KgCO2e)
			Electricity Generated (kWh)	Electricity Earnings ($)				
1	19.5	131.56	n/a	n/a	43.2	405.25	52.2	4666.53
2	42.7	363.63	655.99	526.10	60.1	749.09	63.8	6297.02
3	84.2	-	552	463.70	77.5	-	-	-
4	28.2	155.18	n/a	n/a	55.6	589.76	-17.1	3902.75
5	17.4	228.55	n/a	n/a	47.9	420.25	27.7	3219.19

* PV generation and earnings are based on a three-month period, from mid-July to October 2010.

NOTE: Model 3 was used as the demonstration home, and during the post-retrofit metering was not conducted since the home was not occupied. The overall energy usage is skewed, and is not considered to be a true representation of the data.

The information illustrated in Table 13 is based on an annual savings. Therefore, the percentages displaced for the reduction in electricity, natural gas, and water consumption represent the overall reduction for the first year following the retrofit. For models two and three, where solar electricity was included, the percentage reduction of electricity is noticeably higher than the other models, as these homes were able to use solar electricity produced on site rather than from the grid (for a three month period only). Each home demonstrated significant reductions within all these areas, on the exception of model four's water consumption reduction, which was found to be -17%, or in other words an increase of water consumption by 17%. In this particular case, it is assumed that there must have been a metering problem, due to the fact that even without any behavioural changes to the way the tenants used their water, there should have been some water consumption reduction found. This particular situation is addressed in greater detail later on in this chapter.

The electricity savings represented in dollars, is based off of the annual monetary savings of electricity purchased from the grid. In the case of model's two and three, additional monetary savings are displayed as a result of the amount of electricity sold back to the grid, receiving an amount of $0.42/kWh. Therefore, the total annual electricity savings for model 2 was $889.73 (keeping in mind the PV savings are based solely on a three month period, and therefore future annual electricity savings should be higher). The annual overall electricity saving were not calculated for model three due to the fact the home was not occupied during the time the metering took place.

The value illustrated for the reduction in greenhouse gas emissions (table 13), were calculated for each model as follows:

([electricity used pre retrofit (annual kWh) – electricity used post retrofit (annual kWh)] * 0.258)
+
[natural gas pre retrofit (annual m3) – natural gas post retrofit (annual m3)] * 1.902)

The conversion factors used for determining the kilograms of carbon dioxide equivalent ($kgCO_2e$) are based from Natural Resources Canada 2002 conversion factors for Ontario, which were the most recent conversion factors found (published in 2009). A copy of this information in found in Appendix 11. In section 4.1 summary tables for each individual model also illustrated the kgCO2e for both the electricity and natural gas reductions.

Another means of assessing a buildings energy efficiency improvements is through the use of its pre and post EnerGuide for Housing (EGH) score (described in section 2.5.1). According to the pre retrofit energy audits conducted, homes built within the 1940's in Ontario, such as these, typically have an EGH score of 57. The pre-retrofit, predicted, and post retrofit EGH scores for each home is found within Table 14, below. In addition, the pre-retrofit EGH reports are found within Appendix 12 along with pictures taken of the types of test and data collected for an energy audit of a home.

Table 14: EnerGuide for Housing Scores – Pre-Retrofit, Predicted, and Post-Retrofit

Model	EGH		
	Pre-retrofit	Predicated*	Post-retrofit**
1	18	62	77
2	35	67	79
3	28	65	79
4	55	73	81
5	55	73	74

*Predicted EGH scores were determined using RETScreen (a modeling software to help determine what changes to make) and HOT2000 (to determine what the EGH score should be if all the planned changes are carried out)

**Post-retrofit EGH scores are determined as a result of conducting a post-audit and entering the new data into HOT2000 to determine what the new EGH scores are.

4.1 Question 1: Did the Now House Windsor 5 Project (NHW5P) achieve their desired energy saving goals?

There are three possible way of assessing whether or not the NHW5P achieved its energy conservation goals, as listed below:

1. Comparing the EGH scores for before and after the retrofit as determined by a certified energy auditor. (Details of all of the audits are found in Appendix 12)
2. Comparing the predicted and actual GHG emission reductions, based on calculation conducted using conversion factors to determine how much CO_2 is

produced for electricity and natural gas (refer to page 51 for formula used and appendix 11 for conversion tables)

3. Comparing the predicted and actual energy reduction, in terms of percentage of energy reduced.

If one were to solely rely on the EGH scores – predicted and actual (as seen in Table 13) – one would clearly be able to state that the project surpassed its energy conservation goals for each model. However, through the course of this research it was discovered that this governmental tool is not a true representation of the achieved energy (total percentage of electricity and natural gas) and GHG emissions reduction. As seen in the table 14 and figures 12 and 14, in terms of the predicted GHG emission reduction determined by the energy auditor, none of the homes actually achieved this reduction despite receiving a better than expected EGH score following the retrofit. This is due to the fact that the HOT2000 software tool uses a number of assumptions and generalizations when calculating the possible EGH scores and GHG reductions, rather than using actual energy data, such as the actual usage of electricity and natural gas. (This is further assessed in the discussion section of the thesis on pages 93-95). As seen in the figure 13, for both models two and five, the predicted GHG reduction was greater than the actual GHG emission prior to the retrofit. In the case of models one and four the predicted GHG reductions are very similar to the pre-retrofit emissions, and neither of these models were designed to achieve net-zero energy. (The GHG values illustrated in both figures 12 and 13 are based off of actual data for the electricity (in kWh) and natural gas (m^3) using the formula shown on page 50).

Figure 12: Actual Pre and Post GHG emissions vs. predicted GHG emissions reduction

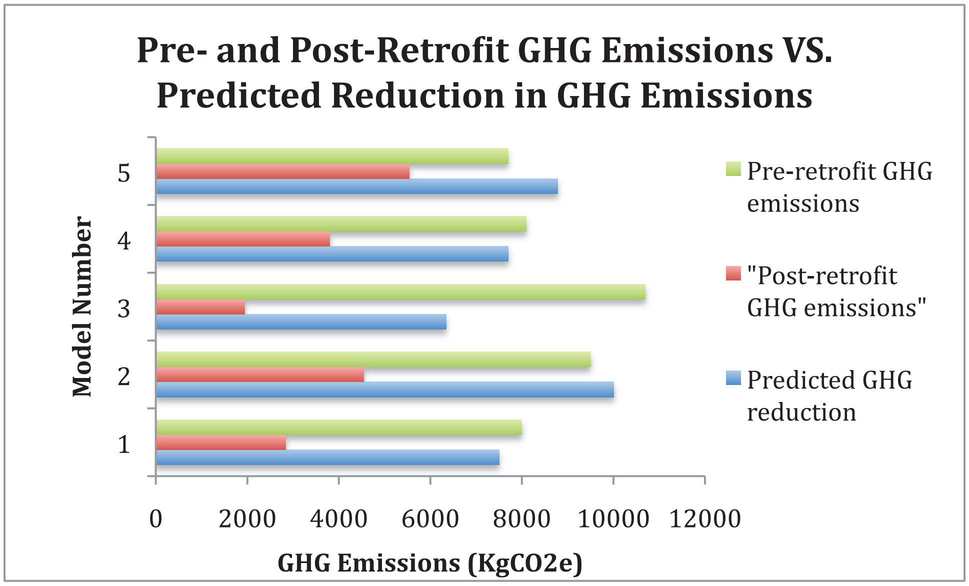
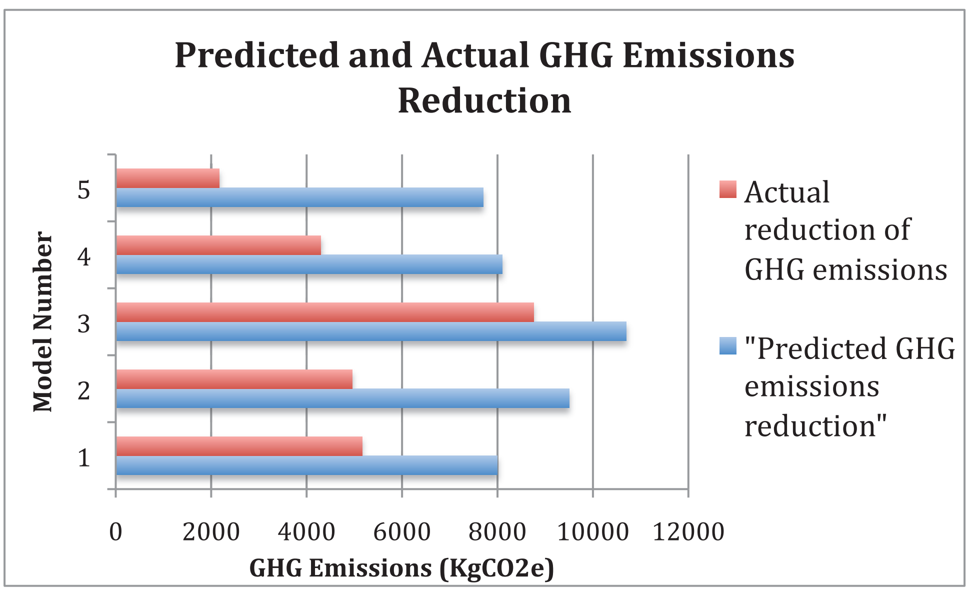


Figure 13: Difference in Actual and Predicted GHG emissions reductions



Despite the difference in the actual and predicted GHG emission reductions, all of the homes achieved measurable electricity, natural gas, and water usage reductions following the retrofits. The following is an energy assessment of each model for both the pre and post retrofit data in terms of electricity, natural gas, and water consumption.

The electricity and natural gas data for each home was evaluated by using a regression model, using the historical utility (electricity and natural gas) billing data to calculate annual energy payments. By doing so, this allowed a baseline of the historical electricity and natural gas data to be compared to post-retrofit data, which also took into account for the difference in temperature over the two-year monitoring period. In order to normalize the data to account for weather the following general equation was used:

Savings = How much energy would have been used this year – This years usage

What this formula is stating is simply, subtracting the actual energy (electricity and natural gas) used following the retrofit from the amount of energy (electricity and natural gas) needed prior to the retrofit to maintain the same interior temperature. Therefore normalization is then done not just for the change in the exterior temperature but also the change in the air tightness of the building envelop. This factor varies for each home and was determined by the energy auditor and found within the energy audit reports in appendix 14.

Heating Degree Days (HDD) were applied to the natural gas consumption for the period of 6 months (November to April) and Cooling Degree Days (CDD) was applied to the electricity usage due to air conditioning for the summer months (May to October).

(This information is based on the degree days established by Environment Canada for the Windsor area).

Calculating the R^2 value allows for determining the best correlations between degree-days and for the energy (electricity and natural gas) consumption regression analysis to be applied to the bills. Therefore, in houses with an R^2 value less than 0.75, no regression analysis was applied, due to the fact there is no correlations between degree days and energy consumption (meaning if the consumption of natural gas for heating (in m^3) during the winter resulted in a R2 value less than 0.75 during the winter, no regression analysis was applied, whereas if the R2 value was higher than 0.75 a regression analysis was applied).

The following is the analysis for individual models in terms of their pre and post retrofit electricity, natural gas, and water consumptions.

Model one – 1307 Rankin Avenue:

Model one consisted of the following retrofits (please refer to appendix 5 for further details of what was entailed for each retrofit).

- Base Model +
- High efficiency tankless water heater
- High efficiency central AC
- High efficiency hydronic furnace
- Heat recovery ventilator

A summary of the general results for this model following the retrofit are illustrated in table 15, below. The "Projected results" are those that were expected as a result of the HOT2000 predictions prior to the retrofit being undertaken.

As seen in table 15, a noticable reduction in the electricity, natural gas, and water consumption were achieved. The percentage of energy reduction is based on electricity and natural gas – it does not include the percentage of water consumption reduction. The predicted outcome established by the HOT2000 software, of an energy reduction of 62%, was not achieved in reality. Despite this, there is a reduction of 1289.90 kWh of electricity (pre retrofit (6595.12 kWh) – post retrofit (5305.22 kWh)) and 1316.76 m^3 of natural gas (3050.61m^3 - 1733.85m^3). The greenhouse gas emission reductions were calculated using the formula illustrated on page 50. The total GHG emission reductions (adding the GHG emission reduction of electricity and natural gas) equated to 2837.27 $kgCO_2e$, which is approximately a reduction of 37.8% of GHG emissions. The home now emits 4666.53$KgCO_2e$ of GHG emissions on an annual basis. The home did not achieve the predicted GHG reduction of 8,000 $KgCO_2e$, however this was not an avchievable goal since the home was only producing 7503.80$KgCO_2e$, meaning there was an over estimation of 496.2$KgCO_2e$ to begin with.

Table 15: Summary of results for model one

	Electrical Consumption	Gas Consumption	Water Consumption	Total	Predicted Results**
Pre-retrofit	6595.12 kWh GHG =1701.54KgCO_2e	3050.61 m^3 GHG =5802.26KgCO_2e	246.27 m^3	GHG: 7503.80KgCO_2e	
Post-retrofit	5305.22 kWh	1733.85 m^3	117.62 m^3		
% Change	19.5%	43.2%	52.2%	**31.35%***	**62%**
Cost Savings	$131.56	$405.25	$34.22	$571.03	
GHG Reduction (KgCO_2e)	332.79	2504.48		**2837.27**	**8000**

*Total average energy reduction = electricity usage + natural gas usage / 2
**Predicted Results were determined through the use of RETscreen and HOT2000 prior to the retrofit being undertaken

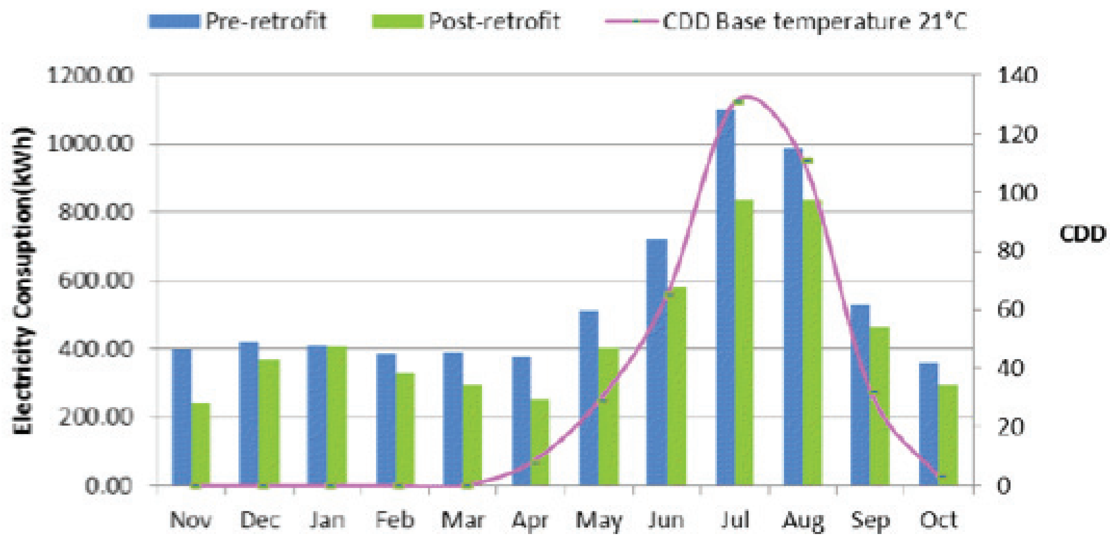
Total GHG emission following retrofit = 4666.53KgCO_2e

Figure 14 through 16, illustrate the homes electricity, natural gas, and water consumption usage for both the pre and post retrofit metered data.

Model One's Electricity Usage:

Figure 14 below outlines both the pre and post retrofitted electricity consumption for model one. Electricity usage for this model was higher than predicted. During a follow-up conducted with the occupants, it was discovered that due to a medical condition, the temperature of the house is set at 21 degrees, requiring the air conditioning to be used consistently throughout the summer months, explaining the slightly higher electricity usage. In addition, it was determined that the overall electricity use for the entire year following the retrofit, was also higher than predicted due to the occupants electricity use habits. Nonetheless there is still a annual savings of 1289.90 kWh for this model.

Figure 14: Electricity consumption for Model One

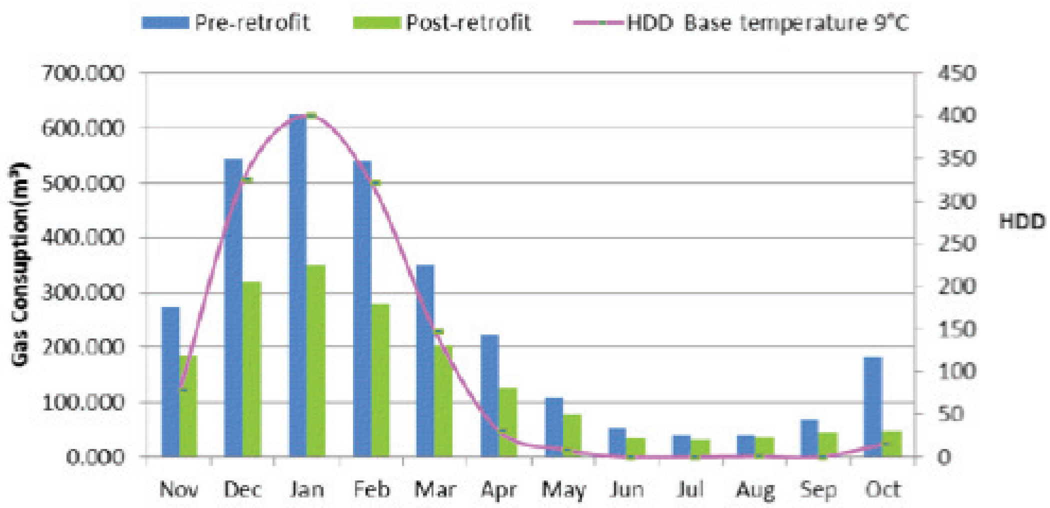


*Note: all the Electricity, Natural Gas, and Water Consumption graphs found within this thesis were produced by CDML for Lorraine Gauthier, the Now House Team Leader.

Model One's Natural Gas Usage:

Figure 15, below illustrates the pre and post retrofit natural gas consumption. Overall savings can be seen between the pre and post-retrofit natural gas consumption. There are no anomalies found within these results (meaning that based on the regression analysis conducted and comparison of the pre-retrofit natural gas consumption, the post-retrofit natural gas usage follows a very similar trend). Based on these results one can make the assumption that the retrofits in regards to the heating systems and improved air tightness of the homes building envelop are working as intended.

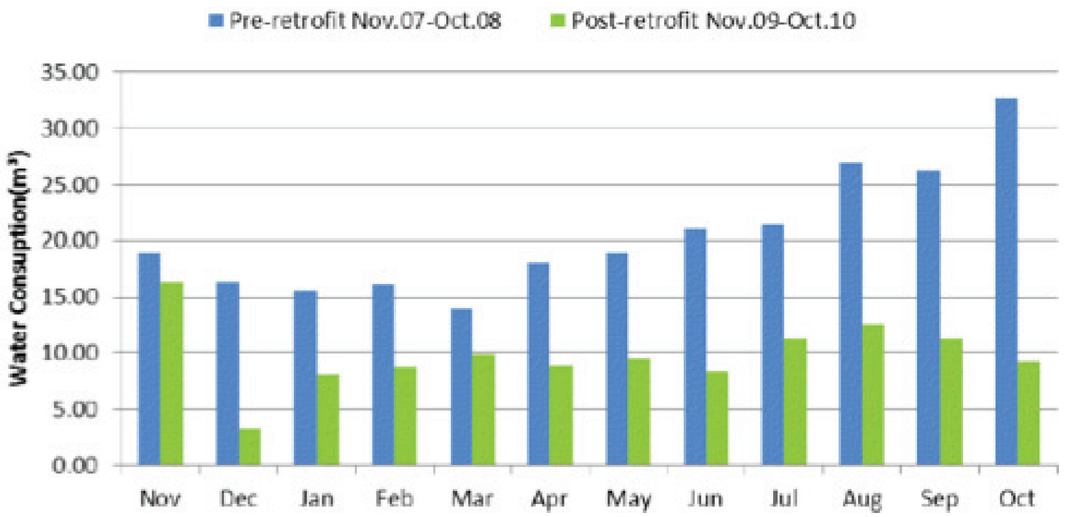
Figure 15: Natural Gas consumption for Model One



Model One's Water Usage:

Figure 16, below, highlights the water consumption for this model. Other than the month of November, significant reduction in water consumption can be seen. When surveying the occupant of this home, there was no known reason for the increased water usage in November following the retrofit. However a water conservation workshop was held during the month of December so one could make the assumption that this workshop may have played a role in the tenant's behaviour in terms of water conservation.

Figure 16: Water consumption for Model One



Although significant energy and water saving can be seen and the EGH scores determined by the energy auditors assessment (pre retrofit 18, predicted 62, post-retrofit 77) indicates that this model was successful. However, this model did not achieve its intended GHG reduction of 8,000 KgCO2e nor the predicted percentage in energy reduction of 62% (this percentage is based on the electricity and natural gas reduction), fall short by slightly over 30%. It is important to note, however, that it was impossible for this home to have achieved its projected GHG reduction of 8,000KgCO_2e since the home was producing 7503.80KgCO_2e of GHG emissions prior to the retrofit.

Model Two – 1301 Rankin Avenue:

Model two consisted of the following retrofits (please refer to appendix 5 for further details of what was entailed for each retrofit).

- Base Model +
- High efficiency forced air gas furnace
- High efficiency central A/C
- Heat Recovery Ventilator
- 2.1 kW solar photovoltaic system

A summary of the general results for this model following the retrofit are illustrated in table 16, below. This model also incorporated solar electricity. It is important to note that due to political issues and clerical delays, the solar PV was only generating electricity and monitored for a period of three months – mid July to mid October.

Similar to the previous model, model two resulted in significant reductions in electricity, natural gas, and water consumption. In addition there is a reduction of GHG emissions of 54.6%. It is important to note that this reduction in GHG emissions does not take into account the emissions associated with the production or transportation of the solar PV itself, but rather just on the reduction of GHG emissions as a result of reduced electricity from the grid and natural gas consumption. It is expected that the electricity consumption from the grid and associated GHG emissions will be less in future years, as the solar PV was only in operation for three months, as well as the cost savings from the PV will increase.

The predicted percentage in energy (electricity and natural gas) reduction for this model was expected to achieve 63% and a reduction of GHG emissions of 9,500KgCO_2e.

Although the data indicates that the desired goals were not achieved, they did come close and it is assumed that they will improve in the following years, since the solar PV is now working. If one were to assume that PV would continue to generate approximately 218.66 kWh per month during the summer months (May through October), and 50% of that (equating to 109.33kWh per month) during the winter months (November through April) (summer and winter months as determined by Environment Canada; solar energy potential as determined by the solar potential map found in Appendix 3), there is a potential of an additional reduction in electricity of 1967.94 kWh and 499.86KgCO_2e of GHG emissions (as seen below):

Electricity = (218.66*6) + (109.33*6)	GHG Reduction = 1967.94 * 0.254
= 1311.96 kWh + 655.98 kWh	= 499.86KgCO_2e
= 1967.94 kWh	

This would therefore theoretically mean that this model could achieve an energy reduction of 70.4% and a GHG emission reduction of 5041.52 KgCO_2e, thus surpassing the predicted energy percentage reduction, but still not achieving the desired GHG emission reductions.

Table 16: Summary of results for Model Two

	Electrical consumption	Gas consumption	Water consumption	Total	Predicted Results
Pre-retrofit	8382.14kWh GHG: 2162.59KgCO_2e	4127.29 m3 GHG: 7850.09KgCO_2e	459.87 m3	GHG: 10012.69KgCO_2e	
Post-retrofit	4802.38kWh	1647.03 m3	166.43 m3		
% Change	42.71%	60.1%	63.8%	**51.4%**	**63%**
Cost Savings	$362.63	$749.09	$78.06	$1189.78	
GHG Reduction (KgCO_2e)	1239.01	3133.41		**4372.42**	**9500**
Revenue	$526.10			$1715.88	
GHG PV (KgCO_2e)	169.24			4541.66	

Total GHG emission following retrofit = 5471.03 KgCO_2e

The electricity generated from the 2.1 kW solar photovoltaic system consist of:

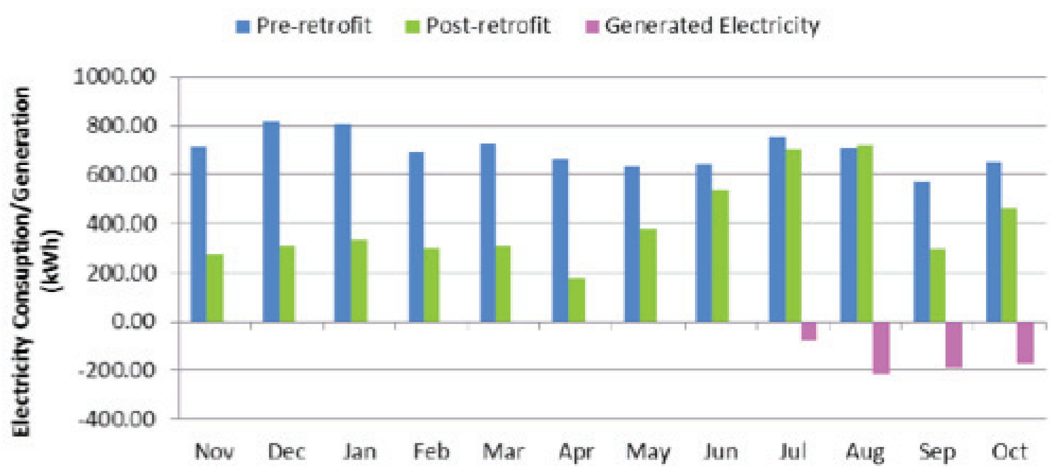
Electricity produced	655.99 kWh
Revenue	$526.10
Reduction in GHG	169.24 KgCO_2e

Figures 17 through 19 illustrate the pre and post electricity, natural gas, and water consumptions for model two.

Model Two's electricity usage:

Electricity consumption has reduced overall following the retrofit. Due to problems getting the PV cells connected to the grid, only 3 months (mid July through to mid October) of data are available. It was predicted that the roof mounted 2.1 kW solar PV array would generate 2,956 kWh/yr, with the Ontario Power Authority (OPA) paying back 80.2 cents/kWh, generating a potential $2,371 reduction electricity, and a net gain of $1,125. Based on the data collected to date, the PV array has generated 655 kWh – therefore it is estimated that the PV array may produce closer to 2400 kWh/yr. The month of August electricity usage was higher for the post-retrofit stage. This could be due to weather changes (warmer summer) causing the increase of AC usage. The occupant did not indicate any behavioural changes in electricity usage that may have been responsible for this increase.

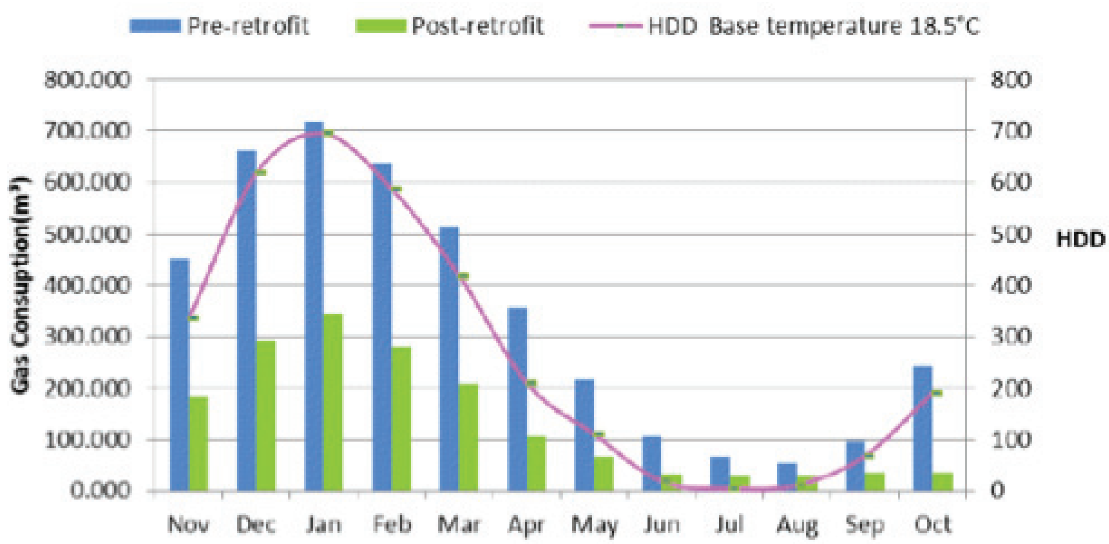
Figure 17: Electricity consumption for model two



Model two's natural gas usage:

As seen in figure 18, overall the Natural Gas consumption has reduced. There appears to be no abnormalities, meaning no noticeable or unexpected natural gas consumption data following the retrofit. The new heating systems, gas appliances stove, and improved building envelop are working as planned.

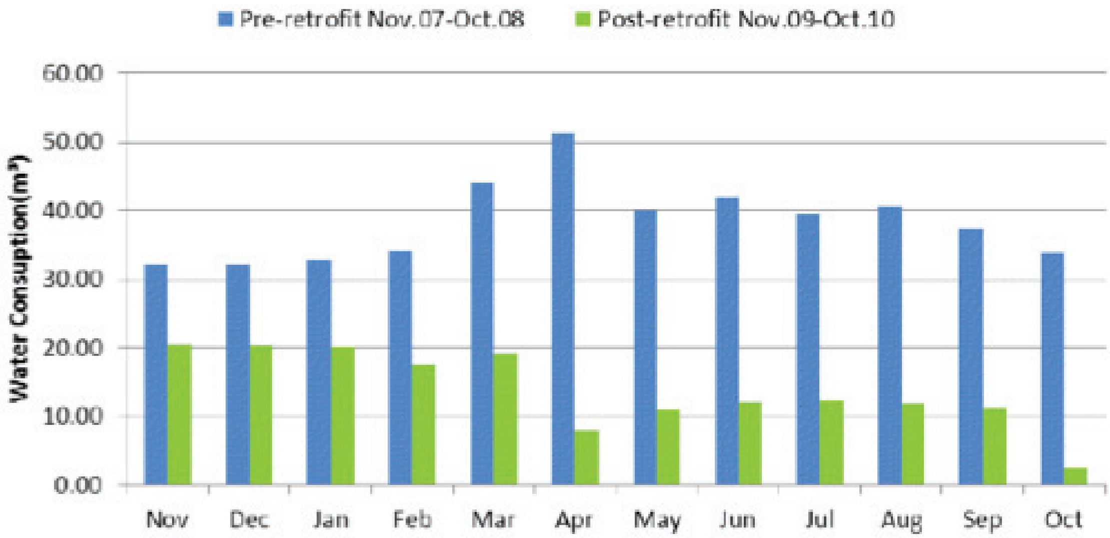
Figure 18: Natural Gas consumption for Model Two



Model two's water usage:

Significant reduction in water consumption can be seen. In particular, water consumption reduced further as of the month of April. Based on the interview with the tenant no known behavioural changes were consciously made.

Figure 19: Water consumption for Model Two



Based on the assessment of the energy usage of this model, it is clear that this model came close, but did not achieve the desired energy goals based on the percentage energy reduction of 63%. Although if one were to make the assumption that the home would reduce its electricity usage by 1967.94 kWh per year from the grid as a result of the solar PV, this model could then achieve an energy reduction of 70.4%, surpassing its goal. As in model one, the goal for reducing the GHG emissions was not obtained, but was still able to achieve an overall GHG emission reduction of 54%, which is a significant reduction.

Model 3 – 1291 Rankin Avenue:

Model three consisted of the following retrofits (please refer to Appendix 2 for further details of what was entailed for each retrofit).

- Base Model +
  - High efficiency hydronic forced air gas heating system
  - High efficiency central A/C
  - Heat Recovery Ventilator
  - Solar thermal system
  - 2.1kW solar photovoltaic system

Model three has been used as the demo house, and therefore the data sets for this model are not complete. This model was used as the demonstration home due to the fact it had the most significant retrofits done, and due to the fact the original tenant did not feel comfortable returning to this home feeling the changes were beyond their comprehension (this is discussed further in section 4.3). A summary of the general results for this model following the retrofit are illustrated in table 17, below.

As in model two, the solar PV was only in operation of a three month period (mid-July through mid-October), and therefore the results indicated for the solar PV are less than that expected for the future when the solar PV is in operation twelve months of the year. Although this home was not occupied during the post-retrofit metering period, timers for the electricity were set for security reasons, and heat on to prevent any water pipes from cracking. Although the electricity and natural gas reductions are impressive, it would be expected that once the home is occupied these consumption values will increase. Despite the limited consumption, surprisingly, this model did not achieve its predicted percentage energy or GHG reductions. One would have assumed that these goals would have been achieved, since there was limited electricity and natural gas consumption needed.

Table 17: Summary of results for model three

	Electrical consumption	Gas Consumption	Water consumption	Total	Predicted Results
Pre-retrofit	1692.14kWh GHG= 429.80KgCO_2e	3189.61m^3 GHG= 6066.64KgCO_2e	214.40m^3	GHG: 6496.44KgCO_2e	
Post-retrofit	1073.64kWh	718m^3	n/a		
% Change	57.61%	77.49%	n/a	**67.55%**	**71%**
Cost Savings	n/a	n/a	n/a		
GHG Reduction (KgCO2e)	429.80	1365.64		**1795.43**	**10,700**
Revenue	$463.70				
GHG PV (KgCO2e)	142.42			1937.85	

Total GHG emission following retrofit = 4,558.59 KgCO_2e

The electricity generated from the 2.1 kW solar photovoltaic system consist of:

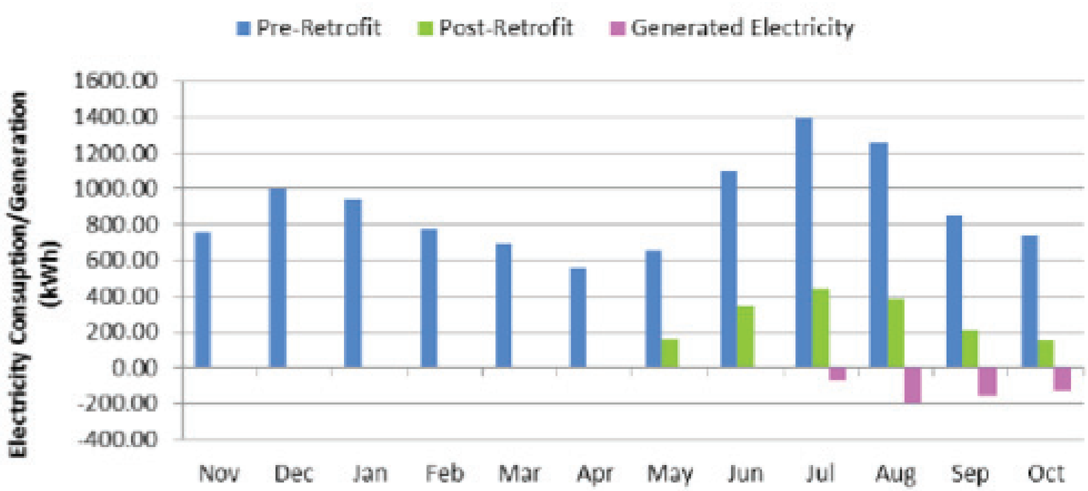
Electricity produced	552.00 kWh
Revenue	$463.70
Reduction in GHG	142.42 KgCO_2e

Figures 20 through 22, are the individual results for this models electricity, natural gas, and water consumption.

Model three's electricity usage:

For the few months that there is a comparison of the pre and post retrofit for electricity use and there is a significant reduction; however these results are not representative, as the home has not been occupied and is being used as the demonstration home. In Figure 20, the post-retrofit electricity consumption (shown in green) is of the electricity purchased from the grid and the electricity generated on the solar PV, which was sold back to the grid. The values for the solar PV are represented as negative values because this value represents less that electricity required from the grid. Therefore, the consumption (in green) is the electricity purchased from the grid plus the electricity produced by the solar PV.

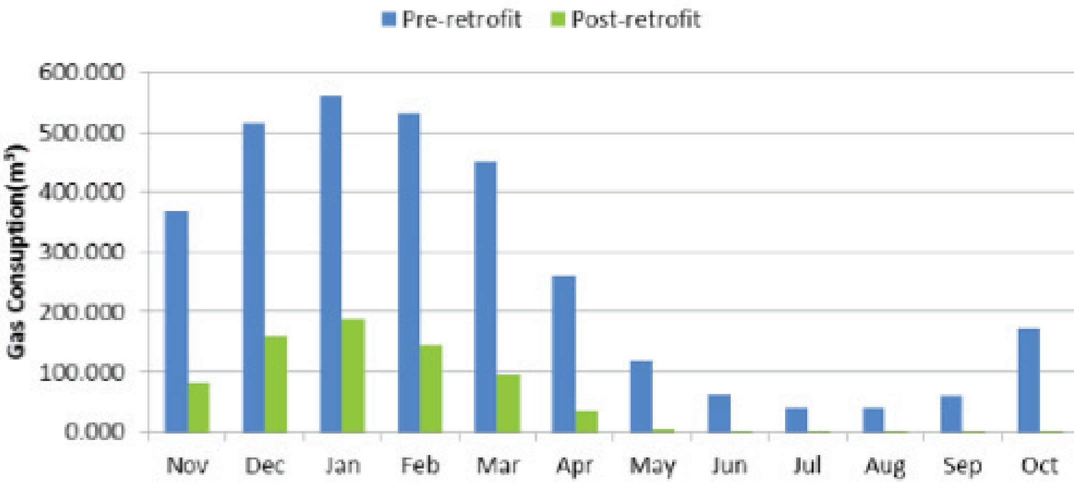
Figure 20: Electricity consumption for model three



Model three's natural gas usage:

As seen in Figure 21, the natural gas was only used during the winter months to avoid pipes from cracking. This minimal consumption is not a true representation of future natural gas usage for this home.

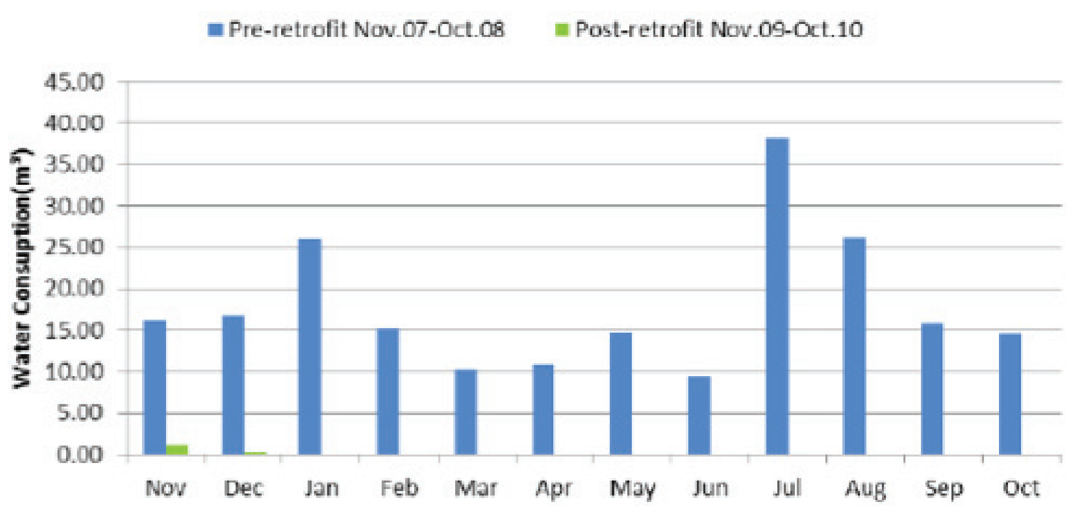
Figure 21: Natural Gas consumption for Model Three



Model three's water usage:

No water consumption evaluation can be made at this point, due to the unavailability of data. Only the pre-retrofit data is present in Figure 22, on the exception from when minor construction and cleaning was being done to prepare the demonstration displays during the months of November and part of December.

Figure 22: Water consumption for model three



Based on the fact this home was not occupied during the post retrofit phase, the home was not evaluated as to whether or not the home met the energy reduction goals. Further monitoring would be needed once the home is occupied to be able to assess its overall success.

Model 4 – 1283 Rankin Avenue:

Model four consisted of the following retrofits (please refer to Appendix 2 for further details of what was entailed for each retrofit).

- Base Model +
- High efficiency forced air gas furnace
- High efficiency central A/C
- Heat Recovery Ventilator

A summary of the general results for this model following the retrofit are illustrated in Table 18, below. Noticeable reductions in the electricity and natural gas can be seen, but an increase in water consumption was observed. This unexpected result is assumed to be a monitoring error, due to the fact that even if no behavioural changes were made by the tenants a reduction in water consumption still should have been noticed, like in the other model. Due to this, the overall saving for this retrofit are not accurate, since an addition of $7.54 from the base water utilities bills were found. The other (habited) models had a water savings value between $16 to $78 annually.

The projected results determined by the HOT2000 software, indicated an percentage energy reduction of 63% and a GHG emission reduction of 8,100KgCO_2e. These projected goals are considered to be over ambitious, due to the fact the electricity, natural gas, and water consumption prior to the retrofit were already conservative in comparison to the other models. These tenants were already aware of the importance of conserving resources, and thus had made some changes to the home, such as using energy efficient light bulbs, programmable thermostat, and energy efficient appliances. The HOT2000 software does not take into actual energy consumption for making these predictions. (This is discussed further in the discussion section). In addition it is important to note that the goals of reducing the GHG emissions by 8,100KgCO_2e, were impossible, as the home was emitting 7702.81KgCO_2e prior to the retrofit – meaning the predictions indicated an additional 397.19KgCO_2e than what was already being emitting, and this model was not aimed to achieve net-zero energy and emissions.

Table 18: Summary of results for model four

	Electrical consumption	Gas consumption	Water consumption	Total	Predicted Results
Pre-retrofit	5432.28 kWh GHG= 1401.52KgCO_2e	3312.99 m3 GHG= 6301.29KgCO_2e	165.44 m3	GHG: 7702.81KgCO_2e	
Post-retrofit	3900.40kWh	1468.86m3	193.78m3		
% Change	28.20%	55.66%	-17.13%	**41.93%**	**63%**
Cost Savings	$155.18	$589.76	-$7.54	$737.40	
GHG Reduction (KgCO_2e)	1006.30	2793.75		**3,800.05**	**8,100**

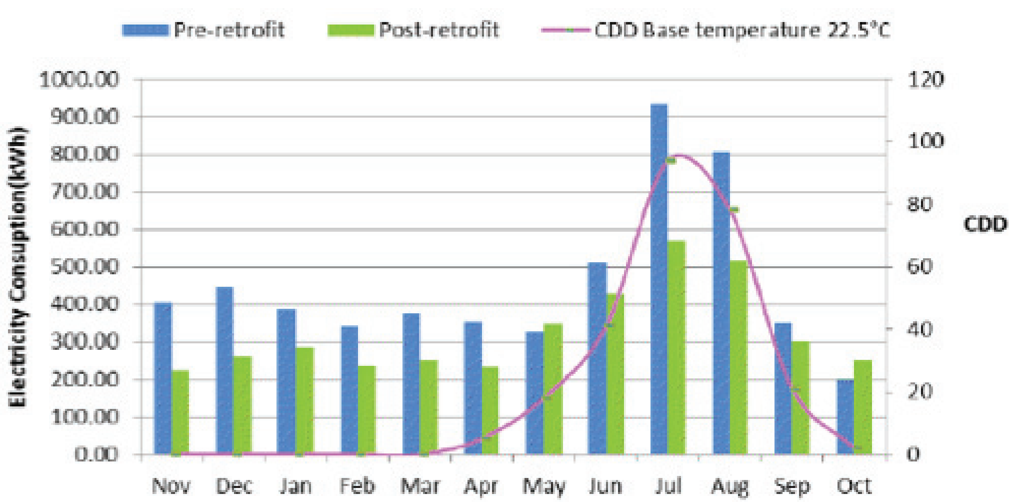
Total GHG emission following retrofit = 3,902.76 KgCO_2e

Figures 23 through 25 illustrate this homes individual electricity, natural gas, and water consumption for both pre and post retrofit.

Model fours electricity usage:

Overall a noticeable reduction in electricity can be seen (refer to Figure 23), except for the months of May and October. The occupant could not think of a reason why these months had an increase in electricity usage. In fact, the month of October is of particular interest, since the occupants were away for a week at the end of this month. Based on conversation with the tenant, one would have expected an overall greater electricity reduction since the household made conscious efforts to reduce their electricity usage; making behavioural changes, such as, turning off the bar power switch at night, powering down electronics when not in use, avoiding using the dryer whenever possible, and so on. Due to this, it is assumed that there may have been problems with the meters, whether it was not calibrated correctly, or human error when reading the results.

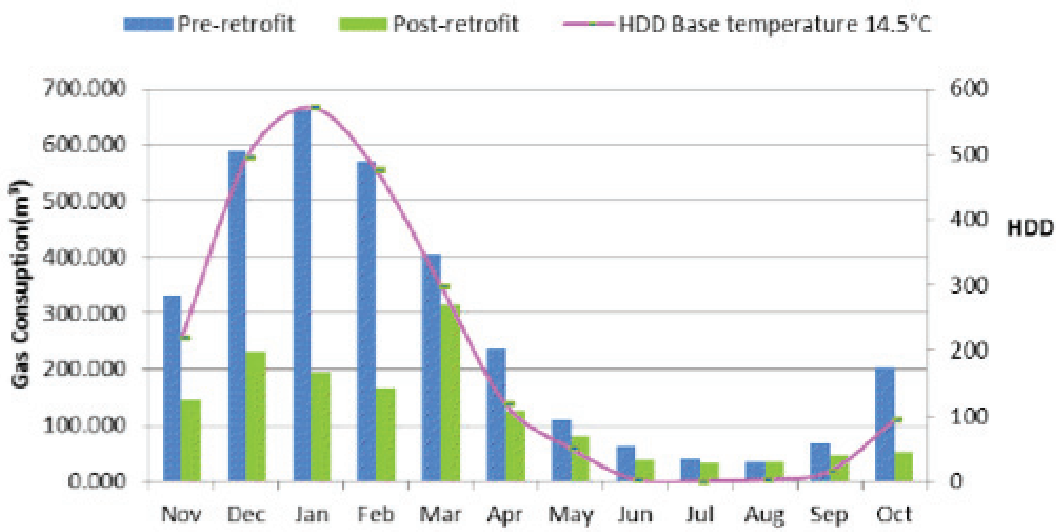
Figure 23: Electricity consumption for Model Four



Model four's natural gas consumption:

Significant reduction in natural gas was observed overall, as seen in Figure 24. An increase in natural gas consumption is seen for the month of March, however, the external temperature during this period post retrofit was colder than the pre-retrofit time period and according to the heating degree days (HDD) the natural gas consumption falls within the expected usage considering the change in weather.

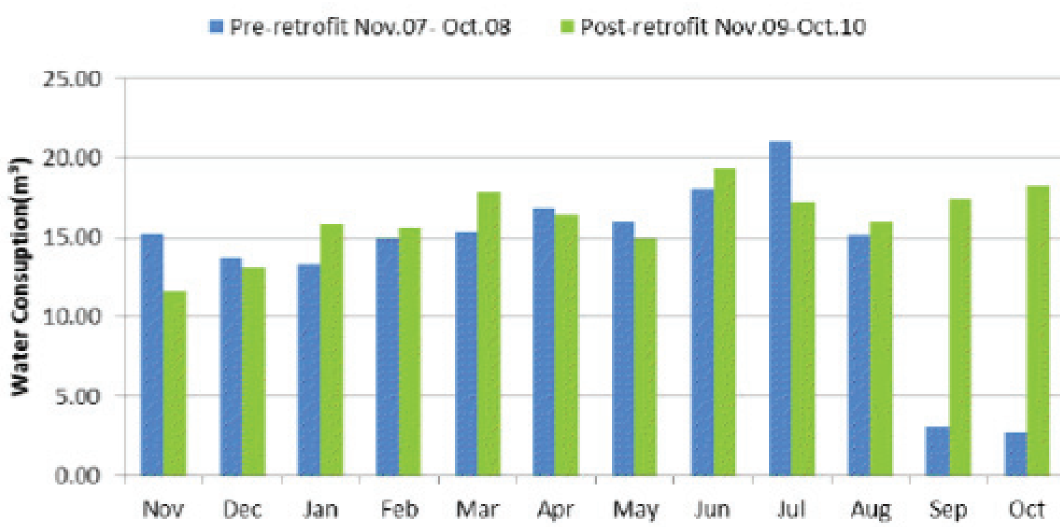
Figure 24: Natural Gas consumption for Model Four



Model four's water consumption:

The water usage results following the retrofit were not expected. There was an overall increase of 17%. Based on a conversation with the tenants, it is assumed that there was a metering problem. A decrease in water usage should have been observed, even if the occupants did not make any behavioural changes in the water usage, due to the water efficient retrofit measure made to the home (refer to Appendix 3 for details). It was discovered through surveying the head of household, that behavioural changes to conserve water were made, such as using a timer when showering to avoid spending too much time when washing, not watering the grass as frequently, doing laundry when there was a full load, and so on. The contractor was asked to check the meter, but this was not followed through.

Figure 25: Water consumption for Model Four



Although this model had an energy reduction of 41.93%, it did not achieve the desired 63% energy reduction. The estimated 8.1 tonnes of GHG emission reduction was not obtained, however this goal was not feasible, as the home was producing just over 7.7 tonnes of GHG emissions before the retrofit.

Model 5 – 1275 Rankin Avenue:

Model five consisted of the following retrofits (please refer to appendix 2 for further details of what was entailed for each retrofit).

- Base model only

A summary of the general results for this model following the retrofit are illustrated in table 19, below. This home was chosen for the base model, due to the fact it was the only brick home retrofitted – which meant there were some limitations due to the increased potential costs if some of the other retrofits had of been made with this model.

As seen in Figure 29 (page 86), model five has the highest electricity consumptions of all five models. (This is assumed to be due to the tenants normal habits and the frequent use of electronics). With the previous models, this model did not achieve the projected energy and GHG emission reductions. Despite this, the natural gas reduction, of 47.94%, is significant. If the electricity had of reduce further than the 17.39% - which could have been done if some behavioural changes to electricity usage had been made - this model could have achieved or come close to achieving the projected percentage energy reduction of 58%. The projected goals for the GHG emission reduction are considered to be ambitious, since the home was only emitting just over 10,000KgCO_2e prior to the retrofit, and this home only received the base model. Despite this model reduced its GHG emissions by 63%, which is considered significant. The home is now emitting 5533.99KgCO_2e less than it was prior to the retrofit.

Table 19: Summary of results for model five

	Electrical consumption	Gas consumption	Water consumption	Total	Predicted Results
Pre-retrofit	12557.28kWh GHG= 3239.77KgCO_2e	2912.44 m3 GHG= 5539.46KgCO_2e	229.93 m3	GHG: 8,779.23KgCO_2e	
Post-retrofit	10272.50 kWh	1516.14 m3	166.3 m3		
% Change	17.39%	47.94%	27.67%	**32.67%**	**58%**
Cost Savings	$228.55	$420.25	$16.93	$665.73	
GHG Reduction (KgCO_2e)	2650.3	2883.69		**5533.99**	**7,700**

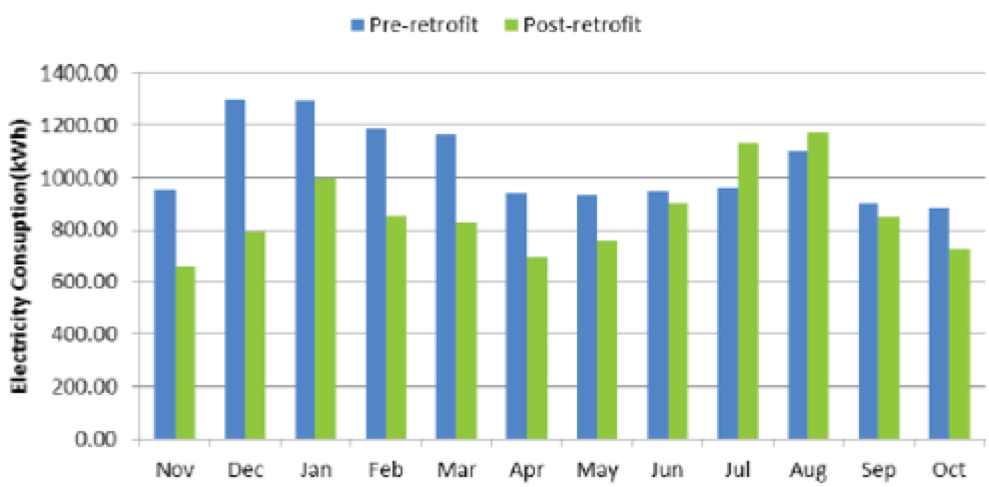
Total GHG emission after the retrofit = 3,245.24KgCO_2e

Figures 26 through 28 illustrate this models electricity, natural gas, and water consumption for before and after the retrofits.

Model five's electricity usage:

Electricity usage for model five has the highest usage of all of the models, both before and after the retrofit. This is due to the tenant's usage behaviour. It was observed during the survey process, that the occupants have a habit of leaving unused electronics on throughout the day, such as computer and television. It was also observed that the household has two full size refrigerators on the main floor of the home. The tenants did not attend any of the educational workshops provided. The increase in electricity following the retrofit for the months July and August are due to the use of three non-energy star portable air conditioners. (The occupants were asked not to use these appliances, however they stated that it was too hot and went ahead and installed them without notifying anyone). In addition, work was done in the home to the HVAC system during the month of June, also contributing to the increase in electricity usage. Despite this, there was still a reduction of just over 17% in electricity as a result of the basic retrofit model.

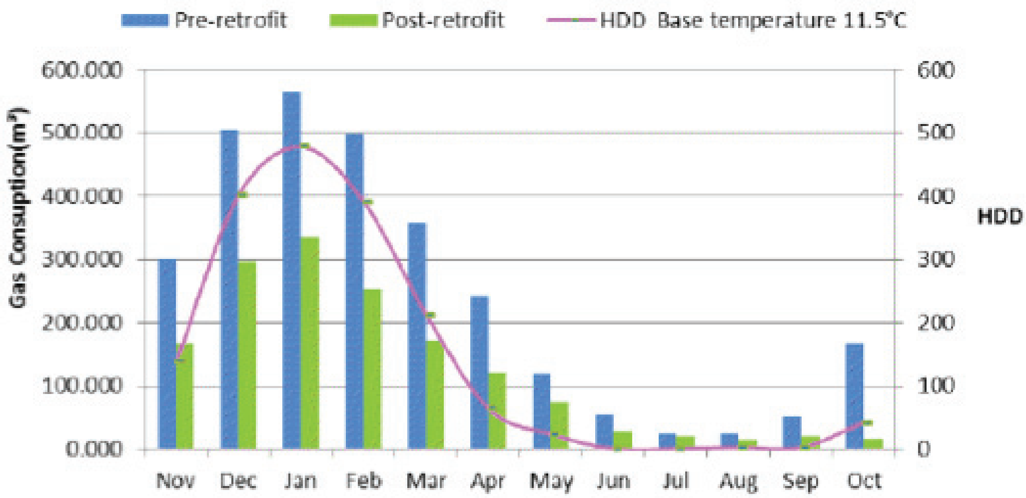
Figure 26: Electricity consumption for Model Five



Model five's natural gas usage:

Natural gas usage decreased as expected, with the exception of April and May, where it would have been anticipated that consumption would have been lower (refer to Figure 27). For the months of November through February, the natural gas consumption is lower than expected, however, it was discovered that two of the tenants were still partly living in a hotel for the month of November and then living in other accommodations through the week and only at home for the most part on weekends. The third tenant was overseas visiting family during the months of November through January. This absences could explain why for all of the utilities (electricity, natural gas, and water) consumptions are lower during these months compared to the rest of the year.

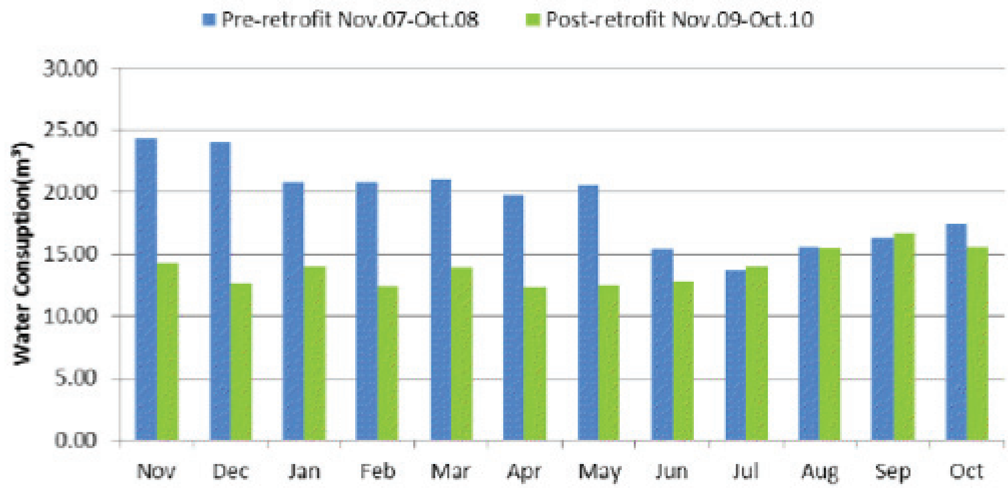
Figure 27: Natural Gas consumption for model five



Model five's water usage:

Water consumption decreased for the months November to June, however increased above the pre-retrofit usage for the months July through September. Upon surveying the tenants it was revealed that one of the occupants purchased a new car, and frequently washed all the cars during the summer months. In addition, two of the residents are students who were away for most of the summer during the pre-retrofit phase, however living within the home full-time during the post-retrofit metering period. As a result there would have been an increase in water consumption for showers and toilet usage.

Figure 28: Water consumption for model five



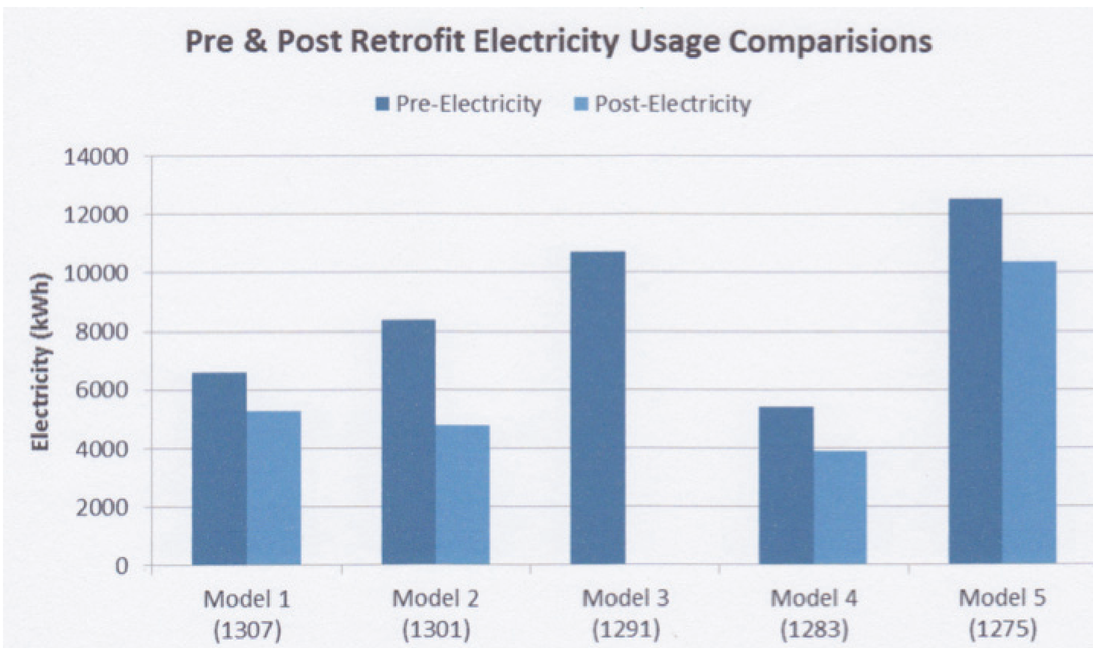
The outcome for model 5 is the same, as Models 1 through 4, where the EGH score increased after the retrofit, however, the home did not achieve its desired GHG emission reduction or percentage of energy reduction.

All of the models showed a noticeable reduction in energy and water consumption (on the exception of Model 4's water consumption), however none of the models achieved its energy or GHG emission reduction goals as projected by the HOT2000 software and home energy audits. This issue is discussed later in chapter five.

4.2 Question 2: What stage of retrofitting is most beneficial and practical when considering both financial and environmental benefits? At what point, if any, are energy efficiency retrofits no longer advantageous?

Retrofitting can be an expensive and timely undertaking. Based on the five models used for this study, it is clear to see from Figure 29 to 32, that overall model 2 showed the greatest decrease in electricity, natural gas, and water consumption.

Figure 29: Comparison of the Annual Electricity usage of all five models pre- and post-retrofit



Note: the electricity usage here illustrates what was used by the home. For those models which include solar PV, the amount which was generated and sold back to the grid is not included in these figures

Figure 30: Comparison of the Annual Natural Gas usage of all five models pre- and post-retrofit

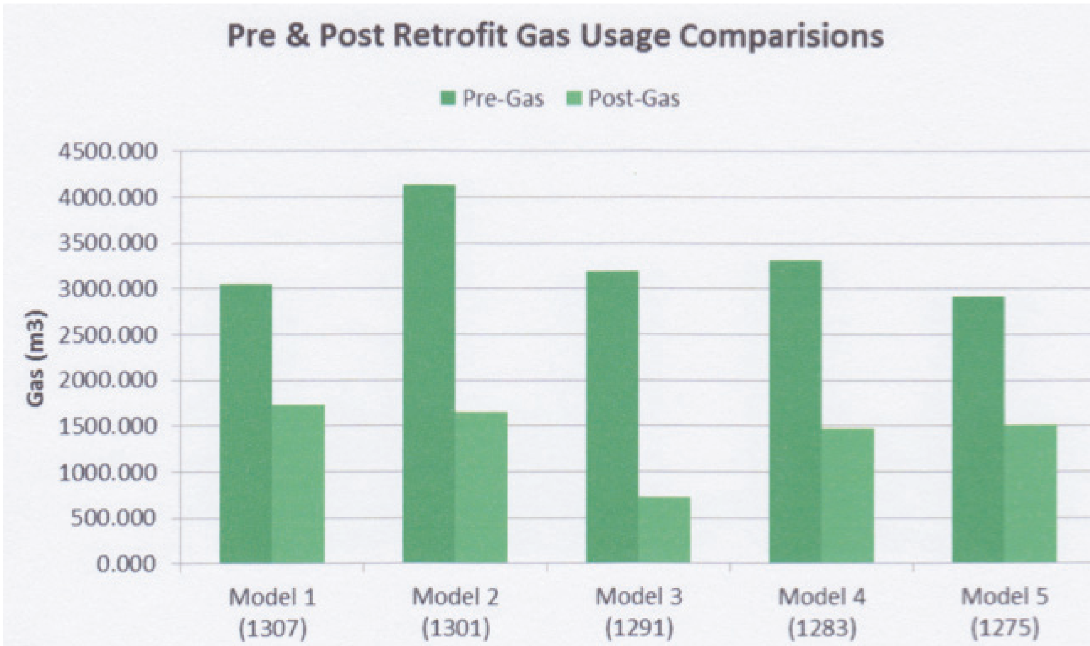
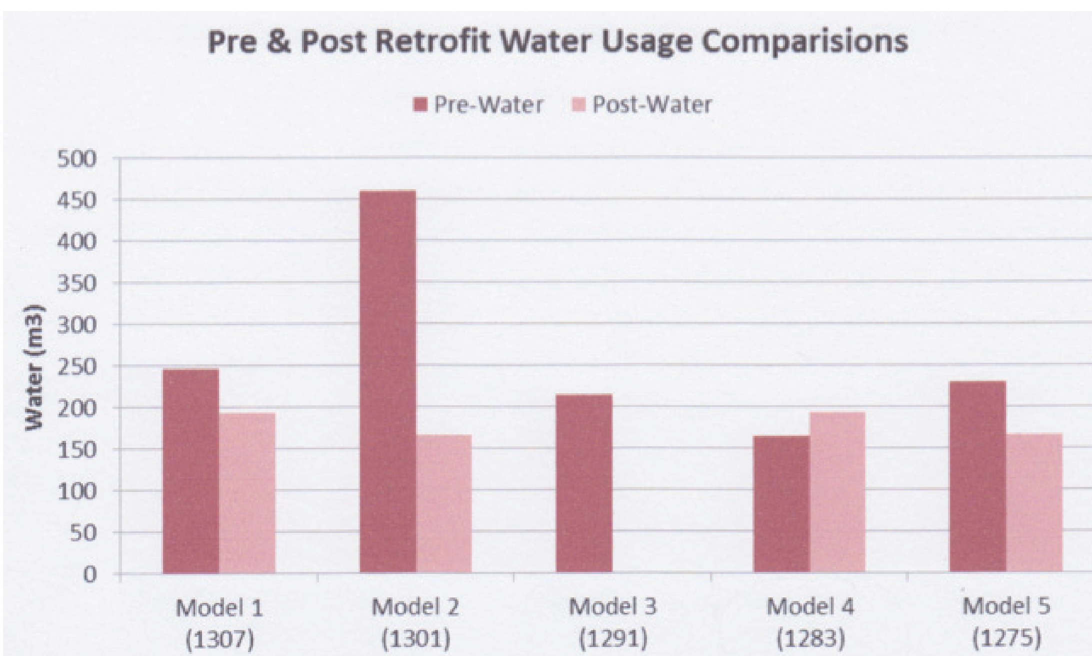


Figure 31: Comparison of the Annual water consumption of all five models pre- and post-retrofit



When considering the financial aspect of retrofitting, again model 2 has the shortest payback period, when making the following assumptions:

1. A 2% inflation rate, based on the inflation rate of the Central Bank of Canada
2. A 3% discount rates from the Treasury Board of Canada

Based on these assumptions, the payback period for each model is displayed in the table 20 below.

Table 20: Payback period for each model

Model	Cost of Retrofit	Payback Period (Years)
1	$41,686.23	150
2	$65,325.01	61
3	$81,172.41	n/a
4	$41,126.96	82
5	$31,260.23	66

It is likely that the payback period in reality will be shorter than that expressed in the table above, as the inflation rate tends to be greater than 2%. These payback periods would be reduced further in the event that energy prices increase, or if a carbon tax were to be implemented.

While considering the above information, model one was the least successful, in terms of financial costs, whereas model five had the least reduction in GHG emissions. The limited GHG emissions for model five are most likely due to the way energy is used within the home, as none of the occupants attended any of the educational workshops nor made any efforts to change their energy behaviour.

Although solar energy involves a greater up front financial cost, this study, and other studies published (Bell & Lowe, 2000; Voss 2000; Charron & Athienitis 2006; Verbruggen, 2008), clearly show that solar energy in the long term are both environmentally and financially beneficial. In Ontario, homeowners have the additional benefit of paying between $0.05-$0.10/kWh of electricity depending on time of day the electricity is used, while receiving $0.82/kWh when the extra electricity from the solar energy is put back into the grid.

4.3 Question 3: What environmental educational material(s) and promotion(s) of the Windsor 5 Project was the most effective in encouraging homeowners in making changes to conserve energy?

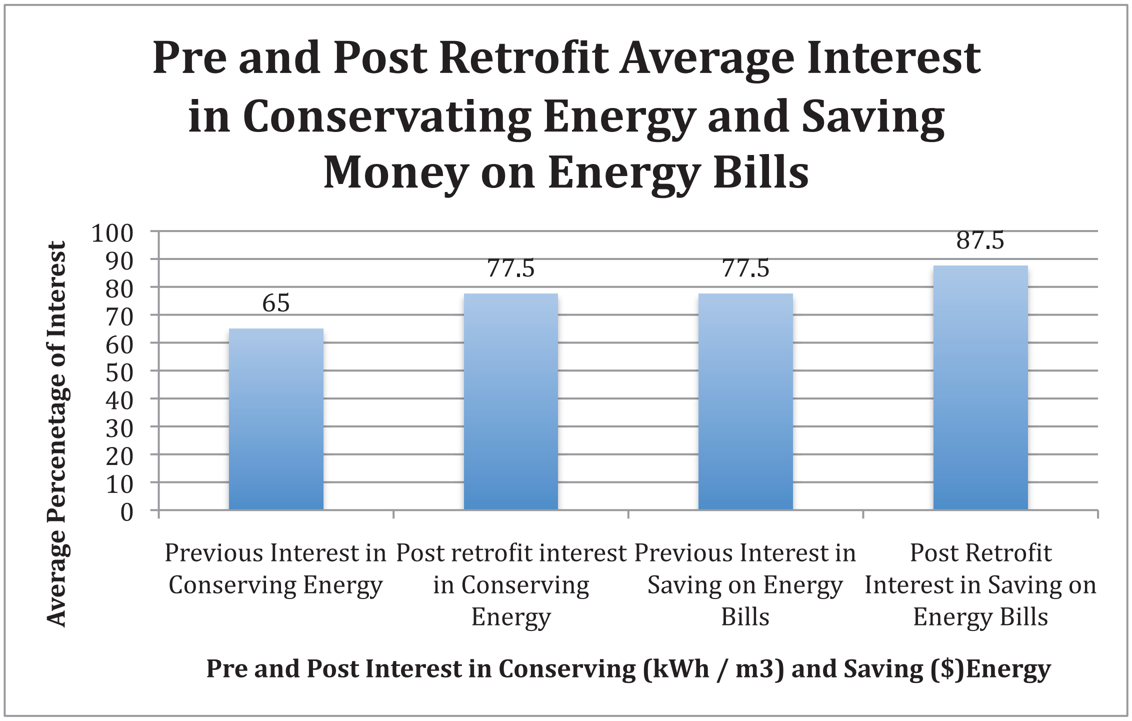
All of the "head of household" of the Windsor Five Project participants completed an energy awareness survey (found in appendix 6) covering the following sections:

1. General demographic information
2. Social related questions, used to assess interest in energy conservation both before and after the retrofit
3. Technical questions, which address any unexpected energy results to determine if changes in behaviours or other factors could have contributed to these anomalies.

The general demographics section of this survey showed that all four households surveyed have three occupants living within each of the dwellings, with fifty percent of the head of households ranging in age of 31-40 and the other fifty percent ranging in age of 41-50. The overall education level of the occupants are consistent with that found within the district of Essex, ranging between those whom had attended some high school, to a maximum education level of attending some university, but not completed a degree (City of Windsor, 2001; Table 11 and Appendix 12)

All tenants were asked what their interest was in conserving energy and saving money on their energy bills before and after the retrofit, on a scale of zero to ten – where zero is no interest at all and ten being extremely interested. The rang of response for conserving energy prior to the retrofit were between five (moderate interest) to eight (high interest), and following the retrofit the range of interest were primarily between eight to ten (extremely high interest), with the exception of model five, where they indicated no increase in interest in conserving energy following the retrofit with a response of five. In terms of the tenants interest in saving money on their energy bills before and after the retrofit the responses ranged between five to eight before the retrofit, and eight to ten, with the exception of model five who indicated a decrease interest in saving money following the retrofit with a score of seven. The results are illustrated in Figure 32, where most of the participants indicated an increased interest in both conserving energy and saving money on their energy bills following the retrofit. It is important to note however, that an increased interest in saving money on energy bills would have been expected due to the fact prior to the retrofit the tenants were not responsible for paying their own energy bills; however come the renewal of their lease they will be expected to pay their own utility costs. (This is addressed in greater detail within the Discussion section of this thesis). It is anticipate that once the tenants are officially responsible for paying their own utility bills, further efforts will be made to make behavioural changes to the way they use electricity, natural gas, and water.

Figure 32: Pre and Post retrofit interest in conserving energy and saving money



The increased interest in conserving energy following the retrofits coincides with the technical data obtained from the homes. As seen in the tables 12, all four models resulted in a fair reduction in both percentage of electricity and natural gas, not to mention achieved a greater than expected post EGH score.

The education materials and workshops used during this study were:

- Bridgeview Community Event
- Opening event for first retrofitted house
- Opening for the Now House Windsor 5 Project
- Attended 1 of the 10 open house events
- Read the resident's handbook on energy up-grades
- Attended the residents training day

(A definition / explanation of what was involved for each of these events is found in Appendix 6)

All of these events were listed above made available to the entire community, not just the tenants of these five homes. The data presented in Figure 33 is based solely on the attendance of the occupants of these homes retrofitted. Based on the survey the occupants indicated that they attended the following, as seen in table 21:

Figure 33: Attendance of the different events

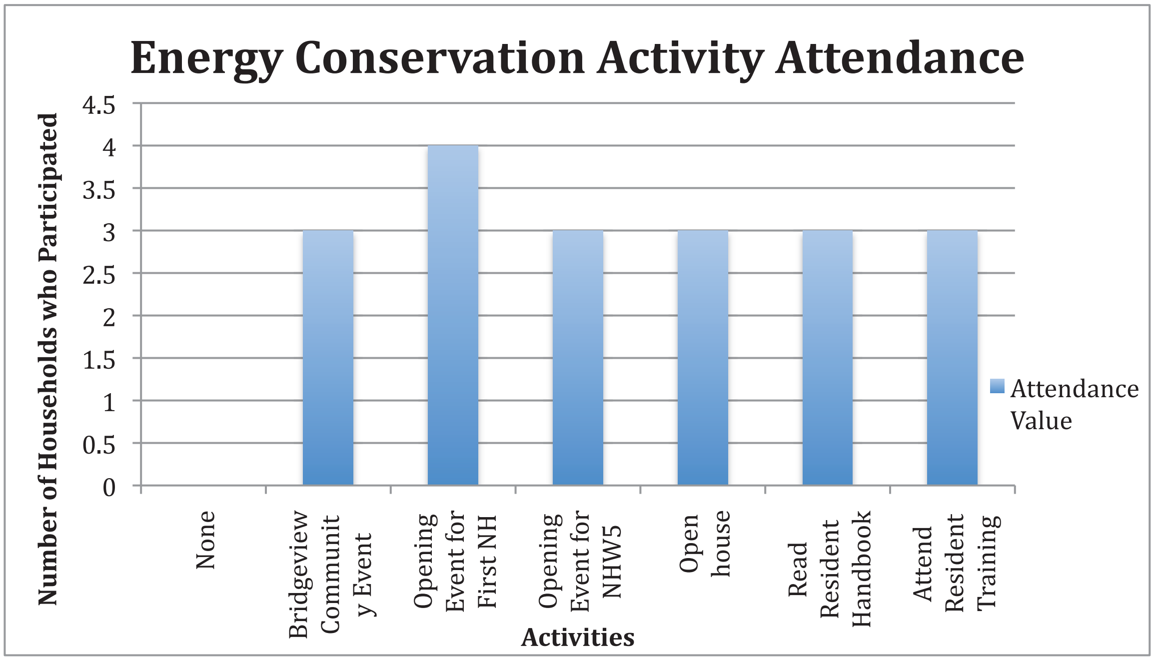
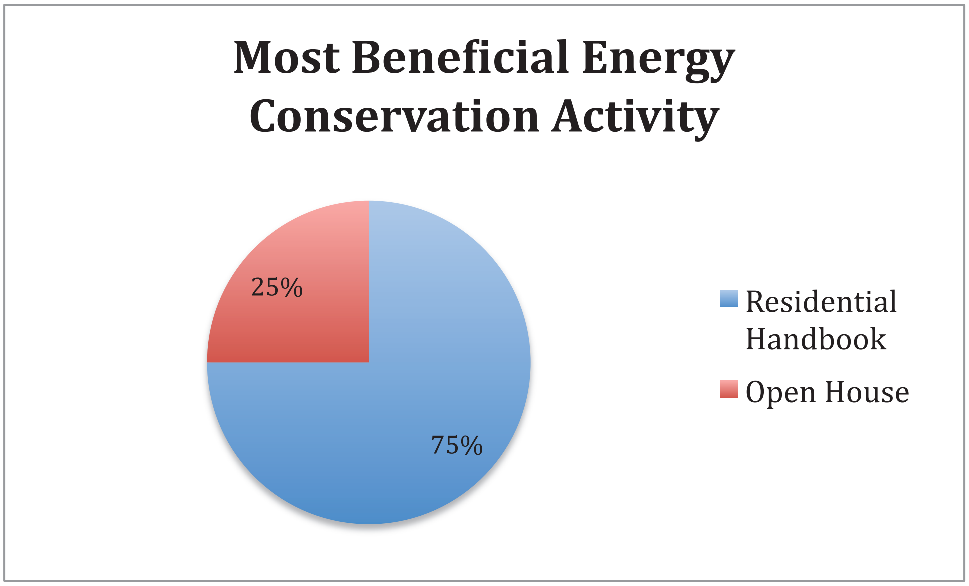


Table 21: Attendance of the different events

Activities	Model 1	Model 2	Model 4	Model 5
Bridgeview Community Event	√	√	√	
Opening Event for the First NHW5P	√	√	√	√
Opening Event for the NHW5P	√	√	√	
Open House	√	√	√	
Read Residential Handbook	√	√	√	
Attend Residential Training	√	√	√	

Of all of the events and workshops the tenants indicated the following as being the most beneficial, as seen in Figure 34.

Figure 34: Most beneficial energy conservation activity:



All of the participants indicated that all of the activities were beneficial in one form or another, with a 100% responding that there were no activities that were not found beneficial. The only real criticism was that the residential training day should have been done sooner, as the occupants had moved back into their homes for a number of months prior. As a result, a number of the occupants had a difficult time adjusting to the new gas appliances, such as the gas stove and dryer.

All of the occupants indicated some behavioural changes following the retrofit of their home, except for model five. Table 22, below, illustrates the energy conservation behaviours for each model before and after the retrofit.

Table 22: Energy Conservation Behaviours:

	MODEL 1		MODEL 2		MODEL 4		MODEL 5	
Behaviour	PRE	POST	PRE	POST	PRE	POST	PRE	POST
Turning off lights when not in room	√	√	√	√	√	√	√	√
Powering down electronics	√	√	√	√	√	√	√	√
Turning off power bar	√	√			√	√		
Hanging up laundry					√	√		
Turning off water when not in use	√	√	√	√	√	√	√	√
Setting thermostat (up in summer, down in winter)	√	√		√	√	√	√	√
Other*	√	√			√	√		

* Other behaviours:

Model 1:

Pre-retrofit = change light bulbs to energy saving ones, do washing after hours, limit shower times

Post-retrofit = use dryer less frequently

Model 4:

Pre-retrofit: change light bulbs to energy saving ones

Post-retrofit = using a timer when taking showers to prevent taking showers longer than necessary. (Timer was set for 20 minutes)

In the case of model five, the occupants indicated they turn off lights when not in the room as well as powering down electronics; however, during a home visit by a representative of the WECHC over the years and myself when conducting the survey (following the retrofit), it was observed that during bright sunny days all the main floor interior lights were left on, as well as a large flat screen T.V left on and muted and two computers on while not being used.

It is interesting to note that so little benefit was given, by the participants, to the demonstration home, due to the fact the literature tends to indicate that demonstration homes have had a large impact on encouraging people to become more energy efficient.

Chapter 5: Discussion

5.0 Discussion

The Windsor Essex Community Housing Corporation (WECHC) undertook the Now House Windsor 5 Project as a pilot project, for one of their low-income housing communities. The rental units managed by the WECHC establish the individual rents based on the household income, and all utilities were included. Caseworkers noticed a trend that majority of the tenants within these units would leave lights and electronics on at all hours of the day (including when no one was home), as well as windows open when the heat or air conditioning was running. As a result there were higher than expected utility costs. By retrofitting the homes to make them more energy efficient, the WECHC hoped to reduce energy costs, making the homes more affordable to run. Although no official changes have been made to date to the lease agreements, it is planned that when the leases are renewed, the rent will be reduced, but the occupants will be responsible for paying their own utility bills. The purpose for this is to reduce the WECHC costs while transferring some responsibility and ownership onto the tenants without jeopardizing their financial security.

5.1: Did the Now House Project Achieve its desired goals?

The goals for these retrofits had high expectations, with total energy reductions (meaning electricity and natural gas consumption combined) ranging between 58-71%, and greenhouse gas emission reductions targeted for 7.7 to 10.7 tonnes (or 7,700 to 10, 700 kgCO_2e). These targets were set by using HOT2000, which is a computer software tool designed and developed by the Canadian Federal Government. The program helps energy auditors assess energy efficiency of buildings for both pre and post construction. This tool is meant to assist in determining what impact individual changes will have to a buildings overall efficiency, to determine what improvements would be most beneficial. This tool, however, does have its limitations, and its ability to accurately predict overall energy and GHG emission reductions have come into question. Studies have indicated that there can be inflation within the predicted results ranging from 16% to 35% (Haltrecht, D and Fraser, K, Date unknown, from Scanada, 1996). According to a survey conducted by two independent engineering firms, enerQuality and Lio and Associates (March 2010), almost 20% of the certified energy auditors surveyed, indicated that the program was inaccurate when assessing energy efficiency for:

- Air conditioning;
- Drain water heat recovery systems;
- Solar hot water tanks; and
- Solar panels

In addition, modeling limitations were also expressed when determining possible energy efficiency for windows, foundation improvements, and building envelopes (enerQuality and Lio and Associates, 2010; Haltrecht, D, and Fraser, Date unknown). Questions have been raised as to whether or not the large range in inflation could be due to the level of experience and knowledge of the energy auditors (enerQuality and Lio and Associates, 2010). The requirements and training to obtain the certification requires a two-week training course, an exam, and two years experience within the building trade (specific details can be found within Appendix 10). Evidence of the varying results, potentially due to different levels of knowledge and experience, is demonstrated in the Toronto Star article, "Home Energy Audits Flawed" (2007). Four different energy auditors assessed the same home, and each came up with a different EGH score (based off of the energy audits and the auditors ability to use HOT2000 software), ranging from 37 to 46 out of 100 (refer to Appendix 3 for copy of the article). However, this study used the same individual to conduct all of the energy audits on the five homes, and the variability between the actual and predicted percentage of energy reduction varied from 11.6% to 30.64% (refer to table 22). Based on this information it would appear that the difference was due to the inaccuracies of the computer software, and other possible unknown variables rather than the auditors ability or knowledge to do his job.

Although none of the homes achieved the actual predicted energy reduction, they all lie within the possible reduction, as seen in Table 23, below:

Table 23: Percentage Difference for Predicted and Actual Energy Reduction

Model	Actual Energy Percentage change	Predicted Energy Percentage Change	Difference
1	31.36%	62%	**30.64%**
2	51.4%	63%	**11.6%**
3	57.02%	71%	**13.98%**
4	41.94%	63%	**21.06%**
5	33.07%	58%	**24.93%**

This pilot project overall is deemed as a success by the WECHC, not solely based on the outcomes of these five homes, but also due to the fact that the perceived success of this project by other agencies and private firms, which lead to the WECHC securing enough funding to make the following retrofits to the remain 195 homes with the neighbourhood:

- New insulation
- Energy efficient windows
- Energy efficient appliances
- Energy efficient furnaces

5.2 The payback

The costs of the retrofits undertaken range from approximately $31,000 to $81,000 per house and pay back periods ranging from 61 to 82 years. The up-front cost and payback period for these five models are not realistic for the average homeowner. What makes this project unique is that the homes are owned by an organization supplying low-income housing. According to Goldman and Ritschards (1985) and Carter (1997), individuals occupying low-income housing gain the most benefit from such energy efficiency projects, as their utility costs can drastically reduce. Although the tenants have yet to pay their own utility bills, they will still receive this benefit once their new leases come into effect and will then be responsible for their own energy and water consumption. Due to the fact the WECHC have owned these homes for over 20 years, and will continue to do so for the foreseen future, the investment has other additional benefits. Other than the reduced cost in utility bills (and transfer of energy costs to the tenant), the WECHC also has the potential for gaining a small income if energy use is less than that produced by the solar PV by selling back to the grid for a premium. The tenants are also given some control, by giving them a home, which is as energy efficient as possible, and if energy consumption is used responsibly, they have the opportunity of an overall reduced cost as well.

In addition, two other important factors were not included in the calculations for the payback periods. They are:

1. Ontario's fluctuating energy cost's based on time of use. Section 5.2.1. (www.ontario.ca/energyplan)
2. Higher inflation rate, which has been demonstrated based on history but not sited by the Bank of Canada. (Refer to section 5.2.2 and Figure35)

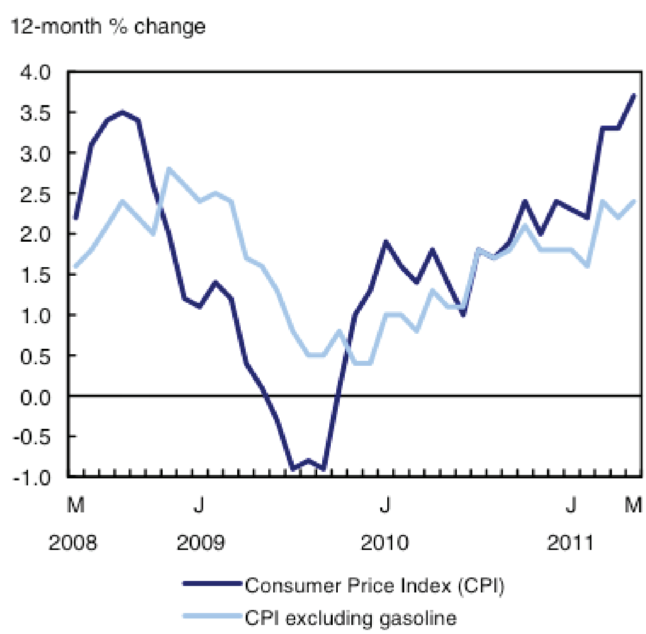
5.2.1 Time of use energy plan

As of May 1st 2011, The Ontario Government, introduced "smart meters" across Ontario, which has set different electricity costs based on the time of day during the week and weekends, based on the season (refer to Appendix 16 for copy of flyer). This program has been implemented to try and encourage people to minimize their electricity cost during demand periods. Details of this plan are found within Appendix 13. Prices for the electricity rang between 5.9 cents/kWh during "off peak-periods" and 10.7 cents/kWh during "on-peak periods". The calculations for the payback periods were calculated based on the 10.7 cents/kWh (demand period price); whereas if the homeowner were to use energy during the low demand periods (for a portion of their electricity consumption), then this would have an affect in reducing the calculated payback periods.

5.2.2 Energy inflation rates

A 2% inflation rate was used when calculating the payback periods for the retrofits. However, based on a report recently published by Statistics Canada (June 2011), energy cost rose 26.4% (excluding gasoline) within the last year alone as of April 2011, as seen in the figure below (Statistics Canada, 2011). If higher inflation rates were used, the payback periods could be reduced by any where from 16 to 40 years (if an inflation rate of 26% were applied).

Figure 35: Energy Consumer Price Index



Source: Statistics Canada, 2011. Latest release from the consumer price index (June 29th 2011)

5.3 Educational Material

In an attempt to give or provide the tenants with all the necessary tools and knowledge to reduce their energy and water consumption, educational materials and events were provided to them (refer to methodology and appendix 6 for details). With the exception of the tenants in model five – who participated solely in the opening event - everyone attended all of the events. According to the literature, demonstration homes or buildings are found to encourage people to start thinking and talking about making energy efficient improvements to their homes (Voss, 2000); however, no literature was found on whether or not people follow through with these intentions. The only study found, which somewhat addresses this issue, is the REEP study (which is examined within the literature review, pages 35-40), conducted in the region of Waterloo. Participants were asked what their willingness would be to pay a premium for "greener" energy providers. The study found that as much as 80% of participants indicated their willingness to pay as much as $25 more a month (Rowlands et al, 2003). However, when electricity was privatized in Ontario, these same participants were asked, one year after the privatization took place, whether or not they had made the switch to "greener" electricity sources. Only 0.3% had actually done so (Goodwin, 2002; Parker et al, 2003), the main reason for not following through being the idea of *'why should I pay more for the service, when those who are not paying the premium will receive the same benefit*' – commonly referred to as "free-riders" (Parker et al, 2003). Therefore, it is reasonable to assume that the same response may be true for demonstration buildings (until such time that a study is conducted to prove whether or not this is true).

For this study, occupants who attended all the events stated that although the demonstration home was “interesting”, they found the residential handbook and training day most beneficial. Tenants stating that prior to reading the handbook and receiving the training, they felt uncomfortable and unsure as to how to use the new equipment in their home. Some of the examples given include:

- The tenant who originally lived in model three prior to the retrofit requested a move to model two, since they felt the up-grades were too sophisticated and beyond their comfort level and knowledge;
- Another tenant indicated that prior to the training day they were unfamiliar with proper use of the gas stove (which was switched from an electric one), and therefore prepared their food in the microwave until they were shown how to use it; and
- More than one tenant indicated that although prior to the retrofit they knew how to program their thermostat, they were not comfortable programming the new thermostats (as it was different to what they were accustomed to) until they were taught how to use it properly.

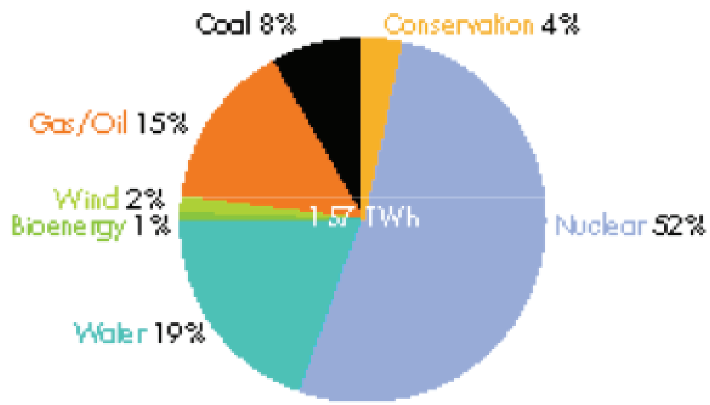
Based on the finding from this study, it is suggested that including some form of training element in future energy programs - whether they are provided by the contractors, energy auditor, or another qualified person - as part of the government grant programs may be helpful in improving the successfulness of energy conservation efforts when retrofitting.

Chapter 6: Conclusions

The residential sector is responsible for as much as 16% of Canada's greenhouse gas emissions (Natural Resources Canada, 2006). The increasing populations within Ontario alone means that there is a predicted electricity use increase of at least 15% or more as of 2030, as seen in figure 36 (Ontario Government, 2010). With concerns for the environment and goals for reducing greenhouse gas emissions, the global community is looking at different ways of reducing consumption without affecting the quality of living people are accustom to. One means of reducing the greenhouse gas emissions is by making use of more "cleaner" or "greener" energy sources. According to the Ontario Government, by 2030 it is anticipated that electricity consumption will increase by 15% (from 157 TWh in 2010 to 198 TWh). However, just over 30% of this electricity is projected to come from renewable energy sources, while an additional 14% is predicted to be saved through conservation or produced by individual homes, such using solar PV systems (totalling a projected amount 44% to be produced by "cleaner" energy sources - as seen in the figures below) (Ontario Government, 2010).

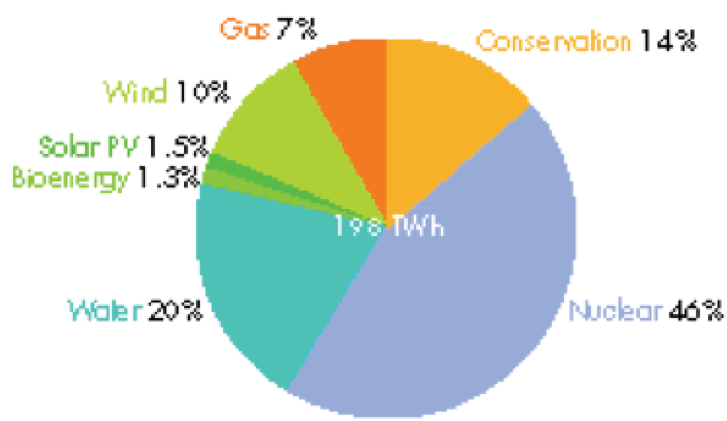
Figure 36: Comparison of Ontario's electricity sources for 2010 and projected for 2030

2010 electricity sources



Source: Ontario Government, 2010. Ontario's Long-term Energy Plan.

Projected electricity sources for 2030



Source: Ontario Government, 2010. Ontario's Long-term Energy Plan.

In order for these projected results to become a reality, in particular the 14% predicted conservation goal, retrofitting homes will play an important role. Although 40% of Canadians indicated their intention to make renovations to their home in 2008, only 5% of them were with the intention of making improvements to conserve energy (refer to Figure 1 on page 2; Statistics Canada, 2008 and CMHC, 2009). Reasons for this response was mainly due to homeowners thinking that improvements were not needed or were too costly (refer to Figure 2, on page 3; Natural Resources Canada, 2007). As a result, like many countries, Canada has designed and developed a number of different energy programs to educate and encourage homeowners to make upgrades to their homes to become more energy efficient. Overall there has been a low response to these programs, which is typically attributed to the public's lack of awareness of the benefits and of the governmental programs for financial assistance (Natural Resources Canada, 2007).

Demonstration buildings have become a popular means of communicating this message to the public. A number of studies, (including a survey conducted by the Now House Team of the demonstration home for the Now House Windsor 5 Project – refer to Appendix 14 for report) found that those who attended indicated their interest and intent of making changes to their own home; however no studies were found which illustrated how many actually followed through with their intentions. In fact, the major finding of this research discovered that although people were interested in the demonstration home, those participants who attended all of the educational events (refer to Table 20 of the results section for list) found the training day and homeowners manual most beneficial.

Occupants illustrated their lack of comfort using the new equipment or technology in their homes until such time that someone showed them how to use it effectively and explained how it works. Therefore, it is recommended that some form of training or explanation to the occupants of homes, which are retrofitted, would be greatly beneficial in order to allow for individuals to feel more confident with the use of their home while achieving the greatest benefit.

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