The Adoption of Energy Efficient Residential Building Technology in Canada: Understanding Canadian Adoption Levels

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By

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Abstract

Canadians have access to an abundance of relatively low cost energy and Canadians are very high consumers of energy. Residential energy use accounts for 16% of total energy use in Canada and is a significant contributor to GHG emissions. A typical Canadian home uses energy for space heating, domestic hot water and lights, appliances and mechanical equipment.

Many tried and proven technologies are available to reduce energy use in residential homes. The Government of Canada has implemented the EcoENERGY Program to encourage Canadians to implement these technologies. Many provinces have followed with similar matching programs. Homeowners investing in energy saving technologies through the EcoENERGY program will recognize two types of economic benefits. The first benefit is the EcoENERGY grant. This grant is a one-time payment based on the technologies that are implemented by the homeowner. The second benefit is the reduction in energy costs. This reduction in energy costs is on-going and will benefit the homeowner long in to the future.

The objective of this study is to assess the levels of adoption of these technologies and to determine the impact the grants and energy cost savings are having on adoption of the technologies.

The research was completed in three phases. The first phase was a study of adoption theory. The second phase was research on the EcoENERGY program including the technologies used in construction of energy efficient homes, the impact those technologies have on energy consumption and the federal and provincial grants available to homeowners implementing the technologies. The third phase was the analysis of a Natural Resources Canada database of over 640,000 homeowners that enrolled in the EcoENERGY program between its conception in 2006 and June 30, 2010.

The research clearly supports the argument that grants impact the level of adoption of the energy saving technologies. The research also shows that although the energy savings from the implementation of the technologies is higher than the grants, energy savings do not appear to impact the level of adoption.

Acknowledgements

This has been an incredible journey and I am proud to have worked with so many great people.

I spent 30 years as a chartered accountant and certified management consultant at Deloitte, Canada's largest professional services firm. Deloitte always has and continues to be very good to me. Over the years of working with incredibly bright people serving outstanding clients in Canada, United States and Australia, I developed the business skills necessary to complete this study. I will always be thankful for everything I learned and everyone I met at Deloitte.

The transition from being a well-paid business executive to a 'struggling' graduate student was easier than it could have been because of the unwavering support of my family. I thank my beautiful, intelligent, charming wife Gwen for never questioning the logic of my return to school. She has been and continues to be at my side every day of this journey. Our eight children, Trevor, Evan, Meghan, Cameron, Paul, David, Katy and Mark have all contributed in different ways. I am especially blessed that our twins, Katy and Mark (in their third year at the UofS) still meet me for our weekly lunch date to discuss the trials of being a university student.

Dr. Peter W.B. Phillips has been my supervisor and much more. I am always amazed at how clearly he understands what I am trying to accomplish. I admire his ability to focus in on what is important. A businessman as well as an academic, Peter encouraged me to understand green home construction far beyond what was required for this study. Peter enabled me to travel to Germany to study the adoption of energy saving building technologies in Europe. Peter encouraged me to design and build the VerEco Home, a net zero demonstration home that was on exhibit at the Western Development Museum for nearly a year. Peter is also responsible for attracting the perfect student advisory committee for this study. I want to thank Dr. Hayley Hesseln, Dr. Carey Simonson, and Dr. Robert Patrick for their contributions.

I was blessed to meet Dr. Rob Dumont very early in my work. Rob is considered the grandfather of energy efficient housing. He is well known in Canada and internationally for his contributions to the industry. Rob helped me to understand the nuances of building energy efficient homes and most importantly introduced me to many of the individuals and organizations that shaped my research. He is the source of most of what I know about energy efficient construction. I thank Rob for the countless hours spent working with me on this study.

Over the years, I have had the opportunity to work and study with a number of professors at the UofS and other distinguished schools. Dr. Josef Schmutz stands out

above the rest. He has an innate ability to transfer his knowledge to his students in a way that is fun and challenging. I thank him for that.

There were dozens of others that helped me with this study. At the risk of missing someone, I thank (in no particular order) Bryan McRae, Tom Keesey, Gordon Howell, Peter Amerongen, Martin Gaudet, Anil Perekh, Dave Spencer, Amy Hassett, Lorne Klassen, Tom Waiser, Catherine Hynes, Al Horvath, Sebastian Pfeifer, Tamara Bell, Ann Huse, Matthew Ferrier, Heiko Schroder, Ulrike Blohm, Craig Zawata, Keith Hansen, Kelly Winder, George Papadatos, Jaqueline Neusch, Chris James, Rob Norris, Eric Penner de Waal, Bob Neufeld, Jim Moorhead, Angie Budd, Paul Gatineau, Kim Greybiel, Bill Elliot, Daren Mclean, Dave Palibroda, Heather Trueman, Brent Veitch, Phil Foster, Paul Gatineau, Sterling Summach, Jeff Repski, Brian Taylor, Bruce Kell, Shelley Brown, Annette Horvath, David Klatt, Brandon Alexander, Jeff Espeleta, Jeannie Armstrong, Mark Klassen, Dianne Craig, Mike Schulte, Brian Jackson, Roger Bell, Myles Shedden, Rick Olmstead, and Jocelyn Schreimer. Everyone contributed to this study in some way.

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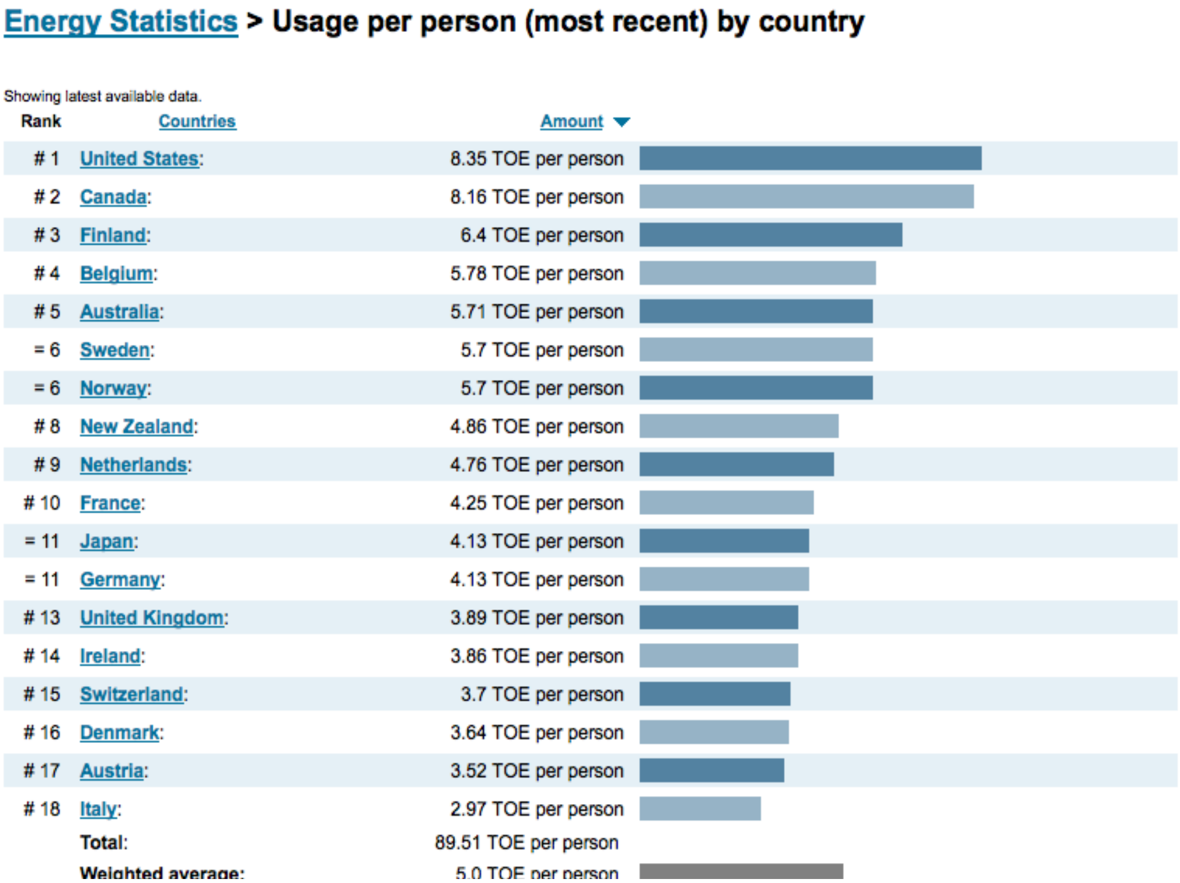
1 Introduction

1.1 Issue – Adoption of Energy Saving Building Technologies in Canada

Canadians have access to an abundant amount of relatively low cost energy. Canadians are very high consumers of Energy. Figure 1-1 shows the energy consumption of OECD countries measured in tonnes of oil equivalent (TOE) per person.



Energy Statistics > Usage per person (most recent) by country

Showing latest available data.

Rank	Countries	Amount
# 1	United States:	8.35 TOE per person
# 2	Canada:	8.16 TOE per person
# 3	Finland:	6.4 TOE per person
# 4	Belgium:	5.78 TOE per person
# 5	Australia:	5.71 TOE per person
= 6	Sweden:	5.7 TOE per person
= 6	Norway:	5.7 TOE per person
# 8	New Zealand:	4.86 TOE per person
# 9	Netherlands:	4.76 TOE per person
# 10	France:	4.25 TOE per person
= 11	Japan:	4.13 TOE per person
= 11	Germany:	4.13 TOE per person
# 13	United Kingdom:	3.89 TOE per person
# 14	Ireland:	3.86 TOE per person
# 15	Switzerland:	3.7 TOE per person
# 16	Denmark:	3.64 TOE per person
# 17	Austria:	3.52 TOE per person
# 18	Italy:	2.97 TOE per person
	Total:	89.51 TOE per person
	Weighted average:	5.0 TOE per person

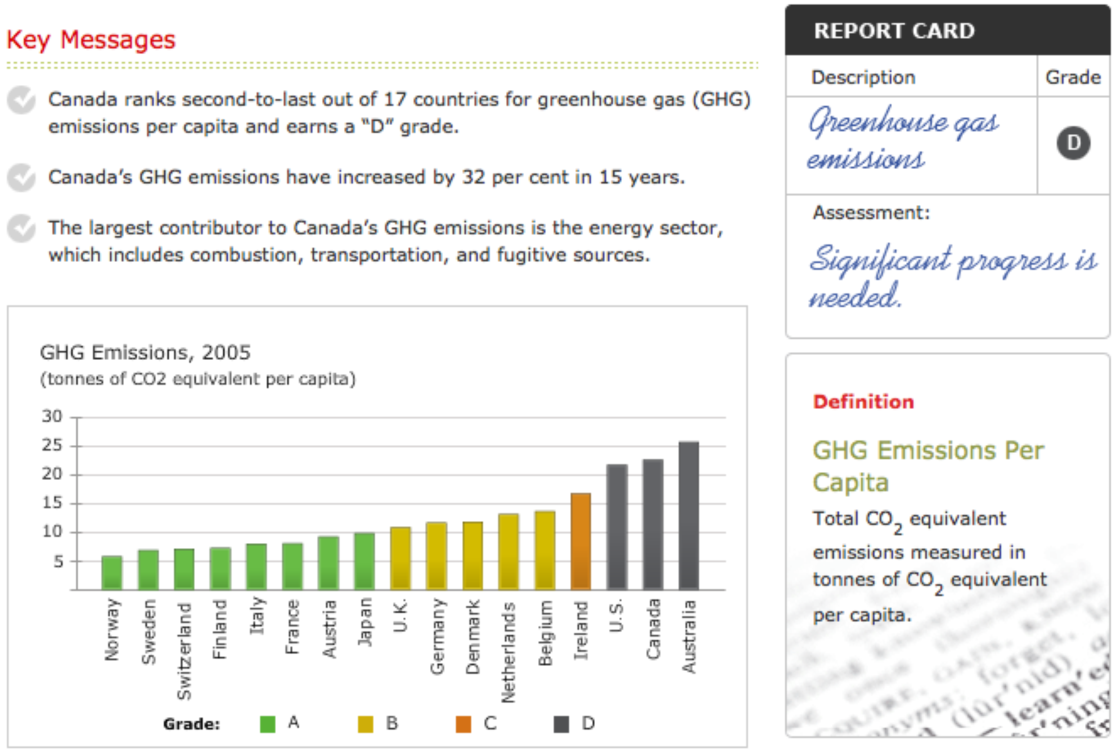
Figure 1-1 Per capita energy consumption (Nationmaster, 2010)

Energy consumption is a major contributor to Green House Gas emissions. As a result of their high energy use, Canadians fair poorly in the area of Green House Gas emissions:

> ‘Canada is one of the world’s largest GHG emitters. Canada ranks 16th out of 17

OECD countries on GHG emissions per capita and scores a "D" grade. In 2005, Canada's GHG emissions were 22.6 tonnes per capita, almost double the 17-country average of 12.4 tonnes per capita. Canada's per capita GHG emissions were also almost four times greater than Norway's, the top performer.

While Canada's GHG emissions per capita have risen since 1990, Norway managed to decrease its GHG emissions per capita by 30 per cent between 1990 and 2005.'



Key Messages

- ✓ Canada ranks second-to-last out of 17 countries for greenhouse gas (GHG) emissions per capita and earns a "D" grade.
- ✓ Canada's GHG emissions have increased by 32 per cent in 15 years.
- ✓ The largest contributor to Canada's GHG emissions is the energy sector, which includes combustion, transportation, and fugitive sources.

REPORT CARD

Description	Grade
Greenhouse gas emissions	D

Assessment:

Significant progress is needed.

Definition

GHG Emissions Per Capita

Total CO_2 equivalent emissions measured in tonnes of CO_2 equivalent per capita.

Figure 1-2 - Conference Board of Canada Scorecard on Greenhouse Gas Emissions. Source:(Conference Board of Canada, 2009)

Natural Resources Canada's Office of Energy Efficiency publishes statistics (Natural Resources Canada - Office of Energy Efficiency, 2006) on energy use in Canada. Residential energy use accounts for 16% of total energy use in Canada:

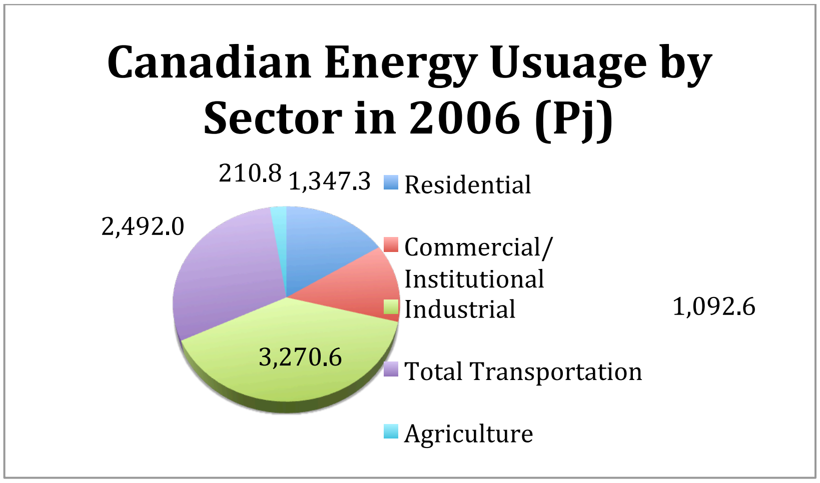


Figure 1-3 - Canadian Energy Usage by Sector (Water Footprint Network, 2009)

1.2 Canadians can reduce the energy they use

Proven and available energy saving building technologies exist today that can significantly reduce the energy consumption of every home in Canada. Although adoption is increasing, Canada falls far behind other developed nations. There are many reasons why Canadians should adopt energy saving technologies in their homes, including to reduce the impact on the environment, as part of a healthy life-style, and to lower energy costs.

Reducing impact on the environment is one of the reasons why energy reduction is important. Gases that trap heat in the atmosphere are known as green house gases (GHG). Carbon dioxide is a green house gas that traps long-wave radiation emitted from the earth's surface and creates a warming effect on the atmosphere (Smith & Smith, 2001).

Climate Change is any long term change in weather patterns. The Intergovernmental Panel on Climate Change (IPCC) was established by the United Nations Environment Program and the World Meteorological Organization to provide the world with a scientific view of climate change.

In their Nobel prize winning report 'Climate Change 2007 – Synthesis Report' (IPCC, 2007), the IPCC observed that average temperatures are warming, sea levels are rising, precipitation levels are changing and the frequency of extreme events (tropical storms) is increasing. These changes will impact:

- Agriculture, Forestry and Ecosystems,
- Water Resources,
- Human Health, and
- Industry, settlement and society.

Smith and Smith, in their text 'Ecology and Field Biology' (Smith & Smith, 2001) identify similar concerns about climate change. They identify a number of impacts on the ecology that are summarized in the following table:

Table 1-1 Impacts of Climate Change on the Ecology

Species Distribution	• Distribution of both plants and animals will be affected
Community Dynamics	• Direct influence on the growth and reproductive rates of species
Ecosystem Processes	• Decomposition proceeds faster under wetter, warmer conditions
Distribution of Ecosystems	• Global climate patterns will seriously affect the distribution and abundance of ecosystems on the earth's surface
Sea level rise and coastal environments	• Sea levels could rise 1 meter by 2100 displacing 100s of millions of people
Agricultural Production	• Changes in the environment will directly influence the sustainability and productivity of many plant species
Human Health	• Direct effects include increase heat stress, asthma and other respiratory ailments • Indirect effects include increased incidence of communicable disease, natural disasters, changes in diet and nutrition

The adoption of energy saving building technologies will reduce green house gas emissions and climate change.

Another reason to reduce energy consumption is that it is becoming a lifestyle choice. In their study 'Measuring the Market for Green Residential Development' (Robert, Charles, Lessor and Co., 2008), Robert, Charles, Lessor and Co (RCLCO) identifies three motivations that drive demand for green homes:

1. the environment,
2. energy savings, and
3. health benefits.

Homeowners focused on lifestyle (health benefits) are concerned more with health and wellness and less concerned with the return on investment of green technologies. RCLCO found this group to be better educated, have higher incomes and to have a stronger tendency to invest in health and wellness with no expectation of financial return.

The third reason to reduce energy consumption is to reduce energy costs. The design and construction of a home will determine how much energy will be consumed over the life of the home. There are a number of technologies readily available that can significantly reduce the energy consumption in a home. The introduction of these technologies will reduce annual energy costs for the life of the home.

These technologies are available for new home construction as well as for retrofits. At the time of writing, federal and provincial governments programs were focused on retrofits through the EcoENERGY program.

1.3 EcoENERGY Program

In 2005, the government of Canada implemented what is now known as the EcoENERGY Housing Retrofit program to help property owners make home retrofit choices that improve the comfort and energy efficiency of their homes. The program was based on economic incentives (grants) for property owners that invested in energy saving technologies.

The EcoENERGY Housing Retrofit program was available to Canadian property owners and involved several steps:

1. The homeowner would contact a licensed service organization to book a pre-retrofit evaluation ("D" audit).
2. The service organization would visit the house and complete the evaluation. The evaluation would explain to the owner how certain upgrades or new equipment would reduce energy and/or water consumption. The evaluation would use HOT2000 (CanmetENERGY has developed HOT2000, a building energy simulation tool that is currently used for EcoENERGY Housing Retrofit Program and is the basis for government policy work in energy efficiency in Canadian housing.) to estimate current energy consumption and forecast energy reductions and cost savings from the implementation of the proposed technologies. The evaluation also provided information on eligible federal and provincial grants for each recommended technology adopted by the homeowner.
3. The homeowner had one year to complete the implementation of the recommended technologies.
4. A post-retrofit evaluation ("E" audit) was completed to qualify for a grant. The

post retrofit evaluation would use HOT2000 to estimate energy consumption and related costs as a result of the adoption of the new technologies.

5. The service organization would submit the file to Natural Resources Canada and the homeowner would receive the appropriate grant.

Hundreds of thousands of Canadian property owners have taken advantage of this program. Natural Resources Canada (NRCan) provided a database of nearly 1 million records (635,000 "D" audits and 345,000 "E" audits). This comprehensive database is used in this study.

1.4 What Motivates This Study?

It is clear that Canadians use more than our share of energy. We also understand that a significant amount of this energy is used in our homes. We now have the technologies to reduce (potentially eliminate) the energy used in our homes. Our governments have chosen to provide an economic incentive in the form of the EcoENERGY program to encourage homeowners to invest in these technologies. Yet, only a small percentage of Canadian homeowners have implemented the technologies.

This study is a result of a personal interest: Is the EcoENERGY program impacting adoption of these energy saving technologies? Are the energy savings resulting from adoption sufficient to encourage adoption?

1.5 Objective and Research Questions

The objective of this study is to determine the impact of economic incentives on the adoption of energy saving building technologies such as those included in the EcoENERGY Housing Retrofit program.

The research questions for this thesis include:

1. What is the impact of economics on enrollment in the EcoENERGY Program?
    - .1 Will the provinces with higher grants achieve a higher level of enrollment in the program?
    - .2 Will provinces with higher energy costs achieve higher levels of enrollment in the program?
2. What is the impact of economics on the adoption of energy saving building technologies?
    - .1 Will homeowners being offered higher grants have higher levels of

adoption?

.2 Will homeowners with higher potential energy savings have higher levels of adoption?

The research questions lead to a number of testable hypotheses:

Table 1-2 Testable Hypothesis

Ho$_1$	Provinces with higher grants will achieve a higher level of enrollment in the EcoENERGY program.
Ho$_2$	Provinces with higher energy costs will achieve higher levels of enrollment in the EcoENERGY program.
Ho$_3$	Homeowners being offered higher grants will have higher levels of adoption of energy saving building technologies.
Ho$_4$	Homeowners with higher potential energy savings will have higher levels of adoption of energy saving building technologies.

1.6 Methodology

This research will be divided into three distinct phases:

1. A study of the theory of adoption.
2. Review of the EcoENERGY program and the attributes of energy saving building technologies.
3. Analysis of impact of economics on adoption of energy saving building technologies in Canada related to the EcoENERGY program:
    - Provincial and federal grants.
    - Energy cost savings.

The first phase is a study of adoption theory. This study examines a number of methodologies. A literature review was completed on technology adoption in other fields. A field trip to Europe reviewed the adoption of the PassivHaus (PassivHaus Institute) building standard in Germany.

The second phase of the study involves review of the EcoENERGY program and attributes of the green construction technologies included in the program:

- Heating systems (includes geothermal system)
- Cooling systems
- Ventilation systems
- Domestic hot water equipment
- Building envelope
    - Ceiling insulation
    - Exterior Wall insulation
    - Exposed floor insulation
    - Basement insulation
    - Basement header insulation
    - Crawl space insulation
    - Air sealing
- Windows/Doors/Skylights
- Water conservation

This phase includes a number of different types of research. A literature review was completed on each of the technologies. This review focused primarily on the research completed by Canada Mortage and Housing Corporation, articles in trade publications and information from various manufacturers.

A number of field trips were completed to observe the practical application of the green housing technologies. The field trips focused on demonstration homes built as part of CMHC's EQuillibrium project (Canada Mortgage and Housing Corporation) and other similar projects.

In the third phase, a statistical analysis of the NRCan database was completed to determine the impact of economic impact (government grants and energy cost savings) on the adoption of energy saving building technologies in Canada. Data from Natural Resources Canada's EcoENERGY program is used. The EcoENERGY Housing Retrofit program provided two types of economic benefits to Canadian homeowners.

The first economic benefit was a grant directly related to the technology that was implemented. The federal portion of the grant was the same across Canada but each province matched the federal grant in various ways. For instance, Ontario provided a matched payment equivalent to 100% of the federal grant where Saskatchewan matched 80% and Manitoba did not contribute at all.

The second economic benefit available to the homeowner was the ongoing cost savings from reduced energy consumption. This would also vary by region because of different energy costs and the availability of different energy types (i.e. Newfoundland does not have natural gas).

As the homeowners in different provinces received significantly different grants and realized significantly different energy cost savings, the levels of enrollment and adoption were measured to determine the impact of these economic benefits on adoption.

A range of methodologies was used to examine each of the research questions as follows:

Table 1-3 Summary of Research Questions

Research Question	Methodology
1. What influences adoption of new technologies?	• Literature review • Field trip
2. What is the EcoENERGY Home Retrofit program and what are the attributes of energy saving building technologies in Canada	• Literature review • Field trips
3. What is the impact of economics on enrollment in the EcoENERGY Program? a. Will the provinces with higher grants achieve a higher level of enrollment in the Program	• analysis of the percentage of total households in each province that enrolled in the EcoENERGY program in relation to the size of grants available
b. Will provinces with higher energy costs achieve higher levels of enrollment in the program?	• analysis of the percentage of total households in each province that enrolled in the EcoENERGY program in relation to the energy costs

Research Question	Methodology
4. What is the impact of economics on the adoption of energy saving building technologies? a. Will homeowners being offered higher grants have higher levels of adoption?	- Analysis of the levels of adoption relative to size of grants available to homeowners enrolled in the EcoENERGY program
b. Will homeowners with higher potential energy savings have higher levels of adoption?	- Analysis of the levels of adoption relative to energy costs for homeowners enrolled in the EcoENERGY Program

1.7 Organization of the thesis

This thesis is organized into five distinct chapters:

1. Introduction
2. Adoption Theory
3. The EcoENERGY Program
4. The impact of economic incentives on the adoption of energy saving building technologies
5. Conclusions

2 Adoption Theory

2.1 Introduction

There are a number of theories on the adoption of new technologies. Although the EcoENERGY program focuses on economic benefits through a grant and the energy cost savings related to implementation of new technologies, it is important to understand that other attributes may also impact adoption levels.

Everett Rogers, in his book 'Diffusion of Innovations' (Rogers, 2003) develops a model for the adoption of new technologies. Geoffrey Moore's 'Crossing the Chasm' (Moore, 2002) adds the concept of a 'chasm' to Rogers' model.

2.2 Rogers' Diffusion of Innovations model

Rogers (2003), defines diffusion as 'the process by which an innovation is communicated through certain channels over time among the members of a social system'.

An **innovation** can be an idea, practice or object that is perceived as new by an individual or group. Innovations are typically related to new technology.

Rogers identifies a number of attributes that are important in determining how quickly an innovation will be adopted:

1. **Relative advantage –** is the advantage the innovation has over the status quo. This can include economic, social prestige, convenience and satisfaction.
2. **Compatibility –** how compatible is the innovation with existing values, past experiences and needs.
3. **Complexity –** the level of difficulty to understand and use the innovation.
4. **Trialability –** the degree to which an innovation may be experimented with on a limited basis.
5. **Observability –** the degree to which the results of an innovation are visible to others.
6. **Communication strategy -** Rogers defines **communication** as the process by which participants create and share information to come to a common understanding about an innovation. A **communication channel** is the means by which messages move between individuals. There are two basic types of communications channels. **Mass media channels** access a large number of participants with a single message. **Individual channels** are one-to-one communications between participants. Rogers found that individuals do not evaluate an innovation on the basis of scientific studies but depend on the subjective evaluation of other individuals like themselves who have already

adopted the innovation. This implies that individual channels are much more important than mass channels in bringing a new innovation to market.

7. **Group Characteristics** - Individuals typically adopt new innovation gradually over time. The individual will go through a five-stage innovation-decision process:

   - **Knowledge** – when the individual first becomes aware of the existence of the innovation,
   - **Persuasion –** where the individual develops an attitude (positive or negative) about the innovation,
   - **Decision –** the process where an individual chooses to adopt or reject the innovation,
   - **Implementation** – where the innovation is put to use, and
   - **Confirmation –** where the individual seeks reinforcement that the correct decision was made.

   Adoption typically starts slowly, speeds up over time and then slows as saturation is reached.

   These trends are most easily understood when represented graphically. Rogers uses two types of curves to show adoption trends. The S-curve shows cumulative adoption. Incremental adoption is represented by a bell curve. Rogers uses both formats interchangeably. Figure 7 shows a number of examples of s-shaped curves showing cumulative adoption. Figure 8 shows an example of a bell curve representing incremental adoption. The incremental adoption curve also identifies the different social systems. Rogers uses standard deviations from the mean to approximate the size of the various social groups. Figure 9 shows the relationship between the two curves.

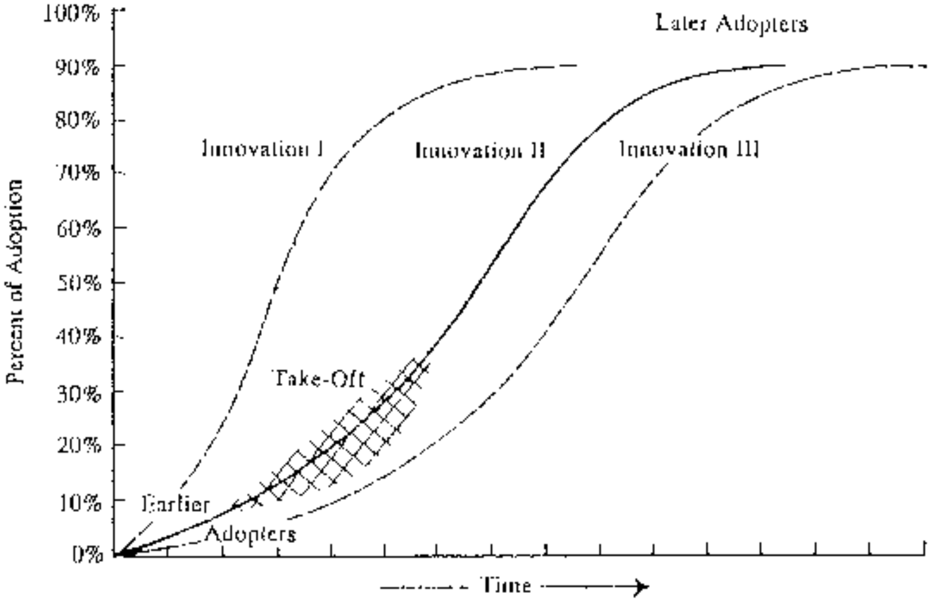
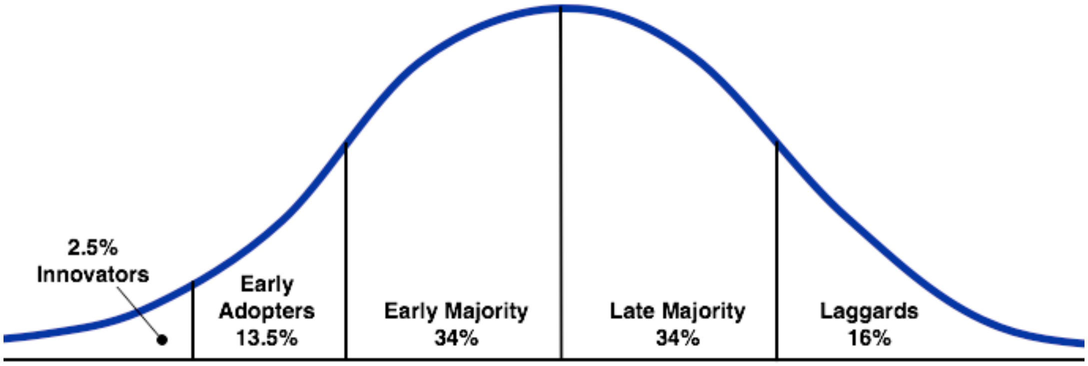


Figure 2-2-1 Roger's diffusion of innovation theory (Rogers, 2003)



Source: Everett Rogers *Diffusion of innovations model*

Figure 2-2-2 Rogers Diffusion of Innovation (Rogers, 2003) shown incrementally - In this diagram, Rogers also introduces the various key groups of adopters

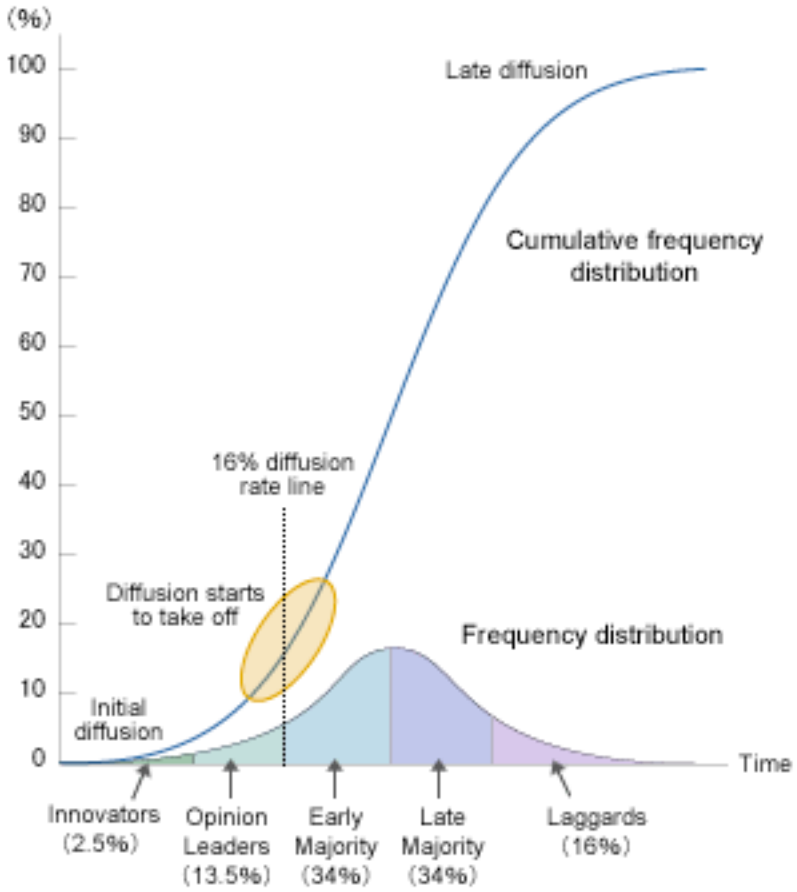


Figure 2-2-3 The relationship between the S-curve (cumulative adoption) and the bell curve (incremental adoption) (Rogers, 2003)

Rogers uses the term **Social System** to define the individuals, informal groups, or organizations seeking to solve a common problem to reach a mutual goal. The rate of adoption of an innovation will be affected by many of the attributes of the social system.

Rogers identifies five categories of adopters based on how quickly they will adopt the innovation. **Innovators** (two or more standard deviations before the mean adopter) are the first category to adopt a new innovation. They are venturesome and willing to take a risk. They often adopt for the sake of adventure and may not be respected by the rest of the social system.

The second category is **Early Adopters** (defined as those adopting between one and two standard deviations earlier than the mean adopter). They are typically more integrated into the social system and make a much more informed decision about adoption. Early adopters serve as a role model for other adopters and play a critical role in the successful diffusion of any innovation.

The **Early Majority** involves those adopting up to one standard deviation earlier than the mean adopter). They have a much longer innovation-decision process. They interact frequently with other individuals in the social system but they are seldom decision leaders.

The fourth category is the **Late Majority**, adopting up to one standard deviation after the mean adopter**.** They are typically driven by an economic necessity and the result of increasing peer pressure. They have relatively scarce resources and any uncertainty about a new idea must be removed before they are willing to adopt.

The fifth category is **Late Adopters**, adopting between one and two standard deviations after the mean adopter. These very skeptical individuals will adopt when it is an economic necessity and/or as a result of peer pressure.

The final category is **Laggards**, individuals that will resist adoption until the very end. This small group of users adopts more than two standard deviations after the mean.

2.3 The influence of Attributes of New Technologies on Their Adoption

In my paper 'The Influence of Attributes of New Technology on Their Adoption' (Lepage, 2010) I study adoption of new technologies in the fields of geography, mechanical engineering, fire prevention and PassivHaus standards.

In that study, a literature review was completed to determine the impact of various attributes on adoption of the technologies. Twenty different articles were reviewed:

- Eight publications were selected related to adoption of new technologies in one or all of:
    - Watershed planning and management.
    - Source water protection.
    - Collaborative planning.
    - Sustainable land use.
    - Integrated water resource management.
- Five publications were selected related to the adoption of Heating Ventilation and Air Conditioning technologies.
- Seven publications were selected related to the adoption of fire prevention technologies.

In addition, the writer conducted a field trip to study the adoption of PassivHaus residential construction standard in Europe.

Each publication was reviewed to determine which attributes had the highest impact on adoption of technologies. The attributes were given a relative weighting of:

0 – no impact – the attribute had no impact on the adoption decision
1 – low impact – the attribute had a small impact on the adoption decision
2 – medium impact – the attribute had a significant impact on the adoption decision
3 – high impact – the attribute had a large impact on the adoption decision.

The total scores in each area are summarized in the following table:

Table 2-1 Impact of Various Attributes on the Adoption of Technologies

Attribute (see definitions in section 2.2 above)	Geography	Mechanical Engineering	Fire Prevention	PassivHaus Standard	Total
1) Relative advantage					
. Economic	10	11	10	10	41
. Social prestige	10	3	10	4	27
. Convenience	4	0	2	0	6
. Satisfaction	9	1	16	8	34
2) Compatibility	0	1	7	8	16
3) Complexity	0	1	0	0	1
4) Trialability	0	2	0	0	2
5) Observability	0	1	0	0	1
6)Communication strategy	2	1	3	0	6
7) Group Characteristics	3	1	1	6	11

The literature review concludes that relative advantage is the most significant attribute with economics (total score 41), satisfaction (34) and social prestige (27) scoring the highest.

2.4 Modifications to Rogers' model based on 'Crossing the Chasm' by

Geoffrey Moore

> " Every truly innovative high-tech product starts out as a fad – sometimes with no known market value or purpose with "great properties" that generate a lot of enthusiasm within an "in crowd." That's the early market. Then comes a period during which the rest of the world watches to see if anything can be made of this; that is the chasm. If in fact something does come out of it – if the value proposition is discovered that can be predictably delivered to a targetable set of customers at a reasonable price – than a mainstream market forms…"(Moore, 2002)

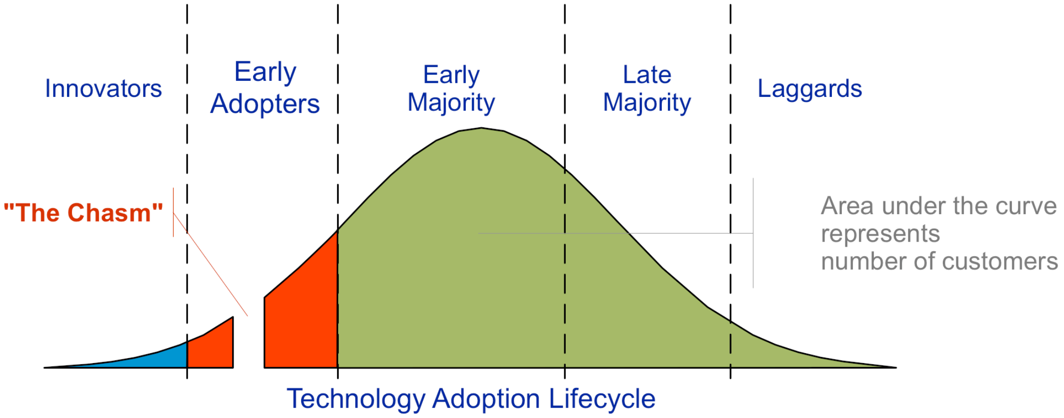


Figure 2-2-4 [From Wikipedia] - Moore's adaptation of Roger's Diffusion of Innovations theory

In those few lines, Moore clearly defines a very important addition to Rogers' diffusion adoption theory.

Moore adds the concept of a chasm to the theory. This is an important consideration in terms of the significant investment being made in the EcoENERGY program by the federal and provincial governments. Based on Moore's theory, the government would want to continue with the grant program until the market has 'crossed the chasm' which is approximately 13% of homeowners. At June of 2010, approximately 3% (see table 4-11) of homeowners had adopted through the EcoENERGY program.

2.5 Conclusion

Rogers identifies a number of attributes that impact the adoption of new technologies. Our analysis shows that the most significant of those attributes is relative advantage. Economics is the most important relative advantage followed by satisfaction and social prestige.

Our federal and provincial governments have selected an economic incentive (the

EcoENERGY grant) as their strategy to encourage adoption and this would appear to agree with the theories presented by Moore.

In the following section, we further analyze the impact of two types of economic benefits on the adoption of energy saving technologies in residential housing.

3 The EcoENERGY Program

3.1 Introduction

A number of technologies are available to reduce energy consumption and Green House Gas emissions from residential housing.

In Canada, homeowners investing in energy saving technologies will recognize two types of economic benefits:

- Government incentive – the owner will receive a one-time grant for the installation of qualified technologies. During the period of the study, the grant had a federal and a provincial component. The federal component is consistent across the country. The Provincial component varies by province.
- Energy Savings – the owner will save energy costs that will continue over the life of that technology. Because energy costs vary from province to province, the amount of savings will vary by province.

Section 3.2 presents the EcoENERGY grant available to homeowners in Canada. Section 3.3 provides information on the energy savings from a sample of the technologies.

3.2 The EcoENERGY Program

In 2005, the government of Canada implemented the EcoENERGY program to help property owners make home retrofit choices that improve the comfort and energy efficiency of their homes. The program was based on economic incentives (grants) for property owners that invested in energy saving technologies.

CanmetENERGY has developed HOT2000, a building energy simulation tool that is currently used for the EcoENERGY program, the EnerGuide New Housing Program and is the basis for government policy work in energy efficiency in Canadian housing.

HOT2000 is used in the EcoENERGY program. The EcoENERGY Housing Retrofit program was available to Canadian property owners and involved several steps:

1. The homeowner would contact a licensed service organization to book a pre-retrofit evaluation ("D" audit).
2. The service organization would visit the house and complete the evaluation. The evaluation would explain to the owner how certain upgrades or new equipment would reduce energy and/or water consumption. The evaluation would use HOT2000 to estimate current energy consumption and forecast energy reductions and cost savings from the implementation of the proposed technologies. The evaluation also provided information on eligible federal and provincial grants for each recommended technology adopted by the homeowner.
3. The homeowner had one year to complete the implementation of the

recommended technologies.

4. A post-retrofit evaluation ("E" audit) was completed to qualify for a grant. The post retrofit evaluation would use HOT2000 to estimate energy consumption and/or water consumption and related costs as a result of the adoption of the new technologies.
5. The service organization would submit the file to Natural Resources Canada and the homeowner would receive the appropriate grant.

Hundreds of thousands of Canadian property owners have taken advantage of this program.

The EcoENERGY program does not provide grants for all energy saving technologies. The Federal program included grants for the following technologies:

- Heating systems (includes geothermal system)
- Cooling systems
- Ventilation systems
- Domestic hot water equipment
- Building envelope
    - Ceiling insulation
    - Exterior Wall insulation
    - Exposed floor insulation
    - Basement insulation
    - Basement header insulation
    - Crawl space insulation
    - Air sealing
- Windows/Doors/Skylights
- Water conservation

Appendix D provides detailed information on the energy saving technologies commonly used in energy efficient home construction and retrofit. Most but not all of these technologies are included in the EcoENERGY program

Many of the provinces and territories have similar matching programs. Some provinces such as Ontario matched 100% of the Federal program with small adjustments so if the Federal program resulted in a grant of $1000, the Ontario program contributed an additional $1000. Other provinces contributed in different ways. For instance, Saskatchewan and Alberta matched the Federal program but at a lower percentage. Nova Scotia made more significant changes to the program to reflect the significant differences related to their lack of natural gas. Some provinces such as Manitoba did nothing.

The following table outlines a sample of technologies for which the grants were available and the amount of the federal grant and the provincial grant in Saskatchewan, Ontario, Alberta and Manitoba. A full list of the technologies included in the grant is included in Appendix B.

Table 3-1 Sample of Provincial and Federal EcoENERGY Grants

Eligible Improvement/Retrofits	**Federal Grant**	**Sask**	**Ont**	**Alta**	**Man**
HEATING SYSTEM					
Replace your heating system with an ENERGY STAR® qualified gas furnace that has a 92.0 percent annual fuel utilization efficiency (AFUE) or higher	$375	$300	$375	$400	NA
COOLING SYSTEM (Replacement Only)					
Replace your central air-conditioning system with an ENERGY STAR qualified system that has a SEER of 14.5 or higher (complete system replacement, including indoor coil and outdoor components).	$375	$75	$375	NA	NA
VENTILATION SYSTEM (New installation or replacement)					
Install a ventilation system that is certified by the Home Ventilating	$375	$300	$375	NA	NA
DOMESTIC HOT WATER EQUIPMENT					
Install a solar domestic hot water system that includes solar collectors that meet the CAN/CSA F378.87 standard **AND** that provides a minimum energy contribution of 6 gigajoules per year (GJ/yr).	$1250	$1000	$1250	NA	NA
Replace your domestic hot water heater with an ENERGY STAR qualified instantaneous, gas-fired water heater that has an energy factor (EF) of 0.82 or higher	$315	$250	$315	$250	NA
CEILING INSULATION					
Increase the insulation value of your attic from R12 or less to R40	$500	$400	$500	$375	NA
EXTERIOR WALL INSULATION					

Eligible Improvement/Retrofits	**Federal Grant**	**Sask**	**Ont**	**Alta**	**Man**
Increase the insulation value of exterior wall by R3.8 ~ R9 for 20% of wall	$225	$180	$225	$168.75	NA
AIR SEALING					
Perform air sealing to improve the air-tightness of your home to achieve the air change rate indicated in your EcoENERGY Retrofit – Homes report.	$190	$150	$190	NA	NA
DOORS/WINDOWS/SKYLIGHTS (heated space only)					
Replace windows and skylights with models that are ENERGY STAR qualified for your climate zone. (*per unit replaced)	$40	$30	$40	NA	NA

3.3 Economic Savings from Energy Reductions

The energy savings and economic impact of adopting these new technologies is specific to each home. HOT2000 is used to calculate the energy savings from the implementation of various technologies on each of the homes in the NRCAN database.

Green homes are based on integrated design where each of the adopted technologies is closely integrated to maximize their impact on the overall performance of the home. Using HOT2000, the impact of the adoption of each technology can be determined as if it was the only technology adopted.

A HOT2000 model is used to illustrate how the implementation of energy saving building technologies can save energy and costs. This is accomplished by generating a HOT2000 model on a base home and then generating additional models showing the impact of adding various levels of insulation to main walls, foundation walls, ceiling and under the slab.

For purposes of the HOT2000 model, the following parameters are used for the base home:

- Located in Saskatoon
- Front of the home facing north
- 32 feet wide by 48 feet deep bungalow (1536 square feet exterior and 1457 sq foot interior)
- 8 foot ceilings on the main floor and in the basement

- 2x6 wall construction on the main floor with R20 insulation (equivalent to R16.72)
- R40 insulation in the ceiling (equivalent to R 36.4)
- 36 square feet of double glazed windows on the north side of the home and 90 square feet on south side. No windows on the east and west sides of the home.
- Exterior doors are standard wood construction.
- Concrete foundation (8 inch) with no insulation
- To simplify the calculations, we will assume the home is powered entirely by electricity.
- There is no heat recovery ventilation system.
- All appliances are standard appliances.
- Home lighting is provided by incandescent lighting.
- 4 occupants (2 adults and 2 children)
- Occupants use 300 liters/person/day of potable water including 225 liters/day of domestic hot water.

Based on HOT2000, the base home will use 50,215 kWh of energy each year. At an approximate cost of $.11/kWh, the cost of that electricity in Saskatoon is $5559.18.

The following tables illustrate the energy and related cost savings resulting from the addition of insulation to the base home:

Table 3-2 Cost Savings From Additional Insulation in Main Walls

	Base Home	Increase insulation in main wall to:					
Insulation (R)	R16.72	R30	R40	R50	R60	R70	R80
Change in R value from base	na	R13.28	R23.28	R33.28	R43.28	R53.28	R63.28
Energy (kWh)	50,215	47,625	46,931	46,515	46,235	46,041	45,894
Cost	$5559	$5,284	$5,210	$5,167	$5,137	$5,116	$5101

	Base Home	Increase insulation in main wall to:					
Cumulative cost savings/year		$275	$348	$393	$422	$443	$459

The data in table 3-2 suggests increasing wall insulation would save at most about 8.5% of annual costs.

Table 3-3 Cost Savings From Additional Insulation to Foundation Walls

	Base Home	Increase insulation in foundation walls to:			
Insulation (R)	R 1.96	R13.96	R21.96	R41.96	R61.96
Change in R value from base	na	R12	R20	R40	R60
Energy (kWh)	50,215	35,538	33,600	31,843	31,136
Cost	$5559	$4,002	$3,796	$3,610	$3,535
Cumulative cost savings/year		$1,556	$1,762	$1,948	$2,023

The data in table 3-3 suggests adding insulation to the walls could cut more than a third of the heating costs.

Table 3-4 Cost Savings From Additional Insulation in Attic

	Base Home	Increase insulation in attic		
Insulation (R)	R36.4	R60	R80	R100
Change in R value from base	na	R23.6	R43.6	R63.6
Energy (kWh)	50,215	49,033	48,576	48,296
Cost	$5559	$5,434	$5,385	$5,356
Cumulative cost savings/year		$125	$ 174	$ 204

The data in table 3-4 shows that increasing insulation in the attic would save at most about $200 per year, or only about 3.7% of annual costs.

Table 3-5 Cost Savings From Additional Insulation Under Foundation Slab

	Base Home	Increase insulation under foundation slab		
Insulation (R)	R0	R20	R40	R60
Change in R value from base	na	R20	R40	R60
Energy (kWh)	50,215	41,952	38,629	37,361
Cost	$5559	$4682	$4330	$4195
Cumulative cost savings/year		$877	$ 1,229	$ 1,364

The data in table 3-5 shows that increasing insulation in the foundation slab could save as much as $1364 or almost 25% of annual costs. Under slab insulation is not included in the EcoENERGY program and would be very costly to do as part of a retrofit. We have included this for illustration only.

The savings from the addition of insulation in various areas of the base home is summarized in Figure 3-1.

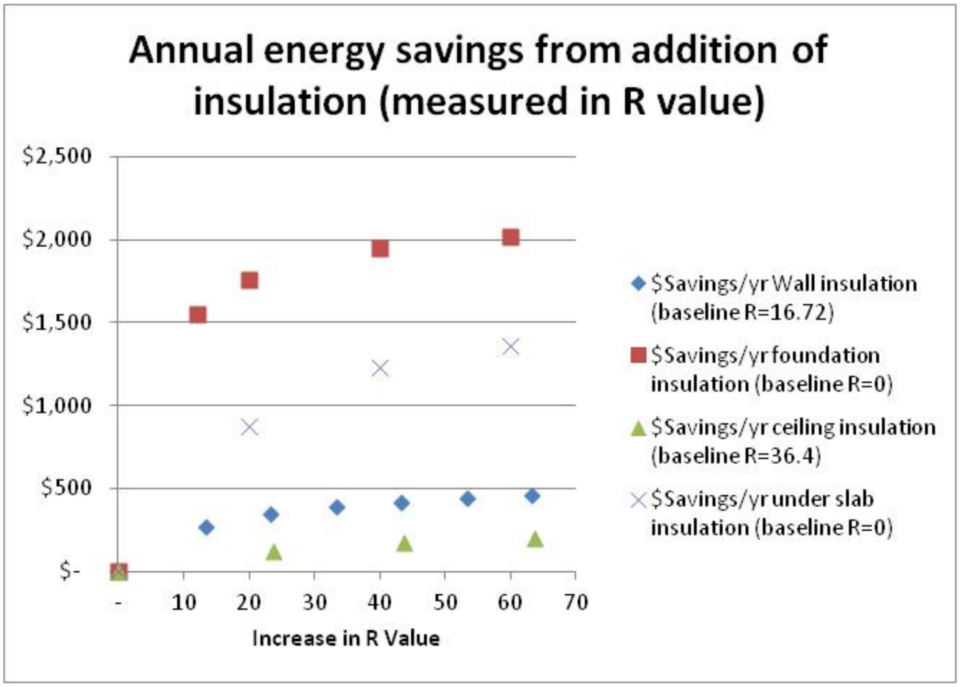


Figure 3-1 - Annual Energy Savings from addition of insulation

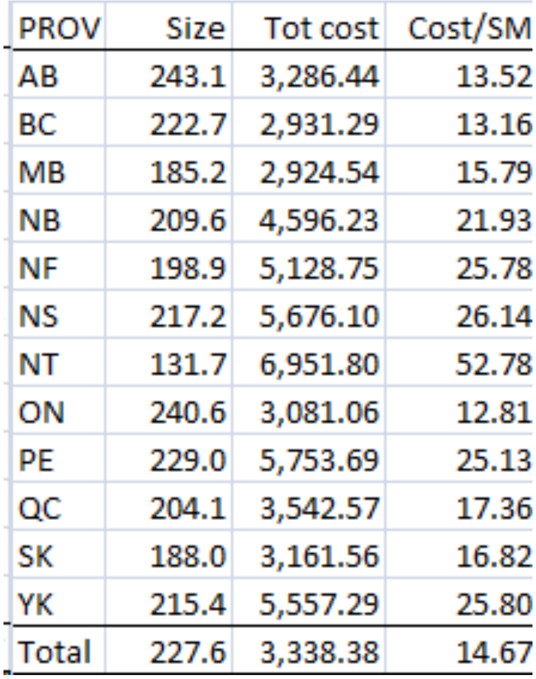
The NRCan database contains several important data points related to energy costs:

1. During the "D" audit, a HOT2000 model is used to estimate the energy consumption of the home. An energy cost calculation is completed based on actual energy costs for the region in which the home is located.
2. As part of the "D" audit, the reviewer makes recommendations on things the owner could do to reduce energy consumption. A HOT2000 model is generated to estimate the energy consumption if the recommendations are implemented and the estimated energy costs are calculated.
3. As part of the "E" audit completed after the new technologies have been adopted, a HOT2000 model is used to estimate the energy consumption after the implementation of the new technologies. The estimated energy costs are calculated.

This provides important information for this research. The difference between 1 and 2 above determines the amount of the economic benefit that the owner would understand is available if he should adopt the new technologies. The database also provides information on whether or not the owner did go ahead with the adoption and if so, the cost savings from that investment.

Based on the information in the NRCan database, a typical home in Canada spends $3,338.38 per year on energy. At an average size of 227.6 square meters, this average home spends $14.67/square meter on energy each year.

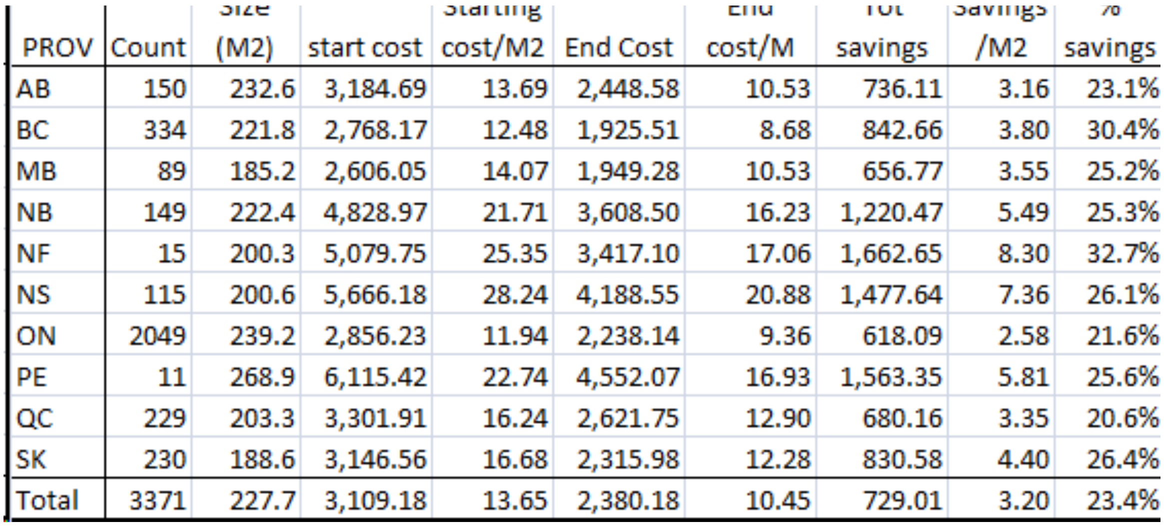
Table 3-6 Cost of Energy per Square Meter



PROV	Size	Tot cost	Cost/SM
AB	243.1	3,286.44	13.52
BC	222.7	2,931.29	13.16
MB	185.2	2,924.54	15.79
NB	209.6	4,596.23	21.93
NF	198.9	5,128.75	25.78
NS	217.2	5,676.10	26.14
NT	131.7	6,951.80	52.78
ON	240.6	3,081.06	12.81
PE	229.0	5,753.69	25.13
QC	204.1	3,542.57	17.36
SK	188.0	3,161.56	16.82
YK	215.4	5,557.29	25.80
Total	227.6	3,338.38	14.67

The cost per square meter varies significantly from province to province. This is caused by age and quality of the homes, climate differences, energy prices and the types of energy available. The 337,000 homeowners that implemented green technologies as part of the EcoENERGY program recognized average savings of $729.01 or $3.20/square meter. That represents an average 23.4 % decrease in energy costs for homes participating in the EcoENERGY program.

Table 3-7 Cost Savings After the Implementation of New Technologies



PROV	Count	Size (M2)	start cost	Starting cost/M2	End Cost	End cost/M	Tot savings	Savings /M2	% savings
AB	150	232.6	3,184.69	13.69	2,448.58	10.53	736.11	3.16	23.1%
BC	334	221.8	2,768.17	12.48	1,925.51	8.68	842.66	3.80	30.4%
MB	89	185.2	2,606.05	14.07	1,949.28	10.53	656.77	3.55	25.2%
NB	149	222.4	4,828.97	21.71	3,608.50	16.23	1,220.47	5.49	25.3%
NF	15	200.3	5,079.75	25.35	3,417.10	17.06	1,662.65	8.30	32.7%
NS	115	200.6	5,666.18	28.24	4,188.55	20.88	1,477.64	7.36	26.1%
ON	2049	239.2	2,856.23	11.94	2,238.14	9.36	618.09	2.58	21.6%
PE	11	268.9	6,115.42	22.74	4,552.07	16.93	1,563.35	5.81	25.6%
QC	229	203.3	3,301.91	16.24	2,621.75	12.90	680.16	3.35	20.6%
SK	230	188.6	3,146.56	16.68	2,315.98	12.28	830.58	4.40	26.4%
Total	3371	227.7	3,109.18	13.65	2,380.18	10.45	729.01	3.20	23.4%

The EcoENERGY grant discussed in section 3.2 is a onetime economic benefit. The value of that benefit is obvious to the owner. The energy cost savings are a recurring benefit that will go on as long as those technologies are in the home. Calculating the value of these technologies is a bit more complicated. The standard tool for calculating today's value for a series of future benefits (energy cost savings) is Net Present Value (NPV). This financial tool is commonly used in business but is often misunderstood by less sophisticated individual purchasers.

$$NPV = -C_0 + \frac{C_1}{(1+r)} + \frac{C_2}{(1+r)^2} + \ldots + \frac{C_T}{(1+r)^T}$$

Table 3-8 Definitions of Elements in Net Present Value Calculations

$-C_0$	Initial investment	This reflects the initial investment in the technology.
C_x	Cash Flow	Cash flow is the energy savings each year. The current year savings can be calculated from the NRCan database. An assumption of the rate of inflation for energy costs is required to determine future energy savings.
r	Discount rate	This requires an assumption of the cost of capital for the homeowner
T	Time	This requires an assumption of the estimated useful life of the technology being implemented.

The **initial investment** information is not available from the NRCan database. Given fair market conditions that exist in Canada, it is safe to assume that the cost of the technologies would be relatively the same in each province. For instance, the cost of a new furnace would be the same in Ontario as it is in Saskatchewan. As the important factor is the relative savings from the new technologies, the initial cost will be considered to be constant in each jurisdiction so will not have a causal effect on adoption rates between provinces.

As shown above, the average energy savings (**cash flow**) at the time the investment decision is made can be calculated from the NRC database. The inflation rate for energy costs will differ by province and by type of fuel. It was beyond the scope of this study to try to accurately predict the inflation levels but we wanted a reasonable assumption that we could use consistently across all of the data. Based on our current understanding we used what we believe is a conservative estimate of 4% inflation.

The cost of capital (**discount rate**) of adding these technologies to a home would be best represented by typical mortgage rates. Again this will vary by owner depending on the term of the mortgage, etc. We used the TD rate for a fixed 5 year term mortgage. At the time of writing, that rate was 4.04%.

Each of the technologies adopted will have a different estimated life (**time**). For instance, insulation should last the remaining life of the building and in most cases that should exceed 50 years. Other technologies such as water heaters may only last 10 years and furnaces may only last 20 years. Again, it is beyond the scope of this study to accurately predict the life of each of the technologies. We used a conservative overall estimate of 20 years.

In table 3-9 the years are labeled C0 to C20 to represent the annual cash flow.

Based on the above, the Net Present Value of FutureBenefits (energy savings) in each province can be easy be calculated.

Table 3-9 Net Present Value of Future Benefits from Implementation of New Technologies

Energy Cost Increases: 4%
Cost of Capital: 4.04%

PROV/CASH FLOW	AB	BC	MB	NB	NF	NS	ON	PE	QC	SK	TOT
C0	0	0	0	0	0	0	0	0	0	0	0
C1	736	843	657	1,220	1,663	1,478	618	1,563	680	831	729
C2	766	876	683	1,269	1,729	1,537	643	1,626	707	864	758
C3	796	911	710	1,320	1,798	1,598	669	1,691	736	898	788
C4	828	948	739	1,373	1,870	1,662	695	1,759	765	934	820
C5	861	986	768	1,428	1,945	1,729	723	1,829	796	972	853
C6	896	1,025	799	1,485	2,023	1,798	752	1,902	828	1,011	887
C7	931	1,066	831	1,544	2,104	1,870	782	1,978	861	1,051	922
C8	969	1,109	864	1,606	2,188	1,944	813	2,057	895	1,093	959
C9	1,007	1,153	899	1,670	2,275	2,022	846	2,140	931	1,137	998
C10	1,048	1,199	935	1,737	2,366	2,103	880	2,225	968	1,182	1,038
C11	1,090	1,247	972	1,807	2,461	2,187	915	2,314	1,007	1,229	1,079
C12	1,133	1,297	1,011	1,879	2,560	2,275	952	2,407	1,047	1,279	1,122
C13	1,179	1,349	1,052	1,954	2,662	2,366	990	2,503	1,089	1,330	1,167
C14	1,226	1,403	1,094	2,032	2,768	2,460	1,029	2,603	1,133	1,383	1,214
C15	1,275	1,459	1,137	2,113	2,879	2,559	1,070	2,707	1,178	1,438	1,262
C16	1,326	1,518	1,183	2,198	2,994	2,661	1,113	2,816	1,225	1,496	1,313
C17	1,379	1,578	1,230	2,286	3,114	2,768	1,158	2,928	1,274	1,556	1,365
C18	1,434	1,641	1,279	2,377	3,239	2,878	1,204	3,045	1,325	1,618	1,420
C19	1,491	1,707	1,331	2,472	3,368	2,993	1,252	3,167	1,378	1,683	1,477
C20	1,551	1,775	1,384	2,571	3,503	3,113	1,302	3,294	1,433	1,750	1,536
Total	21,920	25,093	19,557	36,343	49,511	44,001	18,406	46,554	20,254	24,733	21,708

NPV	14,099	16,140	12,579	23,376	31,845	28,302	11,838	29,943	13,027	15,908	13,963

Average annual savings of $729.01 are significant when considered over the life of the implemented technologies. Assuming an average 20 year life and an energy inflation rate of 4% the total savings range from $18,406 (Ontario) to $49,511 (Newfoundland) with an average of $21,708.

Using a cost of capital of 4.04%, the average net present value of the savings over 20 years is $13,963. This ranges between $11,838 in Ontario and $31,845 in Newfoundland.

3.4 Conclusion

Adopting energy saving technologies can generate significant economic benefits over the life of a home. The EcoENERGY Program provides economic incentives for homeowners to adopt energy saving technologies. The homeowner will also recognize a significant economic benefit from energy cost savings as a result of adopting energy saving technologies.

In the next section, we will study the impact of these two types of economic benefits on the adoption of energy saving technologies in Canada.

4 The Impact of Economic Incentives on the Adoption of Energy Saving Building Technologies

This chapter uses data from the NRCan database to assess how homeowners balance economic cost and benefits in their decision-making related to energy saving building technologies.

4.1 About the NRCan Database

Natural Resources Canada (NRCan) made available for this study a database including all of the “D” and “E” audits completed in 2007, 2008, 2009 and the first 6 months of 2010. There were a total of 984,826 records including 637,443 “D” records and 347,383 “E” records. Each record had 251 different data elements. The data was provided in Excel format and was separated into 8 different files for ease of use. Each record had a unique identifier for each home. This identifier was used to match the “D” record with the “E” record. All records were anonymous.

As previously described there are four basic groupings of information available from two separate records on each household enrolled in the program. The ‘D’ record contains actual information about the existing home (labeled EGHF) and forecasted information about the home if the owner implements the recommendations made by the auditor (labeled UGHF). The ‘E’ record contains a duplicate of the information about the existing home before implementation of the new technologies (labeled EGHF) and then information about the home after the implementation of the new technologies (labeled UGHF).

Record	EGHF	UGHF
‘D’	Contains actual information on the home prior to the implementation of any energy saving technologies	Contains forecasted information on the home if the homeowner were to implement the recommended technologies
‘E’	Contains actual information on the home prior to the implementation of any energy saving technologies	Contains information on the home after the new technologies have been implemented

4.2 About the Sample data

Sample data was extracted from the total database for use in this study. A sample size of 9,751 was chosen to allow for a high confidence level in our testing and to ensure we had appropriate representation for some of the smaller provinces and territories.

To select the sample, a random number generator was used to select a number between 1 and 100. Using extraction tools available in Excel, every 100th ‘D” record was selected from the file by matching the last two digits of the unique identification number to the random number selected. The associated “E” records were also extracted where available. As not all homeowners actually implemented the NRCan recommendations, not every “D” record had an accompanying “E” record.

As expected from the sampling technique used, the sample was close to 1% of the total population (table 4-1).

Table 4-1 Sample Population

Sample population			
	Tot Pop	Sam Pop	%
Total “D” Records	637,443	6,380	1.00%
Total “E” records	347,383	3,371	0.97%
Total Records	**984,826**	**9,751**	**0.99%**

The sample included a broad range of homes of all ages (Table 4-2) and sizes (table 4-3).

Table 4-2 Ages of Homes

Decade Built	Column Labels												
Province:	AB	BC	MB	NB	NF	NS	NT	ON	PE	QC	SK	YK	Total
1899		1	1	10		22		119	4	25			182
1900	2	7	9	14		13		140	1	16	10		212
1910	4	12	19	5		10		81	1	15	22		169
1920	3	22	10	11	1	15		123	1	19	16		221
1930	5	17	6	4		12		114		14	7		179
1940	8	32	18	20	1	25		179	4	31	20		338
1950	45	63	22	35	10	32		451	3	79	71	1	812
1960	45	87	31	35	6	24		461	1	74	87		851

Decade Built	Column Labels												
1970	89	175	41	89	5	49	2	577	7	122	112	2	1,270
1980	68	120	33	56	10	47	7	873	5	72	59		1,350
1990	27	82	8	25	4	18	2	413	8	44	10		641
2000	10	10		12	4	8		83	2	13	12	1	155
Total	**306**	**628**	**198**	**316**	**41**	**275**	**11**	**3,614**	**37**	**524**	**426**	**4**	**6,380**

Table 4-3 Sample Size of Home

Average Floor area		
Province:	M2	Ft2
AB	243.1	2,617.2
BC	222.7	2,396.9
MB	185.2	1,993.4
NB	209.6	2,255.9
NF	198.9	2,141.1
NS	217.2	2,337.6
NT	131.7	1,417.8
ON	240.6	2,589.3
PE	229.0	2,464.9
QC	204.1	2,196.7
SK	188.0	2,023.6
YK	215.4	2,318.8
Total	**227.6**	**2,450.0**

The sample populations also contained a wide range of homes with various levels of energy efficiency as shown by the average EnerGuide ratings (table 4-4). As expected, newer homes were generally more energy efficient. There were no significant differences in the overall energy efficiency by province:

Table 4-4 Average EnerGuide Rating

Average Energuide Rating													
Provinc	AB	BC	MB	NB	NF	NS	NT	ON	PE	QC	SK	YK	Total
1899		46.0	6.0	38.0		41.9		37.5	43.0	49.6			39.7
1900	24.5	34.1	35.1	32.5		32.5		41.9	50.0	57.1	44.4		41.3
1910	36.3	36.7	41.7	38.8		42.3		43.9	50.0	47.7	44.8		43.2
1920	21.3	45.6	38.3	56.5	61.0	39.1		45.8	50.0	50.1	49.6		45.9
1930	46.6	47.0	46.8	57.0		44.5		46.2		50.8	49.6		46.9
1940	54.3	49.6	53.3	55.7	52.0	52.6		52.1	58.3	52.1	51.0		52.2
1950	57.0	55.2	58.2	61.1	34.4	53.6		56.7	64.0	57.1	59.8	22.0	56.7
1960	58.0	57.4	62.8	64.8	51.7	59.8		60.3	70.0	63.4	62.0		60.5
1970	59.0	59.8	65.7	66.5	65.0	62.0	59.5	63.0	64.9	67.1	62.9	69.0	63.0
1980	61.1	61.1	66.8	70.4	63.1	68.7	66.9	65.0	62.2	69.4	68.2		65.2
1990	63.9	66.7	69.4	72.9	62.8	69.8	68.0	67.7	67.8	70.0	66.1		67.8
2000	66.8	71.7		73.3	68.8	69.5		71.2	67.0	72.5	68.2	73.0	70.8
Total	**58.5**	**58.2**	**57.7**	**63.2**	**54.9**	**56.1**	**65.7**	**59.3**	**61.0**	**62.1**	**60.5**	**58.3**	**59.5**

Average total energy costs/square meter varied significantly by province (table 4-5). The highest provincial average home energy costs were in the Northwest Territory and the lowest in Manitoba. The average cost per M2 ranged from $52 in the NWT to $13 in BC. This would be a result of significantly different climates as well as differences in energy types and costs.

Table 4-5 Average Energy Cost

Average Energy Cost			
Provinc	Avg Cost	Avg Size (M2)	Avg Cost/M2
AB	$3,286.44	243.1	$13.52
BC	$2,931.29	222.7	$13.16
MB	$2,924.54	185.2	$15.79
NB	$4,596.23	209.6	$21.93
NF	$5,128.75	198.9	$25.78
NS	$5,676.10	217.2	$26.14
NT	$6,951.80	131.7	$52.78
ON	$3,081.06	240.6	$12.81
PE	$5,753.69	229.0	$25.13
QC	$3,542.57	204.1	$17.36
SK	$3,161.56	188.0	$16.82
YK	$5,557.29	215.4	$25.80
Total	**$3,338.38**	**227.6**	**$14.67**

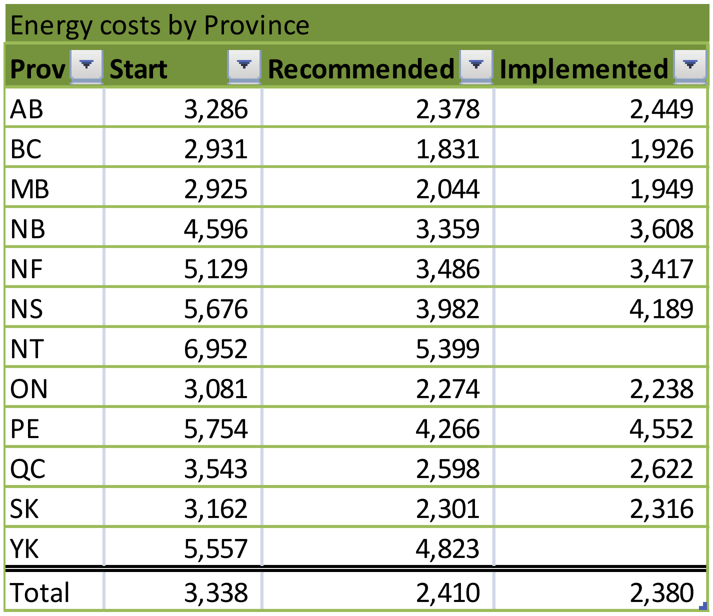
The percentage of homeowners that adopted the recommended technologies is shown by the existence of a “E’ record. The percentage varies significantly by province, from a high of 36% in Ontario to as low as 23% in PEI (table 4-6).

Table 4-6 Average Percentage of Homeowners Adopting

Percentage adoption by Province				
Provinc	d	e	Total	%
AB	306	150	456	32.9%
BC	628	334	962	34.7%
MB	198	89	287	31.0%
NB	316	149	465	32.0%
NF	41	15	56	26.8%
NS	275	115	390	29.5%
NT	11		11	0.0%
ON	3,614	2,049	5,663	36.2%
PE	37	11	48	22.9%
QC	524	229	753	30.4%
SK	426	230	656	35.1%
YK	4		4	0.0%
Total	**6,380**	**3,371**	**9,751**	**34.6%**

The amount of energy savings from adoption of new technologies is significant. In table 4-7, the column labelled ‘Start’ shows the energy costs of the average home in the sample before they implemented any technologies. The column labelled ‘Recommended’ shows the average forecasted energy costs if the homeowner implements all of the recommendations of the energy auditor. The column labelled ‘implemented’ shows the average energy costs after the homeowner implements the new technologies.

Table 4-7 Average Energy Costs by Province



Energy costs by Province

Prov	Start	Recommended	Implemented
AB	3,286	2,378	2,449
BC	2,931	1,831	1,926
MB	2,925	2,044	1,949
NB	4,596	3,359	3,608
NF	5,129	3,486	3,417
NS	5,676	3,982	4,189
NT	6,952	5,399	
ON	3,081	2,274	2,238
PE	5,754	4,266	4,552
QC	3,543	2,598	2,622
SK	3,162	2,301	2,316
YK	5,557	4,823	
Total	3,338	2,410	2,380

On average, individuals in this program realized most of the savings recommended. On average, program users realized savings of about 28.7%. The largest relative savings were realized in BC (34%) and the lowest relative savings in PEI (21%).

4.3 Is economics a significant factor in the adoption of new technologies?

In Section 3 we presented a number of different models for the adoption of new technologies. All models identify economics (sometimes described as the business case) as a significant factor in the decision making process.

In Canada, homeowners would typically recognize two types of economic benefits from the adoption of the technologies included in the EcoENERGY grant program:

1) the government grant directly related to the implementation of that technology
2) the cost savings related to the reduced energy use from the implementation of that technology.

In the following section, we will use statistical analysis to determine if these two types of economic benefits affect the level of enrollment in the EcoENERGY program and the level of adoption of the recommendations from the EcoENERGY program.

4.4 What is the impact of government grants and cost savings on enrollment?

Although the Federal EcoENERGY program is applied consistently to all provinces and territories, each province and territory could chose to supplement the program in different ways. As a result, the total grant available to a homeowner varies by province/territory. This is best illustrated in table 4-8 which shows the total grant (federal and provincial) for a sample of technologies covered by the grant:

Table 4-8 Available Grants

Comparison of grant available for a sample of technologies

Prov / Terr	Furnace	DHW	Ceiling insulation	Foundation wall insulation	Exterior Wall insulation	Total	Relative Weighting
	Replace your existing furnace with an ENERGY STAR qualified gas furnace or oil furnace that has a 94.0 percent AFUE or higher and a brushless DC motor	Replace your domestic hot water heater with an ENERGY STAR qualified instantaneous, condensing gas-fired water heater that has an EF of 0.90 or higher	Increase the insulation value of your attic from R12 or less to R40	Increase the insulation value of basement wall by R10 ~ R23 for 100% of wall	Increase the insulation value of exterior wall by R3.8 ~ R9 for 100% of wall		
AB	1,422	675	900	1,125	2,025	6,147	1.80
BC	790	685	680	865	1,265	4,285	1.25
MB	790	375	500	625	1,125	3,415	1.00
NB	790 + 20% of cost	375 + 20% of cost	500+20% of cost	625 + 20% of cost	1125 + 20% of cost	-	-
NF	1,580	750	1,000	1,250	2,250	6,830	2.00
NS	790	375	900	1,125	2,025	5,215	1.53
NT	1,290	675	Variable	625	1,125	3,715	-
ON	1,580	750	1,000	1,250	2,250	6,830	2.00
PE	790 +15% of cost	375 +15% of cost	500+15% of cost	625+15% of cost	1125+15% of cost	-	-
QC	790	375	500	625	1,125	3,415	1.00
SK	1,420	675	900	1,125	2,025	6,145	1.80

The relative weighting of each province/territory is an indicator of the level of additional grant provided by each province. For instance, in provinces with no matching program (i.e. Quebec and Manitoba), the homeowner would receive only the federal grant. These provinces are assigned a relative weighting of 1.0. In provinces/territories that match the federal grant the homeowner would receive double the grant. These provinces are assigned a relative weighting of 2.0.

Some provinces/territories cannot be weighted using this method. For instance New Brunswick does not match the federal grant but grants the homeowner based on the cost of retrofit. This information is not available in the NRCan database so these provinces/territories are excluded from this analysis.

4.4.1 Will provinces with higher grants achieve higher enrollment in the program?

Ho_1	Provinces with higher grants will achieve a higher level of enrollment in the EcoENERGY program.

We are able to obtain information on the number of households in each province from data maintained by Stats Canada (Statistics Canada, 2012):

Table 4-9 Number of Households in Each Province

Prov/ Terr	Total households
AB	1,162,800
BC	1,481,765
MB	402,170
NA	7,598
NB	279,200
NF	194,980
NS	348,245
NT	13,115
ON	3,831,265
PE	50,380
QC	3,004,555
SK	369,580
YK	11,350
Total	11,157,003

From the information in the NRCan database we know the number of households in each province/territory that enrolled in the program (completed the 'D' audit) (Table 4-10).

Table 4-10 Number of Households Enrolling in EcoENERGY Program

Prov/ Terr	Sample total	Estimated total
AB	306	30,600
BC	628	62,800
MB	198	19,800
NA		-
NB	316	31,600
NF	41	4,100
NS	275	27,500
NT	11	1,100
ON	3,614	361,400
PE	37	3,700
QC	524	52,400
SK	426	42,600
YK	4	400
Grand T	6,380	638,000

From this information, we calculated the percentage of households that enrolled in the program (Table 4-11). While 5.7% of Canadian households enrolled, the provincial rates ranged from as high as 11% in Saskatchewan and New Brunswick to as low as 17.% in Quebec.

Table 4-11 Percentage of Households Enrolling in EcoENERGY Program

PR	Total households	Tot enrolled	% enrolled	Tot adoption	% adoption
AB	1,162,800	30,600	2.6%	15,000	1.3%
BC	1,481,765	62,800	4.2%	33,200	2.2%
MB	402,170	19,800	4.9%	8,800	2.2%
NA	7,598	-	0.0%	-	0.0%
NB	279,200	31,600	11.3%	14,900	5.3%
NF	194,980	4,100	2.1%	1,500	0.8%
NS	348,245	27,500	7.9%	11,500	3.3%
NT	13,115	1,100	8.4%	-	0.0%
ON	3,831,265	361,400	9.4%	204,400	5.3%
PE	50,380	3,700	7.3%	1,100	2.2%
QC	3,004,555	52,400	1.7%	22,800	0.8%
SK	369,580	42,600	11.5%	22,800	6.2%
YK	11,350	400	3.5%	-	0.0%
Total	11,157,003	638,000	5.7%	336,000	3.0%

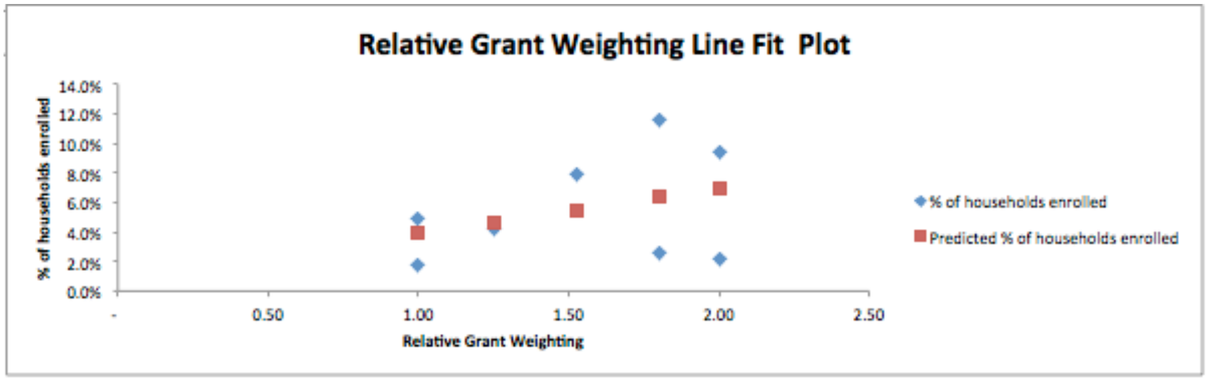
We can then compare the level of enrollment to the relative weighting of the grant size for the provinces/territories where we were able to assign a relative weighting, we find in table 4-12, as illustrated in figure 4-1, that the relative grant weighting does tend to encourage enrolment.

Table 4-12 Comparison of Relative Weighting of Grant Size to Enrollment Percentage by Province (All Provinces)

Prov/ Terr	Relative Grant Weighting	% of households enrolled
AB	1.80	2.6%
BC	1.25	4.2%
MB	1.00	4.9%
NF	2.00	2.1%
NS	1.53	7.9%
ON	2.00	9.4%
QC	1.00	1.7%
SK	1.80	11.5%

Using Microsoft Excel's regression tool, we obtain the following information about the relationship between the relative grant size in each province (independent variable) and the percentage of households (dependent variable) enrolling in the program (Figure 4-1).

Figure 4-1 - Regression Analysis Relative Grant Size to Enrollment % (all provinces)



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.349163237
R Square	0.121914966
Adjusted R Square	-0.024432539
Standard Error	0.036952096
Observations	8

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	0.008408306	0.053351068	0.157603328	0.879939507

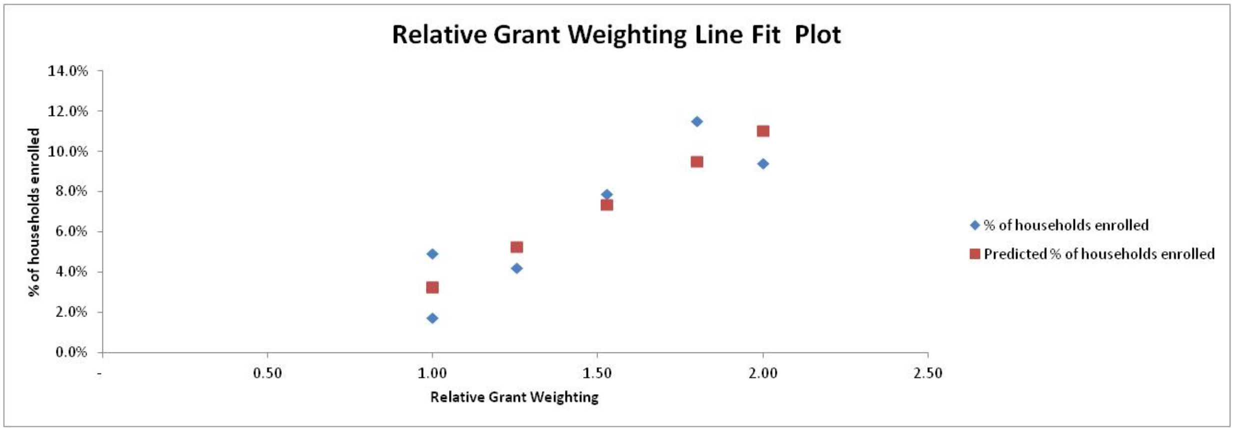
Relative Grant Weighting	0.030505351	0.033422596	0.91271639	0.396583072

The t Stat of .91 indicates no statistical correlation. A simple review of the data shows that there are two major outliers, Alberta and Newfoundland. Alberta (1.80, 2.6%) is significantly lower than is observed in other provinces with similar subsidies. This could be caused by the much higher relative incomes in Alberta that would make the program less significant to the average owner. Newfoundland (2.00, 2.1%) is also significantly lower than expected. This is most likely caused by much lower incomes affecting the homeowner's ability to pay for the improvements. These two observations will be removed from the data.

To test to see if there might be a better fit without the outliers, the analysis was repeated with the provinces of Alberta and Newfoundland removed.

Using Microsoft Excel's regression tool, we obtain the following information about the relationship between the relative grant size in each province (independent variable) and the percentage of households (dependent variable) enrolling in the program (Figure 4-2).

Figure 4-2 Regression Analysis - Household Enrollment vs. Relative Grant Weighting (excluding Alberta and Newfoundland)



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.895
R Square	0.801
Adjusted R Square	0.751
Standard Error	0.018
Observations	6

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-0.04508	0.029	-1.569	0.192
Relative Grant Weig	0.07786	0.019	4.011	0.016

The formula describing the relationship between relative grant size (independent variable) and the level of enrollment in the EcoENERGY Program is:

Enrollment % = -4.51% + 7.78% * Relative Grant Size

Where the coefficient on the relative grant size is statistically significant at 95% confidence.

So,

Hypothesis		Conclusion
Ho$_1$	Provinces with higher grants will achieve a higher level of enrollment in the EcoENERGY program.	Hypothesis is accepted – there is a correlation between the enrollment % and relative grant size.

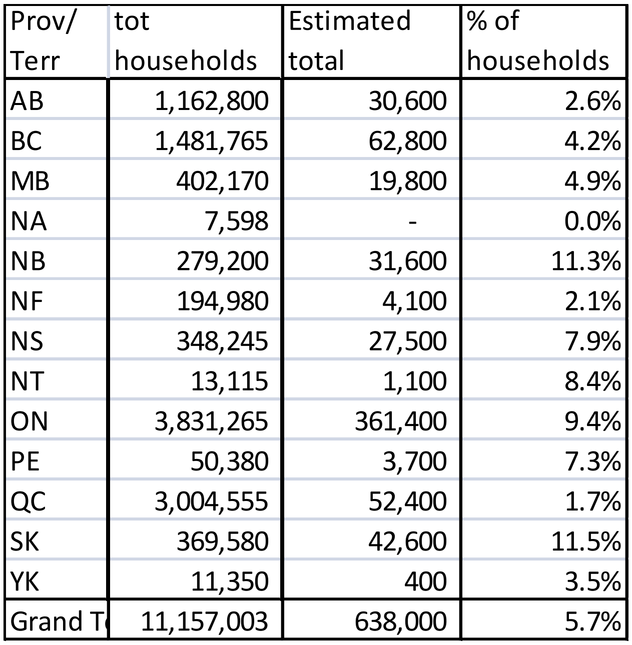
4.4.2 Will provinces with higher energy costs achieve higher levels of enrollment?

Ho$_2$	Provinces with higher energy costs will achieve higher levels of enrollment in the EcoENERGY program.

The NRCan database provides information on each household that enrolled in the program. For every household that enrolled in the program, there is a 'D' record and for each household that implemented new technologies and completed the second audit before June 30, 2010, there is an 'E' record. From this information, we can identify which technologies were recommended at the time of the 'D' audit and which technologies had been implemented at the time of the 'E' audit.

At the point of making the decision to enroll in the EcoENERGY program, the homeowner will be aware of their own energy costs but will not typically have data on the amount of energy savings from implementation of the new technologies.

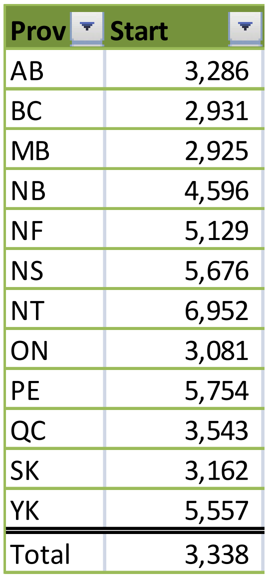
As previously indicated, we can calculate the percentage of households that enrolled in the program (figure 4-3).



Prov/ Terr	tot households	Estimated total	% of households
AB	1,162,800	30,600	2.6%
BC	1,481,765	62,800	4.2%
MB	402,170	19,800	4.9%
NA	7,598	-	0.0%
NB	279,200	31,600	11.3%
NF	194,980	4,100	2.1%
NS	348,245	27,500	7.9%
NT	13,115	1,100	8.4%
ON	3,831,265	361,400	9.4%
PE	50,380	3,700	7.3%
QC	3,004,555	52,400	1.7%
SK	369,580	42,600	11.5%
YK	11,350	400	3.5%
Grand T	11,157,003	638,000	5.7%

Figure 4-3 - Percentage of Households Enrolled by Province

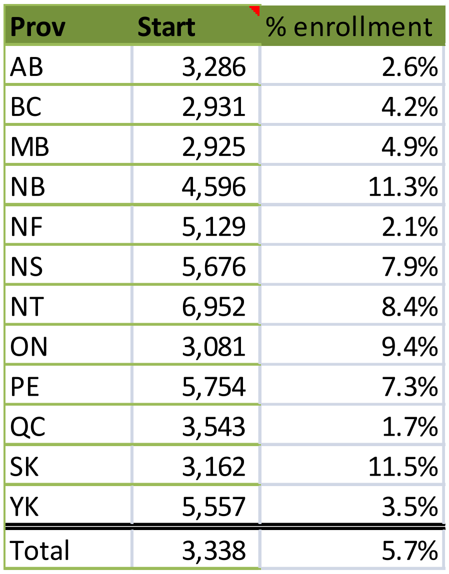
From the NRCan database, we have the average cost of energy in each province/territory figure 4-4).



Prov	Start
AB	3,286
BC	2,931
MB	2,925
NB	4,596
NF	5,129
NS	5,676
NT	6,952
ON	3,081
PE	5,754
QC	3,543
SK	3,162
YK	5,557
Total	3,338

Figure 4-4 - Average Energy Costs per Household by Province

We can then compare the level of enrollment to the average energy consumption for each provinces/territories (figure 4-5).

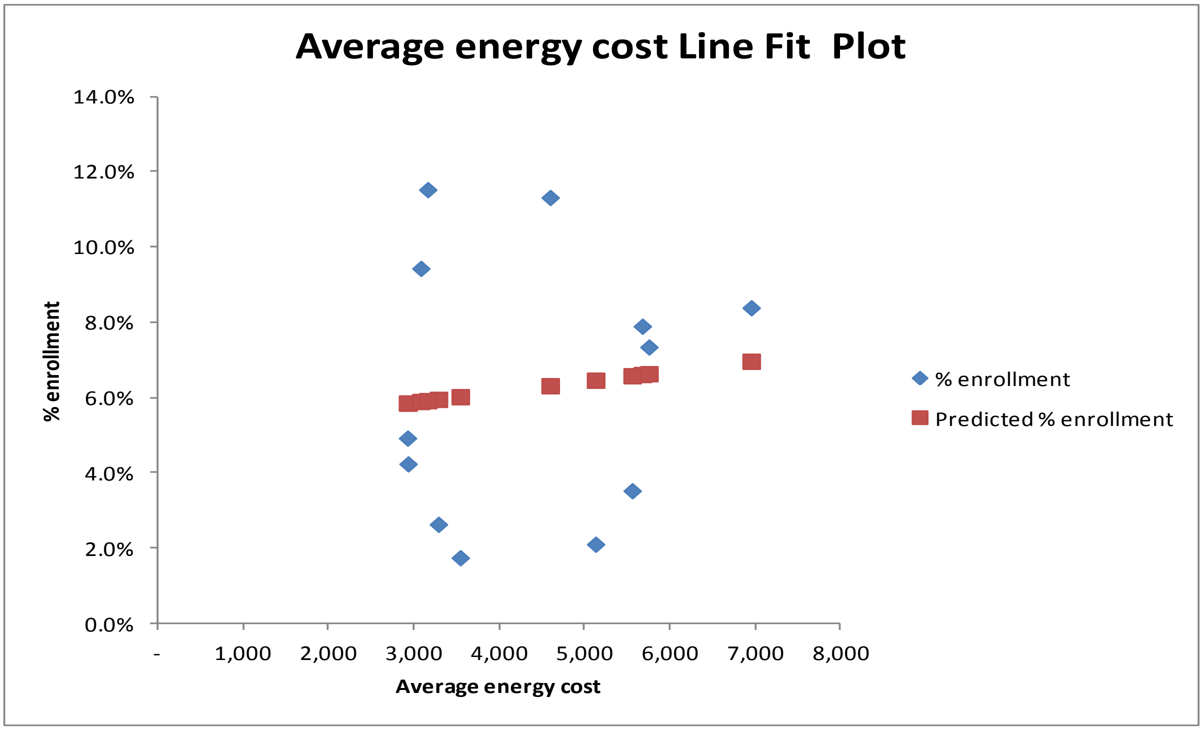


Prov	Start	% enrollment
AB	3,286	2.6%
BC	2,931	4.2%
MB	2,925	4.9%
NB	4,596	11.3%
NF	5,129	2.1%
NS	5,676	7.9%
NT	6,952	8.4%
ON	3,081	9.4%
PE	5,754	7.3%
QC	3,543	1.7%
SK	3,162	11.5%
YK	5,557	3.5%
Total	3,338	5.7%

Figure 4-5 Percentage Enrollment and Average Energy Costs by Province

Using Microsoft Excel's regression tool, we obtain the following information about the relationship between the average energy cost in each province (independent variable) and the percentage of households (dependent variable) enrolling in the program.

Figure 4-6 - Regression Analysis - Percentage Enrollment vs. Average Energy Costs



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.1097
R Square	0.0120
Adjusted R Square	-0.0868
Standard Error	0.0367
Observations	12

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	0.050452	0.0363	1.3917	0.1942
Average energy cost	0.000003	0.0000	0.3491	0.7342

So that,

Enrollment % = 5.04% + .0003% * Average Energy Cost

Neither the coefficients for the independent variable nor the intercept are significant at any measureable level of significance.

So,

Hypothesis		Conclusion
Ho$_2$	Provinces with higher energy costs will achieve higher levels of enrollment in the EcoENERGY program.	Hypothesis is rejected – there is no statistical correlation between the enrollment % and average energy cost.

4.5 What is the impact of government grants and cost savings on adoption?

As indicated in section 4.2, the database contained 637,443 'D' records and 347,383 'E' records (table 4-13).

Table 4-13- Total and Sample Populations of 'D' and 'E' Records

Sample population	Tot Pop	Sam Pop	%
Total "D" Records	637,443	6,380	1.00%
Total "E" records	347,383	3,371	0.97%
Total Records	**984,826**	**9,751**	**0.99%**

There is a 'D' record for every home that enrolled in the program prior to June 30, 2010. There is an 'E' record for every home that adopted new technologies and completed the 'E' audit prior to June 30, 2010. There are several reasons why a home may have a 'D' record but no 'E' record:

1) The homeowner did not adopt new technologies and did not require a 'E' audit
2) The homeowner did adopt new technologies but decided not to proceed with an 'E' audit
3) The homeowner did adopt new technologies and completed the 'E' audit after June 30, 2010.

4.5.1 Will households with higher grants have a higher level of technology adoption?

Ho$_3$	Homeowners being offered higher grants will have higher levels of adoption of energy saving building technologies.

The NRCan database provides detail on each household that enrolled in the EcoENERGY program. From the 'D' database, we can determine the technologies in the home at the time of the 'D' audit and the recommendations made by the auditor. By a review of the EcoENERGY program in each province, we can determine the size of the grant available for each recommended new technology.

For the analysis in the remainder of this section, we are using a subsample including records from Alberta, Manitoba, Ontario and Saskatchewan. These provinces have been selected because they provide a range in the way they matched the federal grant. Manitoba did not match the grant in any way, Saskatchewan matched 75%, Alberta matched 80% and Ontario matched 100% of the Federal grant.

In our sample of 6380 'D' records, 4544 were from the four provinces identified above (table 4-14).

Table 4-14 Total Adoptions in Alberta, Manitoba, Ontario and Saskatchewan

Total Records for AB, MB, ON, and SK		
Prov	**Recommendations**	**Adoptions**
AB	306	150
MB	198	89
ON	3614	2049
SK	426	229
Total	**4544**	**2517**

Of the 4544 homes in our subsample, all received a recommendation to add at least one technology to their home. From the grant information, we can determine the amount of grant (both federal and provincial) they would receive from installing the recommended technology. From information in the 'e' record, we can determine what they actually adopted. We completed this analysis for a sample of technologies including:

- Ceiling insulation
- Furnace
- Foundation wall insulation
- Main Wall insulation
- Heat Recovery Ventilation
- Windows, and
- Domestic Hot Water.

Using Microsoft Excel's regression tool, we obtain the following information about the relationship between the grants available to each homeowner for installing the recommended technologies (independent variable) and the percentage of households (dependent variable) that adopted the recommendation.

Table 4-15 summarizes the results. The detail on each can be found in the Appendix A.

Table 4-15 Testing the Impact of Grants on Adoption

Ho3	Homeowners being offered higher grants will have higher levels of adoption of energy saving building technologies.			
Recommended Technology	Formula	t-Stat *	Change in Adoption % per $1000	Conclusion re hypothesis
Ceiling insulation	Adoption % = 35.71% + .017%*Ceiling grant	7.3047	17%	Accepted
Furnace	Adoption % = 40.40% + .01%*Furnace Grant ($	4.5575	10%	Accepted
Foundation Insulation	Adoption % = 53.47% + .0014% * Foundation Wall Grant	1.03	1.4%	Rejected
Main Wall Insulation	Adoption % = 27.23% + .0046% * Main Wall Grant	3.86	4.6%	Accepted
Heat Recovery Ventilation	Adoption % = 16.97% + .0250% * Ventilation System Grant	3.1895	25%	Accepted
Windows	Adoption % = 36.33% + .0033% * Window Grant	2.2126	3.3%	Accepted
Domestic Hot Water	Adoption % = 43.98% + .0051% * Domestic Hot Water Grant	1.8985	5.1%	Rejected

*based on 95% confidence level.

Based on a sample of 7 technologies, five show a statistical relation between the adoption of the new technology and the grant size while two do not. As such, the hypothesis is accepted.

4.5.2 Will households with higher potential energy savings have higher levels of technology adoption?

Ho_4	Homeowners with higher potential energy savings will have higher levels of adoption of energy saving building technologies.

The NRCan database provides detail on each household that enrolled in the EcoENERGY program. From the 'D' database, we can determine the status of the home at the time of the 'D' audit and the recommendations made by the auditor. The NRCan database provides information on the energy consumption of the home before any changes and forecasts the energy consumption of the home if **all of the recommendations** are adopted. Using this information, we can determine the forecasted energy savings for each household if all recommendations are adopted and the level of adoption at various levels of energy savings.

In our sample of 6380 'D' records, all received a recommendation to add at least one technology to their home. From the NRCan database, we can determine the amount of energy savings that would be realized from the adoption of the recommended technologies.

Using Microsoft Excel's regression tool, we looked for correlation between the decision to adopt and potential energy savings in several different tests. The detailed results can be found in appendix B. A summary follows in Table 4-16.

Table 4-16 Correlation of Adoption to Forecasted Energy Costs

	Null Hypothesis	Conclusion re hypothesis
$Ho_{4.1}$	Homeowners with higher potential energy savings will have higher levels of adoption of energy saving building technologies.	Hypothesis is rejected – there is a negative statistical correlation between the adoption % and the size of the energy savings.
$Ho_{4.2}$	Homeowners with higher forecasted home energy cost savings/square meter will have higher levels of adoption of energy saving building technologies.	Hypothesis is rejected – there is a negative statistical correlation between the adoption % and the size of the energy savings per square meter.

	Null Hypothesis	Conclusion re hypothesis
$Ho_{4.3}$	Homeowners with higher forecasted total home energy costs adjusted by average provincial family income will have higher levels of adoption of energy saving building technologies.	Hypothesis is rejected – there is a negative statistical correlation between the adoption % and the size of forecasted total home energy costs adjusted by average provincial family income.
$Ho_{4.4}$	Homeowners with higher forecasted total home energy cost savings/square meter adjusted by average provincial family income will have higher levels of adoption of energy saving building technologies.	Hypothesis is rejected – there is a negative statistical correlation between the adoption % and the size forecasted total home energy cost savings/square meter adjusted by average provincial family income

Although logic would suggest that increased energy savings would result in an increase in adoption levels, our testing shows that there is a negative correlation and the increased energy savings actually result in a decrease in adoption levels. Although it is outside of the scope of this study we hope that further research will be conducted to better understand this relationship.

5 Summary and Conclusions

5.1 Introduction

This thesis has evaluated the impact of energy cost savings and government grants on the adoption of energy saving technologies in residential housing. The following sections (6.2 and 6.3) summarize the findings and offer some observations on the impact to the residential housing industry and suppliers of energy efficient technologies.

5.2 Summary of major findings

The four hypotheses and the results of the analysis are outlined below:

Ho_1	Provinces with higher grants will achieve a higher level of enrollment in the EcoENERGY program.

The study determines that there is a statistically positive relationship between the grant size and the level of enrollment in the Eco Energy program; therefore the hypothesis is accepted. Although a number of other factors may influence the level of enrollment in the program, the study implies that there is a direct correlation between the level of enrollment and the size of the grants in each province.

This suggests that if Federal government and the Provinces wish to encourage enrollment, they can do so by increasing the grants at a federal and provincial level. There is also a significant concern that if the program is cancelled that Canadian homeowners will significantly reduce their adoption of these energy saving technologies.

Ho_2	Provinces with higher energy costs will achieve higher levels of enrollment in the EcoENERGY program.

The study determined that there is no statistically valid relationship between the level of enrollment and energy prices; therefore the hypothesis is rejected. This was a surprising result. The energy savings related to these technologies over the life of the technology are often significantly higher than the size of the grants, yet they do not appear to have a major influence on decision-making.

This suggests that Canadian homeowners to not understand the significance of the energy savings over time or they highly discount these energy savings in their decision.

Ho$_3$	Homeowners being offered higher grants will have higher levels of adoption of energy saving building technologies.

The study tested this hypothesis on 7 different technologies. The results of the analysis are summarized in table 5-1

Table 5-1 - Summary of Analysis of Adoption of Recommended Technologies

Recommended Technology	Conclusion re hypothesis
Ceiling insulation	Accepted
Furnace	Accepted
Foundation Insulation	Rejected
Main Wall Insulation	Accepted
Heat Recovery Ventilation	Accepted
Windows	Accepted
Domestic Hot Water	Rejected

The hypothesis is accepted for 5 of the 7 technologies. This suggests that there is a significant causal relationship between the size of the grant and the level of adoption, although this relationship is different for each technology.

This suggests that Federal and Provincial governments have the ability to impact adoption levels for each technology by adjusting grant levels.

Ho$_4$	Homeowners with higher potential energy savings will have higher levels of adoption of energy saving building technologies.

The study determines that there is a statistically valid relationship between the level of enrollment and energy prices; therefore the hypothesis is accepted. Surprisingly, the relationship is a negative correlation. Higher energy cost savings negatively impact levels of adoption.

As in hypothesis Ho_2 above, this suggests that homeowners do not understand the significance of the energy savings over the life of the technology.

5.3 Implications for the residential housing industry

Canadian housing stock is not energy efficient with an average EnerGuide rating of 59.5 (section 4.2). The EcoENERGY program has had a significant impact on the implementation of energy saving technologies to reduce energy consumption. The average energy cost before implementation is $3,338/home. The average energy cost post implementation is $2,380/home. This is a significant 28.7% ((3,338-2,380)/3338) (see section 4.2) decrease in energy cost per home that adopted new technologies.

Any changes to the grant program will have significant impact on the levels of enrollment and adoption. This would impact the residential housing industry and all suppliers of these energy saving technologies. A reduction in the grant program will significantly reduce the level of enrollment and adoption in the EcoENERGY program. An increase in the grant program could significantly increase the level of adoption in the EcoENERGY program. The respective changes to energy use and green house gas emissions will follow in the same direction.

The work completed by Geoffrey Moore (see section 2.4) suggests that there is an adoption 'chasm' at approximately 13% adoption level. Total adoption rate for the country was at 5.7% at June of 2010. Cancellation of the EcoENERGY program will have a negative impact on adoption of these technologies.

Somewhat surprisingly, this study clearly suggests that homeowners do not understand the significance of the energy savings from the implementation of these technologies. This suggests that there is an opportunity for our governments and the industry to educate home owners about potential energy savings from adoption of these technologies.

It is not in the scope of this study to research all of the alternatives available to our governments and the industry but a number of options have been considered. These incentives typically take the form of financial incentives or rules regulations and policies:

Financial incentives include:

- Personal tax incentives – income tax credits and incentives to reduce the expense of the purchase and installation of energy saving technologies
- Sales tax incentives – exemption from or refund of sales taxes
- Property tax incentives – exemptions, exclusions abatements or credits typically based on the value of the technologies adopted
- Rebate programs – funding for the cost of the technologies
- Grant programs – typically designed to reduce the cost
- Loan programs – low or zero interest loans

Rules, regulations and institutional interventions include:

- Public benefit funds - funds to support energy efficiency supported by a small surcharge on energy consumption
- Net metering – allows for the flow of consumer generated electricity back to the grid
- Building codes – require minimum energy standards for construction
- Appliance/equipment efficiency standards – establish minimum efficiency standards for certain equipment and appliances
- Solar and wind access policies – establish a right to install and operate a solar or wind energy system.

5.4 Limitations

Limitations are inherent in any research. For this research project, there are two key limitations.

1) There is no information available on specific energy savings for each technology implemented. This study clearly identifies economics as a significant factor in the

adoption of new technologies. Economic benefits are typically measured using both the value of the benefits and the costs of implementation. We identify two groups of economic benefits. The first benefit is the grant available to the homeowner for the implementation of a new technology. The second benefit is the energy savings from the implementation of the technologies. Analysis of the EcoENERGY program provides us with the size of the grant available to a homeowner based on the implementation of a specific technology. The NRCan database used for the analysis provides us with the value of the cost savings from energy savings available to a homeowner based the implementation of a mix of technologies.

2) The database does not include any information on the cost of adoption of the new technologies.

These limitations result in the following implications:

Table 5-2 Limitations and Implications

Limitation	Implication
No information available on specific energy savings for each technology implemented.	When the homeowner receives the report from the 'D' audit, they do not have information on specific energy savings for each technology. They make their decision to adopt based on the report's total energy saving forecast. We use the same information provided to the homeowner in our study.
No data available on the actual cost of implementation of the new technologies.	The cost of implementation of new technologies is assumed to be reasonably consistent across the country so should not have a causal effect on the results of our analysis.

5.5 Extensions

The first potential extension to this study is to further examine the negative correlation between adoption levels and energy cost savings. This would help to determine what will be required to maintain adoption levels when our governments reduce or eliminate the grant programs.

The process related to the EcoENERGY audit and reporting is necessarily streamlined. A second potential extension would be to research the impact of the format of the report presented to the homeowners after the 'D' audit. Would a different format result in a higher adoption rate?

The third potential extension arises from the second limitation. A rational homeowner would consider the net cost of the implementation (actual cost less grant) in making the adoption decision. Although the cost of implementation will be relatively consistent across the country, this study would provide insights in to the optimum grant size for each technology.

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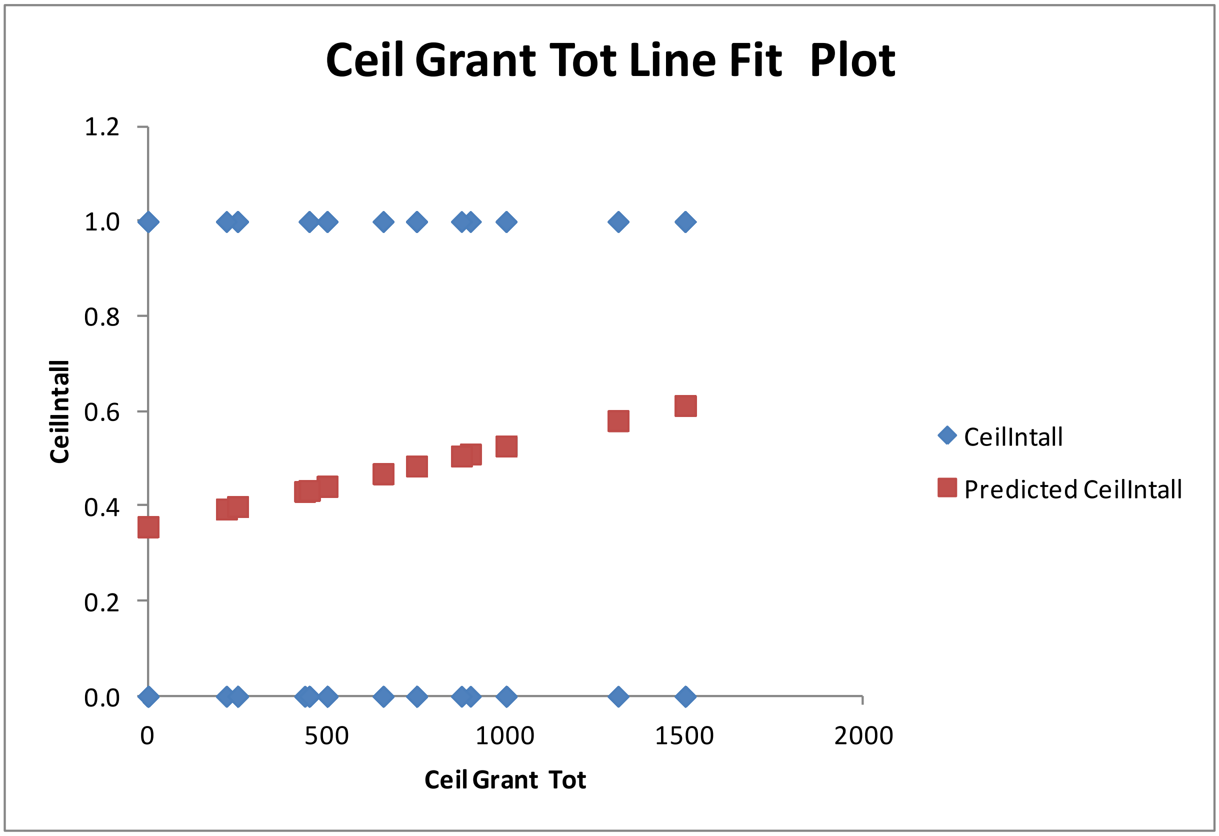
Appendix A.

Regression Analysis – Adoption of Technologies vs Grant Size

Ceiling insulation

Of the 4544 homes in our subsample from Alberta, Manitoba, Ontario and Saskatchewan, 2800 received recommendations to add additional insulation to their ceilings and 1090 installed the recommended insulation. In the data, we have used 1 to indicate that the homeowner did adopt the ceiling insulation as recommended and we have used a 0 to indicate that the homeowner did not adopt.

Using Microsoft Excel's regression tool, we obtain the following information about the relationship between the grants available to each homeowner for installing ceiling insulation (independent variable) and the percentage of households (dependent variable) that actually installed the insulation.



Summary results

Regression Statistics	
Multiple R	0.137
R Square	0.019
Adjusted R Square	0.018
Standard Error	0.483
Observations	2800

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	0.357097	0.0101	35.2206	0.0000
Ceil Grant Tot	0.000170	0.0000	7.3047	0.0000

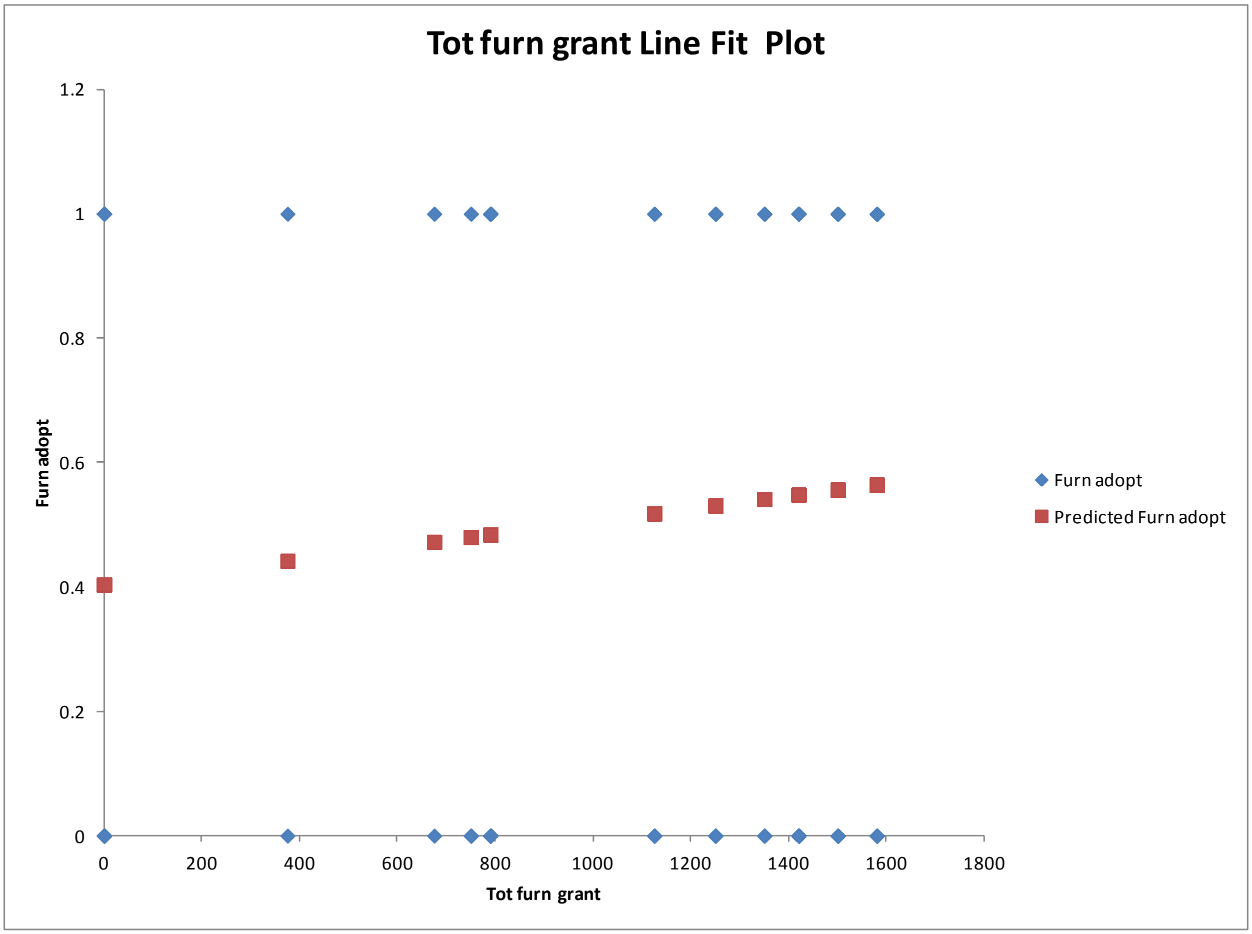
Adoption % = 35.71% + .017%*Ceiling grant

Hypothesis		Conclusion
Ho$_{3.1}$	Homeowners being offered higher grants will have higher levels of adoption of additional ceiling insulation.	Hypothesis is accepted – there is a statistical correlation between the adoption % and the ceiling grant.

Furnace

Of the 4,544 homes in our subsample from Alberta, Manitoba, Ontario and Saskatchewan, 3,143 received recommendations to install a new furnace and 1,711 adopted the recommendation.

Using Microsoft Excel's regression tool, we obtain the following information about the relationship between the grants available to each homeowner for installing a new furnace (independent variable) and the households (dependent variable) that actually adopted the recommendation.



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.0811
R Square	0.0066
Adjusted R Square	0.0063
Standard Error	0.4965
Observations	3143

	Coefficients	*Standard Error*	*t Stat*
Intercept	0.404011	0.0320	12.6062
Tot furn grant	0.00010147	0.0000	4.5575

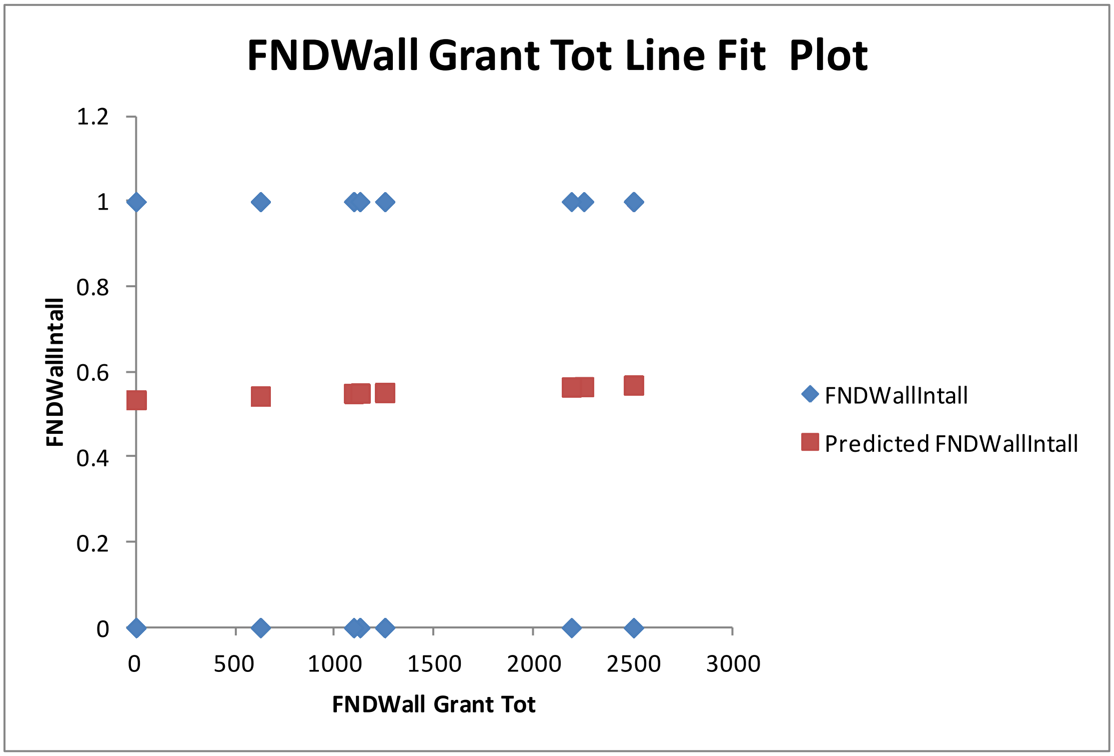
Adoption % = 40.40% + .01%*Furnace Grant ($)

Hypothesis		Conclusion
$Ho_{3.2}$	Homeowners being offered higher grants will have higher levels of adoption of new furnaces.	Hypothesis is accepted – there is a statistical correlation between the adoption % and the size of the Furnace Grant.

Foundation insulation

Of the 4,544 homes in our subsample from Alberta, Manitoba, Ontario and Saskatchewan, 2,259 received recommendations to add additional insulation to their foundations and 1,236 adopted the recommendation.

Using Microsoft Excel's regression tool, we obtain the following information about the relationship between the grants available to each homeowner for installing foundation insulation (independent variable) and the percentage of households (dependent variable) that adopted the recommendation.



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.02172
R Square	0.00047
Adjusted R Squar	0.00003
Standard Error	0.49788
Observations	2259

	Coefficients	*tandard Err*	*t Stat*	*P-value*
Intercept	0.534777	0.0159	33.5973	0.0000
FNDWall Grant T	0.000014	0.0000	1.0320	0.3022

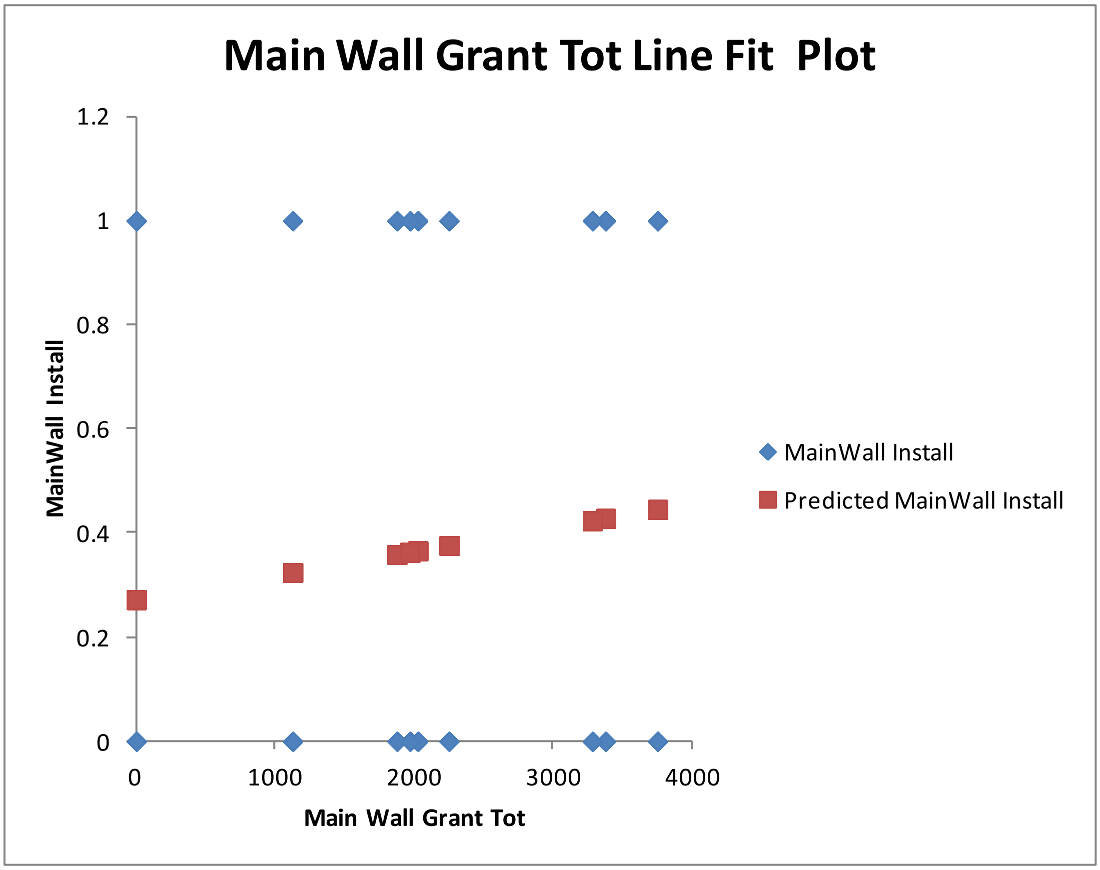
Adoption % = 53.47% + .0014% * Foundation Wall Grant

Hypothesis		Conclusion
Ho$_{3.3}$	Homeowners being offered higher grants will have higher levels of adoption of additional foundation wall insulation.	Hypothesis is rejected – there is no statistical correlation between the adoption % and the size of the Foundation Wall Grant

Main Wall Insulation

Of the 4544 homes in our subsample from Alberta, Manitoba, Ontario and Saskatchewan, 918 received recommendations to add additional insulation to their main walls and 595 adopted the recommendation.

Using Microsoft Excel's regression tool, we obtain the following information about the relationship between the grants available to each homeowner for installing additional main wall insulation (independent variable) and the percentage of households (dependent variable) that adopted the recommendation.



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.1090
R Square	0.0119
Adjusted R Squar	0.0111
Standard Error	0.4830
Observations	1243

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	0.272297	0.031199	8.727722	0.000000
Main Wall Grant T	0.000046	0.000012	3.861316	0.000119

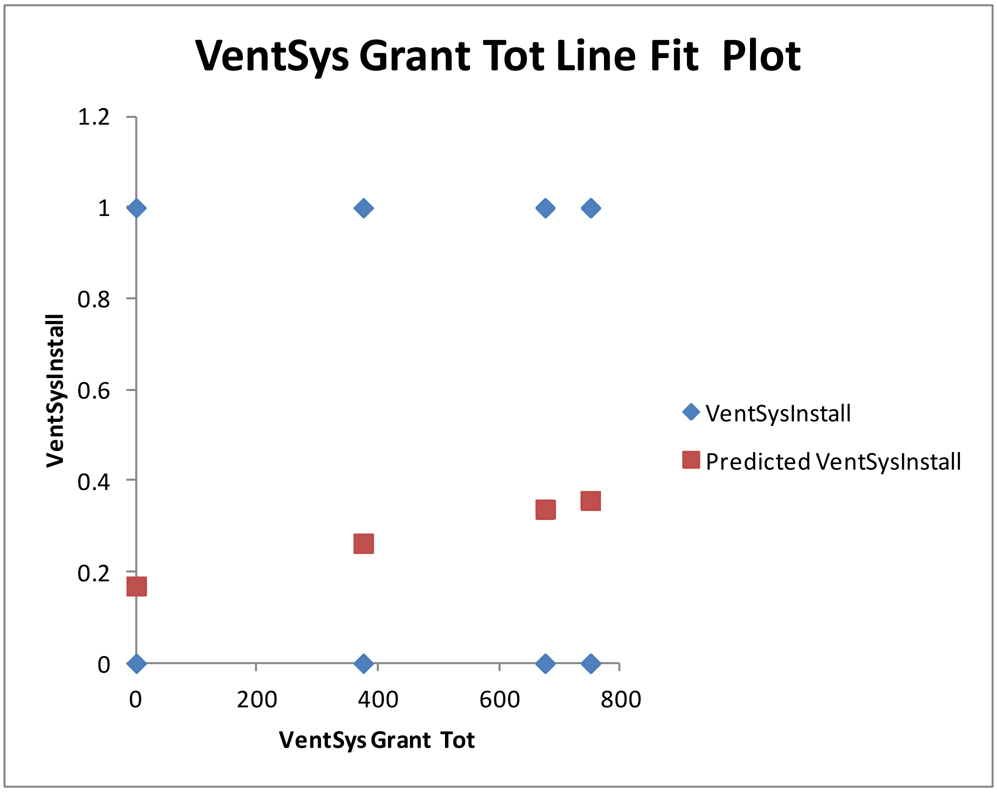
Adoption % = 27.23% + .0046% * Main Wall Grant

Hypothesis		Conclusion
$Ho_{3.4}$	Homeowners being offered higher grants will have higher levels of adoption of main wall insulation.	Hypothesis is accepted – there is a statistical correlation between the adoption % and the size of the Main Wall Grant

Heat Recovery Ventilation

Of the 4,544 homes in our subsample from Alberta, Manitoba, Ontario and Saskatchewan, 1,510 received recommendations to install a heat recovery ventilation system and 518 adopted the recommendation.

Using Microsoft Excel's regression tool, we obtain the following information about the relationship between the grants available to each homeowner for installing a heat recovery ventilation system (independent variable) and the percentage of households (dependent variable) that adopted the recommendation.



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.0819
R Square	0.0067
Adjusted R Square	0.0060
Standard Error	0.4734
Observations	1510

	Coefficients	*andard Err*	*t Stat*	*P-value*
Intercept	0.169666	0.0557	3.0456	0.0024
VentSys Grant Tot	0.000250	0.0001	3.1895	0.0015

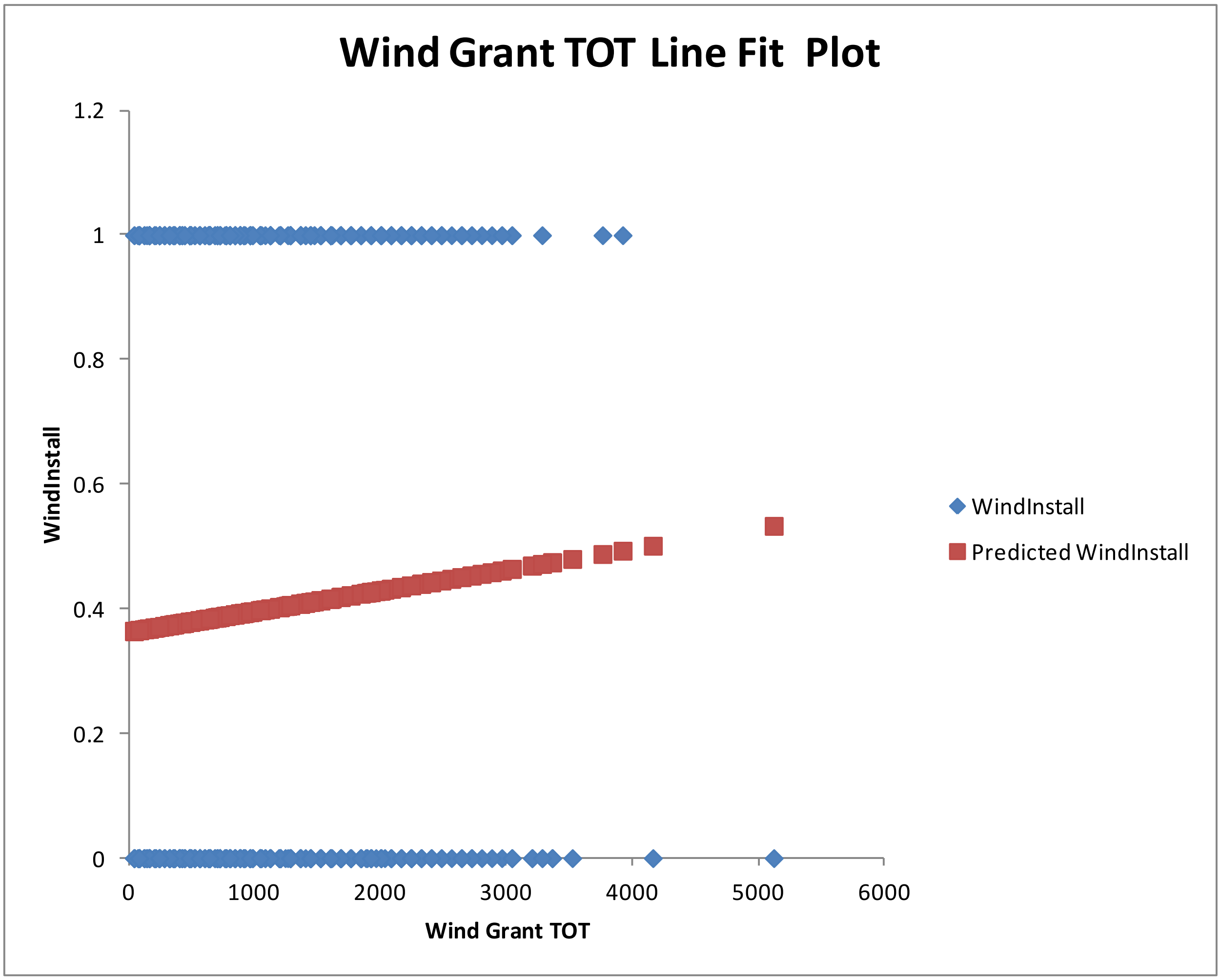
Adoption % = 16.97% + .0250% * Ventilation System Grant ($)

Hypothesis		Conclusion
$Ho_{3.5}$	Homeowners being offered higher grants will have higher levels of adoption of heat recovery ventilation.	Hypothesis is accepted – there is a statistical correlation between the adoption % and the size of the Ventilation System Grant.

Windows

Of the 4,544 homes in our subsample from Alberta, Manitoba, Ontario and Saskatchewan, 2,824 received recommendations to add install new windows and 1,105 adopted the recommendation.

Using Microsoft Excel's regression tool, we obtain the following information about the relationship between the grants available to each homeowner for installing new windows (independent variable) and the percentage of households (dependent variable) that adopted the recommendation:



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.0416
R Square	0.0017
Adjusted R Square	0.0014
Standard Error	0.4878
Observations	2824

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	0.363333	0.0156	23.2651	0.0000
Wind Grant TOT	0.000033	0.0000	2.2126	0.0270

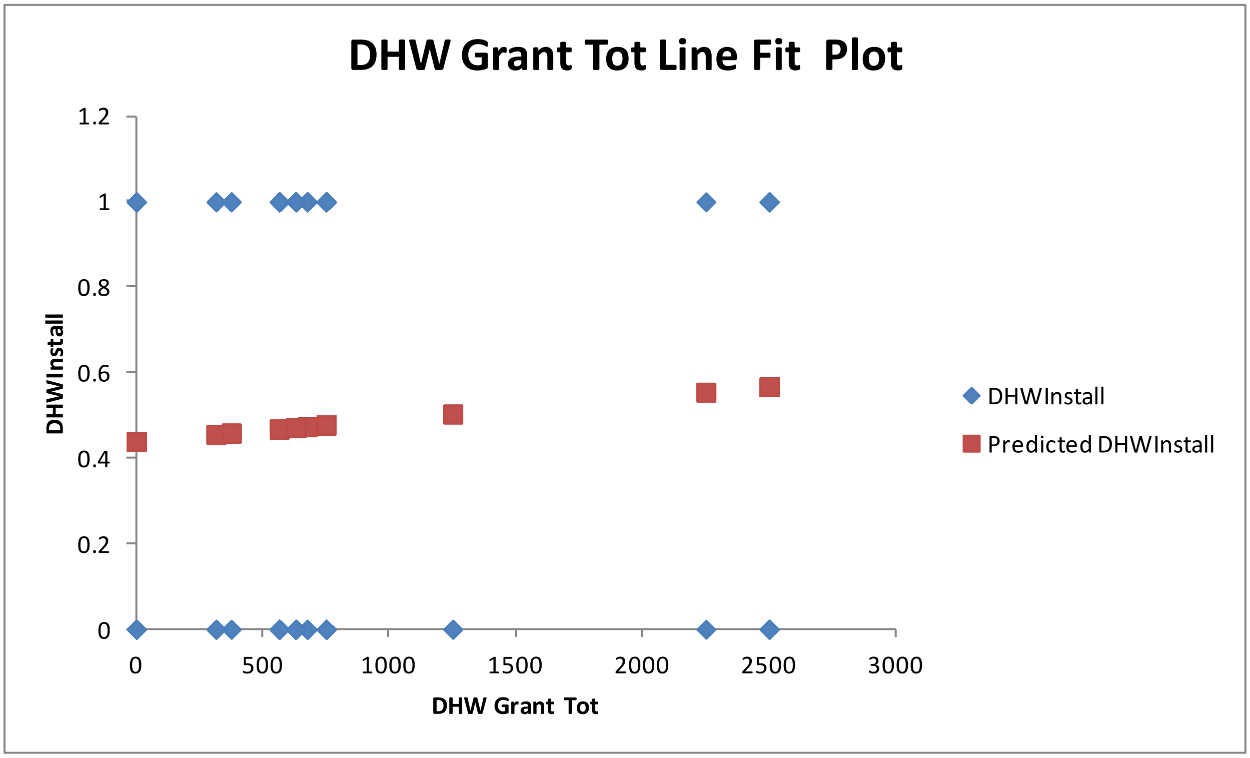
Adoption % = 36.33% + .0033% * Window Grant ($)

Hypothesis		Conclusion
Ho$_{3.6}$	Homeowners being offered higher grants will have higher levels of adoption of new windows.	Hypothesis is accepted – there is a statistical correlation between the adoption % and the size of the Window Grant.

Domestic hot water

Of the 4,544 homes in our subsample from Alberta, Manitoba, Ontario and Saskatchewan, 2,618 received recommendations to install new domestic hot water heating systems and 1,238 adopted the recommendation.

Using Microsoft Excel's regression tool, we obtain the following information about the relationship between the grants available to each homeowner for installing a new domestic hot water heating system (independent variable) and the percentage of households (dependent variable) that adopted the recommendation.



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.0371
R Square	0.0014
Adjusted R Square	0.0010
Standard Error	0.4991
Observations	2618

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	0.439790	0.0200	22.0185	0.0000
DHW Grant Tot	0.000051	0.0000	1.8985	0.0577

Adoption % = 43.98% + .0051% * Domestic Hot Water Grant ($)

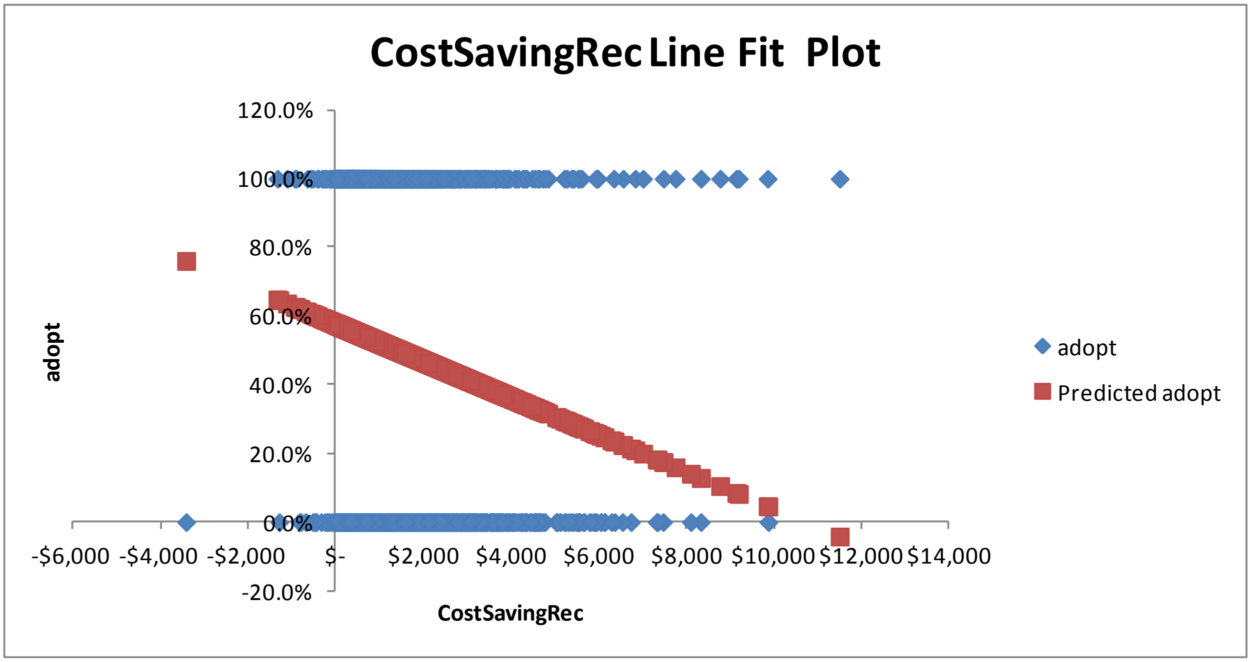
Hypothesis		Conclusion
$Ho_{3.7}$	Homeowners being offered higher grants will have higher levels of adoption of Domestic Hot Water systems.	Hypothesis rejected – The tStat of 1.8985 is too low to accept this as a statistically valid number. As such, there is no statistical correlation between the adoption % and the size of the Domestic Hot Water Grant.

Appendix B.

Regression Analysis – Adoption of Technologies vs Projected Energy Savings

Adoption Of Technologies Vs Total Projected Energy Savings

Using Microsoft Excel's regression tool, we obtain the results below that show the relationship between the forecasted energy cost savings to each homeowner (independent variable) and the percentage of households (dependent variable) that adopted at least one of the recommendations.



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.10771646
R Square	0.0116
Adjusted R Square	0.0114
Standard Error	0.4965
Observations	6380

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	0.576586	0.0085	67.9783	0.0000
CostSavingRec	-0.000054	0.0000	-8.6528	0.0000

So that,

Adoption% = 57.65% - .0054% * Cost Savings ($)

Both the co-efficients are significant at the 95% level. A $1000 increase in the total projected energy cost savings results in a 5.4% decrease in adoption. The tests show a negative correlation between adoption and projected home energy cost savings.

Thus,

Hypothesis		Conclusion
$Ho_{4.1}$	Homeowners with higher potential energy savings will have higher levels of adoption of energy saving building technologies.	Hypothesis is rejected – there is a negative statistical correlation between the adoption % and the size of the energy savings.

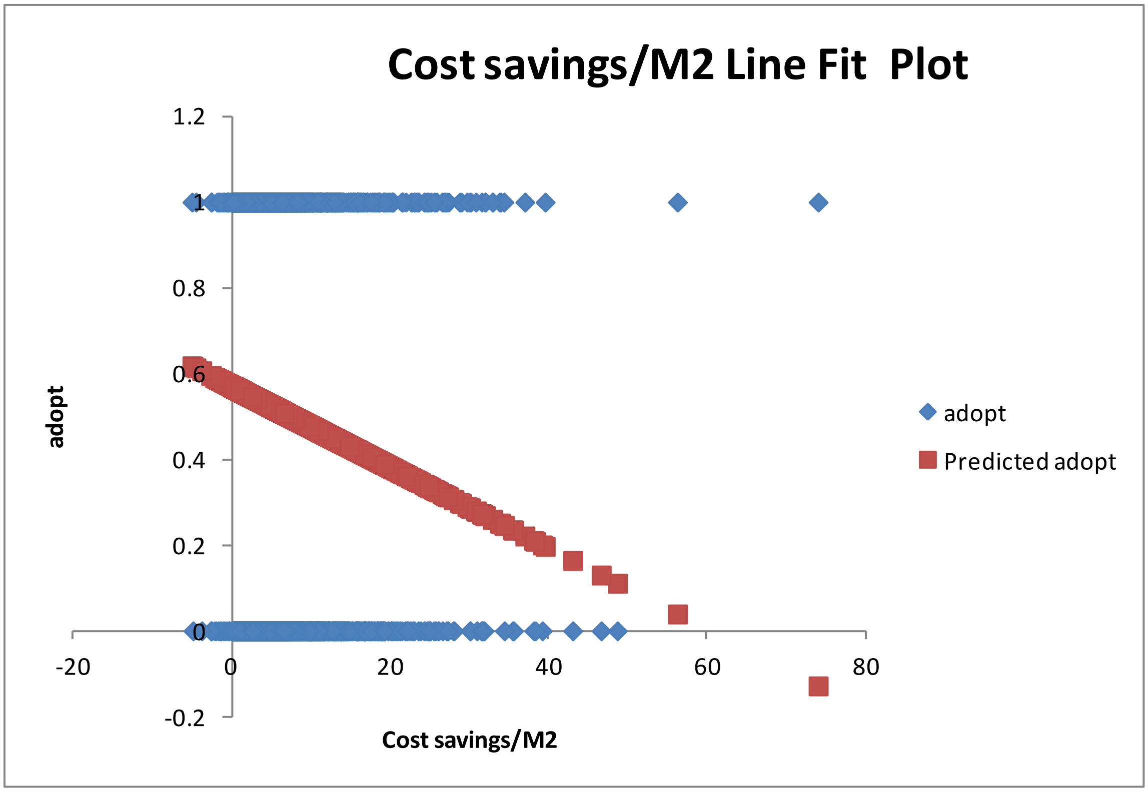
In an attempt to understand the negative correlation between projected energy cost savings and adoption, we attempted a number of other tests comparing adoption to:

- Projected energy savings per square meter
- Projected energy savings adjusted for provincial average family incomes
- Projected energy savings per square meter adjusted for provincial average family incomes.

Adoption Of Technologies Vs Total Projected Energy Savings Per Square

Meter

Using Microsoft Excel's regression tool, we obtain the results below that show the relationship between the forecasted energy cost savings per square meter to each homeowner (independent variable) and the percentage of households (dependent variable) that adopted at least one of the recommendations.



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.094822
R Square	0.008991
Adjusted R Square	0.008836
Standard Error	0.497118
Observations	6380

	Coefficients	*andard Err*	*t Stat*	*P-value*
Intercept	0.570131	0.008451	67.46611	0
Cost savings/M2	-0.94%	0.001241	-7.60699	3.21E-14

Adoption %= 57.01% -.94*cost saving per M2

Both the co-efficients are significant at the 95% level. A $10 increase in the forecasted cost savings per square meter results in a 9.4% decrease in adoption. The tests show a negative correlation between adoption and projected home energy cost savings per square meter.

Thus,

Hypothesis		Conclusion
Ho$_{4.2}$	Homeowners with higher potential forecasted home energy cost savings/square meter will have higher levels of adoption of energy saving building technologies.	Hypothesis is rejected – there is a negative statistical correlation between the adoption % and the size of the energy savings per square meter.

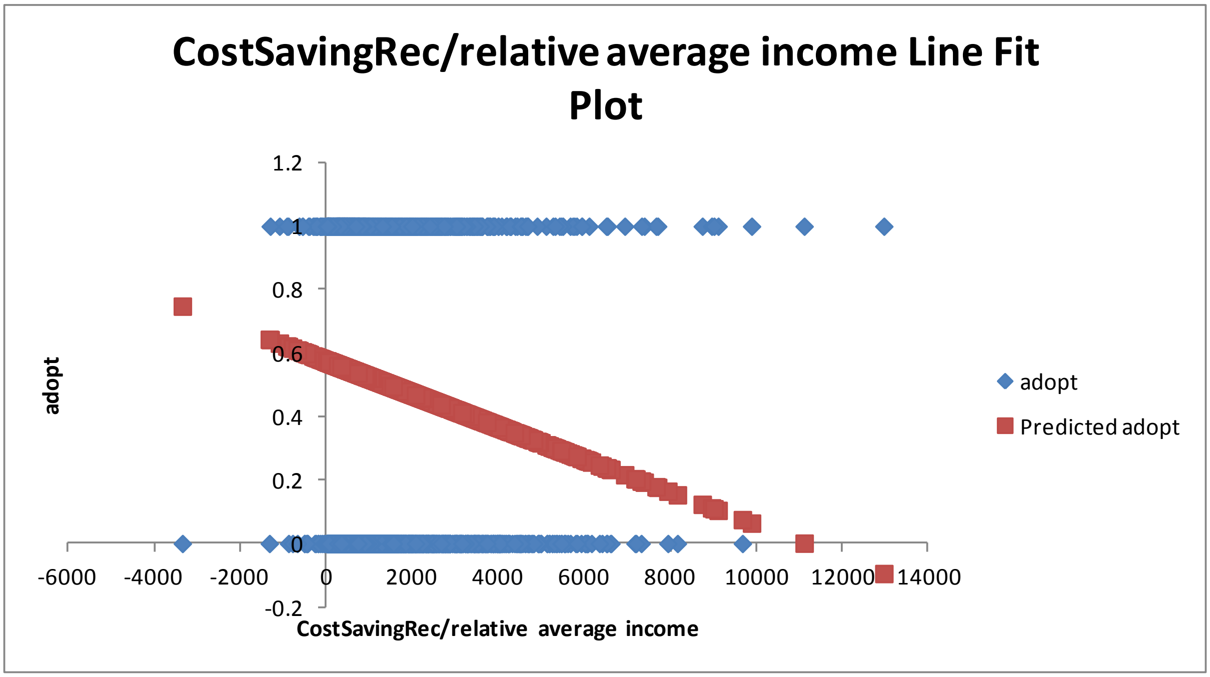
Adoption Of Technologies Vs Total Projected Energy Savings Adjusted For Provincial Average Family Incomes

We also tested the impact of family incomes on the projected energy savings. The average family incomes ((Statistics Canada) were used to create a weighting:

	2009 average family income	Relative Weighting
Total	68,410	
AB	60,290	0.88
BC	62,110	0.91
MB	62,550	0.91
NB	60,670	0.89
NF	64,420	0.94
NS	69,790	1.02
NT	65,550	0.96
ON	70,790	1.03
PE	83,560	1.22
QC	66,700	0.98
SK	84,640	1.24
YK	98,300	1.44

The total projected savings adjusted to reflect family incomes in each province by dividing the total projected savings by the weighting in each province.

Using Microsoft Excel's regression tool, we obtain the results below that show the relationship between the forecasted energy cost savings per square meter to each homeowner (independent variable) and the percentage of households (dependent variable) that adopted at least one of the recommendations.



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.1064
R Square	0.0113
Adjusted R Square	0.0112
Standard Error	0.4965
Observations	6380

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	57.49%	0.0084	68.4818	0.0000
Total Projected Cost savings/ Relative Average Income	-0.0052%	0.0000	-8.5465	0.0000

Adoption % = 57.49% + .0052%*Total Projected Cost savings/Relative Average Weighting

Both the co-efficients are significant at the 95% level. A $1000 increase in weighted cost savings results in a 5.2% decrease in adoption. The tests show a negative correlation between adoption and weighted projected home energy cost savings.

Thus,

Hypothesis		Conclusion
Ho$_{4.3}$	Homeowners with higher forecasted total home energy costs adjusted by average provincial family income will have higher levels of adoption of energy saving building technologies.	Hypothesis is rejected – there is a negative statistical correlation between the adoption % and the size of the energy savings per square meter.

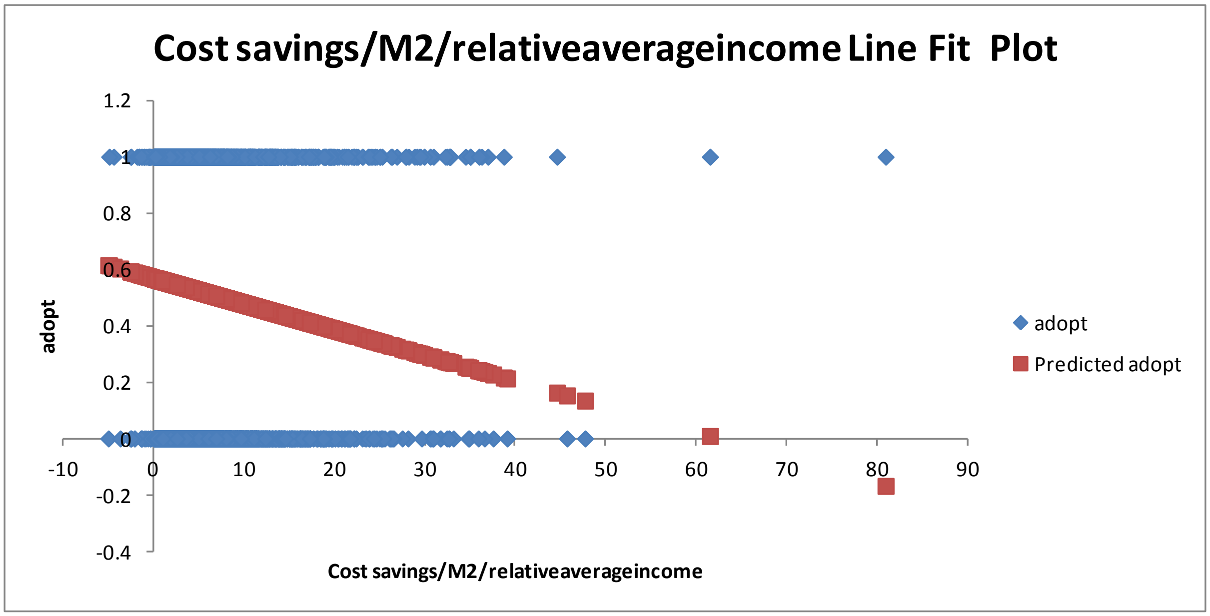
Adoption Of Technologies Vs Total Projected Energy Savings Per Square Meter Adjusted For Provincial Average Family Incomes

We also tested the impact of family incomes on the projected energy savings per square meter. The average family incomes ((Statistics Canada) were used to create a weighting:

	2009 average family income	Relative Weighting
Total	68,410	
AB	60,290	0.88
BC	62,110	0.91
MB	62,550	0.91
NB	60,670	0.89
NF	64,420	0.94
NS	69,790	1.02
NT	65,550	0.96
ON	70,790	1.03
PE	83,560	1.22
QC	66,700	0.98
SK	84,640	1.24
YK	98,300	1.44

The projected energy savings per square meter was adjusted to reflect family incomes in each province by dividing the total projected savings by the weighting in each province.

Using Microsoft Excel's regression tool, we obtain the results below that show the relationship between the forecasted energy cost savings per square meter adjusted for average family income to each homeowner (independent variable) and the percentage of households (dependent variable) that adopted at least one of the recommendations.



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.09386
R Square	0.00881
Adjusted R Square	0.00865
Standard Error	0.49716
Observations	6380

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	56.89%	0.0084	67.9043	0.0000
Cost savings/M2 /relative Average income	-0.9106%	0.0012	-7.5288	0.0000

Adoption% = 56.89% - .9106%*Cost Savings Per Square Meter Adjusted For Average Family Income

Both the coefficients are significant at the 95% level. A $10 increase in weighted cost savings/square meter results in a 9.1% decrease in adoption. The tests show a negative correlation between adoption and weighted projected home energy cost savings.

Thus,

Hypothesis	Conclusion

Ho$_{4.4}$	Homeowners with higher forecasted total home energy cost savings/square meter adjusted by average provincial family income will have higher levels of adoption of energy saving building technologies.	Hypothesis is rejected – there is a negative statistical correlation between the adoption % and the size of the weighted energy savings per square meter.

Appendix C.

Government Grant by Technology for a Sample of Provinces

Eligible Improvement/Retrofits	**Federal Grant**	**Sask**	**Ont**	**Alta**	**Man**
HEATING SYSTEM					
Replace your heating system with • an ENERGY STAR® qualified gas furnace that has a 92.0 percent annual fuel utilization efficiency (AFUE) or higher	$375	$300	$375	$400	NA
. an ENERGY STAR qualified gas furnace that has a 92.0 percent AFUE or higher and a brushless DC motor	$625	$500	$625	$500	NA
. an ENERGY STAR qualified gas furnace or oil furnace that has a 94.0 percent AFUE or higher and a brushless DC motor	$650	$520	$650	$500	NA
. an ENERGY STAR qualified gas furnace or oil furnace that has a 94.0 percent AFUE or higher and a brushless DC motor (when installing a condensing furnace for the first time)	$790	$630	$790	$500	NA
. an ENERGY STAR qualified condensing gas boiler that has a 90.0 percent AFUE or higher	$750	$600	$750	$600	NA
. an ENERGY STAR qualified oil boiler that has an 85.0 percent AFUE or higher	$750	$600	$750	$600	NA
. an ENERGY STAR qualified oil furnace that has an 85.0 percent AFUE or higher	$375	$300	$375	NA	NA
. an ENERGY STAR qualified oil furnace that has an 85.0 percent AFUE or higher and a brushless DC motor	$625	$500	$625	NA	NA
In the case of mobile homes (only) • where a zero-clearance furnace is being replaced, an ENERGY STAR qualified zero-clearance gas furnace that has a 90.0 percent AFUE or higher	$375	$300	$375	$400	NA

Eligible Improvement/Retrofits	Federal Grant	Sask	Ont	Alta	Man
Install an earth-energy system (ground or water source) that is compliant with CAN/CSA-C448 and certified by the Canadian GeoExchange Coalition (www.geo-exchange.ca) – applies to a new system or a complete replacement.	$4375	$3500	$4375	NA	NA
Replace a heat pump unit of an existing earth-energy system (ground or water source). The system must be compliant with CAN/CSA-C448 and certified by the Canadian GeoExchange Coalition (www.geo-exchange.ca). (*per equipment replaced)	$1750	$1400	$1750	NA	NA
Replace your existing space and domestic water heating equipment with an integrated mechanical system (IMS) that has an overall thermal performance factor of 0.90 or higher. The system must be compliant with the CSA P.10-07 standard and meet or exceed the standard's *premium* performance requirements. (*per equipment replaced)	$1625	$1300	$1625	NA	NA
Replace your wood-burning appliance with a model that meets either CSAB415.1- M92 or the U.S. Environmental Protection Agency (EPA) (40 CFR Part 60) wood-burning appliance standard; an indoor wood pellet-burning appliance (includes stoves, furnaces and boilers that burn corn, grain or cherry pits); or a masonry heater. (*per equipment replaced)	$375	$300	$375	NA	NA
Replace your solid fuel-fired outdoor boiler with a model that meets CAN/CSA-B415.1 or the U.S. EPA Outdoor Wood-fired Hydronic Heater (OWHH Method 28) Program, Phase 1 or 2. The capacity of the new boiler must be equal to or smaller than the capacity of the boiler being replaced.	$375	$300	$375	NA	NA
Install a minimum of 5 electronic thermostats for electric baseboard heaters. Electric baseboard heating must be the primary space heating system. (*for each set of 5 electronic thermostats)	$40/5	$30/5	$40/5	NA	NA

Eligible Improvement/Retrofits	**Federal Grant**	**Sask**	**Ont**	**Alta**	**Man**
Install an ENERGY STAR qualified air-source heat pump for both heating and cooling that has a seasonal energy efficiency ratio (SEER) of 14.5 or higher and a minimum heating capacity of 12 000 Btu/hour.	$500	$400	$500	NA	NA
COOLING SYSTEM (Replacement Only)					
Replace your central air-conditioning system with an ENERGY STAR qualified system that has a SEER of 14.5 or higher (complete system replacement, including indoor coil and outdoor components).	$375	$75	$375	NA	NA
Replace your window air conditioner(s) with an ENERGY STAR qualified unit(s) (per unit replaced max 5 units).	$25	$20	$25	NA	NA
VENTILATION SYSTEM (New installation or replacement)					
Install a ventilation system that is certified by the Home Ventilating Institute (HVI) as a heat- or energy-recovery ventilator	$375	$300	$375	NA	NA
DOMESTIC HOT WATER EQUIPMENT					
Install a solar domestic hot water system that includes solar collectors that meet the CAN/CSA F378.87 standard **AND** that provides a minimum energy contribution of 6 gigajoules per year (GJ/yr).	$1250	$1000	$1250	NA	NA
Replace your domestic hot water heater with an ENERGY STAR qualified instantaneous, gas-fired water heater that has an energy factor (EF) of 0.82 or higher	$315	$250	$315	$250	NA
Replace your domestic hot water heater with an ENERGY STAR qualified instantaneous, condensing gas-fired water heater that has an EF of 0.90 or higher	$375	$300	$375	$300	NA
Replace your domestic hot water heater with a condensing gas storage type water heater that has a thermal efficiency of 94 percent or higher	$375	$300	$375	$300	NA

Eligible Improvement/Retrofits	**Federal Grant**	**Sask**	**Ont**	**Alta**	**Man**
Install a drain-water heat recovery (DWHR) system with an efficiency between 30.0 and 41.9 percent	$95	$75	$95	NA	NA
Install a drain-water heat recovery (DWHR) system with an efficiency of 42.0 percent or higher	$165	$130	$165	NA	NA
CEILING INSULATION					
Increase the insulation value of • your attic from R12 or less to R40	$500	$400	$500	$375	NA
• your attic from >R12 ~ R25 to R40	$250	$200	$250	$187.50	NA
• your attic from R12 or less to R50	$750	$600	$750	$562.50	NA
• your attic from >R12 ~ R25 to R50	$375	$300	$375	$281.25	NA
• your attic from >R25 ~ R35 to R50	$125	$100	$125	$93.75	NA
• your flat roof and/or cathedral ceiling from R12 and less to R28	$750	$600	$750	$562.50	NA
• your flat roof and/or cathedral ceiling from >R12 ~ R25 to R28	$250	$200	$250	$187.50	NA
Add a minimum insulation value of RSI 1.8 (R-10) to your uninsulated flat roof and/or cathedral ceiling	$500	$400	$500		NA
EXTERIOR WALL INSULATION					
Increase the insulation value of exterior wall: . by R3.8 ~ R9 for 20% of wall	$225	$180	$225	$168.75	NA
. by R3.8 ~ R9 for 40% of wall	$450	$360	$450	$337.50	NA
. by R3.8 ~ R9 for 60% of wall	$675	$540	$675	$506.25	NA
. by R3.8 ~ R9 for 80% of wall	$900	$720	$900	$675.00	NA
. by R3.8 ~ R9 for 100% of wall	$1125	$900	$1125	$843.75	NA
. by > R9 for 20% of wall	$375	$300	$375	$281.25	NA
. by > R9 for 40% of wall	$750	$600	$750	$562.50	NA
. by > R9 for 60% of wall	$1125	$900	$1125	$843.75	NA

Eligible Improvement/Retrofits	**Federal Grant**	**Sask**	**Ont**	**Alta**	**Man**
. by > R9 for 80% of wall	$1500	$1200	$1500	$1125	NA
. by > R9 for 100% of wall	$1875	$1500	$1875	$1406.25	NA
EXPOSED FLOOR INSULATION (overhangs and floors above an unheated space, excluding crawl spaces)					
Insulate your entire exposed floor and increase its insulation value by a minimum of RSI 3.5 (R-20). A minimum floor area of 14 square metres (150 square feet) must be insulated to qualify.	$190	$150	$190	$142.50	NA
BASEMENT INSULATION					
Increase the insulation value of basement wall: . by R10 ~ R23 for 20% of wall	$125	$100	$125	$93.75	NA
. by R10 ~ R23 for 40% of wall	$250	$200	$250	$187.50	NA
. by R10 ~ R23 for 60% of wall	$375	$300	$375	$281.25	NA
. by R10 ~ R23 for 80% of wall	$500	$400	$500	$375	NA
. by R10 ~ R23 for 100% of wall	$625	$500	$625	$468.75	NA
. by > R23 for 20% of wall	$250	$200	$250	187.50	NA
. by > R23 for 40% of wall	$500	$400	$500	$375	NA
. by > R23 for 60% of wall	$750	$600	$750	$562.50	NA
. by > R23 for 80% of wall	$1000	$800	$1000	$750	NA
. by > R23 for 100% of wall	$1250	$1000	$1250	$937.50	NA
BASEMENT HEADER INSULATION					
Seal and insulate your entire basement header area, increasing its insulation value by a minimum of RSI 3.5 (R-20)	$125	$100	$125	$93.75	NA
CRAWL SPACE INSULATION					
Increase the insulation value of the crawl space's total exterior wall area, including the header area					

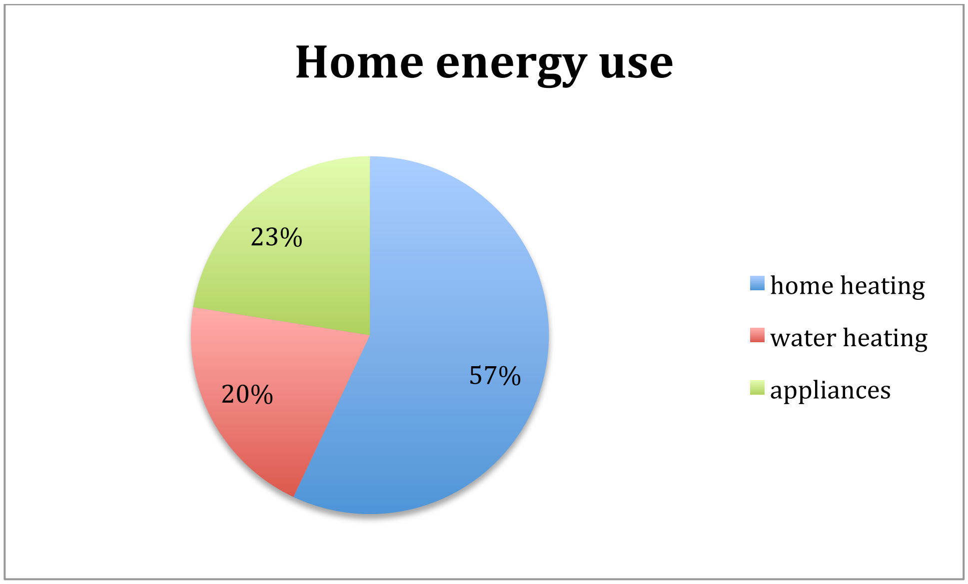
Eligible Improvement/Retrofits	**Federal Grant**	**Sask**	**Ont**	**Alta**	**Man**
. by R10 ~ R23 for 100% of the area	$500	$400	$500	$375	NA
. by >R23 for 100% of the area	$1000	$800	$1000	$750	NA
Insulate 100 percent of the floor above the crawl space to increase its insulation value by a minimum of RSI 4.2 (R-24).	$250	$200	$250	$187.50	NA
AIR SEALING					
Perform air sealing to improve the air-tightness of your home to achieve the air change rate indicated in your EcoENERGY Retrofit – Homes report.	$190	$150	$190	NA	NA
BONUS: exceed target by 10%	$120	$95	$120	NA	NA
BONUS: exceed target by 20%	$240	$190	$240	NA	NA
DOORS/WINDOWS/SKYLIGHTS (heated space only)					
Replace windows and skylights with models that are ENERGY STAR qualified for your climate zone. (*per unit replaced)	$40	$30	$40	NA	NA
Replace your exterior door(s) with an ENERGY STAR qualified model(s) for you climate zone. (*per unit replaced)	$40	$30	$40	NA	NA
WATER CONSERVATION					
Replace your toilet with a low-flush or dual-flush toilet rated at 6 litres per flush or less (*per unit replaced)	$65	$50	$65	NA	NA

Appendix D.

Energy saving technologies

Introduction

Canadian residences use energy in three areas: space heating and cooling, domestic hot water heating and electrical appliances. Gordon Howell, P.Eng with Howell-Mayhew Engineering, in ahis presentation (Howell, 2008) on the Riverdale NetZero project[1] in Edmonton, Alberta, indicated that the split of energy use in a conventional home is approximately 57% for home heating, 23% for appliance sand 20% for water heating (Figure 4.1):



Home Energy Use

The strategies for energy reduction vary depending on the type of use. The typical strategies for reduction in home heating costs (percentages represent the portion of the cost that could be reduced by the strategies) include:

- Building envelope - Energy efficiency from improvements to the building envelope and mechanical systems (53%)
    - High R value wall ceiling and floor construction
    - High efficiency windows

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[1] The Riverdale NetZero Project is one of 12 EQuillibrium homes sponsored by CMHC.

    - Reduced air leakage
    - Heat recovery system on air exchange
- Building envelope improvements leading to internal gains from electricity and people (13%)
- Passive solar heating (19%)
- Active solar heating (10%) and/or geothermal, and
- Solar PhotoVoltaic (5%).

The strategies for reduction in water heating costs include:

- Water efficiency and heat recovery (75%)
    - Restricted shower heads and faucets
    - Water conserving dish washer
    - Water conserving clothes washer
    - Drain water heat recovery system
- Active Solar heating (23%)
- Solar Photovoltaic (2%)

The strategies for reduction in energy use for electrical appliances include:

- Energy efficiency (52%)
    - Most efficient EnerGuide rated appliances
    - Energy efficient lighting
    - Energy efficient motors
    - Control of Phantom Electrical loads
- Solar PV (48%)

Space Heating and Cooling

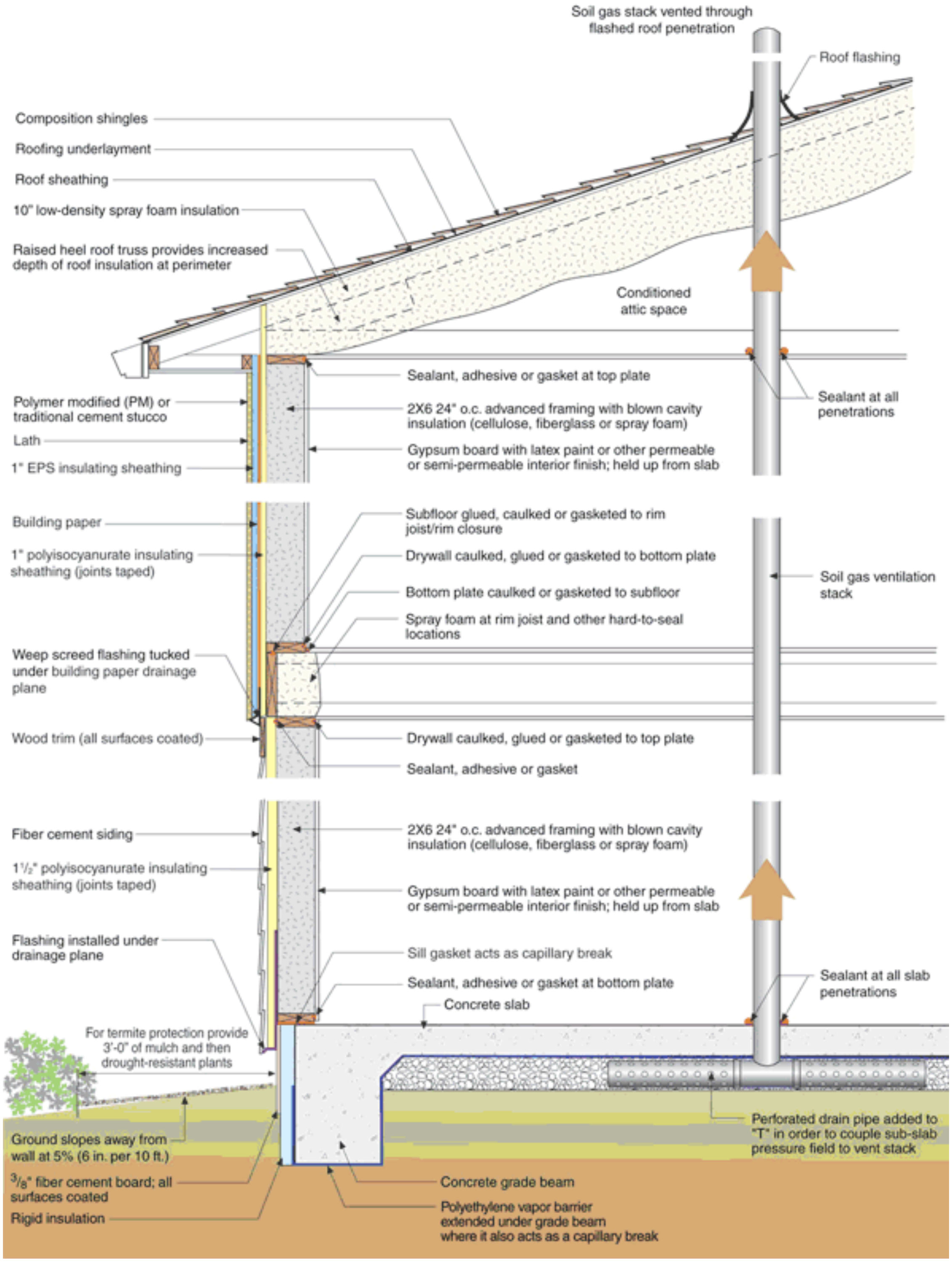
Building envelope

The building envelope is the exterior surface of the building and includes the foundation, walls, windows, doors and roof. The building envelope is made up of the following elements:

- Interior finish
- Air barrier
- Vapor barrier
- Structure
- Insulation

- Rain shield
- Exterior finish.

The following diagram (Sacramento Municipal Utility District) provides an overview of the elements of the building envelope.



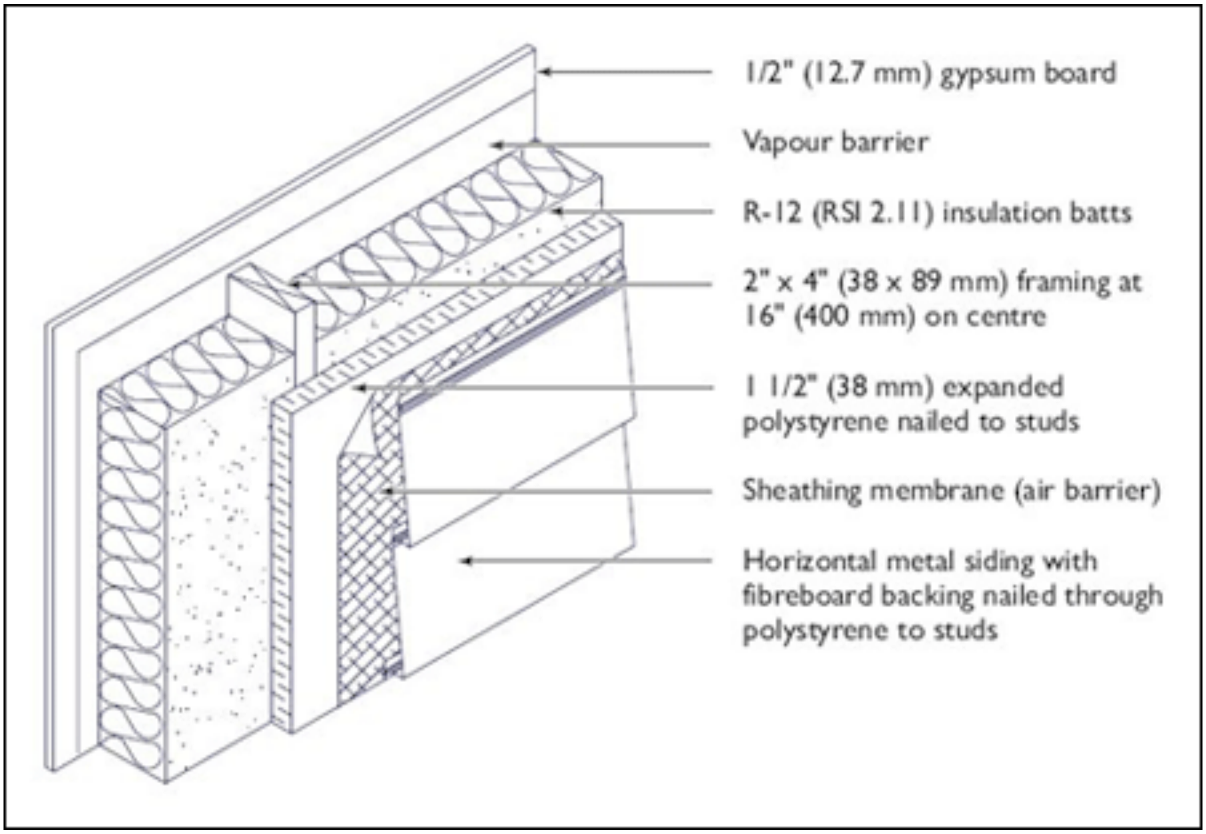
The elements of a modern building envelope (source: Sacramento Municipal Utility District –

Building the Home of the Future)

Energy efficiency starts with a well-constructed building envelope. The key focus for energy efficiency is super insulation and a high quality air barrier.

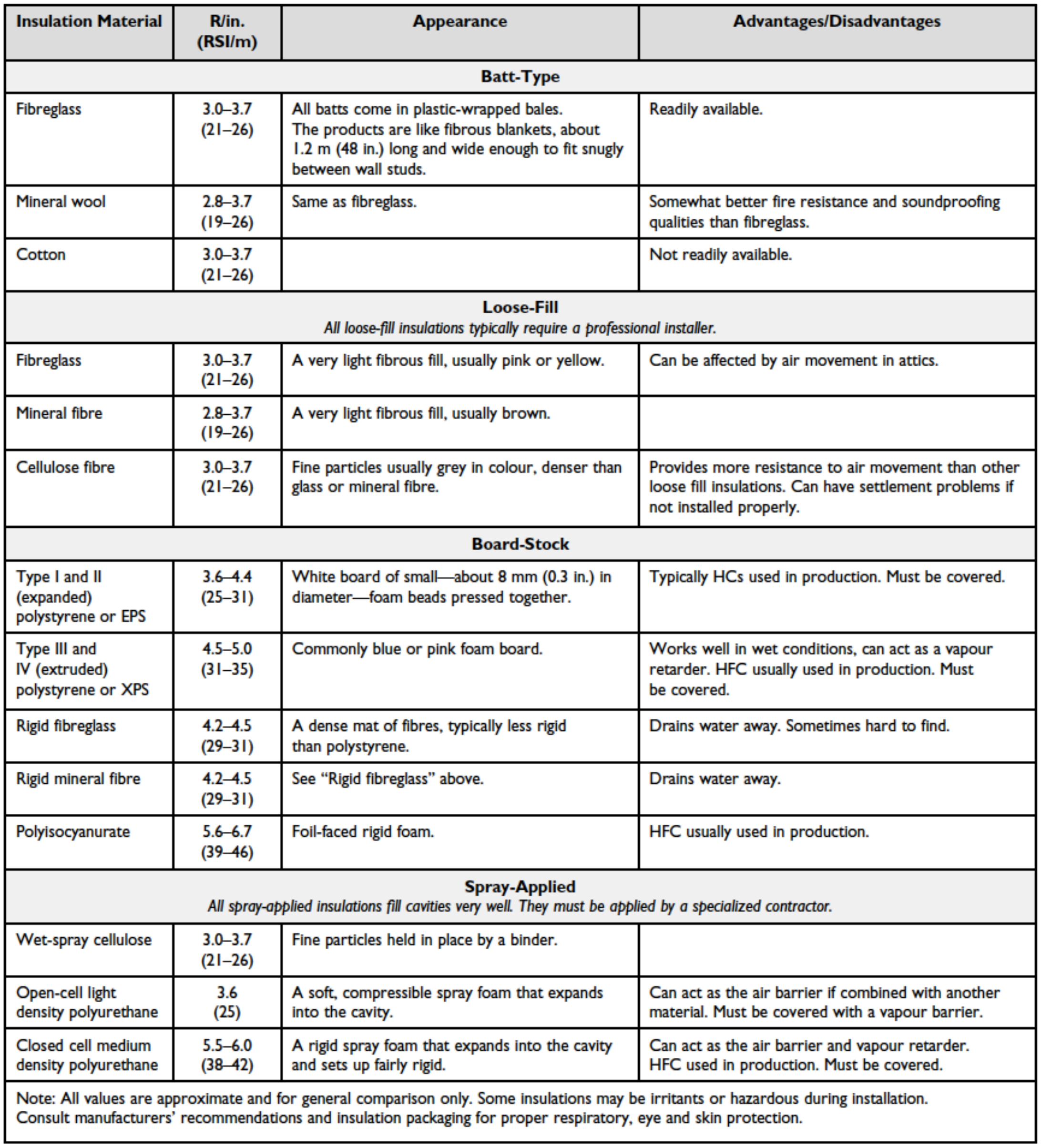
The effectiveness of insulation is measured in R values or the metric equivalent RSI values. The higher the R value or RSI value, the more resistant the insulation is to the movement of heat.

Typical Canadian construction techniques use a wooden frame with insulation inserted between the studs in the frame (CE 19 Canada Mortgage and Housing Corporation). The following CMHC diagram provides an overview of a typical wall construction.



Typical framed wall construction (source: CMHC About your House - Insulating your house)

There are a number of commonly used insulation materials. The choice of the most appropriate material is usually determined by the cost and the application. CMHC provides an excellent summary of insulation materials. In most cases there are multiple options and no unambiguously optimal choice.



Insulation Material	R/in. (RSI/m)	Appearance	Advantages/Disadvantages
Batt-Type			
Fibreglass	3.0–3.7 (21–26)	All batts come in plastic-wrapped bales. The products are like fibrous blankets, about 1.2 m (48 in.) long and wide enough to fit snugly between wall studs.	Readily available.
Mineral wool	2.8–3.7 (19–26)	Same as fibreglass.	Somewhat better fire resistance and soundproofing qualities than fibreglass.
Cotton	3.0–3.7 (21–26)		Not readily available.
Loose-Fill *All loose-fill insulations typically require a professional installer.*			
Fibreglass	3.0–3.7 (21–26)	A very light fibrous fill, usually pink or yellow.	Can be affected by air movement in attics.
Mineral fibre	2.8–3.7 (19–26)	A very light fibrous fill, usually brown.	
Cellulose fibre	3.0–3.7 (21–26)	Fine particles usually grey in colour, denser than glass or mineral fibre.	Provides more resistance to air movement than other loose fill insulations. Can have settlement problems if not installed properly.
Board-Stock			
Type I and II (expanded) polystyrene or EPS	3.6–4.4 (25–31)	White board of small—about 8 mm (0.3 in.) in diameter—foam beads pressed together.	Typically HCs used in production. Must be covered.
Type III and IV (extruded) polystyrene or XPS	4.5–5.0 (31–35)	Commonly blue or pink foam board.	Works well in wet conditions, can act as a vapour retarder. HFC usually used in production. Must be covered.
Rigid fibreglass	4.2–4.5 (29–31)	A dense mat of fibres, typically less rigid than polystyrene.	Drains water away. Sometimes hard to find.
Rigid mineral fibre	4.2–4.5 (29–31)	See "Rigid fibreglass" above.	Drains water away.
Polyisocyanurate	5.6–6.7 (39–46)	Foil-faced rigid foam.	HFC usually used in production.
Spray-Applied *All spray-applied insulations fill cavities very well. They must be applied by a specialized contractor.*			
Wet-spray cellulose	3.0–3.7 (21–26)	Fine particles held in place by a binder.	
Open-cell light density polyurethane	3.6 (25)	A soft, compressible spray foam that expands into the cavity.	Can act as the air barrier if combined with another material. Must be covered with a vapour barrier.
Closed cell medium density polyurethane	5.5–6.0 (38–42)	A rigid spray foam that expands into the cavity and sets up fairly rigid.	Can act as the air barrier and vapour retarder. HFC used in production. Must be covered.
Note: All values are approximate and for general comparison only. Some insulations may be irritants or hazardous during installation. Consult manufacturers' recommendations and insulation packaging for proper respiratory, eye and skin protection.			

Common Insulation Materials (Source: CMHC About your house - Insulating your house)

The first strategy to improve energy efficiency is to increase the insulation of the building envelope. A typical Canadian home built today would have walls with an R value of 16-18. There are a number of techniques used to increase the R value significantly. Homes built as part of CMHC's EQuillibrium program[2] typically has walls

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[2] EQuilibrium™ is a national housing initiative led by Canada Mortgage and Housing Corporation (CMHC). Together, the private and public sectors are building homes designed to address occupant health and comfort, energy efficiency, renewable energy production, resource conservation, reduced environmental

with an R value of 50-60 and attics with an R value of 90-100. The insulation of choice for most of the EQuillibrium homes is cellulose fiber.

Passive design

Passive design is an approach to building design that uses architectural design to reduce traditional energy consumption and provide thermal comfort to the home. Passive design is very specific to the location of the home in terms of climate, orientation, etc. The City of Vancouver has developed extensive guidelines for the construction of passive design homes: 'Passive Design Toolkit – Best Practices' (Mikler, Bicol, Beisnes, & Labrie, 2008). Although the specific application will vary for every location and climate, the basic strategies are the same:

- Passive Heating – combines a well insulated building envelop with a design to capture solar radiation to provide heat energy for the home. Considerations include orientation of the building, shape of the building, strategic placement of windows, thermal mass to store solar energy, and appropriately designed shading.
- Passive Ventilation – use naturally occurring air flow patterns to bring fresh air into the home
- Passive Cooling – are often combined with passive ventilation strategies to draw heat from the home during periods when the outside air temperature is lower than the inside temperature
- Daylighting – maximizes the use of natural sunlight to reduce the need for electrical lighting.

The US Department of Energy's web site on Energy Savers (United States Department of Energy) describes the 5 elements of a passive solar home:

> 'The following five elements constitute a *complete* passive solar home design. Each performs a separate function, but all five must work together for the design to be successful.
>
> Aperture (Collector) - the large window area through which sunlight enters the building.
>
>> Typically, the aperture(s) should face within 30 degrees of true south and should not be shaded by other buildings or trees from 9 a.m. to 3 p.m. each day during the heating season.

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impact and affordability. Fifteen teams have been selected to build EQuilibrium™ demonstration projects across Canada… Source: http://www.cmhc-schl.gc.ca/en/co/maho/yohoyohe/heho/eqho/index.cfm

Absorber - the hard, darkened surface of the storage element.

> This surface—which could be that of a masonry wall, floor, or partition (phase change material), or that of a water container—sits in the direct path of sunlight. Sunlight hits the surface and is absorbed as heat.

Thermal mass - the materials that retain or store the heat produced by sunlight.

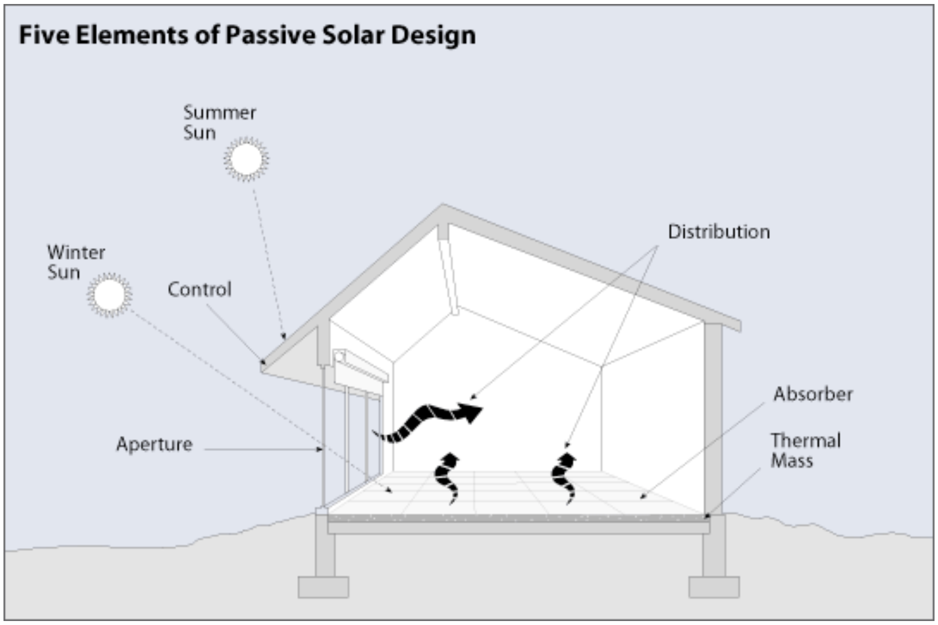
> The difference between the absorber and thermal mass, although they often form the same wall or floor, is that the absorber is an exposed surface whereas thermal mass is the material below or behind that surface.

Distribution - the method by which solar heat circulates from the collection and storage points to different areas of the house.

> A strictly passive design will use the three natural heat transfer modes—conduction, convection, and radiation—exclusively. In some applications, however, fans, ducts, and blowers may help with the distribution of heat through the house.

Control - roof overhangs can be used to shade the aperture area during summer months.

> Other elements that control under- and/or overheating include electronic sensing devices, such as a differential thermostat that signals a fan to turn on; operable vents and dampers that allow or restrict heat flow; low-emissivity blinds; and awnings.’



Five elements of Passive Solar Design (United States Department of Energy)

The primary objective of passive solar heating is to use solar energy to heat the house. An unfortunate side effect of passive solar heating is that it can also result in overheating in summer months. There are a number of strategies to resolve this problem.

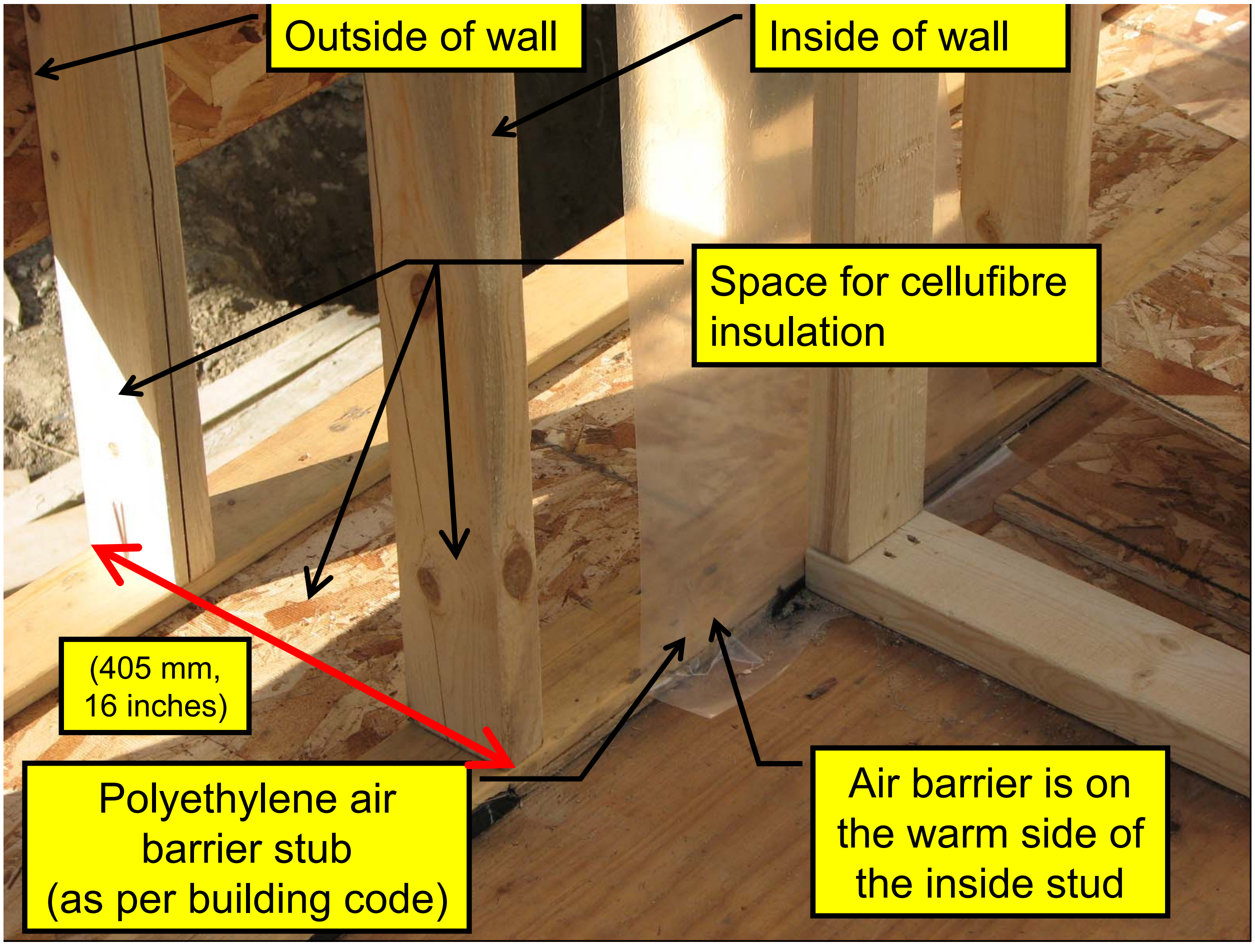
CMHC, in its study *The Effects of Reflective Interior Shades on Cooling Energy Consumption at the CCHT Research Facility* (07-102 Canada Morgage and Housing Corporation, 2007) tested the effects of Reflective interior shades. Although the tests found that cooling costs could be reduced by approximately 10%, CMHC found that the shades significantly increased window surface temperatures and as a result could not safely recommend their use.

Super-insulated walls

There are a number of techniques to build super-insulated walls. These include double wall construction, structured insulated panels (SIPs), insulated concrete forms (ICFs) and other less conventional techniques such as straw bales, cord word, adobe, cob and rammed earth.

Double Wall Construction

A wall insulated with batt type or loose fill insulation would have to be a minimum of 16 inches thick to obtain an R value of 60 (see chart above – batt and loose fill insulation will provide an R value of up to 3.7/inch). One of the construction techniques pioneered by Rob Dumont and used in many of the EQuillibrium homes is the double wall construction with cellulose fibre insulation (Howell, 2008).



Double wall construction (Source: Gordon Howell presentation on the Riverdale Net Zero Home)

There are a number of advantages and disadvantages of the double wall construction. The main trade-offs is that while the technology is a proven, cost-effective, environmentally-friendly approach, few builders use it and it tends to require both more lumber and more floor space.

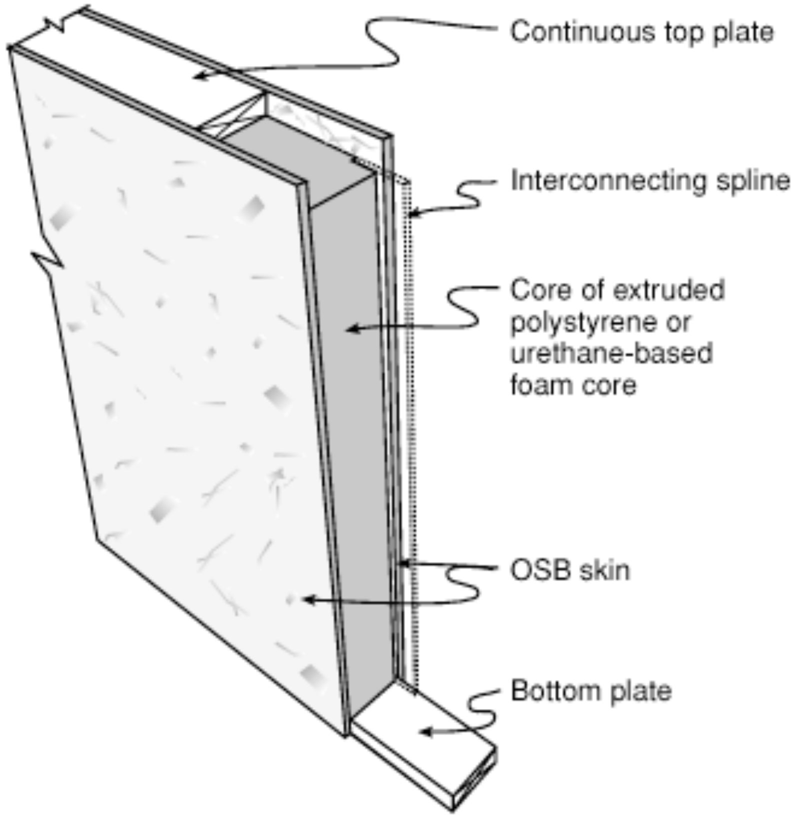
Advantages and Disadvantages of Double Wall Construction

Double Wall Construction with Cellulose Fibre Insulation	
Advantages	Disadvantages
• Cost effective • Eliminates most thermal bridging • Cellulose is environmentally friendly option • Uses proven (framed wall) construction techniques • Flexible	• Not many builders with experience • May use more lumber than a standard wall construction • Takes up significant interior floor space

Structured Insulated Panels (SIPs)

The Structural Insulated Panel Association defines SIPs as follows (Structural Insulated Panel Association):

> Structural insulated panels (SIPs) are high performance building panels used in floors, walls, and roofs for residential and light commercial buildings. The panels are typically made by sandwiching a core of rigid foam plastic insulation between two structural skins of oriented strand board (OSB). Other skin material can be used for specific purposes. SIPs are manufactured under factory controlled conditions and can be custom designed for each home.



Typical SIP (National Reserach Council Canada, 1996)

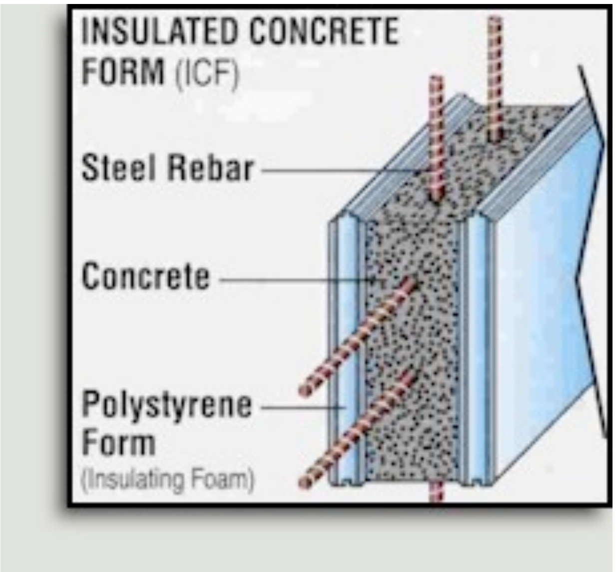
There are a number of advantages and disadvantages of SIPs (Table 4-2). The main trade-off is that while they are often more effective barriers, they involve higher costs, and embody more energy.

Advantages and Disadvantages of Structured Insulated Panels

Structural Insulated Panels	
Advantages	Disadvantages
• SIPs use rigid foam plastic insulation, they have a higher R value per inch than batt and loose types of insulation • Eliminates most thermal bridging • Can be assembled by untrained labor • Much tighter air barrier	• More expensive • Higher embodied energy • Concerns about durability in Canadian climate

Insulated Concrete Forms

Insulated concrete forms (Treehugger, 2007), illustrated in Figure 4-8) '… are rigid plastic foam forms that hold concrete in place during curing and remain in place afterwards to serve as thermal insulation for concrete walls. The foam sections are lightweight and result in energy-efficient, durable construction.'



Insulated Concrete Forms (Treehugger, 2007)

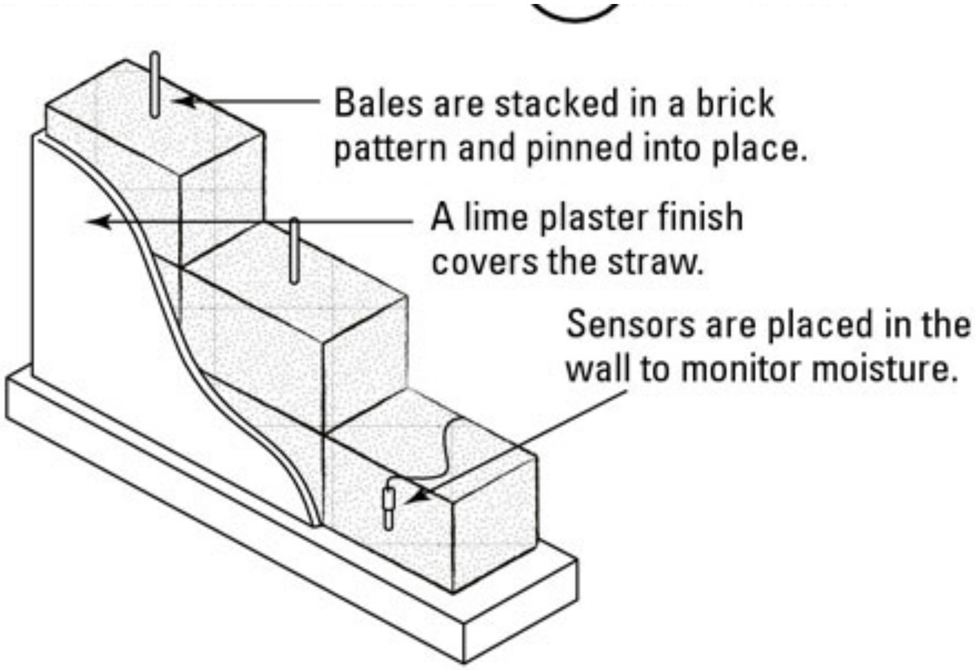
Once again, expense tends to be traded off for effectiveness.

Advantages and Disadvantages of Insulated Concrete Forms

Insulated Concrete Forms	
Advantages	Disadvantages
• Much tighter air barrier • Becoming generally accepted as an alternative for foundation construction • Higher R value then the equivalent thickness of standard framed wall construction	• General resistance for use as general wall construction • More expensive • Difficult to install properly

Straw Bale Construction

Straw-bale construction is a construction technique that uses straw as structural elements and or insulation (Figure 4-9). A typical wall will start with straw bales then will be covered with 1 to 1.5 inches of plaster.



Straw bale construction

While this technology offers some attractive advantages, it suffers from concerns about durability that are reflected in the resale value of homes constructed using the technology.

Advantages and Disadvantages of Straw Bale Construction

Straw Bale Construction	
Advantages	Disadvantages
• High thermal mass (Strawbale.com) • R value of approximately 28 (02-115 Canada Morgage and Housing Corporation, 2002) • Three times more fire resistant than a typical (Strawbale.com) • Lower construction costs for materials • Built from waste straw that would typically be burned • High mass in the walls results in better sound proofing (Strawbale.com)	• General resistance for use as general wall construction • Significant concern about resale value • Higher construction costs if labor is included

Other Building Techniques

There are a number of other building techniques available that can be considered for super-insulated walls, all with a balance of advantages and disadvantages (Table 4-5):

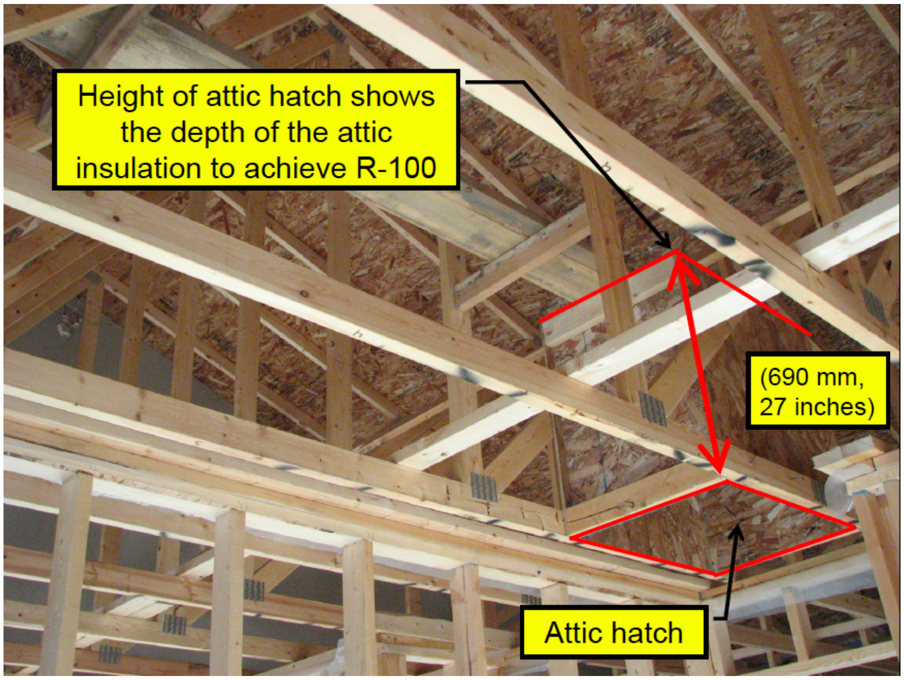
- **Cordwood** construction stacks up short, round lengths of wood into a wall. The cordwood is held together with mortar, creating a wall with both high insulation and high thermal mass.
- **Adobe** construction is made of bricks of mud and straw.
- **Cob** is a mixture of clay, sand, straw, water, and earth, which makes it very similar to adobe, but instead of being formed into bricks, cob is built up a handful at a time.
- **Rammed earth** is essentially just man-made stone. Rammed earth walls are formed by packing, or *tamping,* a mix of soil with a tiny amount (around 3 percent) of Portland cement, which acts as a binding and strengthening agent, within a two-sided form. The finished rammed earth wall is nearly as strong as concrete.

Advantages and Disadvantages of Other Building Techniques

Other building techniques	
Advantages	Disadvantages
- Typically higher thermal mass - Typically lower construction costs for materials	- General resistance for use as general wall construction - Significant concern about resale value - Higher construction costs if labor is included

Attic Insulation

As discussed above, the typical R Value for attics in EQuillibrium home construction is R 100. Using batt or loose fill insulation, this will require 27 to 30 inches (100/3.7) of insulation. Building homes with a high R value in the attic is not typically a challenge because the design of most modern Canadian homes provides ample room to add 30 inches insulation in the attic.

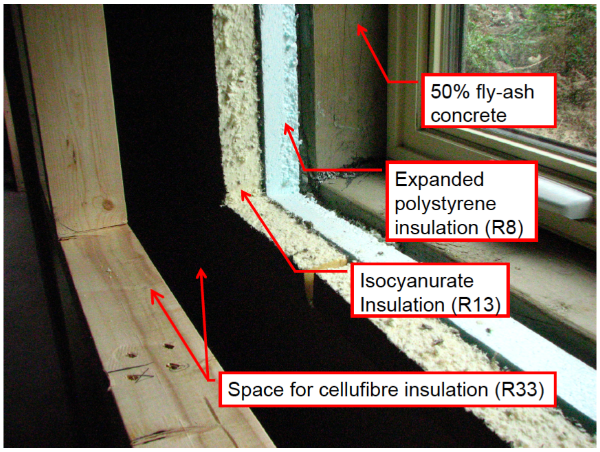


Typical attic construction (Howell, 2008)

Foundation Insulation

There are very few options available for insulating underneath a concrete floor. The typical insulation is board-stock. EQuillibrium homes typically target R 24 insulation under the floor and this is accomplished using 5 inches of extruded polystyrene.

Foundation walls are a simpler problem and any of the techniques used for walls can be applied to basement walls. The typical configuration is a combination of board stock insulation with an internal wall allowing for additional cellulose or other insulation (Howell, 2008).



Foundation wall structure (Howell, 2008)

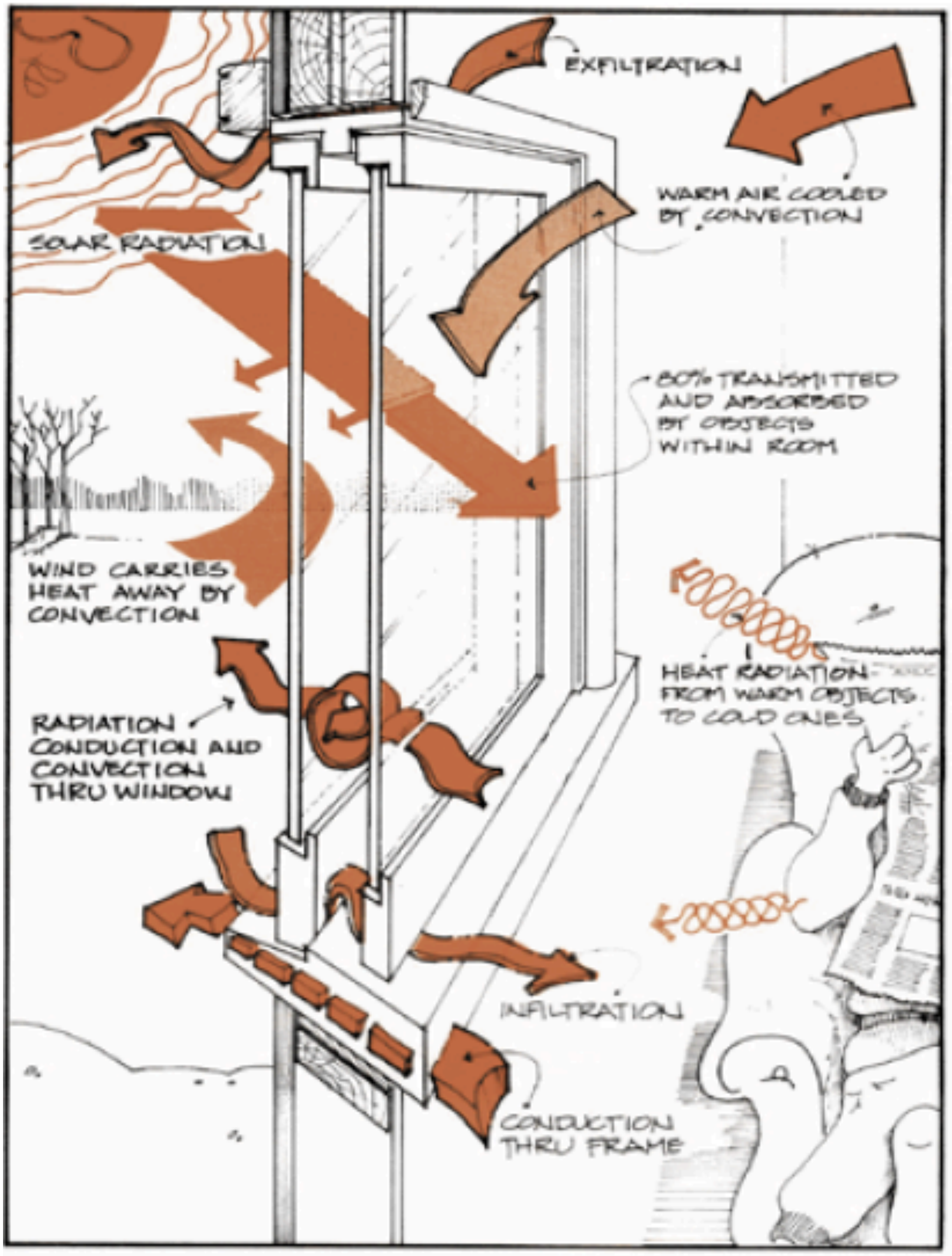
The Dumont house in Saskatoon has a wood basement with double wall construction with space for cellulose insulation.

Windows

Windows are a key element to every home. They are often a key part of the architectural design of a home. Windows are a source of light, passive heat and ventilation. Poorly designed windows can cause overheating in the summer and cold drafts in the winter. Windows affect both indoor living comfort as well as Energy savings.

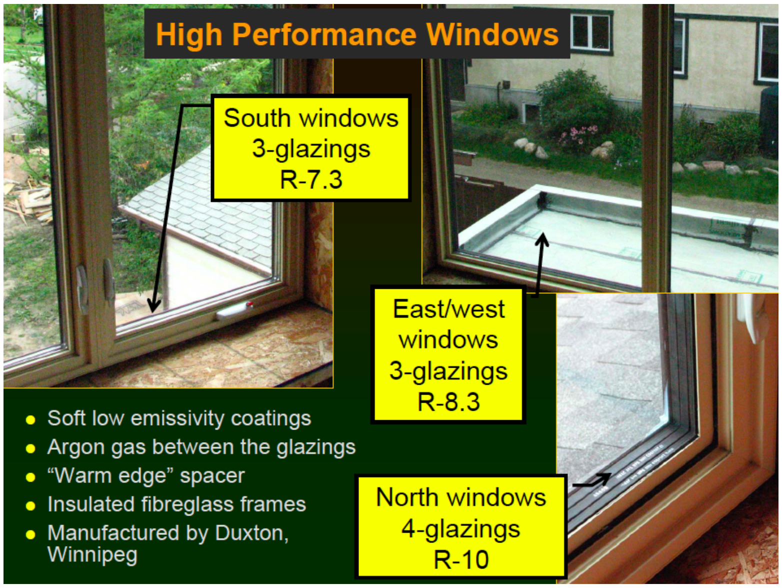
Heat moves through windows in four ways (Carbon Dioxide Reduction Edmonton, 2004):

- Conduction is the transfer of heat energy through the molecules of a substance. Conduction always transfers heat from a region of higher temperature to a region of lower temperature. Materials that are low conductors have a high resistance to heat flow. This resistance is measured in R value
- Convection is the movement of heat in liquids and gases due to temperature difference. Air is a poor conductor but will convect heat because warm air is light and tends to rise while cold air is heavy and tends to sink.
- Radiation is heat radiated by an object because of the object’s temperature.
- Air Leakage is air leaking into the house (infiltration) or leaking out of the house (exfiltration). Air leakage is caused by a pressure difference between the inside of the house and the outside as a result of wind or appliances such as exhaust vents. Air leakage occurs through poorly fitted or weather stripped windows.



Sources of heat loss in windows (Carbon Dioxide Reduction Edmonton, 2004)

Windows are considered the weakest link in the envelope as windows typically have a very low R value. The strategy used by most EQuillibrium homes is to minimize the glazing on the north, west and east walls while increasing the glazing on the south wall to approximately 6-10% of the heated floor area for passive solar heating.


High Performance Windows

- Soft low emissivity coatings
- Argon gas between the glazings
- "Warm edge" spacer
- Insulated fibreglass frames
- Manufactured by Duxton, Winnipeg

High performance windows (Howell, 2008)

Air Barriers

Air leakage can account for 30% or more of heat loss in residential homes (Carbon Dioxide Reduction Edmonton, 1994). Reducing air leakage will reduce energy usage but air change in homes is needed for healthy living. This section will cover the use of air barriers to properly seal a home to reduce heat loss. The section on ventilation will cover requirements for air change.

Quirourette, Marshall and Rousseau (2000) identify four requirements for an air barrier system:

- **Continuity** requires that all of the air barriers of all components (wall, roof, windows, etc) be continuous.
- **Air Impermeability** means the air barrier materials and system must be virtually airtight.
- **Strength** means the air barrier system must have the strength to resist excessive deflection, cracking, rupture or pull through at fasteners.
- **Durability** means that the air barrier system be built to last the life of the building envelope.

CMHC, in their 1996 report on Air Barriers (96-231 Canada Mortgage and Housing Corporation, 1996), identified four basic approaches to air leakage control:

- Traditional (no special measures to control air leakage)

- Poly (fold, lap, staple, tape, and seal the vapour barrier to make it airtight)
- ADA (Airtight Drywall Approach; uses the drywall as an air barrier, with gaskets and seals at edges and penetrations)
- EASE (Exterior Air System Element; uses a vapour-pervious spun-bonded polyolefin paper between layers of pervious sheathing as an exterior air barrier)

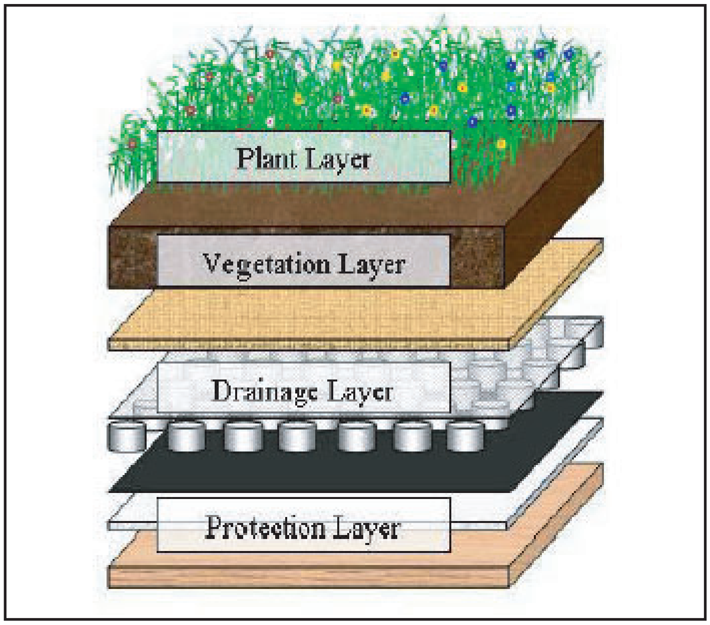
The air barrier system of choice in residential housing and in the Equilibrium homes is Poly.

Green Roofs

CMHC in their report 'Design Guidelines for Green Roofs' (Canada Mortgage and Housing Corporation, 2005) define green roofs as ' a green space created by adding layers of growing medium and plants on top of a traditional roofing system. Green roofs have been around for hundreds if not thousands of years. Although relatively new to North America, green roofs have been accepted in Europe for some time. Older residents of the Canadian prairies will remember the sod hut construction of many homes of early settlers.

CMHC's 'Green Roofs: a Resource Manual for Policy Makers' (CMHC, 2006) identifies the following elements in a green roof:

- Structural support
- Vapour control
- Thermal insulation
- Water proofing membrane
- Roof drainage layer
- Root protection layer(Earth Pledge, 2005)
- Synthetic planting media
- Plant layer



Source: CMHC Green Roofs: a Resource Manual for Policy Makers

There are two types of green roofs. Extensive green roofs are thinner and use a substrate depth of between 5 and 15 cm. Extensive green roofs are cheaper to install and easier to maintain but they are restrictive in the types of plan life they support.

Intensive green roofs have a deeper substrate layer and will support a greater variety of plants. They can be designed to be a recreational space such as a roof top garden and often are designed to provide public access. Intensive green roofs are more expensive. They will require a much stronger roof structure and often have irrigation systems to support the plant growth. Intensive green roofs will require more materials and labor to design and install.

Earth Pledge, in their publication *Green Roofs – Ecological Design and Construction* (Earth Pledge, 2005) identify a number of tangible and intangible benefits to green roofs:

- Mitigation of environmental problems
- Creation of life-enhancing value
- Energy savings
- Acoustic insulation
- Roof membrane replacement
- Greening the cityscape for owners and residents of neighbouring buildings
- Cooling of the urban landscape (urban heat islands)
- Managing storm water
- Preserving wildlife and building habitat
- Connect city dwellers to the earth
- Integrate living plants into buildings challenging the traditional perception that cities are places apart from nature

Heat Recovery Ventilators

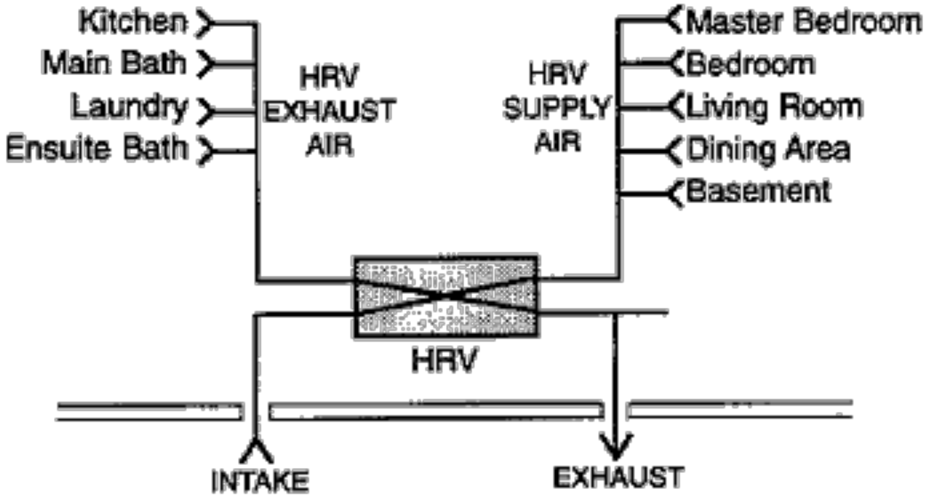
Ventilation is the exchange of indoor and outdoor air. Natural ventilation is exchange of air without the use of fans. Mechanical ventilation is air exchange created by fans.

Improving the quality of the air barrier will result in a much tighter building envelope. This reduces the fresh air that enters the house through infiltration. More tightly sealed homes will result in improved energy usage but can cause problems with combustion appliances (furnaces, water heaters), condensation problems, or air contaminants.

Homes with a high quality air barrier will require mechanical ventilation systems. In the cold of winter, this involves bringing cold outside air into the home and will result in higher energy costs. Heat Recovery Ventilators (HRV's) are air-to-air heat exchangers. They transfer the heat energy from warm stale air to the cold fresh air entering from outside.

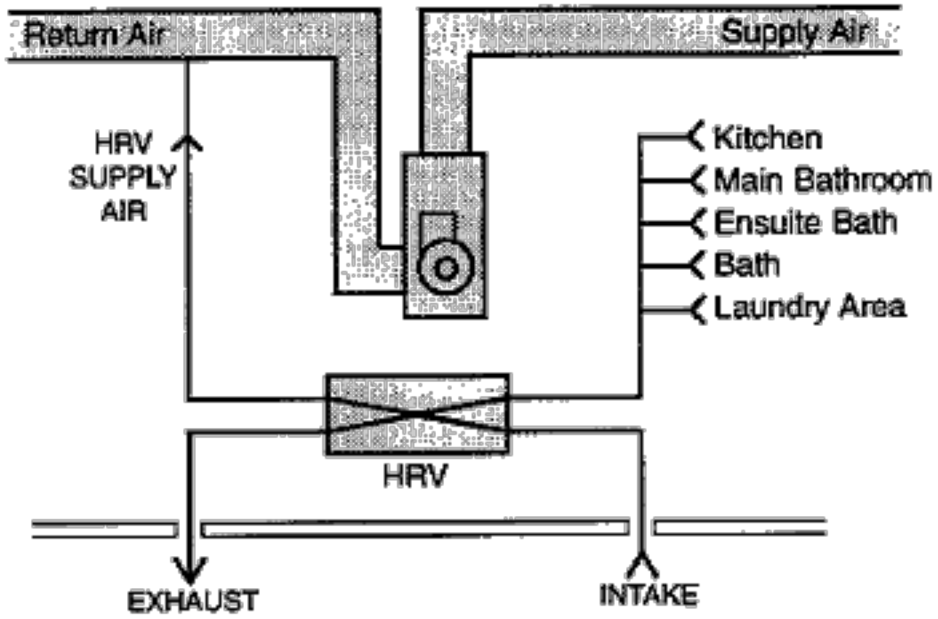
CMHC in their Research Highlight 'Field Survey of Heat Recovery Ventilation Systems (96-215 Canada Mortgage and Housing Corporation, 1996) identified four types of HRV's:

Fully Ducted HRV Installations are completely independent of any other air circulating devices. Air is exhausted from areas of high contamination and humidity and supplied directly to other rooms throughout the house.



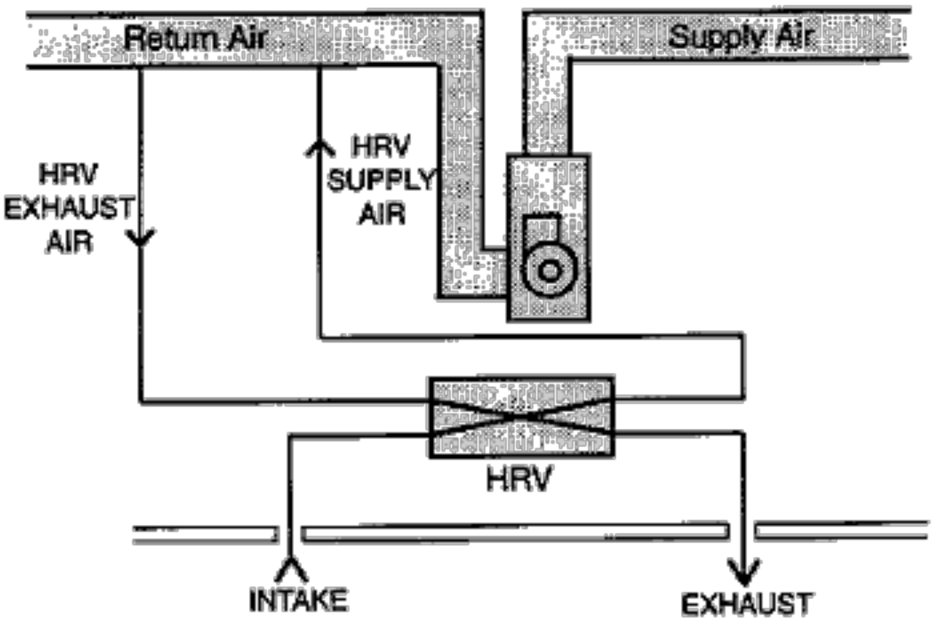
Fully ducted HRV (96-215 Canada Mortgage and Housing Corporation, 1996)

Extended HRV Installations exhaust air from the kitchen and bathrooms and supply air into the furnace return. The furnace fan circulates the ventilation air throughout the house.



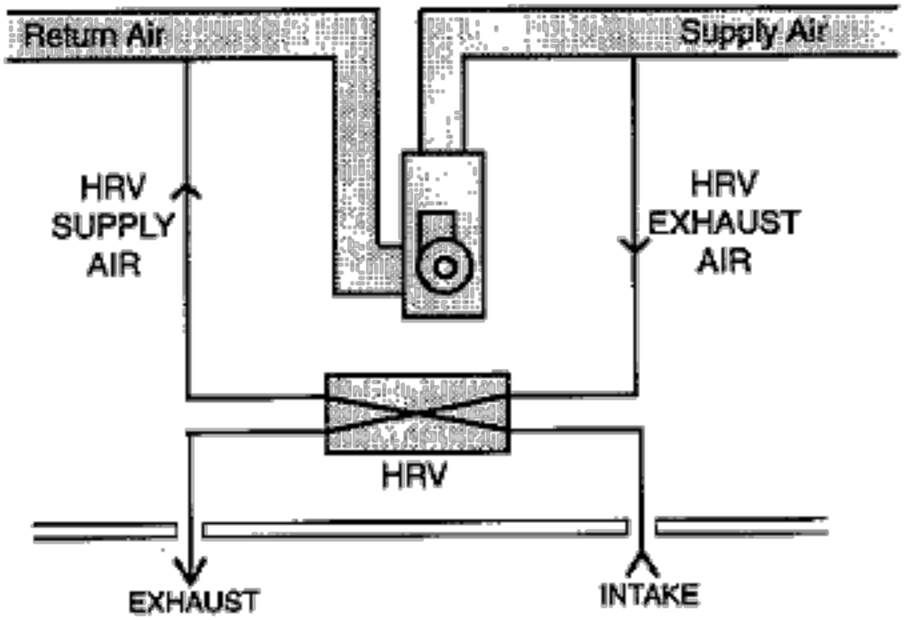
Extended HRV (96-215 Canada Mortgage and Housing Corporation, 1996)

Simplified Standard HRV Installations exhaust air from the furnace return air plenum and supply air to the furnace return air plenum (downstream of where air is exhausted). The furnace fan circulates ventilation air.



Simplified Standard HRV (96-215 Canada Mortgage and Housing Corporation, 1996)

Simplified Cross-Furnace HRV Installations are a modification of the Simplified Standard installation in which air is exhausted from and supplied to the furnace ductwork and circulated via the furnace fan.



Simplified Cross-Furnace HRV (96-215 Canada Mortgage and Housing Corporation, 1996)

Thermostat settings

House temperatures are typically controlled by a programmable thermostat or in the case of older homes manual adjustments to the thermostat. Temperature setting can have a significant impact on energy consumption for both winter heating and summer cooling.

There are a number of programmable thermostats readily available. The typical application is to ‘set back’ the temperature during winter days when residents are at work and overnight when residents are sleeping and to ‘set forward’ the temperature during the same periods on summer days.

CMHC, in their study *Effects of thermostat setting on energy consumption* (05-100 Canada Mortgage and Housing Corporation, 2005), determined that significant savings could be achieved. Tests showed that various combinations of night and day set-back/set-forward (11:00PM to 6:00AM and 9:00AM to 4:00PM) resulted in winter season savings of up to 13% of the gas and 2.3% on electricity and even greater summer savings.

Effects Of Thermostat Setting On Energy Consumption (05-100 Canada Mortgage and Housing Corporation, 2005)

Winter Gas Savings	22 degree benchmark	18 degree night setback	18 degree night and day setback	16 degree night and day setback
Furnace Gas Consumption (Mj/year)	66,131	61,854	59,231	57,241
% savings from benchmark		6.5%	10%	13%

Winter Electrical Savings	22 degree benchmark	18 degree night setback	18 degree night and day setback	16 degree night and day setback
Winter Furnace fan electrical consumption (kWh/yr)	2,314	2,295	2,270	2,261
% savings from benchmark		0.8%	1.9%	2.3%

Summer Electrical Savings	22 degree benchmark	24 degree 24 hours per day	25 degree day (9:00AM to 4:00PM) set forward
Summer fan and AC consumption (kWh/yr)	3,104	2,381	2,771
% savings from benchmark		23.3%	10.7%

The study noted that a number of factors will impact these results and that savings should be modeled against the specific design of each building.

Furnaces

Furnaces can be classified by the type of energy source (Canada Mortgage and Housing Corporation). The primary energy sources used in Canada include:

- natural gas
- propane
- fuel oil
- electricity
- and wood

Furnaces can also be classified by furnace type. The furnace type varies based on the fuel that is used. There are several major furnace types to be considered:

- forced air systems
- Fan coil systems
- Heat pumps and air conditioning units
- Convection heating systems
- Radian heating sytems
- Boilers

Forced air systems

Forced air system can be either a heating or cooling plant which re-circulates house air. The basic components of a forced air system are:

Furnace - furnaces can be either fuel-burning or electric.

Fans - furnace fans are typically squirrel cage type blowers made from slotted steel cylinders. Blowers can be belt-driven by separate motor or could have a direct drive motor.

Filters - furnace filters are normally located where the return air enters into the furnace cabinet.

Supply and return duct work - air from the furnace is delivered to the rooms of the home through supply ductwork. Air return to the furnace is delivered via air return ductwork.

Grills, registers, and diffusers - a grill is a slotted plate with no adjustments that is typically used for return air. The register is a plate with a damper that can be adjusted to control air volume and sometimes air direction. Diffusers are most commonly located in ceilings and walls and are typically used for ventilation or cooling supply air.

Humidification - a humidifier passes the forced air through an absorbent material that is moistened from a water reservoir. This adds humidity to the air when required.

Heating and cooling controls - the traditional basic control is a thermostat located centrally in the home. More sophisticated thermostats are now available that can be programmed for different temperatures settings on a weekly cycle.

Forced air systems can provide ventilation through an added outdoor air intake or by integrating to a heat recovery ventilation system, offering a range of advantages and disadvantages.

Advantages and Disadvantages of Forced Air Systems

Forced Air Systems	
Advantages	Disadvantages
• moderate capital cost • ability to provide ventilation, air filtration and/or humidification • same system can also be used for cooling	• can be noisy • air movement can cause discomfort (drafts) and stir dust • duct work can accumulate dust.

Fan coil systems

Fan coil systems heat or cool the air by re-circulating house air through coils which can operate with different water temperatures. Fan coil systems are typically used in commercial applications but can be found in residential homes as well.

Fan coil systems include the following components:

Fans - fans are similar to those used in furnaces but typically smaller.

Heating and cooling coils - the heating coils are typically copper with aluminum fins.

Filters - fan coil units are usually equipped with a basic filter at the return inlet.

Controls - the basic control is a low voltage thermostat that operates the pump which circulates hot or cool water through the coils.

Fan coil systems can be integrated with ventilation systems similar to the way a furnace works, offering a range of advantages but at a cost.

Advantages and Disadvantages of Fan Coil Systems

Fan Coil Systems	
Advantages	Disadvantages
• little charring of dust • easy integration with water radiant floors • can provide ventilation, filtration, cooling, and central humidification • adjustable temperature of supply air • aypically quieter than a furnace	• water leaks can cause damage • more costly • discomfort from air movement • air movement stirs dust • ductwork can accumulate dust • significant space required for ducts

Heat Pumps and central air conditioning systems

Heat pumps use a fan coil forced air system supplied by a heat pump or air-conditioner. A heat pump operates in a manner similar to a refrigeration system which moves heat from one point to another using a vapor compression cycle. When used for heating, heat is drawn from a low-temperature source such as outside air or ground water, and transferred to the supply air in the home. When used for cooling, heat from the air in the home is moved to outside air or ground water. Note that the familiar air-conditioner is simply a heat pump that provides cooling only.

The components of an air source heat pump include:

Outdoor unit - contains the compressor, heat exchange coils, and a fan

Connections to the home - electrical supply and insulated refrigerant lines

The components of a ground source heat pump include:

Indoor or outdoor unit - contains a compressor, heat exchange coils, and a pump

Liquid exchange pipes - buried in the ground

While arguably a more efficient option, heat pumps are more expensive and have a range of practical disadvantages.

Advantages and Disadvantages of Heat Pump Systems

Heat Pump System	
Advantages	Disadvantages
• minimal heating of dust • can provide heating and cooling in one unit • can provide ventilation and filtration • dehumidifies while cooling • can use air or ground water as heat source • is an energy efficient use of electricity	• high capital costs • discomfort from low temperature air movement • air movement stirs dust • ducts accumulate dust • space required for ducts • outdoor air source units may be noisy • higher maintenance costs

Convection heating systems

Convection heating systems typically consist of long narrow heaters that heat space by warming air adjacent to the heat element which rises. Cooler air enters the heater from below. Convection systems may use electricity, or are sometimes supplied with hot water, with a range of advantages and disadvantages.

Advantages and Disadvantages of Convection Heating Systems

Convection Heating System	
Advantages	Disadvantages
• minimal charring of dust • zoned heating controls • little circulation of dust • hydronic heat can be done with any type of fuel • hydronic heat can be combined with hot water radiant floor systems	• higher capital costs • furniture placement is affected by baseboard locations, • no air filtration, • no ability to provide humidification or dehumidification • difficult to clean • electric heat is expensive to operate.

Radiant Heating Systems

Radiant heating systems function by heating people and objects directly instead of heating the air in the room. To work effectively, a typical radiant heating system in a home will require heating large surfaces such as floors, walls, and ceilings. Radiant heating in floors is particularly effective because the temperature of the feet regulates human comfort.

Electric radiant heating systems come in a number of forms that can be used in a multitude of ways in home construction. Hydronic radiant heating systems typically use plastic piping cast into a concrete slab, included in lightweight concrete topping on wood sub floors, or attached below a wood framed floor in the floor joist cavity.

Advantages and Disadvantages of Radiant Heating Systems

Radiant Heating System	
Advantages	Disadvantages
• take advantage of low temperature energy sources such as those that could be available from a solar collector • minimal stirring or burning of dust • excellent comfort • lower air temperatures • accurate local control • no obstruction to furniture placement • can be integrated with the domestic hot water system • can use low temperature energy sources • can take advantage of thermal mass of materials for heat stability	• high capital cost • slow response time • cannot provide air filtration, cooling, or ventilation • cannot control humidity • cannot be used with carpeted floors or some hardwoods.

Boilers

A boiler is a device for heating water for space heating or domestic hot water supply. Modern boilers are very compact, and provide a reliable option. Boilers can be classified by the fuel type they use: electric, gas or propane, and oil.

Advantages and Disadvantages of Boilers

Boilers	
Advantages	Disadvantages
• can be used in conjunction with a fan coil unit to provide a low temperature forced air system that eliminates dust burning in the heat element • may also be used for domestic hot water by providing a second coil or heat exchanger and a storage tank	• for electric boilers, space heating with electricity is expensive and is especially inefficient in regions where electricity is generated thermally

Heat Pump

Heat pumps use electrical energy to move heat from a cool space to a warm space. In the winter, heat pumps move heat into the house. In the summer, heat pumps move heat out of the house.

Heat pumps can be air source or geothermal (earth source or water source). Air source heat pumps transfer heat between your house and the outside air. Geothermal heat pumps transfer heat from the ground or a nearby water source. Both types offer great efficiencies but at a high capital cost.

Advantages and Disadvantages of Heat Pumps

Heat Pumps	
Advantages	Disadvantages
• Because they move heat rather than generate heat, heat pumps can provide up to 4 times the amount of energy they consume. • Low temperature heat exchange eliminates burning of dust	• High capital cost

Integrated Mechanical System

Natural Resources Canada (Natural Resources Canada) describes an Integrated Mechanical System (IMS) as a system that groups the functions of space heating, water heating and heat recovery ventilation into a single package. This new single combined appliance provides homeowners with:

- Forced air space heating;
- Domestic water heating;
- Outdoor air ventilation (with heat recovery); and
- Hydronic heating.

As with any more sophisticated technology, costs rise accordingly.

Advantages and Disadvantages of Integrated Mechanical Systems

Integrated Mechanical Systems	
Advantages	Disadvantages
• Material and energy efficiency • Reduced footprint • Labour efficiency on installation	• High capital cost

Lights, Appliances and Mechanical

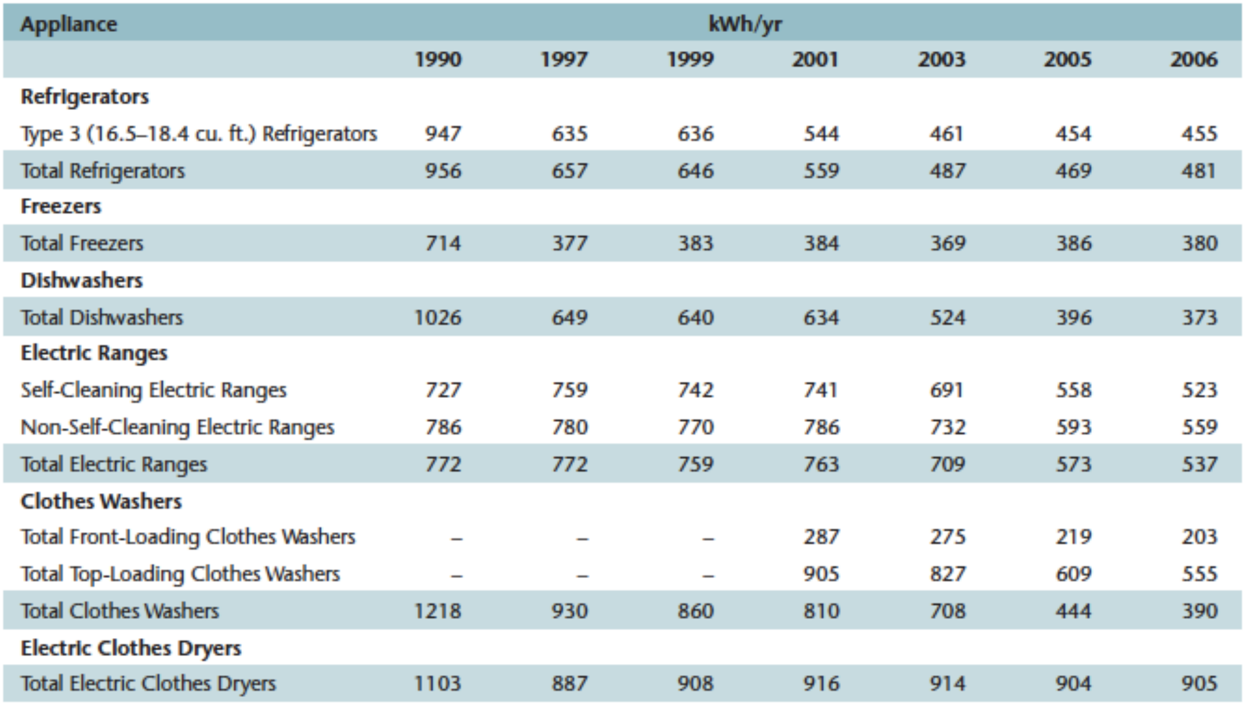
Introduction

The average Canadian home contains most of the six major appliances, which include a refrigerator, freezer, dishwasher, range, clothes washer and clothes dryer. In an average home, appliances are responsible for 23% of all home energy consumption (Howell, 2008).

The Major Appliances

Natural Resource Canada's Office of Energy Efficiency shows the amount of energy used by each of these appliances in an average home in Canada (Natural Resources Canada, 2009):

Average Annual Unit Energy Consumption for Selected Years



Appliance	kWh/yr						
	1990	1997	1999	2001	2003	2005	2006
Refrigerators							
Type 3 (16.5–18.4 cu. ft.) Refrigerators	947	635	636	544	461	454	455
Total Refrigerators	956	657	646	559	487	469	481
Freezers							
Total Freezers	714	377	383	384	369	386	380
Dishwashers							
Total Dishwashers	1026	649	640	634	524	396	373
Electric Ranges							
Self-Cleaning Electric Ranges	727	759	742	741	691	558	523
Non-Self-Cleaning Electric Ranges	786	780	770	786	732	593	559
Total Electric Ranges	772	772	759	763	709	573	537
Clothes Washers							
Total Front-Loading Clothes Washers	–	–	–	287	275	219	203
Total Top-Loading Clothes Washers	–	–	–	905	827	609	555
Total Clothes Washers	1218	930	860	810	708	444	390
Electric Clothes Dryers							
Total Electric Clothes Dryers	1103	887	908	916	914	904	905

Using 1990 as a base line, appliances in the average home in Canada used 5,789 KWH of energy annually. Energy consumption can be reduced significantly through the use of Energy Star appliances. Using more efficient appliances (Energy Star where applicable) can result in a 49% ((5789-2969)/5789) decrease in energy use. The table below offers an example of what could be accomplished using some of the more highly rated appliances available (U.S. Environmental Protection Agency).

Energy Savings From Use of Energy Star Appliances

Appliance	Average Energy Consumption in kWh/year in Canada (1990)	Energy Consumption in kWh/year using modern Energy Star appliances	Savings in kWh/year	Energy Star Brand/Model
Refrigerators	956	387	569	GE/GTK181BX
Freezers	714	435	279	Kenmore/15202

Appliance	Average Energy Consumption in kWh/year in Canada (1990)	Energy Consumption in kWh/year using modern Energy Star appliances	Savings in kWh/year	Energy Star Brand/Model
Dishwashers	1,026	279	747	Jenn-Air /JDB3200AW
Electric ranges	772	772		*
Clothes Washers	1,218	191	1,027	GE/WPDH8910K
Clothes Dryers	1,103	905	198	*
Total	5,789	2,969	2820	

* Electric ranges and clothes dryers are not rated as part of the Energy Star program because there is little difference in energy use among models. We have used the Natural Resources Canada energy use statistics for 2006.

Domestic Hot Water

There are a number of strategies for reducing energy use for hot water:

- More efficient water heaters
- More efficient distribution of heated water
- Reduce the amount of hot water used
- Recapture heat from waste hot water.

Energy Efficient Water Heaters

A number of different types of water heaters are available:

- Storage Tank Water heaters – heat and store water in a tank
- Tankless water heaters – do not have a storage tank but heat water only when it is needed
- Integrated space/water heating systems – combine household heating with household hot water requirements
- Solar water heaters – use the sun's energy to heat water.

Natural Resources Canada (Natural Resources Canada, 2009) indicates that storage tank water heaters are the most common in Canada. According to NRCan, energy efficient models have a number of energy saving features including extra insulation, a better heat exchanger, factory installed heat traps, electronic ignition, powered exhaust and improved control of flue baffles and dampers.

Tankless water heaters are typically installed for specific needs and are most effective near point of use.

Integrated space/water heating systems can save money on total system installation but often lack efficiency because the heating system has to be sized for the coldest winter day but will likely be used only 3-4 months a year.

Solar water heaters will significantly reduce a household's heating costs. Solar heating will be discussed in more detail in another section.

Efficient distribution of heated water

Another source of heat loss is through the distribution system. Hot water pipes made of copper or plastic will quickly loose heat. This is not an issue during heating months when the heat energy lost from the hot water pipes will contribute to the heating of the house. During the rest of the year, this energy is lost or can even contribute to overheating of the home during cooling months.

An integrated approach to home design will place the water heaters close to the primary users such as baths, kitchen (dish washers) and laundry rooms.

All hot water pipes should be properly insulated to reduce heat loss.

Reduce the amount of hot water used

There are a number of strategies available to reduce the amount of water used, specifically hot water (Carbon Dioxide Reduction Edmonton, 2004):

- Repair any leaking faucets;
- Install low flow shower heads;
- Install low flow faucet aerators;
- Purchase Energy Star clothes washer and dish washer.

A leaking faucet dripping only one drop per second will waste 8000 litres of water per year. If this is hot water, the cost is even more significant. Repairing any leaking faucets is an easy and cost effective way to save energy.

Low flow shower heads will reduce hot water usage by 30 to 50% without significantly reducing the feel of the shower. These are inexpensive to purchase and easy to install.

Low flow faucet aerators thread into existing faucets. They reduce flow rates by up to 50% by mixing air into the water. This can translate into overall water savings of 30% on a typical faucet.

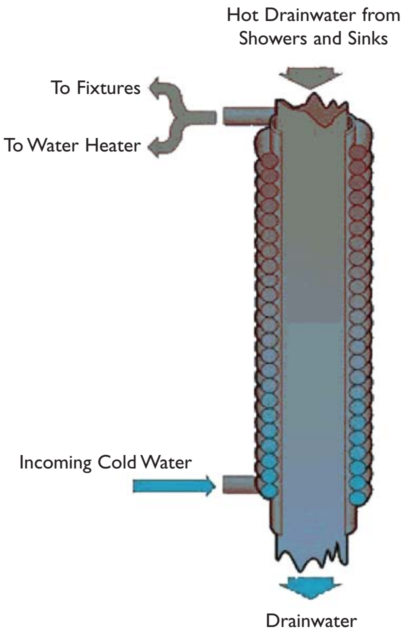
Front loading Energy Star clothes washers will use 30-50% less water than regular clothes washers. They also do a better job of extracting water from clothes during the spin cycle which will further reduce energy costs related to drying clothes.

Energy Star dish washers use at least 25% less water and can save 20% on heating costs by heating incoming water.

Recapture heat from waste water

Drain water heat recovery (DWHR) is a relatively simple technology to reduce household hot water energy consumption and to prolong the availability of hot water during periods of high demand or continuous use.

IN 2007, CMHC completed a study (07-116 Canada Mortgage and Housing Corporation, 2007) of Drain Water Heat Recovery units. CMHC explains that drain water heat recovery units take advantage of the fact that as water drains it clings to the sides of vertical drainpipes due to surface tension. This creates a very high surface-contact-to-volume ratio, allowing heat to be recovered from the drain water by wrapping the incoming cold water supply pipe around the vertical drain line.



CMHC drawing of Drain Water Heat Recovery System

In most homes, drain water will come in three types:

- Hot – from dishwashers, showers, bath tubs
- Cold – from toilets
- Hot or cold – from clothes washers and sinks

The steadiest source of hot drain water will come from showers as the hot water is continuously entering the drain for the duration of the shower. The other important feature to note about drain water from showers is that this drain water is simultaneous with hot water requirements.

The study investigated two different configurations. In the first configuration (A) the DWHR system was connected to the hot water heater. In the second configuration (B) the DWHR system was connected to the hot water heater AND the cold water tap on the shower.

The savings for a typical family of 4 was significant. The following is a subset of the results of the study and shows the savings for the most effective DWHR unit tested (PowerPipe R60).

Energy Savings From Implementation of Drain Water Heat Recovery

	Configuration	
	A	B
PowerPipe R60	1,145 kWh/year	1,385 kWh/year

This is a significant saving given the relatively low cost of installing a DWHR, its long useful life and the fact that it will require no maintenance once installed.

CMHC tests suggested (07-116 Canada Mortgage and Housing Corporation, 2007) that the benefits from delayed hot water requirements was minimal. The study came to several interesting conclusions:

- 'Although the devices are very similar, the performance of comparable units can vary widely based on the way in which the soft copper tube is shaped and then wrapped around the drainpipe section.
- The efficiency and effectiveness of DWHR units is lifestyle dependent. Households with high shower use will obtain more benefit from installing a DWHR unit than households where baths are more prevalent.
- Households in rural areas without access to a municipal water supply will need to look at units that have designs that minimize reductions in water line pressure' (page 7).

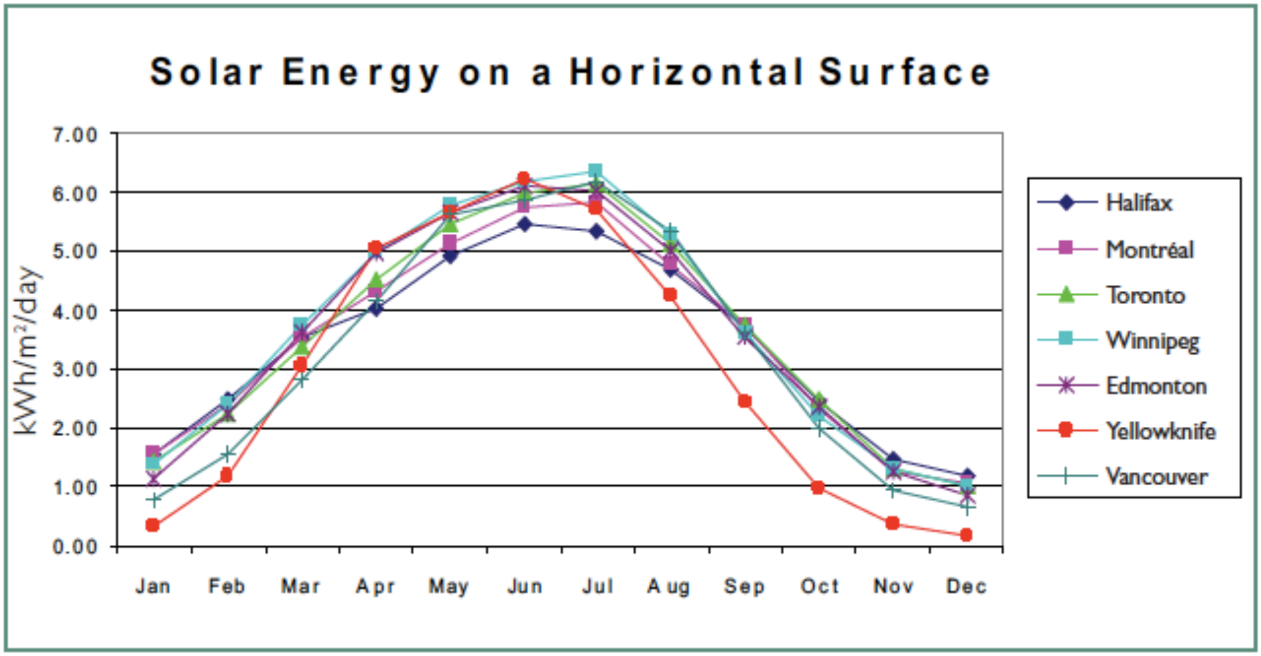
Alternative Energy Sources

There are a number of sources of alternative energy available. The more commonly used alternative energy sources include solar, wind, water and geothermal.

Solar Water Heating Systems (SWHS)

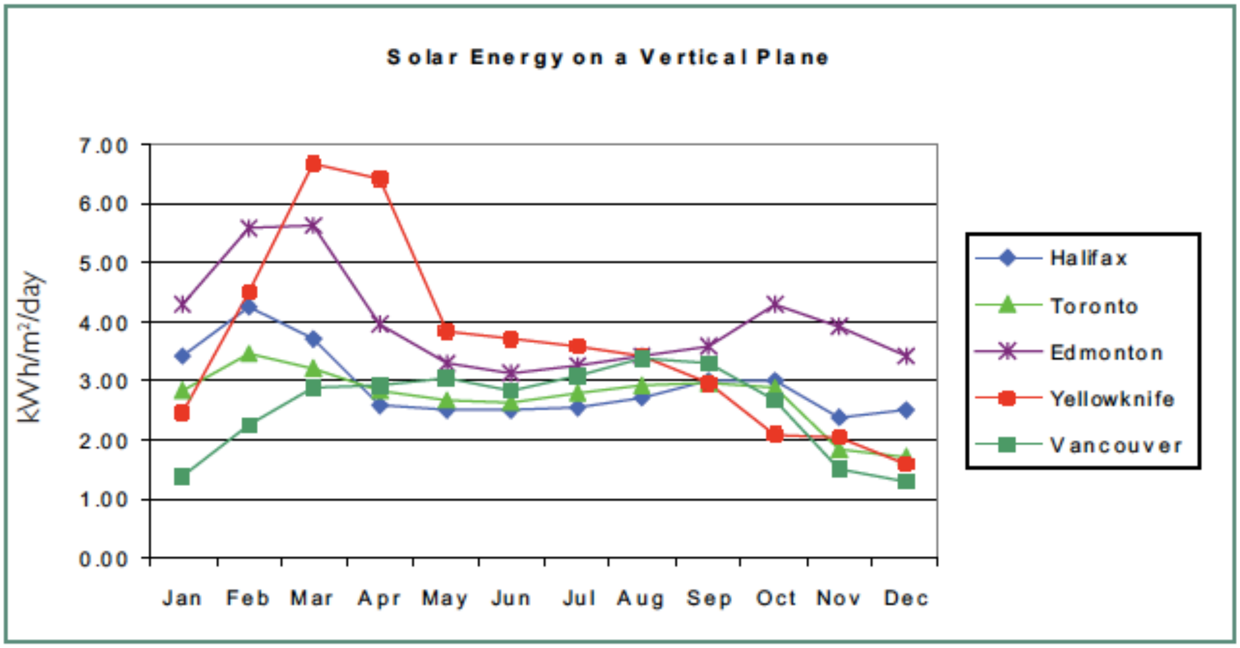
A significant amount of energy comes from the sun each day (Canada Mortgage and Housing Corporation). The solar constant, the amount of the sun's energy that reaches the earth's atmosphere each day is about 1350W/m2. Not all of this energy reaches the surface of the earth because the atmosphere reflects, absorbs and scatters some of the energy. The peak solar intensity is the amount of the sun's energy that reaches the earth's surface. This varies depending on location, sky conditions etc. The peak solar intensity in Canada varies from 900W/m2 to 1,050W/m2. This is at solar noon when the sun is exactly in the south.

The amount of energy reaching the earth's surface in an average day will be affected by all of these factors. The figure below provides information on how much sun will reach the earth at various locations in Canada.



Solar energy reaching a horizontal surface in various Canadian cities each month Source: (Canada Mortgage and Housing Corporation)

The angle of the solar collector has a big influence on the amount of solar energy collected. The chart below shows the significant difference if the surface is vertical such as a window. The difference in the energy generated per day in any one city over the year varies by at least a factor of 3 and between cities by more almost a factor of seven.



Solar energy on a vertical plane. Source: (Canada Mortgage and Housing Corporation)

There are a number of technologies available to capture solar energy for use in residential housing.

There are four main types of Solar Water Heating Systems. SWHS can be either active or passive. Active systems use electric pumps to circulate fluid through the collectors. Passive systems have no pumps and rely on thermo-siphoning to circulate water. SWHS can also be classified as open-loop or closed-loop (figure 4-22). An open-loop system circulates potable water through the collector while a closed loop uses glycol and a heat exchanger to transfer the heat to the potable water.

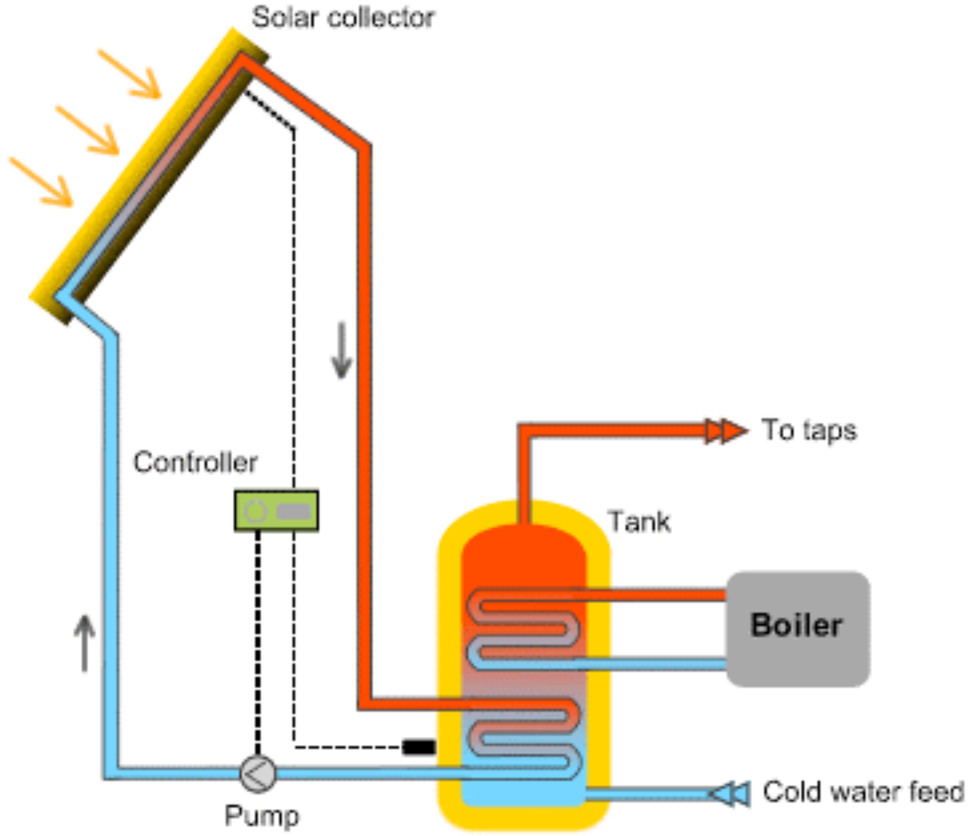
Energy captured by SWHS can be used for heating domestic hot water and/or for home heating.

The characteristics of the four types are summarized in table below.

Characteristics of Solar Thermal Systems

	Open-loop	Closed-loop

Active	- Use pumps to circulate potable water through collectors - Popular in regions with no subzero temperatures - Drain back systems can be used in sub zero temperatures. Pumps are used to circulate potable water through the collectors. When the pump is turned off, the water drains out of the collectors - Drain back systems are more expensive to install - Drain back systems can be turned off when the system gets too hot	- Use pumps to circulate Glycol through the collectors - Heat exchangers transfer the heat from the fluid to water stored in tanks - More expensive than open-loop systems - Glycol must be checked yearly and replaced every few years - Some building codes will require a more expensive double wall when Glycol is used to prevent contamination of the potable water.
Passive	- Thermo-siphon systems rely on natural convection to circulate the water. - More reliable, less expensive and longer lasting - Require the tank to be located above the thermal collector - Batch heaters are a simple configuration with a storage tank in an insulated box with a glazed side facing the sun	- Passive closed loop is not a typical configuration because a pump is required to circulate the glycol through the heat exchanger



Active Closed water heating system (source http://www.petervaldivia.com/technology/energy/solar-power.php)

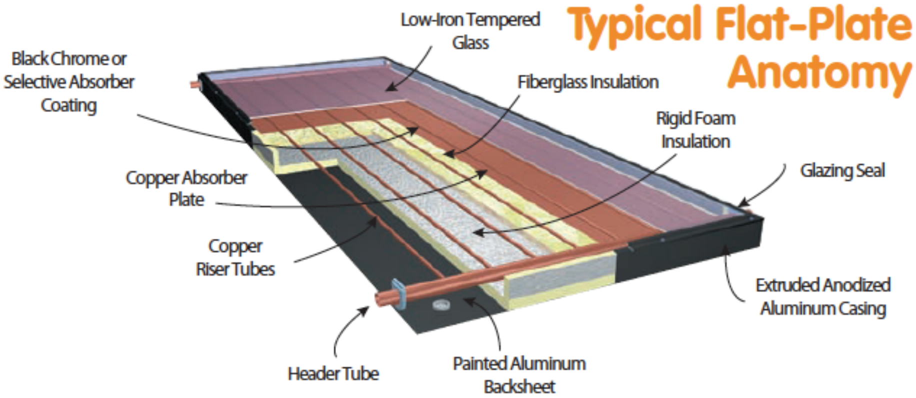
There are several different types of collectors used in SWHS:

- Unglazed collectors
- Flat panel collectors
- Evacuated tube collectors.

Unglazed collectors are simple and inexpensive collectors usually used for heating pools or spas. Typically made of polypropylene with no insulation, these systems can only be used in very warm climates.

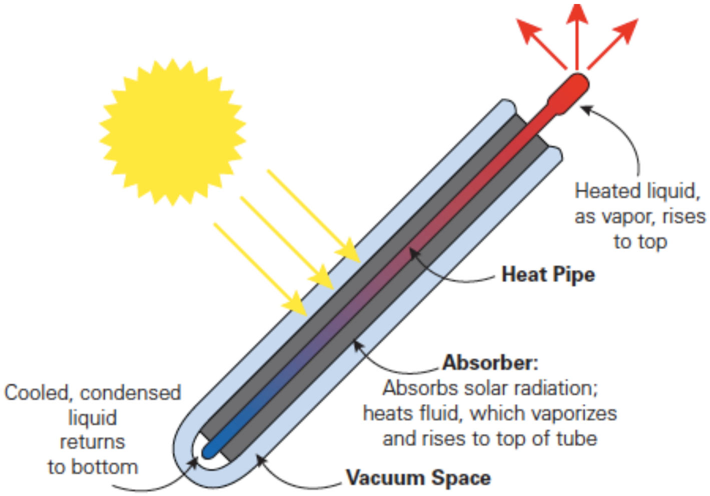
Unglazed collector. Source: (Marken, 2009)

Flat-Panel collectors are made of a wood or metal enclosure, insulation, copper tubing to absorb the sun's energy and tempered glass (figure 4-24). These collectors are more robust and are used in typical domestic hot water and home heating applications.



Flat panel collector. Source: (Marken, 2009)

Evacuated tube collectors use vacuum technology to improve heat retention. These collectors are typically more expensive but are more efficient in colder climates.



Evacuated tube collector. Source: (Marken, 2009)

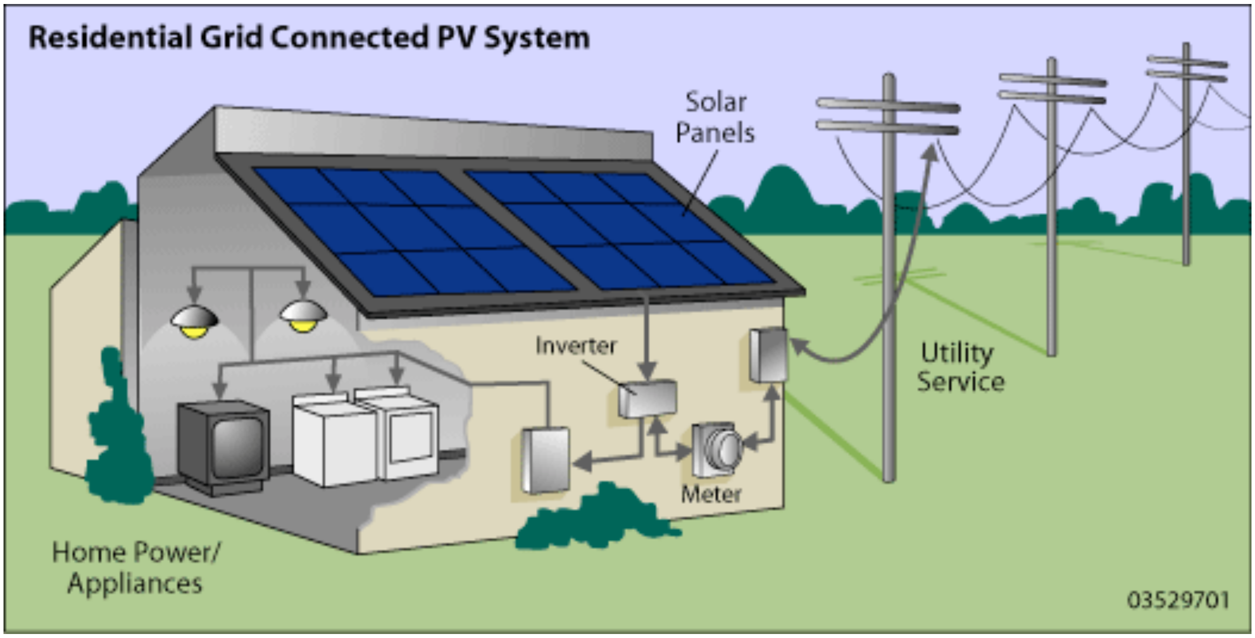
Photo voltaic

Photovoltaic or PV systems are systems used to convert the sun's energy into electricity. The efficiency rating is a measure of how efficient the module converts the photons in sunlight to DC power. Typical PV systems vary between 10 and 20% efficiency (Sanchez, 2009) although higher efficiency systems are being developed. Most residential PV systems are about 14% efficient so will capture about 130 W/m2 in bright sunlight. An average 1 square meter PV panel in Canada will generate 400WH/day or 100KWH annually (Canada Mortgage and Housing Corporation). This will of course vary by location.

PV systems can be either off-grid or grid connected. 'Grid' is the term used to the electrical company's infrastructure that typically supplies electricity to homes and businesses.

Off-grid systems require a battery system to store electricity for use at night or during cloudy periods. Off-grid systems are usually used in combination with another energy source such as an engine or wind generator.

Grid connected PV systems are usually connected to an inverter that combines the PV generated electricity with electricity from the grid (figure 4-26). If the PV system is generating excess power, the excess is fed back in to the grid to be used by other customers. Grid connected PV systems require a much more sophisticated inverter but there is no need for batteries to store the energy.

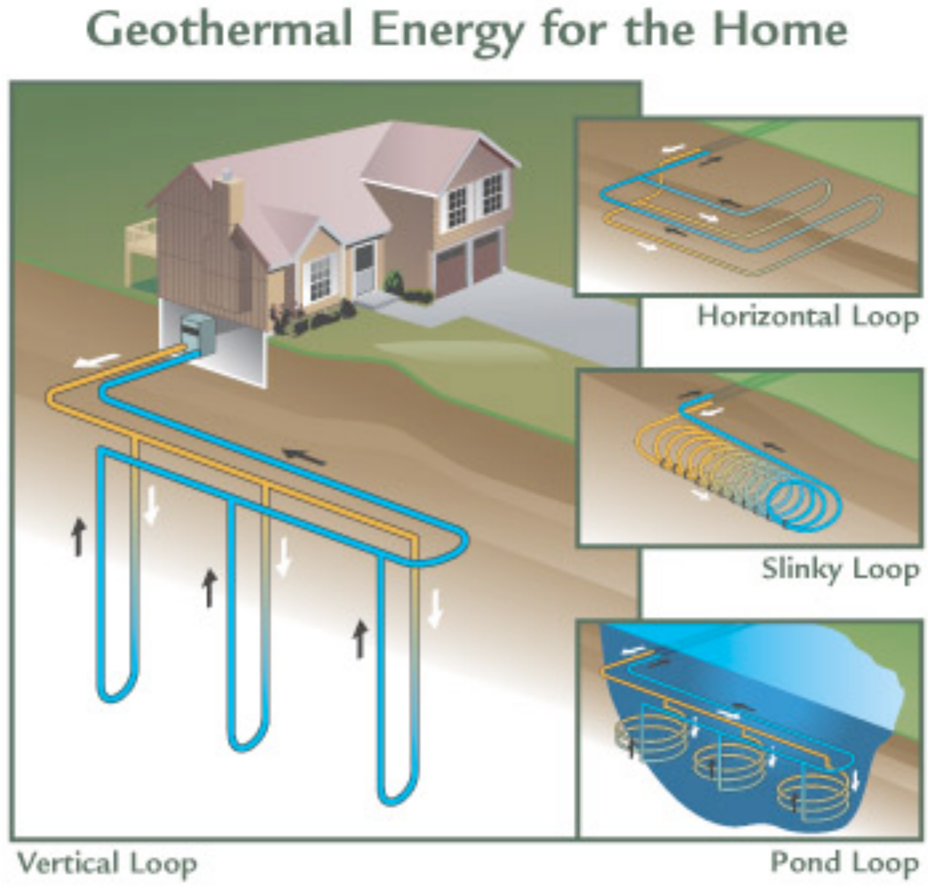


Grid connected PV system. Source: http://www.energyeducation.tx.gov/renewables/section_3/topics/photovoltaic_cells/f.html

Geothermal pumps

The earth's temperature remains at about 10 degrees Celsius (NextEnergy Inc) all year around. That means the earth can be a source of heat in the winter and a source of cooling in the summer.

Geothermal systems access the energy stored in the earth by burying ethanol filled pipes into the ground. In the winter, the ethanol absorbs heat from the ground and that heat is used to heat the home. In the summer, the ethanol takes heat from the home and is cooled in the ground (figure 4-27). There are a number of different types of looping approaches that vary depending on the conditions where the application is being installed.



Different approaches to looping geothermal systems. Source: http://www.engineer.gvsu.edu/house/altenergy.html

GeoThermal systems require significant amount of electricity to drive the pumps. As a result, geothermal is not often a good replacement for natural gas systems especially in provinces such as Saskatchewan and Alberta where coal generated electricity production results in relatively high CO2 emissions per KWH of electricity.

Micro Wind generation

Wind energy is growing rapidly as a source of clean renewable energy. Large generators can be used individually or grouped together in wind farms 9figure 4-28).

Offshore wind farm. Source: http://www.sulangaenergy.com/images/wind-turbines-370-x-283.jpg

Although wind energy is typically used in large scale applications, many homes and cottages in remote areas rely on wind energy for electricity and to drive other equipment such as pumps (figure 4-29).

Old fashioned windmill used to pump water. Source: http://econewmexico.com/system/files/images/wind-turbine-wind-mill.jpg

Wood Burning

Wood has been the main energy source for Canadians until 150 years ago. Wood burning has seen resurgence over recent years. There are several types of wood burning appliances available (Canada Morgage and Housing Corporation, 2008). The most common category is space heaters, which are designed to heat space directly compared to a central home heating system that uses hot air or water to distribute heat throughout the house. Space heaters include wood stoves, cook stoves, pellet stoves, fireplaces and masonry heaters.

Wood burning central heating systems are not common and should only be considered in very special circumstances.

Making sense of the choices

Given the array of choices, it is difficult to see how they a priori fit together. In the context of this research program, the author designed and built the VerEco Net Zero Energy home in Saskatoon, in collaboration with 24 partners. This 1440 square foot home is designed to demonstrate and make use of one configuration of these seven technologies.

Built to standard construction code, this home would use approximately 40,000 ekWh of energy per year in Saskatoon.

The VerEco Home includes the following technologies:

Technologies included in the VerEco Home

Technology	Comments
Passive Solar design	Home specifically designed to take advantage of passive solar energy
Super insulated wall	16 inch double wall with cellulose insulation. Approximate R value of R60
Attic Insulation	Approximately 30 inches in cellulose insulation. Approximate R value >R100
Foundation Wall Insulation	ICF construction with additional R24 of batt insulation. Approximate R value of R36.
Under Slab insulation	6 inches of rigid Styrofoam insulation. Approximate R Value of R20
Windows	EnergyStar triple glazed argon filled double e coatings. Special coatings to reduce solar gain on west facing windows
Air Barrier	6 ml poly vapor barrier on interior walls. Headers sealed with spray foam
Heat Recovery Ventilator	Fully Ducted Van EE Venmar AVS HRV EKO 1.5.
Thermostat settings	Individual zone control

Technology	Comments
Furnace	Electric baseboard heaters and radiant hot water heater (to use excess energy from the solar thermal collectors)
Major Appliances	EnergyStar refrigerator and dishwasher. Efficient electric range. Clothes washer and dryer to be purchased at a later date.
Energy Efficient water heaters	Not installed in the demonstration home. To be purchased by owner.
Efficient Distribution	Two water heaters (one near ensuite and second near kitchen/second bath) to reduce distribution losses
Reduced consumption	Low flow shower heads and faucets installed in bathrooms
Recapture heat from waste water	Drain water heat recovery system installed in ensuite configured so cold water to the shower is preheated by DWHR
Solar Water Heating System	Closed Loop active system with three 32 square foot flat-panel collectors used to heat Domestic Hot Water and provide space heating
Photo Voltaic	18 245 watt Opsun PV panels (total 4.4 kW), Kaco 5002xi grid tie inverter, grid tied to SaskPower for Net metering

Using the technologies identified in the above table, the VerEco Home should produce as much energy as it consumes on an annual basis reducing energy consumption by 40,000 ekWh each year.

One consideration in the choices made in the VerEco home was the various incentives and economic effects of the choices on the capital and operating cost of the home.