Estimated Benefits of Achieving Passivhaus and Net Zero Energy Standards in the Region of Waterloo Residential Sector and the Barriers and Drivers to Achieve Them

by

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Author’s declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners. I understand that my thesis may be made electronically available to the public.

Abstract

As the third largest energy consumer, the residential sector in Canada is responsible for 17% of energy consumption and 15% of greenhouse gas emissions. With the increase in population, the number of new houses is expected to increase by 2.8 million from 2005 to 2020, and more energy is expected to be consumed despite the emergence of better insulated houses and more efficient heating methods. The primary objective of this study is to determine the prospects of reducing CO_2 emissions from the residential sector in Waterloo Region by achieving a higher building standard, such as the Passivhaus (PH) and Net Zero Energy (NZE). The profile of the building envelope, including the initial CO_2 emissions was compared against the requirements of the PH and NZE standards, using the Residential Energy Efficiency Project dataset (2007-2012). The second objective evaluates the barriers and drivers that influence the setting of higher building envelope standards. Ontario Building Codes (1975-2012) were analysed to determine the changes to insulation requirements over time, and Ontario Legislative Assembly debates (1970-2012) were reviewed to determine the barriers and drivers expressed in political debates. Content analysis was applied to the Legislative Assembly of Ontario's documents to determine the frequency of nine word categories prior to each new building code. This study identified three main categories of drivers: awareness of environmental issues, resource limitation, and the implications of climate change; and three categories of barriers: financial, political and structural, and barriers related to information, promotion, and education. The findings of this study confirm that existing houses in Waterloo Region can achieve substantial reductions in CO_2 emissions and energy usage by meeting higher building standards. Building code improvements have certainly played an important role in the evolution of Ontario houses, and the 2012 building code, achieves the R-2000 standard universally. More advanced standards show the potential for greater savings, but have only been adopted on a voluntary basis.

Key words: building retrofits, content analysis, Legislative Assembly of Ontario, Ontario Building Code, Passivhaus, Net Zero Energy.

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Thank you all for helping me achieve my dream.

Dedication

I dedicate this research to my family. Thank you for all your support and guidance during my educational career.

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Chapter 1
Introduction

> *"The world will not evolve past its current state of crisis by using the same thinking that created the situation."*– Albert Einstein

1.0 Energy Outlook and Greenhouse Gas Emissions

Providing adequate clean energy worldwide is one of the many challenges of the 21st century (Carlisle et al., 2008). However, an even more significant challenge is finding ways to reduce current and future emissions resulting from energy consumptions. The Intergovernmental Panel on Climate Change (IPCC) (2007a) reports that 70% of total global greenhouse gas emissions (e.g., CO_2, CH_4, and NO) are energy related. This includes "fossil fuel combustion for heat supply and electricity generation and transport" (IPCC, 2007a, p. 253). World energy consumption is expected to grow by 56% from 2010 to 2040 (U.S.EIA, 2013). In 2008, the U.S. Energy Information Administration (2011b) reported that 6% of the world's energy consumption was from the commercial sector, 52% from the industrial, 14% from the residential, and 27% from the transportation sector.

Due to Canada's climate, size, and resource based economy, it is one of world's largest energy per capita consumers and emitters (Adkins-Hackett et al., 2011; IEA, 2010). About 75% of Canada's energy comes from fossil fuels (Best et al., 2010). According to the World Development Institute (WDI) (2012), in 2011, Canada was the fifth highest energy user per capita in the world. During this period, Canadians used four times more energy per capita (7534 kg of oil equivalent per capita) than the world average (1790 kg of oil equivalent) (WDI, 2012). Between 1990 and 2009, the residential sector was Canada's third largest energy consumer (17%), after the industrial and transportation sectors (37% and 30%, respectively) (OEE, 2011a). About 85% of Canada's GHG emissions come from energy consumption, production, and distribution; 60% of this is from the energy consumption, whereas the remaining 40% is from production and distribution of energy (NRCan, 2006). Canada's GHG emissions have increased from 589 $MtCO_2e$ in 1990 to 702 $MtCO_2e$ in 2011. Under the "no government involvement" scenario, emissions are projected to be 850 Mt in 2020 (Environment Canada, 2012a). However, if the proposed government measures are adopted, then emissions are expected to be 785 Mt in 2020 (Environment Canada, 2012a).

1.1 Residential Sector and Greenhouse Gas Emissions

"On a global scale, buildings will continue to contribute a third of greenhouse gases by 2030" (Zabaneh, 2011, p. 3237). As the third largest energy consumer, the residential sector is responsible for 15.3% of GHG emissions (Larsson, 2010). Almost half of the energy consumed in buildings is used for space heating and cooling (Zabaneh, 2011). Additionally, about 85% of this energy is generated from fossil fuels; therefore, reducing these emissions from buildings through efficiency is significant (Zabaneh, 2011). Greenhouse gas emissions are expected to continue to grow, especially in the developing world where there is a high demand for economic growth and, hence, building construction (U.S.EIA, 2011a). Furthermore, with the future population growth, it is expected that additional homes will be built and more energy consumed despite the emergence of better insulated homes and more efficient heating methods.

The residential sector in Canada has 13.9 million homes (Environment Canada, 2013) and is comprised of different building types: mobile homes, apartments, single attached, single detached, etc. About 67% of the total homes are single detached (Hamilton, 2010). According to Hamilton (2010), 34% of the homes consume electricity for heating, and 61% use natural gas and fuel oil. Single detached houses and apartments consume most of the energy (NRCan, 2011a) (Appendix 1, Figure 1.1). Overall, 63% of all residential energy is used for space heating, and 17% for water heating (together 1,422.3 PJ = 80% of total residential energy) (Appendix 1, Figure 1.2). The remaining 20% of total residential energy is used for appliances, lighting, and space cooling.

Between 1990 and 2009, Canada's population increased by 22% (6.0 million people), the number of households grew by 36% (3.5 million households) (Behidj et al., 2011). Simultaneously, the average living space increased from 116m^2 to 129m^2 (Table 1.1). However, the number of total occupants per space declined from 2.8 to 2.5 people (Table 1.1). This increase in population, households, average living space, and appliances has contributed to an 11% increase in the total residential energy use (Behidj et al., 2011).

Table 1.1: Comparison of residential energy indicators, 1990 and 2009

1990	• 2.8 people per household • 116 m^2 of living space • 9.9 million households • 15 appliances per house • 23 percent of occupied floor space cooled
2009	• 2.5 people per household • 129 m^2 of living space • 13.4 million households • 21 appliances per house • 44 percent of occupied floor space cooled

Source: Behidj et al., 2011, p. 13.

Canada's residential CO_2 emissions peaked in the early 1970s and declined due to "the high oil prices and government programs in the early 1970s and 1980s" (Parker et al., 2003). The GHG emissions in Canada's building sector have increased by 15 Mt between 1990 and 2005; however, due to energy improvements in commercial buildings, GHG emissions declined between 2005 and 2010 by 6 Mt (Environment Canada, 2012a). In the report written by the Canadian Home Builders' Association, the GHG emissions from Canadian houses fell by 4.7% between 1990 and 2010 even with the 35.6% increase in houses, "while total Canadian emissions from all sources rose by 17.5%" during the same period (CHBA, 2013, p. 1). According to Parker et al. (2000), houses built in the 1990s were, on average, three times more efficient in space heating than the houses built in the 1800s. This trend continues and since 1990, energy use per household has decreased by 18% (25% in energy use per square meter) (OEE, 2011a). According to Environment Canada (2012a), the number of households is expected to increase by 2.8 million from 2005 to 2020 and the GHG emissions over this period are expected to remain stable. Additionally, due to the use of cleaner energy sources, the total GHG emissions between 1990 and 2010 decreased by 0.5% (Behidj et al., 2011). However, with the future population growth, it is expected that additional houses will be built, and consequently, more energy is expected to be consumed despite the emergence of better insulated houses and more efficient heating methods (NRCan, 2010). Variability in Canada's climate will also affect the heating and cooling costs significantly (Best et al., 2010).

1.2 Need for Reduction of Energy Consumption and Associated Emissions

The negative impacts of energy consumption are evident. Every year, GHG emissions from energy consumption continue to increase (IPCC, 2007b). The use of energy sources (e.g., fossil fuels) results in environmental, climate change, and health issues (IPCC, 2007b). Reducing energy consumption can, therefore, minimize many negative outcomes (Best et al., 2010).

As part of the Kyoto Protocol, between 2008 and 2012, countries were required to meet reduction targets below 1990 CO_2 emissions (UNFCCC, 2012). In December 2009, Canada signed the Copenhagen Accord and committed to reduce its GHG emissions to 17% below 2005 levels, establishing a target of 607 Mt by 2020 (Environment Canada, 2012a, p. 1). However, Canada, which was supposed to cut its emissions by 6% by 2012 based on 1990 levels, actually *increased* them by a third and then withdrew from the Protocol in December 2011. Additionally, in 2011, Canada's GHG emissions were projected to reach 785 Mt CO_2e by 2020 (Environment Canada, 2012a). Since "energy consumption and the associated GHG emissions have damaging effects on the environment" (Best et al., 2010, p. 23), Canada needs to take serious actions to reduce the negative impacts from energy consumption. Delaying energy reduction and associated emissions has negative outcomes, including resource shortages, resulting in instability in energy prices (Jaccard, 2005; OECD, 2008); higher cumulative emissions resulting in higher costs to achieve drastic emission reductions (IPCC, 2007b); drastic adaptation measures to avoid serious damages (IPCC, 1996; IPCC, 2007b); as well as physical implications in the form of climate change (IPCC, 2007b).

"Securing energy consumption, using the current energy mix, presents significant risks to environmental security" (Best et al., 2010, p. 23); therefore, necessary actions need to be taken to minimize these risks. In comparison to the other sectors, the building sector is the largest sector that offers the highest emission reductions at the lowest cost by 2030 (Figure 1.1) (Ürge-Vorsatz, 2008). According to Ürge-Vorsatz (2008), "globally, approximately 30% of all buildings related CO_2 emissions can be avoided by 2020" (sl. 8). The major savings can be achieved in new buildings; however, performing high efficiency retrofits on existing buildings is possible, but more expensive. There are many benefits of GHG mitigation in buildings: improving social welfare, increasing employment, creating new business opportunities, improving energy security, reducing energy costs, and improving outdoor air quality.

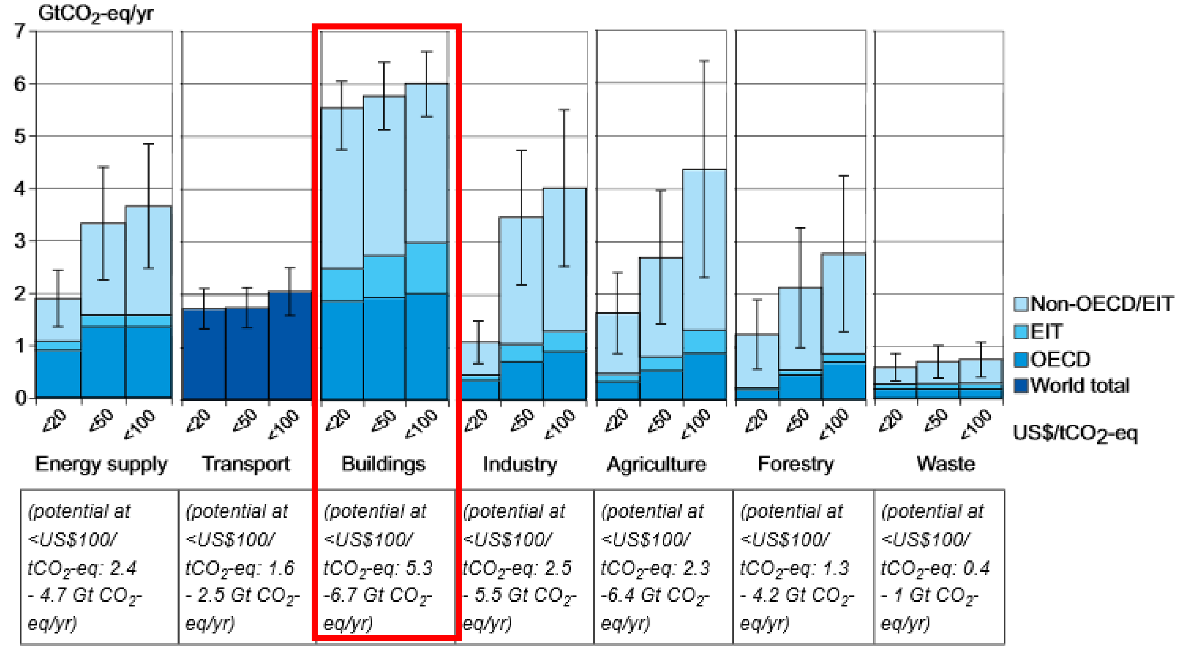

Figure 1.1: Estimated sectoral economic potential for global mitigation for different regions as a function of carbon price in 2030 from bottom-up studies, compared to the respective baselines assumed in the sector assessments. Source: IPCC, 2007a, p. 11.

1.2.1 Energy Efficiency in Canadian Houses

Over the past four decades, the marketplace for buildings, houses, and communities has been transformed as part of a larger sustainable revolution (Fedrizzi, 2008). This revolution involves sustainable buildings and sustainable growth in the construction sector, with the idea to make houses healthier and more energy-efficient (Dong, Kennedy, & Pressnail, 2005; Fedrizzi, 2008). Baird et al. (2010) believe that “if buildings work well, they enhance our lives, our communities, and our culture” (p. 1). Additionally, retrofitted houses, which create less carbon emissions, contribute to one of the many climate change mitigation strategies.

Canada has responded to the negative implications of climate change in many ways. For example, as part of the Climate Action on Climate Change programme, the Canadian government has committed to an “aggressive” approach to climate change by developing policies, programs, and research to achieve environmental and economic benefits (Government of Canada, 2013). Provincial and territorial governments also have focused on emission reduction from several sectors, including "electricity generation, residential, commercial and institutional buildings, transportation, agriculture, and waste management" (Government of Canada, 2013). With respect to the residential sector, in April 2010, the government invested $500 million for research on emission reduction from building construction. In September 2011, the government also announced an additional investment of $195 million from 2011 to 2016 to improve energy efficiency in buildings and industries in Canada (Government of Canada, 2013).

Additionally, the Office of Energy Efficiency (OEE) administers programs to educate Canadians about the importance of conservation and also initiates incentives to help individual citizens make their houses more energy efficient (Best et al., 2010). Some of these programs include the R-2000 standard, EnerGuide for Houses (EGH), ecoENERGY, and 7ENERGY STAR appliance certification scheme that help advance clean energy solutions (established in 1982, 1997, 2007, and 2005, respectively) (OEE, 2011b). The Natural Sciences and Engineering Research Council of Canada (NSERC) Smart Net-Zero Energy Buildings Strategic Network (SNEBSN), expects to achieve similar educational goals by 2030 (NSERC, 2012). The SNEBSN's challenge is to focus on research and the design of Net Zero Energy buildings concept that will be beneficial for Canadian houses (NSERC, 2012); however, this challenge is for new construction only. Furthermore, "in 2011, the IEA reported that, among 16 countries, Canada was second only to Germany in its rate of energy efficiency improvement"[i] (NRCan, 2013a, p. 2). Furthermore, at the Energy and Mines Minister Conference in August 2013, the government agreed to follow a series of IEA recommendations for actions summarised in Table 1.2.

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[i] between 1990 and 2008

Table 1.2: IEA set of recommendations for action

IEA RECOMMENDATIONS	CANADIAN ACTION
Normalize higher efficiency in standards as technologies advance	National Energy Code for Buildings implementation underway in 12 jurisdictions; energy performance standards cover 47 products
Make energy efficiency affordable	640,000 households received grants and are now saving $400 million/year on energy; seven projects in five jurisdictions are piloting ways to shift financing away from governments
Make energy performance visible to the market	Energy performance labels on homes, vehicles and equipment; home electricity audits; systems for tracking and reporting energy performance in buildings, industry and transportation
Monitoring and verification are essential to realizing savings	Portfolio Manager benchmarking tool provides concrete and quantifiable measurement for reduction in building energy use
Raise the profile and importance of energy efficiency	Energy and Mines Ministers reiterated the importance of energy efficiency in 2012

Source: NRCan, 2013a, p. 1.

1.3 Interest and Objectives

The residential sector is a major consumer of natural resources (e.g., energy, land, water, and raw materials) during production, operation, retrofit, and demolition or conversion, and this sector is responsible for 15% of GHG emissions in Canada (CMHC, 2007). “Energy savings will be limited unless improvements are made to the existing stock” (CMHC, 2007, p. 9). Some of the most cost-effective measures include upgrading insulation, installing high efficiency furnaces, and increasing air-tightness with caulking. However, some of these measures can be achieved through implementation of more aggressive building standards, such as Net Zero Energy (equivalent EGH 100), the Passivhaus (equivalent to EGH 88) and would lower emissions and conserve energy (Red Door Energy Advisors, 2013). The current Ontario Building Code imposes mandatory requirements for new houses to achieve EGH 80 or better. Although existing houses are responsible for most of the emissions from the residential sector, the new code does not require them to meet the EGH 80 standard.

Therefore, the first objective of this study is to estimate the potential savings of energy and CO_2 emissions from retrofitted houses if Waterloo Region adopts the Passivhaus or Net Zero Energy standards. The PH and Net Zero Energy standards are used worldwide to achieve deep emission and energy reduction and will be defined in detail in Chapter 2.

The second research objective is to identify the barriers and drivers that influence the setting of new building envelope standards, such as the PH and NZE. To achieve the second research objective, a few sub-objectives are included

a) To identify the frequency and types of changes made to the building code, including changes to the insulation standards
b) To analyse political discussions about achieving higher building standards through revisions to the Ontario Building Code, including the frequency of legislative debates and the stakeholders involved
c) To identify the motivations and barriers identified by various stakeholders

Over the years, Ontario has been a leader in developing building codes and setting higher energy standards (Lio & Associates, 2010). However, it is noted that the code has gone through a series of changes where standards have been raised or lowered depending on the government of the day. Evaluating the legislative debates and associated stakeholder interests should result in a better understanding of the motivations and barriers faced when attempting to strengthen building codes to reduce energy consumption and GHG emissions.

Therefore, if these barriers are identified, they can potentially be overcome, allowing for deep retrofits, which would result in significant emission and energy reduction.

1.4 Outline of the Thesis

This thesis consists of six chapters. Since this thesis focuses on residential buildings, the second chapter introduces and defines building structures and their elements. This chapter also introduces and describes the development of sustainable buildings, standards, policies, and provincial building code requirements. Chapter three presents the selected methods to achieve the two research objectives. Chapter four presents the findings of the research study in three parts. The first part includes the results of the potential reductions when a higher building standard is met. The second part of the chapter includes the change in the insulation requirements from 1975 to the present. The third part of the results chapter represents the findings from the analysis of word frequency in the Ontario Legislative Assembly documents from 1972 to 2012. Chapter five integrates the research findings of the study. It summarizes and synthesizes major findings of the two research questions and compares them with the literature findings. Chapter six reviews the intent, limitations and importance of the research, the major research findings, as well as opportunities for future research.

Chapter 2

Literature Review

> *"Houses are built to live in, and not to look on; therefore let use be preferred before uniformity, except where both may be had"* - Bacon, 1909, p. 114

This chapter aims to identify the research gaps within the scope of the research topic. The literature on sustainable buildings is rich, however, no studies have made close comparison between the Ontario Building Code and the barriers to achieve higher building standards over the past four decades. This chapter is divided into three parts. The first part briefly introduces buildings and their structures. The second part summarizes the history of building research between 1900 and 1960 and from the 1960 to the present. In particular, this section focuses on the development of sustainable buildings during the three waves of the sustainability movement. Additionally, several building standards including the PH, NZE, and the R-2000 are defined, described and evaluated. The end of the chapter summarizes the barriers to achieving higher building code standards identified in the literature. The third part of this chapter reviews the development of Canadian architecture, policies, and building codes.

PART I

2.0 Building Structures

A building is a closed system that separates the indoor environment from the outdoor environment (Szokolay, 2008). Buildings are complex systems which "from the thermodynamic viewpoint are considered as open thermodynamic systems" (Fracastoro & Lyberg, 1983, pp. I a-2). Buildings consist of three major parts: the *superstructure* – the above-ground portion of the building); the *substructure* – the habitable below-ground portion; and the foundation – the component of the building that transfers its loads into the soil (Allen & Joseph, 2009, p. 39). The part where the building physically separates the interior with the exterior environment is known as the building envelope or building enclosure (Figure 2.1) (Straube, 2006). The role of the envelope is "to provide structural support for the walls and roof, protect the structure from deterioration, allow for natural lighting of the interior and serve as a means of getting in and out" (OEE, 2007, p. 7). The envelope consists of the following major elements:

- the base floor system(s) (or basement)
- the below-grade wall system(s),

- the above-grade wall system(s) including windows and doors, and
- the roof system(s) (Straube, 2006, p. 3).

The enclosure is also considered as a thermal system “with a series of heat inputs and outputs” (Szokolay, 2008, p. 35) presented as:

$$\Delta S = \mathrm{Qi} + \mathrm{Qc} + \mathrm{Qs} + \mathrm{Qv} + \mathrm{Qe} \tag{1}$$

where:

Qi – internal heat gain

Qc – conduction heat gain or loss

Qs – solar heat gain

Qv – ventilation heat gain or loss

Qe – evaporative heat loss

ΔS – change in heat stored in the building

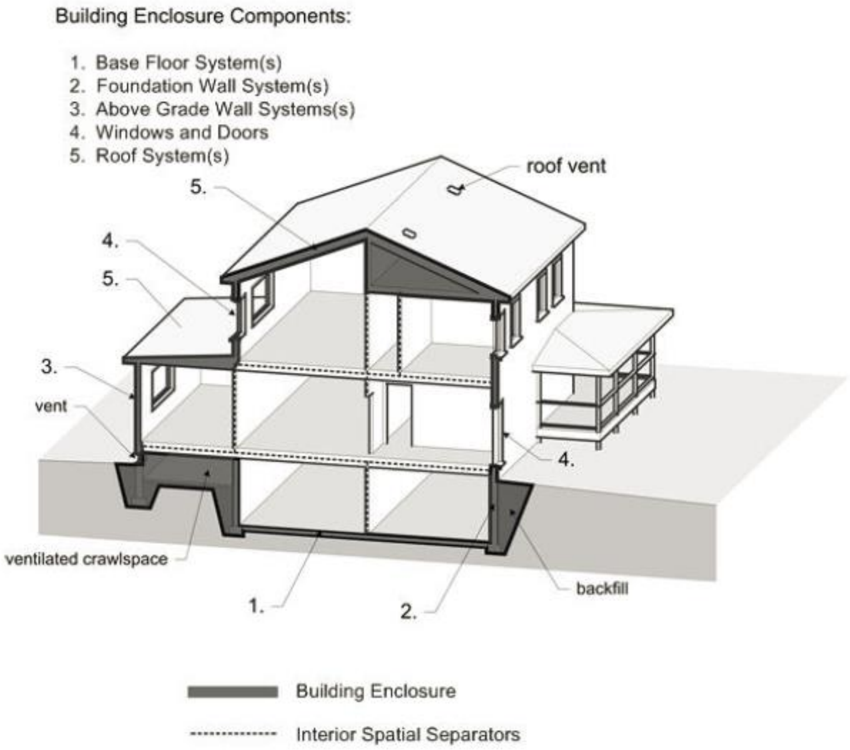

Figure 2.1: The building as a set of separated spaces and the as-built separators.
Source: Straube, 2006, p. 2.

The below-grade and above-grade wall systems play an important role in involving three interactive components of the building envelope: “the exterior environment(s), the enclosure system, and the interior environments(s)" (Straube, 2006, p. 1). The interior part of a building is affected by factors, such as "temperature, relative humidity, airflow rate, and air quality" (Straube, 2006, p. 5), all associated with the physical needs of people. The exterior part of a building is affected by the external microclimate (Straube, 2006). Certain parts of the building are impacted by different microclimates. As well, depending on the completeness of the building enclosure, buildings provide partial or full protection from environmental factors, such as sun, wind, and precipitation (Hutcheon & Handegord, 1983).

Prior to 1940 (Figure 2.2), external walls typically consisted of wallpaper, sand and lime plaster, wood lath, 2 x 4 studs (which were heavier than today's studs, or $1\frac{5}{8}$ inches thick by $3\frac{5}{8}$ inches wide), 52 square inches of airspace, building paper, cement stucco on wood lath, and brick or stone veneer (with an overall R-value of 3.7 to 4.7) (Watson, 1983, pp. 67-69). In colder climates, exterior walls were sometimes filled with materials, such as sawdust, shavings, or redwood bark as insulators. However, over time the "fills usually settled to a greater density causing reduced thermal efficiency and gaps at the top of wall cavities" (Watson, 1983, p. 70).

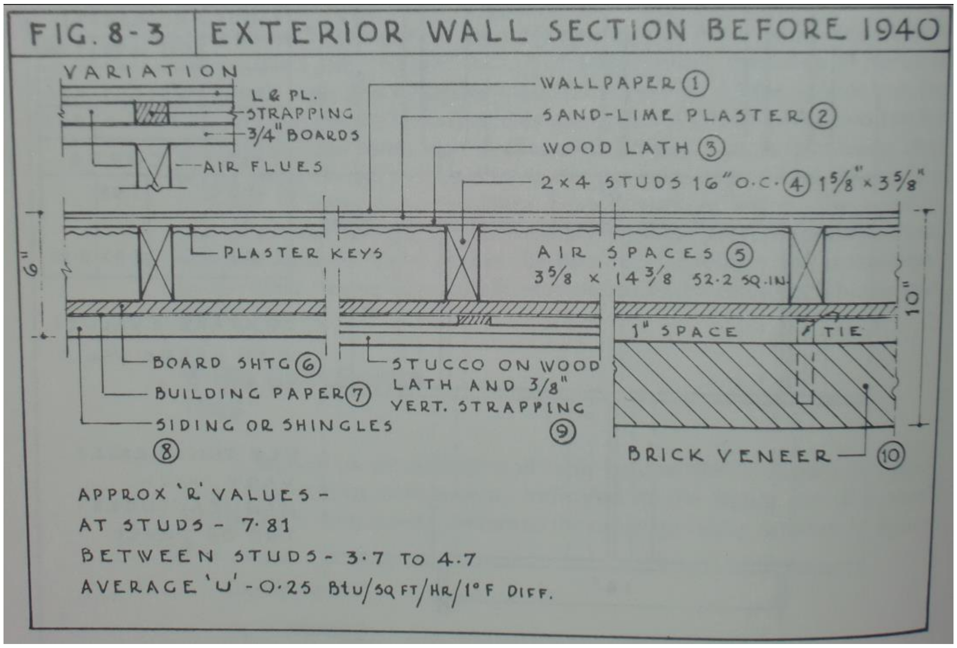

Figure 2.2: Exterior wall section before 1940. Source: Watson, 1983, p. 68.

From 1930s to the 1960s, new cooling methods changed inner-city building construction. The "invention of air conditioning, reflective glass, and structural steel popularized the enclosed glass and steel buildings that litter the American city today" (Marble Institute of America, 2008, p. 1). These buildings were heated and cooled using massive HVAC systems, which used a lot of energy (Marble Institute of America, 2008).

Houses built between 1940 and 1980 consisted of various components presented in Figure 2.3. External walls consisted of a $\frac{3}{8}$ inch gypsum lath 16 x 46 inch covered with paper on both sides, including plaster (Watson, 1983). Besides plaster, some walls also had $\frac{1}{2}$ inch wood fibre (Watson, 1983). In comparison to the walls built before 1940 (Figure 2.2), exterior walls built between 1940 and 1980 were 16 inches on centre, and stud walls had an R-value of 7.81 and R 10.44 between studs (Watson, 1983, pp. 76-77). Additionally, the walls were covered with paper-wrapped wood fibre or rock wool insulation, including a vapor-resistant paper over studs. In the 1980s external walls had $\frac{3}{8}$ or $\frac{1}{2}$ inch gypsum board bound to paper (Watson, 1983) and thicker studs, 2 x 6 inches (Watson, 1983). External walls also included structural sheathing panels, higher quality of building paper and an air barrier. The R-value of studs was 9.8, whereas between studs, the thicker insulated area had an R 23 (Watson, 1983). Over time, the wall structure changed. The trend shows an improvement in wall structure and increase in wall thickness, as well as an increase in insulation.

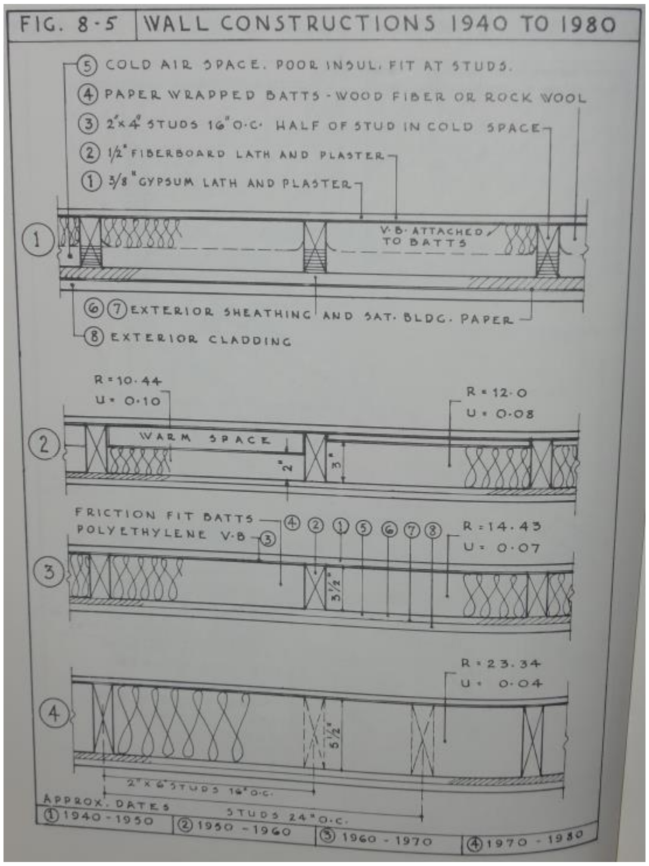

Figure 2.3: Exterior wall section between 1940 and 1980. Source: Watson, 1983, p. 76.

PART II

2.1 Brief Review of Building Research

The following subsections briefly describe building research during the 1900-1960 period and then from 1960 to the present. Different standards that have been developed to reduce emissions and energy usage in houses and some of the barriers associated with implementing the standards are also described.

2.1.1 Building Research Between 1900 and 1960

Building research started in the early 1900s and focused on the chemistry and physics of building materials and their use, and applied mathematics (Dick, 1975). Very soon, research on heating and ventilation, including lighting and sound insulation, was carried out. During this period, a large portion of the building literature also looked at the relationship between foundations and the soil on which buildings were placed (Dick, 1975). Two prominent building research institutions were established in 1921: one in the United Kingdom, the other in the former Union of Soviet Socialist Republics (Hutcheon & Handegord, 1983).

After 1945, many building research institutions were established worldwide. Building research extended to site operations, the economics and maintenance process of buildings, as well as the needs of users living or working in buildings (Dick, 1975). This postwar research illustrates the drive for "development of methods of assessing technical performance, of research on productivity and in particular the initiation of a systematic development of user needs in housing" (Dick, 1975, p. 643).

In 1947, the National Research Council of Canada (NRCC) established Canada's first Division of Building Research, whose main role was to provide the construction industry and the Canada Mortgage and Housing Corporation (CMHC) with a research service about house construction (Legget, 1950). The Division also provided research to assist decisions regarding the National Building Code of Canada. The role of the Division, however, was not to provide research on architectural or community planning (Legget, 1950). Given the extreme weather conditions in Canada, climatology became a very important part of the Division's scientific research agenda (Legget, 1950). Furthermore, the correlation between climatic conditions and building problems was studied.

During the 1950s, building research was impacted mainly by the energy due to post World War II boom in consumption and production. During this period, in Canada, Legget (1950) called for further building research on building materials, building performance, design factors, and the further development of the National Building Code. Legget (1950) strongly believed that the micro-climate should be a major consideration of Canadian houses.

2.1.2 Building Research After 1960 – Three Waves Towards Sustainable Buildings

In the 1960s, building research focused on the quality of the built environment, such as suitability of houses, transportation, and environmental pollution (Knight, 2009). This period has also been identified as the first wave towards environmental architecture due to the growing awareness of environmental issues which "[led] to the emergence of environmental action groups” (Knight, 2009, p. 4), during which the “glass box” style of high rise buildings became the icon of the North American city (Marble Institute of America, 2008). Additionally, in the 1970s, building research was affected by the increased awareness of natural resource limitations, leading to an increase in oil, plastic, and wood prices (Dick, 1975). The oil crises of 1973 changed the behaviour and direction of building structure, design, and energy consumption. In Canada, from 1973 to 1974 the total energy consumption in the residential/commercial sector declined (Figure 2.4). Decline in final consumption for other years (e.g., 1987, 1997-98, and 2006) is also evident; however, the overall trend for residential/commercial sector shows an increase (Figure 2.4). The impacts of conventional design on the environment began to be questioned and the focus turned to energy conservation (Abelson, 1979; Blair et al., 1973; Knight, 2009; Lepore et al., 1975; Leach, 1976; Schaefer et al., 1978).

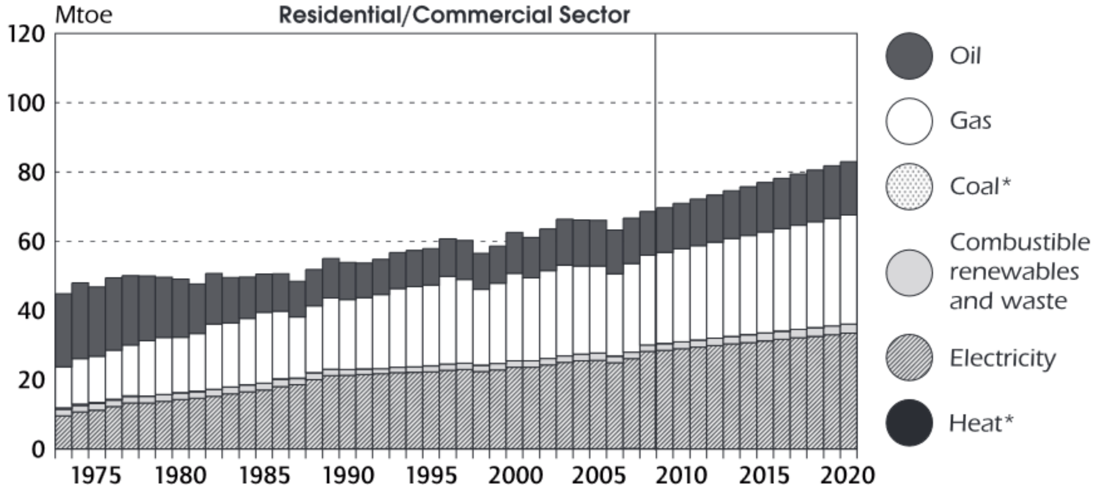

Figure 2.4: Total final consumption for the residential/ commercial sector by source, 1973 to 2020. Source: IEA, 2010, p. 67.

According to Boake (2004), the second wave towards environmental architecture began with the energy crises of the 1970s. The building literature also looked at the technical improvements of houses (Jurovics et al., 1985), as well as behavioural patterns in energy use and conservation (Becker, 1978; Black et al., 1985; Cook & Berrenberg, 1981; Ministry of Ontario, 1977). Additionally, the environmental crisis of 1980s, which includes the Bhopal and Chernobyl disasters, “resulted in increased environmental and safety legislation” (Knight, 2009, p. 3) and more environmentally conscious behaviour.

From 1978 to 1981 the consumption of oil was in decline as a result of the increase in price (Figure 2.4). Therefore, in 1978, many families made larger investments to improve their houses, such as switching house fuel from oil to gas. Additionally, some homeowners built super-insulated houses to reduce energy consumption. For example, in the United States, fuel consumption in super-insulated houses was reduced by 75% compared with houses built before 1973 (Bevington & Rosenfeld, 1990). These super-insulated houses had heavy insulation in the walls (originally R11, upgraded to R30) and ceilings (originally R19, upgraded to R60), with very tight-fitting components, as well as heat recovery ventilation systems. Some of these super-insulated houses included designs for passive solar heating through windows. A Canadian example of a super-insulated house is the Saskatchewan Conservation House built in 1977 (R40 in the basement and R60 in the attic).

Furthermore, several programs were created to assist homeowners with energy reduction. In Ontario, several loans and grant programs were developed to assist homeowners to reduce energy usage in their houses, for example, the Ontario Home Renewal Program through which homeowners with a family income below $12,500 were eligible to receive up to $7,500 in grants (Ontario Housing Corporation, 1975); Home Improvement Loans; and $100,000 Energy Management Program established "for the development and evaluation of energy saving measures in existing and future homes" (Ministry of Housing, 1976, p. 43). Additionally, in response to the rising energy demand, "a $58-million federal and provincial agreement [was] introduced for the development and demonstration of renewable energy and energy conservation technology" (Ontario Housing Corporation, 1979, p. 2). This five year program was created to stimulate Ontario's growing renewable energy and conservation intensity (Ontario Housing Corporation, 1979).

The 1973 – 1980 period was when the fuel prices were the highest and when the household energy consumption dropped the most (Baker & Frieden, 1983; Bevington & Rosenfeld, 1990). However, after 1980 energy consumption increased again (Figure 2.4). The focus of the 1970s was energy conservation, but that was soon to change.

The third wave towards environmental architecture began in 1987, with the World Commission on Environment and Development's definition of sustainable development. The third wave as described by Knight (2009) was also "about the growing realisation that actions we have taken so far are not sufficient to halt the impending crises of global warming and climate change" (p. 4). In the 1990s, building research continued to look at various strategies to achieve energy reduction and began to analyse past policies more critically. Building research also examined improving the functionality of building structures – how to keep the building warm and dry (Latta, 1973; Knight, 2009). Particularly, the building literature between 1987 and 1999 focused on the definition of sustainable design, whereas after 2000, the literature focused on the rating of green designs (Boake, 2004). Additionally, building research addressed improvements in building structures in the context of environmental issues, including climate change and threats to biodiversity (Bevington & Rosenfeld, 1990; Clarke & Maver, 1991; Gardner & Stern, 2002; Lovins, 1992; Zmeureanu & Doramajian, 1992). By the early 21st century, sustainable buildings integrated a variety of considerations: "building design, construction, operation and maintenance practices to provide healthier living and working environments to minimize environmental impacts" (Commission for Environmental Cooperation, 2008, p. 16). Examples of sustainable buildings developed during this period are NZE and the PH, described in the next section.

2.2 Sustainability Drivers

2.2.1 Sustainability

Sustainability, a buzzword of the new era (Roosa, 2010), is used extensively by different disciplines (Marshall & Toffel, 2005). As part of the environmental movement in the 1960s, sustainability was discussed initially in terms of famine, overpopulation (Meadows et al., 1972; Redclift, 1987; Roosa, 2010), resource depletion, air pollution, and spread of the chemicals and heavy metals in the environment; however, today, much of the debate focuses on "the function of ecosystems and the consumption of natural resources" (Marshall & Toffel, 2005, p. 673). Furthermore, being sustainable is the socially preferable approach in many areas: sustainable communities, sustainable agriculture, sustainable buildings and design, and sustainable practices.

There are many definitions of sustainable development. In the report *"Our Common Future"* by the World Commission on Environment and Development (1987), sustainable development was defined as “development that meets the *needs* of the present without compromising the ability of future generations to meet their own needs” (p. 41). This definition includes two key concepts: the ‘needs’ of the world’s poor and the state of technological and social organisational ‘limitations’ on the environment’s ability to not only meet present but, future needs (World Commission on Environment and Development, 1987). Although this definition has been widely used, it has been criticised by many “as being difficult or impossible to operationalize and implement” (Marshall & Toffel, 2005, p. 673). Marshall and Toffel (2005) point out that in order to not hinder “the ability of future generations to meet their own needs”, current generations must predict the needs and the abilities of the future generations, and this requires forecasting available technologies of future generations. Marshall and Toffel (2005) state that predicting the needs and abilities of future generations is a difficult task given that it is already challenging to develop a consensus on current generations’ needs and abilities. Furthermore, critics of sustainable development believe that this definition is oxymoron – “How can something develop if it is to remain the same (i.e., “sustainable”)?” (White, 2013, p. 214). Although criticised by many, sustainable development remains an important concept (Roosa, 2010). As Roosa (2010) points out

> “sustainability is evolving and growing in strength, changing how we think, changing our agendas, changing how we design buildings and infrastructure, changing the processes we use and the changing the technological solutions we implement” (p. 35).

2.2.2 Sustainable-energy Buildings

Energy conservation has widely been identified as the most promising, “highly feasible, painless and safe” (Baker & Frieden, 1983, p. 445) solution to the world’s energy problems. In buildings specifically, energy-saving measures can be achieved through standard measures, such as “improving the building envelope, modernisation of heat sources and ventilation, introduction of automation and heat metering; improvement of other installed equipment” (Chwieduk, 2003, p. 212). However, to complete the sustainability of buildings, it is necessary to include environmentally-friendly energy technologies for reduction in energy consumption (Chwieduk, 2003). Chweiduk (2003) identifies three different methodologies to achieve energy conservation and environmental protection in buildings: “standard methods of energy efficiency which are economically feasible; energy-saving measures which are beneficial to the environment; and equilibrium between present and future energy needs and environmental requirements” (p. 212).

From these three methodologies, Chweiduk (2003) defined three building categories: energy-efficient buildings, environmentally-friendly buildings, and sustainable buildings.

2.2.2.1 Energy-efficient Buildings

Energy efficiency in buildings is an important part of sustainable design. Energy efficiency has played an important role in the public policy agenda of most developed countries (Patterson, 1996). According to Patterson (1996), energy efficiency can be defined as "using less energy to produce the same amount of services or useful output" (p. 377). The importance of energy efficiency as described by Patterson (1996) is "linked to commercial, industrial competitiveness and energy security benefits, as well as increasingly to environmental benefits, such as reducing CO_2 emissions" (p. 377). The European Union Directive (2006) defines energy efficiency as "a ratio between an output of performance, service, goods or energy, and an input of energy" (p. L114/67).

According to Chweiduk (2003), energy efficient measures are often developed for old buildings that need to be refurbished or for new buildings prior to their construction. Reduction in energy demand in older buildings can be achieved by improving the elements of the building envelope, reducing heat loss in heat distribution systems and heat sources, as well as by replacing or exchanging the heat sources (Chwieduk, 2003). When refurbishing older buildings to achieve energy-efficiency, economic costs are usually taken into consideration.

Energy conservation, on the other hand, "is associated with changes in human behaviour regarding energy demand" (Grösser, 2013, p. 10). An example of energy conservation could be reducing the average house temperature by a degree and wearing more clothes (Grösser, 2013). Although this behaviour helps with reduction of energy use, it does not enhance energy efficiency because no alterations have been made to the heating and insulation technologies to adjust the average room temperature (Grösser, 2013). Making this distinction between the two terms is necessary because this paper focuses primarily on energy efficiency. Hoicka et al. (2014), point out that culture, the built environment, and technology also influence energy conservation.

In contrast to conventional structures, energy efficient structures require minimal amounts of energy for heating and cooling (Almusaed, 2011). Efficient buildings consist of well insulated interior and exterior walls, minimal thermal bridges, and airtight construction (Almusaed, 2011; UNEP, 2007). Highly insulated walls tend to be thicker than normal walls filled with an insulating material that has higher R-value. Some of these buildings have green covering to help save energy. A study conducted by Almusaed (2011) states that green building covering can help decrease the heating costs by 13%, consequently reducing GHG emissions. Double skin façade is another component of energy efficient buildings. It protects the external building elements from strong summer sun (Almusaed, 2011). Ground source heat pumps and district heating are other mechanisms for efficient heating systems (UNEP, 2007). Building structures are large users of materials that have high embodied energy[ii] (UNEP, 2007). Generally, highly processed materials have higher embodied energy. For instance, the manufacturing process of steel beams is two to three times more energy intensive than the manufacturing of glulam or timber beams (UNEP, 2007). As a result, the choice of building materials can be another way to save energy. For example, reusing building materials, such as clay bricks and roofing clays reduces the use of resources and energy for production of new materials, and has been shown to have 55% less impact on the environment (UNEP, 2007).

2.2.2.2 Environmentally-friendly Buildings

In comparison to energy-efficient buildings, environmentally-friendly buildings consider the broader global energy-conservation and supply issues, rather than focus only on the demand side of the building. In addition, environmentally-friendly buildings have energy-efficient design and construction, appropriate building materials, design practices, and efficient appliances to reduce the total GHG emissions (National Timber Development Council, 2001). Specifically, environmentally-friendly buildings use renewable energy sources, leading to less fossil-fuel use, and consequently, less polluting the environment. When building or converting conventional buildings to environmentally-friendly building status, it is necessary to consider the following requirements: the type of fuel used for energy production, the method of energy conversion applied, the amount of pollution in the environment from the energy generation process, energy

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[ii] Embodied energy – energy used during the manufacturing of building materials and components (UNEP, 2007, p. 7).

transmission, and the end use (Chwieduk, 2003). Apart from the standard energy conservation solutions, builders of environmentally-friendly buildings should also consider the following technologies and measures:

- bioclimatic building design and orientation;
- integration of solar-active thermal and photovoltaic systems into building structures;
- short and long term (seasonal) energy storage (e.g., underground thermal energy storage);
- space heating accomplished by heat pumps based on renewables or waste heat;
- heat recovery; including sewage system, ventilation and air conditioning systems;
- waste sorting, collecting and utilisation or re-use of wastes;
- water management, including introduction of water-saving equipment, water treatment, re-use of waste water and rain water. (Chwieduk, 2003, pp. 214-215)

2.2.2.3 Sustainable Buildings

Just as there are many definitions for sustainability and sustainable development, there are many definitions for sustainable buildings. In some cases, buildings have been defined as sustainable even when they are slightly less energy demanding than conventionally built buildings (Harvery, 2006). In other cases, buildings have been labelled as sustainable in terms of minimizing energy use or the use of natural resources (Harvery, 2006). However, as Harvey (2006) points out, just because buildings use fewer natural resources, it does not mean that they are sustainable. According to Chweiduk (2003), sustainable buildings contain elements of energy-efficient and environmentally friendly buildings. In sustainable buildings, the emphasis is placed on the quality of the indoor environment, the residential area, and the building materials (Chwieduk, 2003). The primary goal of sustainable buildings according to Barnett and Browning (2007, p. 2) is

> “to lessen the harm poorly designed buildings cause by using the best of ancient building approaches in logical combination with the best of new technological advances...that are net *producers* of energy, food, clean water and air, beauty and healthy human and biological communities.”

The idea of sustainable buildings is to incorporate the complete life cycle of buildings, the environmental and functional quality, as well as future values (SESAC, N.A.). The European Sustainable Energy Systems in Advanced Cities (SESAC) (N.A.) identifies five objectives for sustainable buildings: resource efficiency (e.g., present and future protection of energy, water, and materials), energy efficiency (e.g., GHG emissions reduction), pollution prevention, harmonisation with environment, and integrated and systemic approaches. The building standards have to incorporate these objectives. In the following sections examples of sustainable buildings will be drawn from North America and Europe.

2.3 Building Standards

Housing is a major contributor to CO_2 emissions worldwide, and construction of new and retrofit of older houses provides an opportunity to address this issue (Williams, 2012). For example, carbon neutral, energy plus, low-energy, LEED, net-zero energy, passivhaus, R-2000, or zero carbon standards (UKGBC, 2013; Voss, 2008) are being adopted more often across Europe and North America (Williams, 2012). Specifically, the presence of low energy (Sweden), energy-plus (Germany), and passivhaus (Germany) standards have been observed in Europe, and LEED, R-2000, and net-zero standards are more common in North America (Williams, 2012). For the purpose of this research, the following subsections define, describe, and analyse three important examples of the above building standards.

2.3.1 Net Zero Energy

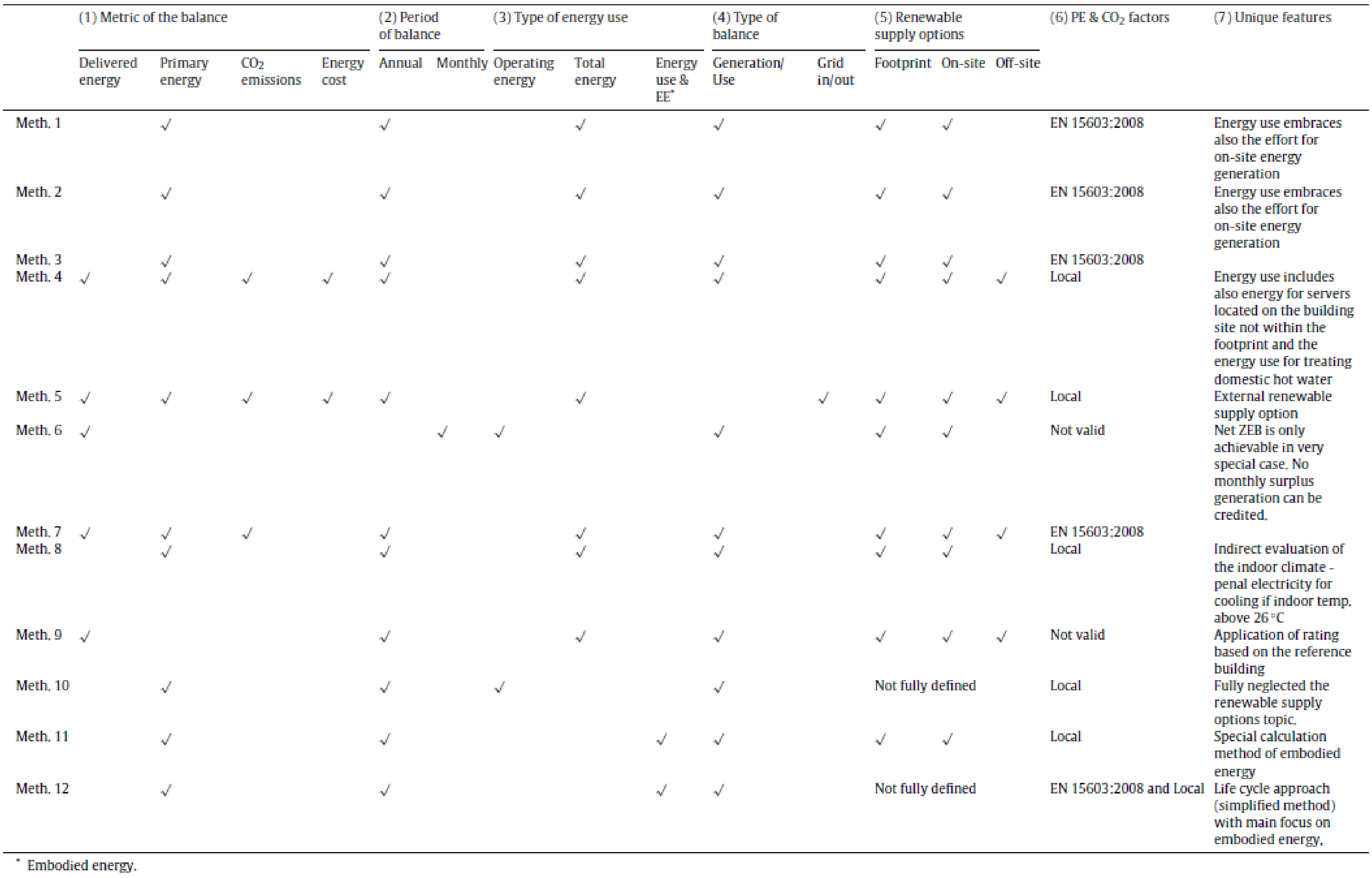
The Net Zero Energy Building (NZEB) is identified “as a realistic solution for the mitigation of CO_2 emissions and/or the reduction of energy use in the building sector” (Marszal et al., 2011, p. 971). In the existing literature the NZEB is described using different terminology, such as zero energy, zero carbon, carbon neutral, or equilibrium buildings (Marszal et al., 2011; Voss, 2008). In Europe alone there are seventeen other different terms for low and zero energy homes (European Commission, 2009). Although NZEBs are known under several different names, each of these terms focuses on different aspects, such as cost, design, energy, or carbon (Torcellini et al., 2006). For example, the aim of a zero carbon house is to reduce CO_2 emissions, whereas the aim of a zero net energy house is to consume less energy and to generate more energy than it consumes (Box 2.1). However, other definitions also incorporate carbon and/or energy.

Zero Net Energy Buildings are buildings that over a year are neutral, meaning that they deliver as much energy to the supply grids as they use from the grids. Seen in these terms they do not need any fossil fuel for heating, cooling, lighting or other energy uses although they sometimes draw energy from the grid.
Zero Stand Alone Buildings are buildings that do not require connection to the grid or only as a backup. Stand alone buildings can autonomously supply themselves with energy, as they have the capacity to store energy for night-time or wintertime use.
Plus Energy Buildings are buildings that deliver more energy to the supply systems than they use. Over a year, these buildings produce more energy than they consume.
Zero Carbon Buildings are buildings that over a year do not use energy that entails carbon dioxide emission. Over the year, these buildings are carbon neutral or positive in the term that they produce enough CO_2 free energy to supply themselves with energy.

Box 2.1: Definining ZEBs. Source: Laustsen, 2008, p. 71.

Laustsen (2008) explains that a ZEB can be "a traditional building, which is supplied with a very large solar collector and a solar photo voltage systems. If these systems deliver more energy over a year than the use in the building the goal of zero energy is met" (p. 71). Similarly, Iqbal (2004) defines ZEBs as "the annual energy consumption is equal to the annual energy production" (p. 277). However, these two definitions do not give any information on energy efficiency of the house, the insulation levels, or the annual emissions. It can be concluded that there is a lack of commonly agreed definition and a robust calculation methodology for NZEBs (Marszal et al., 2011). For the NZEB concept to progress internationally, a commonly agreed definition and guidelines are required (Marszal et al., 2011). According to Marszal et al. (2011), before new NZEB definitions are developed, the seven categories listed in Table 2.1 need to be considered.

Table 2.1: Matrix with methodologies' features



	(1) Metric of the balance				(2) Period of balance		(3) Type of energy use			(4) Type of balance		(5) Renewable supply options			(6) PE & CO_2 factors	(7) Unique features
	Delivered energy	Primary energy	CO_2 emissions	Energy cost	Annual	Monthly	Operating energy	Total energy	Energy use & EE*	Generation/ Use	Grid in/out	Footprint	On-site	Off-site		
Meth. 1		✓			✓			✓		✓		✓	✓		EN 15603:2008	Energy use embraces also the effort for on-site energy generation
Meth. 2		✓			✓			✓		✓		✓	✓		EN 15603:2008	Energy use embraces also the effort for on-site energy generation
Meth. 3		✓			✓			✓		✓		✓	✓		EN 15603:2008	
Meth. 4	✓	✓	✓	✓	✓			✓		✓		✓	✓	✓	Local	Energy use includes also energy for servers located on the building site not within the footprint and the energy use for treating domestic hot water
Meth. 5	✓	✓	✓	✓	✓			✓			✓	✓	✓	✓	Local	External renewable supply option
Meth. 6	✓					✓	✓			✓		✓	✓		Not valid	Net ZEB is only achievable in very special case. No monthly surplus generation can be credited.
Meth. 7	✓	✓	✓		✓			✓		✓		✓	✓	✓	EN 15603:2008	
Meth. 8		✓			✓			✓		✓		✓	✓		Local	Indirect evaluation of the indoor climate - penal electricity for cooling if indoor temp. above 26 °C
Meth. 9	✓				✓			✓		✓		✓	✓	✓	Not valid	Application of rating based on the reference building
Meth. 10		✓			✓		✓			✓		Not fully defined			Local	Fully neglected the renewable supply options topic.
Meth. 11		✓			✓				✓	✓		✓	✓		Local	Special calculation method of embodied energy
Meth. 12		✓			✓				✓	✓		Not fully defined			EN 15603:2008 and Local	Life cycle approach (simplified method) with main focus on embodied energy.

* Embodied energy.

Source: Marszal et al., 2011, p. 973.

For example, the definition of NZEB can be influenced by factors, such as “the project goals, intentions of the investor, the concerns about the climate and green-house gas emissions, and the energy cost” (Marszal et al., 2011, p. 972). Therefore, Torcellini et al. (2006) identify four types of NZEB definitions: net zero site energy, net zero source energy, net zero energy costs, and net zero energy emissions. Additionally, political factors can also have an impact on the NZEB definition (Voss, 2008). For example, in the U.S. and England, NZEBs are defined for political reasons so that they can define their future goals for energy reduction and conservation in the building sector, or for environmental reasons (Voss, 2008). In some European countries, such as Germany, this approach has not been the case (Voss, 2008). Additionally, different stakeholders are concerned with various aspects of NZEBs. For example, building owners are concerned about energy costs, governmental organisations about national energy numbers, a building designer about site energy use for energy code requirements, and stakeholders about the environment and pollution and, therefore, are interested in emissions reduction (Torcellini et al., 2006).

In the United Kingdom, NZE houses are called net zero carbon houses. In the U.K., over the years, NZE houses have been given several definitions. The first definition of zero carbon houses was used within the context of the Level 6 (zero carbon for all uses and appliances) of the code for Sustainable Homes (Communities and Local Government, 2011a; European Commission, 2009), “used as a method for assessing and certifying sustainable design and construction of new homes” (Designing Buildings, 2013a). The code, introduced in 2006 and in operation since 2007, was designed to help reduce emissions and create sustainable houses in the U.K. (Designing Buildings, 2013a). The first definition requires yearly building carbon emissions to be NZE (Communities and Local Government, 2011a). To achieve net-zero carbon emissions, zero carbon houses have to take into account

- emissions from space heating, ventilation, hot water and fixed lighting
- expected energy use from appliances
- exports and imports of energy from the development (and directly connected energy installations) to and from centralised energy networks
- be built with high levels of energy efficiency
- achieve at least a minimum of carbon reductions through a combination of energy efficiency, onsite energy supply and/or (where relevant) directly connected low carbon or renewable heat and

- choose from a range of (mainly offsite) solutions for tackling the remaining emissions. (Communities and Local Government, 2011a, p. 10)

However, because there was scepticism for meeting the initial U.K. NZE targets and understanding the zero carbon definition, efforts were made to improve both (Designing Buildings, 2013b). The current definition of zero carbon houses in the U.K. imposes two sets of requirements shown in Box 2.2:

1. Achieving minimum Fabric Energy Efficiency Standards (FEES) based on space heating and cooling:
    - 39 kWh/m^{2}a for apartments and mid-terraced houses
    - 46 kWh/m^{2}a for end of terrace, semi-detached and detached houses
2. Using low and zero carbon technologies and connected heat networks to limit on site built emissions:
    - 10 kg CO_{2eq}/m^{2}a for detached houses
    - 11 kg CO_{2eq}/m^{2}a for attached houses
    - 14 kg CO_{2eq}/m^{2}a for low-rise apartments

Box 2.2: Update of zero carbon houses requirements. Sources: Communities and Local Government, 2011b, p. 12; Designing Buildings, 2013b; Zero Carbon Hub, 2012.

If the regulated CO_2 emissions could not be reduced using the on-site measures presented in Box 2.2, emissions can be mitigated using off-site solutions, such as the do-it-yourself option (Designing Buildings, 2013b).

In Germany, a net zero house is achieved using the requirements in Box 2.3:

The average U – value: the building envelope (transmission heat loss (HT) based in W/m^{2}K to the building envelope) must be at least 45% below the requirements of the Energy Conservation Act of 16.11.2001 (EnEV), thus, ensuring minimal heat loss at high comfort

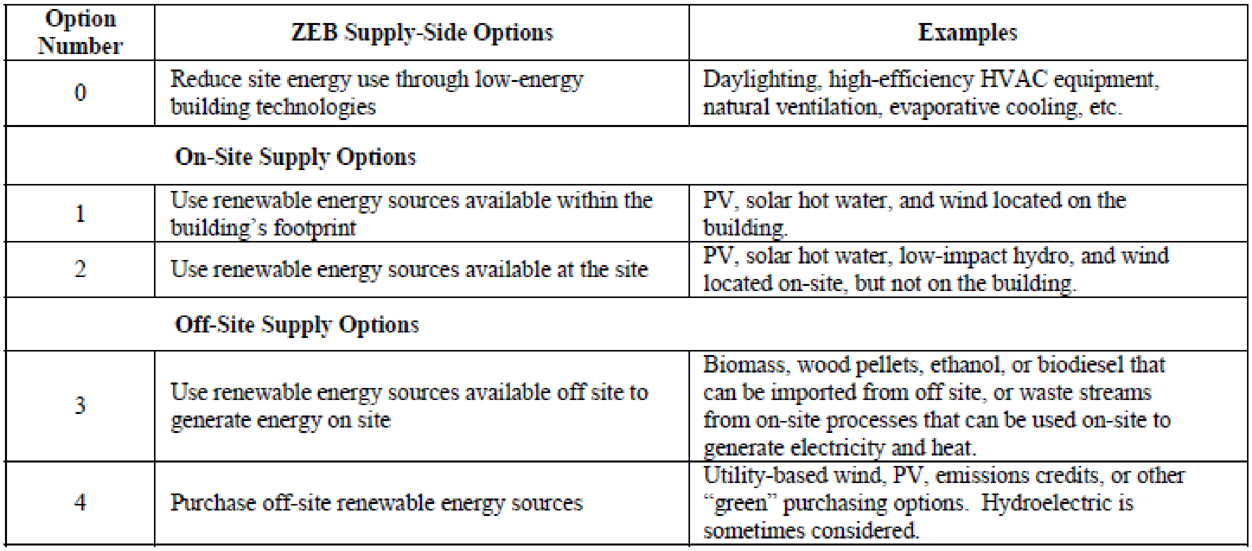
QP <100 kwh/m^{2}a: The total primary energy consumption must be less than 100 kWh/m^{2}a. The total energy intake for the building includes heating, hot water, and electricity.

CO_2 balance = 0 kg/m^{2}a: CO_2 emissions must be reduced to 0 kg/year in the annual balance sheet via regenerative self-supply or over purchase of renewable energy in the form of assets or investments.

Box 2.3: Requirements of Net Zero Energy. Source: zeroHaus, N.A.

Depending on the connection of the energy infrastructure, NZEBs can also be on-grid or off-grid (Marszal et al., 2011). Due to their high cost, off-grid ZEBs have not gained significant international attention yet, still seen as an intermediate step towards grid connected NZEBs (Marszal et al., 2011). Furthermore, renewable energy can be supplied on-site (e.g., solar or wind) and off-site (e.g., biomass). According to Torcellini et al. (2006), when on-site generation does not meet the loads, zero energy buildings (ZEB) can also use traditional energy sources, such as electricity and natural gas. Torcellini et al. (2006) add that NZEBs can also produce energy on-site by using or by purchasing renewable energy sources off-site. Torcellini et al. (2006) believe that achieving NZE without the grid is challenging due to limited generation storage technologies. As well, NZEB may also depend on outside energy sources, such as propane for space heating and cooling, cooking, and water heating (Torcellini et al., 2006). Torcellini et al. (2006) have identified several other barriers to achieving NZE. For example, wind power is seen as a limited resource for NZEBs because of structural, noise, and wind pattern consideration, and is normally not installed on buildings. Table 2.2 includes a list of possible ZEB renewable energy supply options. Torcellini et al. (2006) conclude that “a good ZEB definition should first encourage energy efficiency, and then use renewable energy sources available on site” (p. 3). In this thesis a NZE building is defined as an energy efficient building that produces renewable energy on site to supply itself and stores excess energy for night-time; has 0 $kgCO_2/m^2a$ emissions; and has a total primary energy consumption of $<100kWh/m^2a$.

Table 2.2: ZEB renewable energy supply option hierarchy



Option Number	ZEB Supply-Side Options	Examples
0	Reduce site energy use through low-energy building technologies	Daylighting, high-efficiency HVAC equipment, natural ventilation, evaporative cooling, etc.
	On-Site Supply Options	
1	Use renewable energy sources available within the building’s footprint	PV, solar hot water, and wind located on the building.
2	Use renewable energy sources available at the site	PV, solar hot water, low-impact hydro, and wind located on-site, but not on the building.
	Off-Site Supply Options	
3	Use renewable energy sources available off site to generate energy on site	Biomass, wood pellets, ethanol, or biodiesel that can be imported from off site, or waste streams from on-site processes that can be used on-site to generate electricity and heat.
4	Purchase off-site renewable energy sources	Utility-based wind, PV, emissions credits, or other “green” purchasing options. Hydroelectric is sometimes considered.

Source: Torcellini et al., 2006, p. 3.

Many NZE houses have been built in warm temperate climates and fewer in polar and arid regions (Figure 2.5a and b). Figure 2.5 b demonstrates that Germany is the leader in NZE buildings, whereas Canada is third after the U.S. in number of identified NZE buildings.

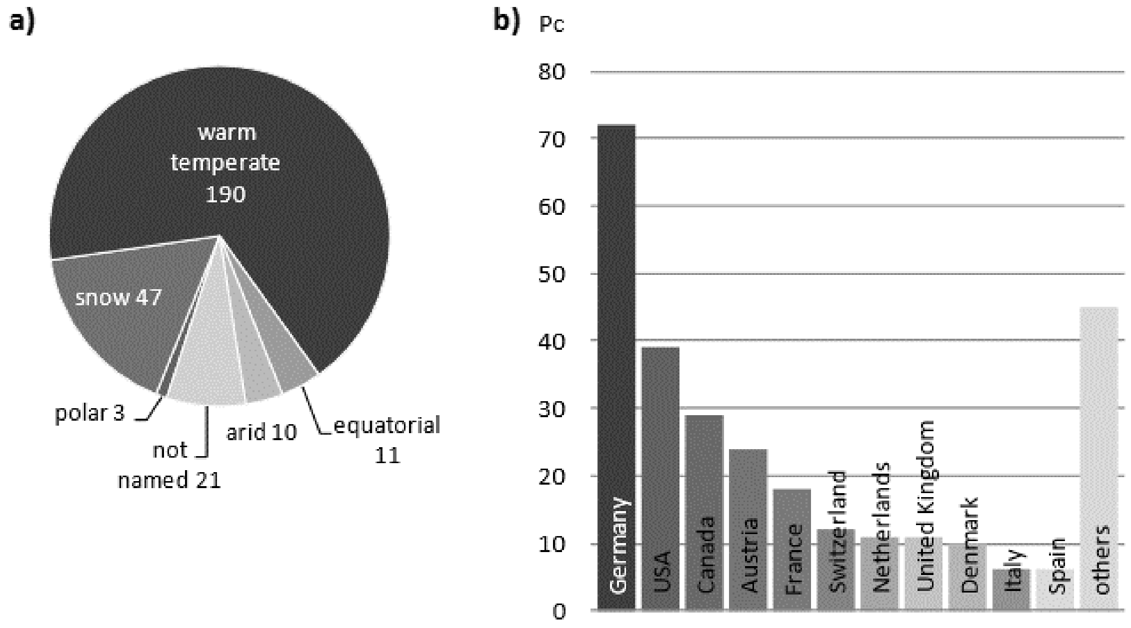


Figure 2.5: a) Frequency of different climate types. b) Number of identified Net Zero Energy buildings in different countries. Source: Musall et al., 2010, p. 3.

In 2010, countries within the European Commission adopted the Directive on Energy Performance of Buildings (Musall et al., 2010). This directive calls for all buildings to become nearly zero energy buildings by 2019, and emissions associated with buildings are expected to decrease anywhere between zero and six percent in the entire EU by 2020 (Musall et al., 2010). This directive also requires EU countries to develop appropriate national plans in order to achieve this directive. The American Institute of Architects (AIA) has created a plan to reduce energy usage by 50% in existing buildings and to further increase savings by 2030 (Maver et al., 2009). Not surprisingly, the Natural Sciences and Engineering Research Council of Canada (NSERC) Smart Net-Zero Energy Buildings Strategic Network (SNEBSN) expects to achieve similar goals by 2030. SNEBSN's challenge is to focus on research and design of the NZEBs concept that will be beneficial for Canadian houses (NSERC, NSERC smart net-zero energy buildings strategic network, 2012); however, this challenge is for new construction only. According to Voss (2008), balancing energy and emissions to achieve a NZE house is not as simple as it appears to be. It requires procedural details and complexity, and as Voss (2008) points out, "to date, there have been hardly any procedures available for balancing" (p. 1).

In Canada, several attempts have been made to bring houses to NZE standard. The EcoTerra, located in Eastman, Québec, is Canada's first nearly NZE house (CMHC, 2011). Henderson and Mattock (2007) analysed several existing houses located across Canada that were retrofitted to near net zero levels and found that the oldest houses, e.g., pre WWII, showed the biggest reductions, whereas newer houses, e.g., built after 2000, showed the lowest reductions. Across the country, space heating reductions ranged from 56% to 96%. Due to regional differences in construction and climate, houses built in Vancouver had the highest space heating reductions (85%), whereas houses in Halifax had the lowest (72%). Henderson and Mattock (2007) also found that the bungalow house type, with its simple structure and shape, can easily achieve NZE standard.

The Now House in Toronto is an example of an existing house, built in 1946, that has successfully achieved the near net zero target (CMHC, 2010). The Now House, is a post war, 1 ½ storey, 139m^2 house (Now House, 2013). The initial heat demand of the house was 85 kWh/m^{2}a, and the total energy was 176 kWh/m^{2}a. The main walls were upgraded to R41, the attic to R36, foundation above grade R28 and R25 below grade, basement slab to R25, and exterior walls to R39 (CMHC, 2010). The heat loss reduction brings the house to an EGH 84 (initial EGH 68), and the on-site production of energy with solar panels increases the EGH 94. The annual energy consumption is 96.9 kWh/m^2 (13,475 kWh), where 23.1 kWh/m^2 is used for space energy; however, with the on-site energy production of 39.4 kWh/m^2, the annual energy consumption is expected to be 57.6 kWh/m^2 (8004 kWh) (Now House, 2013). Initial annual GHG emissions of the house were 9.7 tonnes, and after the retrofit, the house emits only 3.7 tonnes, resulting in savings of 6 tonnes. The total costs for this near net zero project were $85,000.

2.3.2 Passivhaus

The concept of the Passivhaus (PH) originates from a research program conducted in 1988 by Dr. Bo Adamson who was an advisor to the Chinese government at the time (Energy Design Update, 2008). Due to limited fuel availability in some areas in China, residences could not be heated. Therefore, the idea of the program was to improve the thermal comfort in houses without using active heating systems (Energy Design Update, 2008). The concept was later extended to

Central Europe through the work of Dr. Wolfgang Feist, who is known as “the primary developer of the German Passivhaus program” (Grin, 2008, p. 16). The first PH was built in 1990 in Darmstadt Kranshichstein (Feist, 2008). However, according to Wimmers (2011), the first PH originated in Canada. In 1977, a group of Canadian researchers, including William Shurcliff and Harold Orr, built the first PH in Regina, Saskatchewan. “The Saskatchewan Conservation House had 2x double glazed windows, R-40 wall insulation, R60 roof insulation and one of the world’s first heat-recovery ventilators” (Wimmers, 2011, p. slide 13). It should be noted that Adamson’s and Feist’s ideas were based on the previous work done by William Shurcliff and Harold Orr (Energy Design Update, 2008).

The PH is one of the “most aggressive, proven, voluntary approaches to radical energy reduction, assured indoor air quality, durability, and thermal comfort in the world” (Brew, 2011, p. 51). Today, there are over 25,000 PHs in 20 countries worldwide, mostly in Germany, Austria and various places around the European Union (Wimmers, 2011). In North America, there are approximately 13 certified projects (Brew, 2011). In Canada, there are more than 30 PHs projects, few of which are certified (Wimmers, 2011). The first certified PH in Canada is in Ottawa, ON, constructed by Vert Design Inc., and Homesol Building Solutions (Homesol Building Solutions, 2012).

The PH requirements for new buildings include

- annual space heat demand ≤ 15 kWh/m^{2}a[iii]
- cooling demand ≤ 15 kWh/m^{2}a
- heating load ≤ 10 W/m^2
- excessive temperature frequency ≤ 10% (> 25°C)
- primary energy demand ≤ 120 kWh/ m^{2}a
- window unit U-value ≤ 8 kWh/m^2/K (U-Factor = 0.14; R = 7.1)
- ventilation system with heat recovery with ≥ 75% efficiency with low electricity consumption at 0.45 Wh/m^3
- thermal bridge free construction ≤ 0.01 W/mK. (Brew, 2011, p. 52; Feist, 2008, p. 2)

[iii] No more than 1.5*L* of heating oil or 1.5m^3 of natural gas (Passive House Institute & Passivhaus Dienstleistung GmbH, 2010, p. 4)

As well, the standard requires very good insulation of the building envelope (Feist, 2008). The insulation requirements are twice the requirements of the 2006 Ontario Building Code (Grin, 2008). Approximately, PH includes R-40 to R-60 in walls, R-50 to R-90 in roofs and R-30 to R-50 in slabs (Straube, 2009).The standard also requires a building to be very air-tight, and this is four times higher than the requirements of the Canadian ENERGY STAR (Grin, 2008). PHs are also thermal bridge free due to properly designed structures. The building system is not actively heated because it uses use passive heat gains and has excellent thermal insulation (Passive House Institute & Passivhaus Dienstleistung GmbH, 2010). The PH design also requires knowledge of the climatic zones in order to know the amount of materials and energy required to heat and cool the space (Keeler & Burke, 2009). The "energy conservation in a passivhaus is over 80% lower than in a conventional building – regardless of the regional climate" (Passive House Institute & Passivhaus Dienstleistung GmbH, 2010, p. 2). The PH can be built so that it uses 10 times less energy than a typical Canadian house and 50% less energy than a Platinum LEED house (Leonard, 2009). PHs reduce energy costs by 85% and, consequently, reduce CO_2 emissions by 65% (Leonard, 2009).

A study conducted by the U.K. Passive House Organisation (2011) found that a 47% reduction of CO_2 (kg/m^2a) can be achieved by meeting the space heating demand, 15kWh/m^2. Another study shows that the PH standard already reduces CO_2 emissions by 80% (Community Solutions, 2013). A study conducted by Joosten et al. (2006) found that an average existing household in Austria, Belgium, Denmark, Finland, Germany, Ireland, Netherlands, Norway, and U.K., emits about 6000 kg of CO_2 annually, and a new household emits about 4400 kg of CO_2. The same households retrofitted to a PH standard emit only 2100 kg of CO_2, equivalent to a 50 to 65% reduction. For example, in Austria, a PH uses ten times less energy for space heating than existing houses (Joosten et al., 2006) (Table 2.3). The CO_2 reduction of an Austrian PH is 1879 kg compared to an additional reduction of 3987 kg from a refurbished PH. In Finland, a PH uses 40 kWh/m^2a as opposed to 15 kWh/m^2a and saves about 55% of the energy use (Joosten et al., 2006). Due to its geographical location and high energy uses, Finnish PHs show CO_2 reduction of only 182 and 406 kg in new and refurbished PH, respectively. In addition, most of the CO_2 reduction which is achieved for direct heating, has a low CO_2 conversion factor, resulting in low CO_2 reduction in Finish PHs (Joosten et al., 2006).

In Germany, the primary energy use of a PH is only 28% of that of an existing house, and the CO_2 per PH is 2140 kg for new and 4226 kg for refurbished PHs. In comparison to Germany, in Norway, the primary energy use of a PH is 32%, whereas in the Netherlands, it is 45% of an existing house and 72% of a new house. A study conducted by Janson (2010) on four PH sites in southern Sweden (Frillesås, Lidköping, Värnamo, & Alingsås) found that the weighted energy use of the sites was below the required level of 60 kWh/m^2a[iv]. "An alternative requirement for non-weighted annual bought energy was set by FEBY [Forum for Energy Efficient Buildings] to 50 kWh/m^2a, or 30 kWh/m^2a if the energy for space heating is electricity" (Janson, 2010, p. 345).

Table 2.3: Primary energy requirements and CO_2 emission reduction for Passivhaus

Country	Primary energy use of a PH	New PH (kg CO_2)	Refurbished PH (kg CO_2)
Austria	10 times less than an existing house	1879	3987
Belgium	10 times less for space heating	5556	7130
Finland	40 kWh/m^2a	182	406
Germany	28% of an existing house	2140	4226
Ireland	x	2742	5070
Netherlands	45% of an existing house	885	2260
Norway	32% of an existing house	x	x
United Kingdom	32% of an existing house	x	x

Source: Joosten et al., 2006, pp. 15-16. *Note: x denotes no information.*

Reinberg and Reinberg (2010) retrofitted a historic, nineteenth century villa in a suburb of Vienna, Austria. The historic appearance and structure of the villa required detailed planning to bring the villa to a PH standard. Thirty centimeters of external insulation was installed in the attic, 26 cm of composite insulation in the external façade, and 20 cm in the basement. New windows with a 0.85 W/m^2K rate of heat transfer were also installed. However, because of the high ceilings and a number of details in the basement and around the foundation, the PH standard was not met. Hence, the space heating of the villa was brought down to 20 kWh/m^2a, instead of 15 kWh/m^2a.

[iv] "The weighted levels of total measured annual energy use in Swedish Passive houses as recommended by FEBY should be below 60 kWh/m^2a in Climate zone 3" (Janson, 2010, p. 345).

Dokka and Andresen (2006) carried out a PH study for three different building types (apartment, row house, & detached house) at three locations across Norway (Oslo, Lillehammer, Karasjok) and compared their findings to buildings in Zurich (Switzerland). Lillehammer (-25°C) and Oslo (-17.5°C) have cold winter temperatures, whereas Karasjok (-43.4°C), located in northern Norway, has extremely cold temperatures. Zurich (-9.4°C), on the other hand, has milder winter temperatures. To bring Norwegian buildings to a PH standard, the Passive House Design Package (PHPP) requires houses in the four regions to meet the requirements presented in Table 2.4. For example, in order to meet the PH standard, row houses located in Karasojk (69.4819° N, 25.1050° E), need very high insulation levels within the building envelope, whereas in Zurich (47.3667° N, 8.5500° E) row houses need lower insulation levels. The building requirements for detached houses in Table 2.5 show higher requirements than for row-houses. The results for apartments are very similar to the row houses.

Table 2.4: Building standard for the row section necessary to meet PH of 15kWh/m^{2}a

Climate	**Oslo**	**Lillehammer**	**Karasojk**	**Zurich**
Roof construction	R81	R81	R95	R41
External wall, main facade	R52	R52	R81	R38
External wall, gable wall	R57	R63	R95	R38
Floor (slab on ground)	R71	R71	R81	R38
Windows (total U-value)	0.08 W/m^{2}K	0.65 W/m^{2}K	0.54 W/m^{2}K	0.80 W/m^{2}K
Ventilation per m^2 (heat recovery)	1.02 m^3/hm^2	1.02 m^3/hm^2	1.02 m^3/hm^2	1.02 m^3/hm^2
Air tightness	N50=0.6ach	N50=0.45ach	N50=0.3ach	N50=0.6ach
Specific heat loss	0.36 W/m^{2}K	0.31 W/m^{2}K	0.22 W/m^{2}K	0.47 W/m^{2}K
Annual space heating demand	15 kWh/m^{2}a	14.9 kWh/m^{2}a	14.8 kWh/m^{2}a	14.9 kWh/m^{2}a
Peak heat load	10.0 W/m^2	10.6 W/m^2	8.8 W/m^2	10.6 W/m^2

Source: Dokka & Andresen, 2006, p. 226.

Table 2.5: Building standard for the detached house necessary to meet PH of 15kWh/m^{2}a

Climate	**Oslo**	**Lillehammer**	**Karasojk**	**Zurich**
Roof construction	R81	R81	R114	R57
External wall, main facade	R63	R71	R114	R47
External wall, gable wall	R63	R71	R114	R47
Floor (slab on ground)	R81	R81	R114	R57
Windows (total U-value)	0.65 W/m^{2}K	0.54 W/m^{2}K	0.35 W/m^{2}K	0.80 W/m^{2}K
Ventilation per m^2 (heat recovery)	0.99 m^3/hm^2	0.99 m^3/hm^2	0.99 m^3/hm^2	0.99 m^3/hm^2

Air tightness	N50=0.45ach	N50=0.45ach	N50=0.3ach	N50=0.6ach
Specific heat loss	0.38 W/m^2K	0.33 W/m^2K	0.20 W/m^2K	0.51 W/m^2K
Annual space heating demand	15.1 kWh/m^2a	15.1 kWh/m^2a	15 kWh/m^2a	14.9 kWh/m^2a
Peak heat load	10.9 W/m^2	11.5 W/m^2	10.2 W/m^2	12 W/m^2

Source: Dokka & Andresen, 2006, p. 225.

Elliot and Magneron (2012) made suggestions about several houses in Canada using the PHPP software. For the Now House for example (Table 2.6), increasing the insulation level in the entire envelope, especially in the uninsulated existing slab (R1), reduced the heating demand by 29.7 kWh/m^2a to reach the EnerPHit's retrofit limit of 25 kWh/m^2a. To reach the PH requirement of 15kWh/m^2a and to increase the envelope insulation even further, the house would require two 2.5m x 2.5m windows on the southernmost side of the house.

Table 2.6: The Now House upgrade list

	Initial Upgrade	Upgrade to 25 kWh/(m2a)	Upgrade to 15 kWh/(m2a)
Window frames	R3.5, 76mm	R7.9, 140mm	R7.9, 140mm
Window installation Psi value	0.040 W/(mK)	0.020 W/(mK)	0.020 W/(mK)
Window glazing	R4.3 (0.49)	R9.4 (0.54)	R9.4 (0.54)
Additional glazing			Two 2.5m x 2.5m windows
ACH50	2.9	0.6	0.6
Duct lengths	1.8288m	1m	1m
Duct insulation thickness	25mm	50mm	50mm
HRV	67%	92%	92%
Thermal bridges kWh/(m^2a)	13.28	-1.76	-1.76
Original slab	R1	R30	R47
Lowered slab	R13	R30	R47
Foundation wall	R25	R41	R53
Exterior wall	R39	R58	R76
South roof	R30	R66	R77
North roof	R25	R67	R79
Attic roof	R36	R60	R78

Source: Elliott & Magneron, 2012, p. 115. Note: Table has been modified.

Although the principle of a PH can be used worldwide, due to geographic differences and differences in national building regulations, it is challenging to have one common set of guidelines for energy use for space heating (Janson, 2010). For instance, even though there are many examples of PHs in colder climates, some researchers believe that achieving a PH standard is difficult. Following Dr. Fesit's statement in 2008, Straube (2009) expressed his concerns about achieving a PH standard in North America:

> "The definition of a Passivhaus does not need any number. As long as you build a house in a way that you can use the heat-recovery ventilation system — a system that you need anyway for indoor air requirements — to provide the heat and cooling, it can be considered a Passivhaus." (Energy Design Update, 2008, p. 3)

Straube (2009) points out that many buildings throughout North America that use the heating and cooling system to provide ventilation can be in fact PHs (Holladay, 2011; Straube, 2009). Straube (2009) also expressed his concern about the window requirements due to the difficulty in finding local "commercially-available operable windows" that will be able to meet the PH criteria. Such windows can be imported, however, at a much higher cost. Straube (2009) adds that only very few houses in N.A. have been able to achieve this requirement. Moreover, the <10 W/m^2 peak heating demand is not mandatory as it is based on the air ventilation heating. Standard calculation methods have shown that the <10 W/m^2 peak heating demand is difficult to achieve especially in cold climates (Straube, 2009). Although it is possible to retrofit an existing house to the PH standard, depending on the age, condition, size, and shape of the house, it might not be the most cost-effective measure (CanPHI, 2013a; Feist, 2012). However, meeting a PH standard in an existing house leads to "considerable improvements with respect to thermal comfort, structural longevity, cost-effectiveness over the building cycle and energy use" (Feist, 2012, p. 1). Existing houses that are undergoing deep retrofits to fulfill the PH standard will receive the EnerPHit designation (Fesit, 2011). In houses where "more than 25% of the opaque exterior wall surface has interior insulation," (Feist, 2012, p. 1) the houses will receive the EnerPHit^{+1} designation. In 2011, "only buildings located in the cool temperate Central Europe climate are being certified" (Fesit, 2011, p. 2). The following are the requirements designed by Feist (2012, pp. 1-15) for the EnerPHit designation:

- annual heating demand: $Q_H \leq 25$ kWh/m²a
- opaque building shape:
  - exterior insulation: $f_t \bullet U \leq 0.15$ W/m²K
  - interior insulation: $f_t \bullet U \leq 0.35$ W/m²K
- for the window as a whole: $U_{W,\ Installed} \leq 0.85$ W/m²K
- for g and U_g-value of glazing: $g \bullet 1.6$ W/m²K $\geq U_g$
- external doors: $f_t \bullet U_{D,\ Installed} \leq 0.80$ W/m²K
- ventilation: $\eta_{HR,\ eff} \geq 75\%$
- primary energy demand: $Q_P \leq 120$ kWh/m²a + ((Q_H - 15 kWh/m²a) ● 1.2)

- specific electricity consumption of the entire system: ≤ 0.45 Wh/m^3
- airtighthness:
    - limit value: $n_{50} \leq 1.0\ h^{-1}$
    - target value: $n_{50} \leq 0.6\ h^{-1}$
- protection against moisture: R_{sI} of 0.25 m^2/K/W
- thermal comfort:
    - exterior wall: $f_t \bullet U \leq 0.85$ W/m²K
    - roof/uppermost ceiling: $U \leq 0.35$ W/m²K
    - floor: thermal resistance at least 17˚C
    - windows/exterior doors: $U_{W/D,\ Installed} \leq 0.85$ W/m²K
    - thermal bridge[v]: $\leq +0.01$ W/mK

If the annual heating demand of 25 kWh/m² is exceeded, then to receive the certificate, all other general requirements must be met. It can be concluded that homeowners have the option to retrofit their houses using the PH targets for new houses or the EnerPHit for existing houses. The EnerPHit can be more easily met because it is flexible.

2.3.2.1 Design Parameters for achieving Passive House Standard

The requirements of the Passivhaus remain fixed regardless of location. The fundamental requirements of the PH include the primary energy demand, space heating demand, heating load, airtightness, thermal comfort, and efficient building shape (CanPHI, 2013b). According to the Canadian Passive House Institute (2013c), the following design parameters have major impact on the space heating demand, important for meeting the PH standard:

- Building Envelope: $U \leq 0.15$ W/(m²K), thermal bridge-free
- Triple-glazing: $Ug \leq 0.8$ W/(m²K), g-value (SHGC glass) > 50%
- Mechanical Ventilation: ventilation with ≥ 75% heat recovery over total system

2.3.2.2 Main Criteria for Passivhaus Certification

The PH certification is a rigorous procedure used to determine whether a house has been designed to meet the PH standard. In Canada, three main criteria must be met for a house to receive the PH certification:

- Space Heat Demand: max. 15 kWh/m²a **or** Heating load max. 10 W/m²
- Pressurisation Test Result: max. 0.6 ACH @ 50 Pa (pressurizing and depressurizing)
- Total Primary Energy Demand: max. 120 kWh/m²a. (CanPHI, 2013d)

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[v] Thermal bridges in retrofitted existing buildings are hard to be eliminated

PH practitioners can follow two approaches to obtain certification: before (design review) and after (streamlined) construction review of the project. The design review process is suggested for unexperienced practitioners.

2.3.3 R-2000

The R-2000 standard was introduced in the mid-1970s with the idea of building much more energy efficient houses (CHBA, 2011). R-2000 is a voluntary and an industry-endorsed standard "for energy efficiency, indoor air tightness quality, and environmental responsibility in home construction" (OEE, 2010). R-2000 focuses on the "house as a system" concept where all components of the house work together (CHBA, 2011). Over the years, the standard has been frequently updated "to ensure that R-2000 houses represent the leading edge of cost-effective housing technology" (NRCan, 2012, p. 4). The energy performance requirements of the current R-2000 exceed energy requirements of the current Canadian building codes (NRCan, 2013b). Houses built according to R-2000 need 30% less energy than conventional houses (NRCan, 2013b). The standard requires buildings to be energy efficient, to have good indoor air quality, and to be built and operated in an environmentally responsible manner (OEE, 2012). The R-2000 certificate gives homeowners the option to choose "construction techniques, building products, mechanical equipment, lighting, and appliances" (OEE, 2012, p. 4). R-2000 focuses on residential buildings included under Part 9 of the NBC:

- detached houses, including houses with secondary suites;
- attached houses, which include semi-detached houses, row houses, and attached houses with secondary suites; and
- multi-unit residential building, which include stacked townhouses, duplexes, triplexes and apartment buildings. (OEE, 2012, p. 4)

In comparison to the PH standard (≤15 kWh/m^{2}a), in a typical Canadian climate, an R-2000 house uses approximately 100 kWh/m^{2}a (CanPHI, 2013a). The New Generation R-2000 has higher insulation requirements than the older R-2000 and the 2012 OBC (Table 2.7). As well, the NG-R2000 requires an ERS 86 and a 50% reduction of space heating and hot water consumption (Parekh, 2012b).

Table 2.7: NG-R-2000 insulation requirements

Measure	BC	AB	SA	ON	NS
Ceiling	R51	R60	R60	R60	R60
Main walls	R29.5	R40 (dbl)	R22 w/2 rigid	R44 (dbl)	R44 (dbl)
Floor header	R20		R22 w/2 rigid	R40	R40
Windows	Triple low-E-Ar	Triple low-E-Ar	Triple low-E-Ar	Zone C	Triple low-E-Ar
Found wall	R22	ICF	R10+R22	R40 full	R40 full
Found floor	R12	R7.5	R10	R10	R10

Source: Parekh, 2012a, slide 31.

2.4 Building Retrofits

Worldwide, new buildings add only 1% per year to the existing stock, whereas the remaining 99% of existing buildings produce about 27% of the total global carbon emissions (Power, 2008). Yet, the main emphasis so far has been on new buildings (Smith, 2005). On average, older buildings contain very little insulation and less environmentally-friendly materials. Demolishing these houses is a major task that requires a lot of time and resources, and causes challenges related to waste management, and, therefore, retrofitting is usually considered. According to the Building Research Establishment's Environmental Assessment Method (BREEAM), buildings should be demolished or rebuilt when it is no longer economically or practically feasible to reuse, adapt or extend them (SESAC, N.A.).

Retrofits are usually performed to improve the efficiency and performance of the house. Fracastoro and Lyberg (1983) define retrofits as "an alteration of an existing system aiming at the improvement of its performance with regard to its function, but not introducing new uses of the system" (p. I a-3). As well as, improving energy efficiency of a house and, consequently, reducing its emissions, the goal of retrofits is to improve the comfort of living and to help save money (OEE, 2012). Comfort can be improved by adding extra insulation and extra window glazing. However, if a house is super-insulated then incoming solar radiation and internal heat gains will not dissipate through the building envelope, resulting in uncomfortable temperatures during summer months and mid-seasons (Fracastoro & Lyberg, 1983).

Retrofitting a house is a long process that requires careful preparation. It is important to take into consideration the following information (Personal Knowledge):

- the age of the house, location of the house, house type (e.g., single, detached), the number of storeys, dimensions of the house, floor or volume of heated space, and dimensions for walls on each floor;
- furnace type, space heating, fuel type, and yearly usage;
- dimensions of door and window space, types of doors and windows;
- amount of insulated space, type of insulating material and/or R-value for basement, walls, and attic insulation;
- amount and type of energy usage (electricity, natural gas, oil, propane, renewable), cost of energy usage (yearly/per type of energy source);
- heat loss at foundation, main floor, attic, doors, windows, floors, walls; and
- rating of house prior to retrofitting, and annual emissions.

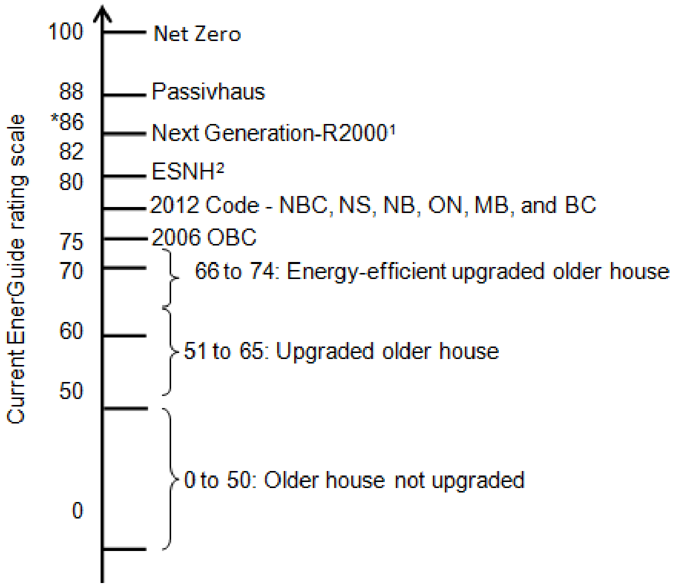

Figure 2.6: Comparison of several building standards, EnerGuide for Houses rating scale.
Source: Parekh, 2012b; Sampson, 2012; OEE, 2011b.
Note:
[1] a best-in-class performance brand, 50% better than the code for premiere builders, leading energy performance and innovation;
[2] a prescriptive energy performance brand 20% better than the code;
* 86 is key point where renewables are required to achieve a higher score

2.4.1 Insulation

Thermal insulation is the most important component that dictates the performance of a building envelope. Insulation provides resistance to heat flow through a building structure and reduces heat loss during winter and heat gain during summer, thereby reducing heating and cooling costs (Ball, 1961). Insulation of foundations, basement walls, main walls, attic, and roofs is an essential feature of energy efficient houses (Kim & Moon, 2009). Due to their "heat-insulating effect, [insulating materials] save heating and cooling energy and hence contribute to reducing carbon dioxide emissions” (Pfundstein et al., 2008, p.7). Latta (1973) believes that newer buildings must be better insulated and be more efficient. Almusaed (2011, pp. 277-80) includes a few more reasons for thermal insulation installation:

- limiting heat transfer in a dynamic system or limiting the temperature change;
- controlling condensation on the membrane surface and within the insulation system on cold piping, ducts, chillers, and roof drains; and
- providing fire protection.

Furthermore, insulation can be classified according to its composition (e.g., raw materials) and functionality depending on where it is installed. There are two main categories of insulation materials: organic and inorganic. Both categories are further subdivided into natural or synthetic according to the processing of the raw materials. In terms of its functionality and placement, insulation can be permanent or movable (Almusaed, 2011). Permanent insulation includes cellular and all fibrous and granular insulations.

The functionality and application of insulation material depend on its properties, such as thermal conductivity (λ), density, resistance, transmittance, heat capacity, moisture content, temperature and emittance of boundary surfaces, strength, stability, and breathability (Flynn, 2005; Pfundstein et al., 2008). Thermal conductivity is an important property because it determines “the capacity of a substance to transport thermal energy” (Pfundstein et al., 2008, p. 8). The effectiveness of insulation is determined by its thermal conductivity (Flynn, 2005). Insulating materials should have low conductivity to prevent heat losses. Conductivity is measured in watts/meter · kelvin (W/mK). The lower the conductivity, the lower the heat flow through the material (Pfundstein et al., 2008). Insulation materials have different thermal conductivity:

- < 0.030 W/mK – very good,
- 0.030 to 0.050 W/mK – good,
- ~ 0.060 W/mK – moderate, and
- > 0.070 W/mK – relatively high. (Pfundstein et al., 2008, p. 8)

Density (kg/m^3) of insulation is another critical property that is also related to the porosity of a material (Pfundstein et al., 2008). Low density materials usually have low porosity, which signifies lower thermal conductivity. For example, materials, such as aerogel, cotton, flax, hemp, phenolic foam, and cellulose fibres have lower density, whereas wood-boards, ceramic fibres and foam, vacuum insulation panel, insulating clay bricks, and polyethalene foam have higher density (Flynn, 2005; Pfundstein et al., 2008). The most favorable insulation density ranges from 20 to 100 kg/m^3 because “at lower densities heat transmitted by radiation increases, [whereas] at higher densities, the heat transmitted by conduction increases” (Pfundstein et al., 2008, p. 9). The thermal resistance of a material is also an important property. Materials with a high R-value have a greater heat-insulating effect and a higher resistance to heat flow (Figures 2.7 a and b) (Porter, 2007). Studies have shown that insulation thickness can have a significant effect on thermal performance, as well as economic and environmental benefits (Jeffrey & Dennis, 1999; Pfundstein et al., 2008; Kim & Moon, 2009; Almusaed, 2011). In addition, properly installed high levels of insulation can reduce thermal bridges and improve air tightness of the structure (Pfundstein et al., 2008).

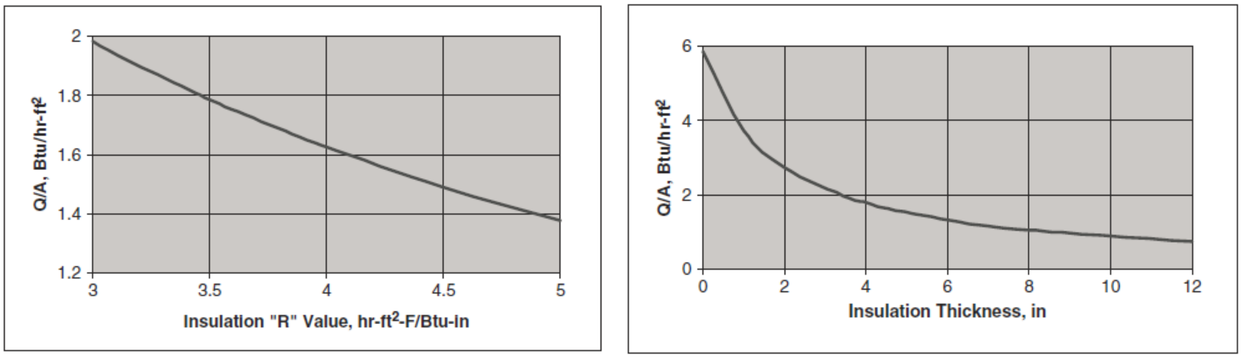

Figure 2.7: a) Wall heat loss versus insulation R-value; b) Wall heat loss versus insulation thickness. Source: Atesmen, 2009, pp.8-9.

The literature shows that prior to 1960s houses were built without sustainability in mind, however, as of 1960s provincial building codes and building standards have kept in step to use old buildings and be able to retrofit and make them more sustainable. Unfortunately, there are many barriers associated with older house retrofits and these are addressed in the following section.

2.5 Summary of Barriers to Achieving a Higher Building Standard

The literature has identified several barriers related to constructing more efficient buildings and meeting higher standards. Willand et al. (2012) group barriers under the external factors umbrella: technical, regulatory, economic, internal, and social. Willand et al. (2012) explain that retrofit decisions can be made based on the technical aspects of the house, such as the age and condition of the house, the renovation rate, the potential for energy savings and GHG reduction, and lifecycle considerations. The regulatory factors includes the building code requirements, but it may not require homeowners to take an initiative (Willand et al., 2012). Renewable energy regulations as regulatory factors can, however, provide incentives for use of renewable energies. Decisions for retrofits can also be made based on the external economic factors, including increasing energy prices, a homeowner's length of stay, and a homeowner's awareness of the overall economic benefits of retrofits (Willand et al., 2012). Internal factors, on the other hand, are associated with individual goals, attitudes, and personal characteristics, which can explain the decision making of actors. The external social factors, such as the level of retrofit awareness in the neighbourhood, can impact a household's decision whether to retrofit. Energy security issues and climate change resilience can also encourage a retrofit (Willand et al., 2012). On the other hand, most common barriers to achieving a higher building standards are economic and financial; hidden costs and benefits; market failures; behavioural and organisational; political and structural; and informational, promotional, and educational (Table 2.8).

Financial barriers are most commonly identified and vary among countries. A study conducted by Beillan et al. (2010) finds that the energy efficient retrofit market is not at the same stage of development in five[vi] developed European countries. For example, the housing renovation market in Spain is not well developed, whereas in Germany, Switzerland, France, and more recently in the northern parts of Italy, it appears to be developing steadily as a result of available financial tools and incentives.

[vi] Spain, Germany, Switzerland, France, and Italy

Table 2.8: Major barriers to energy efficient buildings

Barrier categories	Examples
Direct economic and financial	High initial costs often involved Higher up-front costs for more efficient equipment Lack of long-term perspective Lack of access to financing and energy subsidies
Hidden costs and benefits	Costs and risks due to potential incompatibilities, performance risks, and transaction costs
Market failures	Administrative and regulatory barriers (e.g., incorporation of distributed generation technologies) Fragmented market structure Limitations of the typical building design process Landlord/tenant split and misplaced incentives Lack of internalisation of environmental, health, and other external costs Unavailability of energy efficient equipment
Behavioural and organisational	Lack of visibility of energy usage Organisational failures (e.g., internal split incentives) Tendency to ignore small energy saving opportunities Tradition, behavior, and lifestyle Transition in energy expertise: loss of traditional knowledge and non-suitability of Western techniques
Political and structural	Control and regulatory mechanisms Gaps among regions at different economic levels Insufficient enforcement of standards Inadequate energy service levels Lack of detailed guidelines, tools, and experts Lack of incentives for energy efficiency investments Lack of governance leadership/interest Lack of equipment testing/certification Slow process of drafting local legislation
Informational, promotional, and educational	Factors internal to the individual, such as attitudes, norms, mental models, and capabilities Lack of awareness among consumers, building managers, construction companies, and politicians Lack of financial understanding Lack of neutral information Lack of support and information programmes Low priority of energy efficiency

Sources: Beillan et al., 2010; Carbon Trust, 2005; Deringer et al., 2004; European Commission, 2012; Evander et al., 2004; Häkkinen & Belloni, 2011; Hoicka, 2012; Hoicka et al., 2014; IPCC, 2007; Koeppel & Ürge-Vorsatz, 2007; Meacham, 2010; Tuominen et al., 2013; Yao et al., 2005; Ürge-Vorsatz et al., 2007; Zhang & Wang, 2013.

Furthermore, when financial incentive programs are created, it is often believed that "energy users act on a principle of cost minimization" (Stern et al., 1986, p. 148). Policy analysts believe that the available tax credits, rebates, and low-interest loans will minimize costs (Stern et al., 1986); however, in the U.S., these rates of investment are "far below what they would be if energy users minimized costs" (Stern et al., 1986, p. 148). Stern and Aronson (1984), Stern et al. (1986), and Tuominena et al. (2012) explain that there are both financial and non-financial reasons, such as program variables[vii] and client characteristics[viii] (Stern et al., 1986), that influence homeowner participation in energy efficiency.

Although reduced energy costs can make a difference for low income consumers, the lack of finances or even access to financial help prevents them from retrofitting. In contrast, higher income consumers tend to lack motivation to make an investment in energy efficiency (Tuominena et al., 2012). Additionally, high income consumers do not want to pay higher up-front costs for energy efficient equipment because they believe that they will not get a quick return on an investment or because they have limited understanding of the benefits of energy efficient houses (Tuominena et al., 2012). Homeowners and buyers tend to be more interested in the aesthetics, the visible characteristics (e.g., arrangements and number of rooms), and the physical condition of the house. For that reason, energy consumption and energy efficiency are not seen as the key factors in homebuyers' agendas (Tuominena et al., 2012).

However, studies have also shown that financial programs have limitations (Bird, 2006; Hoicka, 2012; Hoicka et al., 2014; Parker et al., 2003; Stern et al., 1986). For example, the EnerGuide for Houses and the ecoEnergy programs in Canada offered financial incentives to homeowners, but the funding did not come until the retrofits were completed, and took several months to arrive (Bird, 2006; Hoicka, 2012). Hence, homeowners' "motivation for action understandably declines when residents are distanced from the incentives, either over time or due to uncertainty about the efficacy of their actions" (Bird, 2006, p. 15). Hoicka and Parker (2011) also found that participants in the ecoEnergy program undertook fewer improvements than participants in the EnerGuide program. Pitts and Wittenbach (1981) examined the efficacy of the 1978 Residential Energy Conservation Tax Credit[ix] program as a means of stimulating behavior. The value of the income tax credit is a function of household tax bills, and because, on average, insulation is not expensive (ranging between $100 and $400), the subsidy was very small as well (Pitts &

[vii] "type of incentive; size of incentive; size of target population; type of target population; period of time studied; and a range of qualitative features including credibility of sponsor, motivation of sponsor…and restrictions on participation" (Stern et al., 1986, p. 149).

[viii] "household income, number of household members, education, size of home, type of structure, appliance holdings, type of heating and cooling system, fuels used, home ownership, and energy-related attitudes and beliefs" (Stern et al., 1986, p. 150).

[ix] "The program was passed as a means of achieving the goal of insulating 90 percent of the homes needing insulation over the life of the credit" (Pitts & Wittenbach, 1981, p. 355).

Wittenbach, 1981). Therefore, the tax credit program, according to the respondents, did not affect their insulation investment decision. Instead, the decision to purchase insulation was affected primarily by the needs and the purchasing power of the consumer (Pitts & Wittenbach, 1981).

Several studies have also looked at the costs of undertaking deep retrofits. For example, Henderson and Mattock (2007) discuss the costs of NZE retrofits in existing homes in the United States. Four levels of retrofits, from a general to a near zero retrofit, were identified:

- Low hanging fruit: cost about US$ 1500/house, saves 1,000 kWh and 1.6 GJ annually
- Extensive retrofit: cost about US$ 10,000/house, saves 4,000 kWh and 6.4 GJ annually
- Deep retrofit: cost about US$ 50,000/house, saves 7,000 kWh and 9.6 GJ annually
- Deep retrofit + 3kW PV: cost about US$ 75,000/house, saves 7,000 kWh and 9.6 GJ annually and produces an additional 4,300 kWha. (Henderson & Mattock, 2007, p. 2)

It was calculated that a low-level retrofit would pay for itself in seven years, whereas a deep retrofit with PV would pay for itself in 35 years and would result in a 20% annual CO_2 emission reduction and a 70 to 90% reduction in total energy use in single or multifamily houses (Henderson & Mattock, 2007). Henderson and Mattock (2007) believe there is a little likelihood of homeowners doing deep retrofits at a cost of $75,000 without any financial support. Add-ons, such as high-priced PVs, are seen as the final option for most homeowners, with a decent incentive program, a 2 kW PV system will benefit homeowners with an annual return on investment of roughly 9% (Henderson & Mattock, 2007).

Parekh (2012b) looked at the performance requirements and cost for achieving 25%-50%-75% better than the ERS80 across Canada (Table 2.9). According to Parekh, the new house market is first driven by price and location, and second by specifications (e.g., consumers) (Parekh, 2012b). Parekh (2012b) also found labour and market constraints to be a major barrier. For example, labour and unions are resisting new construction methods (Parekh, 2012b). Additionally, current costs for renewable energy is still fairly high and at this point “are not in line with production building pricing” (Parekh, 2012b, p. 41), but solar ready features, such as pre-plumbing and pre-wiring, are economically feasible. There is also a great need for further development of the solar and PV market (e.g., industry, installers, and service providers) (Parekh, 2012b).

Table 2.9: Comparisons of different scenarios to reach Net Zero Energy in Canada

Components	ERS 75 2006 OBC	ERS 80 (2012 OBC)	25% better	50% better	75% better	Net Zero Energy
Ceiling	R40	R50	R60	R60	R80	R80
Main walls	R19	R24 w/brick veneer	R22 batt + R5 foam	R44 (double wall)	R44 (double wall)	R44 (double wall)
Floor header	R19	R24 w/brick veneer	R22 batt + R10 foam	R40	R40	R40
Window	Low-E 0.10 soft, 12mm argon, insul. space vinyl frame	Low-E + Argon, Vinyl	Low-E + Argon, Vinyl	Low-E + Argon, Vinyl	Low-E + Argon, Vinyl	Low-E + Argon, Vinyl
Foundation wall	R12	R12 blanket full height	R20 blanket full height	R40 blanket full height	R40 blanket full height	R40 blanket full height
Slab			R10 entire slab	R10 entire slab	R10 entire slab	R10 entire slab
HRV efficiency	Exhaust Fan.	60%	75%	81%	81%	81%
Space heating	92% AFUE	92% AFUE	96% AFUE	97% AFUE	Ground source heat pump with HSPF≥10	Ground source heat pump with HSPF≥10
Domestic hot water	0.58 EF	0.62 EF	0.67 EF	0.82 EF	SDH of 6 GJ capacity + EF 0.9 tankless	SDH of 6 GJ capacity + EF 0.9 tankless
ACH		3.02@ 50Pa	2.0@ 50Pa	1.2@ 50Pa	1.0@ 50Pa	1.0@ 50Pa
Other				DWHR	DWHR	DWHR
Electricity generation						8.9 kWp PV panels
Median cost			$6,850	$18,700	$31,200	$96,000

Note: An efficient building envelope consists of R51 walls (double stud); R48 foundation walls; R90 ceiling; triple glazed windows (W,S,E) and quad glazed windows (N) = ERS 87. Source: Parekh, 2010; Parekh, 2012b.

Market failures have also been identified as one of the key barriers "that prevent the benefits of energy efficiency investments" (Ürge-Vorsatz et al., 2007, p. 391). "Buildings are rarely built to use energy efficiently, despite the sizeable costs that inefficient designs impose on building owners, occupants, and the utility companies that serve them" (Lovins, 1992, p. 5). Ürge-Vorsatz et al. (2007) point out that, in most cases, the end users of the buildings do not have any participatory role in the creation of the building where they end up living or working. According to Lovins (1992), the reason for these massive market failures is the institutional framework (e.g., financing, designing, construction, and operation of buildings) and the actors involved in it.

Lovins (1992) also explains that changing the system that creates and operates buildings (e.g., the structure, information flows, decision making process, technical, and social work systems) can help overcome these market failures. However, as Lovins points out, the crucial part is to understand the failures that arise at each stage of the building process. Therefore, it is necessary to understand who makes the decisions in the building business and how, and to be able to differentiate how they have been made from how they should have been made. In the building business, the real-estate developers and investors make the ultimate decision on the type of buildings that will be built, and typically, they want cheap buildings, “as cheap, that is, as the aesthetic character, comfort, and functionality demanded by a local market will permit” (Lovins, 1992, p. 8). Since the primary focus of developers is to reduce building costs, the investment in energy efficienent equipment is poor (Ürge-Vorsatz et al., 2007). The real-estate developers and the investors are interested in maximising the net present and net future value of the building. Normally, the developer, who controls the design choices, does not own the building or pay for its operating costs, and only very few developers install energy efficient equipment (Lovins, 1992).

Many studies have also identified political and structural barriers. Several studies have found political barriers in most developing and some developed countries, where a lack of governance leadership, equipment testing, and a lack of enforcement of standards exists (Deringer et al., 2004; Zhang & Wang, 2013). Tuominena et al. (2012) discovered in most of the countries barriers with respect to certification, energy audits, and voluntary agreements. Additionally, in comparison to the other ten participatory countries, Germany was the only country where the government pays attention to energy efficiency, especially in its own building investments, e.g., social housing (Tuominena et al., 2012).

Hoicka (2012) and Huber et al. (2011) found that usually, people involved in energy efficiency retrofits are not motivated by energy savings. They also found that there is a lack of skilled labour to perform energy efficient retrofits in residential buildings. For example, in Germany, energy consultants are responsible for energy efficient retrofitting, whereas in countries, such as Switzerland, France, and Italy, architects usually plan and supervise the retrofitting project (Huber et al., 2011). Huber et al. (2011) conclude that France, Italy, Switzerland, Spain and even “not all advisors were motivated by concern for the environment or climate change”; two advisors out of 12 (16%) “said that they do not think that greenhouse gas emissions are a pressing problem” (p. 168).

Many studies have also identified barriers related to information, promotion, and education regarding energy efficient retrofits. In their study, Tuominena et al. (2012) found energy efficient retrofits to be a low priority among many stakeholders. A lack of neutral information and knowledge about retrofits and energy efficiency, as well as a lack of research and information on the results of efficient retrofits was also identified (Tuominena et al., 2007). According to Hoicka et al. (2014), there are also “factors that are internal to the individual, such as attitudes, norms, mental models, and capabilities; and contextual factors, such as competing priorities, availability of information and products, and the local supply of contractors” (p. 595). Pitts and Wittenbach (1981) discovered that many homeowners had limited knowledge about the available subsidies, particularly the tax credit program. About 39% of respondents learned about the tax credit after their purchase.

Although several common barriers to constructing buildings to higher standards have been identified, assessing the energy and housing policies and the building code of Ontario could clarify the barriers in the case of Ontario. For that reason, the following sections summarize the changes to the Ontario Building Code and policies over the past forty years.

PART III

2.6 Canadian Houses

This section briefly describes Canadian architecture from the early First Nations to the present. Its purpose is to explain the evolution of building structures, specifically in Ontario. Furthermore, insulation has been a primary concern from the earlier settlers to today's households. Therefore, this section also gives a brief historical overview of how insulation played an important role in housing. The adaptation process of early settlers to the local climate can be connected to the current struggle of a modern people to adapt to the effects of climate change. This section is also intended to make connection with the development of the Ontario Building Code, to the changes in building code insulation found in the analysis of the REEP data.

2.6.1 Brief Overview of Canadian Houses

> "Lucullus answered Pompey well; who, when he saw his stately galleries, and rooms so large and lightsome, in one of his houses, said, *Surely an excellent place for summer, but how do you in winter?* Lucullus answered, *Why, do you not think me as wise as some fowl are, that ever change their abode towards the winter."*
> − Francis Bacon, 1909, p. 114.

Humans have continuously been manipulating their environment to make it suitable for living (Hutcheon & Handegord, 1983). Inherited from previous generations, building practices have been altered to climate, social habits, economy, and aesthetics to increase comfort levels (Hutcheon, 1953). Legget (1950) states that climatic conditions are very important because they dictate the way buildings are built. Weather conditions, on the other hand, are the "major determinant of the physical environment" (Hutcheon & Handegord, 1983, p. 11). Therefore, knowledge of temperature changes and the properties of snow, rain, and freeze-thaw can be of great value in construction, design, planning, and thermal performance of buildings. All these factors were taken into consideration by Canada's First Nations, the first builders of Canada.

According to Kalman (2000), the First Nations developed appropriate building structures in each of Canada's geographical regions using locally available materials, such as wood, rocks, sod, snow, skins, and bones, which were used according to the local climate (Kalman, 2000). Building structures were built seasonally and for each activity (e.g., hunting, fishing, etc.). Very well insulated structures were required for the winter season, whereas good ventilation was required for the summer (Kalman, 2000).

European settlers superimposed their architectural and technological heritage on the Canadian landscape. Examples of early colonial structures include the Norse[x] settlement structures on the east coast, the Newfoundland fishing stations[xi], the Arctic outposts found in the eastern part of Baffin Island, Frobisher Bay and Hudson Bay, and *habitation*[xii] in Nova Scotia (Kalman, 2000). The primary concern during the early settlement period was to build shelters, such as shanties or hovels for protection from the weather and the indigenous people (Hutchins, 1982). As a result of the weather and geographic location, built structures had “steeper roofs, porches, weather-boarding, and deeper foundations” (Rempel, 1980, p. 5).

Later, more substantial structures were built. European settlers brought their “preconceived ideas of what the house should consist of, both in style and physical content” (Hutchins, 1982, p. 26). The domestic architecture of early French settlements are believed to be made of wood; however, some scholars believe that they were made using stone and wood with clay or stone infill (Kalman, 2000). Only a small number of these early houses remain standing. Although it is still unclear what types of materials were used in the early structures of New France, scholars are certain that the majority of the rural houses built after 1660 were constructed using wood, with and without masonry infill (Kalman, 2000). These houses built during the early period were not well suited to the environmental conditions for the designated geographical area because the exterior walls and foundation were made of fieldstone (e.g., stones of various shapes and sizes), which, although a strong and durable material, is a poor insulator. To protect the houses from deteriorating and to retain warmth during cold winters, the exterior walls were covered with “a stucco-like layer of lime plaster known as *crépi*” (Kalman, 2000, p. 47). The roofs of these houses were fairly steep with an angle of about 60˚, which is far more than French houses of the same period. Other examples of climate adaptations include “raising the ground floor high, insulating the floors, using double windows and sashes and doors, insulating shutters,

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[x] “walls and roofs covered with sod for good insulation placed over a wooden frame” (Kalman, 2000, p. 25).

[xi] “cabins or shacks made out of spruce logs and filled with moss” (Kalman, 2000, p. 27).

[xii] “Rubble-stone foundations for most of the walls, hearths, and chimneys at an average depth of 53cm below the present surface of the ground” (Kalman, 2000, p. 34).

experimenting with central heating" (Kalman, 2000, p. 55). Using wood as a building material could have also been a response to the regional climate because it is a better insulating material than stone. It should be noted that, although there was no building code, a by-law in effect from 1820 to 1840 required log houses to be well constructed "with the minimum dimensions of 16'0" by 20'0"" (Roy, 1952, p. 45).

The earliest buildings in Ontario developed slowly over time from the beginning of the early settlement of the province to 1840 (Arthur, 1938). Newer influences in the structure and aesthetics of the houses took place after 1840 (Arthur, 1938). However, due to the rapid growth of cities, such as Toronto, many earlier buildings were destroyed (Arthur, 1938). The Canadian Loyalist refugees who settled along the northern part of the St. Lawrence River built farm houses (Kalman, 2000). Most of these Loyalist farm houses were not permanent; however, over time some of these farm houses were transformed into permanent living spaces. Almost all of these houses were built from logs because they were inexpensive and easy to use (Kalman, 2000). During this period, people believed that log houses were only temporary and would be replaced by more substantial structures (Kalman, 2000). Although log houses varied across Upper Canada, an average basic log house was "about 4.9 by 6.1m, which, in 1798, was stipulated in a general regulation as the minimum dimensions for houses" (Kalman, 2000, p. 132). Log houses also had small windows and a single door. Soon, log houses were replaced with frame, brick and stone houses (Arthur, 1938; Kalman, 2000). Besides the strong influences of Italian and English architecture, Ontario architecture was also influenced by the colonial architecture of the United States, especially, by the early German settlers from Pennsylvania. Examples of 19th century houses can be found in Waterloo Region.

Between the two World Wars (1918-1939), Canadian architecture began to modernize; however, its development was highly dependent on imported styles (Kalman, 2000). It was not until the end of World War II that Canadian building construction started to deviate from old preconceived ideas. Soon, new structural materials, such as steel and concrete, which were normally disguised by the traditional structures, were introduced (Kalman, 2000). Appendix 2, Table 2.1 summarizes some of the building characteristics of Canadian houses from 1800 until present.

As a result of the geographic location and climate, in Canada, people have always been concerned to keep heat in and make their houses more energy efficient. The following section summarizes policies and programs that were developed over time to assist with energy conservation in houses.

2.6.2 Energy Policy in Canada

For the past sixty years, energy policy in Canada has been central to public policy (Jarvis, 2005). The purpose of energy policy is to influence and shape the supply of energy sources, demand of various energy users, and the environmental impacts of energy use (Doern, 2005). However, Doern (2005) points out that core energy interests among "interest groups…and in the strategies and lobbying activities of key firms (e.g., individual corporations), players (e.g., scientists), and groups (e.g., native peoples)" (p. 41), have changed over time. Furthermore, historical record shows that energy policies were dominated by a single element or a major driver. In the 1950s and 1960s, regional and national industrial development were the driving force in energy policy. During this period, the oil industry was supported by governments to begin developing their capacity (Jarvis, 2005). After the oil crisis in 1973, security of energy supply was the driving force in energy policy. Many efforts, such as off-oil programs, hydro and nuclear development, and research and development programs, were developed to reduce the oil dependency (Jarvis, 2005). Competitiveness in the energy sector, due to energy supplies in Canada and worldwide, was the driving force in energy policy after 1985 (Jarvis, 2005). Canada's spectacular success in the amount and value of exports from the energy sector increased the pressure on the environment. As a result, in the early 1990s, the environmental issues became the driving force in energy policy (Jarvis, 2005). At this point, the focus of energy policies was on efficient energy use, which was economically and environmentally necessary. The environmental issues continued to be part of the energy policy agenda. In the late 1990s, the consequences of climate change became a dominant issue in Canada's energy policy (Jarvis, 2005). According to Winfield (2012), since the mid-1990s, provincial governments have been "the dominant actors in the formulation and implementation of environmental policy" (p. 2). The provinces have played an important role in the management of the environment and natural resources (Winfield, 2012). Unfortunately, in Canada, the literature on environmental policy formulation and implementation at the provincial level, is very limited (Winfield, 2012). Winfield (2012) points out that Canadian environmental policy in particular, has often been overlooked in governmental and political documents. In addition, historical analysis of the role of the environment in Ontario politics' has also received a very little attention (Winfield, 2012).

2.6.3 Policies and Programs on Energy Efficiency in Houses

In Canada, programs are developed to promote energy efficiency in existing houses, whereas policies, such as building codes address new houses. Over the years the government has initiated several programs to improve existing houses, as well as to reduce energy consumption and associated emissions (Table 2.10). The very rapid increase in oil prices, affected Nova Scotia and Prince Edward Island the most in terms of high energy prices (United States Congress, 1979). In response to these increases, in 1975, the Canadian Government decided "to provide subsidies for improvements in energy efficiency rather than subsidies of a direct nature for electrical price increases" (Armstrong, cited in United States Congress, 1979, p. 2). In 1977, the Canada Mortgage and Housing Corporation (CMHC) created the Canadian Home Insulation Program (CHIP) (United States Congress, 1979). The purpose of the program was "to lower the energy demand in Canada...and to reduce oil imports" (Lague, cited in United States Congress, 1979, p. 3). In response to the Iranian situation (1978-79), several major revisions, including higher energy conservation measures, were added to the program in April 1979. The CHIP program ended on March 31, 1986, at a cost of $2.2 billion (Office of the Auditor General of Canada, 1983), with a "total of 2,582,392 grants for approximately 150 various types and brands of insulation products" (Anderson, 2012). According to Stern et al. (1986), the CHIP program was seen as a very successful program, which offered a grant of 60% to cover the recommended conservation measures and cut energy use 12.8% per household.

Table 2.10: List of energy efficiency programs and initiatives in Canada

1974	Ontario Home Renewal Program
1977	Canadian Home Insulation Program
1978	EnerGuide Labeling Program
1980	National Energy Program
1980	Heat Save Energy Conservation Program
1980	Super Energy Efficient Home Program
1980	Canada-Ontario Bilateral Energy Demonstration Program
1982	R-2000
1982	Big Energy Saving Team Program
1982	Alternative Energy Program
1982	Super Energy Efficient Program
1985	HeatSave Program
1985	Enersearch Program
1989	Power Smart in BC
1991	Power Smart in Manitoba
1992	Energy Star
1992	Energy Efficiency Act
1992	Canada Fuel/Oil Substitution Program
1992	EnerMark Program
1992	Bienergy Program
1992	Off-Electric Program
1992	Ontario New Home Warranty Program
1994	EnviroHome
1998	Novoclimat
1998	EnerGuide for Houses
2001	Energy Star Program
2002	LEED
2003	Built Green™ Alberta
2003	Efficiency Ontario
2005	Power Smart Program
2005	Canadian Building Improvement Program
2005	Canadian Net Zero Energy Healthy Housing
2007	ecoENERGY
2009	Clean Energy Act and Green Energy and Green Economy Act
2009	Ontario Home Energy Audit program
2009	Ontario Energy Conservation Program
2009	Home Retrofit Program
2010	EnerGuide for New Houses

Source: CHBA, 2004, pp. 1-2; CMHC, 2013; Legislative Assembly of Ontario, 1977-2009.

In 1978, the government introduced the EnerGuide labeling program for appliances as part of the Consumer Packaging and Labelling Act (OEE, 2009). The purpose of the program was to label the energy consumption of appliances. By 2013, the EnerGuide program included labeling for heating and ventilation equipment as well as houses and vehicles.

In 1980, in response to skyrocketing oil prices, the federal government introduced the National Energy Program (NEP) (Suzuki & Moola, 2010), which focused on conservation, renewable energy, and oil substitution (Office of the Auditor General of Canada, 1983). Between 1982 and 1983, the NEP distributed over $500 million ($224 million for CHIP and $153 million for Canada Oil Substitution Program (COSP) for conservation, renewable energy, and oil substitution (Office of the Auditor General of Canada, 1983). According to Suzuki and Moola (2010), in 1984, when the federal Conservative government came into power, “they dismantled the divisive plan”. Suzuki and Moola (2010) add

> “although the program did accomplish some of its goals, reducing foreign ownership of the oil industry as well as our dependence on oil, its most lasting legacy was to entrench a great divide between the oil-rich west and the federal government. Since then, no one has dared to even mention the idea of an energy strategy for Canada. Canada is now one of the only developed nations without a coordinated energy plan.”

In 1982, the R-2000 program was introduced by the Government of Canada (OEE, 2010). The R-2000 standard exceeded the current building code requirements. Houses built using this standard are more energy efficient, with high levels of insulation, ensure comfort, and are environmentally friendly. A further description of R-2000 houses can be found in Box 2.4. The R-2000 standard is also the basis of many options presented in the 2012 Ontario Building Code.

High insulation levels in walls, ceilings and basements
High-efficiency windows and doors
High-efficiency heating
Whole-house mechanical ventilation
Testing to ensure minimal air leakage
Water-conserving fixtures
Constructed by trained builders who are licensed by the Government of Canada
Evaluated, inspected and tested by an independent third-party inspector
Certified by the Government of Canada

Box 2.4: Features of an R-2000 house. Source: OEE, 2010.

In 1992, along with other nations, Canada signed an agreement with the United Nations Framework Convention on Climate Change (UNFCC) (CACC, 2012) to reduce greenhouse gas emissions to 6% below 1990 levels by 2010 (Jaccard et al., 2002). Additionally, as part of the agreement Canada was also required to:

- provide greenhouse gas emissions data on an annual basis;
- report on our progress in reducing net greenhouse gas emissions;
- provide financial and technical resources to developing countries, especially the poorest and most vulnerable, to assist them in combating climate change; and
- conduct scientific observations of the world's climate system and research on climate change and its impacts. (CACC, 2012)

Canada’s first Energy Efficiency Act was passed by the Parliament in 1992, and the first *Energy Efficiency Regulations* came into effect in 1995 (NRCan, 2009). The Act “provides [information] for the making and enforcement of regulations concerning minimum energy-performance levels for energy-using products, as well as the labelling of energy-using products and the collection of data on energy use” (NRCan, 2009). All the Amendments to the Energy Efficiency Regulations can be found in the Canada Gazette. Additionally, in 1992, the provincial government also introduced the Building Code Act 1992, “the legislative framework governing the construction, renovation and change-of-use of a building” (Ontario Building Officials Association, 2009). The Act also initiates water and energy conservation in buildings.

In reaction to the climate change threat, following the Kyoto conference in 1997, Canada created the National Climate Change Process (NCPP) in early 1998 (Jaccard et al., 2002). In October 2000, a National Implementation Strategy on Climate Change created by the NCPP was accepted by all provincial governments except Ontario (Jaccard et al., 2002). Additionally, to meet its Kyoto target, the Government of Canada has also called for action from all citizens to reduce their emissions by one tonne per year (SEEDS, 2006).

The EnerGuide for Houses (EGH) is an example of another successful program initiated in 1998 by the Office of Energy Efficiency (OEE) and the CMHC (CHBA, 2004). The program includes both existing and new houses. The purpose of the program was to increase energy efficiency of low-rise residential houses by achieving energy use reduction by 20%, as well as to reduce the impact of housing on the environment (CHBA, 2004). The EGH also included a rating system to provide a standard measure of a house’s energy performance on a linear scale of 0-100 with 80 equal to the performance of an R-2000 house. In 2003, the program received $73.4 million to provide financial incentives to homeowners to retrofit their houses (Gamtessa, 2006). The EGH program was cancelled in May 2006 after the election of the new Federal government in January 2006 (Gleidt, 2011; Parker and Rowlands, 2007).

The ecoENERGY program was introduced in April 2007 by NRCan as a new initiative which used the same software and rating score as EGH, but replaced the performance-based incentives with list-based incentives. The initial goal of 250,000 registrations was reached and the program considered to be a success (NRCan, 2011b). NRCan provided up to $5000 in grants to homeowners to retrofit their houses to higher levels of energy performance (CMHC, 2007).

British Columbia and Ontario are two of the leading Canadian provinces in implementing legislation to regulate GHG emissions. In 2008, the government of British Columbia introduced the revenue-neutral carbon green tax "to encourage individuals, businesses and others to use less fossil fuel and reduce emissions" (B.C. Ministry of Finance, 2013). In 2009, Ontario's Minister of Energy and Infrastructure introduced Bill 150, the Ontario *Green Energy and Green Economy Act* (GEGEA) (CIELP, 2009). The purpose of the Act is to "remove barriers and promote opportunities for green energy development and use ... and also aims to improve the current slow and uncertain approval process that has been a challenge for green projects" (CIELP, 2009, p. 1). Furthermore, GEGEA encourages energy conservation in residential and commercial buildings. The GEGEA also provides the means to increase energy efficiency for businesses and individuals.

The national and provincial building codes in Canada have been improved to reduce energy consumption and associated emissions. The 2012 Ontario Building Code in particular, has been transformed to limit GHG emissions and the release of pollutants, as well as to help conserve resources (MMAH, 2012). According to the OMMAH (2010a), the 2012 OBC requires residential buildings to "meet the performance level that is equal to a rating of 80 or more when evaluated in accordance with Natural Resources Canada, "EnerGuide for New Houses: Administrative and Technical Procedures, *or to conform to Supplementary Standard SB-12"* (slide 6). According to the new standards, houses built after 2011 will have a 35% increase in energy efficiency compared to houses built prior to 2006 (OMMAH, 2010b). The code will help save energy to power 380,000 houses, as well as "to reduce greenhouse gas emissions equivalent to 250,000 fewer cars in Ontario's roads" (OMMAH, 2010b). In terms of additions to existing buildings, walls should have a thermal resistance of R24, and basement walls should have a value of R20.

2.6.4 Overview of Energy Use in Ontario Houses

To understand the context of the evolution of the Ontario Building Code, and, therefore, to understand the trends in residential development, it was important to review the Ontario electricity sector, which is tightly connected to the development of Ontario houses, energy use, and of course the associated emissions.

The Hydro Electric Power Commission of Ontario, also known as Ontario Hydro, was created in 1906 (McKay, 1983). In the next five decades, Ontario Hydro continued to be successful despite the two World Wars, and the economic, industrial and population growth during the post-war period resulting in higher electricity demand (McKay, 1983). With the rapid increase in electricity demand, Ontario Hydro was no longer able to supply the demand from hydro sources. As a result, in 1951, Ontario Hydro built the first coal-fired generating stations. In the 1960s, the first nuclear power plant was built. However, the arrival of natural gas to south Ontario in the mid-1950s caused municipal utility companies to panic because natural gas was cheaper than electricity. Furthermore, hot-water heaters, which were previously controlled by Ontario Hydro and municipal electric utilities, made it to the market fairly quickly. In response to the arrival of natural gas, Ontario Hydro, along with municipal utilities, associations of electric supply firms prepared a major marketing counter-attack, known as the "*Live Better Electrically"* campaign (McKay, 1983).

"*Live Better Electrically"*, known as the 20 year epoch of energy consumption (1954-1974), was an extraordinary and "extravagant but harmless promotional campaign that overplayed the lifestyle themes of convenience and conspicuous consumption" (McKay, 1983, p. 36). By 1961, 80% of all Ontario houses had electric lighting and electric appliances (e.g., washers, televisions, and refrigerators). During the 20-year period (1954-1974), domestic per-capita consumption of electricity tripled. The increase in electricity consumption forced Ontario Hydro and other utilities to build new generating systems. Two nuclear plants, each with four reactors at Douglas Point and later eight reactors at Pickering were built (Swift & Stewart, 2004). By the 1970s, plans for the Darlington nuclear plant were underway, "with four mega-reactors of 900 megawatts each, the largest Hydro would ever build" (Swift & Stewart, 2004, p. 13). In 1979, according to Joe Vise, a nuclear physicist, "Darlington represented everything that was wrong with the rapid expansion of technologies that centralize too much energy production in one place, rendering the whole electrical system more vulnerable than it needed to be" (Swift & Stewart, 2004, p. 14). However, natural gas was still 40% cheaper than electricity, and the heating time of a gas hot water-heater was five times faster than electric one. Nevertheless, natural gas was still not available in many rural and urban areas. In 1961, Ontario Hydro deliberately reduced electricity prices by 10% and "metered rates for electric space and water heating were replaced by flat rate charges" (McKay, 1983, p. 40). As part of this strategy, Ontario Hydro along with the municipalities signed a contract to build 5,500 Gold Medallion houses. In order to sell more electricity during off-peak hours, Ontario Hydro built the Gold Medallion Homes with more insulation than conventional homes at the time (6" in the attic, 3" in the walls, and 2" in the basement two feet below grade) (PC17, 1992). These requirements were later incorporated into the building code. Although Gold Medallion houses (Figure 2.8) had more insulation than conventional homes, they consumed up to five times more electricity than conventional houses every year, contributing GHG emissions to the atmosphere (coal powered plants).

Between 1960 and 1975, tens of thousands of Gold Medallion houses were built (Hampton, 2009). As well, between 1954 and 1974 houses were designed to use electric heat and featured large glass surfaces. In addition, the number of electrically heated houses increased from less than 1000 to more than 25,000 (McKay, 1983).

ELECTRIC HEAT . . . the heating system of tomorrow, is yours to enjoy today in a Gold Medallion home. Recessed baseboard units heat the whole room . . . no more cold drafty corners! Room-by-room controls let you keep living rooms and bathrooms comfortably warm while bedrooms stay cool for sleeping. And electric heat is clean as electric light.

Figure 2.8: Advertisement for a Gold Medallion House. Source: The Altamont Enterprise and Albany County Post, 1962, p. 6.

Hydro and utility companies soon became victims of their own success. Due to the rising demand for electricity and the inability to meet the winter peak demand, Hydro had built new and more costly generating stations and nuclear reactors. In May 1973, Hydro's annual report predicted that "nuclear power's contribution to provincial electricity production, then at 9%, would hit 60-70% by 1990" (Swift & Stewart, 2004, p. 19). Nevertheless, the dramatic oil embargo in 1973 changed the direction of electricity consumption and made Ontario Hydro more towards conservation. The International Energy Agency predicted that, by the turn of the century, a barrel of oil would cost $100 (Swift & Stewart, 2004). As a result, by 1974, the Live Better Electrically campaign had disappeared, and Ontario Hydro was advertising conservation campaigns (McKay, 1983). At this time, the Gold Medallion houses were difficult to sell

(Hampton, 2009). Various policy papers on the oil embargo showed that nuclear power could be used to supply electricity “to energy-starved nations of the industrialized world” (Swift & Stewart, 2004, p. 18). Ontario Hydro’s new plan was to build nine new energy centers exclusively fueled by uranium and coal. This plan was based on a 7% annual growth in electricity demand (Swift & Stewart, 2004). Additionally, this report did not take into consideration energy conservation and environmental impacts at all (McKay, 1983). Hydro’s goal was to change its image, from an “electric lobby frontman” to “a passive servant” trying to meet the “public’s innate demand for electricity” (McKay, 1983, p. 57). However, the oil crisis in the 1970s interrupted the period of endless growth (Figure 2.9). Although the recession following the oil crisis cut the oil demand, Figure 2.9 shows continuous increase in peak consumption.

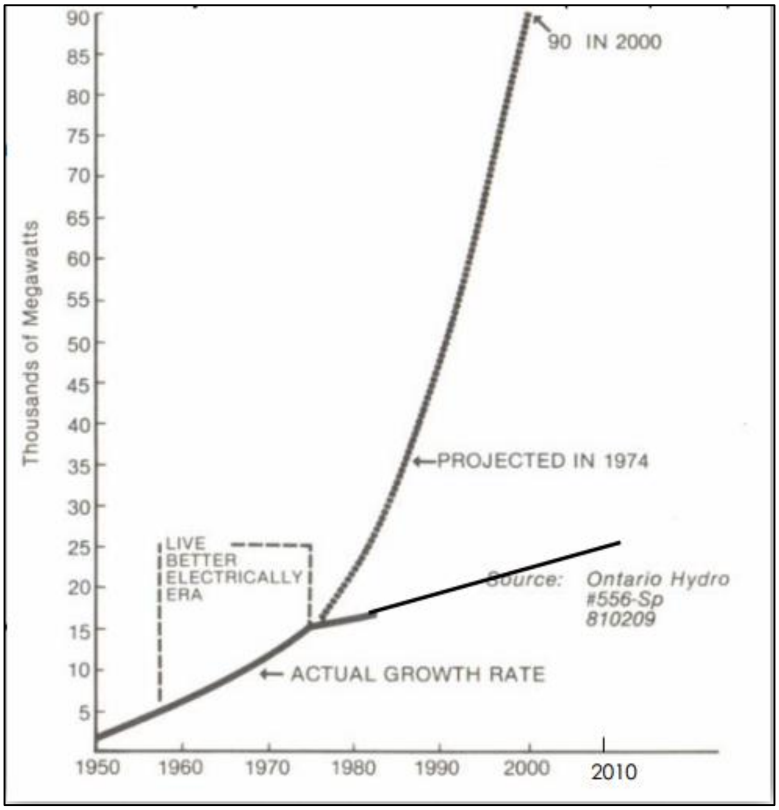


Figure 2.9: Growth in peak electric demand 1950-2000. Source: Rosenbloom, 2012, sl. 8.

2.7 Building Codes

This section first introduces Canada's National Building Code and then briefly discusses the Ontario Building Code from 1975 until 2006. In particular, it looks at the thermal insulation requirements within the building envelope: foundation, walls, and attic. This section briefly explains the history of Canada's National Building Code as it has played an important role in Ontario's Building Code development. Lastly, the paper also briefly summarizes the prospects of the Ontario Building Code going forward.

2.7.1 Overview of Canada's Building Codes

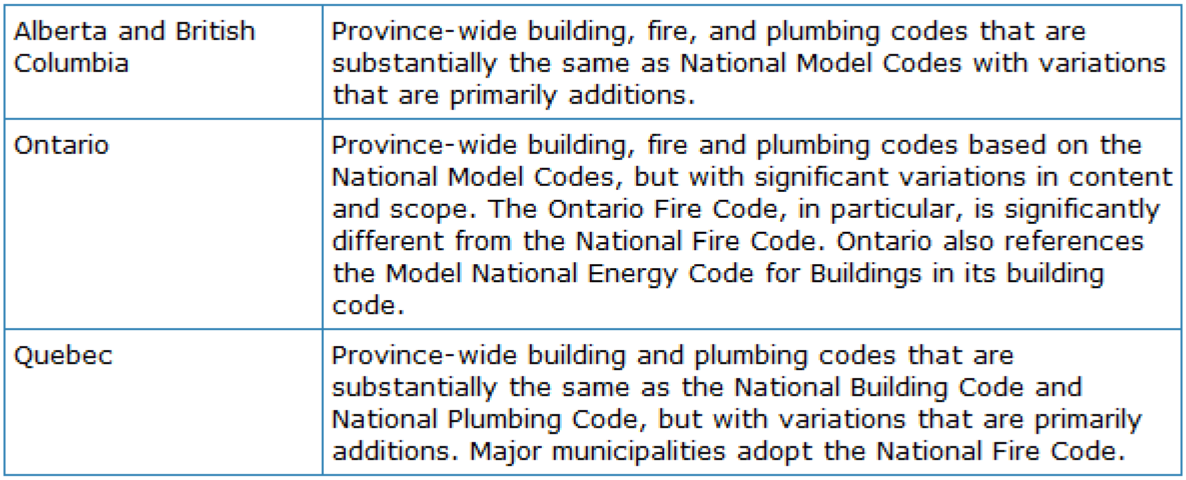
A code is "a collection of requirements, policies, rules or guidelines pertaining to a specific subject or activity, to set standards which pertain to that subject or activity" (Ontario Building Officials Association, 2009, p. 1). A building code then represents a principal government document that governs existing and newly constructed building infrastructures (Harrison & Johnston, 1990). Building codes are instruments that regulate buildings (Hutcheon, 1971). Their purpose is to set minimum standard requirements for the components of a building (e.g., materials), the safety of a building (e.g., plumbing and fire protection systems), and other systems that are part of the building (e.g., grey-water collector) (Ontario Building Officials Association, 2009). The code, however, "does not regulate conditions in existing buildings if construction or change of use are not contemplated (e.g., does not require retrofit)" (MMAH, 2010, p. 10). Building codes also depend on other codes and standards (Hutcheon, 1971). Additionally, the Building Code Act (BCA), 1992 "regulates the construction, renovation, and change of use buildings" (MMAH, 2010, p. 3). The BCA has to be followed by contractors, engineers, architects, building officials, and other individuals working in the construction field (Harrison & Johnston, 1990). In the past, individual builders and investors were allowed to determine the structural design of buildings. In the 1970s, provincial governments took direct control of building regulations. However, all municipalities in Canada are allowed to "exercise jurisdiction within the limits set by permissive provincial legislation" (Hutcheon, 1971, p. 3). As a result, building laws and regulations vary widely "in content and degree of development from one municipality to another" (Hutcheon, 1971, p. 3).

The first Building Code of Canada was the National Building Code (NBC), which was published in 1941. The NBC was created by the National Research Council Canada. As described in the official British publication, the code was considered to be the best at the time (Legget, 1950). After 1941, a further eleven editions of the NBC were published (1953, 1960, 1965, 1970, 1975, 1977, 1980, 1985, 1990, 1995, and 2005), and the newest edition is expected to come into effect by January of 2014 (NMCCD, 2011a). As well, in 1965, the first Canadian residential building code, known as the R*esidential Standards*, was developed from the NBC (NMCCD, 2011b). According to the National Model Construction Code Documents (2012), the NBC is part of the National Model Construction Codes, which also include

- National Fire Code of Canada
- National Plumbing Code of Canada
- National Energy Code of Canada for Buildings
- Model National Energy Code of Canada for Houses
- National Farm Building Code

For the NBC to have a legal status, it first needs to be adopted by a specific jurisdiction (NMCCD, 2011b). Prior to the 1970s, provinces and territories in Canada had the option to adopt the NBC under their jurisdiction. Some of the provinces, territories, and a few municipalities adopted and later modified the NBC to meet their standards. However, because Canada has numerous climatic zones and many provinces have more than one, the NBC did not appear to be very effective in terms of thermal insulation requirements. For that reason, the three provinces, Ontario, Quebec, and British Columbia, decided to create their own Building Codes suitable for their regional climatic zones (Table 2.11), whereas, the rest of the provinces and territories adopted the NBC with some modifications (Table 2.12).

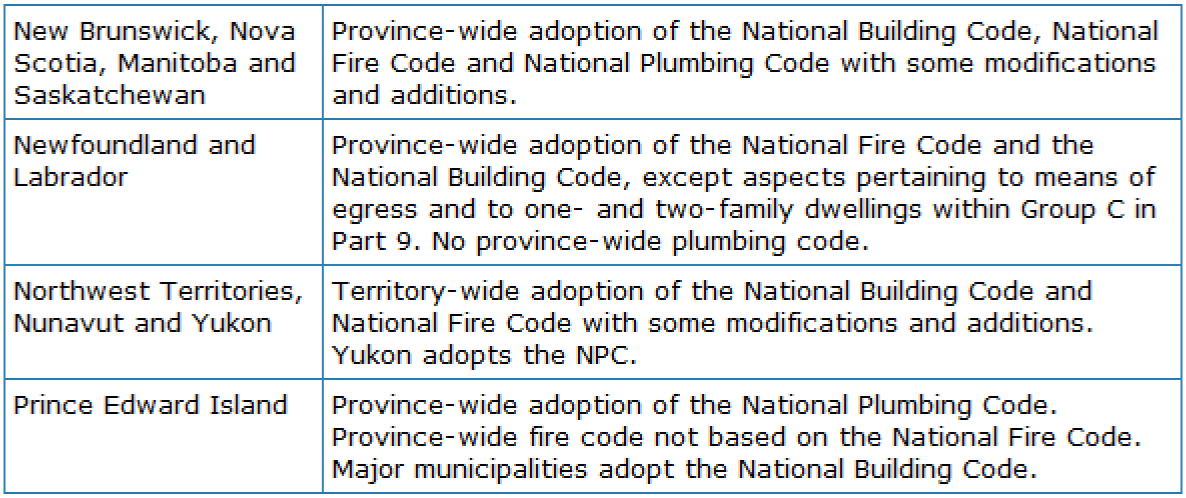
Table 2.11: Provinces that have published their own codes based on the National Model Codes



Alberta and British Columbia	Province-wide building, fire, and plumbing codes that are substantially the same as National Model Codes with variations that are primarily additions.
Ontario	Province-wide building, fire and plumbing codes based on the National Model Codes, but with significant variations in content and scope. The Ontario Fire Code, in particular, is significantly different from the National Fire Code. Ontario also references the Model National Energy Code for Buildings in its building code.
Quebec	Province-wide building and plumbing codes that are substantially the same as the National Building Code and National Plumbing Code, but with variations that are primarily additions. Major municipalities adopt the National Fire Code.

Source: NMCCD, 2011b.

Table 2.12: Provinces and territories that have adopted or adapted the National Model Codes



New Brunswick, Nova Scotia, Manitoba and Saskatchewan	Province-wide adoption of the National Building Code, National Fire Code and National Plumbing Code with some modifications and additions.
Newfoundland and Labrador	Province-wide adoption of the National Fire Code and the National Building Code, except aspects pertaining to means of egress and to one- and two-family dwellings within Group C in Part 9. No province-wide plumbing code.
Northwest Territories, Nunavut and Yukon	Territory-wide adoption of the National Building Code and National Fire Code with some modifications and additions. Yukon adopts the NPC.
Prince Edward Island	Province-wide adoption of the National Plumbing Code. Province-wide fire code not based on the National Fire Code. Major municipalities adopt the National Building Code.

Source: NMCCD, 2011b.

The Ontario Building Code (OBC) is a regulation under the Ontario Building Code Act 1992. In the OBC, a *building* is defined as:

a) a structure occupying an area greater than ten square metres consisting of a wall, roof and floor or any of them or a structural system serving the function thereof including all plumbing, works, fixtures and service systems appurtenant thereto,
b) a structure occupying an area of ten square metres or less that contains plumbing, including the plumbing not located thereto,
c) plumbing not located in a structure, a sewage system; or
d) structures designated in the building Code. (Service Ontario, 2011, p. 1.1.)

The first Ontario Building Code was published in 1975, and subsequent editions were published in 1983, 1986, 1990, 2006, and 2012 (Appendix 2, Table 2.2). Several factors influence building code changes:

- government priorities
- emergency situations
- innovations in building design and construction
- changes brought forward at the national or provincial level
- recommendations from coroner's jurisdictions, and
- requests from stakeholders. (MMAH, 2010, p. 13)

The OBC and the BCA are administered by the Ministry of Municipal Affairs and Housing (MMAH). Along with other ministries, the MMAH uses the horizontal policy approach for building regulations. The MMAH also supports the Building Code Commission, Building Materials Evaluation Commission, Building Advisory Council, and the Building Code Energy Advisory Council (MMAH, 2010). Any potential building code changes are reviewed by the Building Code Technical Advisory Committees (TACs) and the general public is consulted (MMAH, 2010). After the changes have been reviewed and the technical feasibility, enforceability, and stakeholder impacts have been considered, the TACs provide the government with recommendations. Final changes to the code are approved by the Cabinet (MMAH, 2010).

2.8 Summary of Literature Review

The literature review of this thesis focused on three different themes. The first part focused on building science, using Ontario houses as examples. The second part focused on building research between 1900 and 1960 and from the 1960 to the present. This section also, discussed the differences between the PH and NZE standards and the challenges with definitions and technical requirements. The PH standard has very specific requirements for existing and new houses. Furthermore, although the PH standard for new houses has been adopted in the northern Scandinavia, the standard has not become popular in North America. In addition, the EnerPHit, which is a PH requirement for existing houses is only available in Europe. The definitions and requirements of NZE standard on the other hand, vary extensively, making it necessary to choose a reference definition in order to make comparisons to the PH standard. In this thesis a NZE building is defined as an energy efficient building that produces renewable energy on site to supply itself and stores excess energy for night-time; has 0 $kgCO_2/m^2a$ emissions; and has a total primary energy consumption of <100kWh/m^{2}a. The PH and NZE requirements for existing houses in southwestern Ontario are addressed in the following chapter. Moreover, the third part of this chapter focused on the development of Canadian architecture, policies, and building codes. The literature revealed that insulation has been a primary concern from the earlier settlers to today's modern society. However, the literature also revealed that there are several barriers to achieving higher building code standards.

Chapter 3

Methodology

Social science research uses two types of methods: qualitative and quantitative (Palys, 1997). According to Kidder and Fine (1987), quantitative research involves numerical precision and scientific explanation, whereas qualitative research focuses on data that are rich in detail. Quantitative approaches have focused mainly on data collection (e.g., surveys) and data analysis (e.g., statistical techniques) (Calder, 1977; Corbetta, 2003). Detailed descriptions of both approaches can be found in Appendix 3, Table 3.1. Although each approach uses different empirical procedures, Lund (2005) argues that “the two approaches should be considered grounded on similar perspectives with respect to ontological and epistemological questions about reality and knowledge construction” (p. 115). Corbetta (2003) concludes that the difference between the two approaches is their application to research - “planning, data collection, data analysis and scope of findings” (p. 52).

This research uses both qualitative and quantitative approaches, also known as the mixed-methods approach (Collins et al., 2006). The idea of the mixed-methods approach is “to draw from the strengths and minimize the weaknesses of both in single research studies and across studies” (Johnson & Onwuegbuzie, 2004, pp. 14-15). Johnson and Onwuegbuzie (2004) believe that the strength of mixed-methods research lays in its “methodological pluralism or eclecticism” (p. 14) which results in superior research compared to mono-method research; hence, the mixed-methods approach is used in this research.

Since both qualitative and quantitative approaches are valuable, combining the two approaches will achieve richer results. Using the mixed-methods approach in this research is very appropriate for the following reasons. The quantitative approach will provide good quality information on

- the energy profile and initial CO_2 emissions of selected houses in Waterloo Region (REEP dataset 2006-2012);
- the CO_2 emissions reduction of selected houses in Waterloo Region when upgraded to a Passivhaus and Net Zero Energy standards;

- the frequency of selected words in the Ontario Legislative Assembly documents (1972-2012) to determine the importance of imposing stricter requirements for more efficient houses as part of the Ontario Building Code; and
- the frequency of comments by stakeholder groups involved in the decision making process.

The qualitative approach, on the other hand, is intended to provide information on

- the evolution of Ontario Building Code requirements (1975-2012); and
- the outcomes of the Ontario Legislative Assembly documents (1972-2012) for higher building standards and efficient houses.

3.0 Quantitative Methods

Quantitative research is based on pre-defined and structured design, using logical sequential phases (deductive approach) (Corbetta, 2003). In the quantitative approach, the researcher's attitude towards the research subject is neutral and detached. Additionally, data collection from various sources is performed in a standard format. The data analysis is focused on the relationship among variables that are examined using "mathematical procedures and statistical tools" (Corbetta, 2003, p. 52). Finally, the goal of quantitative research is to produce generalisations using the findings.

3.1 The Process of Social Science Research Using the Quantitative Approach

The research in this study was conducted under the umbrella of social sciences. Generally speaking, science is based on logic and observation (Babbie & Wagenaar, 1999). Babbie and Wagenaar (1999) introduce three elements in the traditional model of science: theory, operationalisation, and observation. Theory describes the logical relationship among variables; operationalisation measures the variables so that they can be empirically examined; observation involves collection of data to test hypothetical relationships among selected variables (Babbie & Wagenaar, 1999). Together, these elements help social science define what exists and why (Babbie & Wagenaar, 1999).

3.2 Research Process

The research process of this thesis can be divided into three parts (Figure 3.2). The first part of this research consists of the research design: formulation of the research questions and objectives, collection of data from primary and secondary sources, and methodological design. The second part of the research design consists of merging and presentation of research findings, and summary of the secondary literature. The last part includes the analysis of the research findings. Detailed representation of the research framework can be observed in Figure 3.3.

The main objective of this study is to determine the potential of reducing CO_2 emissions from the housing sector in Waterloo Region by achieving a higher building standard (e.g., PH or NZE).

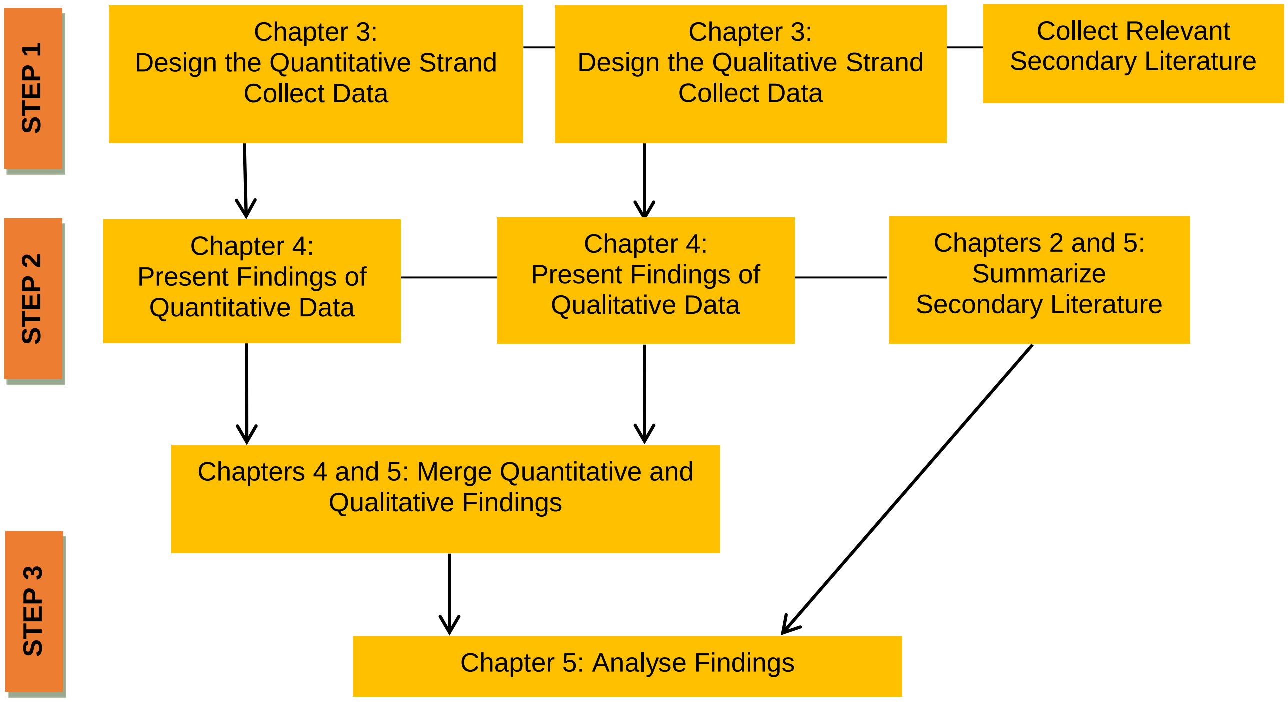


Figure 3.1: Mixed-methods research design. *Note: Framework adapted and adjusted from Hoicka, 2012, p. 65 (initially designed by Creswell and Clark, 2007).*

The first part of this thesis uses the REEP dataset. To achieve the first objective, several variables will be selected from the dataset to identify the energy profile of houses. Initial and reduced emissions from selected houses will then be calculated and compared.

The second objective of this study is to critically evaluate the barriers and drivers that influence the setting of new building envelope standards, such as the PH or NZE. To determine the barriers and drivers *Part 9: Housing and Small Buildings* of each building code will be analysed to identify changes in insulation requirements in Ontario residential buildings. In parallel, the Ontario Legislative Assembly documents will be analysed to identify the issues that raised by various stakeholders. This part of the research will identify factors that serve as barriers or drivers to achieving higher building standards.

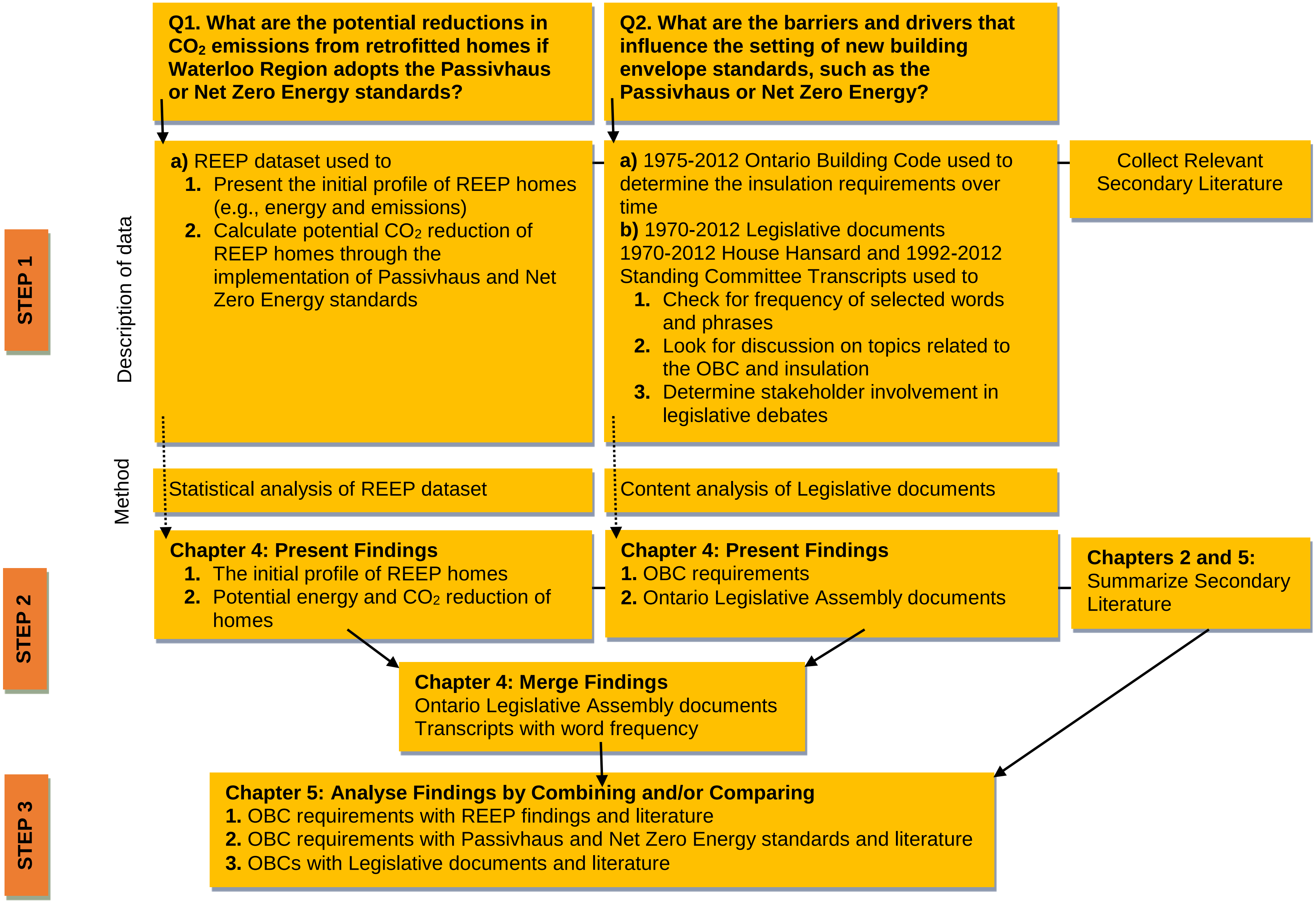


Figure 3.2: Research process of the study.

3.3 Data Collection

This research is comprised of quantitative (first research question) and qualitative (second research question) data. Consequently, the use of different sources allows triangulation, defined as “a validity procedure where researchers search for convergence among multiple and different sources of information to form themes or categories in a study” (Creswel & Miller, 2000, p. 126). Denzin (1978) defines four types of triangulation: data or data source, investigator, theoretical, and methodological triangulation. Data triangulation, which is applied in this thesis, uses different data for validation purposes. Data triangulation can be divided by time (when the data was collected), space (where the data was collected), and person (people involved in the data collection process) (Denzin, 1978; Begley, 1996). Over the years, there has been a debate about whether triangulation is possible. Some researchers argued that methodological triangulation was impossible because of epistemological and ontological differences (Hunt, 1991; Morse, 1991; Phillips, 1988); however, contemporary researchers argue that it is possible (Denzin, 1978; Hinds, 1989; Jick, 1979). The researchers disagreed mainly about the purpose and benefits of triangulation as well as the location of its implementation (Risjord et al., 2002). The following section describes the data collection for each research question.

3.3.1 Methods for Research Question 1

For the first research question – What are the potential reductions in CO_2 emissions from retrofitted houses if Waterloo Region adopts the Passivhaus and Net Zero Energy standards? – residential energy data were selected from the REEP dataset. The following subsections explain the background of the REEP project as well as the REEP dataset and the procedures to calculate emissions from the selected houses.

3.3.1.1 Background of Residential Energy Efficiency Project (REEP)

REEP Green Solutions is a not-for-profit organisation situated in the Region of Waterloo in southwestern Ontario, Canada (REEP, 2012). The aim of the REEP project is to educate the regional community about climate change issues and to provide them with “technical information and social dialogue about the link to personal energy consumption” (Parker et al., 2000, p. 19). Specifically, REEP provides homeowners with various tools, programs, and services to help them improve their houses by reducing energy and water consumption (REEP, 2012). The project was established by the University of Waterloo (Faculty of Environment), the

Elora Centre for Environmental Excellence, and Environment Canada (Adaptation and Impacts Research Group). Started as a pilot project in 1999, the program acted as a delivery agent for the national EnerGuide for Houses (EGH) program in Waterloo Region (Parker et al., 2000). For the EGH program, REEP used HOT2XP software, which produced a “comprehensive report of individual house energy efficiency using a standard scale” (Parker et al., 2000, p. 20). The objective of the project was not only to improve houses in terms of their energy efficiency but also to reduce carbon dioxide emissions and addresses the negative health impacts associated with them (Parker et al., 2000). After the cancellation of the EGH program in 2006, the Federal government introduced the ecoENERGY program in 2007. For this program, REEP used a slightly modified version of HOT2000 software to prepare individualized energy models of retrofitted houses (Hoicka & Parker, 2011). The EGH and ecoENERGY programs enabled REEP to model key energy attributes and assessed the energy efficiency of more than 14,000 houses (equivalent to 10% of the eligible housing stock) within the Waterloo Region (REEP, 2012) by 2012. Additionally, through the house retrofits, CO_2 emissions were reduced by more than 21,000 tonnes per year (REEP, 2012).

3.3.1.2 Description of REEP Data Collection

REEP used various versions of the residential energy modelling software, HOT2XP and HOT2000, to document attributes during both initial evaluations that were conducted prior to the retrofit process (so that appropriate retrofit recommendations could be made) as well as follow-up evaluations after the retrofit process (to measure all the changes made in the house) (Hoicka & Parker, 2011). HOT2000 software, developed by the federal government, provides measures for variables, such as heat loss, so that the house energy evaluator can identify actions that homeowners can take (Hoicka & Parker, 2011). The resulting information includes house type (e.g., one, two storey), volume of house, year built, furnace type and efficiency, and amount of insulation.

The process of the initial data collection (prior to first retrofit) is described below. Homeowners interested in retrofitting their houses request certified home auditors to evaluate their house. Then, during a 2-3 hour period, evaluators conduct a detailed inspection to determine the house’s condition (Parker et al., 2000). The inspections are commenced outside of the house to determine the following information (O’Neill, 2012):

- accurate location of the house with respect to north;
- type of house (e.g., one, two, three storey);
- shape of the roof (e.g., flat, triangular, gable, shed, mansard);
- number of corners of roof;
- area and slope of the roof;
- number of doors and windows;
- size of the house; and
- calculation of the stack effect to determine the air movements into and out of the house.

After this process, evaluators go inside the house where they conduct further inspections. The first indoor inspection begins in the basement where the evaluator checks the furnace and water heater type and efficiency. Other steps that the evaluators perform include (O’Neill, 2012)

- measurement of the basement floors and walls;
- type of basement floor (e.g., concrete, wood) and thickness;
- type of basement walls and thickness;
- thickness of insulation in the basement walls;
- water issues in walls and floors; and
- type, number, and size of windows and doors.

The interior inspection moves to the main floor and is similar to that of the basement but with additional information on exterior walls (i.e., thickness, type of material, and insulation in exterior and interior walls) (O’Neill, 2012). The next inspection in the attic involves the same steps. In addition, the evaluators collect information on the heating and cooling equipment (Parker et al., 2000). They also perform the blower door test to determine the total air leakage in the house. The information is entered using the software. A seven-page report with detailed information on house improvements is given to the homeowners, who then decide whether they are going to make any improvements. Once house retrofits are completed, the evaluators inspect the house again to assess the effectiveness of the changes that have been made. After inspections are made, the updated values are entered into the software for comparison purposes (O’Neill, 2012).

3.3.1.3 Description of Procedure

The dataset used for this research consisted of 6775 houses is equivalent to 4% of the eligible Region of Waterloo’s housing stock (REEP, 2012). The dataset was compiled by REEP as part of the ecoENERGY program. The initial evaluation files of 6775 homes were electronically available. These initial evaluations consist of "measured and modeled factors related to the house's initial measured home energy performance" (Hoicka, 2012, p. 79). Several variables (Appendix 3, Table 3.2) have been selected from the REEP dataset to analyse the

- profile of the building envelope, including the initial CO_2 emissions;
- profile of houses with an initial EGH rating of 80 or higher
  - % of houses meeting the Passivhaus standard (EGH 88)
  - % of houses meeting Net Zero Energy (EGH 100); and
- CO_2 emission reductions if upgraded to Passivhaus and Net Zero Energy standards.

To analyse the profile of the building envelope and initial emissions, data are grouped by decade. However, because of their small sample, houses built before 1900 were grouped in a single 1800s category. Analysing the building envelope profile and the annual CO_2 emissions by decade, can be used for temporal comparisons with the building code requirements and legislative documents. The annual CO_2 emissions for total and primary energy demand, for each house, were calculated based on the fuel types used:

$$\mathbf{kgCO_2 = E*0.097\ kg/kWh + NG*1.88\ kg/m^3 + O*2.83\ kg/L + P*\ 1.51\ kg/L} \qquad (2)$$

where: E is electricity, NG is natural gas, O is oil, and P is propane.

The emission factors for natural gas, oil, and propane come from the National Inventory Report and Canada's GHG Inventory (Environment Canada, 2013; Environment Canada, 2011). The electricity emission factor of 0.097 was calculated using the total energy supply for Ontario for 2011 (IESO, 2014) and the total CO_2 intensity 14,700 ktCO_2 (Environment Canada, 2013) [Electricity EF = 14700 ktCO_2/149.80TWh/1000 = 0.097].

Furthermore, the primary energy demand (e.g., energy used for heating, cooling, ventilation, hot water, and lighting) for NZE is ≤ 100 kWh/m²a, and for the PH is ≤ 120 kWh/m²a. The REEP dataset includes total energy consumption by source (electricity, oil, natural gas, and propane). Therefore, to compare the primary energy consumption of REEP houses to the PH and NZE standards, the total energy consumption by source first needed to be convertedto primary energy consumption. To do that, the total energy consumption of each fuel type, for each house, was multiplied by its source energy factor[xiii]:

$$\text{Primary energy demand} = E(\text{kWha})*2.47 + NG(m^3)*1.092 + O(L)*1.158 + P(L)*1.158 \qquad (3)$$

The source energy factor for electricity was calculated using the 2011 Independent Electricity System Operator's (IESO, 2014) energy supply breakdown by fuel type: hydro (22.2%), natural gas (14.7%), nuclear (59.6%), wind (2.6%), solar (0.8%), and coal (2.7%). To determine the source energy factor for electricity delivered to buildings, the breakdown of each fuel type was multiplied by its source energy factor:

$$E_{cf} = \text{hydro } (22.2\% * 1.00) + \text{natural gas } (14.7\%*2.629) + \text{nuclear } (59.6\%*3.075) + \text{wind } (2.6\%*1.00) + \text{solar } (0.8\%* 1.00) + \text{coal } (2.7\%*2.993) = 2.47 \qquad (4)$$

The source energy factors by fuel type [hydro (1.00), natural gas (2.629), nuclear (3.075), wind (1.00), solar (1.00) and coal (2.993)] for generating electricity come from the Eastern U.S. region from the Deru and Torcellini's study found in Table B-1 (Deru & Torcellini, 2007, p. 19).
The source energy factors for fuel delivered to buildings [natural gas (1.092), oil (1.158), and propane (1.158)] come from Table 5 of the same study (Deru & Torcellini, 2007, p. 9).

To calculate the total primary energy demand per house, each fuel type was first converted to MJ and then the total was converted to kWh/m^2 to be compared to the primary energy demand of PH and NZE standards:

$$PE\ (\text{kWh/m}^2\text{a}) = \frac{(E*3.6\ \text{MJ/kWh} + NG*37.25/\text{MJ/m}^3 + O*38.52\text{MJ/L} + P*25.59\text{MJ/L})*0.28}{\text{area of house}} \qquad (5)$$

The next step was to calculate the potential CO$_2$ emission reduction of houses that have reached the PH primary energy demand of $\leq$ 120 kWh/m^{2}a. It was assumed that all houses retrofitted to the PH standard would continue to use the same fuel type, but at a reduced rate. The total

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[xiii] These source energy factors "represent the energy required to extract, process, and deliver the fuel to the building per unit of energy in the fuel" (Deru & Torcellini, 2007, p. 9).

primary energy demand of 120 kWh/m²a does not give the breakdown of energy source. Therefore, the breakdown of the primary energy demand (in kWh) of REEP houses was used to determine the weighted factor for each energy source in the 120 kWh/m^2a. This breakdown by energy source was then used to calculate the total CO_2 emissions of 120 kWh/m^2a. To do that, each energy source was converted from kWh to MJ and then to their primary units (electricity in kWh, oil and propane in *l*, and natural gas in m^3). After this conversion, each energy source was multiplied by its emission factor.

Then, the percentage of houses with an initial EGH rating of 80 or higher was calculated to determine the breakdown of houses that have already met the PH and NZE standards. Furthermore, reduction of CO_2 emissions and energy use was calculated using the PH and NZE standards. Following the EnerPHit requirements, the space heating demand of a retrofitted existing house should be brought to ≤ 25 kWh/m²a. However, depending on the characteristics of the house and climatic region it is in, if the heating demand is not met, to receive the EnerPHit certificate, all other requirements must be met (Feist, 2012). As a result of the geographic location, houses built in colder regions require more energy for space heating. Therefore, for the purposes of this research, to meet the PH standard, the space heating demand of existing houses located in southwestern Ontario has to be brought to ≤ 50 kWh/m²a (O'Neill & Parker, 2012). Additionally, the insulation requirements for NZE and PH vary depending on climate and are normally calculated using software. Typically, PH requires R40-R60 for walls, R50-R90 for roofs, and R30-R50 for slabs; however, houses in colder climates can exceed these requirements to meet the PH standard (Straube, 2009) The NZE, on the other hand, requires R48 in the foundation wall, R51 in the main wall, and R90 in the attic; however, some studies, even in Canada, have shown lower insulation requirements (Parekh, 2012b). The information on building envelope profile, energy consumption, and emissions of houses with a rating of EGH 80 or higher was analysed and compared to houses with an initial EGH rating below 80.

3.3.2 Methods for Research Question 2

The following section outlines the procedure for the data collection of the second research question. First, the selected method is defined and its use then explained.

3.3.2.1 Content Analysis

The collected qualitative literature will be analyzed using the content analysis technique. Content analysis can be defined as "a multipurpose research method developed specifically for investigating any problem in which the content of communication serves as the basis of inference" (Holsti, 1969, p. 2). Furthermore, content analysis is a quantitative form of analysis "used to determine the presence of certain words or concepts within texts or sets of texts" (Busch et al., 1994-2012). Examples of texts include articles, advertisements, books, essays, discussions, news items, or other media (e.g., advertising, conversations, concerts, interviews, television, radio programs or films, plays, pictures, speeches, and theatres). The basic idea of this analysis is to reduce and classify the overall content into key measures (Singleton & Straits, 1999).

Berelson (1971) reviewed several early definitions of content analysis that appeared in the technical literature (Table 3.1). Based on these definitions, he categorised content analysis into six groups (Table 3.2).

Table 3.1: Definitions of content analysis

Definition	Author(s)
"Systematic content analysis attempts to define more casual description of the content, so as to show objectively the nature and relative strength of the stimuli applied to the reader or listener"	(Waples & Berelson, 1941, p. 2)
"A social science sentence may be called one of 'content analysis' if it satisfies all of the following requirements: 1) it must refer either to syntactic characteristics of symbols...or to semantic characteristics...2) it must indicate frequencies of occurrence of such characteristics with a higher degree of precision. One could perhaps define more narrowly: it must assign numerical values to such frequencies. 3) it must refer to these characteristics by terms which occur...4) it must refer to these characteristics by terms which occur in universal propositions of social science. One may consider adding to this definition another requirement; 5) a high precision of the terms used to refer to the symbol characteristics studied"	(Leites & Pool, 1942, pp. 1-2)
"The content analyst aims at a quantitative classification of a given body of content, in terms of a system of categories devised to yield data relevant to specific hypotheses concerning that content"	(Kaplan & Goldsen, 1943, p. 1)
"Content analysis' may be defined as referring to any technique for the *classification* of *sign-vehicles*; which relies solely upon the	(Janis, 1943, p. 429)

judgments-which, theoretically, may range from perceptual discriminations to sheer guesses – of an analyst or group of analysts as to which sign-vehicles fall into which categories; on the basis of *explicitly formulated rules*; provided that the analyst's judgements are regarded as the reports of a *scientific observer*. The results of a content analysis state the frequency of occurrence of signs-or groups of signs-for each category in a classification scheme"	
"Attempts to characterize the meanings in a given body of discourse in a systematic and quantitative fashion"	(Kaplan, 1943, p. 230)

Source: Adapted from Berelson, 1971, p.14-18.

Table 3.2: Six categories of content analysis

Category	Author(s)
it applies only to social science generalizations	Leithes & Pool, 1942
It applies only, or primarily, to determine the effects of communications	Waples & Berelson, 1941
It applies only to the syntactic and semantic dimensions of language	Leithes & Pool, 1942
it must be objective	Waples & Berelson, 1941; Leithes & Pool, 1942; Janis, 1943; Kaplan, 1943
it must be systematic	Leithes & Pool, 1942; Kaplan & Goldsen, 1943; Kaplan, 1943
it must be quantitative	Waples & Berelson, 1941; Leithes & Pool, 1942; Janis, 1943; Kaplan & Goldsen, 1943; Kaplan, 1943

Source: Adapted from Berelson, 1971, p.15.

Based on the second definition, Berelson (1971) argued that content analysis can be used and has been used in fields other than social sciences. The purpose of content analysis is to present "what is said" rather than "why the content is like that" (e.g., "motives") or "how people react" (e.g., "appeals" or "responses") (Berelson, 1971). With respect to objectivity, the categories of analysis should be well defined so that they can be reproduced by different analysts and should yield the same results (Holsti, 1969; Berelson, 1971). Content analysis must also be systematic for two reasons (Holsti, 1969; Berelson, 1971). First, all relevant content needs to be analyzed in terms of all the relevant categories, to help eliminate partial or biased analysis which could potentially arise from the selection of specific elements for the thesis. Second, the analysis is "designed to secure data relevant to a scientific problem or hypothesis", and the "results must have a measure of general application" (Berelson, 1971, p. 17).

Earlier definitions required content analysis to be strictly quantitative (i.e., selected categories need to be quantifiable). Therefore, the selected data should be only derived from frequent symbols or themes (Leites & Pool, 1942; Janis, 1943). However, not all studies require numerical values assigned to the categories. For some studies, the categories can be quantified using words, such as "often" or "less" or "more". After reviewing the five definitions, Berelson (1971) defined content analysis as "a research technique for the objective, systematic, and quantitative description of manifest content of communications" (p. 18). Although these three components are not necessarily specific to content analysis, Holsti (1969) believes that they should be part of all scientific inquiry.

Over the years, researchers have debated whether content analysis is qualitative or quantitative (Berg, 2007). Depending on how it is used, content analysis can be divided into two categories: conceptual analysis (quantitative) or relational analysis (qualitative) (Busch, et al., 1994-2012). Conceptual analysis, also known as thematic analysis, has been accepted as a traditional technique of content analysis (Busch, et al., 1994-2012). Conceptual analysis has been used as a tool to examine a chosen concept and to quantify and tally its presence (Busch, et al., 1994-2012). The role of the analysis is to look at the occurrence of selected implicit or explicit concepts in a text, so conceptual analysis does not examine how selected words in a text are related, but, rather, quantifies them. To limit problems with reliability and validity, coding of implicit concepts requires use of specialized dictionaries and (or) contextual translation rules. Studies that use content analysis follow several steps (Figure 3.4a). After the researcher has selected research question(s) for the study, the researcher comes up with sub-questions that will help answer the initial question. To answer these sub-questions, the researcher decides on the type of material needed for the study. A rationale for choosing the particular material is given. Once the data had been collected, the type of analysis is selected. Then, several variables are selected and defined conceptually. Coding categories and schemes are created using the variables, and then, material can be tested to determine whether the categories and schemes will yield the desired results. For the coding to be consistent, the researcher needs to establish consistent steps that must be followed. Then, when the coding process is complete, conclusions can be extracted from the coded data. Finally, the results can be analyzed and interpreted.

Conceptual analysis follows a series of specific steps (Figure 3.4b). Once the concepts have been selected for coding, the researcher decides whether to code for existence (if the concept showed up at least once) or for frequency (counting the number of times one concept appeared in a selected text). Whenever the selected material contains irrelevant information, the researcher determines whether to keep the information and justifies the reasons behind the choice.

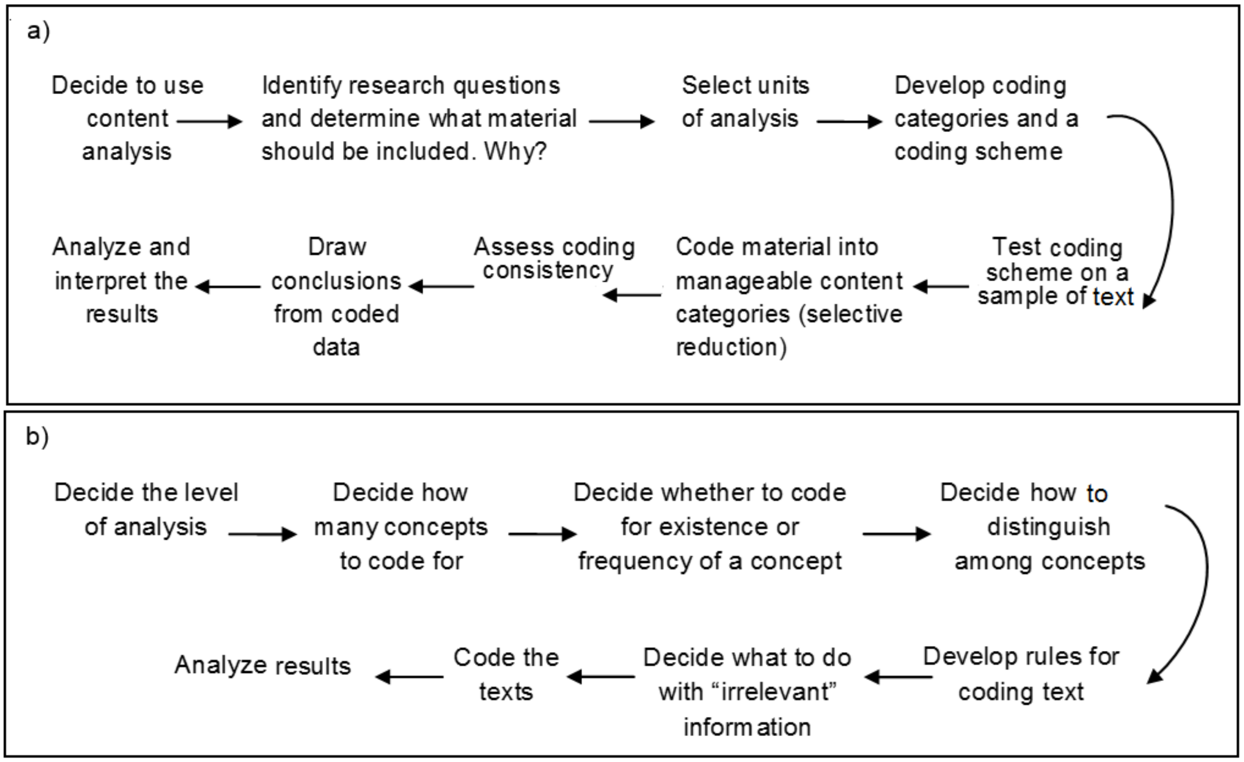

Figure 3.4: a) Steps in content analysis b) Steps in conceptual analysis. Source: a) Zhang & Wildemuth, 2010; Palmquist, 2001; b) Busch, et al., 1994-2012.

Although content analysis has strengths, this method also has several weaknesses. For example, Berg (2007) points out that “content analysis is limited to examining already recorded messages [whether they are] oral, written, graphic or videotaped” (p. 259). Content analysis is also ineffective for testing relationships among variables (Berg, 2007). This is fairly common when the researcher presents the frequency of the observed theme or pattern. In this case, content analysis is appropriate to use because it indicates the magnitude of certain responses. However, in this same case, content analysis is not appropriate if it is used “to attach cause to these presentations” (Berg, 2007, p. 259).

3.3.2.2 Procedure of Data Collection for Conceptual Analysis

The purpose of the first part of the second research question is to identify the barriers and drivers that influence the setting of new building envelope standards, such as the PH and NZE. The second part of the research question pertains to the drivers that lead Ontario to achieve higher building standard requirements. To answer these questions, a few other points need to be addressed:

1. to identify the frequency and types of changes made to the building code, including changes to the insulation standards
2. to analyse political discussions about achieving higher building standards through revisions to the Ontario Building Code, including the frequency of legislative debates and the stakeholders involved
3. to identify the motivations and barriers identified by various stakeholders

In contrast to the variables used for the first research question, the second question uses qualitative variables (Table 3.3). The series of Ontario Building Codes provide primary material for this research. The purpose of the building code analysis is to extract information on changes to the insulation requirements between 1975 and 2012. Analyzing the historical changes of the building code provides information on the type of requirements that have been imposed over time and the direction of the code development (point 1). Legislative documents, including the Ontario House Hansard debates (1970-2012) and the Standing Committee Transcripts (1992-2012), were analysed to further understand the barriers and drivers (points 2 and 3). The Standing Committee "provide[s] the government with a feedback from stakeholders on its legislation" (LAO, 2011, p. 9). The Standing Committee happens before the second reading when Committee members review the proposed bill and make amendments. Committee members may also invite outside witnesses to be present at the Standing Committee (LAO, 2011; Parliament of Canada, 2006). Outside witnesses, which can include individuals or organisations, "can engage in the committee process are by appearing as a committee witness, submitting written material to a committee, or attending committee hearings" (LAO, 2014b). Individuals and organisations interested to participate at the committee hearings must register with the clerk of the committee (LAO, 2014b). At the second reading, the members of the Legislature debate the content of the bill and propose amendments. The Committee members have the final vote on the amended bill and report to the Legislature as a whole (LAO, 2011; Parliament of Canada, 2006). Hansard, on the other hand, is the "verbatim record of daily proceedings of the house and its committees" (LAO, 2014a). Hansard debates happen in the Legislative Assembly where the final decision is made. Finally, to better understand the legislative debates, as well as to make connections between topics and periods, related secondary literature was used. For example, to understand the debates on Gold Medallion Homes, and the rise and fall of Ontario Hydro the literature by McKay, 1983; Swift & Stewart, 2004; Hampton, 2009; Winfield, 2012, was reviewed.

Table 3.3: Data collection for the second research question

Type of documents	**Reason for use**
Ontario Building Codes 1975-2012	To examine the insulation requirements over time.
Legislative Assembly of Ontario's documents 1970-2012	To examine the legislative debates on OBC changes with respect to the insulation requirements over a 40 year period. Legislative documents give insights into the views of various stakeholders and their interests.

3.3.2.1.1 Extraction of Building Code Information

Textual information as well as tables describing the insulation requirements for different building elements were extracted from the 1970-2012 Ontario Building Codes. This information was available under Part 9 of the building code. Updates and changes in the insulation and wall requirements between the codes were extracted mainly from the Ontario Gazette (The Ontario Gazette, 1992; The Ontario Gazette, 1993; The Ontario Gazette, 1995).

3.3.2.1.2 Extraction of Hansard and Standing Committee Transcripts Data

To better understand the discussions prior to the creation of the first OBC and the following OBCs, this study used Ontario Legislative Assembly documents, consisting of House Hansard from 1970 to 2012 and Standing Committee Transcripts from 1992 to 2012. Because the website of the Legislative Assembly of Ontario had an on-line version of the 1980-2012 House Hansard documents only, the 1970-1980 publications were accessed using hard copies. Although the first Ontario Building Code was published in 1975, it was necessary to go through the earlier Ontario Legislative Assembly documents because they might provide information on earlier decisions about the need for development of the first OBC, as well as the improvement of the following codes. Specifically, Ontario Legislative Assembly documents were used to determine whether there were discussions about improving minimum code requirements with respect to existing and new residential buildings (e.g., retrofit of existing houses, insulation upgrades, and reduction in energy usage).

For that reason, Ontario Legislative Assembly documents were used to search for a list of words and phrases, including *'Ontario Building Code', 'energy', insulation', and 'residential housing'*. This list was first used for testing purposes to determine whether more words or phrases needed to be searched within text and whether the context where the selected words appeared related to the points 1-3. Once the testing process was finalised, *'energy'* and *'residential housing'* were excluded from the search because they gave unrelated and broad information, and therefore, *'building code'* was added instead. Both *'energy'* and *'residential housing'* came up within different contexts that were beyond the scope of this research. However, the key words were excluded from the on-line keyword search only, but were still searched within the text. The reason for including "building code" in the key-word search was that in many instances the phrase came up in the context.

The selection of words can be found in Figure 3.8 under the coding branch. On-line Ontario Legislative Assembly documents contained 158 results for *'Ontario Building Code'*, 382 for *'building code'*, and 221 for *'insulation'*. Since Ontario Legislative Assembly documents are lengthy and consist of multiple discussions about different topics, selected words and phrases were searched in the text. Whenever the words and phrases came up within the research context, the quotes, and in some instances, entire paragraphs were extracted and gathered in an excel spreadsheet that contains the following information:

- Date – the date of the legislative debate
- Document type – type of the Ontario Legislative Assembly document
- Sub-title – the title of the session
- Participants – participants who have made a statement with respect to the OBC, insulation, and energy
- Occupation – the occupation of participants including their political backgrounds
- General – climate change, resource shortage, environmental concern
- Building code – issues associated with and proposed changes to the OBC
- Insulation – discussions about requirements over time
- Retrofits – retrofit requirements, strategies used for retrofits
- Energy efficiency/conservation – energy usage

The initial extracted information, which includes key quotations, was used to help the researcher discover new themes and look for patterns. The purpose of this procedure was to extract information that was narrow enough to answer the research questions. However, after an analysis of the findings, it was determined that a much broader content of information would yield richer results and would also identify frequency of word and phrase occurrence.

The second procedure, which repeated the first one, was more thorough. This procedure was also conducted to avoid bias. Both electronic and hard copies of Ontario Legislative Assembly documents were searched for *'insulation'* and *'building code'*. The texts containing either of these two phrases were further searched for terms, including *'climate change', 'energy', 'efficiency', 'incentives', 'standards', 'retrofits', and 'residential households'*. The reason for this secondary search was to investigate the context where *'insulation'* and *'building code'* appeared and to determine the relevance of information extraction to the analysis.

The extracted text was saved in two different folders. One folder included subfolders with files by speaker in a year (Figure 3.5a), whereas the other folder included files that contain all speakers in a year (Figure 3.5b). This division gives researchers the option to analyse the data by period and by speaker. To analyse the selected data, research tools including Concordance, Lexicoder, NVivo, and WordStat were tested for their ability to perform content analysis. NVivo appeared to be the most user friendly and produced results quickly, and was therefore used for this research. NVivo is also extensively used for qualitative and quantitative research in social sciences. Subsequently, all files (by speaker and by year) were uploaded into the NVivo 10 software.

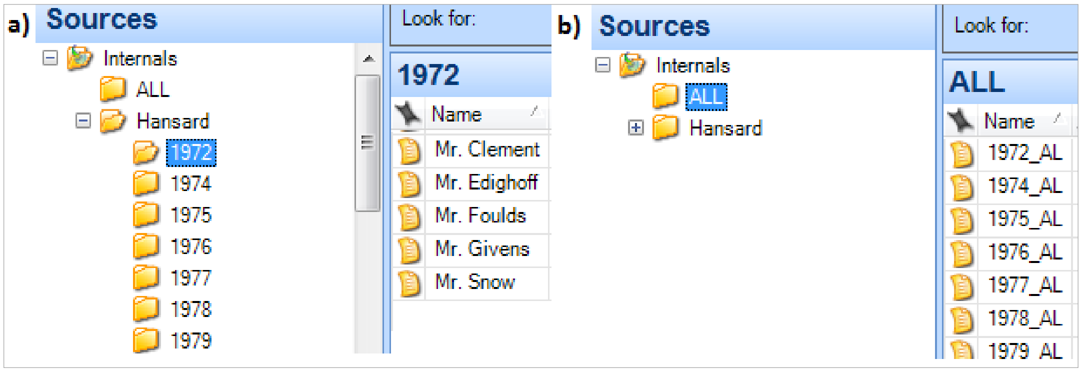

Figure 3.5: Organisation of files in NVivo.

To determine how often specific words and phrases occurred in a text, and to find out the most frequently occurring words and phrases (Table 3.4), pre-selected categories were created (Appendix 3, Table 3.3). Each category contained words and phrases that were searched in the documents. Multiple variations of phrases with a same meaning were created and searched in the text (e.g., insulate house and insulating houses), whereas single words were searched using the ‘including stemmed words’ option (e.g., insulation → insulate, insulating, insulated). Some phrases and words were grouped because they had similar meanings and also because they did not appear very frequently. In addition, the words and phrases under selected categories (e.g., energy, efficiency, etc.) were first searched within the texts. Sections of the text that included relevant information to the research topic were extracted and later analysed. In cases where the phrases and words were present but irrelevant to the research topic, the occurrences were excluded.

Table 3.4: Description of queries used

Query	Description	Examples and explanation
Text Search	Find all occurrences of a word, phrase, or concept.	▪ Find and analyze all occurrences of the word or phrase ▪ Find all references to pre-selected words, and find words similar to them (e.g., insulation, insulating, insulated).
Word Frequency	Find the most frequently occurring words or concepts.	▪ Look for the most frequently occurring words in a set of data. ▪ Find the most frequently occurring themes in a document — where similar words are grouped into concepts.

Source: QSR International, 2012.

3.3.2.1.3 Analysing Legislative Data

Legislative documents (Hansard and Standing Committee Transcripts) were used for two different purposes: for the frequency of words listed under the nine categories and to analyse the text. Of the nine categories, only ‘insulation’ and ‘building code’ were analysed using the text from the legislative documents. Although other categories were not analysed using the textual information from legislative documents, these categories were found to be very useful and very closely connected to the research topic. For example, when participants talked about insulation or the building code, they often discussed energy conservation and efficiency.

The word frequency was analysed in two ways: frequency of a word/phrase per year and frequency of each word per stakeholder over seven periods (prior to each building code). First, frequency of general terms, such as ‘building code’, ‘buildings’ (building(s), home(s), house(s)), ‘conservation’, ‘energy’, ‘insulation’, ‘cost’, ‘retrofit’, ‘programs’, ‘incentives’, ‘standards’ were analysed over time (1970-2012). Then, each of these terms was analysed by a stakeholder over seven periods (1970-1975, 1975-1983, 1983-1986, 1986-1990, 1990-1997, 1997-2006, and 2006-2012) to determine their frequency between each building code (1975, 1983, 1986, 1990, 1997, 2006, and 2012). The data were also analysed against the building code changes during 1991, 1993, 1995, and 1998. Furthermore, to determine the stakeholders involved in the decision making process, as well as the frequency of their participation in certain topics, stakeholders were grouped into seven categories: political parties, consumers, utilities/associations, industry/associations, environmental organisations, labour unions, and government (Appendix 3, Table 3.4). This division was done to illustrate the involvement of stakeholder groups during each period, as well as to avoid any potential bias against certain participants.

Two words/phrases were used for detailed analysis: ‘building code’ and ‘insulation’. These words were analysed using text from the legislative documents along with the previously created frequency tables. First, both words were searched by stakeholder in NVivo and then carefully extracted for analysis. Before the text was extracted, it was determined to use only the text that would help answer the three points listed under section 3.3.2.2 of this thesis. The focus of the first point is on time and type of changes made in the OBC. In this case, only the text that included information on building code changes, specifically, changes to the insulation and energy conservation requirements in residential houses, was extracted. This information was also analysed by stakeholder, to determine stakeholders’ motivations, the frequency of their engagement in the decision making process with respect to building code development, and to answer the remaining two points. To better analyse the text and to avoid any potential bias towards a particular party, stakeholders were given corresponding names. Stakeholders’ names were labeled using the acronyms of the group’s name followed by a digit, which was assigned by chronological order. For example, Mr. Snow made several comments in 1972 and he was the first representative from the Progressive Conservative Party to make a comment on the OBC changes; hence, labeled PC1. The full list can be found in Appendix 3, Table 3.5.

Chapter 4

Results

Part I: REEP Dataset

4.0 Description of the REEP Dataset

The dataset includes houses built between 1815 and 2010 (Table 4.1). There are 6775 houses in total, 53% were built before 1970, and the remaining 47% were built after the 1970. On average, houses built in the 1800s were large, with an average area of 260m^2 and a footprint of 94m^2. The size, footprint, and volume of houses built after the 1800s declined and then gradually started to increase after the 1940s. Additionally, 63% (n = 4238) of houses have two storeys, 30% (n = 2076) have one storey, and 6% (n = 399) have three storeys.

The total annual energy consumption for older houses is higher than for newer houses (Table 4.1). Older houses, on average, use more than 70% of total energy consumption on space heating, whereas newer houses use about 55%. The total primary energy demand for older houses is higher than for newer houses (e.g., for 1910s is 88050 kWh/a, for 1980s is 59206 kWh/a, Appendix 4, Figure 4.1). Total primary energy demand per square meter is also the highest for 1800s-1940s houses and lower for the houses built after (Appendix 4, Figure 4.2). Most of the space heating emissions come from natural gas, followed by electricity and oil (Table 4.1).

Furthermore, the average furnace efficiency is 86%. About 88% (n = 5985) of houses' furnaces use natural gas, 7% (n = 460) use oil, 4% (n = 294) use electricity, whereas less than 1% use mixed wood and propane. The results also show that houses in the 1800s use more fuel for space heating, whereas houses built after the 1800s use less. Electricity and natural gas (over 90%) are the two most common fuels used for space heating, followed by oil (7%) and propane (0.6%). The high percentage of electricity for heating includes heat pumps. Furnace fuel consumption and house type are summarized in Appendix 4, Table 4.1.

Insulation at the foundation wall, main wall, and attic shows an increase over time. An average 1800s house has an R3 of insulation in the foundation wall, R8 in the main wall, and R15 in the attic. In contrast, houses built after 1990s have, on average, an R9 in the foundation wall, R16 in the main wall, and R27 in the attic. In parallel, the highest heat loss occurs in older houses, especially in the foundation and walls.

The average annual CO_2 emissions of older houses are very high, e.g., 13,289 $kgCO_2$/a on average, for houses in the 1800s, and lower for newer houses, e.g., 3521 $kgCO_2$/a for >1990s houses. The average annual CO_2 emissions from primary energy demand are also higher in older houses. For example, the average emissions from primary energy demand in 1800s houses is double the emissions from 1980s and >1990s houses (Figure 4.1). The same trend can be observed in average annual primary energy emissions per square meter (Appendix 4, Figure 4.3).

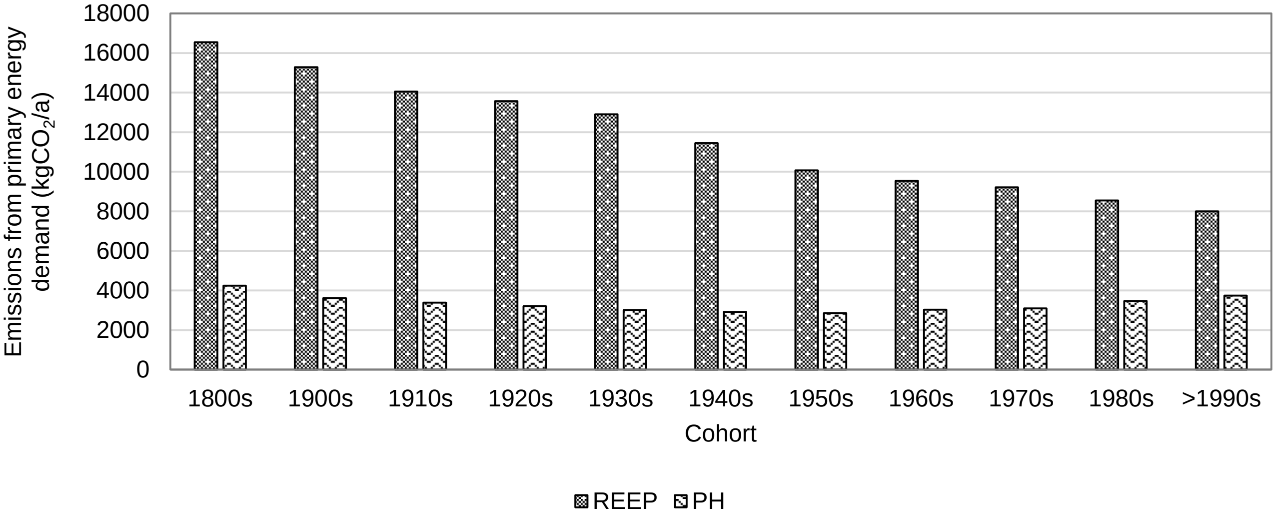

Figure 4.1: Average annual $kgCO_2$ emissions from primary energy demand of REEP houses compared to the emissions of houses that have met the PH primary energy demand.

The findings of the REEP dataset also show that older houses have a lower initial EGH rating (e.g., 1800 house, EGH 47), whereas newer houses have a higher initial EGH rating (e.g., 1980 house, EGH 71). Less than one per cent of houses have an EGH rating of 80 or above.

In addition, to meet the primary energy demand of the PH and NZE standards, on average, REEP houses require a 60% and 67% reduction, respectively. It can also be observed that older houses require larger reductions than newer houses (Appendix 4, Figure 4.4). Moreover, there are already several houses that meet the primary energy demand of both standards. In the REEP dataset 7 houses (0.1%) meet NZE primary energy demand of $\leq$ 100 kWh/m^{2}a, and 12 houses (0.2%) meet the PH primary energy demand of $\leq$ 120 kWh/m^{2}a (Appendix 4, Figure 4.5). As well, 72% (n = 4850) of PHs and 67% (n = 4554) of NZE houses require 50-75% reduction of their primary energy demand (Appendix 4, Figure 4.5). Only 11% of REEP houses require over 75% reduction to meet PH, whereas 25% of REEP houses to meet NZE. In addition, 71 (1%) of the REEP dataset meets the space heating of $\leq$ 50 kWh/m^{2}a (Appendix 4, Figure 4.6).

Furthermore, if REEP houses continue to use the same energy sources in their house, but reduce their primary energy demand to the PH standard, they could achieve 68% (46,503 tCO_2/a) reduction of their annual emissions (Appendix 4, Figure 4.7). The total annual emissions of REEP houses compared to houses that have met the PH primary energy demand are presented in Appendix 4, Figure 4.8. Because of their smaller sample size, the sum of annual emissions for 1800-1940 houses is lower than the sum of annual emissions for 1950-1980 houses (Appendix 4, Figure 4.8). The average annual emission reduction can be greater if houses switch to renewable energy sources. As per the NZE definition, houses have to have zero annual emissions. Therefore, if REEP houses were to meet the NZE standard, they would achieve a 100% emission reduction (68,573 tCO_2/a of the REEP total).

Table 4.1: Summary of residential attributes by decade

Houses	unit	1800s	1900s	1910s	1920s	1930s	1940s	1950s	1960s	1970s	1980s	>1990s	Average	Median	Stdev
Cohort size	#	249	220	181	351	195	384	911	1097	1087	1348	752			
	%	4	3	3	5	3	6	13	16	16	20	11			
Area	m^2	260	230	214	205	195	188	188	204	209	237	257	217	193	90
Footprint	m^2	94	80	73	70	70	78	89	95	95	96	98	91	86	37
Volume	m^3	649	575	535	512	487	470	469	509	522	592	642	542	482	225
Furnace eff	%	86	85	86	86	85	86	87	86	85	86	89	86	83	8
Attic	R	15	14	14	14	14	15	18	21	22	25	27	21	21	8
Foundation	R	3	2	3	3	3	3	3	3	5	8	9	5	3	5
Main wall	R	8	7	7	8	8	9	10	11	11	13	16	11	11	3
Elect	kWh	12816	11301	11466	11114	11198	11398	11842	11507	11349	10573	9904	11168	9283	6237
NGas	m^3	4437	4951	4687	4664	4508	3481	2803	2961	2866	2833	2623	3189	3070	1853
Oil	L	1265	616	490	385	283	461	432	193	157	39	38	260	0	1077
Propane	L	83	183	0	0	0	0	13	10	36	15	43	26	0	439
Total fuel	MJ	263989	253580	234786	228629	219222	189237	164231	159450	154868	146061	135912	169985	156270	63467
Total space energy	kWh/m^2a	233	243	238	236	234	202	161	138	130	106	87	149	130	72
Total energy	kWh/m^2a	304	323	322	322	322	295	252	226	217	185	162	233	219	81
HL air	MJ	64651	61486	53512	51096	46967	38511	29243	27358	27030	27375	26377	33057	27434	20296
HL found	MJ	46966	45476	41098	38861	39202	38128	39719	38817	33076	27718	26298	34970	32487	15746
HL attic	MJ	15291	13263	11762	12520	11200	11427	10225	8750	8184	6852	6442	9109	7505	6632
HL walls	MJ	63900	60343	58846	55299	52188	39426	26970	24088	24829	25398	23199	31621	26907	20074
HL win/door	MJ	35427	29566	30287	30633	27974	25671	24543	24624	25302	25705	27648	26449	23824	13014
EGH rating	scale	47	47	49	50	51	57	63	65	66	69	72	63	66	11
Electricity	kgCO$_2$/a	1243	1096	1112	1078	1086	1106	1149	1116	1101	1026	961	1083	900	605
NGas	kgCO$_2$/a	8341	9308	8812	8768	8475	6544	5270	5566	5388	5326	4930	5995	5771	3484
Oil	kgCO$_2$/a	3580	1743	1386	1090	802	1305	1223	547	444	111	107	737	0	3049
Propane	kgCO$_2$/a	125	276	0	0	0	0	19	15	54	23	64	39	0	664
Emissions	kgCO$_2$/a	13289	12423	11310	10936	10363	8954	7661	7244	6987	6485	6062	7854	7106	3521

Source: REEP database.

4.1 Description of Houses with an EGH Rating ≥ 80

As part of the first research question, the REEP dataset was used to analyse houses with an initial EGH rating ≥ 80 (Table 4.2). Less than one percent (n = 60) of houses met this criterion. As presented in Table 4.2, these houses also have a larger average floor area (296m^2), a larger footprint and volume (96m^2 and 740m^3) than the overall REEP average (91m^2 and 642m^3). Compared to the REEP average, EGH ≥ 80 houses have lower space energy consumption per square meter (36 kWh/m^{2}a versus 81 kWh/m^{2}a), lower than the PH requirement (Figure 4.2). Additionally, EGH ≥ 80 houses, in particular, houses built after 1990, have higher insulation levels throughout the building envelope.

The average primary energy demand of EGH ≥ 80 houses is 51,316 kWh/a. Some houses such as, EGH 81-83 and EGH 88 have higher primary energy demand than EGH 80, 85 and 87, because of their size. For example, an average EGH 83 house has area of 329m^2 and primary energy demand of 59984 kWh/a, whereas, an average EGH 80 house has an area of 175 m^2 and a primary energy demand of 43964 kWh/a (Appendix 4, Figure 4.5). However, the average primary energy demand per square meter for EGH ≥ 80 houses is 202; EGH 80 houses have the highest (272 kWh/m^{2}a), whereas EGH 88 houses (87 kWh/m^{2}a) have the lowest primary energy demand per square meter (Appendix 4, Figure 4.6). Most of the space heating emissions come from electricity, followed by natural gas and oil (Table 4.2).

Additionally, the average furnace efficiency is 96%, and the average EGH rating is 82 for this cohort. About 67% (n = 40) of houses' furnaces use electricity, 27% (n = 16) use natural gas, 5% (n = 3) use oil, whereas 2% use propane. The results also show that EGH 81 (44,994 MJ) and EGH 88 (46,221 MJ) houses use more fuel for space heating, whereas other EGH above 80 houses use less (EGH 80, 29,238 MJ). However, the space energy used per square meter is highest for EGH 80 and lowest for EGH 88 houses (Figure 4.2).

Table 4.2: Summary of residential attributes with an EGH rating ≥ 80

Houses	unit	1940-69	1970s	1980s	>1990s	Average	Median	Stdev
Cohort size	#	12	7	23	18			
	%	20	12	38	30			
Area	m^2	246	352	283	324	296	280	148
Footprint	m^2	124	152	127	129	130	117	67
Furnace eff	%	97	98	97	94	96	100	7
Attic	R	29	23	27	32	29	27	7
Foundation	R	12	8	10	12	11	10	6
Main wall	R	13	13	15	20	16	16	5
Volume	m^3	615	881	708	810	740	699	369
Electricity	kWh	17406	23981	18704	15274	18031	19245	6731
NGas	m^3	535	0	313	848	481	0	607
Oil	L	82	169	0	0	36	0	193
Propane	L	136	0	37	60	60	0	271
Total fuel	MJ	89217	92824	79941	88112	85750	82608	14344
Total energy	kWh/m^2a	114	79	95	102	99	82	46
Total space energy	kWh/m^2a	45	33	30	37	36	33	12
HL air	MJ	27181	35515	25734	25197	27003	25038	12479
HL found	MJ	31249	38577	28005	27874	29848	27628	15585
HL attic	MJ	7479	11930	8366	7625	8382	6940	4676
HL walls	MJ	21288	31226	19998	17739	20888	18394	10926
HL win/door	MJ	25930	36766	27886	31390	29582	27016	17720
EGH rating	scale	81	82	83	82	82	82	2
Electricity	$kgCO_2/a$	1688	2326	1814	1482	1749	1867	653
NGas	$kgCO_2/a$	1006	0	588	1595	905	0	1141
Oil	$kgCO_2/a$	231	477	0	0	102	0	546
Propane	$kgCO_2/a$	205	0	56	90	90	0	409
Emissions	$kgCO_2/a$	3130	2803	2458	3166	2845	2725	844

Source: REEP database.

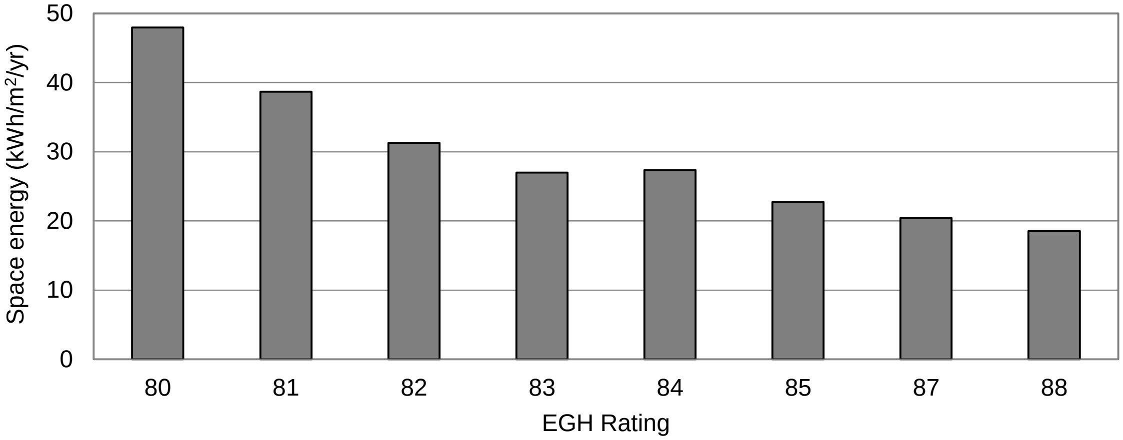

Figure 4.2: Average space energy in REEP houses with an EGH rating ≥ 80.
Source: REEP database.

Compared to the REEP dataset, EGH ≥ 80 houses also have higher average insulation values in the attic, foundation, and main walls (R29, R11, and R16, respectively), but much lower than the PH and NZE standards (Figure 4.3). To meet the PH or NZE standard, EGH 80 houses require the highest insulation upgrades (Table 4.3).

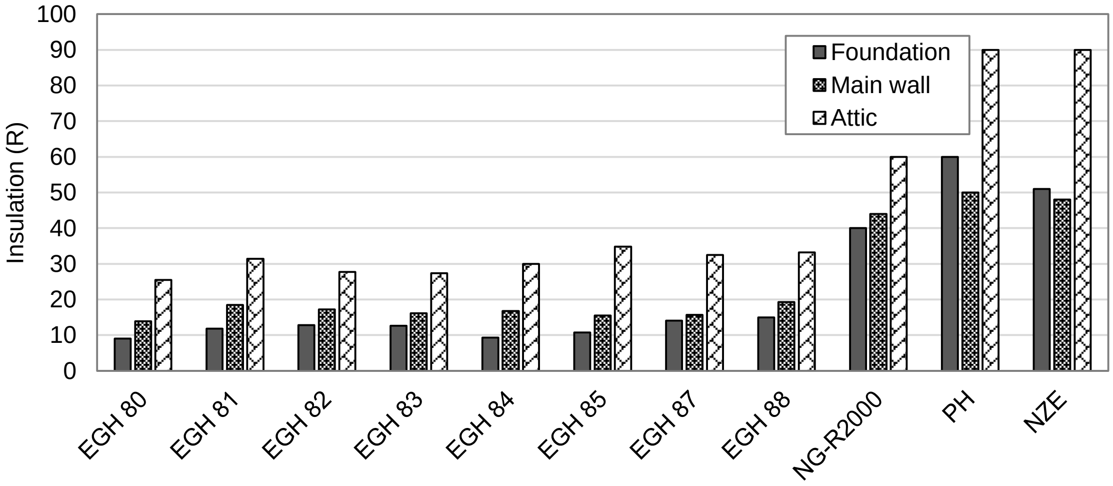

Figure 4.3: Insulation levels in EGH ≥ 80 houses compared to NG-R2000, NZE and PH requirements. Source: REEP database.

Table 4.3: Insulation increase to reach standard, R value

EGH	Passivhaus			Net Zero Energy			R-2000		
	Attic	Main Wall	Foundation	Attic	Main Wall	Foundation	Attic	Main Wall	Foundation
88	3	3	3	3	3	3	2	2	3
87	3	3	4	3	3	4	2	3	3
85	3	3	5	3	3	5	2	3	4
84	3	3	6	3	3	6	2	3	5
83	3	3	4	3	3	4	2	3	3
82	4	3	4	4	3	4	2	3	4
81	3	3	9	3	3	9	2	3	7
80	4	4	23	4	4	22	2	3	18

EGH ≥ 80 houses also have a tighter building envelope, and hence, lower heat loss within the building envelope than houses with an EGH ≤ 80. Figure 4.4 shows an overall trend of decline in air leaks and heat loss throughout the building envelope in EGH ≥ 80 houses. Among the EGH ≥ 80 houses, EGH 88 houses have the lowest heat loss and air leaks per square meter.

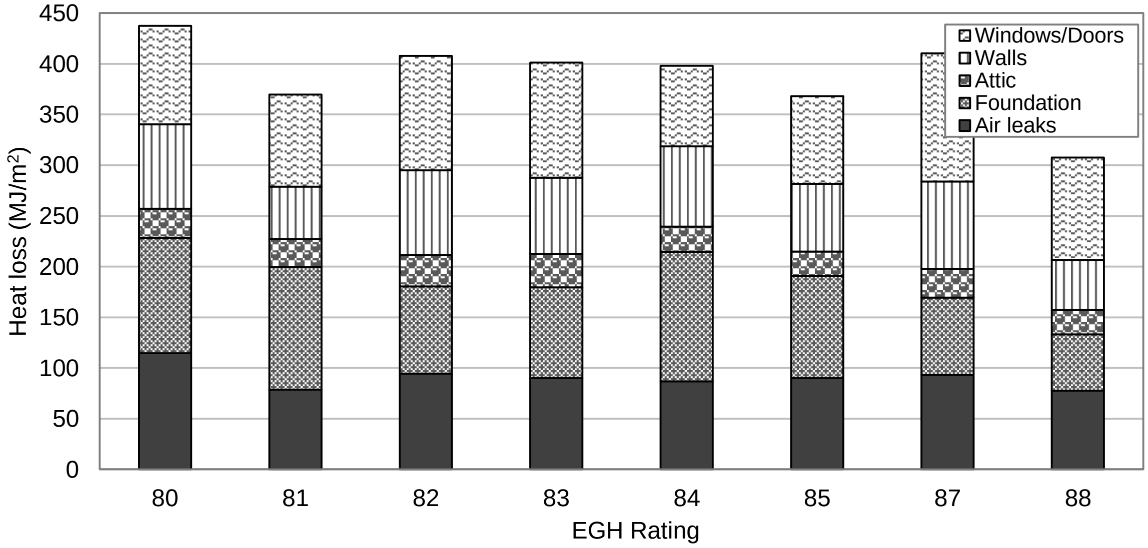

Figure 4.4: Heat loss in houses with an EGH rating ≥ 80. Source: REEP database.

The average annual CO_2 emissions of EGH ≥ 80 houses are 2845 $kgCO_2$ (12 $kgCO_2/m^2$). When calculated per square meter, EGH 80 houses have the highest emissions per m^2 (21.5 $kgCO_2/m^2$), whereas EGH 88 houses have the lowest (3.4 $kgCO_2/m^2$). The average emissions from primary energy demand of EGH ≥ 80 houses are 5,530 $kgCO_2/a$ (Appendix 4, Figure 4.11) and 23

$kgCO_2/m^2a$ (Figure 4.5). From Figure 4.5 it can be seen that EGH 80 houses have the highest average emissions per square meter, whereas from Appendix 4, Figure 11, EGH 88 houses have the highest average overall.

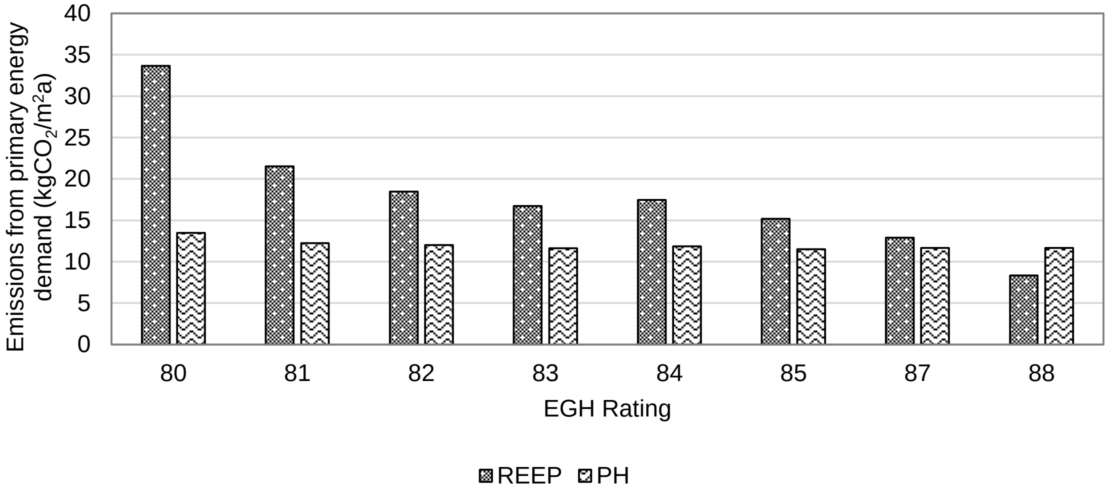

Figure 4.5: Average $kgCO_2/m^2a$ of EGH ≥ 80 REEP houses when the PH primary energy demand is met.

In addition, to meet the primary energy demand of the PH and NZE standards, on average, EGH ≥ 80 houses require 34% and 45% reduction, respectively (Appendix 4, Figure 4.12). It can also be observed that EGH 80 houses require larger reductions than EGH 85 and EGH 87 houses (Appendix 4, Figure 4.12). Furthermore, 5% (n = 3) and 3% (n = 2) of EGH ≥ 80 houses (n = 60) require no reduction to meet the PH and NZE primary energy demand, respectively (Appendix 4, Figure 4.13). In addition, 37% (n = 22) and 42% (n = 27) of EGH ≥ 80 houses require 25-50% reduction to meet PH and NZE primary demand, respectively. As well, 30% of REEP houses require 50-75% reduction to meet PH, whereas 45% of REEP houses to meet NZE (Appendix 4, Figure 4.13). EGH ≥ 80 houses require 37% reduction to cut their emissions to the PH standard and a 100% reduction to meet the NZE standard (Figure 4.5).

Furthermore, if EGH ≥ 80 houses continue to use the same energy sources in their house, but reduce their primary energy demand to the PH standard, they could achieve 37% annual emission reduction (Appendix 4, Figure 4.14). The average CO2 emission reduction of EGH 80 houses is the highest (58%) and lowest for EGH 85 houses (20%), whereas EGH 87 and 88 houses already have low emissions and therefore, require no reduction (Appendix 4, Figure 4.14).

It can be concluded that EGH ≥ 80 houses are more efficient than EGH ≤ 80 houses. Although the REEP dataset includes houses with an EGH ≥ 80, most of these houses do not meet all the requirements of the PH or NZE standard.

Part II: Ontario Building Code

4.2 History of Ontario Building Code

The following subsections review the Ontario Building Code changes from 1975 to 2012.

4.2.1 1975 Ontario Building Code

The first Ontario Building Code came into effect on December 31, 1975. This code was based on the 1975 National Building Code. It is the shortest of all Ontario Building Codes and comprises nine sections listed under Appendix 2, Table 2.3. In the 1975 OBC, insulation requirements are discussed under *Section 9.26. Thermal insulation and vapour barriers*. The code allowed houses to be insulated using batt-type insulation and/or loose-fill insulation (on horizontal surfaces only) (MCCR, 1975). The code also required that “insulation shall be provided between heated and unheated spaces and between heated spaces and the exterior, and around the perimeter of concrete slabs-on-grade” (Ministry of Consumer and Commercial Relations, 1975, 9.29.4.1). The selected insulation material had to also be fully protected from any contact with moisture using moisture barriers so that its functionality was not reduced (Ministry of Consumer and Commercial Relations, 1975). Furthermore, the code required insulation installed around slab on grade to extend more than 24 inches below exterior ground level and positioned in a way to prevent heat from the building to reach the ground.

It can be observed that the 1975 OBC required exposed ceilings to have minimum thermal resistance (R) of 28, exposed roofs R20, and exposed walls R12 (Appendix 3, Table 9.26.4.A).

Moreover, solid foundation walls (e.g., brick, blocks, or concrete) require R8, which is very low, and framed foundation walls (e.g., wood or steel stud frame) required insulation of R12. It can be also noted that both heated and unheated concrete floors have very low insulation requirements (Appendix 3, Table 9.26.4.A).

4.2.2 1983 Ontario Building Code

In 1983, a new OBC was produced. The first OBC had undergone many changes since its introduction. The 1983 OBC version was based on the 1980 National Building Code. Most of the changes in the 1993 OBC were to *Part 3: Use and Occupancy* (e.g., fire protection requirements); *Part 5: Wind, Water and Vapour Protection*; and *Part 6: Heating, Ventilation and Air-Conditioning*.

In terms of insulation requirements, the 1983 code had minor changes. For example, the code introduced insulation requirements for different heating degree days (HHD) – regions below 5000 HHD and above 5000 HHD (Appendix 3, Table 9.39.3.A.). The requirements for the two HDD zones differed especially for an exposed roof or ceiling frame (R32 and R32, respectively); however, for solid foundation walls, the requirements were the same (R27). If the climatic differences in Ontario were considered, it can be concluded that the differences between the requirements for the two zones were very small, so one would have expected both zones to be high, but the R-values for the areas above 5000 HDD had to be even be higher because of the colder temperatures.

Compared to the 1975 OBC, the 1983 OBC increased the insulation requirements in exposed ceilings only (from R28 to R32) (Appendix 3, Table 9.26.2.A). The code also required the insulation to be placed at least 25 mm below the top of the joists. As in the 1975 OBC, foundation walls that have 50% of their area exposed to the outside air and have wood-frame construction had to have a minimum thermal resistance of R12.

Furthermore, the 1983 code does not allow Type 1 polyethylene insulation, which has very light density, to be installed in the roof or near the ground because it absorbs high volumes of moisture and, therefore, its effectiveness was reduced. However, a polyethylene vapour barrier can be used to cover mineral fiber insulation in unfinished basements and cellars to retain its effectiveness.

It should also be noted that requirements listed under Section 9.26.1.1. were only applicable to *thermal insulation* of residential buildings used mainly during the winter months (OMMAH, 1983). Additionally, requirements listed under Section 9.39. were applicable only to thermal design. Builders had the option to use the requirements listed either under Section 9.26.1.1 or Section 9.39. (OMMAH, 1983).

4.2.3 1986 Ontario Building Code

The third version of the OBC, which came into effect on October 20, 1986, was based primarily on the 1985 NBC (OMH, 1986b). This version of the code had eleven sections (Appendix 2, Table 2.3). With the addition of *Part 11: Renovation*, builders had the option to follow different requirements when renovating their houses. In comparison to the 1983 code, this version no longer had the heating degree days and different heating sources under thermal insulation requirements in Section 9.26 (OMH, 1986a). This change can be observed in Table 9.26.2.A. However, this section was reorganized and included broader categories for wall, floor, and ceiling types. As well, each of these categories required higher thermal resistance values, for example, R31 for the attic, R12 for non-foundation walls, R20 for frame foundation walls, and R-25 for slab-on-ground floor. However, under Section 9.26.2.7. (1)., log wall assemblies could have a lower insulation value of R9 if “ceiling values are increased by an equivalent amount” (OMH, 1986b, p. 41). On the contrary, other log wall assemblies had to have an R-value of R20 (OMH, 1986b). As in the 1983 OBC, the 1986 code gave builders an option to use requirements under Section 9.39. instead of Section 9.26 (Table 9.39.3.A.). These requirements were identical to the 1983 OBC.

4.2.4 1990 Ontario Building Code

On October 1, 1990, the fourth OBC was adopted. This code had eleven sections including new information on “design and construction of classrooms, correctional facilities, and farm buildings” (Ontario Ministry of Housing, 1990, p. i). Significant changes were also made with respect to thermal insulation requirements. The 1990 code reintroduced the HDD requirement that had been removed from the 1986 OBC (Table 9.25.2.7. (1)). Moreover, in this version, two categories, “Masonry or concrete foundation wall” and “Frame foundation wall”, were eliminated, and a new one, “Foundation walls enclosing heated space”, introduced (Table 9.25.2.7.(1)). The R-values for zone 1 in the 1990 OBC Table 9.25.2.7. (1) were equivalent to the values in the 1986 OBC, Table 9.39.3.A. with the exception of the non-foundation walls (from R12 to R19) and the newly introduced category foundation walls enclosing heated space (R12). As in the 1983 and 1986 codes, the 1990 code also allowed builders to use Section 9.39. as an alternative to Section 9.26 (Table 9.38.3.1.). These requirements were also identical to the requirements listed in the 1983 and 1986 OBCs. However, no explanation was provided why these changes took place.

4.2.4.1 Ontario Building Codes 1991-1995

After 1990, several changes were made to the Ontario Building. This section lists only the changes that took place between 1990 and 1995. On September 30th, 1991, under the Ontario Regulation 400/91, the provincial government decided to increase the thermal insulation values of all parts of the building envelope in both zones. In comparison to the 1990 values, the 1991 values did not appear to be very high. As well, the values for some categories in zone 1 appeared to be equal or greater than the values in zone 2. For example, the R-values for roof assembly without attic or roof space, foundation walls enclosing heated space, and floor, other than slab-on-ground for both zones are equal (Table 9.38.3.A.). Interestingly, the values for slab-on-ground continued to be very low compared to other categories.

Nevertheless, on July 1st, 1993, under the Ontario Regulation 158/93, the thermal insulation values were brought back to the 1990 standard (Table 9.25.2.A.). The Ontario Regulation did not give any explanation for the reduced requirements.

Furthermore, on January 20th, 1995, under the Ontario Regulation 20/95, the thermal insulation values for both zones were changed to the 1991 standard. Additionally, in this version the *“Electric Space Heating Zone 1 and 2”* was added. The values for the electric space heating were substantially higher than those in the 1993 OBC (Table 9.38.3.A.).

4.2.5 1997 Ontario Building Code

After years of revisions to the previous codes, the Ontario Ministry of Municipal Affairs and Housing developed the fifth official building code. This code was based on the NBC 1995 (NMCCD, 2011). It had twelve sections, four of which were re-developed and included different headings:

- Part 3: Fire Protection, Occupant Safety and Accessibility,
- Part 7: Plumbing,
- Part 8: Sewage Systems, and
- Part 12: Transition, Renovation and Commencement.

The 1997 OBC also accepted the new Model National Energy Code for Buildings (1997) and the Unified Canadian Guideline for Integrated (Combined) Heating Systems (OMMAH, 1998). With respect to thermal insulation, the 1997 code lowered the insulation requirements significantly (Table 9.25.2.1.). Overall, the reductions were made equivalent to the 1990 levels, with the exception of the Zone 1 values for

- Non- foundation wall values were reduced from R18 to R17 (between 1990 and 1997)
- Foundation walls enclosing heated space were reduced from R12 to R8 (between 1990 and 1997 OBC)

In comparison to the 1995 OBC requirements, the 1997 OBC insulation reductions were even larger, a difference of R4:

- Non-foundation wall values were reduced from R21 to R17 (between 1995 and 1997)
- Foundation walls enclosing heated space values were reduced from R14 to R8 (between 1995 and 1997 OBC)

However, in comparison to the 1990 OBC, the 1997 code had higher requirements for the thermal design (Table 9.38.3.1.). For example, heated slab-on-grade in zone 1 had increased from R7 to R10 (between 1990 and 1997).

4.2.6 1998 Ontario Building Code

On April 6th, 1998, under the new Ontario Regulation 22/98, it was requested that

> *"in Table 9.38.3.1. of the Regulation [was] amended [to strike]out "3.7" in Row 5 of Column 2 and [to substitute it with]"3.45" and [to strike]out "2.4" in Row 6 of Column 2 and [to substitute it with] "1.7"." (The Ontario Gazette, 1998).*

Therefore, the thermal insulation requirements were reduced from R21 to R19 (between 1995 and 1998 levels) for the non-foundation walls and from R14 to R10 (between 1995 and 1998 levels) for the foundation walls enclosing heated space. A few sources (Kesik, 2006; Rowlands et al., 2000) explained the potential reasons for such reductions, which were to “lower” the rising building costs.

4.2.7 2006 Ontario Building Code

In 2006, the Ontario Ministry of Municipal Affairs and Housing produced the sixth official Ontario Building Code. The code was “written in an objective-based format [with the intention] to promote innovation and flexibility in design and construction” (OMMAH, 2006, p. i). This version had twelve sections, four of which had different headings than the previous (1997) OBC:

- Part 2: Objectives
- Part 3: Functional Statements
- Part 5: Environmental Separation
- Part 12: Resource Conservation

In comparison to the previous codes, the 2006 Building Code promoted ‘green technologies’, such as:

- solar photovoltaic systems;
- gas fired emergency generators;
- active solar hot water systems;
- wastewater heat recovery systems;
- rooftop storm water retention;
- storm water and grey water use;
- motion sensors for room and minimum lighting; and
- wind turbines. (OMMAH, 2006, p.viii)

As well, under Part 12: Energy Conservation section, the code required:

- more energy efficient windows;
- high-efficiency gas and propane-fired furnaces; and
- higher insulation levels in ceilings, walls, and foundation walls. (OMMAH, 2006, p.viii)

With respect to insulation, Part 12 required a “rating of 80 or more when evaluated in accordance with the [Natural Resources Canada] EnerGuide for New Houses” (OMMAH, 2006, p. 3, Division B-Part 12) standard. For example, ceiling below attic or roof space must have a minimum of R40 for both zones and an R52 for electric space heating (Table 12.3.2.1.). Furthermore, for non-foundation walls, a minimum of R19 (zone 1) and R24 (zone 2) was required. However, the R-value for roof assembly without *attic or roof* space for zone 2 was unusually lower than for zone 1 (R28 versus R22, respectively). Also, both slab-on-ground categories remained unchanged since the 1997 BC. Additionally, on December 31, 2008, *'near-full height basement'* insulation requirements came into effect (OMMAH, 2010a).

Moreover, under Section 12.3.2.2., it was suggested that insulated walls that incorporated wood stud framing elements with an R-value less than 5 could have a thermal resistance "at least equal to 25% of the thermal resistance required for the insulated portion of the assembly" (OMMAH, 2006, p. 6, Division B-Part 12) so that the heat flow through the studs could be restricted. It should be noted that this section excluded foundation walls. As well, the R-values in Table 12.3.2.1. for exposed roofs or ceilings can be reduced near the attic, but the R-value of the insulation above the inner surface of the exterior wall was suggested to be at least R12. This value was increased to a minimum of R20 in the Supplement Standard Sb-12 in December 2011, and took effect January 2012 (OMMAH, 2011). As specified in the 2006 code, builders could use the R-values in Table 12.3.3.3. when the R-value of each building assembly excludes framing or furring. The R-values presented in Table 12.3.3.3. are higher than the ones presented in Table 12.3.2.1. However, this option did not include doors, windows, skylights and other closures. The 2006 OBC included an additional option for builders to use the R-values from Table 12.3.4.2.A. under the following conditions:

> (1) *"[When] the minimum thermal resistance of all walls, ceilings and floors that separate heated space from unheated space, the exterior air or the exterior soil shall conform to Table 12.3.4.2.A"* (OMMAH, 2006, p.12, Division B-Part 12).
> (2) "*Where the top of a foundation wall is less than 1200mm above the adjoining ground level, those portions of the foundation wall that are above ground may be insulated to the level required for the below grade portion of the foundation wall*" (OMMAH, 2006, p.13, Division B-Part 12).

4.2.8 2012 Ontario Building Code

The 2012 Ontario Building Code is expected to come into force on January 1, 2014 and additional requirements are to come into force on January 1, 2015 and January 1, 2017 (OHBA, 2013). The main objectives of Ontario Building Code are resource conservation and environmental integrity (MMAH, 2012). The 2012 building code includes additional objectives

1. to limit the extent to which construction strains infrastructure capacity (e.g., electrical grid capacity)
2. to protect atmospheric quality
    - limiting greenhouse gas emissions

    - limiting the release of pollutants
3. to protect water and soil quality. (MMAH, 2012, p. 8)

A list of all Ontario Building Codes with their content can be found in Appendix 2, Table 2.3.

4.2.8.1 Energy Conservation Requirements

The 2012 building code imposes higher energy conservation requirements than previous codes. As of January 1, 2012, Part 9 of the building code (Figure 4.6) requires the energy efficiency design of houses to

- comply with Supplementary Standard SB-12; or
- achieve a rating of 80 or more when evaluated in accordance with the technical requirements of NRCan, "EnerGuide for New Houses: Administrative and Technical Procedures", January 2005 (MMAH, 2013, p. 2).

As of January 1, 2012, the code requires "new houses to meet standards that are substantially equivalent to EnerGuide 80" (OHBA, 2012, p. 2). Since the building code is prescriptive in nature and the EGH 80 is a performance standard, the Ministry of Municipal Affairs and Housing prepared a set of alternatives presented in the Supplementary Standard SB-12 to the code for builders to follow: prescriptive and performance standards (OHBA, 2012). The prescriptive compliance package can be found under Subsection 2.1.1., and the performance compliance can be found under Subsection 2.1.2. of the Supplementary Standard (MMAH, 2013). The Supplementary Standard SB-12 also includes EnergySTAR requirements for new houses, and the requirements can be found under Subsection 2.1.3. of the Supplementary Standard. The intent of the code is to make Ontario houses more efficient, and all new houses built in 2017 are expected to "consume 50% less energy than homes built before 2006" (OHBA, 2012, p. 2).

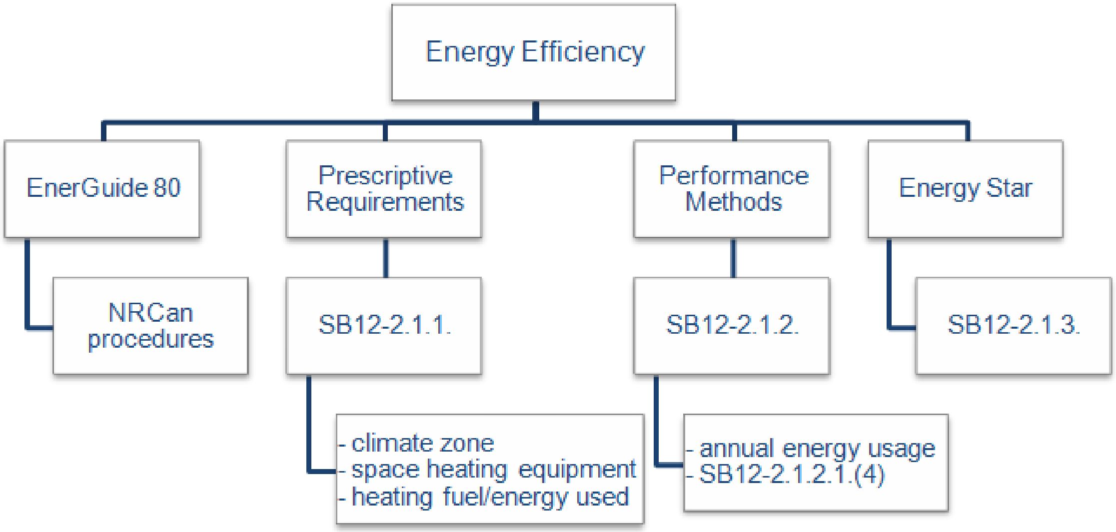

Figure 4.6: Part 9 of 2012 Ontario Building Code. Source: MMAH, 2013, p. 2.

4.2.8.2 Prescriptive Compliance Packages

As part of the prescriptive package, energy efficiency requirements for houses are based on climate zones: zone 1 with less than 5000 heating degree days and zone 2 with 5000 or more heating degree days. With respect to the two climate zones, the code provides specified compliance packages presented in six tables (Table 4.4).

Table 4.4: List of prescriptive compliance packages

Zone 1	Compliance packages for space heating equipment with AFUE[xiv] ≥90%	Table 2.1.1.2.A
Zone 1	Compliance packages for space heating equipment with AFUE ≥70% and <90%	Table 2.1.1.2.B
Zone 1	Compliance packages for electric space heating	Table 2.1.1.2.C
Zone 2	Compliance packages for space heating equipment with AFUE ≥90%	Table 2.1.1.3.A
Zone 2	Compliance packages for space heating equipment with AFUE ≥70% and <90%	Table 2.1.1.3.B
Zone 2	Compliance packages for electric space heating	Table 2.1.1.3.C

Source: OHBA, 2012, pp. 9-17.

For zone 1, Table 2.1.1.2.A provides 13 different compliance options for houses labeled A to M. Table 2.1.1.2.B provides six compliance packages, labeled A to F, and Table 2.1.1.2.C provides only two packages A and B. Each label consists a different set of requirements for the thermal performance of the building envelope and equipment. However, for zone 2, Table 2.1.1.3.B

[xiv] AFUE - annual fuel utilisation efficiency

provides two compliance packages A and B, and Table 2.1.1.3.C provides only one package, labeled A. These tables can be found in Appendix 4, Part B.

The prescriptive path cannot be taken if “the gross area of windows, sidelights, skylights, glazing in doors and sliding glass doors to the gross area of peripheral walls measured from grade to the top of the upper most ceiling is more than 17% but not more than 22%” (MMAH, 2013, p. 9).

4.2.8.3 Performance Compliance Packages

The performance option is based on the annual energy use of a building. The annual energy use is based on zone location, energy source, and equipment efficiency. To use this option, “recognized annual energy use simulation software shall be used to calculate annual energy use, local climatic data shall be used, and the equivalent domestic hot water, appliance and other plug-in loads shall be assumed in both calculations” (MMAH, 2013, p. 22). Additionally, building envelope component properties and characteristics that are not mentioned in the Supplementary Standard SB-12 should be modeled (MMAH, 2013). The software includes: HOT2000 version 9.34c or newer version, software referenced by the Energuide Rating System, or RESNET accredited Home Energy Rating System (HERS) software (OptiMiser, EnergyGauge, EnergyInsights, or REM/Rate) (MMAH, 2013, p. 27).

It can be concluded that the Ontario Building Code has played an important role in the development of Ontario houses. The 1975 OBC, in particular, introduced at a very critical time in terms of energy conservation, is of great significance. The current code is very important because it has surpassed the requirements of all previous OBCs. However, the OBCs alone are not enough to answer the second research question. The technical information of the OBCs combined with the legislative documents will assist in determining the barriers and drivers that influence setting new building envelope standards, potentially affecting more stringent codes, such as the PH or NZE.

Part III: Legislative Documents

4.3 Ontario Legislative Assembly Documents

The following sections include results from the Ontario Legislative Assembly documents from 1970 to 2012. The analysis of legislative documents is designed to provide information about the frequency of words listed under the nine categories and to determine the stakeholders involved in the decision making process, as well as the frequency of their participation in discussions about certain topics.

4.3.1 Stakeholders' Participation

Several stakeholders were identified in the Ontario Legislative Assembly documents and were grouped into seven categories: political parties, consumers, utilities/associations, industry/associations, environmental organisations, labour unions, and government. The frequency of stakeholder participation can be observed in Figure 4.7. During all seven periods, political parties had the highest participation rates. House Hansard debates include only political debates, whereas the Standing Committee Transcripts include diverse participants. Because this thesis examined the on-line version of the 1992-2012 Standing Committee Transcripts, the results show political parties to be the only participatory stakeholders until 1990. Although other stakeholder groups took part in the Ontario Legislative Assembly documents, political parties continued to have the highest frequency in participation. Although the frequency in participation by environmental organisations and governmental agencies was low, the frequency of participation of both stakeholder groups increased from 0.03% (1990-1997) to 0.06% (1997-2012). The participation of the industry/associations was slightly higher (from 0.05% to 0.09% for 1990-2012).

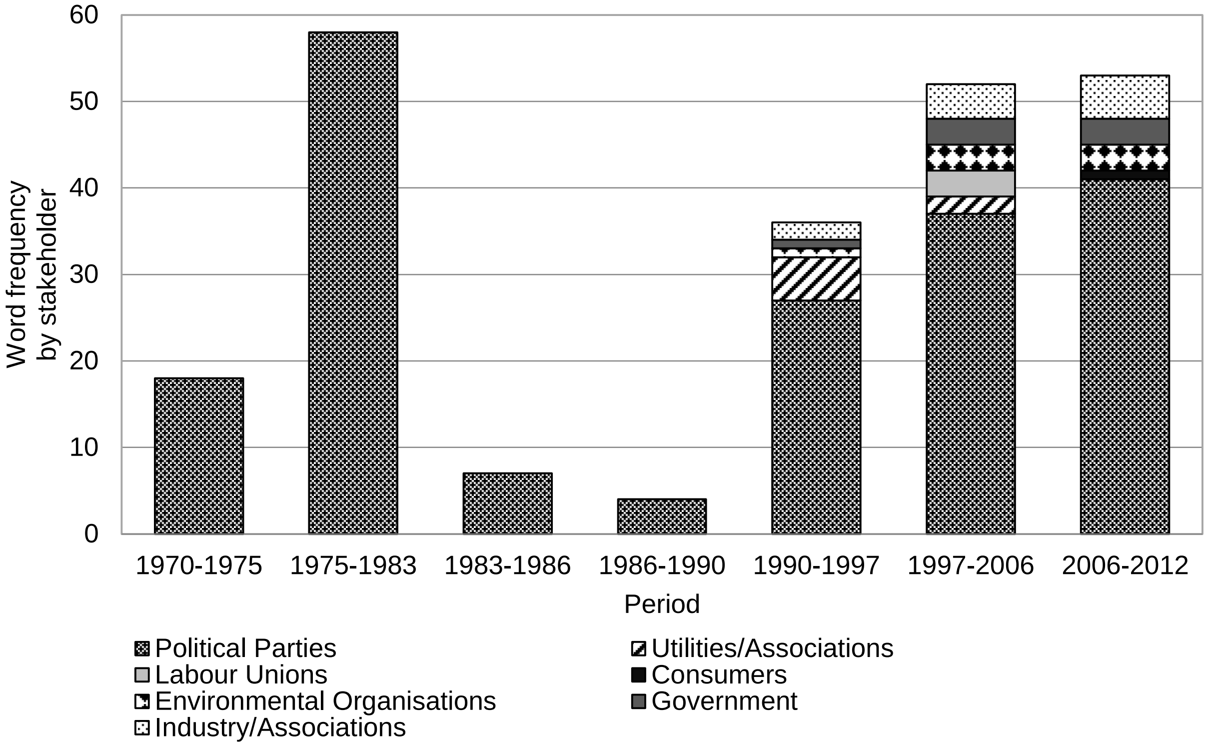

Figure 4.7: Frequency of stakeholder participation. Source: Legislative Assembly of Ontario, 1970-2012.

4.3.2 Ontario Building Code

In the legislative documents, 60 counts of ‘Ontario Building Code’ and 321 counts of ‘building code’ were identified (Figure 4.8). Figure 4.8 shows three major spikes with respect to ‘building code’, in 1992, 2006, and in 2009 (n = 61, n = 49, n = 83). ‘Building code’ was discussed mainly prior to and after the publication of each building code. ‘Ontario Building Code’ was also discussed before and after each building code, however, with lower frequency and only one major spike in 1992 (n = 17). Increased frequency of ‘building code’ and ‘Ontario Building Code’ can be observed from 1991 to 1997 (n = 88 and n = 23, respectively) and from 2005 to 2012 (n = 169 and n = 24, respectively). The figure also shows that ‘building code’ was not recorded in the legislative documents between 1984 and 1990.

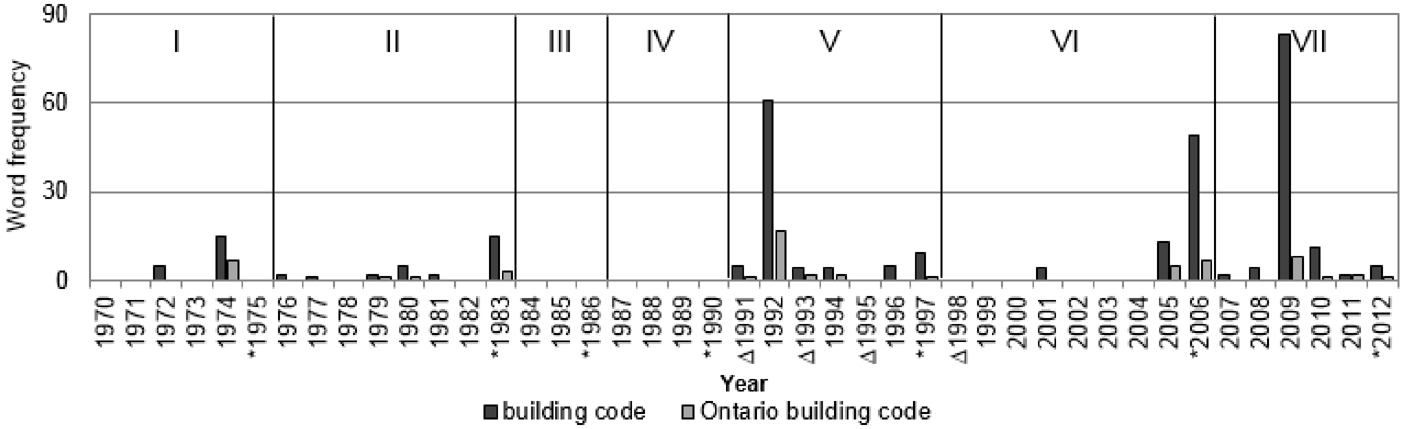

Figure 4.8: Word frequency of ‘building code’ and ‘Ontario building code’. *Note: * represents new building code; ∆ represents changes to the code.*

Figures 4.9 and 4.10 show frequency of ‘building code’ and ‘Ontario Building Code’ discussion per stakeholder during seven periods. Overall, political parties had the highest participation rate over time and were the only participants during the first two periods. As of 1990, other participatory bodies became involved in the building code discussion. Between 1990 and 1997, government and industry/associations were the first two groups involved in a political debate. Diverse stakeholder groups can be observed from 1997 and 2012. Interestingly, the government participated only in the building code discussions before the fifth (high participation n = 16) and seventh code (minimal participation n = 3). The involvement of industry/associations in a building code discussion exsists between 1990 and 2012 (n = 37), with the highest discussion frequency observed between 2006 and 2012 (n = 27) and lowest between 1997 and 2006 (n = 1). Environmental organisations, on the other hand, had very little input in the building code discussion (n = 6 for 1997-2012).

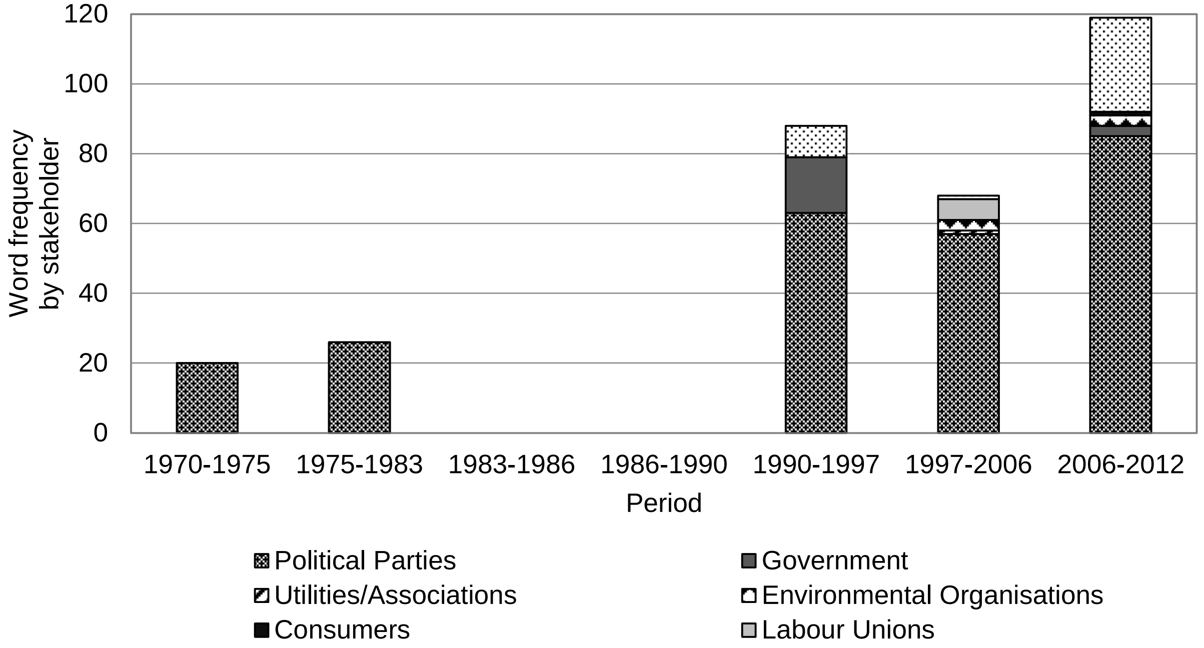

Figure 4.9: Word frequency of ‘building code’ by stakeholder between each building code.

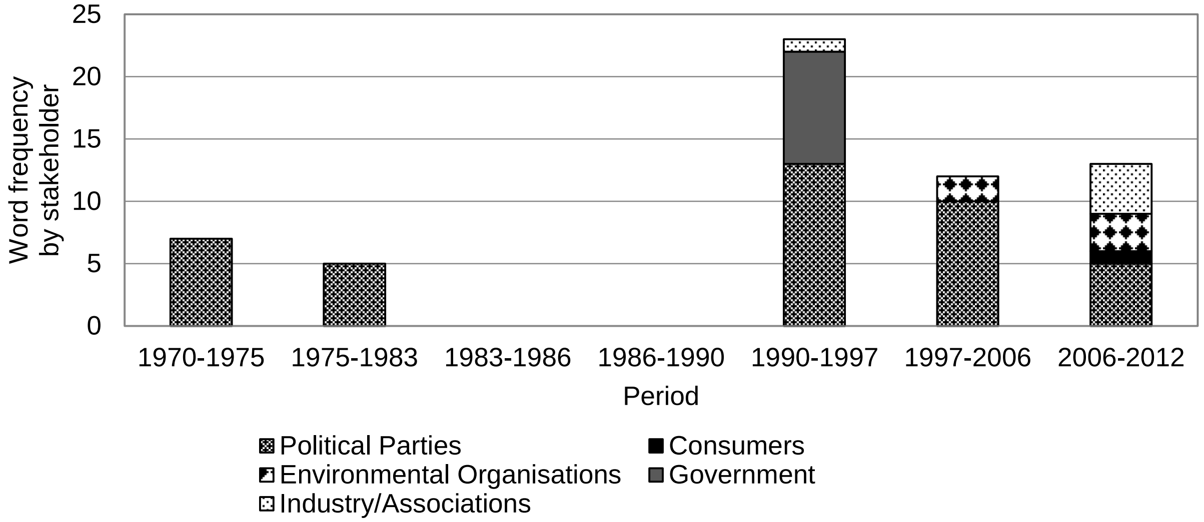

Figure 4.10: Word frequency of ‘Ontario Building Code’ by stakeholder between each building code.

With respect to the building code, stakeholders also discussed the need for a better building code. For example, several themes, such as improved and a better building code were identified. These themes along with ‘new building code’ and ‘changes in the building codes were grouped as ‘need for a better building code’. These themes appeared only before the third, sixth and the seventh building codes (Figure 4.11). Additionally, the need to improve the code was addressed by three stakeholder groups, mainly by the political parties (Figure 4.11).

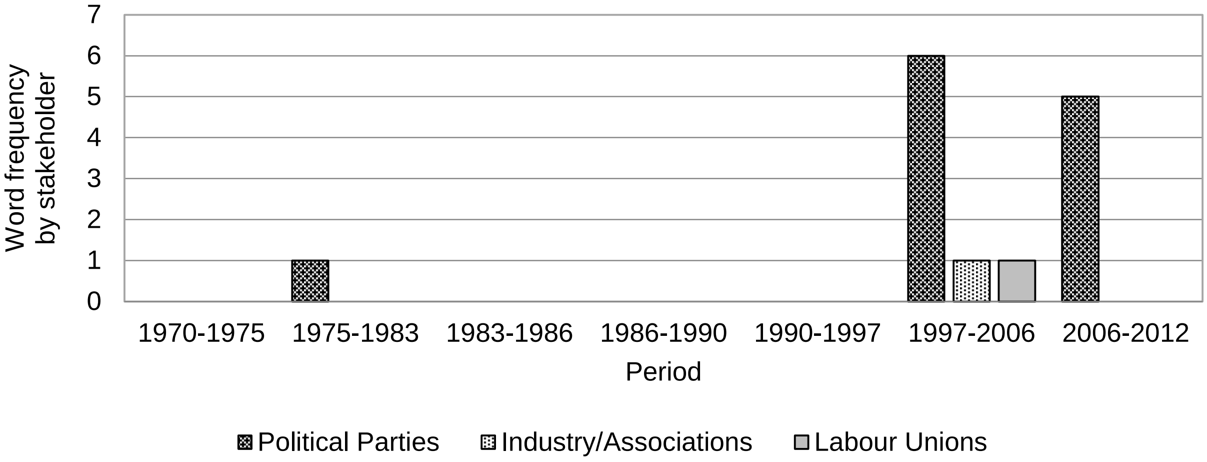

Figure 4.11: Word frequency of ‘need for a better building code’ by stakeholder between each building code. *Note: "Need for a better BC" it is only a collective name for ‘better building code’, ‘improved building code’, ‘new building code’, and ‘changes in the building code’.*

4.3.2.1 Period 1: 1970 – 1975

During this period, participants of political parties discussed the need for uniform building codes across the provinces, with a specific focus on Ontario. According to PC1 (1972), a uniform provincial building code provides one set of guidelines that can be easily followed by various stakeholders including the ministry, the construction industry, the housing industry, and the architects and engineers. The importance of provincial legislation, which provides standards for buildings, was also recognised (NDP8, 1972). NDP8 (1972) added that there is a specific need for standards for the adaptation and modification of older buildings.

Participants also discussed the limitations of Bill 62, an Act to provide an Ontario Building Code. According to LP1 (1974), the bill covers “only new buildings or extensive renovations or substantial enlargements.” LP1 (1974) believed that the building code required sections that “outline standards for rehabilitation of existing buildings.” On December 31, 1975, the first Ontario Building Code came into effect. This code was based on the 1975 National Building Code. It was the shortest of all Ontario Building Codes and comprised nine sections (Appendix 3, Table 3.3).

4.3.2.2 Period 2: 1975 – 1983

After the publication of the first provincial building code, the legislative discussions focused on the improvements to the code. Most of these improvements enforced energy conservation standards in residential buildings (LP2, 1979; NDP8, 1979). According to LP2 (1979), energy efficiency standards were to be enforced for all new construction, including the use of appliances and the electrical load. It was also suggested that the code impose heavier requirements on the type of materials used for retrofit in older buildings and for new buildings (PC2, 1980).

In June 1980, it was announced that the government, along with the public and private sector "would develop residential renovation guidelines to extend the life of residential resources, create rental accommodation and support the renovation industry" (PC3, 1983). A draft residential renovation code was put together by the government, the building industry, municipal organisations, professional associations, and research and standards agencies (PC3, 1983). The draft, which consisted of renovation practices to be followed by builders, contractors and homeowners, was released in 1982 for public comment (PC3, 1983; PC4, 1983). The comments and suggestions were incorporated into the final version. According to PC3 (1983), "renovation or conversion could not always be economically accomplished" when applied to older buildings.

On November 30, 1983, a new OBC was produced. This code had many changes after the first OBC was introduced. This version was based on the 1980 National Building Code. Most of the changes in this code took place under *Part 3: Use and Occupancy* (e.g., fire protection requirements), *Part 5: Wind, Water and Vapour Protection*, and *Part 6: Heating, Ventilation and Air-Conditioning* (Appendix 3, Table 3.3).

In December 1983, *Part 11: Renovation* was added to the Ontario Building Code. According to PC3 (1983), Part 11 allowed renovations to be undertaken under the existing code. Several concerns about the changes to the building code were introduced by two NDP representatives. According to NDP10 (1983), Part 11 of the code did not include all the possible challenges and solutions involved in older home renovation. NDP10 (1983) also expressed their concern about the industry driven requirements that are part of the OBC, that benefited mainly the industry. Additionally, NDP12 (1983) criticised the standards of the code and argued that standards needed to “provide a maximised benefit in terms of how we construct in this province.” NDP12 (1983) added that maximised benefits could be achieved by including energy conservation standards to the code.

4.3.2.3 Period 5: 1990 – 1997

In the early 1990s, the legislative discussions focused on developing a code that would include existing buildings (NDP11, 1991). Several amendments were proposed to create a set of standards that would help regulate not only the construction of new buildings, but also renovation and demolition of existing buildings (NDP11, 1991). The building code changes according to NDP11 (1991) and NDP13 (1992), were made following discussions with the building industry, municipal building officials, house builders, and industry associations.

Furthermore, LP12 (1992) pointed out that the new building code would include “new materials, innovative technologies and services that obviously were not part of the code when it was last amended, some nine years ago.” LP12 (1992) criticised the government for not including existing buildings under the standards of the OBC Act and for giving the cabinet power “to establish standards that existing buildings must meet even though no construction is proposed, including regulations...establishing standards for maintenance, occupancy and repair.” LP12 (1992) also pointed out that, if all existing buildings (including the ones 60 or 70 years old) were made to comply with the current codes, the government would allow owners to increase any rent increase by an additional 3%; however, even by increasing the rent, the renovation costs for the building upgrades would not be covered. LP12 (1992) advised the government to consult other affected stakeholders in the industry before it decided to change the regulations on existing buildings. LP12 (1992) recommended that changes be not only effective and efficient, but also feasible and affordable for the building owners.

Amendments to the Ontario New Home Warranty Program (ONHWP), which were intended to administer, addressed and enforced the Building Code Act in Bill 112, were also discussed. ONHWP established in 1976, a year after the first building code, was intended “to protect consumers by administering and enforcing the ONHW Plan Act to ensure that builders compiled with the act’s requirements” (ONH1, 1992).

4.3.2.4 Period 6: 1997 – 2006

Major discussions about the building code during this period took place in 2001, 2005, and 2006. In 2001, discussions were mainly about policies on conservation and efficiency, and the 2006 building code. According to NDP15 (2001), conservation and energy efficiency were not addressed in the 2006 code. In 2005, the building code was discussed mainly during the legislative debates on Bill 21, an Act to enact the Energy Conservation Leadership Act, 2005. The goal of the legislation was to provide, persons selling or leasing house, energy usage information on the property they were interested in (LP22, 2005). LP22 (2005) added that the 2005 building code would be modified to achieve energy conservation and meet the Kyoto objectives. According to LP22 (2005), 50% of Ontario's energy objectives for Kyoto were associated with energy usage in buildings. Therefore, it was required to have better buildings, which couldbe achieved through the building code. LP22 (2005) also added that the former government did not make any investments in energy conservation, and he was certain that the present government would bring the building code to the next stage. Nevertheless, many representatives voiced out their concern about not having appropriate energy conservation strategies or requirements outlined in the forthcoming building code (NDP16, 2005; PC5, 2005; NDP19, 2005). Given that Ontario had many buildings that were not efficient, NDP16 (2005) pointed out that there was the potential to achieve conservation and efficiency.

NDP20 (2005) also discussed the change in construction requirements of new buildings. NDP21 (2005) stated

> "…the new requirement that all new home construction be two-by-six, rather than even permitting two-by-four, which is certainly no more expensive, as I read in these articles, when you talk about the fact that you can have wider spaces between your vertical studs on a two-by-six framing rather than two-by-fours. You end up at least with the same cost, probably cheaper."

To achieve energy savings, the building code needed to be improved (NDP19, 2005). During the discussion, NDP19 (2005) brought up the Pembina Report, where it was stated that "the provincial building code should be amended to require R-2000, Canadian building improvement program (CBIP) or equivalent energy efficiency performance for all new buildings and building renovations by 2010." NDP19 (2005) also pointed out other requirements that needed to be changed in the code

> "The single largest area for potential energy efficiency gains that the Pembina Institute identified was improvement to building shells -- heating, ventilation and air conditioning -- in the residential, commercial and institutional sector, with potential savings of 30,000 gigawatt hours per year."

NDP19 (2005) also criticised the bill for not requiring the code to be improved and reformed, and for not requiring any progressive changes. NDP19 (2005) suggested that the code required "real reforms" for new structures and for existing buildings with respect to the heat loss during winter and heat gain during the summer. Some of these reforms could be achieved through a program, similar to the Power Smart residential loan program in Manitoba (NDP19, 2005).

In 2006, a representative of the Liberal Party discussed the direction of the 2006 code and the direction of future building codes (LP19, 2006). According to LP19 (2006), the future building code was expected to be an objective-based code. Therefore, if the builder believed that there was an alternative and efficient method to construct a building, then the alternative method had to be allowed. Additionally, by 2011, it was expected that the EnerGude 80 standard would be in operation. Various stakeholders, including the building industry, the energy efficiency industry, and the environmental community, anticipated higher standards to be introduced at an earlier stage (LP19, 2006). LP18 (2006) stated that, during the Liberal government, a number of energy conservation programs had been re-implemented after their cancellation by the previous government. LP19 (2006) continued,

> "...had this work begun 10 or 12 years ago, we wouldn't be rushing to catch up. But we are catching up, and, according to independent analysts, including the Canadian Energy Efficiency Alliance and the Suzuki Foundation, not only are we catching up but we're leading."

By the end of 2006, residential energy standards were expected to increase (LP19, 2006). For example, "changes to the building code's energy efficiency standards will increase home energy efficiency over the current code by more than 21%" (LP19, 2006). By doing so, Ontario was expected to have 13% higher energy-efficiency standards than it had ever had, and the highest standards in Canada (LP19, 2006).

However, according to environmentalists and efficiency experts, the proposed building energy standards to the building code were described as weak, whereas others believed that the standards were not even met (NDP22, 2006; NDP19, 2006). However, many wanted to see changes to the code, in particular with a focus on clean energy projects (OEA1, 2006). According to NDP19 (2006), several organisations, such as the Green Energy Coalition, the David Suzuki Foundation, the Energy Action Council of Toronto, Greenpeace Canada, and the Sierra Club of Canada had made recommendations on how to improve the code. The Conservation Council of Ontario for example, has given several recommendations including,

1. Raise home efficiency standards in the Ontario Building Code to a minimum rating of EGH 80;
2. Require energy efficiency labelling of all houses, starting with new houses and incorporating existing houses on resale;
3. Provide immediate financial incentives in the 2006 budget for investing in conservation, including
    1. i. PST exemption on conservation supplies
    2. ii. linking electricity surcharges to conservation financing;
4. Invest in conservation renewable resources. (NDP19, 2006)

4.3.2.5 Period 7: 2006 – 2012

At the beginning of this period, stakeholders discussed the changes for the 2006 building code. According to LP25 (2009), the 2006 building code was focused mainly on safety and construction standards, and not enough on energy efficiency; however, the future building code, also referred to as the EnerGuide80 standard, was expected to address efficiency (PC18, 2008). Moreover, as previously discussed, stakeholders again proposed higher building standards to be initiated through the code. For these standards to be met, financial incentives to help homeowners were required. Furthermore, homeowners tended to be interested in the payback period of their investment, and as NDP19 (2007) pointed out “as long as you show that they’re going to get their money back within five years, people will willingly sign up because they can see a time horizon within which this makes financial sense.”

In 2009, various stakeholders (AMO1, 2009; LP25, 2009; NDP17, 2009) also discussed the Green Energy and Green Economy Act, an Act to the building code, which imposed energy conservation and water conservation requirements “adding a requirement that the energy conservation provisions of the building code be reviewed within six months and every five years thereafter; and establishing a building code energy advisory council” (LP24, 2009).

Suggestions for the new building code, in terms of energy efficiency, from the council, which consists of various stakeholders, were brought up to the energy advisory board (LP24, 2009). The role of the council was to provide strategic advice to the government in terms of energy reductions in the building code (LP24, 2009). According to LP24 (2009), energy efficiency requirements for houses and large buildings, as well as the promotion of green technologies were the key aspects of the 2012 building code. The goal of the new code was

> "to squeeze as much energy out of hydro as we can, but those resources are limited, so we have to do a better job of energy efficiency in the building code, in our homes, in our offices and in our public facilities, as well as in energy conservation." (LP24, 2009)

LP24 (2009) also added that the government was trying to create "a greener Ontario and a culture of conservation." For example, the 2006 building code was designed in a way to help increase energy conservation in houses and larger buildings and to reduce the barriers for greener energies usage (LP24, 2009). Additionally, these energy conservation requirements of the building code created in a way that still allowed for affordable housing. Furthermore, LP24 (2009) stated that the energy conservation requirements of the 2006 code would save enough energy by 2012 to power 380,000 houses and reduce emissions equivalent to 250,000 cars. Moreover, since December 31, 2008, the code was again changed and required near-full-height basement insulation in houses.

Although the Green Energy Act focused on energy conservation, the Ontario Building Code was designed in a way to also inspire production (NZEHC1, 2009). For many years, the government had focused mainly on policy and regulatory attention to climate change in industry, but had not placed enough emphasis on the residential sector, which was responsible for "16% of our greenhouse gases and 17% of our secondary energy use in Canada" (NZEHC1, 2009). NZEHC1 (2009) suggests that a balanced approached to climate change could be achieved through the expansion of NZE housing.

LP18 (2009) added that if the act was passed, it would have helped green the Ontario government and other public buildings and facilities, as well "[establish] minimum standards for the new buildings that are equivalent to LEED silver." Moving to the LEED standard required skilled workers to be familiar with retrofitting and energy-efficient construction. However, LP18

(2009) argued that in Ontario, in 2009, there were 2.7 million houses that came under Part 9 of the building code (Housing and small buildings) and retrofitting houses to reduce energy consumption would have required a longer payback period. LP18 (2009) stated

> “let’s say just for the air sealing, probably one year, two years; and some of the windows and some of the insulation get up to three, four, five years. But generally, the paybacks on most of these energy retrofits are within the 10 years. I’ve just gone through the 2.7 million homes, and at a one-and-a-half-tonne reduction per home, we could be up to a four-million-tonne or five-million-tonne reduction of greenhouse gases on an annual basis by the time we get all our homes retrofitted in Ontario.”

The progress of the building code over time was also discussed by a representative from Sustainable Buildings Canada. According to SBC1 (2009), the energy code was for the first time introduced in 1993, though which energy efficiency procedures were laid out. In 1997, the province added an alternative document, known as the model national energy code for buildings, to the 1993 code (SBC1, 2009). Besides the City of Victoria, Ontario was the only province in Canada to adopt this part to the code. In 2007, the province also added Part 12 to the code, which included resource conservation, and updated the energy efficiency requirements (SBC1, 2009). SBC1 (2009) stated that the Ministry of Energy and Infrastructure “should become a key resource for municipal building officials who undertake the plan’s examination to determine compliance with the energy efficiency aspect of the building code.” In Ontario, the building code was enforced by the municipalities, and SBC1 (2009) believed that the MMAH had to be responsible for the enforcement.

NDP17 (2009) argued that in order to reduce energy consumption within the residential sector stricter code requirements were necessary. NDP17 (2009) also added that changing the way houses were to be built in the future was not enough. The province also needed to generate less energy as opposed to building large generation plants to meet electricity demands. NDP17 (2009) criticised the government for not being prepared to enforce these kinds of strategies into the code. New technological inventions could save energy consumption through higher quality insulation, efficient doors, and better heating systems (NDP17, 2009). Creating higher building standards that change the way homes were being built, “would go a long way in saving the need to generate electricity and burn fossil fuels to heat and light our homes” (NDP17, 2009).

NDP19 (2009) also criticised government's lack of direct energy conservation enforcement. According to NDP18 (2009), the building code did not impose stricter requirements, and the Liberal government had the power to increase the energy conservation standards without legislation. EC1 (2011) also criticised the building code for not having higher requirements, especially when some homeowners needed to make improvements in their houses. EC1 (2011) stated

> "the Ontario Building Code, which basically says to people who want to do something, "It's okay if you don't do anything." That's why thousands and thousands of houses across Ontario aren't being retrofitted: because the Ontario Building Code is archaic and needs to be drastically brought up to date."

NDP25 (2009) also discussed the solar-ready house concept. This concept involved "constructing buildings to be solar-ready so that they require minimal retrofits in order to install solar water heating or photovoltaics in the future" (NDP25, 2009). In 2008, City of Vancouver revised their building code to include the solar-ready requirement on one and two unit houses. However, the Ontario Building Code did not require houses to be built solar-ready (NDP25, 2009).

In 2012, changes to the next edition building code were discussed. According to PC20 (2012), the new code was developed to meet an energy performance level equivalent to the EGH80, to enhance energy efficiency in houses, to help conserve water, to reduce barriers to the use of greener technologies, and to help homeowners save money. As of January 1, 2012, large buildings and building permits were required "to meet energy efficiency standards that are 25% higher than the model national energy code for buildings" (PC19, 2012).

4.3.3 Insulation

Legislative documents were also analysed for the frequency of use of the term 'insulation' (including: insulation, insulate, insulating). The results presented in Figure 4.12 show that insulation was frequently discussed in the legislative debates. Prior to the first building code, insulation was discussed in 1974 and 1975 (n = 15). The highest number of counts of the term during discussion was between the first and second building code (1975 and 1983, n =136), followed by a decline between the third (n = 4) and fourth building code (n = 4). The frequency of 'insulation' in the parliamentary discussion increased after the fourth building code; n = 45 between 4th and 5th building code; *n* = 60 between 5th and 6th building code, and *n* = 33 between 6th and 7th building code. The results for frequency of 'home insulation' and insulation at different parts of a building can be found in Appendix 4, Figure 4.15-4.16.

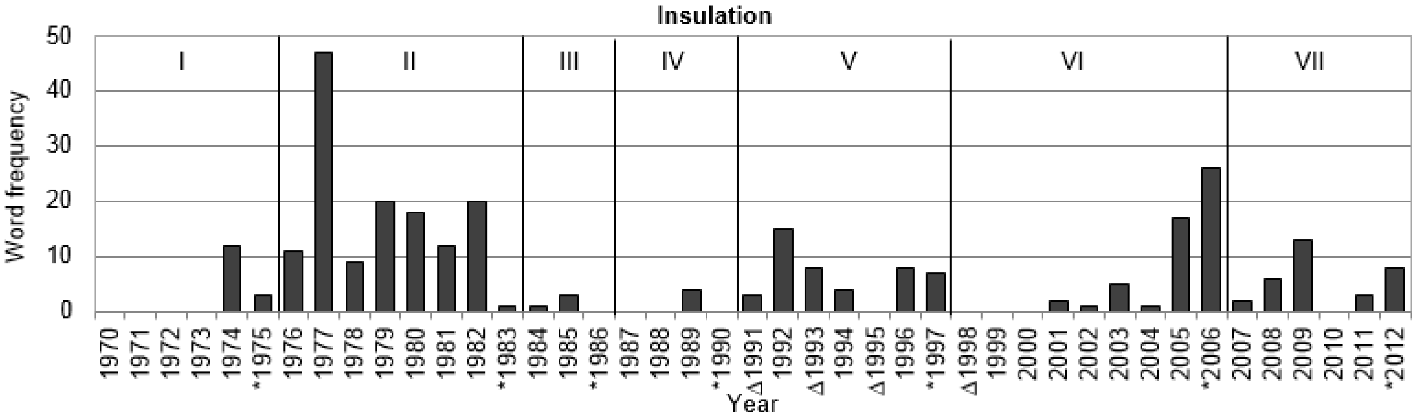

Figure 4.12: Word frequency of 'insulation'. *Note: includes variations of the word insulation (i.e., insulation, insulate, insulating).*

Discussions on insulation were mostly by the political parties, and less frequently by other stakeholder groups (Figure 4.13). During 1990-1997 period, environmental organisations, government, industry/associations, and utilities/associations participated in discussion on insulation. During this period, insulation was most frequently discussed by the political parties (*n* = 33), followed by utilities/assocations (*n* = 3). In the next two periods a slight increase in insulation discussion by the environmental organisations occurred.

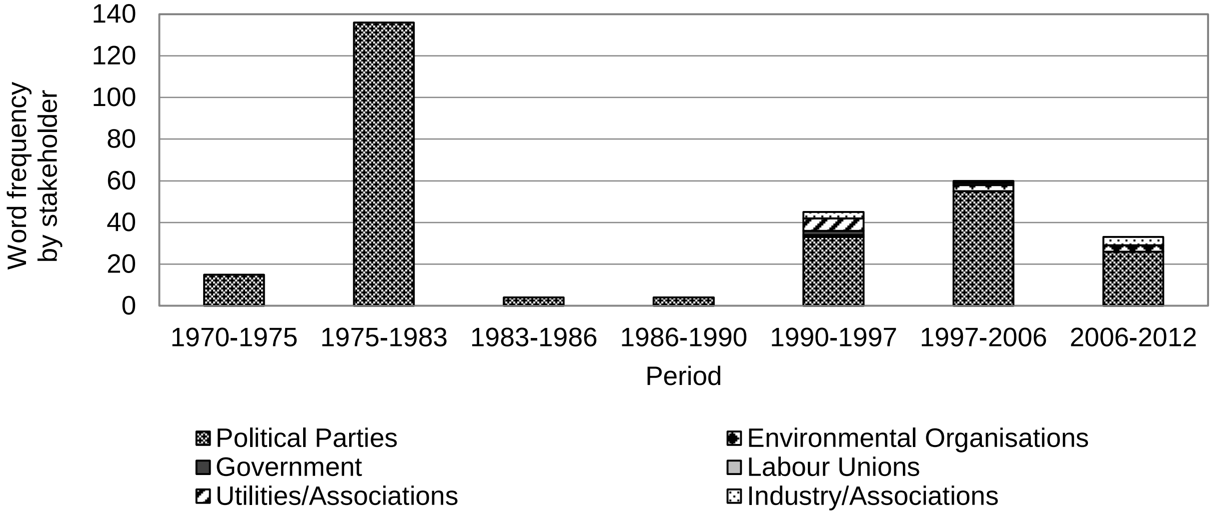

Figure 4.13: Word frequency of 'insulation' by stakeholder.

4.3.3.1 Period 1: 1970 – 1975

Before the first Ontario Building Code was launched, several issues were recorded in the legislative discussions, one of which was the lack of insulation, resulting in an increase in energy consumption in Ontario houses [xv]. According to NDP1 (1974), houses had an insufficient insulation because home builders were not required to install adequate insulation, and by doing so it helped builders save money. It was also stated that, during this period, insulation requirements in houses were dictated by both Ontario Hydro and the political parties (PC1, 1974). In 1975, it was proposed that only existing houses that have little or no insulation had to receive incentives for upgrades (PC7, 1975).

4.3.3.2 Period 2: 1975 - 1983

After the first Ontario Building Code was published, Ontario Hydro along with political parties suggested that insulation be increased to "6 inches, 4 inches"; however, it was not specified at what part of a house (LP3, 1976). In the following year, several participants also argued that the 1975 building code needed to have higher insulation requirements (PC8, 1977; NDP4, 1977; NDP2, 1977). In 1977, the Canadian Mortgage and Housing Corporation administered the Canadian Home Insulation Program (CHIP) (1977-1986 period) with the aim "to encourage energy-saving retrofits" (CMHC, 2013). As part of the program, homeowners where given up to $350 to upgrade the insulation in their houses which, according to PC8 (1977), was seen as an insufficient grant because "it [did] not exceed two-thirds of the cost of insulation" and, therefore, it did not help insulate the houses. It was also pointed out that the Ontario Home Insulation Program was mainly for houses built prior to 1921, which was seen as an issue, especially in northern Ontario, because of the low number of houses from this age bracket (PC9, 1977). To reduce energy consumption in houses, several political parties advocated sales tax exemption for both existing and new buildings (LP5, 1977; LP7, 1977; PC1, 1977; PC10, 1977). Enforced insulation standards for new buildings, as well as, "comprehensive compulsory programme of thermal upgrade, retrofitting and insulation for all existing structures" (LP2, 1977) were also proposed. A full interest subsidy was also suggested to "encourage every house owner in the province to upgrade their insulation standards and save energy. This kind of plan could reach

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[xv] "CMHC introduces the Residential Rehabilitation Assistance Program (RRAP) to help homeowners and landlords restore substandard and deteriorated buildings" (CMHC, 2013).

100,000 houses per year at a cost of $10 million. We estimate it would create 2,300 full time jobs" (NDP2, 1977).

In response to the large investments for nuclear power plants, the government was also greatly criticised for wanting to discard the insulation program (LP7, 1977; LP7, 1978; NDP2, 1977). NDP2 (1977) explained that it was ironic that the government was willing to spend $4-$5 billion for the Darlington nuclear facility, but did not want to spend $5 million on the already promised house insulation program that could have saved homeowners millions of dollars and energy. According to LP7 (1978), with the home insulation program, Ontario had the potential of saving "the equivalent of 25 percent more than one Darlington at about half of the capital cost."

Not long after its proposal, Ontario became the first province to eliminate the provincial sales tax for insulating materials, which encouraged sales (PC10, 1979). However, the government was also criticised for not keeping its promise from the 1977 election campaign about the $100,000,000 program, which was proposed to provide homeowners with low-interest loans for house insulation (NDP2, 1979; LP2, 1979). LP2 (1979) suggested that these loans to be provided by the energy distributors, specifically, the oil and gas distributors, and paid back by the homeowners through their monthly energy bill. LP2 (1979) also suggested the program to assist about 100,000 houses a year, similar to the Warm-up Saskatchewan program, and by doing so, the province would prosper by saving energy (NDP2, 1979).

In 1980, a five-year $4.9 million heat save energy conservation program was established for thermography and house energy audits in 60 major urban cities across Ontario with a population more than 9,000 inhabitants (PC11, 1980). The criterion for the size and location of communities was based on the "severity of the climate, the age of the houses, the extent to which house heating oil is used, the percentage of homeownership and the regional distribution of the communities" (PC11, 1980). The purpose of this program was to assist homeowners in identifying potential savings in their houses through insulation. The goal of the program was "to achieve a reduction of 15% in demand for energy on home heating by 80% of the homes in the province by 1985" (PC11, 1980). Consequently, the five-year program was expected to save about 20 million gallons of fuel oil a year through energy conservation of 175,000 houses (PC11, 1980). Additionally, with the restoration of downtown cores across several cities in Ontario, the government provided more than $110 million to low-income earners to upgrade their houses (PC12, 1980). This program was expected "to provide employment in the construction industry, increase the supply for rental units, stimulate improved insulation practices, provide income for those who are asset-rich but cash poor" (PC12, 1980). According to PC12 (1980), high insulating standards were being incorporated in construction and retrofitting industry. However, this statement contradicted the view of the representatives of other political parties. The need for more affordable and efficient houses, as well as a good house insulation program to assist homeowners in energy conservation, made it to the political agenda again (NDP6, 1980). In 1980, NDP3 revisited their 1979 seven-point program, which was designed to improve energy conservation in Ontario. In terms of insulation, the first two points of the program proposed

- a comprehensive home insulation program based on the model developed in Saskatchewan; and
- building codes that would include energy efficiency standards (NDP2, 1980).

Additionally, LP8 (1980) pointed out that insufficient progress was being made to improve insulation in houses. The wall thickness in Ontario houses has decreased over time, leaving very little space for insulation:

> "We have not made any steps in the direction of meaningful involvement with insulation. In Ontario today we still build homes with what used to be two-by-fours, which now have shrunk to two-by-three-and-a-half and may get smaller. If they take a wall of that thickness and put all the outlets around the outside walls, where do they put the insulation?" (LP8, 1980)

During the same period, research on more efficient houses was being conducted at the University of Waterloo (NDP3, 1981). Similarly to this research, under the NDP supervision, conservation houses were built in Saskatchewan. The goal of these houses was to reduce the energy consumption to $75-$100 a year, compared to the energy costs at $1,500 – $2,000 of conventional houses (NDP3, 1981).

The conservation program of 1977, intended to help homeowners insulate their basements and reduce energy consumption, was also revisited. NDP3 (1981) representative used the case of Peterborough, ON as an example. According to NDP3 (1981), at the time Ontario Hydro had agreed to support conservation; however, because conservation was not part of their mandate, and not in the mandate of the utility company Peterborough PUC, Hydro did not allow Peterborough PUC to give out loans for energy conservation. However, as part of Bill 86, an Act to amend the Power Corporation Act, Ontario Hydro along with the municipal hydro utilities carried out energy conservation program. As part of the bill, Ontario Hydro developed a residential energy advisory program, which included “an assessment of insulation and weatherization of homes, an assessment of the electrical wiring system, an assessment of the home heating system, and loans of up to $2,000 to carry out the recommended work” (PC13, 1981). After the completion, homeowners received follow-up inspections to ensure the proper performance after the changes were made (PC13, 1981). Bill 86, which was created mainly to ‘substitute for electricity’ instead of conservation, was criticized primarily by LP8. According to LP8 (1981), “the bill was not created for conservation purposes, but to justify bad management of Ontario Hydro and that in lieu of good management, good load forecasting and building a Hydro that would supply the needs of the people of Ontario.” LP8 (1981) argued that proper conservation could be achieved through the use of renewable energies (e.g., passive solar) and through the improvement of the provincial building code (e.g., higher insulation levels).

In 1980, changes to the retail sales tax were being made. As part of these changes insulation repair and maintenance labour were no longer tax exempted (PC14, 1981). Ironically, in 1981, the PC government ran the slogan “Life is Good, Ontario; Preserve it, Conserve it” and on number of occasions expressed their concern for energy conservation (LP9, 1982; NDP9, 1982; NDP11, 1983). Yet, it was still decided to put tax on conservation materials, such as insulation and doors (LP9, 1982). Additionally, as part of the CHIP, some inhabitants were still eligible for the federal grants; only up to $600 were given out for home insulation. Unfortunately, 7% of the federal grant toward insulation was taken by the provincial government (LP10, 1982; LP9, 1982; NDP9, 1982). To achieve quick results in the area of residential energy conservation, a 4-point program was proposed by the NDP (NDP11, 1982). The program offered “a free energy audit, loans financed by Ontario Hydro, approval and guarantee of contractors and a complete re-inspection” (NDP11, 1982). In the first year of the program 15,000 - 20,000 jobs were expected to be created (NDP11, 1982).

4.3.3.3 Period 5: 1990 – 1997

As presented in Figure 4.12, the frequency of insulation discussions increased between 1990 and 1997. During this period the insulation requirements of the building code were changed several times, greatly impacting homeowners. For example, changes in the 1990 building code resulted in an additional construction cost of $2,500 per house, and the proposed changes to the basement insulation alone, would contribute an additional $3,000 (CDC/OHBA1, 1992). A letter written by a builder, addressed to PC16, explained that the additional $3,000 to the price of new house could hinder the affordability of housing (PC16, 1992). The PC16 (1992) member added

> "When you compare it to what the building code is attempting to do with heat efficiency, the equation of $3,000 for the price of new home, my constituent in Bolton tells me, will have an average carrying cost of $300, while the resulting energy savings will be approximately 14% of a typical heating bill. That's an annual saving of $120 to $140. So already we have a development from the building code which is going to cost $150 or more because of this new requirement for full-height insulation in all residential basements. This doesn't make sense with the economy that we have, specifically in the housing industry."

Due to the lack of full basement insulation in houses, homeowners were faced with two issues, leaky basements and high energy consumption (OHWP1, 1992). OHWP1 (1992) added that the problem of leaky basements could be fixed using full basement insulation, "but until that day it's going to be very expensive for everyone."

PE1 and COHA1, both members of the Ottawa Oil Heat Association and the Canadian Oil Heat Association, revisited the CHIP (1992). Both representatives strongly believe that homeowners took advantage of the 1980s insulation program:

> "You cannot economically rip down the walls and re-insulate them. You can do the attic and you can do the basement. Hand in hand with our equipment, we also have programmable thermostats that can better manage the heating system in a home so that when people are away they are not heating dead space. But we wholeheartedly would support a conservation program if Hydro chose to make that part and parcel of any type of fuel substitution program as well." (COHA1, 1992)

During the 1992 discussion, several representatives reviewed the insulation requirements of the all-electric Gold Medallion houses, built in 1967-75 era (PC17, 1992). Gold Medallion houses had slightly better insulation, 6" in the attic, minimum of 3" in the walls, and 2" in the basement two feet below grade, than houses built during the same period (COHA1, 1992; PC17, 1992). These standards, set by Ontario Hydro, later came into the building code.

> “Gold Medallion home built in the 1960s had slightly superior insulation qualities to other homes that were built during that period. You would probably be looking at an expense of between $4,500 and $5,500; and again, we would have a bit of a problem with people who have finished the basements in their homes.” (COHA1, 1992)
>
> “In the 1967 era and again in the 1975 era where, because of the cost of Ontario Hydro’s fuel, it was not competitive. The only way it could market the off-peak load at that time was by having a home designed, such as the Gold Medallion home that had the extra insulation, six inches in the attic and a minimum of three inches in the walls and so on, and two inches in the basement two feet below grade. Those were standards that were set by Ontario Hydro and eventually came into the building code. But it was because of the price of their fuel at the time that they were trying to get an off-peak [electrical] load of the market.” (PC17, 1992)

In 1993, the 1990 building code was revised, and required a full-basement insulation standards for new housing, as well as higher energy efficiency standards for electrically heated houses (LP14, 1993; NDP14, 1994). Ministry of Housing along with the members of the house builders’ associations, the insulator’s representatives, and energy consultants, “to work out the most effective way of providing that new housing would have full-height basement insulation” (NDP5, 1993). The cost of full-height basement insulation was estimated to be under $10 a month added to the mortgage cost, which could help the homeowner economically in the long run (NDP5, 1993). Implementation of important regulations, changes to the building code, and full-height basement insulation had been delayed, and, hence, the cost of each issue resulted in increased costs between $3,000 and $5,000 per home (LP14, 1993).

In 1996, the government again decided to change the insulation standards. As NDP15 (1996) states “the government is planning to turn its back on 20 years of steady progress in building energy performance standards by returning to the insulation requirements of the building code from the 1970s.” The government proposed to reduce the insulation requirements, giving the homeowners the option to choose how much insulation they need. Additionally, the government decided to introduce an energy performance labelling system (NDP15, 1996). NDP15 (1996) argued that this decision is in the builders’ best interest, helping them save money. NDP15 also believed that homeowners would not receive the best advice on energy-efficient insulation.

LP15 (1997) also added that “many builders in the south would like to reduce the building code for some requirements on how to build, especially for insulation.” Builders preferred insulation requirements to be less stringent, which would have resulted in lower cost (LP15, 1997). However, LP15 (1997) pointed out that such changes to the building code would have not worked in the northern regions. Unfortunately, with the reductions in insulation requirements house prices did not go down, but in fact they increased. The cost of installing full-height insulation was estimated to be more than $2,000 (NDP16, 1997). Additionally, the Ministry of Municipal Affairs and Housing proposed to reduce insulation levels in new houses by 33%. The Canadian Energy Efficiency Alliance also proposed “to increase the cost of owning a new Ontario house between $3,000 and $15,000, depending on [the houses] fuel type, over the life of a 25-year mortgage” (NDP16, 1997).

4.3.3.4 Period 6: 1997 – 2006

During the 2000s, legislative discussions focused mainly on reviewing programs from provinces across Canada, as well as programs created by political parties. Discussions were also about the improvements of older houses using incentives. In 2001, LP16 representative revisited the Hydro grants given out to homeowners to put electric furnaces or other electric equipment. LP16 (2001) proposed the Ontario Legislative Assembly’s committee to use the Ontario Hydro’s strategy but in the “other way”:

> “... say if you went to a heat pump rather than an electric furnace, if you went to this particular level of insulation even though it’s far above the building code? Any sense of whether it’s in the public good to do that?”

In 2003, another LP representative discussed the success of some past programs which have helped improve insulation in homes. For example, between 1990 and 1995, the Efficiency Ontario project helped deliver several programs to assist homeowners with energy conservation (LP17, 2003). In particular, these measures include “basement wall insulation, energy-efficient windows and proper caulking and sealing” (LP17, 2003). As part of the NDP government’s green communities program, homeowners were granted free audits. The NDP government also switched several public housing buildings from electric heating to natural gas, and improved insulation in buildings (LP17, 2003). However, in 1995, the Conservative government took over and immediately cancelled the program (LP17, 2003). As a result, audits were no longer free and there were very few incentives available (LP17, 2003). LP17 (2003) added that the LP government would have liked to implement the NDP's approach under their proposal - "*Public Power: Practical Solutions for Ontario."*

NDP representatives also discussed the inefficient houses in Ontario and the high energy bills associated with them. According to NDP18 (2003), homeowners could have saved $360 a year from their energy bill if they had installed insulation, replaced doors and windows. NDP17 (2003) visited several old and electrically heated houses. One house in particular, that had no insulation and old windows, usually paid about $400 for the month of January and $450 for February. However, in 2003, the energy bill for this same house doubled to almost $900 for the month of January. As a result, the homeowners of this particular house decided to change the electric heating to something else.

Lack of incentives to make houses more energy efficient was brought up again (NDP19, 2004). NDP19 (2004) stated that there were no financial incentives to help residents re-insulate their houses or to purchase new energy-efficient appliances. According to the Pembina Institute, serious conservation program intended to upgrade houses would have cost $18 billion (NDP19, 2004). And although "energy efficiency was the way to go", some stakeholders were still focused on the nuclear program, which was expected to cost $32 billion (NDP19, 2004). NDP19 (2004) pointed out that all of Toronto's apartment buildings and all of the office buildings were poorly insulated, resulting in high energy consumption. However, this problem was persistent across Ontario. NDP17 (2005) suggested that upgrading these buildings would have not only saved energy, but it would have also taken the pressure off the supply side. Furthermore, because many of these buildings across Ontario were electrically heated, tenants living in these buildings were subject to high energy bills. Landlords were also not required to upgrade their dated appliances and to upgrade the buildings (e.g., convert from electric heat and water heaters or install energy-efficient doors), and this impacts the tenants (NDP20, 2005). Additionally, LP19 (2005) suggested that home buyers had to be advised about the energy use of the property they were interested in. For example, the information on the energy use of the property had to include the level of insulation, the type of heating, and the cost and type of furnace if available.

Hydro One, along with Natural Resources Canada (NRCan) and Canada Mortgage and Housing Corporation (CMHC) teamed up “to provide financial incentives for energy-efficiency upgrades to low-income Hydro One customers” (CMHC, 2005). Specifically, a $3000 incentive was given out to customers that heated their houses with electricity (LP19, 2005).

In addition, energy-efficiency programs from Québec and Manitoba were used as good examples. For instance, under Manitoba Hydro’s Power Smart program, homeowners who were serious about energy-efficiency received audits of their houses (NDP19, 2005). Through audits, insulation levels, efficiency of windows and doors, as well as heating and ventilation system were inspected. Homeowners whose houses did not meet the insulation standard were eligible for a $5,000 low-interest loan to re-insulate their houses. The loan was also allowed to be used for energy-efficient windows or for energy-efficient appliances (NDP19, 2005). Additionally, in Manitoba, homeowners could get all their money back spent on insulation materials (NDP19, 2006). In Québec, through the Energy Wise program houses, businesses, and public buildings were audited to determine the energy efficiency of buildings, as well as to determine best practices for reduction in energy consumption (NDP19, 2005). Through the Energy Wise program, audits were free, and homeowners could receive low-interest loans to upgrade their houses. The money saved from energy bills could be used to “pay back the low-interest loan” (NDP19, 2005). Hydro-Québec also provided homeowners with an “incentive that is double the federal grant” (NDP19, 2006). NDP19 (2006) added that Saskatchewan, Nova Scotia, Newfoundland and Labrador “matched the federal EnerGuide for Houses retrofit grant.” Additional grants were also given to seniors in Nova Scotia and to moderate-income households in Saskatchewan for improving the energy efficiency in their homes (NDP19, 2006). Furthermore, low-income homeowners also received additional free services, such as “heating system tune-ups, weather-proofing, [and] programmable thermostats” (NDP19, 2006). NDP19 (2006), therefore, criticized Ontario for not offering low-interest loans to help homeowners improve their houses.

According to LP18 (2006), the Liberal government had successfully led the way towards energy efficiency and conservation. Houses built in 2007 would also be required to reach higher insulation standards. For example, insulation in ceilings would be “increased by 29%, walls by 12% and foundation walls by 50%” (LP18, 2006). Additionally, the next building code would require houses to have high-efficiency gas or propane-fired furnaces and better windows (LP18, 2006). Some of these improvements were expected to be effective when EGH 80 becomes mandatory, whereas others are expected to come into effect sooner (LP18, 2006).

In response to the insulation requirements, a representative from the Toronto and York Region Labour Council revisited the past changes in insulation requirements. TYRLC1 (2006) stated

> "We couldn't understand why the builders some years ago lobbied like crazy to remove some of the environmental considerations that were previously in the building code, things like full-height basement insulation. They went nuts to remove that stuff from the building code -- very short-sighted, not understanding the savings that this would provide to homeowners in the long term, not understanding the health effects around mould and so on."

In 2005, 965 people participated in the We Conserve program designed by the Conservation Council of Ontario. CCO1 (2006) explained that

> "72% of homeowners have installed one or more compact fluorescent light bulbs; 69% have draft-proofed doors; 64% have upgraded to more energy-efficient appliances; 40% have reported adding insulation to their home; and 37% reported upgrading insulation levels in the basement."

Furthermore, the interviewed participants were willing to support improved efficiency standards and financial incentive

> "95% of respondents want new homes to be insulated to meet the highest energy efficiency standards; 93% felt that renovations should also meet the highest energy efficiency standards; 89% support an energy efficiency label for new homes, similar to what is currently on appliances; 85% want the government to invest in incentives and low-interest loans for conservation; and 80% support increasing energy efficiency standards in the Ontario Building Code. So Ontarians are willing to pay a premium for energy efficiency, especially if it will result in low energy bills." (CCO1, 2006)

NDP19 (2006) believed that for homeowners to take part in energy efficiency and conservation, the government needed to provide them with incentives, "say a low-interest loan to put in energy-efficient windows and better insulation, a lot of people would do that." However, according to NDP19, the government had not been providing homeowners with financial assistance to re-insulate their houses, or to put in energy-efficient windows. The NDP19 representative also introduced the work of Green Communities Canada, a non-for-profit organisation and the most effective driver for promoting energy efficiency in Ontario. Green

Communities performed audits through which they determined the efficiency of houses and provided homeowners with recommendations (NDP19, 2006).

4.3.3.5 Period 7: 2006 – 2012

In 2008, the Home Energy Act was introduced by the Liberals' government (LP22, 2008). Although European countries (e.g., England and Germany) and some states in the U.S. followed the advice of the Home Energy Rating Act and were already successful at energy conservation in houses, provinces across Canada were also making progress (LP22, 2008). For instance, in 2004, Ontario was ranked with a D by the Canadian Energy Efficiency Alliance. However, in 2008, Ontario was ranked with an A, and this was achieved during the Liberal government (LP22, 2008). With the Home Energy Rating Act, homebuyers had the right to get the energy performance characteristics of a house they were interested to purchase (LP18, 2008). The Act also "allows consumers to understand the value of insulating in the walls, efficiency of appliances, heating and cooling and the lighting system" (LP18, 2008).

The legislative committee also discussed the funding available for homeowners to upgrade their houses. According to LP18 (2009), as part of the ecoEnergy program, with an audit fee of $150 homeowners were eligible for several improvement retrofits. For example, homeowners could receive up to $600 for an energy-efficient furnace; up to $7,000 for a groundwater source heat pump; up to $1,200, $1,800, $1,000, and $800 for attic insulation, exterior wall insulation, basement, and crawl space, respectively (LP18, 2009).

During the 2009 legislative discussions, the issues with energy inefficient rental apartments were also revisited. NDP22 (2009) believed that

> "if tenants are stuck with the cost of heating, those windows will never be fixed, because the landlords will never have any incentive to actually replace them with the kind of triple glazing that's required. If tenants are stuck with the cost of heating, they will never have the money to insulate the outer walls of those buildings to reduce energy consumption. The whole focus of this government is wrong in terms of actually achieving the ends and transforming energy use in this province."

LP24 (2009) also discussed the improvements in current residential houses to the houses built 40 years ago, in terms of insulation, windows, and appliances. According to LP24 (2009),

> "house that was built 40 years ago compared to a house today, with the type of insulation and the types of windows and appliances, it really is night and day. We've come a long

> way. Since December 31, 2008, for instance, one of these changes requires a near-full-height basement insulation in homes, which makes the basement more energy-efficient and cuts down on greenhouse gas emissions."

In 2011, an EnviroCentre representative highlighted the success of the 15,000 house energy audits for the past ten years. EC1 (2011) reported that people upgraded their furnaces, improved the basement insulation, and draft proofed gaps to prevent heat loss. EC1 also discussed the difficulties of the program before its closure. Across Ontario there are many old and inefficient houses, and performing audits and upgrades before end of March 2011 was very challenging. EC1 stated

> "But you actually now have to get your first audit done; you've got to run out and get a furnace contractor or an insulating company to get in there and do all the work; get the second audit done; and get all of that done before the end of March. It's going to be very, very difficult to do that, and it's certainly regrettable. Let me conclude by noting that over the last year, EnviroCentre has invested in a new demonstration project in this old brick house in Ottawa. There are hundreds, thousands, probably tens of thousands like it across the province. It had a 43-year-old boiler. It had enormous air leakage. It had no insulation in the walls."

In 2012, Bill 75, An Act to amend the Electricity Act, 1998 was discussed. NDP22 (2012) argued that Bill 75 "would lead to even more costly power, and frankly, I don't think this Legislature should support that." NDP22 (2012) also added that Ontario could likely achieve one per cent reduction in power consumption by houses. Higher power reduction could be achieved if the government was to provide homeowners with low-interest loans so that homeowners could "dramatically increase their insulation", which in return would help them reduce their consumption. NDP25 (2012) also pointed out that conservation is very important for consumers, because it helped them save money, and this could be achieved through creation of conservation programs. NDP24 (2012) added that, across Ontario, there are people who "live below the poverty level, [and] they can't even pay their hydro bill." These people lived in houses that required more insulation and new windows, and these residents were unable to borrow $10,000 to improve their houses.

Discussions on house insulation show a slight increase in the third phase (*n* = 10). Insulation at various parts of a house did not make it to the legislative discussions until 1991. Wall insulation in particular was found in the 1991, 2003, 2009 and 2011 debates (Appendix 4, Figure 4.16). Full height insulation along with insulation in the basements was on the legislative agenda between 1992 and 1997, and again in between 2006 and 2011 (Appendix 4, Figure 4.16). Attic insulation which was not introduced in the legislative debates until 2005 was again discussed in 2006 and 2009 (Appendix 4, Figure 4.16). Both attic and wall insulation were debated by the political parties and environmental organisations. Basement insulation on the other hand, was discussed by the industry/associations, the government, labour unions, but mainly by the political parties and the environmental organisations (Appendix 4, Table 4.2). Additionally, the issue of little to no insulation in residential foundations and walls was addressed by the political parties and the environmental organisations (Appendix 4, Table 4.2).

4.3.4 Buildings

Given that this research is focused on residential infrastructure, words, such as houses, houses and buildings were selected to determine their frequency in the legislative records. All these words were merged together and counted as residential infrastructure. Appendix 4, Figure 4.17 shows that residential infrastructure was discussed mainly prior to each building code, as well as during the year when the code was published (e.g., 2006). Residential infrastructure has very high frequency in 1992 (n = 378), 2006 (n = 314) and 2009 (n = 622) (Appendix 4, Figure 4.17).

With respect to word frequency by stakeholder, political parties tend to have the highest word frequency, especially in the first four periods when no other stakeholders are involved (Figure 4.14). However, after 1990 other stakeholders become more involved in discussion on residential infrastructure. Over time both government and utilities/associations experience decline, whereas environmental organisations and industry/associations experience increase in discussion on residential infrastructure (Figure 4.14).

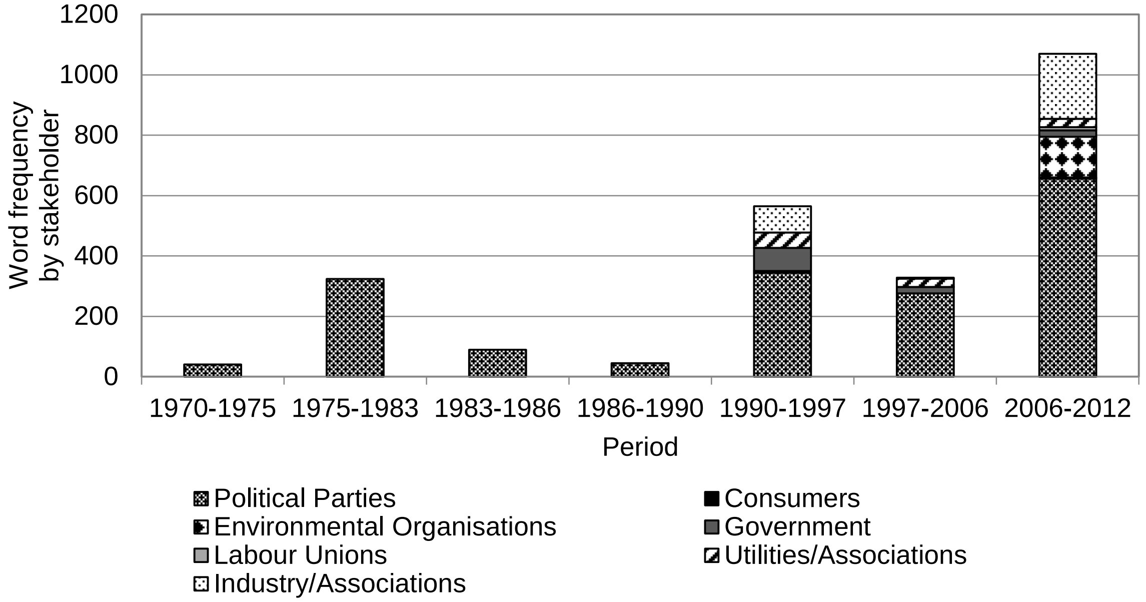


Figure 4.14: Word frequency of 'residential infrastructure' by stakeholder between each building code. *Note: includes 'house(s)', 'home(s)' and 'building(s)'.*

Moreover, the legislative discussions focused mainly on newer infrastructure rather than older infrastructure (Appendix 4, Figure 4.18). The overall trend shows lower frequency of older and newer infrastructures discussions between 1970 and 1991 (*n* = 9 and *n* = 17 respectively) and higher frequency between 1992 and 2009 (*n* = 11 and *n* = 97 respectively). Both older and newer infrastructure is largely discussed by the political parties. Between 1990 and 1997 older infrastructure is only discussed by the industry/associations (Figure 4.15). During the same period, newer infrastructure is discussed mainly by the government and political parties (Figure 4.15). Interestingly, between 2006 and 2012, environmental organisations, industry/associations and political parties participated in legislative debates on older infrastructure, whereas for newer infrastructure there are more diverse stakeholder groups involved (Figure 4.15 and 4.16). Furthermore, there is a decline in government's input on new infrastructure, but an increase in input by industry/associations (Figure 4.16).

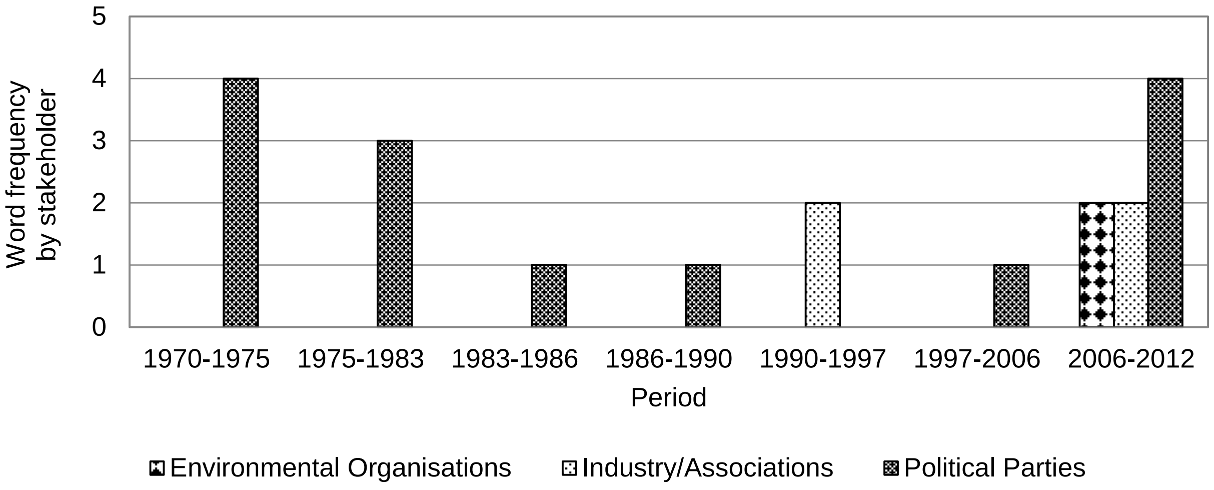


Figure 4.15: Word frequency of ‘older infrastructure’ by stakeholder.

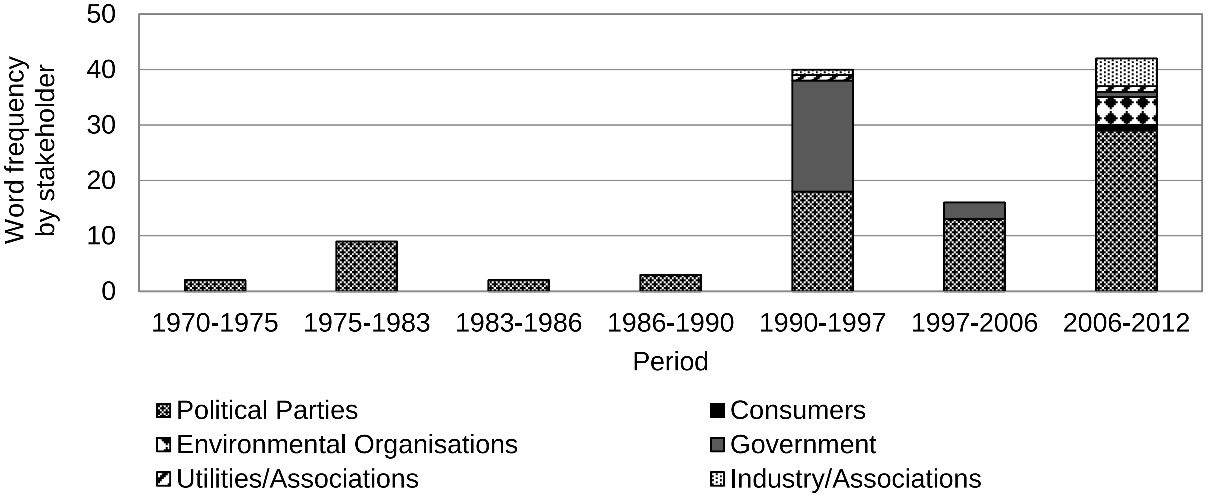


Figure 4.16: Word frequency of ‘newer infrastructure’ by stakeholder.

The importance of building envelope improvements and the need for better residential infrastructures were also part of the legislative discussions, however, these were not frequently discussed (Appendix 4, Table 4.3). Political parties were again the most involved, including the utility/associations and environmental organisations.

4.3.5 Energy

The next category of this research focused on the energy, used to help with analysis of the building code and insulation requirements. Specifically, ‘energy’ was used to determine whether participatory stakeholders discussed the need to reduce energy usage in buildings. Energy was discussed during the all seven periods. The most frequency energy discussion is during the second (n = 570), sixth (n = 659), and seventh period (n = 795), and the least during the first (n = 8) and fourth period (n = 34) (Appendix 4, Figure 4.19). During the first four periods, 'energy' was only discussed by the political parties (n = 783), whereas after the fifth period there is a diverse engagement from other groups (Figure 4.17). The Industry/Associations and Environmental Organisations are the second largest, followed by the Utilities/Associations. Consumers and the labour unions have the lowest discussions on 'energy'. The most frequent discussion on 'energy' was during the second, sixth, and seventh period (n = 571, n = 507 and n = 463 respectively) (Figure 4.17).

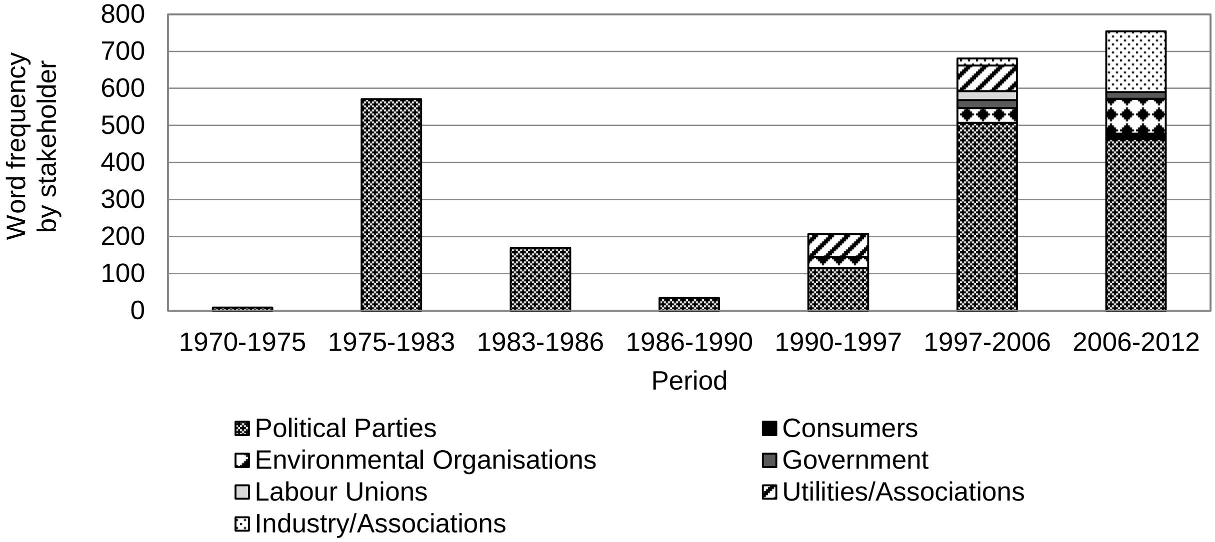


Figure 4.17: Word frequency of 'energy' by stakeholder.

Other words associated with energy were also analysed and these include: 'energy crisis', 'energy issues', 'energy loss', 'energy shortages', and 'energy demand' observed in Figure 4.18. From Figure 4.18 it can be determined that 'energy crisis' appeared only twice (third and seventh period; n = 2), whereas 'energy issues' appeared three times (third, sixth, and seventh period; n = 4) in the selected legislative documents. 'Energy shortages' was discussed three times (second, third, and fifth period; n = 3). The highest frequency was observed for 'energy demand' which appeared between the second and seventh period (n = 9).

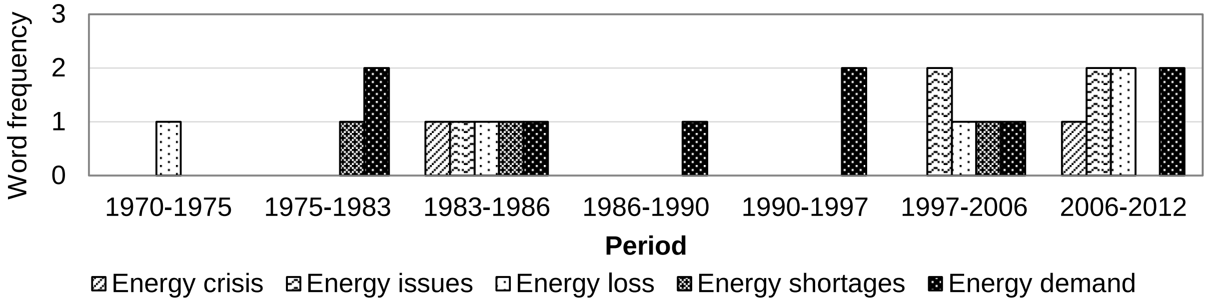


Figure 4.18: Word frequency of ‘energy crisis’, ‘energy issues’, ‘energy loss’, ‘energy shortages’, and ‘energy demand’.

Legislative documents were also observed for words, such as ‘reduce energy’, ‘reduce energy consumption’, ‘save energy’, and ‘less energy’ (Figure 4.19). An average increase in word frequency can be observed from the fourth to the seventh period, especially for ‘reduce energy’ (n = 1 to n = 16) and ‘save energy’ (n = 1 to n = 23).

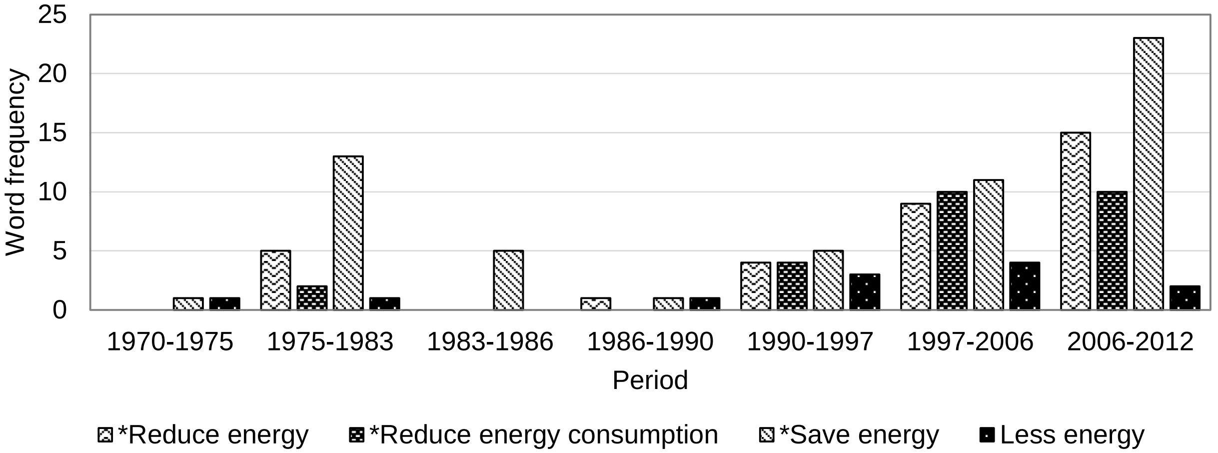


Figure 4.19: Word frequency of ‘reduce energy’, ‘reduce energy consumption’, ‘save energy’, and ‘less energy’. *Note: *reduce energy includes: ‘reduce energy’, ‘reducing energy’; *reduce energy consumption includes: ‘reduce energy consumption’, ‘reduce energy use’, ‘reduce energy usage’, ‘use less energy’;* *save energy includes: *‘save energy’, ‘saving energy’, ‘savings in energy’, ‘energy saving’.*

Word frequency of three categories, including ‘save energy’, ‘reduce energy’, and ‘reduce energy consumption’ were analysed by stakeholder (Figure 4.19 - 4.21). The word frequency of all three categories is mostly used by political parties and environmental organisations (Figure 4.20 and 4.21). ‘Save energy’ appears to be discussed the least prior to the first building code (n = 1) (Figure 4.20). An increase in energy savings discussion by political parties can be observed before the second building code (n = 12), followed by a decline after the second code (third period n = 4 and fourth period n = 1). However, after the fourth building code an increase in the energy savings discussion can be observed (n = 5, n = 7, n = 12). From 1997 to 2012 government, the industry/associations, and environmental organisations engaged in the energy savings discussions. Discussion on energy reduction was discussed primarily before the first code only by the political parties and then again after the third code (Figure 4.21). Reduction in energy consumption was also heavily discussed by the political parties and also not as frequently (Figure 4.22).

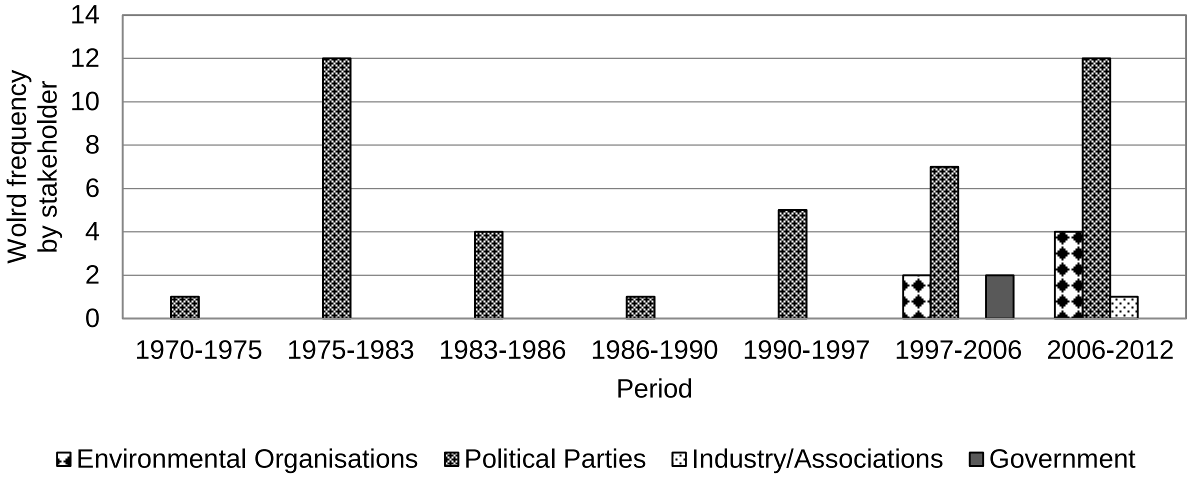


Figure 4.20: Word frequency of ‘save energy’ by stakeholder. *Note: includes ‘saving energy’, ‘savings in energy’, and ‘energy saving’.*

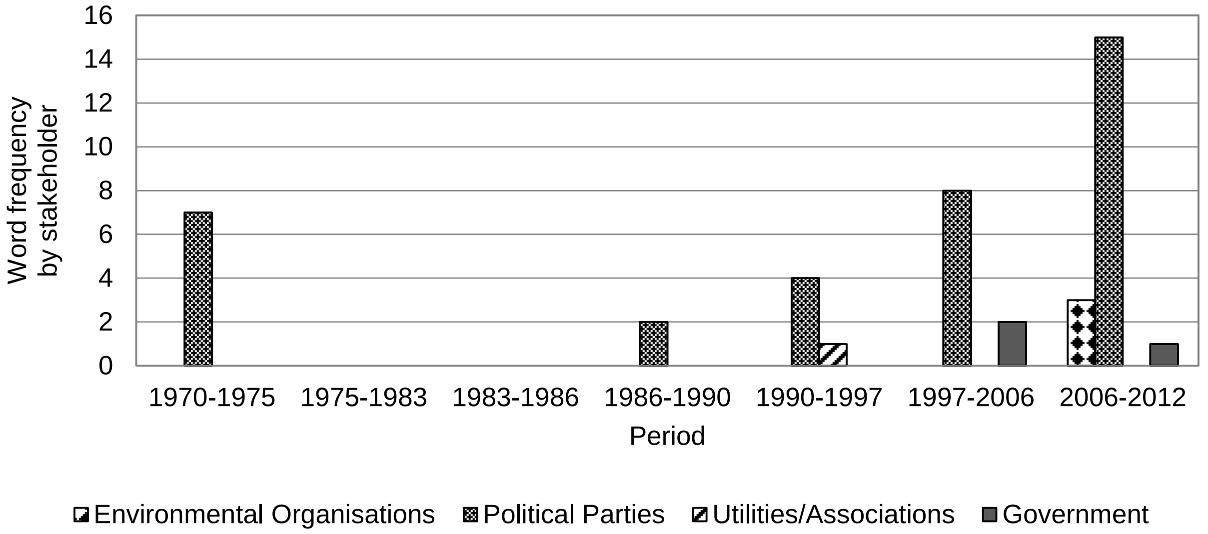


Figure 4.21: Word frequency of ‘reduce energy’ by stakeholder. *Note: includes ‘reduce energy’ and ‘reducing energy’.*

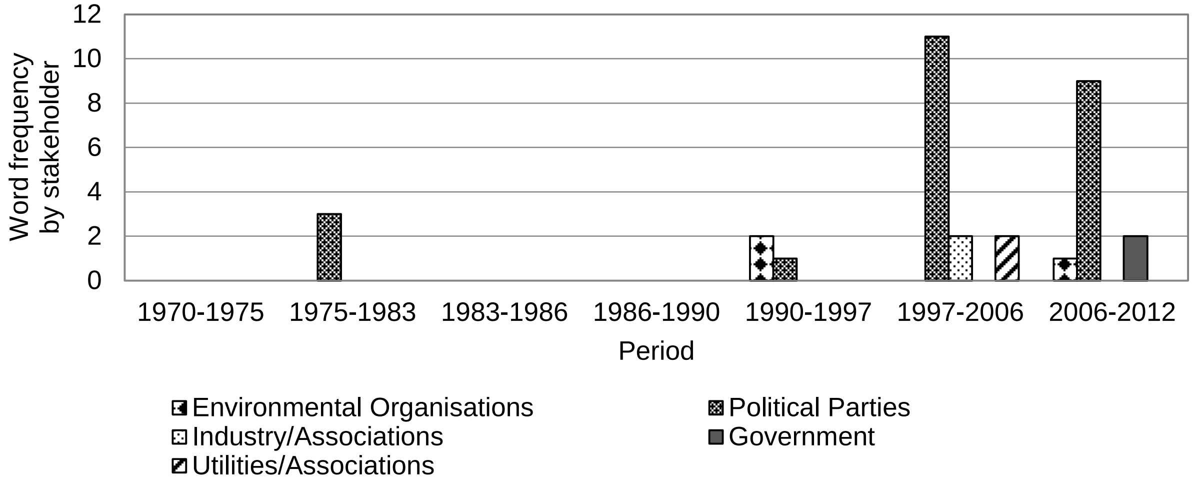


Figure 4.22: Word frequency of ‘reduce energy consumption’. *Note: includes ‘reduce energy consumption’, ‘reduce energy use’, ‘reduce energy usage’, and ‘use less energy’.*

4.3.6 Efficiency

Efficiency is another word analysed in the legislative documents. The results show variations in the frequency of the use of ‘efficient’ (Appendix 4, Figure 4.20). ‘Efficient’ was not discussed prior to the first building code. The highest frequency can be observed during the sixth period (n = 358) and seventh period (n = 203). No involvement in discussion on efficiency from other stakeholders besides the political parties can be found during the first four periods (Figure 4.23). The word frequency is the highest for the political parties (n = 47), followed by the industry/associations (n = 9), the environmental organisations (n = 7), and the utilities/associations (n = 5). Consumers (n = 1), the labour unions (n = 2), and the government (n = 2) have least discussed efficiency.

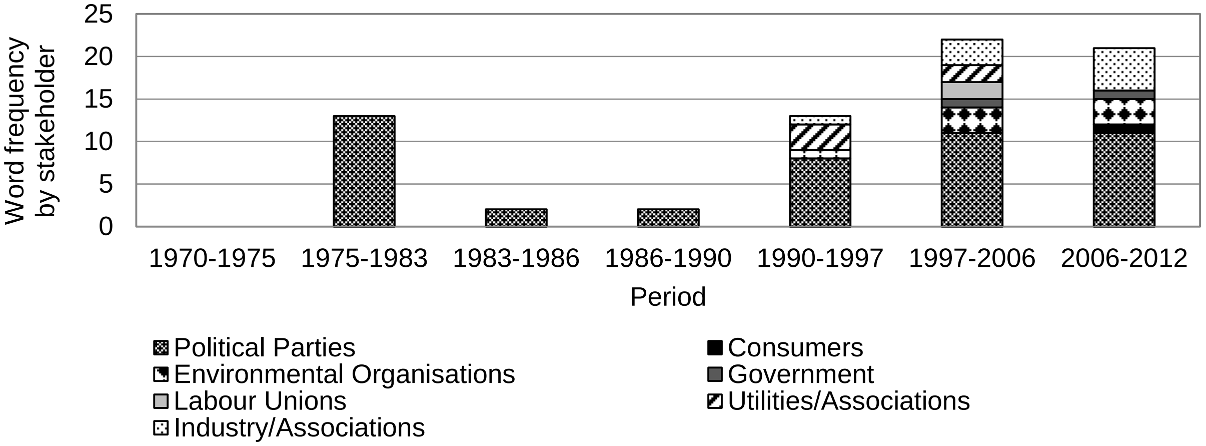


Figure 4.23: Word frequency of ‘efficient’ by stakeholder.

Word frequency by stakeholder for energy efficiency was analysed during the past 40 years. Results show that energy efficiency was not discussed during the first and fourth period (Figure 4.24). The highest frequency is during the sixth and seventh period during which several stakeholders were involved. The political parties again have the highest usage for energy efficiency (n = 28), whereas the government (n = 1) and consumers have the lowest (n = 1).

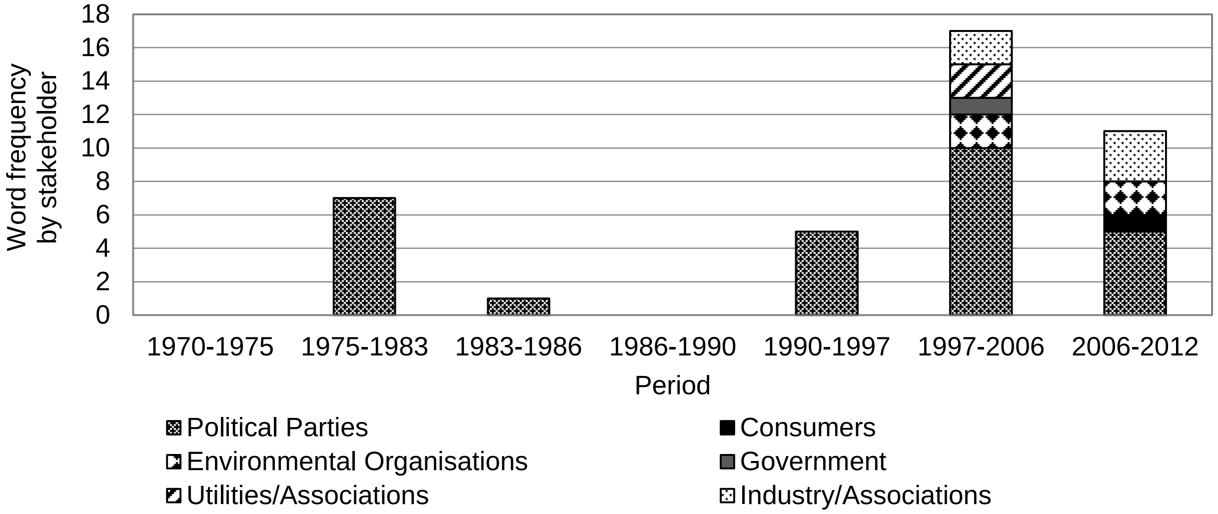


Figure 4.24: Word frequency of 'energy efficient' by stakeholder.

Legislative discussions were also analysed for efficient buildings (Figure 4.25). Overall, efficient buildings were not frequently discussed. No discussion of efficient buildings appears before the first, third, and fourth building code. Additionally, only three stakeholder groups were associated with this topic; political parties (n = 15), utilities/associations (n = 1), and industry/associations (n = 1).

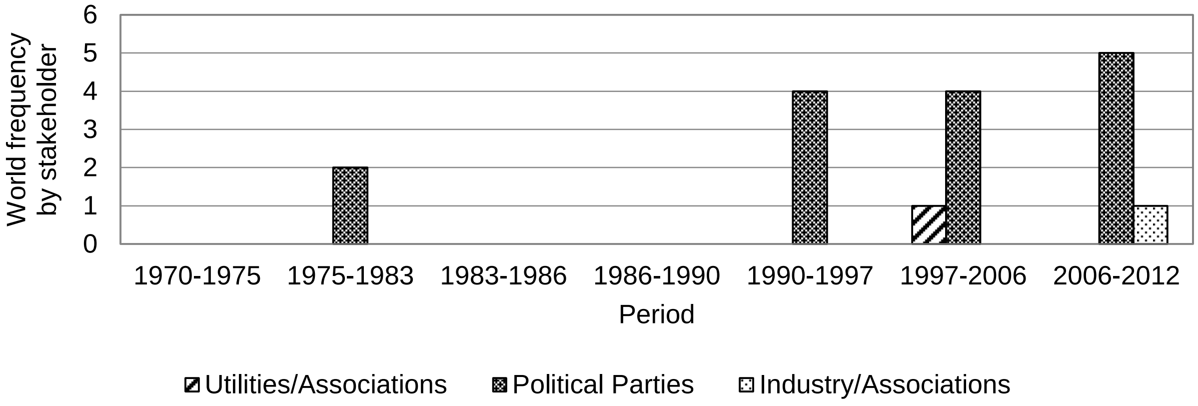


Figure 4.25: Word frequency of 'efficient buildings' by stakeholder. *Note: includes 'building',' house', and 'homes'.*

4.3.7 Conservation

Legislative documents were also analysed for the occurrence of the term conservation. Over the 40 year period conservation was discussed often (n = 875, Appendix 4, Figure 4.21). The highest frequency of 'conservation' is during the second (n = 254) and sixth (n = 316) period, and the lowest during the first (n = 2) and fourth (n = 5) period. The frequency of 'conservation' during the frequent building code changes is low (n_{1991} = 7, n_{1993} = 2, n_{1995} = 0, and n_{1998} = 0).

With respect to frequency by stakeholder, the highest frequency is by the political parties, who are the only stakeholders discussing conservation during the first four periods (n_{total} = 717, n = 306 for first four periods), whereas the consumers have the lowest frequency and only appeared during the seventh period (n = 3) (Figure 4.26). Interestingly, environmental organisations have the second highest use of the word conservation, especially between 1997 and 2006 (n = 59) (Figure 4.26). Political parties also tried to promote conservation in 1979 (n = 1), 1981 (n = 2), and in 1985 (n = 1).

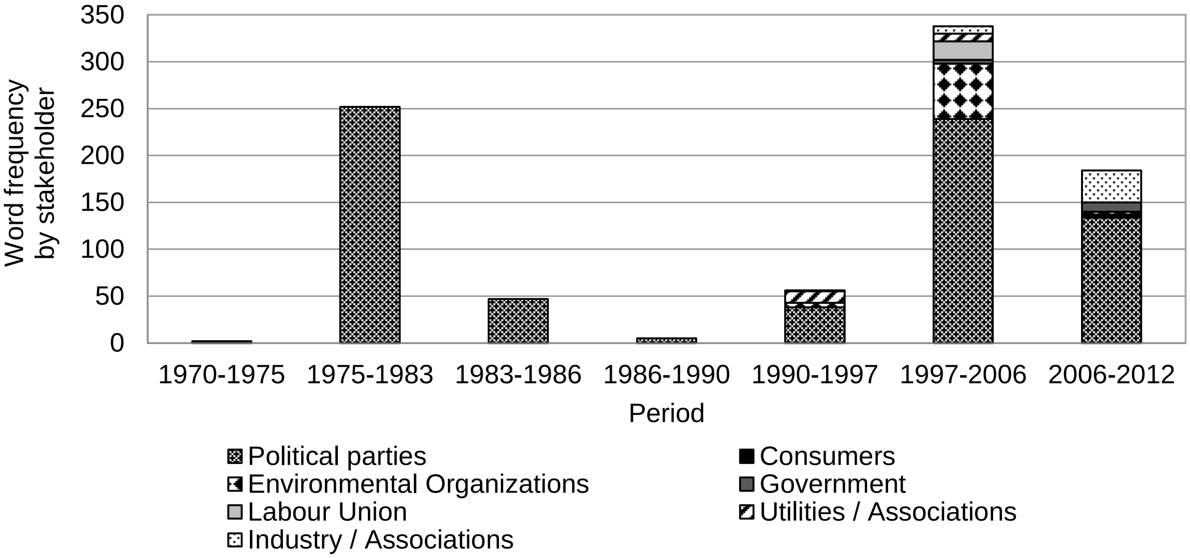


Figure 4.26: Word frequency of 'conservation' by stakeholder.

Furthermore, documents were also analysed for 'energy conservation' (n = 303) (Figure 4.27). Just as 'conservation', 'energy conservation' was mostly discussed during the second (n = 99) and sixth (n = 112) period. From Figure 4.27 it can be seen that six different stakeholders discussed energy conservation in residential houses; however, only political parties have the highest frequency, specifically, between second (n = 99) and sixth period (n = 95). The lowest discussion on energy conservation is during the first and fourth period (n = 1 for both periods).

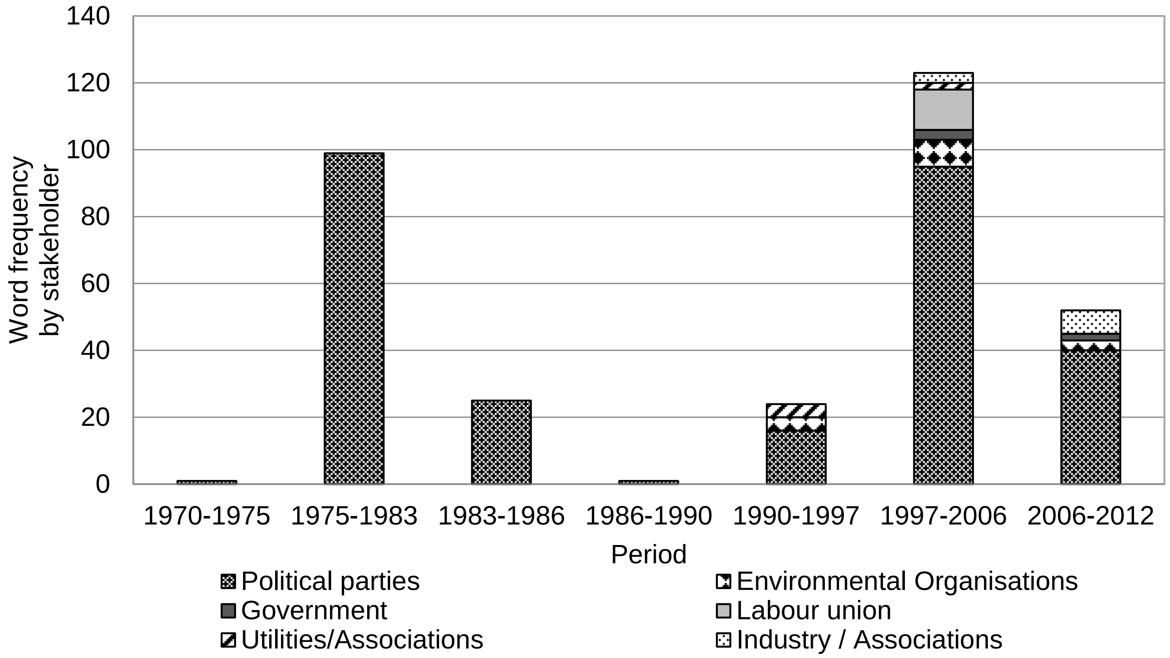


Figure 4.27: Word frequency of 'energy conservation' by stakeholder.

4.3.8 Programs

To determine whether any residential energy programs, incentives and standards were discussed during the debates, Legislative documents were also analysed for these words. The word 'programs' appeared frequently and was fairly discussed by six stakeholders (Figure 4.28). No programs were discussed during the first and fourth period. The most frequent occurrence of programs is between 1975 and 1983 (n = 227). Besides the political parties, utilities/associations and the government appear to have high frequency of discussions on various 'programs' especially, between 1990 and 1997 (n = 116), when the building code underwent a lot of changes. Several programs with respect to residential houses listed in Appendix 4, Table 4.4 were part of the legislative agenda. Particularly, these programs can be grouped into three categories: insulation, conservation, and retrofit programs. The most common examples of most frequent programs include the ecoEnergy, EnerGuide for Houses, and the R-2000 (Appendix 4, Table 4.5). The frequency of these programs was found to be the highest during the last three periods (Appendix 4, Table 4.5).

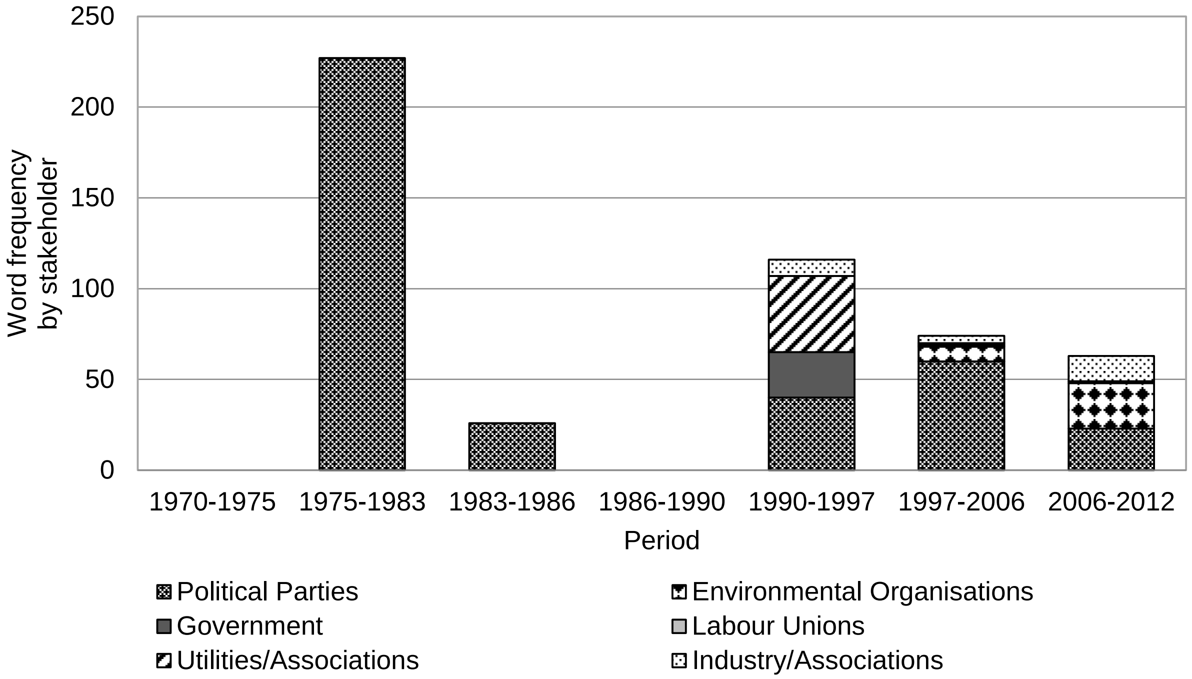


Figure 4.28: Word frequency of ‘programs’ by stakeholder.

Additionally, stakeholders discussed the need for various standards to the building code. Standards were most frequently discussed in the last three periods, with the highest involvement from the political parties and utilities/associations (Figure 4.29). Some of these standards include the uniform across province building standard, insulation standard, energy-efficiency standard, maintenance standard for existing buildings, existing standard technology, gold medallion standard, standard for labeling residential buildings, and the LEED standard.
As well, incentives were discussed the most by the political parties (n = 51) and utilities/associations (n = 8), and the less frequently by the environmental organisations (n = 3) and industry/associations (n = 1) (Figure 4.30).

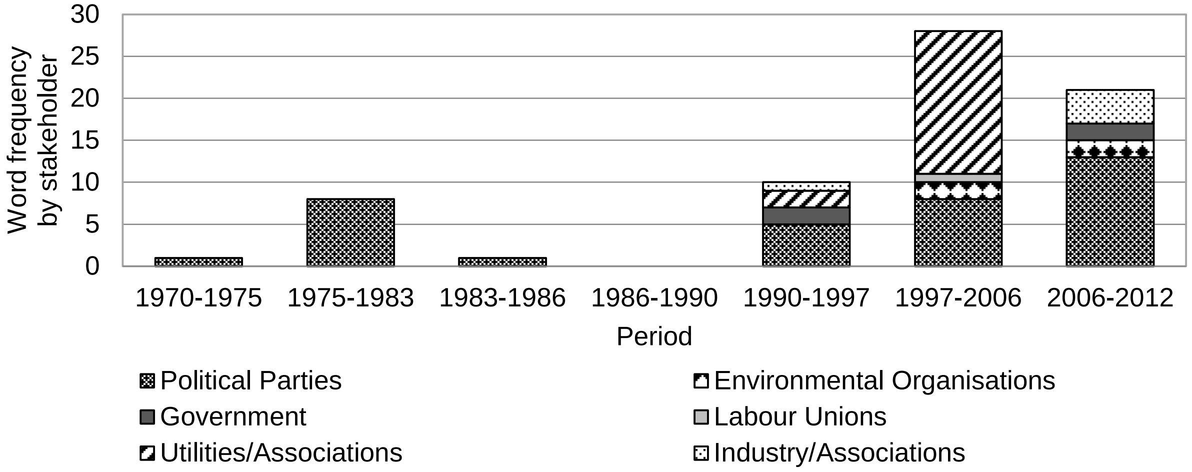


Figure 4.29: Word frequency of ‘standards’ by stakeholder.

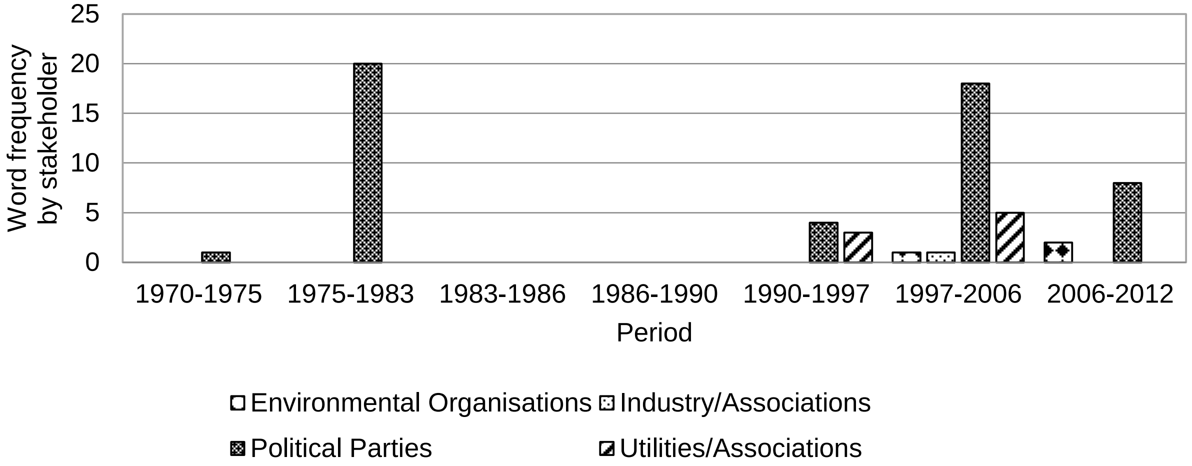


Figure 4.30: Word frequency of ‘incentives’ by stakeholder.

4.3.9 Retrofit

To determine whether any improvements in older houses and buildings were discussed, several phrases which include retrofit were also analysed within the legislative documents. The results show that ‘retrofit’ was not discussed very frequently (Appendix 4, Figure 4.22). Retrofit discussions began after the first building code (n = 13 for the second period). The frequency of retrofit discussions increased after the fifth building code (n = 43 sixth and n = 54 for the seventh period). Between 1990 and 1998, when the code received changes for the insulation requirements, the word ‘retrofit’ appeared only once in 1992 and 1996 and twice in 1994.

The highest frequency is during the sixth and seventh period (n = 46 and n = 53 respectively), predominantly by the political parties (n = 36 and n = 40 respectively) (Figure 4.31). During the last two periods, environmental organisations have the highest frequency on retrofits (n = 12), followed by the government (n = 6), industry/associations (n = 3), utilities/associations (n = 1) and the labour unions (n = 1) (Figure 4.31). Retrofits in houses and buildings were also predominantly discussed by the political parties, especially in the last period (Appendix 4, Table 4.6).

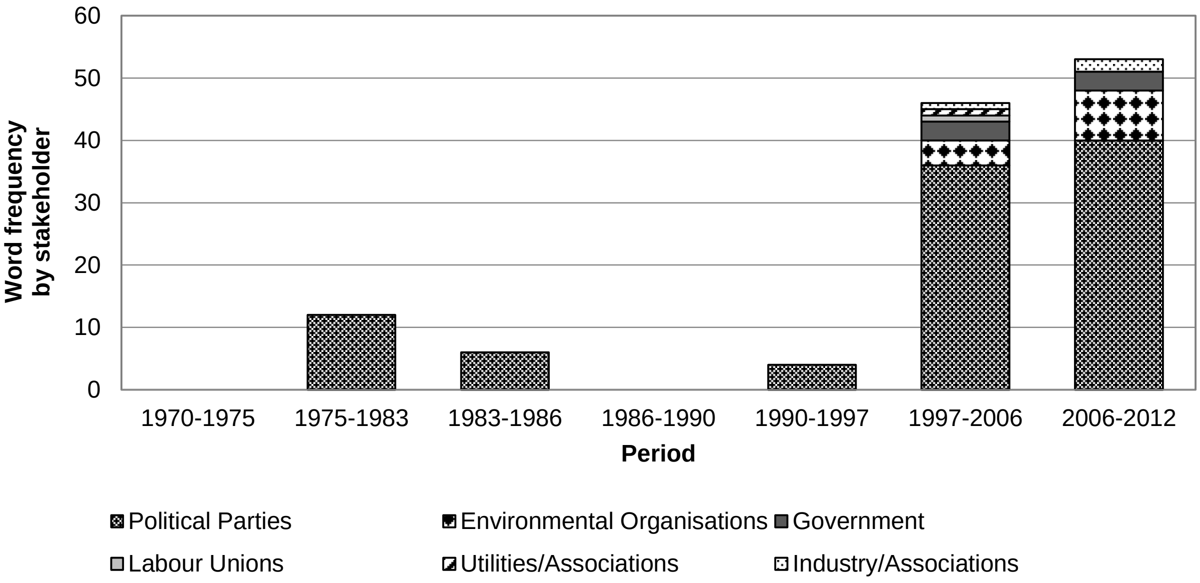


Figure 4.31: Word frequency of 'retrofit' by stakeholder.

Besides retrofits, 'renovation' in houses and buildings also appeared in the legislative debates (Appendix 4, Table 4.6). 'Renovation' was for the first time discussed between 1970 and 1975 (n = 2), before the first code. The highest frequency of 'retrofit' was during the second period (n = 34) (Appendix 4, Table 4.6). However, 'home renovation/upgrades' did not come up as often in the debates (n = 3, for the last two periods).

4.3.10 Potential Drivers for Improved OBCs

Within the legislative discussions on Ontario Building Code and insulation, several topics, such as climate change, emissions, oil embargo, environmental concerns/issues/problems, and global warming were also covered (Figure 4.32). In the documents, 'oil shortage' came up in 1979, 1985, and 1992, whereas 'oil embargo' was discussed in 1985. Between 1990 and 1997 participants discussed ‘climate change’ (n = 12), ‘global warming’ (n = 3), ‘greenhouse gases’ (n = 22) including ‘carbon dioxide’ (n = 21), and environment related issues (n = 16). ‘Climate change’, along with ‘global warming’, ‘greenhouse gases’ and ‘environmental concerns’ were again discussed before the sixth building code. However, during this period, ‘greenhouse gases’ and ‘global warming’ were less frequently discussed (n = 1 and n = 4 respectively). The frequency of ‘climate change’ (n = 20) and ‘greenhouse gases’ (n = 24) increased before the seventh building code. Appendix 4, Table 4.6 shows the frequency of discussion by stakeholders. ‘Carbon dioxide’ discussed by the environmental organisations and the political parties; ‘climate change’ and ‘greenhouse gasses’ by political parties; whereas, environmental concerns by the political parties and the utilities/associations.

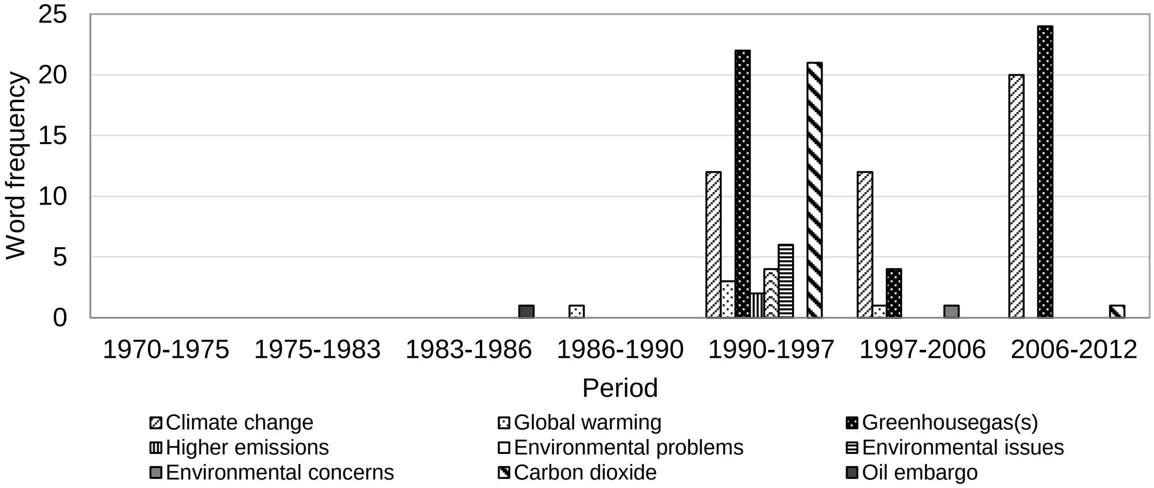


Figure 4.32: Word frequency of potential drivers for improved OBCs by stakeholder.

4.4 Summary of Results

4.4.1 REEP Dataset

- The REEP dataset used for this thesis consists of 6775 houses built between 1815 and 2010.
- Only 0.2% of the evaluated houses meet the European EnerPHit requirements for space energy (≤ 25 kWh/m^{2}a) and 1% meet the ≤ 50 kWh/m^{2}a requirement for space heating.
- To meet the primary energy demand of the PH and NZE standards, on average, REEP houses require 60% and 67% reduction, respectively.

- Moreover, 7 houses (0.1%) meet NZE primary energy demand of ≤ 100 kWh/m^{2}a, and 12 houses (0.2%) meet the PH primary energy demand of ≤ 120 kWh/m^{2}a.
- EGH ≥ 80 houses represent less than one percent (n = 60) of the REEP dataset, and represent the 1940 to 2010 cohort.
- On average, EGH ≥ 80 houses have higher area and footprint, high efficiency furnaces, and lower space energy consumption when compared to the 6775 houses overall. Furthermore, EGH ≥ 80 houses have higher insulation levels than the overall average, but lower than NZE and PH requirements. Additionally, EGH ≥ 80 houses built in 1940s and >1990s have higher heat loss and higher air leaks than EGH ≥ 80 houses built between the 1950s-1980s.
- Compared to the REEP average, EGH ≥ 80 houses have lower space energy consumption per square meter (36 kWh/m^{2}a versus 81 kWh/m^{2}a), lower than the PH requirement. The average primary energy demand of EGH ≥ 80 houses is 51,316 kWh/a or 272 kWh/m^{2}a.
- To meet the primary energy demand of the PH and NZE standards, on average, EGH ≥ 80 houses require 34% and 45% reduction, respectively.
- To meet the PH standard, REEP houses are required to have an EGH rating of 88 or better. The REEP dataset has two houses with an EGH rating of 88. Additionally, the average space heating of these two houses is below 20 kWh/m^{2}a, lower than the EnerPHit, PH, and NZE requirements. In addition, both of these houses surpass the primary energy demand for PH and NZE.
- The insulation levels are also below the PH and NZE requirements. To meet the PH standard, the EGH 88 houses require three times more insulation within the building envelope than their current levels.
- To meet NZE standard, houses have to have an EGH rating of 100. In the REEP dataset no houses have an initial EGH 100. Additionally, EGH ≥ 80 houses have below NZE insulation requirements. To meet NZE standard, houses require three times more insulation within the building envelope than their current levels. Also, two EGH 88 houses of the REEP dataset meet the ≤ 100 kWh/m^{2}a primary energy demand.
- Total annual CO_2 emissions of 6775 REEP houses are 68,573 tCO_2. If REEP houses continue to use the same energy sources in their house, but reduce their primary energy

demand to the PH and NZE standard, they could achieve 68% (46,503 tCO_2/a) and 100% (68,573 tCO_2) reduction in annual CO_2 emissions. EGH ≥ 80 houses require 37% reduction to cut their emissions to the PH standard and 100% reduction to meet the NZE standard.

4.4.2 Changes of the Ontario Building Code and Legislative Discussions

- Ontario Legislative Assembly documents were used to determine the frequency of stakeholder participation and nine word categories. The results revealed that political parties were most frequently involved in discussions about the OBC, energy efficiency and conservation, retrofits, and insulation. Political parties were also the only participants in the legislative documents for the first four periods. After the fourth period, there are participants from other stakeholder groups. Representatives from environmental organisations, the government, and the industry/associations appear in the last three periods (1990 to 2012).
- Furthermore, the frequency of the nine word categories was also studied. The building code was discussed during the first two and last three periods, whereas conservation, energy, and insulation were discussed during all. Efficiency, retrofits, and programs were not discussed until the second period. All word categories appeared in the second and last three periods.
- The first Canadian National Building Code came into effect in 1941, used by provinces and territories across the country. However, due to significant climatic and regional differences, several provinces created their own building codes. As of 2014, seven Ontario Building Codes have been produced.
- The first OBC did not promote sustainability or efficiency in houses. The insulation requirements for residential houses, dictated by Ontario Hydro and political parties, were quite low and had no options for different house types. Participants in the legislative disucssions argued that home builders were not required to install adequate insulation.
- However, insulation requirements have also been improved over time. For example, the second code, based primarily on the 1980 NBC, recognized the climatic differences within the province. During the 1980s, most discussions were about code improvements, energy conservation and energy efficiency enforcements, and higher levels of retrofit

requirements for existing houses. Several programs were created to assist homeowners with retrofits. However, the government at the time was criticised for wanting to discard the insulation program and for investing money in nuclear facilities. Additionally, in 1979, the sales tax exemption for insulating materials, created to reduce in energy consumption in existing and new buildings, was eliminated.

- Discussions about insulation requirements, energy efficiency and conservation, continued to be present in the 1990s. Rising housing costs also became part of the legislative discussion. Additionally, the industry argued that the changes to the 1990 code added $2,500 to the price of the house, and that the basement insulation changes alone contributed an additional $3,000 on an average home. Although the 1993 code increased the basement insulation requirement, in 1997, after twenty years of a steady progress, the government decided to lower the insulation requirements to the 1970s level. This change of course, favoured the building industry. Unfortunately, the lower building costs and the housing costs did not translate into lower-prices for new houses. Consequently, increased prices of houses and reduced insulation requirements affected the homeowners.
- Since 1998, the OBC has undergone major changes. The 2006 building code, for instance, promoted green technologies and energy conservation. The 2006 code required an EGH rating of 80 or higher for new houses. The insulation requirements were higher than the 1997 code; however, the R-values for the two zones were not very different.
- The main focus of the 2012 building code is resource conservation and environmental integrity. As part of the code, residential houses must achieve an EGH rating of 80 or more. Houses built in 2017 are expected to consume 50% less energy than houses built before 2006. The code also provides builders with prescriptive and performance-based requirements. The performance option, which uses simulation software, is based on annual energy use of the building, which depends on zone location, energy source, and equipment efficiency. The insulation requirements for the building envelope surpass the requirements of previous codes.

Chapter 5
Discussions

5.0 Discussions

5.1 Potential Emission and Energy Reduction of Existing Houses in Ontario

A set of 6775 southwestern Ontario residential energy profiles from HOT 2000 software was analysed to determine the initial energy characteristics and the potential of achieving reduction in CO_2 emissions and energy consumption when brought to the PH and NZE standards. The results showed that an average house from the REEP dataset has an area of 217m^2, total energy of 47,218 kWh/a (233 kWh/m^{2}a), and average annual CO_2 emissions of 9,522 kg. About 65% of the energy or 30,913 kWh/a (149 kWh/m^{2}a) is used as space energy. With respect to primary energy demand, only 0.2% (n = 12) and 0.1% (n = 7) of houses meet the PH and NZE primary energy demand requirements. To meet the primary energy demand of the PH and NZE standards, on average, REEP houses require a 60% and a 67% reduction, respectively. About 1% of the houses meet the PH space energy requirements of $\leq$ 50 kWh/m^{2}a, and only 0.2% of the houses meet the $\leq$ 25 kWh/m^{2}a European EnerPHit requirement. Total annual CO_2 emissions of 6775 REEP houses are 68,573 tCO_2. If REEP houses continue to use the same energy sources, but reduce their primary energy demand to meet the PH and NZE standards, they could achieve 68% (46,503 tCO_2/a) and 100% (68,573 tCO_2) reduction in annual CO_2 emissions.

Houses with an initial EGH rating of $\geq$ 80 were analysed because they are close to meeting a higher standards (EGH 80 = R-2000, EGH86 = NG R-2000, EGH88 = PH, and EGH100 = NZE). The REEP dataset has less than 1% (n = 60) of houses with an initial EGH rating of $\geq$ 80. The average total energy consumption is 23,820 kWh/a, and the associated emissions are 5,514 kgCO_2/a. The average primary energy demand of EGH $\geq$ 80 houses is 51,316 kWh/a or 272 kWh/m^{2}a. To meet the primary energy demand of the PH and NZE standards, on average, EGH $\geq$ 80 houses require a 34% and a 45% reduction, respectively. In addition, EGH $\geq$ 80 houses require 37% reduction to cut their emissions to the PH standard and a 100% reduction to meet the NZE standard.

Furthermore, for EGH ≥ 80 houses to meet the PH and NZE standards, EGH ≥ 80 houses are required to increase their insulation up to three times in the attic and the main walls. Houses with a rating between EGH 80 and EGH 81 require much higher foundation insulation levels.
In the EGH ≥ 80 sample, 3 houses (5%) meet PH primary energy demand of ≤ 120 kWh/m^2a, and 2 houses (3%) meet the NZE primary energy demand of ≤ 100 kWh/m^2a.
Although an EGH 88 is equivalent to the PH standard, REEP houses with an initial rating of EGH 88 do not meet the PH requirements unless their building envelope is tight with no thermal bridges, high insulation levels, minimal heat loss, and minimal air leaks.

Although 7 houses (0.1%) in the REEP dataset meet the ≤ 100 kWh/m^2a primary annual energy demand, no houses matches the NZE definition established in this thesis (an energy efficient building that produces renewable energy on site to supply itself, stores excess energy for night-time, has 0 kgCO_2/m^2a emissions, and has a total primary energy consumption of <100kWh/m^2a). To reach NZE, EGH ≥ 80 houses are required to have zero annual emissions, which can be achieved through use of renewable energy sources. Additionally, houses need tighter building envelopes, which can be achieved with higher insulation levels. Given the high installation and maintenance costs of renewable sources, the R-2000 and the PH standards can be seen as a stepping stone to achieving a NZE. Although any of these standards can be achieved, financial assistance is still required. However, other factors such as higher building code requirements are also required for new and existing houses. The following section discusses several barriers to improved OBC that have been identified in the literature and in this thesis.

5.2 Drivers and Barriers to Achieving Higher Building Standards

As part of this study, drivers and barriers to achieving higher building standards were examined. The literature and the findings of this study showed that environmental issues, resource limitations, and implications of climate change, are the key drivers for achieving higher building standards. However, Willand et al. (2012) have also shown that external, internal, and enabling factors can be drivers and barriers to achieving higher building standards and deep retrofits. For instance, the inelastic rising energy prices, location of the house, the community’s awareness and knowledge of the implications of climate change, resource depletion, and environmental issues, can have a significant impact on decisions about achieving greater energy and emission reductions. On the other hand, the literature and this research study have discovered many barriers to achieving higher building standards. Nevertheless, the findings of this study found that only some of the barriers identified in the literature are present in Ontario as expressed in the legislative debates recorded in the legislative documents. The reported barriers are economic and financial, political and structural, informational, promotional, and educational. However, from the reviewed literature, barriers due to hidden costs and benefits, market failures, behavioural and organisational barriers are evident as well. Perhaps, the reason for identifying fewer barriers could be the use of political material, such as the legislative documents and the Ontario Building Codes.

The findings of this research showed that the identified barriers are related to the involvement of the particular stakeholder groups. For example, Ontario Legislative Assembly documents and the literature revealed that changes to the building code and energy conservation programs, between 1970 and 1990, were heavily impacted by the arguments of the political parties, the building industry, and the utility companies (NDP10, 1983; LP3, 1976; LP12, 1992; PC6, 1974; PC3, 1983). After the 1990s, changes to the building code and programs involved the arguments of other stakeholder groups due to the use of Standing Committee Transcripts after 1992.

An example of the impact of utility companies on the building industry and energy consumption was evident during the first wave of sustainable architecture (1960-1975), a period of environmental issues and oil crisis. In Ontario, at this, Ontario Hydro's "*Live Better Electrically"* campaign. The "extravagant but harmless promotional campaign", as McKay (1983) calls it, which promoted convenience and conspicuous consumption, changed the lifestyle of many. Increases in electricity consumption encouraged by the Ontario Hydro and the utility companies, resulted in the creation of nuclear plants. Unable to sell the excess energy, Ontario Hydro built more than 25,000 Gold Medallion Homes, which were designed to use five times more electricity a year than conventional houses. However, the natural resource limitations in the 1970s led to an increase in resource prices. The oil crisis of 1973 changed how buildings were being built. Hence, the "*Live Better Electrically"* campaign disappeared, and Ontario Hydro began to advertise conservation campaigns. The once popular Gold Medallion Homes became difficult to sell.

Having recognized the regional and climatic differences throughout the country, in 1975, Ontario introduced its first building code. Although the first code marks a very significant part of the Ontario building history, the code did not have a strong focus on energy conservation during a very critical period of resource limitations and high oil prices. Therefore, between 1975 and 1983, the Ontario Legislative Assembly documents focused on improving the 1975 building code, enforcing energy conservation, and requiring higher insulation levels. However, LP8 (1980) pointed out that insufficient progress was being made to improve the insulation levels due to the decreasing wall thickness, allowing for little insulation. Additionally, during this period, the first super-insulated house was built in Saskatchewan, which along with other examples worldwide, was used in the creation of the passivhaus standard.

During the second wave (1976-1987), two other building codes were developed. For example, a draft residential renovation code for the 1983 code was put together by the government, the building industry, municipal organisations, professional associations, and research and standard agencies (PC3, 1983), and the 1983 code, according to NDP10 (1983), was mainly industry-developed. Additionally, the insulation levels in residential homes were influenced by the Ontario Hydro and the political parties (LP3, 1976). During the second wave, stakeholders, such as the industry, utility companies, and the political parties were more persuasive than other stakeholder groups; however, this was yet to change. Nevertheless, neither of these codes includes detailed guidelines on challenges and solutions for renovation of existing houses (NDP10, 1983).

The third wave towards environmental architecture (1987-present) called for a greater awareness and action to halt the looming crisis of climate change (Knight, 2009). Since the Brundtland Commission report in 1987, many building standards, such as the R-2000, PH, NZE and LEED, and programs have been developed to promote sustainability. However, between 1990 and 1998, the OBC received a lot of changes by the provincial government, some of which, unfortunately, required to lower the insulation requirements due to ‘the rising building costs’ (The Ontario Gazette, 1998). This decision benefited the building industry, but hindered the homeowners. During the legislative debates, it was concluded that the insulation reduction did not result in lower house prices. As in the previous code, the new code did not require existing houses to meet the OBC (LP12, 1992). As Lovins (1992) points out, despite the large costs of inefficient designs for buildings, buildings are often not built to use energy efficiently. According to Lovins (1992), it is the building industry (e.g., real-estate developers) and the investors that make the ultimate decision on the type of buildings we have built, and they prefer buildings to be as cheap as possible, hence the investment on energy efficient equipment is low (Ürge-Vorsatz et al., 2007).

During the second (1975–1987) and third waves (1987–present), the Canadian Government created several programs to financially assist homeowners with energy efficiency improvements. However, results from the Ontario Legislative Assembly documents show that political parties and the utilities are involved in the creation and cancellation of financial incentive programs. For example, programs, such as the CHIP, the National Energy Program, the EnerGuide, and the ecoEnergy, initially introduced by one federal government, were cancelled with the arrival of a new federal government. Ironically, during 1981, the Conservative government ran the *"Life is Good, Ontario; Preserve it, Conserve it"* campaign (LP9, 1982; NDP9, 1982; NDP11, 1983). To take initiative in house retrofits, appropriate financial incentives are required (NDP19, 2006).

According to PC9 (1977), the famous CHIP program gave out insufficient grants to homeowners, and 7% of the federal grant toward insulation was taken by the provincial government (LP10, 1982; LP9, 1982; NDP9, 1982). Additionally, the Ontario Home Insulation Program, which targeted houses built prior to 1921, was not of great assistance to all Ontario residents. First, the grants for insulation were insufficient ($350), and second, northern Ontario does not have many houses built before 1921. Furthermore, the structure of these programs was created, such that, in order to receive any financial incentive, retrofits needed to be performed first. The literature shows that when homeowners are distanced from financial incentives, homeowner's motivation for action declines (Bird, 2006). As well, prior to the 2006 OBC, NDP19 (2004) pointed out the lack of incentives for houses re-insulation and upgrade of energy-efficient appliances. As estimated by the Pembina Institute, a serious conservation program would cost about $18 billion, but, a $32 billion nuclear power program was favoured (NDP19, 2004). Even though the OBC has improved over time, and several conservation programs have been created to assist homeowners, a large portion of houses across Ontario have been poorly insulated, resulting in high energy consumption. Many of these houses are also electrically heated, homeowners are not required to upgrade their dated appliances or to even upgrade the houses, and hence, tenants are subjects to high energy bills (NDP20, 2005).

Moreover, the government removed sales tax on energy saving products, including insulation, to initiate conservation. However, the sales tax exemption was soon removed by the government (PC10, 1979; PC14, 1981). On the other hand, literature shows that homeowners' purchasing decision making is not heavily impacted by tax credits, because of their low value (Pitts & Wittenbach, 1981). Additionally, the $5 million home insulation program in Ontario was discarded and $4-$5 billion was spent on Darlington nuclear facility instead (LP7, 1977; LP7, 1978; NDP2, 1977). The proposed one billion dollar program to provide homeowners with low-interest loans for house insulation was also not created (LP3, 1979; NDP2, 1979).

Financial programs have also been created by the utility companies. For example, Ontario Hydro has given out grants for electric furnaces and other electric equipment to homeowners (LP6, 2001; McKay, 1983; PC13, 1981). While the utility companies have produced grants for consumers to upgrade their electric appliances, the NDP government has switched the electric heating to natural gas in several public housing buildings (LP17, 2003). NDP government also offered free audits to homeowners. Unfortunately, with the arrival of the Conservative government, in 1995, the program initiated by the NDP was terminated, and the free audits no longer existed (LP17, 2003). With the arrival of the Liberal government in 2003, the government decided to take the NDP approach. This time, Hydro One, NRCan, and CMHC teamed up to provide financial incentives for energy-efficiency projects. As part of this initiative, homeowners were given incentives to heat their houses with electricity (LP19, 2005).

From the Ontario Legislative Assembly documents and the literature, we have also seen that those involved in the discussions on higher building standards have different priorities and agendas. Additionally, those who perform energy efficient retrofits are not necessarily driven by the negative outcomes of climate change or environmental issues (Hoicka, 2012; Hubert, 2011). Studies have also shown that in Canada, there is still lack awareness and knowledge of the importance of higher building standards that can mitigate the negative outcomes of climate change (Willand et al., 2012). Despite the available programs to assist homeowners in house retrofits, Ontario still does not have enough skilled labour to perform detailed deep retrofits (Parekh, 2012b).

Chapter 6

Conclusions

6.0 Conclusions

The purpose of this research is to study the potential reductions in CO_2 emissions from retrofitted homes if Waterloo Region adopts the Passivhaus and Net Zero Energy standards. This study also reviews the drivers and barriers that influence the setting of a new building envelope standards, such as the PH or NZE.

This study identified three main categories of drivers: awareness of environmental issues, resource limitation, and the implications of climate change; and three categories of barriers: financial, political and structural, and barriers related to information, promotion, and education.

The findings of this study confirm that existing houses in REEP dataset can achieve 68% (46,503 tCO_2/a) and 100% (68,573 tCO_2/a) reduction in annual CO_2 emissions by meeting the PH and NZE standard, respectively. To meet the primary energy demand of the PH and NZE standards, REEP houses require 60% and 67% reduction, respectively. If all REEP houses met both standards, their total final primary energy demand will be 176,324,904 kWh/a (PH) and 146,937,420 kWh/a (NZE) (61% and 68% reduction, respectively). Even though several international and national studies have proven that existing houses are able to meet the PH and NZE, several barriers were identified.

To get to PH (EGH 88) and NZE (EGH 100), Region of Waterloo houses first need to be able to meet the R-2000 standard. The building code has certainly played an important role in the development of Ontario houses, and with the new building code, achieving these standards is more feasible because builders and their trades are gaining experience with higher performance construction techniques. However, the current building code does not require existing houses to meet the R-2000, but, certain requirements for existing houses are expected to come in force in 2017. This is of a great concern, because it is still unclear what kind of requirements will come in force in 2017 and whether it will be mandatory for existing houses to meet higher building standard (OHBA, 2013).

Furthermore, houses in southwestern Ontario built before 1900 are bigger and less efficient, whereas houses built after the 1975 are more efficient. Although houses built before 1900s are bigger, houses built after 1940s have also increased in size. The insulation levels of houses built before 1900s are fairly low and higher in houses built after 1975. However, houses from the REEP dataset, built between 1975 and 2010 use up to seven times more energy resources and emit far more emissions than the R-2000, the PH, and NZE houses.

The R-2000 standard can be seen as a stepping stone to achieving the PH and NZE standards and the R-2000 requirements are becoming normal practice in new housing construction. Achieving deep retrofits in existing houses to meet the R-2000, the PH, or NZE, in Region of Waterloo is not an easy task. First, studies show that to perform deep retrofits, in colder climates, and in existing houses, with the end goal to meet the PH or requirements, is possible, but technically challenging. Many existing houses are extremely inefficient, not air tight, lack insulation, have high heat losses, and thermal bridges, and, hence, consume a lot of energy and emit a lot of emissions. The PH requirements, in comparison to NZE, are very specific and call for aggressive measures. In several cases, from an economic and technical point of view, it might be unrealistic to make further changes to be building envelope to get the PH certification.

Furthermore, it has been suggested that homeowners require financial assistance to perform these retrofits. Although the federal and provincial governments have created programs and provided homeowners with financial assistance to perform retrofits, according to the legislative debates, neither of these programs have given sufficient funding or guidance to make the deep energy and emission reductions associated with PH or NZE. Secondly, the legislative documents also show that different stakeholders have different priorities and agendas. Whenever programs and financial incentives were given out to homeowners by one government, they have often been immediately dismantled after the arrival of a new government. Additionally, the provincial building code has played an important role in the building industry of Ontario. For instance, the very first building code was developed during a very critical time in terms of energy conservation. However, the insulation requirements of this code were very low and home builders were not required to install adequate insulation.

It is also evident that the industry and the utility companies have played an important role shaping the building code. For example, during the legislative debates, stakeholders argued the insulation changes in the 1990 and 1997 building code. The building industry argued that the changes to the 1990 code and the basement insulation requirements added up to $2500 and $3000 to the price of the house, respectively. However, with the removal of the basement insulation from the 1997 building code, the price of the houses did not decrease.

Moreover, since 2006 we have seen a lot of improvements in the building code. Although the insulation requirements were not as high in the 2012code, progress has been made. The focus of the legislative debates has been on energy conservation and further improvement of the code. In addition, the 2012 code has received input from diverse stakeholder groups and has much higher requirements than any of the codes before. However, currently, the 2012 code does not have any requirements for existing buildings.

The findings of this study confirm that existing houses in Waterloo Region can achieve substantial reductions in CO_2 emissions and energy usage by meeting higher building standards. Emissions and energy use could be reduced greatly if mandatory requirements for existing houses were included in the current code.

6.1 Contribution of the Study

Although this study has many limitations, its findings contribute to understanding the importance of energy savings, emission reductions, and barriers and drivers to achieving ambitious targets. This study is a primer for further research of the Passivhaus and Net Zero Energy standards in colder climates. As well, this study reviews 40 years of legislative debates to understand the barriers to achieving higher building standards. This study also raises awareness about the importance of the standards used as one of the many climate change mitigation strategies. In addition, the findings of this study confirm the positions of stakeholders involved in the development of the building code.

6.2 Study Limitations

This study has several limitations. The first section of this research looked at the potential of achieving higher building standard in Ontario’s houses. The dataset used for this research consisted of 6775 houses, equivalent to 4% of the eligible Region of Waterloo’s housing stock (REEP, 2012). The REEP dataset sample used for this research is fairly small and cannot be used to represent the houses in Region of Waterloo. In addition, some of the initial values of these houses might not be representative of the norm of the houses in Waterloo Region. This includes the already improved furnaces, evident from their high efficiency, and even though some of the houses have low initial insulation value, they could have already had the insulation levels improved. REEP dataset does not include a breakdown of the energy consumption (e.g., behavioural patterns, appliances consumption, and furnace consumption).

To calculate the revise energy, space energy reduction, and emissions reduction for the PH and NZE standards was challenging, because of their different requirements. NZE standard in particular, does not have a specific requirement for space energy as the PH does. In addition, this study used the conversion factors for the Eastern U.S. region. Although Ontario purchases electricity from the U.S., it would have been ideal to get emission factors from Ontario as well. Furthermore, marginal emission factors of each energy source (i.e., in southwestern Ontario) would have been better to use, as opposed to the average emission factors of Ontario.

This study has only looked at the Ontario Legislative Assembly documents to understand the barriers to achieving higher building standards. However, including other literature, such as environmental reports and newspaper articles would have perhaps yielded richer results. Additionally, this study did not look at how policies and decision making is made on a federal and provincial level. Furthermore, the literature identified several drivers and barriers to achieve higher building standards that were not identified in this study. For instance, behavioural and organisational barriers were identified in the literature, but not in the study.

Furthermore, this thesis included only the 1992-2012 Standing Committee Transcripts, and therefore, the findings showed political parties to be the only participatory stakeholders until 1990. Future study should include the 1970-1992 Standing Committee Transcripts as well.

6.3 Future Research

The limitation of this study can be addressed in future research. For example, the use of PHPP or HOT2000 software can be used to determine the exact changes that need to be made to achieve the PH and NZE standards. Although the literature includes the cost of already achieved and potential retrofit, future study can look at the average retrofit costs for houses of different vintage categories. There is also potential for designing more efficient programs that can better assist homeowners with retrofits and to increase their participation in deep retrofits. Future studies can also focus on how to effectively promote deep energy reductions in Ontario and in Canada, as well as internationally. In addition, another study can compare retrofitted REEP houses to the PH and NZE standards.

Chapter 7
Recommendations

7.0 Recommendations

Achieving higher building code standards, and thereby, reducing GHG emissions and energy usage in existing houses is not an easy task. For this process to be successful, a collaborative management from various stakeholders is required. The findings of this research show three categories of barriers: financial, political and structural, and barriers related to information, promotion, and education. Therefore, this thesis proposes several strategies to the identified barriers to implementing advanced standards, such as the Passivhaus and Net Zero Energy.

7.1 Strategies to Address Financial Barriers

The amount of financial capital necessary for deep retrofit in existing houses in the Region of Waterloo is large. To meet these deep energy and emission reductions, homeowners will require assistance. Governments worldwide have always been expected to be the most critical players in providing financial assistance. However, financial assistance can also be created on municipal level through development of carbon credit funds, low-interest bank loans, and efficiency programs. For carbon credit pools to operate, carbon credits must be purchased to offset generated emissions from fuels used (e.g., from personal vehicles, heating homes, etc.). The funding of these carbon credit pools can be created at a municipal level and used by residents to retrofit their homes. However, the size of these credits should be sufficient enough to be seen as significant.

In addition, a study conducted by Neme et al. (2011) suggests that “reduction in the initial cost and the ability to finance repayment at attractive terms” (p. 22) will be necessary to achieve deep reductions and increase in participation. Nemet et al. (2011) add that both public and private partnership is needed to fund deep retrofits to reach aggressive measures. For example, in Great Britain, “homeowners have typically been willing to invest 30% of standard insulation costs, and the other 70% was paid for by the obligated energy supplier” (Neme et al., 2011, p. 22-23). In Germany, successful financial programs have been developed by the Kreditanstalt für

Wiederaufbau (KfW) bank to assist in home retrofits (ADEME, 2008). The KfW bank is one of the largest European financing bodies which give favourable loans, whereas the Federation of German Consumer Organisations gives sufficient advice to homeowners. About 80% of these loans are owned by the German government, whereas the remaining 20% are owned by the federal states (ADEME, 2008). The CO_2 Building Rehabilitation Programme of the Federal Promotional Bank (KfW Förderbank) provides clients with a loan of up to 50,000 Euros per housing unit with very low interest rates (BMVBS, 2006). A repayment bonus of 12.5% of the total amount of the loan is also given for renovations “of 30% below the level for new property” (BMVBS, 2006). Homeowners who do not require loans are allowed to get an investment grant. The CO_2 Building Rehabilitation Programme is also part of the initiative “Housing, Environment, and Growth” launched in 2006 by the German government and the KfW Förderbank (BMVBS, 2006). The KfW Förderbank has provided over 170, 000 loans equivalent to 9 billion Euros and around 41,000 of loans provided (EU 3.3. billion) was for the CO_2 Building Rehabilitation Programme (BMVBS, 2006).

Furthermore, making the transition from fossil fuel based heating sources to non-fossil fuels can be expensive. To reduce energy consumption and associated emissions, as well as energy related costs, the Region of Waterloo can develop a heating and cooling district plant. The City of Copenhagen, is a very successful example, meeting 98% of its energy demand by district heating (Copenhagen Energy, 2005). Since connection to district heating has been made mandatory, the costs to consumers have been reduced. In addition, energy produced from renewable sources (e.g., biomass) is subsidised, whereas energy produced from fossil fuels is heavily taxed (Copenhagen Energy, 2005).

7.2 Strategies to Address Political and Structural Barriers

This research has shown that a top-down approach alone has not necessarily been the most effective in achieving retrofits in existing houses in Ontario. The top down approach on its own can never succeed even in leading countries like Denmark, Germany, or Sweden especially in the absence of community interest and drive. The Region of Waterloo has been very progressive in policy making. Over the past two decades and especially in the past decade there has been an increasing community involvement through local organisations and co-op initiatives, such as the

REEP Green Solutions, the Sustainable Waterloo Region (SWR), the Community Renewable Energy Waterloo, and the Local Initiative for Future Energy. An example of successful programs to reduce GHG emissions are the Regional Carbon Initiative initiated by the SWR, and the ClimateActionWR initiated by the Region of Waterloo, REEP, and SWR. Given the strong local initiative, the Region of Waterloo has the potential to further progress by following the successful Hyllie retrofitting project in the Swedish city, Malmö. The Hyllie project according to Baeten (2011) is ‘normalisation’ or ‘institutionalisation’ of urban neoliberalism,

> “a thinking and practice to effectively remove government interference, or at least to create an atmosphere where planning restrictions are considered to generate ‘suboptimal’ conditions for ‘free’ agents in the business of city building” (p. 24).

Baeten (2011) adds that neoliberalism is “also a philosophy expressed in certain *attitudes* towards society, the individual, employment and, indeed, the city” (p. 24). The core drivers of the project were the response to current climate, quality of life, as well as the aesthetics of the place (Kazmierczak & Carter, 2011). The rehabilitation project was mainly funded by the housing company Malmö Kommunala Bostadsbolag and the City of Malmö, as well as from other investors, such as the Swedish government, the Swedish Department of the Environment, and the European Union Programmes LIFE and URBAN (Kazmierczak & Carter, 2011). Malmö has shown to be a good example of “leadership, external collaboration, public engagement, and cohesive delivery of multiple benefits” (Kazmierczak & Carter, 2011, p. 1) at a neighbourhood level. As part of this project, the public was continuously engaged through “regular meetings, community workshops, and informal gatherings at sports and cultural events” (Kazmierczak & Carter, 2011, p. 6). Authorities of this project had also come to realise that success of the project lied in directly engaging the local people and empowering their decisions in the projects.

7.3 Strategies to Address Informational, Promotional, and Educational Barriers

The literature and this thesis have also identified barriers related to information, promotion, and education regarding energy efficient retrofits. For example, homeowners might be unaware about the inefficiency of their homes and the associated financial costs, the available funding for retrofits, or finding qualified contractors to perform the retrofits. In the Region of Waterloo we already have successful organisations, e.g., REEP, SWR, the City of Kitchener and the City of Waterloo, with skilled personnel that hold informational workshops, lecture series, and town meetings for the general public. At these events, local organisations along with experts from utility companies and the industry, provide locals with informational tools on the importance of retrofits, available financial assistance, and skilled advisors and contractors. Presence of different stakeholder groups is necessary for delivery of objective information. Although there are several established bodies, in the Region of Waterloo there is still a great need for highly engaged and continuous central trusted reference bodies to assist homeowners with information on energy conservation and retrofits.

Appendices

Appendix 1: Introduction

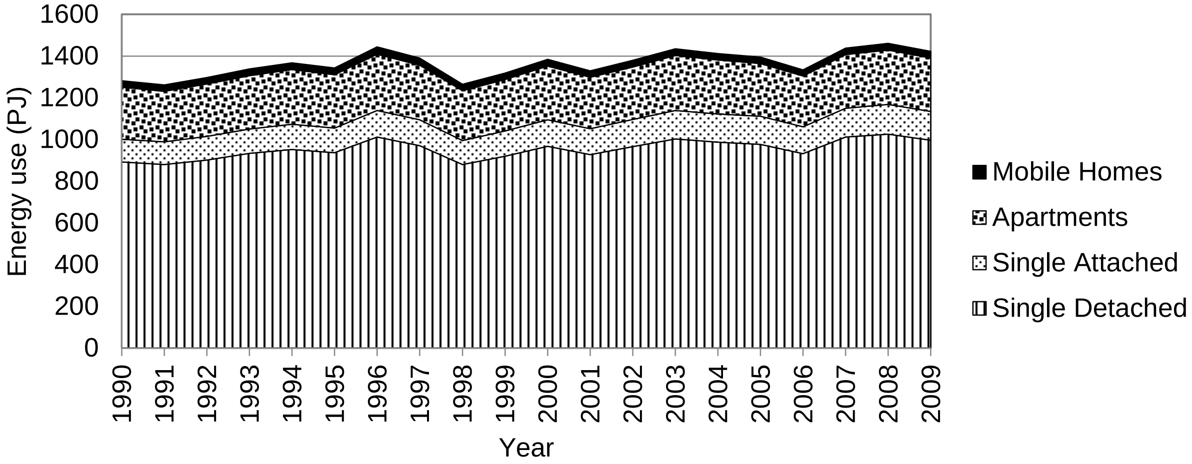


Figure 1.1: Energy use by building type in Canada (PJ). Source: NRCan, 2011a.

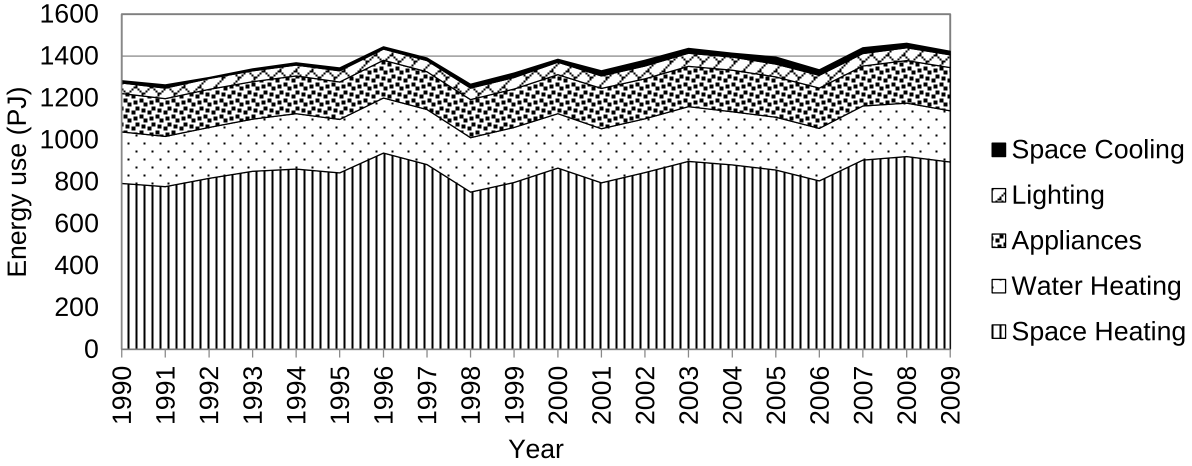


Figure 1.2: Energy use by end-use in Canada (PJ). Source: NRCan, 2011a.

Appendix 2: Literature Review

Table 2.1: Characteristics of Canadian houses

Period	Pre-World War II	Post-War 1½-Storey	Post-1960s Two-Storey	1960s-70s One-Storey
Size		>1,000 000 one and a half storey houses built from 1945-1960	>750,000 two-storey houses built across Canada since the 1970s	>550,000 one-storey houses (bungalows or ranchers)
General description	• Larger 2 or 3-storey houses • Basement used for coal or wood storage, not a living space • Probably has additions or earlier renovations to the original structure (closed-in porch, “summer kitchen”)	• Unfinished basement • Bedrooms within the roof space • Living area on main floor	• Two-storeys • Possibly an attached garage, maybe a “bonus” room over garage • Full basement, ranging from unfinished to finished	• One floor of living space • Uninsulated basement • Possibly finished w/recreation room and utility area
Area	75 m^2 - 360 m^2	< 110 m^2	~ 200 m^2 including basement but can be 400 m^2 or larger	< 110 m^2 including basement
Exterior walls	2 x 4 in. stud walls with R-8 batt insulation; also, solid wood, solid stone masonry and solid brick masonry in some regions, possibly uninsulated in all regions	Newer houses: 2 x 4 in. stud walls with up to R-12 batt insulation Older houses: could be uninsulated	Older houses: 2 x 4 in. stud walls with R-12 batt insulation Newer houses: 2 x 6 in. with walls, R-20 batt insulation; Northern Canada: R-28	2 x 4 in. stud walls with R-12 batt insulation
Ceiling	Coastal B.C. and Atlantic: R-15 Prairies: R-20 Rest: possibly uninsulated	Coastal B.C.: R-12 Quebec and NT: R-24 sloped ceiling areas usually same insulation value as walls	Coastal B.C.: R-28 Prairies and NT: R-40	Atlantic Region: R-19 Prairies and NT: R-23
Foundation	concrete, stone rubble or brick, often without footings, dampproofing or insulation	uninsulated poured concrete or concrete block	concrete, partially insulated, typically to 600 mm below grade; fully insulated, pressuretreated wood in the north	uninsulated poured concrete or concrete block, some insulated at the top 600 mm below grade; uninsulated crawspace with a dug-out portion just big enough to put the furnace
Windows	single-glazed with storms (except for coastal B.C.)	double-glazed or single-glazed with storms (except for coastal B.C.)	double (triple in North) glazed, or single-glazed with storms	double-glazed or single-glazed with storms (except for coastal B.C.)
Doors	solid wood panels	hollow or solid wood panels	typically insulated metal doors	hollow core wood panels
Air leaks	1,500 cm^2	1,130 cm^2	980 cm^2	820 cm^2

Source: CMHC, 2004a-2004d.

Table 2.2: Energy profiles of houses by decade in the Waterloo Region

Period	House type	Size m^2	EGH Rating	Energy consumption MJ	Estimated leakage area cm^2	Typical energy problems	Typical energy solutions
1800	single detached	258	47	302,880	2,586	• large air leaks • walls with little or no insulation • poor attic insulation • uninsulated stone foundations • cold rooms due to duct deficiencies • uneven heating of rooms • single pane windows	• air sealing • blow insulation into wall cavity • upgrade ceiling insulation • replace windows and doors • install exhaust fans • upgrade to higher efficiency furnace • install cold air returns on upper levels
1900	single detached	246	47	299,407	2,442	• uninsulated stone foundations • large air leaks • no ventilation fans • older heating systems • uninsulated walls • poor attic insulation • uneven heating of the house • single pane windows	• insulate top of basement walls • blow insulation into wall cavities • replace windows and doors • air sealing • improve attic insulation • install exhaust fans • upgrade to higher efficiency furnace • install cold air returns on upper floors
1910	single detached	217	45	293,832	2,195	• uninsulated walls • uninsulated stone foundation • older, less efficient heating system • large amount of air leakage • no mechanical ventilation • lower levels of attic insulation • single pane windows	• air sealing • fill wall cavity with insulation • upgrade to higher efficiency heating system • replace windows and doors • improve attic insulation • install exhaust fans • insulate top of basement wall
1920	single detached	217	50	267,288	2,067	• large amount of air leakage • uneven heating of rooms • limited insulation in walls • poor attic insulation • poor insulation in stone foundation • older, less efficient heating systems • no mechanical ventilation • single pane windows	• air sealing • blow insulation into wall cavities • upgrade attic insulation • cold air returns in upper rooms • insulate top of basement wall • upgrade to higher efficiency furnace • install fans in bathrooms, kitchen

1930	single detached	204	52	250,283	1,825	• large amount of air leakage • uneven heating of rooms • limited insulation in walls • poor attic insulation • poor insulation in stone foundation • older less efficient heating systems • no mechanical ventilation • single pane windows	• air sealing • blow insulation into wall cavities • upgrade attic insulation • cold air returns in upper rooms • insulate top of basement wall • upgrade to higher efficiency furnace • bathrooms kitchen
1940	single detached	190	60	201,010	1,603	• significant air leakage • uninsulated basements • single-pane windows • older, lower efficiency heating system • no exhaust fans • uneven heating of rooms • inadequate attic insulation	• air sealing • insulate top of basement • upgrade to higher efficiency heating • install exhaust fans in bathrooms and kitchen • install cold air returns in upper level rooms • upgrade attic insulation
1950	single detached	202	65	180,204	1,379	• significant air leakage • uninsulated basements • single-pane windows • older, lower efficiency heating system • no exhaust fans • uneven heating of rooms • inadequate attic insulation	• air sealing • insulate top of basement • upgrade to higher efficiency heating • install exhaust fans in bathrooms and kitchen • install cold air returns in upper level rooms • upgrade attic insulation
1960	single detached	210	66	178,034	1,079	• insufficient insulation, particularly in unheated floor areas (e.g., above garage) • poor insulation in basement • poor insulation in attic • building addition (e.g., sunroom) above crawl space	• improve insulation in walls and attic • insulate top of basement • provide better insulation in additions • air sealing, especially around additions

1960	row house	127	72	120,084	971	• poor air quality • windows poorly installed • clogged air filters • lower efficiency furnace • poor insulation in attic and basement	• properly functioning exhaust fans • regularly maintenance of systems moving air, especially the heat recovery ventilation • upgrade to high efficiency furnace • add insulation in attic • insulate top of basement
1970	single detached	227	66	179,991	1,073	• poor insulation in unheated floor areas (e.g., above garage) • building additions (e.g., sunrooms) above crawl space • poor insulation in basement • poor insulation in attic	•improve insulation in areas with unheated floor, insulate floor • air sealing, especially around additions • insulate top of basement • improve insulation in attic
1970	row house	154	72	130,545	1,015	• poor air quality • poor windows poorly installed • clogged air filters • lower efficiency furnaces	• properly functioning exhaust fans • regular maintenance of systems moving air, especially heat recovery ventilator • upgrade to higher efficiency furnace
1980	single detached	249	71	159,198	934	• poor ventilation • require makeup air for combustion • low efficiency furnaces	• install heat recovery ventilator • makeup air ducting • improve exhaust fans • switch to higher efficiency furnace
1980	row house	141	77	106,930	796	• lower efficiency furnace • poor air quality • air filters clogged • poor windows poorly installed	• upgrade to high efficiency furnace • ensure that exhaust fans are properly functioning • regular maintenance of systems moving air, especially heat recover ventilators
1990	single detached	264	75	141,742	758	• require improved ventilation • need makeup air for combustion	• install heat recovery ventilator • makeup air ducting • improve exhaust fans
1990	row house	138	76	111,606	1,058	• poor air quality • poor windows poorly installed • air filters clogged	• ensure that exhaust fans are properly functioning • regular maintenance of systems moving air, particularly heat recovery ventilator

Source: REEP, 2013.

Table 2.3: 1975-2006 Ontario Building Code Amendment History

Building Code Edition	Date Filed	Effective Date	Content
O. Reg. 925/75 (1975 Building Code)	November 24, 1975	December 31, 1975	Part 1: Definitions Part 2: Administration Part 3: Use and Occupancy Part 4: Design Part 5: Building Requirements for Handicapped Persons Part 6: Building Services Part 7: Reserved Part 8: Demolition Part 9: Housing and Small Buildings
O. Reg. 583/83 (1983 Building Code)	September 15, 1983	November 30, 1983	Part 1: Definitions and Abbreviations Part 2: General Requirements Part 3: Use and Occupancy Part 4: Structural Design Part 5: Wind, Water and Vapour Protection Part 6: Heating, Ventilation and Air-Conditioning Part 7: Reserved Part 8: Reserved Part 9: Housing and Small Buildings
O. Reg. 419/86 (1986 Building Code)	July 18, 1986	October 20, 1986	Part 1: Scope and Definitions Part 2: General Requirements Part 3: Use and Occupancy Part 4: Structural design Part 5: Wind, Water and Vapour Protection Part 6: Heating, Ventilating and Air-Conditioning Part 7: Reserved Part 8: Reserved Part 9: Housing and Small Buildings Part 10: Reserved Part 11: Renovation A: Renovation B: Imperial Conversion
O. Reg. 413/90 (1990 Building Code)	July 30, 1990	October 1, 1990	Part 1: Scope and Definitions Part 2: General Requirements Part 3: Use and Occupancy Part 4: Structural Design Part 5: Wind, Water and Vapour Protection Part 6: Heating, Ventilation and Air-Conditioning Part 7: Reserved Part 8: Reserved Part 9: Housing and Small Buildings

			Part 10: Reserved Part 11: Renovation A: Explanatory Information B: Imperial Conversion
O. Reg. 403/97 (1997 Building Code)	November 3, 1997	April 6, 1998	Part 1: Scope and Definitions Part 2: General Requirements Part 3: Fire Protection, Occupant Safety and Accessibility Part 4: Structural Design Part 5: Wind, Water and Vapour Protection Part 6: Heating, Ventilating and Air-Conditioning Part 7: Plumbing Part 8: Sewage Systems Part 9: Housing and Small Buildings Part 10: Change of Use Part 11: Renovation Part 12: Transition, Renovation and Commencement
O. Reg. 350/06 (2006 Building Code)	June 28, 2006	December 31, 2006	Part 1: Compliance and General Part 2: Objectives Part 3: Functional Statements Part 4: Structural Design Part 5: Environmental Separation Part 6: Heating, Ventilating and Air-Conditioning Part 7: Plumbing Part 8: Sewage Systems Part 9: Housing and Small Buildings Part 10: Change of Use Part 11: Renovation Part 12: Resource Conservation

Source: MCCR, 1975; OMMAH, 1983; OMH, 1986; OMH, 1990; OMMAH, 1998; OMMAH, 2006; OMMAH, 2010.

Appendix 3: Methodology

Table 3.1: Comparison between quantitative and qualitative research

	Quantitative research	**Qualitative research**
Research planning		
Theory-research relationship	Structured; logically sequential phases	Open, interactive
Function of the literature	Deduction (theory precedes observation)	Introduction)theory emerges from observation)
Concepts	Fundamental in defining theory and hypotheses	Auxiliary
Relationship with the environment	Operationaled	Orientative, open, under construction
Psychological research-subject interaction	Manipulative approach	Naturalistic approach
Physical researcher-subject interaction	Natural, detached, scientific observation	Empathetic identification with the perspective of the subject studied
Role of subject studied	Distance, detachment	Proximity, contact
	Passive	Active
Data collection		
Research design	Structured, closed, precedes research	Unstructured, open, constructed in the course of research
Representativeness	Statistically representative sample	Single cases not statistically representative
Recording instruments	Standardized for all subjects. Objective: data-matrix	Varies according to subjects' interests. Tends not to be standardized
Nature of data	'Hard', objective and standardized (objectivity vs. subjectivity)	'Soft', rich and deep (depth vs. superficiality)
Data analysis		
Object of the analysis	The variable (analysis by variables, impersonal)	The individual (analysis by subjects)
Aims of the analysis	Explain variation ('variance') in variables	Understand the subjects
Mathematical and statistical techniques	Used intensely	Not used
Production of results		
Data presentation	Tables (relationship perspective) Correlations. Casual models	Extracts from interviews and texts (narrative perspective)
Generalizations	Laws. Logic of causation	Classifications and typologies. Ideal types. Logic of classification
Scope of results	Generalizability	Specify

Source: Corbetta, 2003, p. 37.

Table 3.2: List of variables used

Variables	Units
Year built	
Area	m^2
Footprint	m^2
Furnace type	
Furnace efficiency	%
Furnace fuel	
House type	
Attic insulation	R
Foundation wall insulation	R
Main wall insulation	R
Storeys	#
Volume	m^3
Air changes per hour	P
Estimated leakage area	
Fuel electricity	kWh
Fuel natural gas	m^3
Fuel oil	L
Fuel propane	L
Space energy	MJ
Heat loss air	MJ
Heat loss foundation	MJ
Heat loss attic	MJ
Heat loss walls	MJ
Heat loss windows/doors	MJ
EGH rating	
Yearly emissions by source	kgCO$_2$/m^2

Source: REEP database.

Table 3.3: List of nine categories

	Category	Sub-category
I	**Building code**	
	Code	
	Building code	
	Ontario Building Code	
	Need for a better building code	better building code changes in the building code new building code improve the building code
II	**Building**	**Sub-category**
	Building(s)	house(s)/home(s)/housing/building(s)
	Old infrastructure	old(er) building(s)/ old(er) houses(s)/ old(er) homes(s)
	New infrastructure	new(er) building(s)/ new(er) home(s)/ new(er) houses
	Residential housing	residential building
	Building envelope	
	Building envelope improvements	
	Improve building(s)	
	Better buildings	
III	**Conservation**	**Sub-category**
	Conservation	
	Energy conservation	conservation energy conserve energy
	Promoting conservation	
IV	**Efficient**	**Sub-category**
	Efficient	
	Efficient building	efficient buildings/homes/houses
	Energy efficient	
V	**Energy**	**Sub-category**
	Energy	
	Energy crisis	energy issues
	Energy loss	energy shortages
	Energy demand	
	Reduction in energy	less energy save energy saving energy savings in energy energy saving reduce energy reducing energy
	Reduce energy consumption	reduce energy usage reduce energy use use less energy
	Sustainable energy	
VI	**Insulation**	**Sub-category**
	Insulation	
	R-value	thermal insulation
	Insulation inspections	
	Upgrading the insulation	reinsulate
	Calling for sufficient insulation	Insulation should be increased encourage the use of insulation

	Insulation and conservation	
	Full height	
	Attic insulation	insulation in the attic
	Wall insulation	
	Basement insulation	insulation in the basement
	Home insulation	Insulate home/house/building insulation in home(s)/house(s)/ building(s)
	Insulation requirements	
	No insulation	lack of insulation
	Little insulation	not enough insulation
	Better insulation	very good insulation good insulation adequate insulation
	Higher insulation	increased insulation
	Add insulation	adding insulation more insulation
	Reduce insulation	
	exposed floor insulation	
	basement header insulation	
	crawl space insulation	
VII	**Program**	**Sub-category**
	Program	
	Incentive	
	Standard	
	Retrofit program	
	Conservation program	conservation programme conservation programs
	EnerGuide	
	R2000	
	Net Zero Energy	
	LEED	
VIII	**Retrofit**	**Sub-category**
	Retrofit	
	Renovation	
	Home retrofit	retrofitting buildings/homes/houses retrofits in homes building retrofit
IX	**Potential drivers for improved OBCs**	**Sub-category**
	Climate change	
	Global warming	
	Greenhousegas(s)	
	Higher emissions	
	Environmental problems	
	Environmental issues	
	Environmental concerns	
	Carbon dioxide	

Table 3.4: A list of speakers

Stakeholder category	Description
Political parties	New Democratic Party (NDP) Liberal Party (LP) Progressive Conservative (PC)
Consumers	Consumers Council of Canada
Utilities/Associations	Ottawa Oil Heat Association Atikokan Hydro Canadian Oil Heat Association Consumers' Gas's eastern region Ontario Hydro Petroleum Economics Ltd
Industry/Associations	NAIMA Ottawa Real Estate Board Ontario Land Lease Federation Sustainable Buildings Canada Coscan Development Corp. & Ontario Home Builders' Association Greater Ottawa Home Builders’ Association Federation of Rental Housing Providers of Ontario Net Zero Energy Home Coalition Ontario Realty Corp Ontario Energy Association
Environmental Organisations	Canadian Parks and Wilderness Society Conservation Council of Ontario EcoSuperior EnviroCentre Green Energy Coalition SWITCH
Labour Unions	Communications, Energy and Paperworkers Union of Canada CUPE Local 1 Toronto and York Region Labour Council
Government	Management Board Secretariat Ontario New Home Warranty Program Ministry of Municipal Affairs and Housing Property tax policy branch Research and Information Services Association of Municipalities of Ontario

Table 3.5: List of stakeholders

Year	Name	New ID
1972	Mr. Snow	PC1
1974	Mr. Young	NDP1
1974	Mr. Edighoffer	LP1
1974	Mr. Peterson	LP2
1974	Mr. McKeough	PC6
1975	Mr. Meen	PC7
1976	Mr. Haggerty	LP3
1977	Mr. Cassidy	NDP2
1977	Mr. Samis	NDP3
1977	Mr. Blundy	LP4
1977	Mr. Cunningham	LP5
1977	Mr. Epp	LP6
1977	Mr. Taylor	PC8
1977	Mr. Pope	PC9
1977	Mr. Smith	NDP4
1978	Mr. Reed	LP7
1979	Mr. Auld	PC10
1980	Mr. Gigantes	NDP5
1980	Mr. Laughren	NDP6
1980	Mr. Sterling	PC2
1980	Mr. Welch	PC11
1980	Mr. Ramsay	PC12
1981	Mr. Swart	NDP7
1981	Mr. Kerrio	LP8
1981	Mr. Andrewes	PC13
1981	Mr. Ashe	PC14
1982	Mr. Foulds	NDP8
1982	Mr. Wildman	NDP9
1982	Mr. Reid	LP9
1982	Mr. Sweeney	LP10
1983	Mr. Breaugh	NDP10
1983	Mr. Cooke	NDP11
1983	Mr. Bennett	PC3
1983	Mr. Rotenberg	PC4
1989	Mr. Charlton	NDP12
1989	Mr. Collins	LP11
1989	Mr. Cureatz	PC15
1991	Mr. Brown	LP12
1992	Mr. Harrington	NDP13
1992	Mr. Poole	LP13
1992	Mr. Tilson	PC16
1992	Mr. Jordan	PC17
1992	Mr. Dool	CDC & OHBA1
1992	Mr. McCagg	FFO1
1992	Mr. Morrell	PE1
1992	Mr. Rose	OHWP1
1992	Mr. Endenburg	CPAWS1
1993	Mr. Mahoney	LP14
1994	Ms. Haeck	NDP14
1994	Mrs. Homan	OLLF1
1996	Ms. Churley	NDP15
1997	Mr. Marchese	NDP16
1997	Mr. Curling	LP15
2001	Mr. Parsons	LP16
2003	Mr. Bisson	NDP17
2003	Mr. Martin	NDP18
2003	Mr. Delaney	LP17
2004	Mr. Hampton	NDP19
2005	Mr. Prue	NDP20
2005	Mr. Kormos	NDP21
2005	Mr. McNeely	LP18
2005	Mrs. Cansfield	LP19
2005	Mr. Barrett	PC5
2006	Mr. Duncan	LP20
2006	Mr. Gerretsen	LP21
2006	Mr. Cartwright	TYRLC1
2006	Mr. Winter	CCO1
2008	Mr. Ruprecht	LP22
2008	Ms. Pupatello	LP23
2008	Mr. O’Toole	PC18
2009	Mr. Tabuns	NDP22
2009	Mr. Watson	LP24
2009	Mr. Koch	NAIMA1

2009	Ms. McCullum	ORE1
2009	Mr. Hume	AMO1
2009	Mr. Shields	NZEHC1
2009	Mr. Sandals	LP25
2009	Mr. DiNovo	NDP25
2011	Mr. Silk	EC1
2012	Mr. Miller	NDP23
2012	Mrs. Armstrong	NDP24
2012	Mr. Wynne	PC19
2012	Mr. Clark	PC20

Note:

AMO – Association of Municipalities of Ontario
COHA – Canadian Oil Heat Association
CCO – Conservation Council of Ontario
CDC & OHBA – Coscan Development Corp and OHBA
CPWS – Canada Parks and Wilderness Society
EC – EnviroCentre
LP – Liberal Party
NDP – National Democratic Party
NZEHC – Net Zero Energy Home Coalition
OEA – Ontario Energy Association
OLLF – Ontario Land Lease Federation
ONHP – Ontario New Home program
ORE – Ottawa Real Estate
PC – Progressive Conservative Party
PE – Petroleum Economics
TYRLC – Toronto and York Region Labour Council

Source: Legislative Assembly of Ontario, 1972-2012.

Appendix 4: Results

PART I: REEP dataset

Table 4.1: Summary of furnace fuel and house type

Dwelling		1800s	1900s	1910s	1920s	1930s	1940s	1950s	1960s	1970s	1980s	>1990s	Total
Furn Elect	#	7	2	1	7	4	9	34	47	81	82	20	294
	%	2	1	0	2	1	3	12	16	28	28	7	
Furn NGas	#	186	191	164	317	175	322	746	975	950	1242	717	5985
	%	3	3	3	5	3	5	12	16	16	21	11	
Furn Oil	#	51	25	15	27	16	52	128	72	49	16	9	460
	%	11	5	3	6	3	11	28	16	11	3	2	
Furn Mixed wood	#	1	0	0	0	0	0	1	1	0	4	0	7
	%	14	0	0	0	0	0	14	14	0	57	0	
Furn Propane	#	4	3	0	0	0	0	2	3	6	4	6	28
	%	14	11	0	0	0	0	7	11	21	14	22	
One and a half	#	3	2	0	4	1	7	16	1	0	0	0	34
	%	9	6	0	12	3	21	47	3	0	0	0	
One storey	#	7	4	3	8	8	83	482	537	444	365	135	2076
	%	0	0	0	0	0	4	23	26	21	18	6	
Split level	#	0	0	0	0	0	0	1	8	3	11	1	24
	%	0	0	0	0	0	0	4	33	13	46	4	
Two and a half	#	1	0	1	1	0	0	0	0	1	0	0	4
	%	25	0	25	25	0	0	0	0	25	0	0	
Two storey	#	214	178	126	232	152	269	404	531	600	939	593	4238
	%	5	4	3	5	4	6	10	13	14	22	14	
Three storey	#	24	36	51	106	34	25	8	20	39	33	23	399
	%	6	9	13	27	9	6	2	5	10	8	6	

Source: REEP dataset.

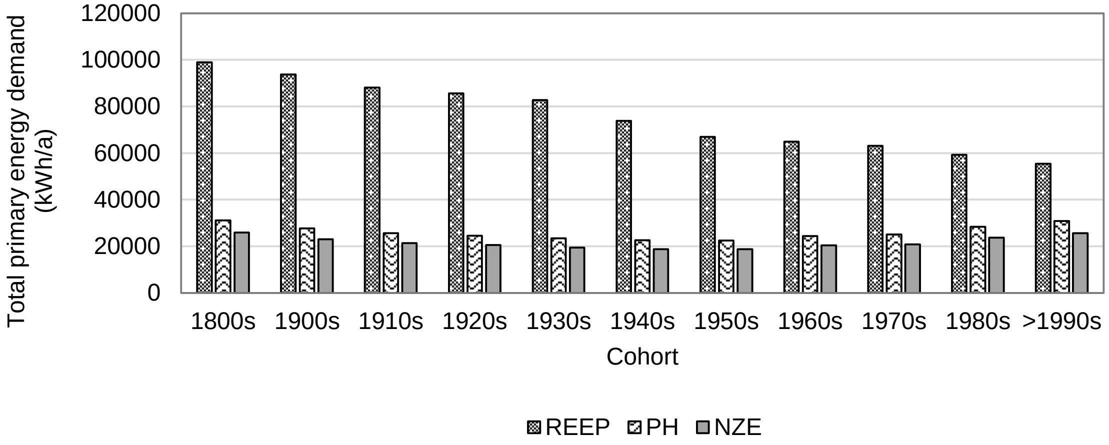


Figure 4.1: Average annual primary energy demand of REEP houses compared to the total PH and total NZE demand.

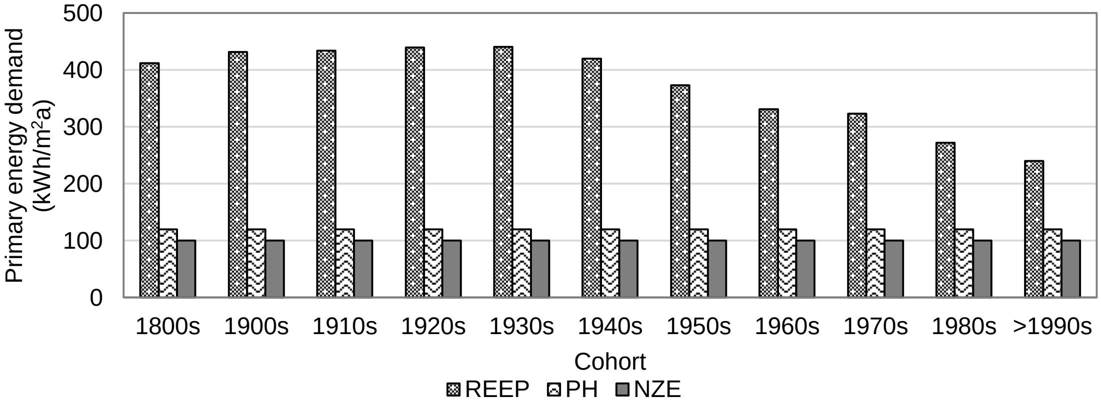


Figure 4.2: Average primary energy demand of REEP houses compared to the PH (≤120 kWh/m^{2}a) and NZE (≤100 kWh/m^{2}a).

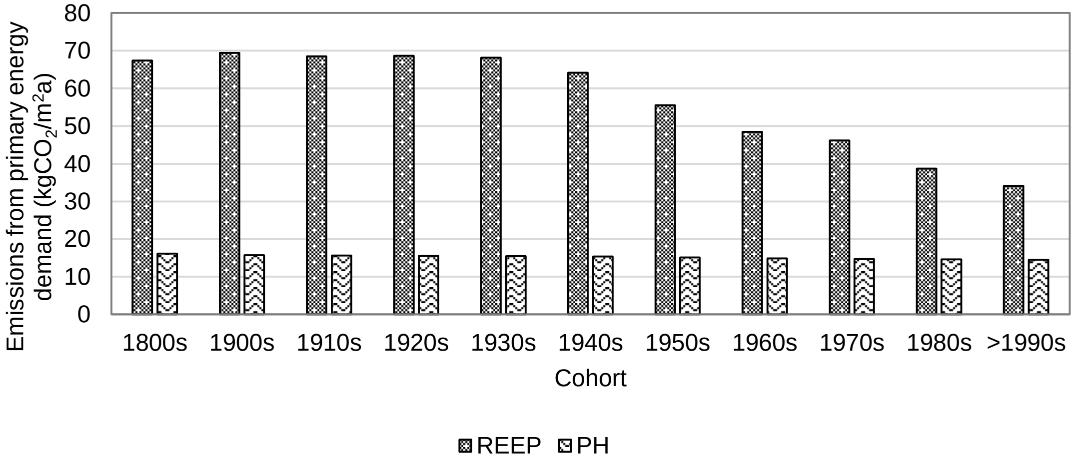


Figure 4.3: Average kgCO$_2$/m^{2}a of REEP houses when the PH primary energy demand is met.

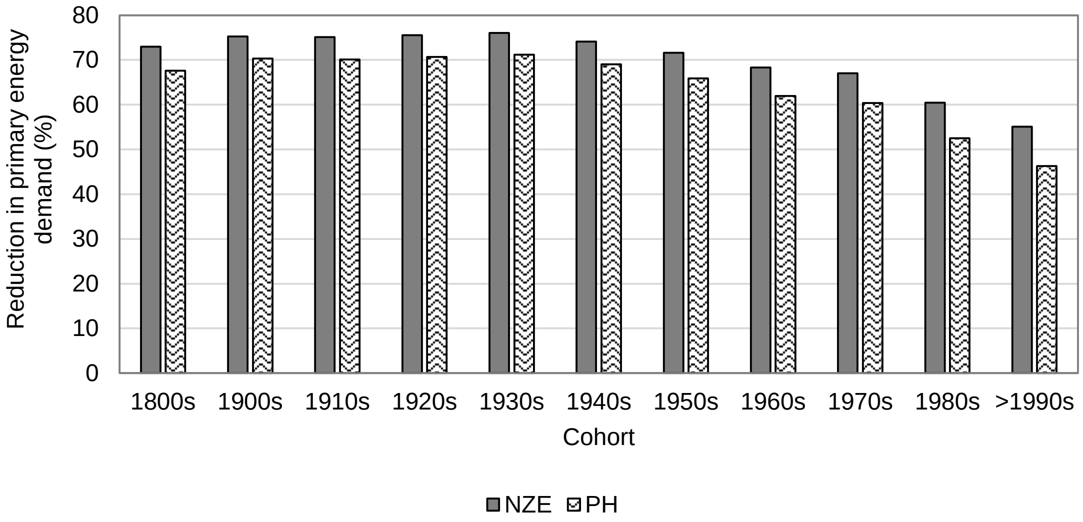


Figure 4.4: Percent reduction in primary energy demand of REEP houses to meet primary energy demand of PH and NZE.

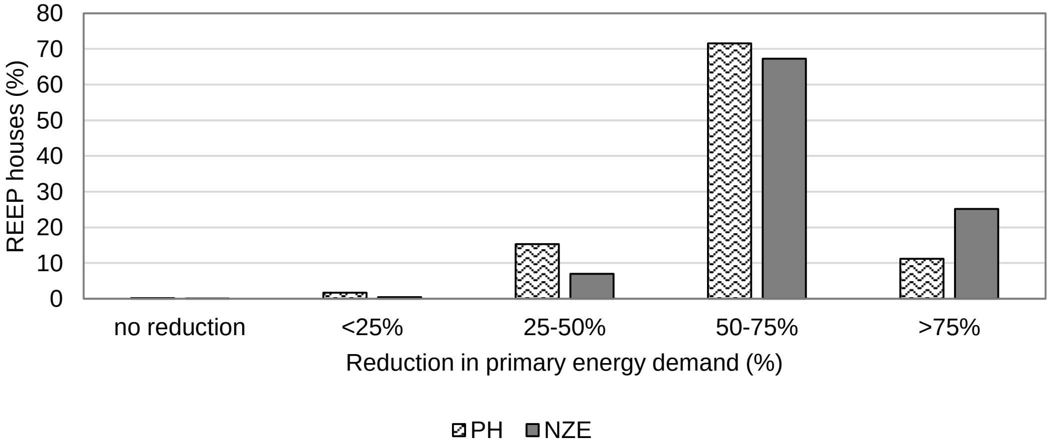


Figure 4.5: Required reduction in REEP houses to meet primary energy demand of PH and NZE.

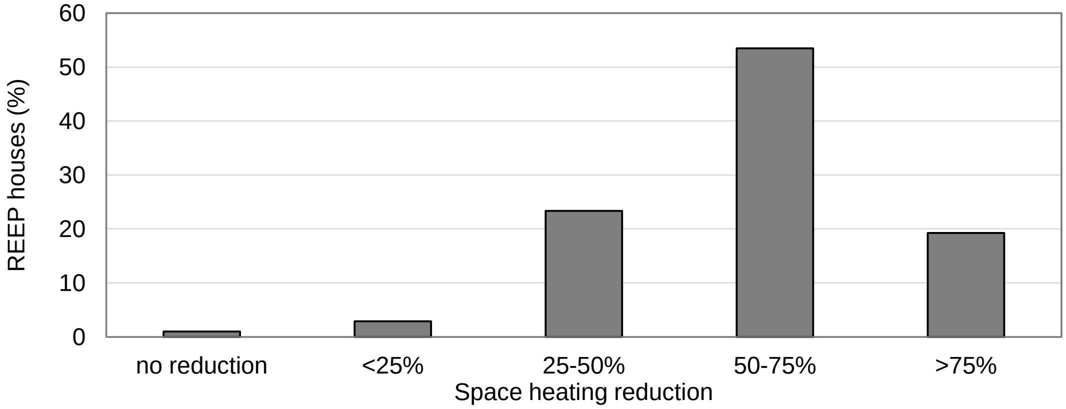


Figure 4.6: Reduction in space heating to meet PH requirements (50kWh/m^{2}a).

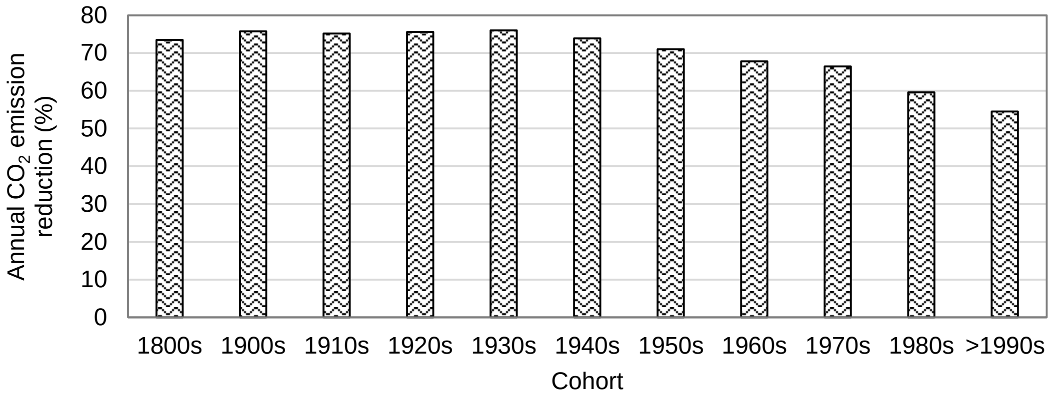


Figure 4.7: Average CO_2 emission reduction of REEP houses that have met the PH primary energy demand.

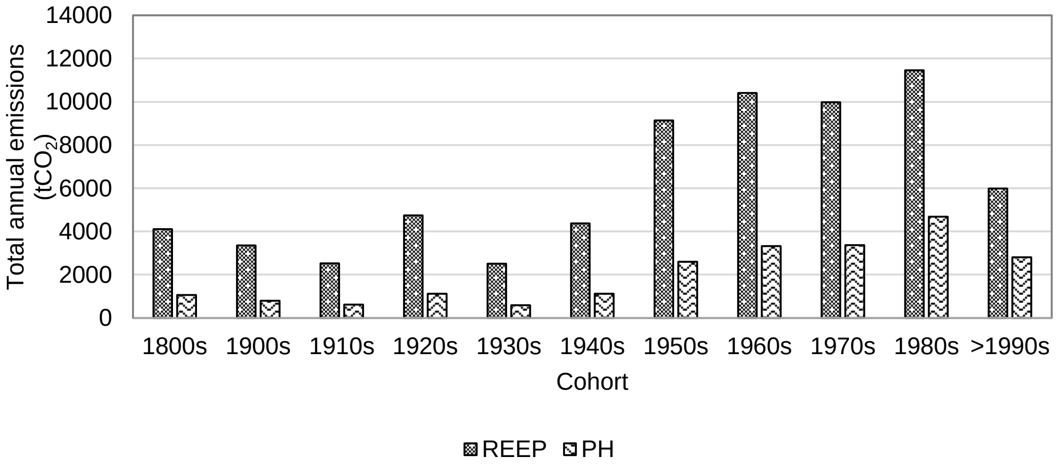


Figure 4.8: Total annual emissions of REEP houses compared to houses that have met the PH primary energy demand.

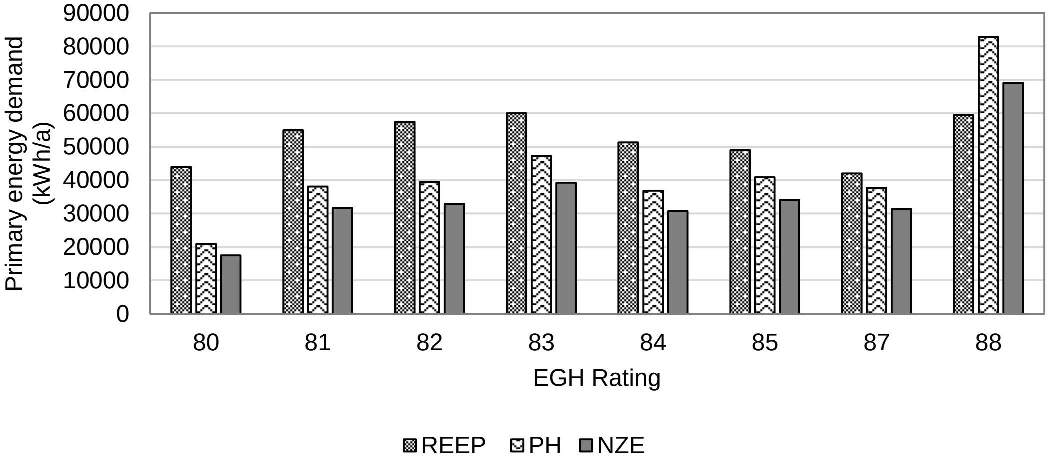


Figure 4.9: Average annual primary energy demand of EGH ≥ 80 REEP houses compared to the total PH and total NZE demand.

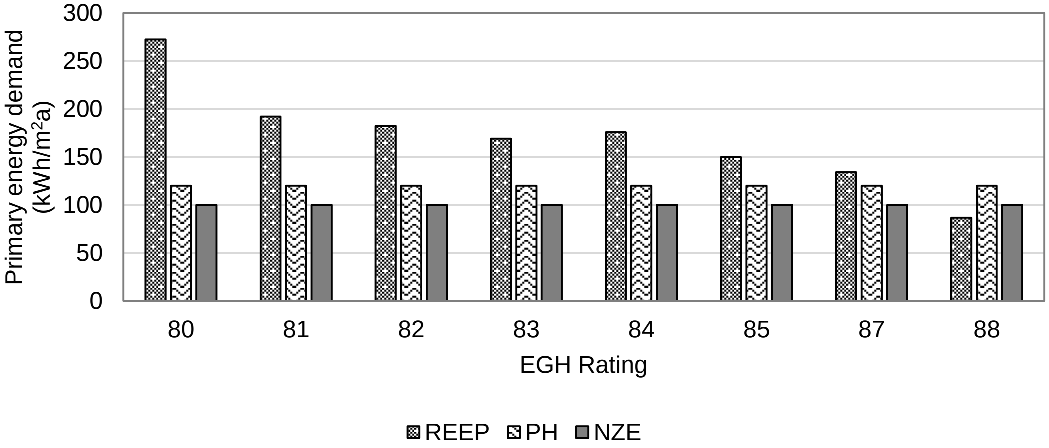


Figure 4.10: Average primary energy demand of EGH ≥ 80 REEP houses compared to the PH (≤120 kWh/m^2a) and NZE (≤100 kWh/m^2a).

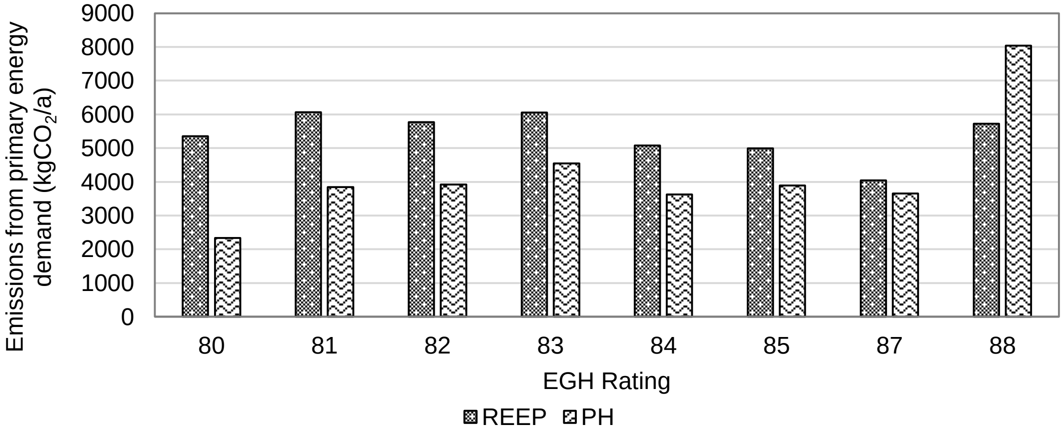


Figure 4.11: Average $kgCO_2/a$ of EGH ≥ 80 REEP houses when the PH primary energy demand is met.

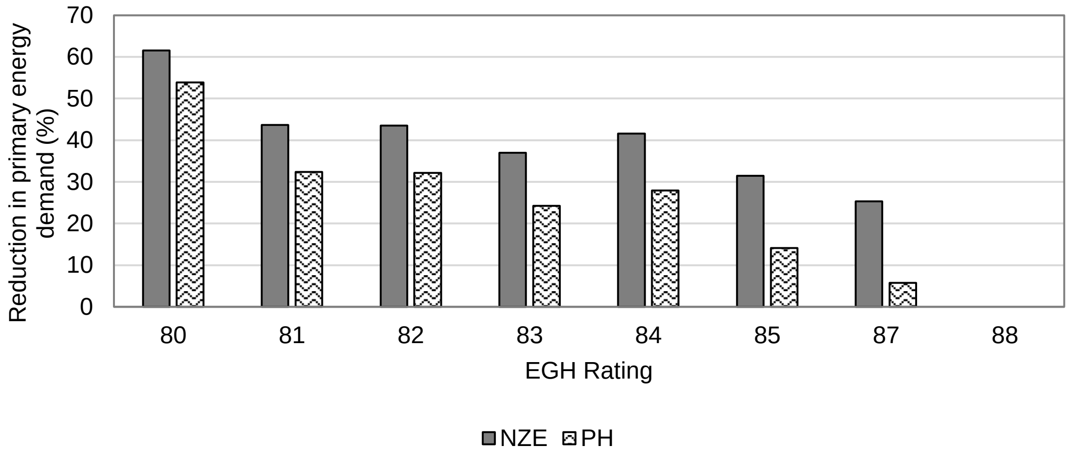


Figure 4.12: Percent reduction in primary energy demand of EGH ≥ 80 REEP houses to meet primary energy demand of PH and NZE.

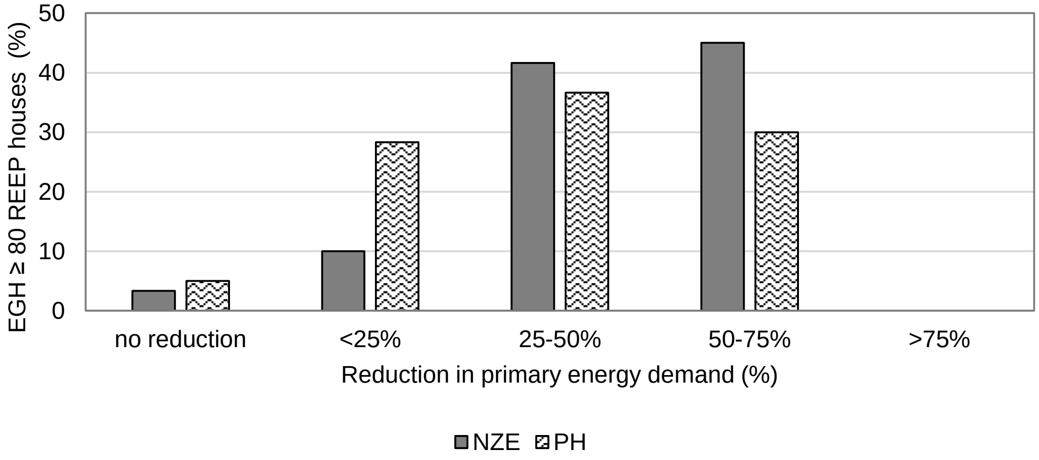


Figure 4.13: Required reduction in EGH ≥ 80 REEP houses to meet primary energy demand of PH and NZE.

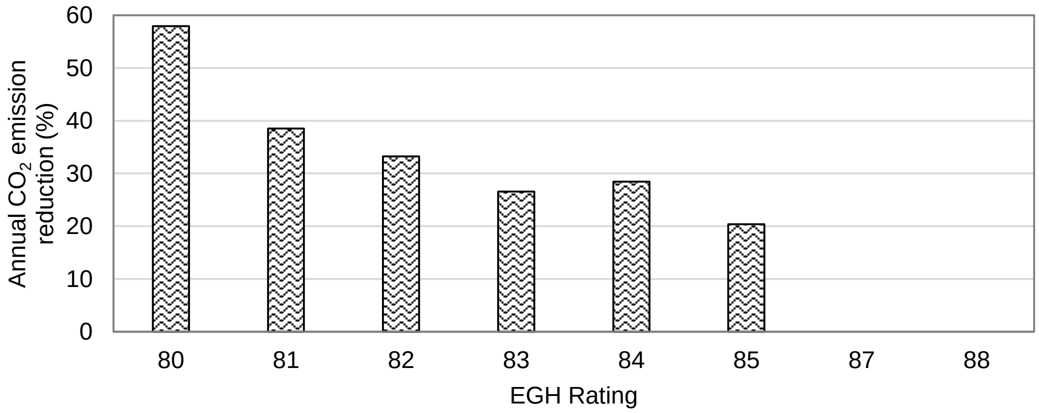


Figure 4.14: Average CO_2 emission reduction of EGH ≥ 80 REEP houses when retrofitted to a PH standard.

PART II: Ontario Building Code 1975-2012

Table: 9.26.4.A. (OBC, 1975)

Construction	RSI (R)-Value Required
Exposed ceiling	4.93 (R28)
Exposed roof	3.52 (R20)
Exposed walls	2.11 (R12)
Foundation walls	
- solid	1.41 (R8)
- frame	2.11 (R12)
Slabs on grade	
- unheated	1.41 (R8)
- heated	1.76 (R10)

Source: Ministry of Consumer and Commercial Relations, 1975, p. 410.

Table: 9.39.3.A. (1983 OBC)

Building Assembly	Maximum Number of Celsius Degree Days	
	≤ 5000	≥ 5000
Exposed walls	3.0 (R17)	3.4 (R19)
Exposed roof or ceiling		
- frame	5.6 (R32)	6.4 (R36)
- solid	3.0 (R17)	3.4 (R19)
Foundation walls		
- solid	1.5 (R8.5)	1.5 (R8.5)
- frame	3.0 (R17)	3.4 (R19)
Exposed floors		
- frame	4.7 (R27)	4.7 (R27)
- solid	3.0 (R17)	3.4 (R19)
Slabs on grade		
- unheated	1.3 (R7)	1.7 (R7)
- heated	1.7 (R10)	2.1 (R12)

Source: Ministry of Municipal Affairs and Hosing, 1983, p. 356.

Table: 9.26.2.A. (OBC 1983)

Construction	RSI (R)-Value Required
Exposed ceiling	5.64 (R32)
Exposed roof	3.52 (R20)
Exposed walls	2.11 (R12)
Foundation walls	
- solid	1.41 (R8)
- frame	2.11 (R12)
Slabs on grade	
- unheated	1.41 (R8)
- heated	1.76 (R10)

Source: Ministry of Municipal Affairs and Hosing, 1983, p. 313.

Table 9.26.2.A (OBC 1986)

Building Element Exposed to the Exterior or to Unheated Space	**RSI (R) -Value Required**
Ceiling below attic or roof space	5.40 (R31)
Roof assembly without attic or roof space	3.52 (R20)
Wall other than foundation wall	2.11 (R12)
Masonry or concrete foundation wall	1.41 (R8)
Frame foundation wall	2.11 (R20)
Floor, other than slab-on-ground	4.40 (R25)
Slab-on-ground containing pipes or heating ducts	1.76 (R10)
Slab-on-ground not containing pipes or heating ducts	1.41 (R8)

Source: Ontario Ministry of Housing, 1986i, p. 337.

Table 9.39.3.A. (1986 OBC)

Building Assembly	**Maximum Number of Celsius Degree Days**	
	≤ 5000	**≥ 5000**
Exposed walls	3.0 (R17)	3.4 (R19)
Exposed roof or ceiling		
- frame	5.6 (R32)	6.4 (R36)
- solid	3.0 (R17)	3.4 (R19)
Foundation walls		
- solid	1.5 (R8.5)	1.5 (R8.5)
- frame	3.0 (R17)	3.4 (R19)
Exposed floors		
- frame	4.7 (R27)	4.7 (R27)
- solid	3.0 (R17)	3.4 (R19)
Slabs on grade		
- unheated	1.3 (R7)	1.7 (R7)
- heated	1.7 (R10)	2.1 (R12)

Source: Ontario Ministry of Housing, 1986i, p. 378.

Table: 9.25.2.7. (1) (OBC 1990)

Building Element Exposed to the Exterior or to Unheated Space	**RSI (R) Value Required**	
	Zone 1 ≤ 5000	**Zone 2 ≥ 5000**
Ceiling below attic or roof space	5.40 (R31)	6.70 (R36)
Roof assembly without *attic or roof* space	3.52 (R20)	3.52 (R20)
Wall other than foundation wall	3.25(R18)	3.87 (R22)
Foundation walls enclosing heated space	2.11 (R12)	2.11 (R12)
Floor, other than slab-on-ground	4.40 (R25)	4.40 (R25)
Slab-on-ground containing pipes or heating ducts	1.76 (R10)	1.76 (R10)
Slab-on-ground not containing pipes or heating ducts	1.41 (R8)	1.41 (R8)

Source: Ontario Ministry of Housing, 1990, p. 9-144.

Table: 9.38.3.1. (1990 OBC)

Building Assembly	Maximum Number of Celsius Degree Days	
	≤ 5000	≥ 5000
Exposed walls	3.0 (R17)	3.4 (R19)
Exposed roof or ceiling		
- frame	5.6 (R32)	6.4 (R36)
- solid	3.0 (R17)	3.4 (R19)
Foundation walls		
- solid	1.5 (R8.5)	1.5 (R8.5)
- frame	3.0 (R17)	3.4 (R19)
Exposed floors		
- frame	4.7 (R27)	4.7 (R27)
- solid	3.0 (R17)	3.4 (R19)
Slabs on grade		
- unheated	1.3 (R7)	1.7 (R10)
- heated	1.7 (R10)	2.1 (R12)

Source: Ontario Ministry of Housing, 1990, p. 9-151.

Table: 9.38.3.A. (OBC 1991)

Building Element Exposed to the Exterior or to Unheated Space	RSI (R) Value Required	
	Zone 1 ≤ 5000	Zone 2 ≥ 5000
Ceiling below attic or roof space	5.60 (R32)	6.90 (R39)
Roof assembly without *attic or roof* space	3.80 (R20)	3.80 (R20)
Wall other than *foundation* wall	3.70 (R21)	4.30 (R24)
Foundation walls enclosing heated space	2.40 (R14)	2.40 (R14)
Floor, other than slab-on-ground	4.70 (R27)	4.70 (R27)
Slab-on-ground containing pipes or heating ducts	2.11 (R12)	1.76 (R10)
Slab-on-ground not containing pipes or heating ducts	2.11 (R12)	1.76 (R10)

Source: The Ontario Gazette, 1992.

Table: Table 9.25.2.A. (OBC 1993)

Building Element Exposed to the Exterior or to Unheated Space	RSI (R) Value Required		
	Zone 1 ≤ 5000	Zone 2 ≥ 5000	Electric Space Heating Zone 1 and 2
Ceiling below attic or roof space	5.40 (R31)	6.70 (R36)	7.0 (R40)
Roof assembly without *attic or roof* space	3.52 (R20)	3.52 (R20)	3.87 (R22)
Wall other than *foundation* wall	3.25 (R18)	3.87 (R22)	4.70 (R27)
Foundation walls enclosing heated space	2.11 (R12)	2.11 (R12)	3.25 (R18)
Floor, other than slab-on-ground	4.40 (R25)	4.40 (R25)	4.40 (R25)
Slab-on-ground containing pipes or heating ducts	1.76 (R10)	1.76 (R10)	1.76 (R10)
Slab-on-ground not containing pipes or heating ducts	1.41 (R8)	1.41 (R8)	1.41 (R8)

Source: The Ontario Gazette, 1993.

Table: 9.38.3.A. (OBC 1995)

Building Element Exposed to the Exterior or to Unheated Space	RSI (R) Value Required		
	Zone 1 ≤ 5000	Zone 2 ≥ 5000	Electric Space Heating Zone 1 and 2
Ceiling below attic or roof space	5.60 (R32)	6.90 (R39)	7.20 (R41)
Roof assembly without *attic or roof* space	3.80 (R22)	3.80 (R22)	4.15 (R24)
Wall other than *foundation* wall	3.70 (R21)	4.30 (R24)	5.15 (R29)
Foundation walls enclosing heated space	2.40 (R14)	2.40 (R14)	3.54 (R20)
Floor, other than slab-on-ground	4.70 (R27)	4.70 (R27)	4.70 (R27)
Slab-on-ground containing pipes or heating ducts	2.11 (R12)	2.11 (R12)	2.11 (R12)
Slab-on-ground not containing pipes or heating ducts	1.76 (R10)	1.76 (R10)	1.76 (R10)

Source: The Ontario Gazette, 1995.

Table: 9.25.2.1. (OBC 1997)

Building Element Exposed to the Exterior or to Unheated Space	RSI (R) Value Required		
	Zone 1 ≤ 5000	Zone 2 ≥ 5000	Electric Space Heating Zone 1 and 2
Ceiling below attic or roof space	5.40 (R31)	6.70 (R36)	7.00 (R40)
Roof assembly without *attic or roof* space	3.52 (R20)	3.52 (R20)	3.87 (R22)
Wall other than *foundation* wall	3.00 (R17)	3.87 (R22)	4.70 (R27)
Foundation walls enclosing heated space	1.41 (R8)	2.11 (R12)	3.25 (R19)
Floor, other than slab-on-ground	4.40 (R25)	4.40 (R25)	4.40 (R25)
Slab-on-ground containing pipes or heating ducts	1.76 (R10)	1.76 (R10)	1.76 (R10)
Slab-on-ground not containing pipes or heating ducts	1.41 (R8)	1.41 (R8)	1.41 (R8)

Source: Ontario Ministry of Municipal Affairs and Housing, 1998, p. 9-108.

Table: 9.38.3.1. (1997 OBC)

Building Assembly	Maximum Number of Celsius Degree Days		
	Zone 1 ≤ 5000	Zone 2 ≥ 5000	Electric Space Heating
Ceiling below attic or roof space	5.60 (R32)	6.90 (R39)	7.20 (R41)
Roof assembly without *attic or roof* space	3.80 (R22)	3.80 (R22)	4.15 (R24)
Wall other than *foundation* wall	3.45 (R19)	4.30 (R24)	5.15 (R29)
Foundation walls enclosing heated space	1.70 (R10)	2.40 (R14)	3.54 (R20)
Floor, other than slab-on-ground	4.70 (R27)	4.70 (R27)	4.70 (R27)
Slab-on-ground containing pipes or heating ducts	2.11 (R12)	2.11 (R12)	2.11 (R12)
Slab-on-ground not containing pipes or heating ducts	1.76 (R10)	1.76 (R10)	1.76 (R10)

Source: Ontario Ministry of Municipal Affairs and Housing, 1998, p. 9-150.

Table: 12.3.2.1. (OBC 2006)

Building Element Exposed to the Exterior or to Unheated Space	RSI (R) Value Required		
	Zone 1 ≤ 5000	Zone 2 ≥ 5000	Electric Space Heating Zone 1 and 2
Ceiling below attic or roof space	7.00 (R40)	7.00 (R40)	8.80 (R50)
Roof assembly without *attic or roof* space	4.93 (R28)	3.80 (R22)	4.93 (R28)
Wall other than *foundation* wall	3.34 (R19)	4.22 (R24)	5.10 (R29)
Foundation walls enclosing heated space	2.11 (R12)	2.11 (R12)	3.34 (R19)
Floor, other than slab-on-ground	4.40 (R25)	4.40 (R25)	4.40 (R25)
Slab-on-ground containing pipes or heating ducts*	1.76 (R10)	1.76 (R10)	1.76 (R10)
Slab-on-ground not containing pipes or heating ducts*	1.41 (R8)	1.41 (R8)	1.76 (R10)
Basement floor slabs located more than 600 mm below grade	-	-	-

Source: Ontario Ministry of Municipal Affairs and Housing, 2006, p. 6, Division B-Part 12.

Table: 12.3.3.3. (OBC 2006)

Building Assembly	Minimum RSI (R) Value Required		
	Zone 1 ≤ 5000	Zone 2 ≥ 5000	Electric Space Heating Zone 1 and 2
Ceiling below attic or roof space	7.24 (R41)	7.24 (R41)	9.00 (R51)
Roof assembly without *attic or roof* space	5.21 (R30)	5.21 (R30)	5.21 (R30)
Wall other than *foundation* wall	3.80 (R22)	4.67 (R27)	5.50 (R31)
Foundation walls enclosing heated space	2.40 (R14)	2.40 (R14)	3.63 (R21)
Floor, other than slab-on-ground	4.70 (R27)	4.70 (R27)	4.70 (R27)
Slab-on-ground containing pipes or heating ducts*	2.11 (R12)	2.11 (R12)	2.11 (R12)
Slab-on-ground not containing pipes or heating ducts*	1.76 (R10)	1.76 (R10)	2.11 (R12)
Basement floor slabs located more than 600 mm below grade	-	-	-

Source: Ontario Ministry of Municipal Affairs and Housing, 2006, p. 9, Division B-Part 12.

Table: 12.3.4.2.A.

Building Assembly	Minimum RSI (R) Value Required	
	Zone 1 ≤ 5000	Zone 2 ≥ 5000
Opaque wall assembly	2.36 (R13)	3.83 (R22)
Wall assembly adjacent to unconditioned space	1.61 (R9)	2.02 (R11)
Below grade wall	2.11 (R12)	2.82 (R16)
Roof assembly	3.91 (R21)	5.68 (R32)
Floor assembly over unconditioned space	4.52 (R26)	4.52 (R26)

Source: Ontario Ministry of Municipal Affairs and Housing, 2006, p. 12, Division B-Part 12.

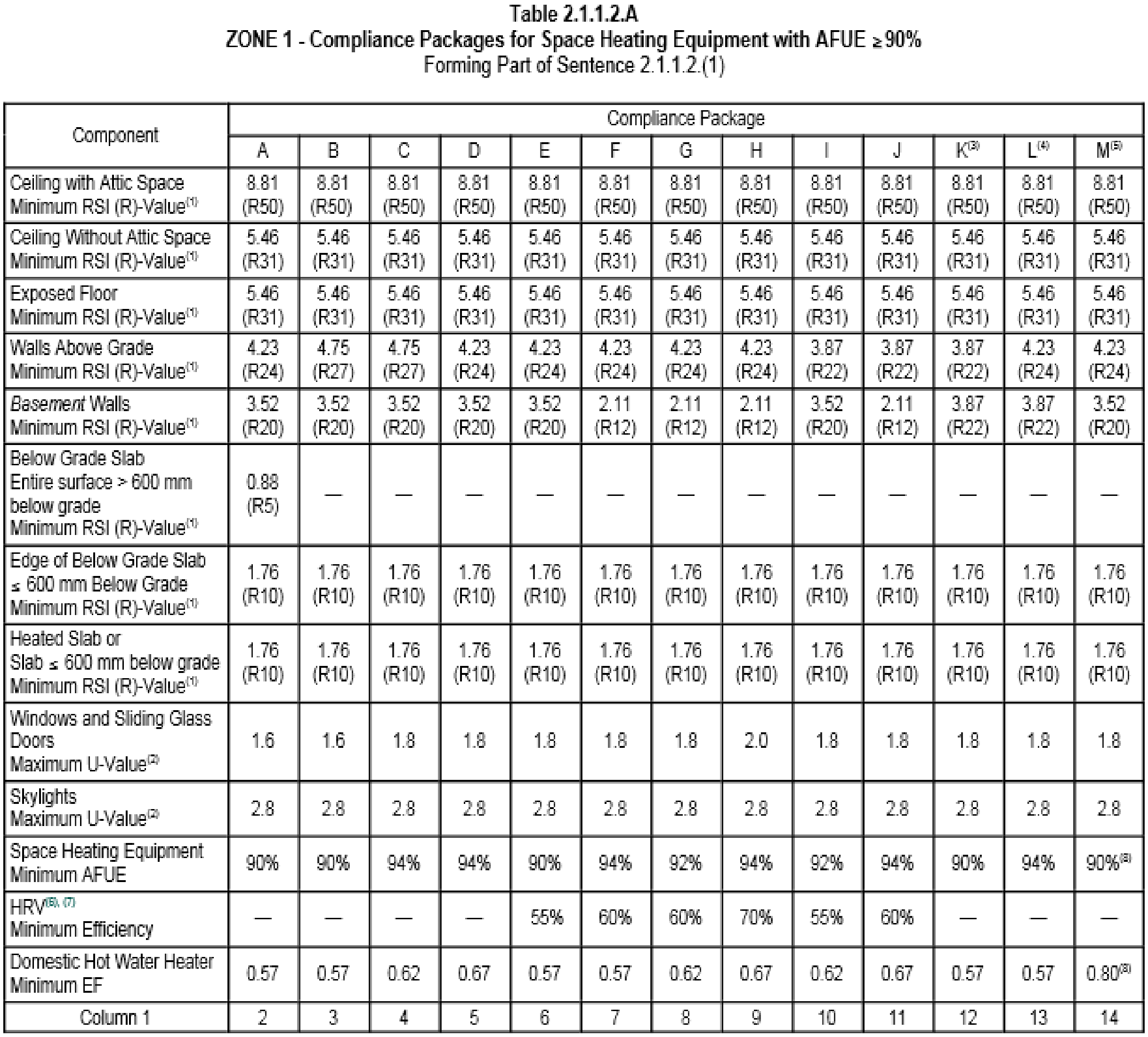


Table 2.1.1.2.A
ZONE 1 - Compliance Packages for Space Heating Equipment with AFUE ≥ 90%
Forming Part of Sentence 2.1.1.2.(1)

Component	Compliance Package												
	A	B	C	D	E	F	G	H	I	J	K(3)	L(4)	M(5)
Ceiling with Attic Space Minimum RSI (R)-Value(1)	8.81 (R50)	8.81 (R50)	8.81 (R50)	8.81 (R50)	8.81 (R50)	8.81 (R50)	8.81 (R50)	8.81 (R50)	8.81 (R50)	8.81 (R50)	8.81 (R50)	8.81 (R50)	8.81 (R50)
Ceiling Without Attic Space Minimum RSI (R)-Value(1)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)
Exposed Floor Minimum RSI (R)-Value(1)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)
Walls Above Grade Minimum RSI (R)-Value(1)	4.23 (R24)	4.75 (R27)	4.75 (R27)	4.23 (R24)	4.23 (R24)	4.23 (R24)	4.23 (R24)	4.23 (R24)	3.87 (R22)	3.87 (R22)	3.87 (R22)	4.23 (R24)	4.23 (R24)
Basement Walls Minimum RSI (R)-Value(1)	3.52 (R20)	3.52 (R20)	3.52 (R20)	3.52 (R20)	3.52 (R20)	2.11 (R12)	2.11 (R12)	2.11 (R12)	3.52 (R20)	2.11 (R12)	3.87 (R22)	3.87 (R22)	3.52 (R20)
Below Grade Slab Entire surface > 600 mm below grade Minimum RSI (R)-Value(1)	0.88 (R5)	—	—	—	—	—	—	—	—	—	—	—	—
Edge of Below Grade Slab ≤ 600 mm Below Grade Minimum RSI (R)-Value(1)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)
Heated Slab or Slab ≤ 600 mm below grade Minimum RSI (R)-Value(1)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)
Windows and Sliding Glass Doors Maximum U-Value(2)	1.6	1.6	1.8	1.8	1.8	1.8	1.8	2.0	1.8	1.8	1.8	1.8	1.8
Skylights Maximum U-Value(2)	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Space Heating Equipment Minimum AFUE	90%	90%	94%	94%	90%	94%	92%	94%	92%	94%	90%	94%	90%(8)
HRV(6), (7) Minimum Efficiency	—	—	—	—	55%	60%	60%	70%	55%	60%	—	—	—
Domestic Hot Water Heater Minimum EF	0.57	0.57	0.62	0.67	0.57	0.57	0.62	0.67	0.62	0.67	0.57	0.57	0.80(8)
Column 1	2	3	4	5	6	7	8	9	10	11	12	13	14

Source: MMAH, 2013, p. 10.

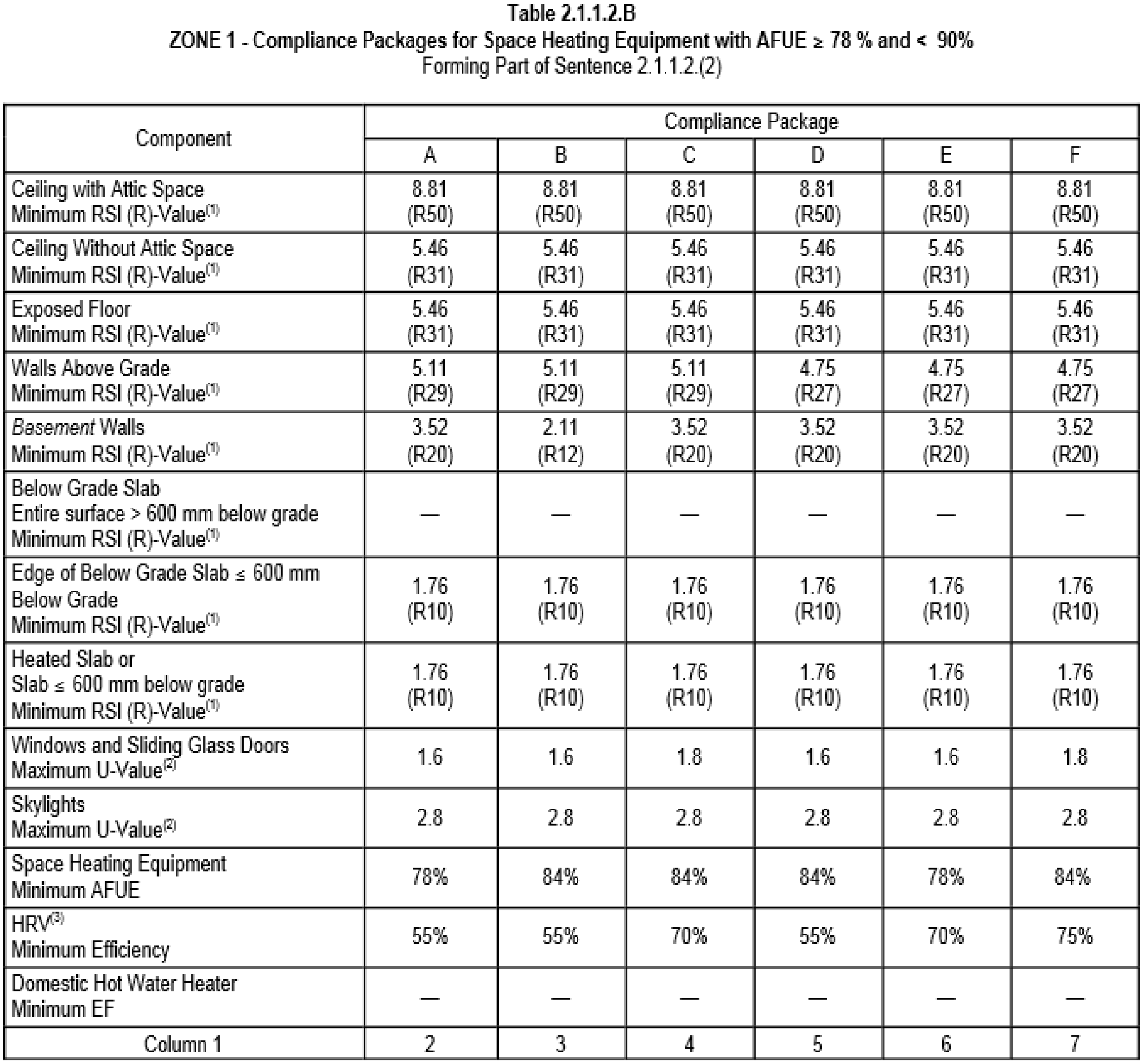


Table 2.1.1.2.B
ZONE 1 - Compliance Packages for Space Heating Equipment with AFUE ≥ 78 % and < 90%
Forming Part of Sentence 2.1.1.2.(2)

Component	Compliance Package					
	A	B	C	D	E	F
Ceiling with Attic Space Minimum RSI (R)-Value(1)	8.81 (R50)	8.81 (R50)	8.81 (R50)	8.81 (R50)	8.81 (R50)	8.81 (R50)
Ceiling Without Attic Space Minimum RSI (R)-Value(1)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)
Exposed Floor Minimum RSI (R)-Value(1)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)
Walls Above Grade Minimum RSI (R)-Value(1)	5.11 (R29)	5.11 (R29)	5.11 (R29)	4.75 (R27)	4.75 (R27)	4.75 (R27)
Basement Walls Minimum RSI (R)-Value(1)	3.52 (R20)	2.11 (R12)	3.52 (R20)	3.52 (R20)	3.52 (R20)	3.52 (R20)
Below Grade Slab Entire surface > 600 mm below grade Minimum RSI (R)-Value(1)	—	—	—	—	—	—
Edge of Below Grade Slab ≤ 600 mm Below Grade Minimum RSI (R)-Value(1)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)
Heated Slab or Slab ≤ 600 mm below grade Minimum RSI (R)-Value(1)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)
Windows and Sliding Glass Doors Maximum U-Value(2)	1.6	1.6	1.8	1.6	1.6	1.8
Skylights Maximum U-Value(2)	2.8	2.8	2.8	2.8	2.8	2.8
Space Heating Equipment Minimum AFUE	78%	84%	84%	84%	78%	84%
HRV(3) Minimum Efficiency	55%	55%	70%	55%	70%	75%
Domestic Hot Water Heater Minimum EF	—	—	—	—	—	—
Column 1	2	3	4	5	6	7

Source: MMAH, 2013, p. 11.

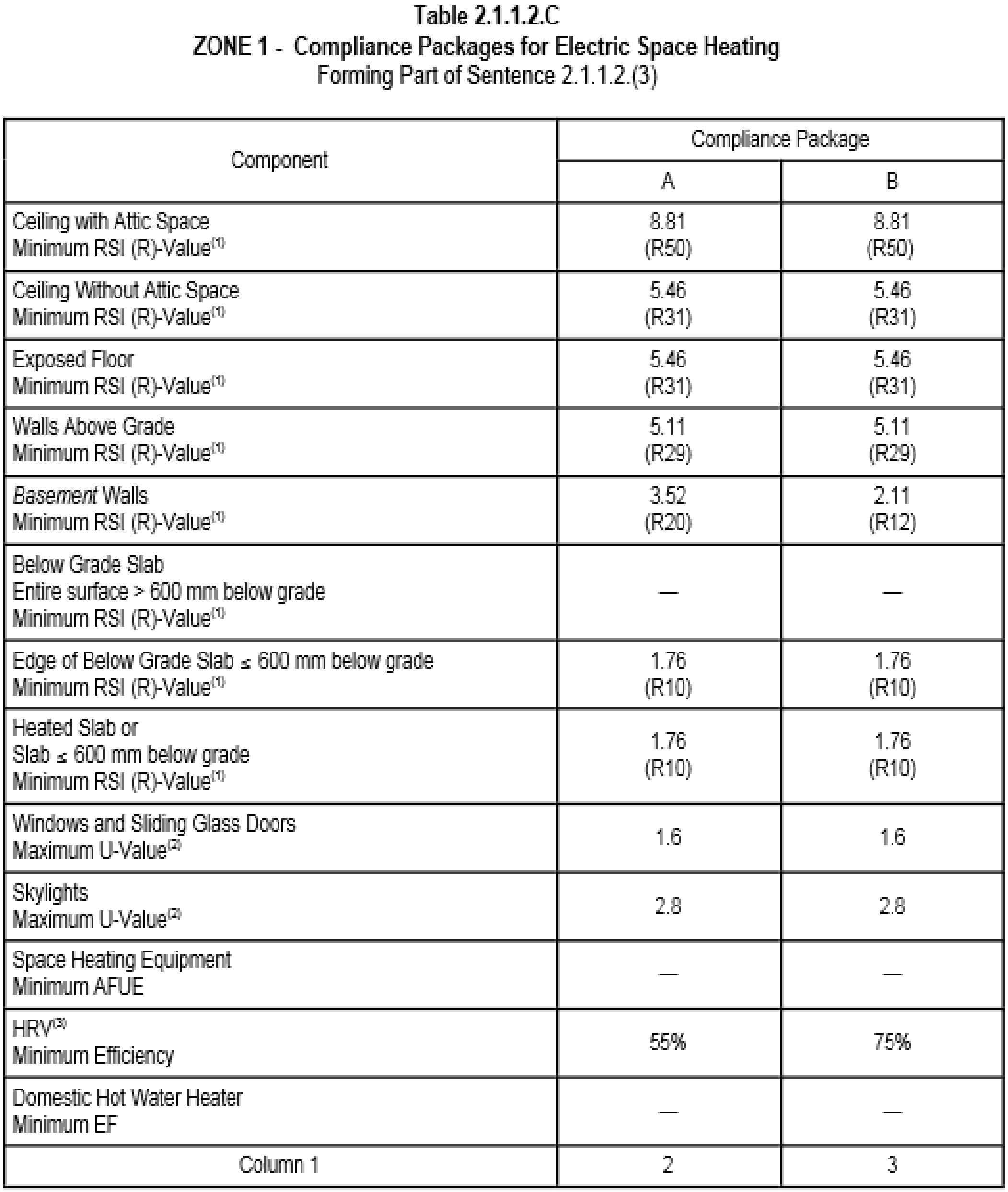


Table 2.1.1.2.C

ZONE 1 - Compliance Packages for Electric Space Heating

Forming Part of Sentence 2.1.1.2.(3)

Component	Compliance Package	
	A	B
Ceiling with Attic Space Minimum RSI (R)-Value(1)	8.81 (R50)	8.81 (R50)
Ceiling Without Attic Space Minimum RSI (R)-Value(1)	5.46 (R31)	5.46 (R31)
Exposed Floor Minimum RSI (R)-Value(1)	5.46 (R31)	5.46 (R31)
Walls Above Grade Minimum RSI (R)-Value(1)	5.11 (R29)	5.11 (R29)
Basement Walls Minimum RSI (R)-Value(1)	3.52 (R20)	2.11 (R12)
Below Grade Slab Entire surface > 600 mm below grade Minimum RSI (R)-Value(1)	—	—
Edge of Below Grade Slab ≤ 600 mm below grade Minimum RSI (R)-Value(1)	1.76 (R10)	1.76 (R10)
Heated Slab or Slab ≤ 600 mm below grade Minimum RSI (R)-Value(1)	1.76 (R10)	1.76 (R10)
Windows and Sliding Glass Doors Maximum U-Value(2)	1.6	1.6
Skylights Maximum U-Value(2)	2.8	2.8
Space Heating Equipment Minimum AFUE	—	—
HRV(3) Minimum Efficiency	55%	75%
Domestic Hot Water Heater Minimum EF	—	—
Column 1	2	3

Source: MMAH, 2013, p. 12.

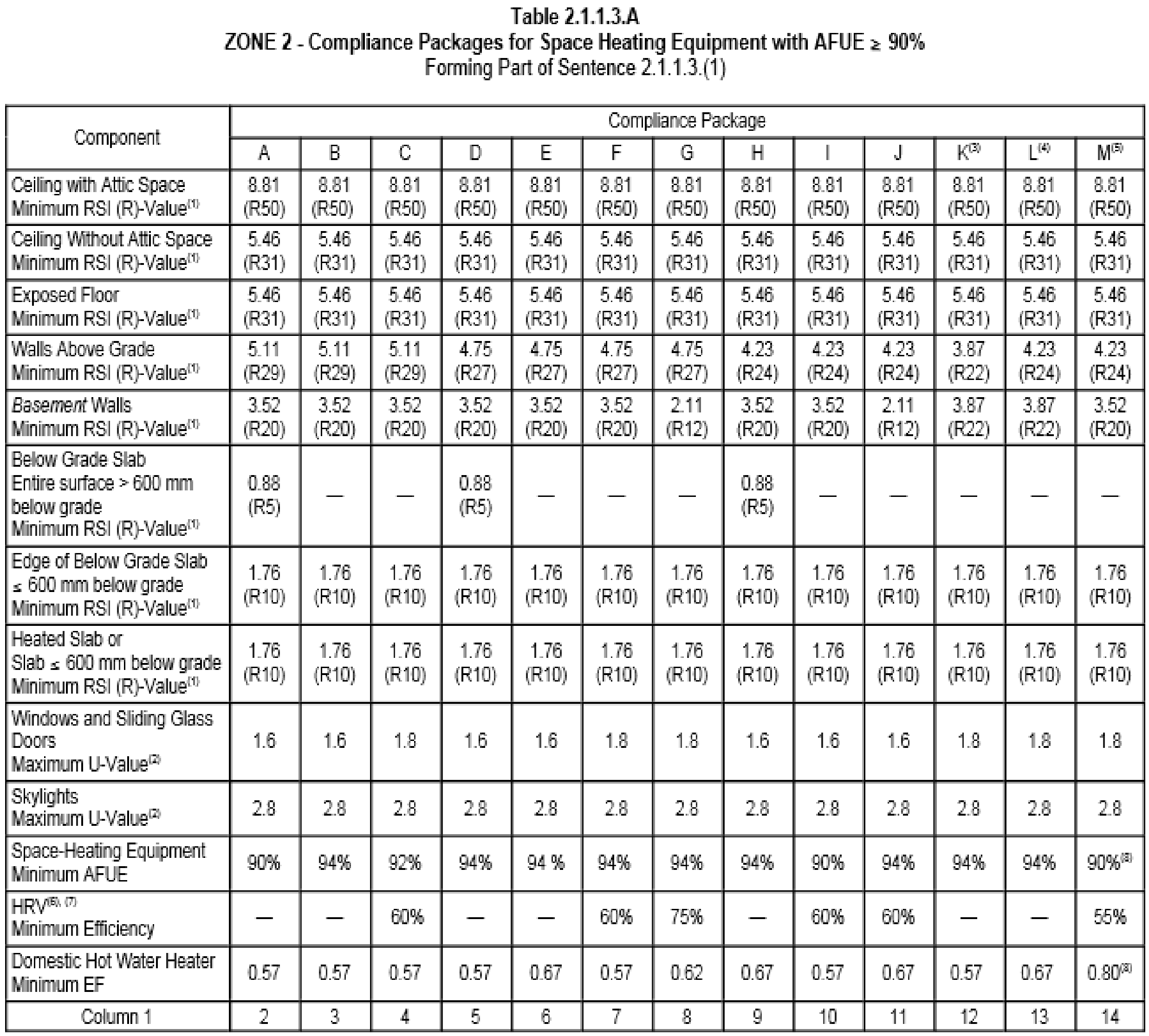


Table 2.1.1.3.A
ZONE 2 - Compliance Packages for Space Heating Equipment with AFUE ≥ 90%
Forming Part of Sentence 2.1.1.3.(1)

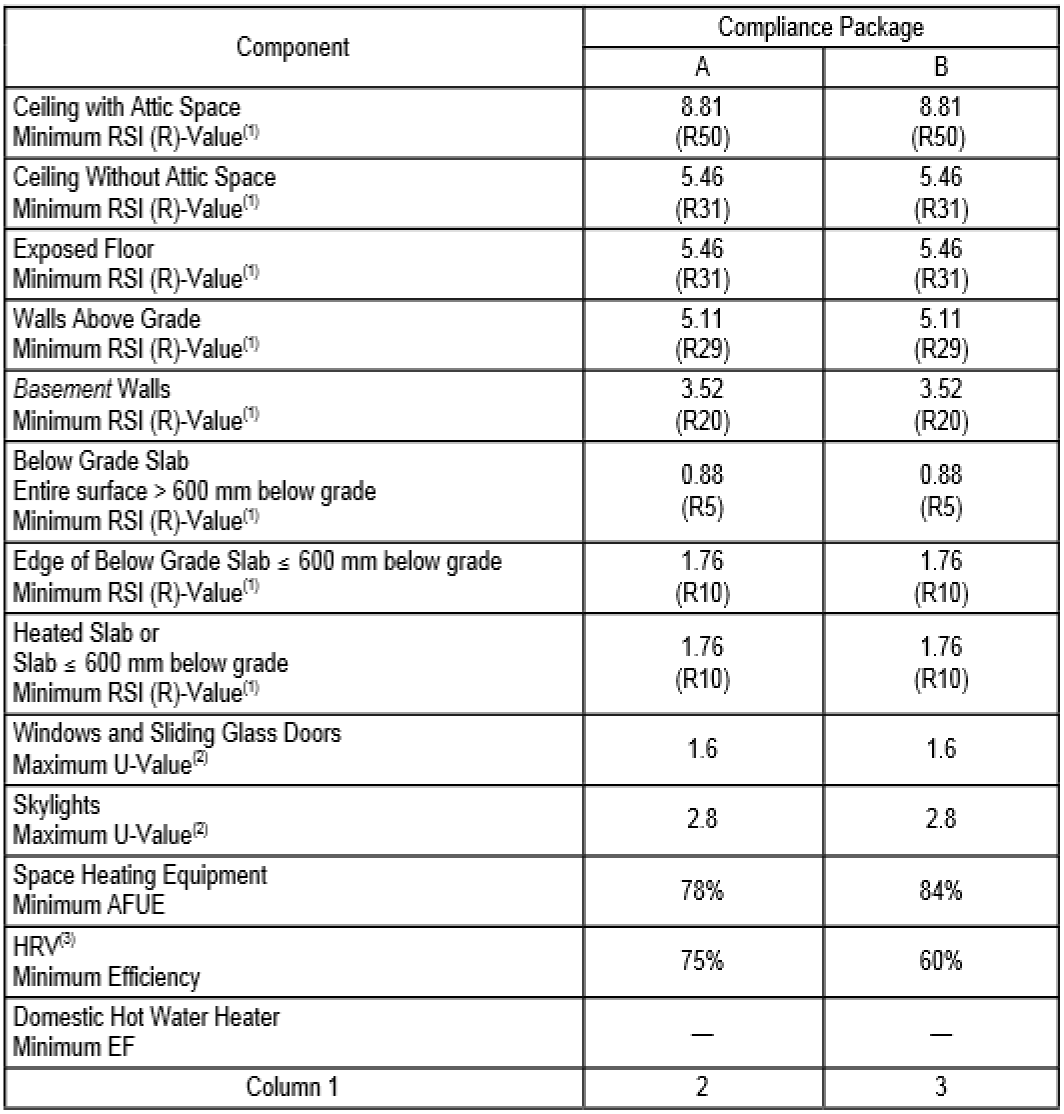
Component	Compliance Package												
	A	B	C	D	E	F	G	H	I	J	K(3)	L(4)	M(5)
Ceiling with Attic Space Minimum RSI (R)-Value(1)	8.81 (R50)	8.81 (R50)	8.81 (R50)	8.81 (R50)	8.81 (R50)	8.81 (R50)	8.81 (R50)	8.81 (R50)	8.81 (R50)	8.81 (R50)	8.81 (R50)	8.81 (R50)	8.81 (R50)
Ceiling Without Attic Space Minimum RSI (R)-Value(1)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)
Exposed Floor Minimum RSI (R)-Value(1)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)	5.46 (R31)
Walls Above Grade Minimum RSI (R)-Value(1)	5.11 (R29)	5.11 (R29)	5.11 (R29)	4.75 (R27)	4.75 (R27)	4.75 (R27)	4.75 (R27)	4.23 (R24)	4.23 (R24)	4.23 (R24)	3.87 (R22)	4.23 (R24)	4.23 (R24)
Basement Walls Minimum RSI (R)-Value(1)	3.52 (R20)	3.52 (R20)	3.52 (R20)	3.52 (R20)	3.52 (R20)	3.52 (R20)	2.11 (R12)	3.52 (R20)	3.52 (R20)	2.11 (R12)	3.87 (R22)	3.87 (R22)	3.52 (R20)
Below Grade Slab Entire surface > 600 mm below grade Minimum RSI (R)-Value(1)	0.88 (R5)	—	—	0.88 (R5)	—	—	—	0.88 (R5)	—	—	—	—	—
Edge of Below Grade Slab ≤ 600 mm below grade Minimum RSI (R)-Value(1)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)
Heated Slab or Slab ≤ 600 mm below grade Minimum RSI (R)-Value(1)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)	1.76 (R10)
Windows and Sliding Glass Doors Maximum U-Value(2)	1.6	1.6	1.8	1.6	1.6	1.8	1.8	1.6	1.6	1.6	1.8	1.8	1.8
Skylights Maximum U-Value(2)	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Space-Heating Equipment Minimum AFUE	90%	94%	92%	94%	94 %	94%	94%	94%	90%	94%	94%	94%	90%(8)
HRV(6), (7) Minimum Efficiency	—	—	60%	—	—	60%	75%	—	60%	60%	—	—	55%
Domestic Hot Water Heater Minimum EF	0.57	0.57	0.57	0.57	0.67	0.57	0.62	0.67	0.57	0.67	0.57	0.67	0.80(8)
Column 1	2	3	4	5	6	7	8	9	10	11	12	13	14

Source: MMAH, 2013, p. 15.

Table 2.1.1.3.B

ZONE 2 - Compliance Packages for Space Heating Equipment with AFUE ≥ 78 % and < 90%

Forming Part of Sentence 2.1.1.3.(2)



Component	Compliance Package	
	A	B
Ceiling with Attic Space Minimum RSI (R)-Value(1)	8.81 (R50)	8.81 (R50)
Ceiling Without Attic Space Minimum RSI (R)-Value(1)	5.46 (R31)	5.46 (R31)
Exposed Floor Minimum RSI (R)-Value(1)	5.46 (R31)	5.46 (R31)
Walls Above Grade Minimum RSI (R)-Value(1)	5.11 (R29)	5.11 (R29)
Basement Walls Minimum RSI (R)-Value(1)	3.52 (R20)	3.52 (R20)
Below Grade Slab Entire surface > 600 mm below grade Minimum RSI (R)-Value(1)	0.88 (R5)	0.88 (R5)
Edge of Below Grade Slab ≤ 600 mm below grade Minimum RSI (R)-Value(1)	1.76 (R10)	1.76 (R10)
Heated Slab or Slab ≤ 600 mm below grade Minimum RSI (R)-Value(1)	1.76 (R10)	1.76 (R10)
Windows and Sliding Glass Doors Maximum U-Value(2)	1.6	1.6
Skylights Maximum U-Value(2)	2.8	2.8
Space Heating Equipment Minimum AFUE	78%	84%
HRV(3) Minimum Efficiency	75%	60%
Domestic Hot Water Heater Minimum EF	—	—
Column 1	2	3

Source: MMAH, 2013, p. 16.

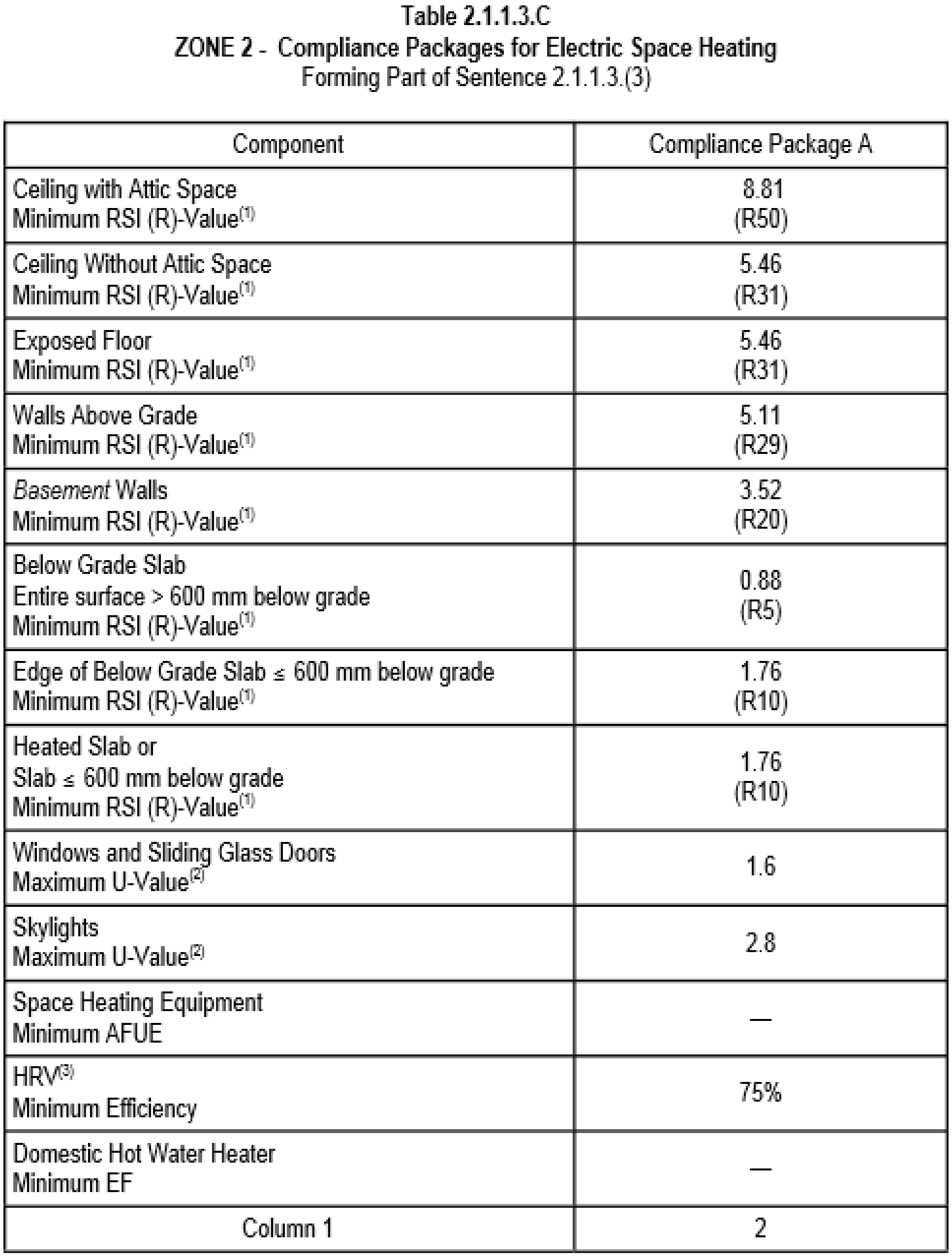


Table 2.1.1.3.C
ZONE 2 - Compliance Packages for Electric Space Heating
Forming Part of Sentence 2.1.1.3.(3)

Component	Compliance Package A
Ceiling with Attic Space Minimum RSI (R)-Value(1)	8.81 (R50)
Ceiling Without Attic Space Minimum RSI (R)-Value(1)	5.46 (R31)
Exposed Floor Minimum RSI (R)-Value(1)	5.46 (R31)
Walls Above Grade Minimum RSI (R)-Value(1)	5.11 (R29)
Basement Walls Minimum RSI (R)-Value(1)	3.52 (R20)
Below Grade Slab Entire surface > 600 mm below grade Minimum RSI (R)-Value(1)	0.88 (R5)
Edge of Below Grade Slab ≤ 600 mm below grade Minimum RSI (R)-Value(1)	1.76 (R10)
Heated Slab or Slab ≤ 600 mm below grade Minimum RSI (R)-Value(1)	1.76 (R10)
Windows and Sliding Glass Doors Maximum U-Value(2)	1.6
Skylights Maximum U-Value(2)	2.8
Space Heating Equipment Minimum AFUE	—
HRV(3) Minimum Efficiency	75%
Domestic Hot Water Heater Minimum EF	—
Column 1	2

Source: MMAH, 2013, p. 17.

PART III: Legislative Assembly and Standing Committee Transcripts 1972-2012

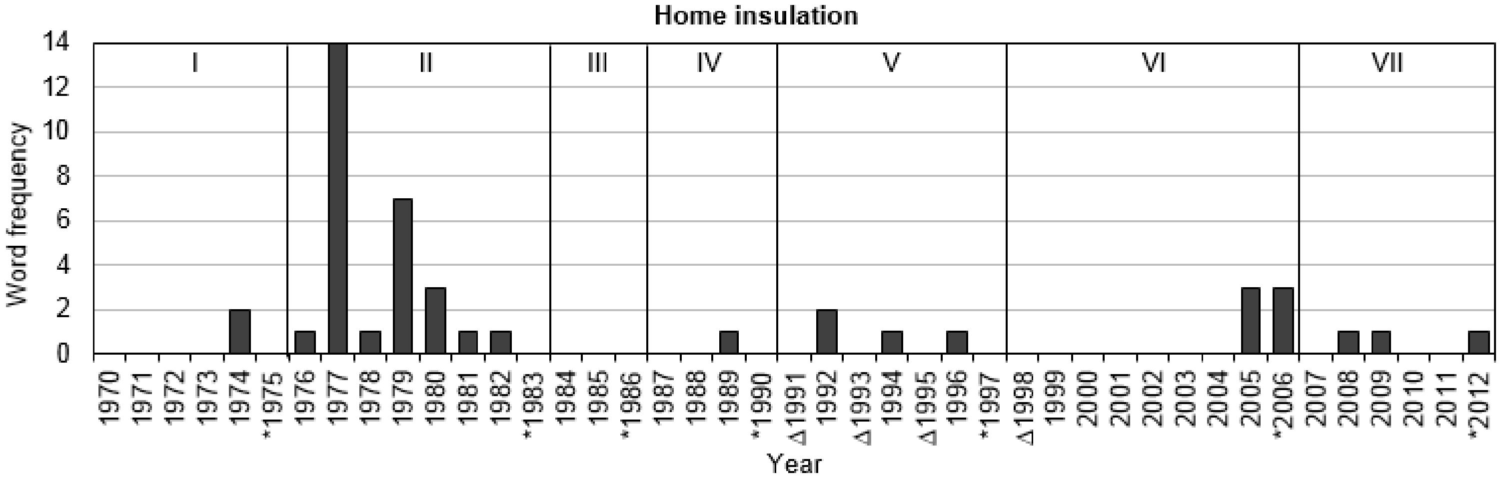


Figure 4.15: Word frequency of ‘home insulation’. *Note: includes ‘insulation in houses’, ‘insulation in home’, ‘insulation in homes’, ‘insulate building’, ‘insulate home’, ‘insulate house’, and ‘home insulation’.*

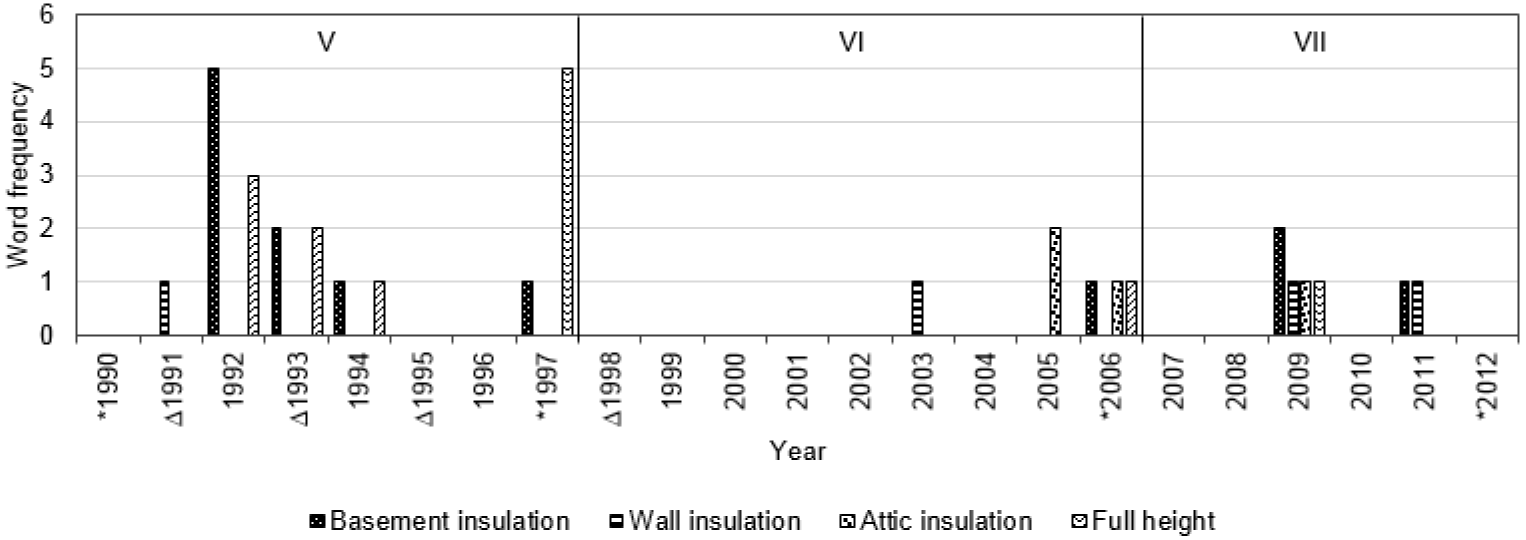


Figure 4.16: Word frequency of insulation at different parts of a building.

Table 4.2: Discussion on selected topics with respect to insulation

Period	I 1970-1975	II 1975-1983	III 1983-1986	IV 1986-1990	V 1990-1997	VI 1997-2006	VII 2006-2012
Count	***n***	***n***	***n***	***n***	***n***	***n***	***n***
Attic insulation							
Environmental Organizations	0	0	0	0	0	1	0
Political parties	0	0	0	0	0	2	1
Note: includes 'insulation in the attic'							
Wall insulation							
Environmental Organizations	0	0	0	0	0	0	1
Political parties	0	0	0	0	1	1	1
Note: includes 'insulation in walls'							
Basement insulation							
Industry / Associations	0	0	0	0	1	0	0
Environmental Organizations	0	0	0	0	0	0	1
Political parties	0	0	0	0	5	0	2
Government	0	0	0	0	3	0	0
Labour Union	0	0	0	0	0	1	0
Note: includes 'insulation in the basement'							
Full height							
Political parties	0	0	0	0	11	0	1
Labour Union	0	0	0	0	0	1	0

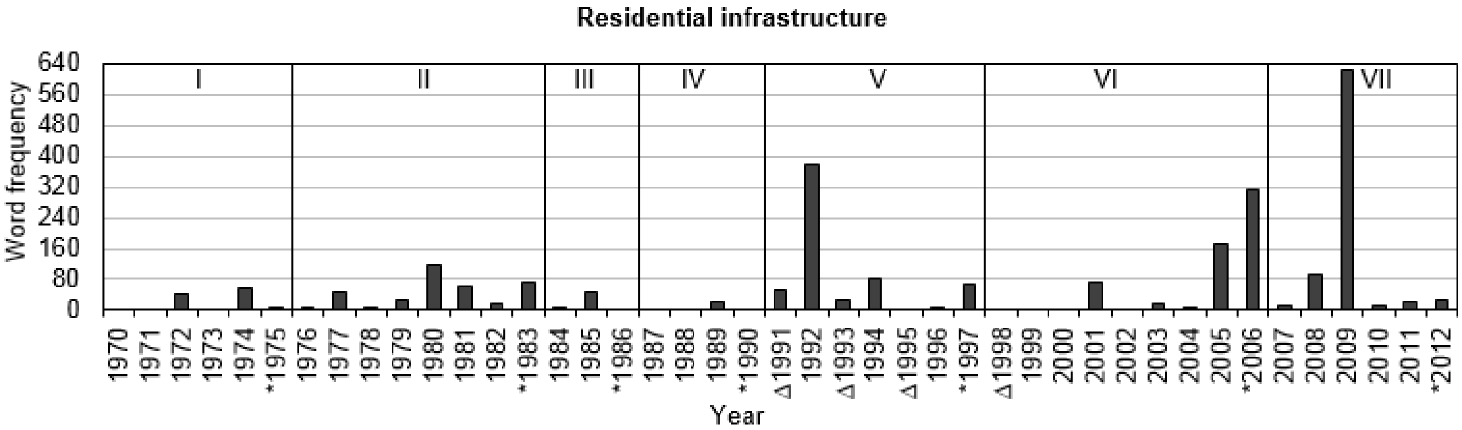


Figure 4.17: Word frequency of residential infrastructure. *Note: includes 'house(s)', 'home(s)' and building(s)'.*

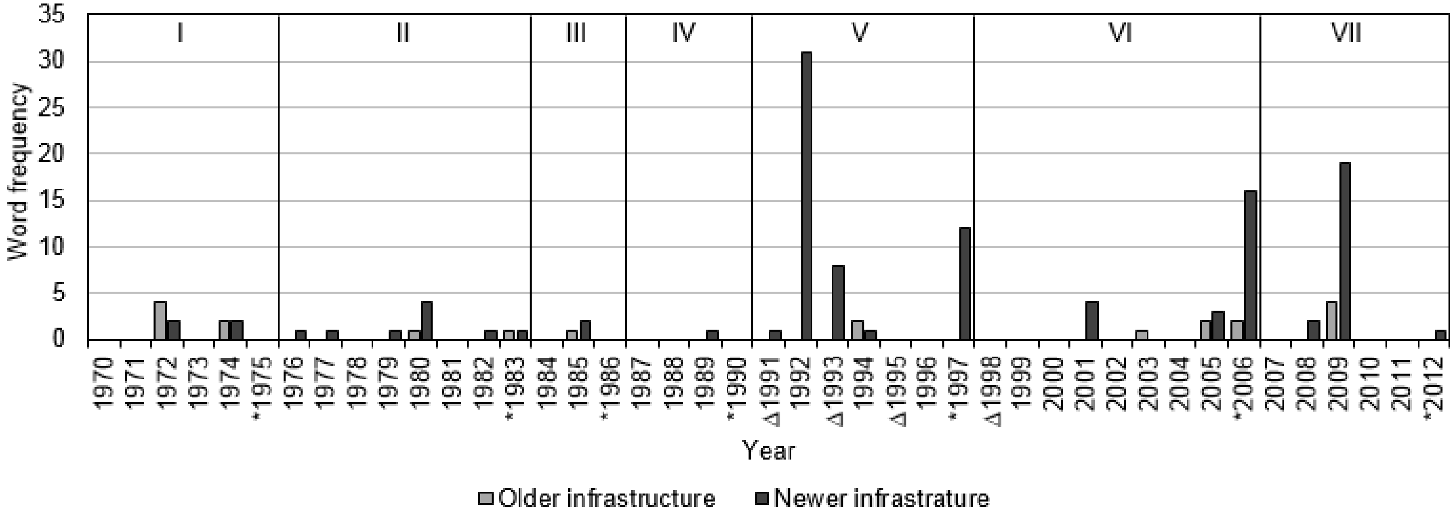
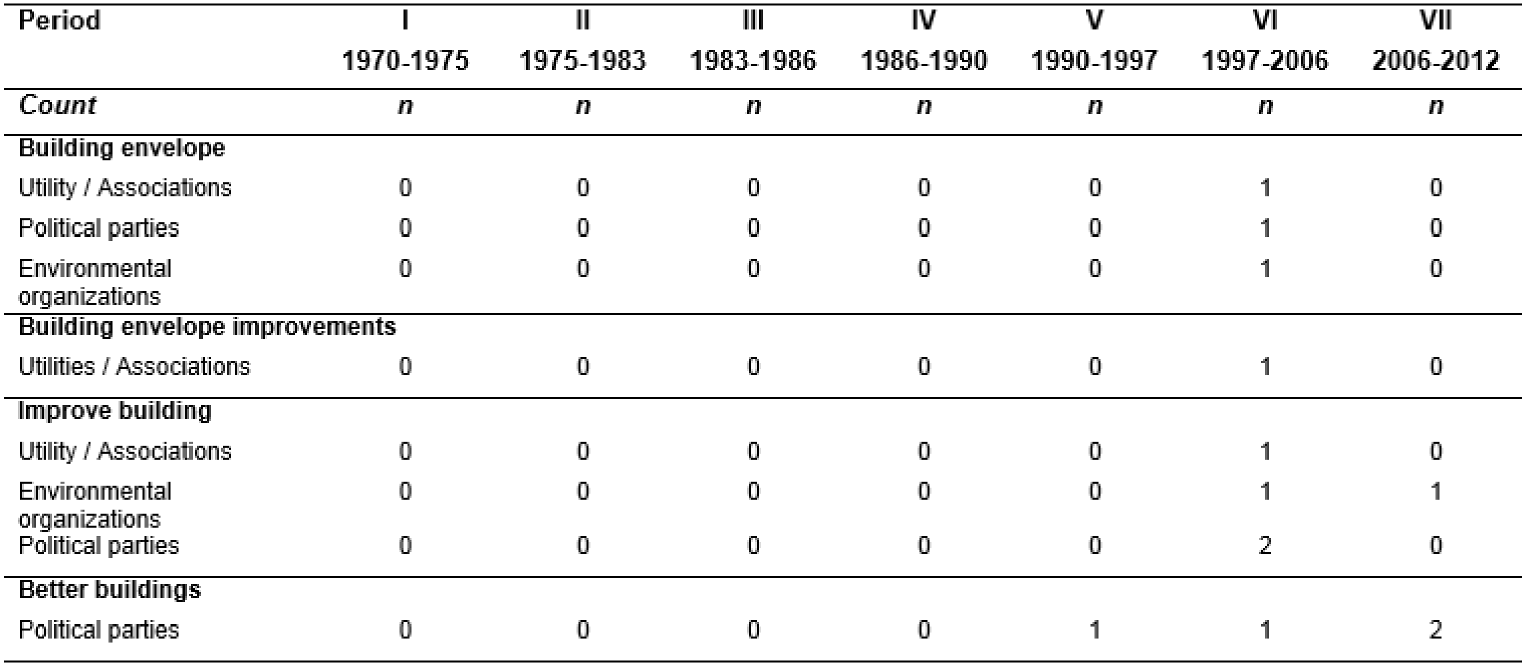


Figure 4.18: Word frequency of older versus newer infrastructure. *Note: older infrastructure includes 'old(er) building(s)', 'old(er) house(s)', and 'old(er) home(s)', newer infrastructure includes 'new building(s)', 'new(er) home(s)', and 'new house(s)'.*

Table 4.3: Discussions on improvements of building envelope and residential infrastructure



Period	I 1970-1975	II 1975-1983	III 1983-1986	IV 1986-1990	V 1990-1997	VI 1997-2006	VII 2006-2012
Count	*n*	*n*	*n*	*n*	*n*	*n*	*n*
Building envelope							
Utility / Associations	0	0	0	0	0	1	0
Political parties	0	0	0	0	0	1	0
Environmental organizations	0	0	0	0	0	1	0
Building envelope improvements							
Utilities / Associations	0	0	0	0	0	1	0
Improve building							
Utility / Associations	0	0	0	0	0	1	0
Environmental organizations	0	0	0	0	0	1	1
Political parties	0	0	0	0	0	2	0
Better buildings							
Political parties	0	0	0	0	1	1	2

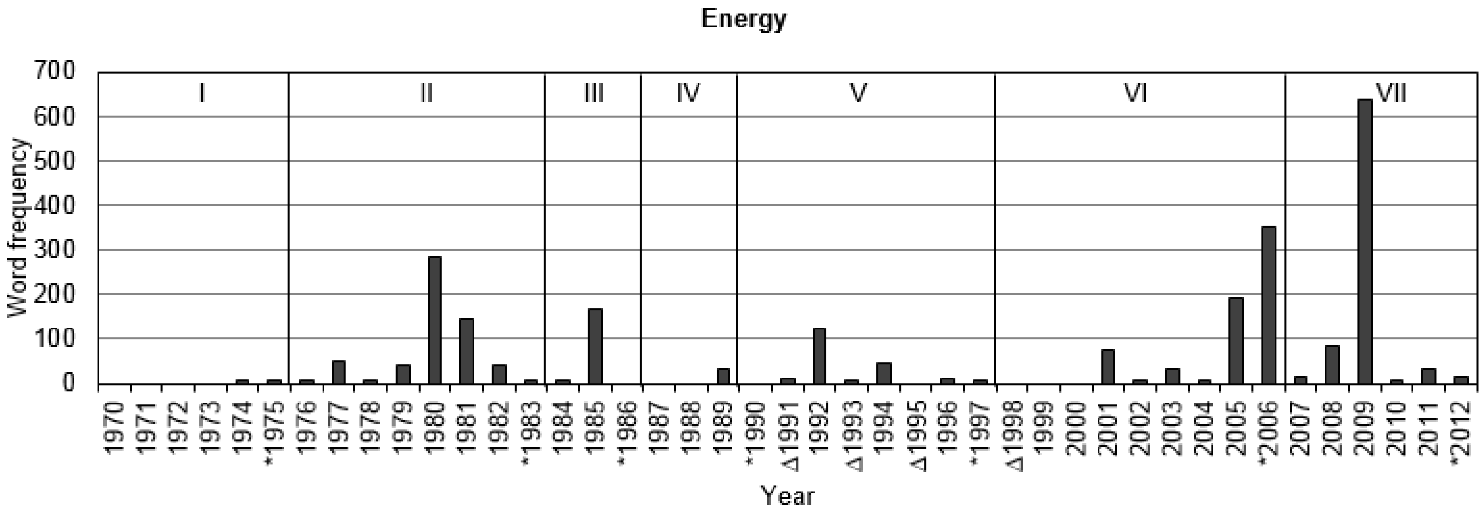


Figure 4.19: Word frequency of ‘energy’.

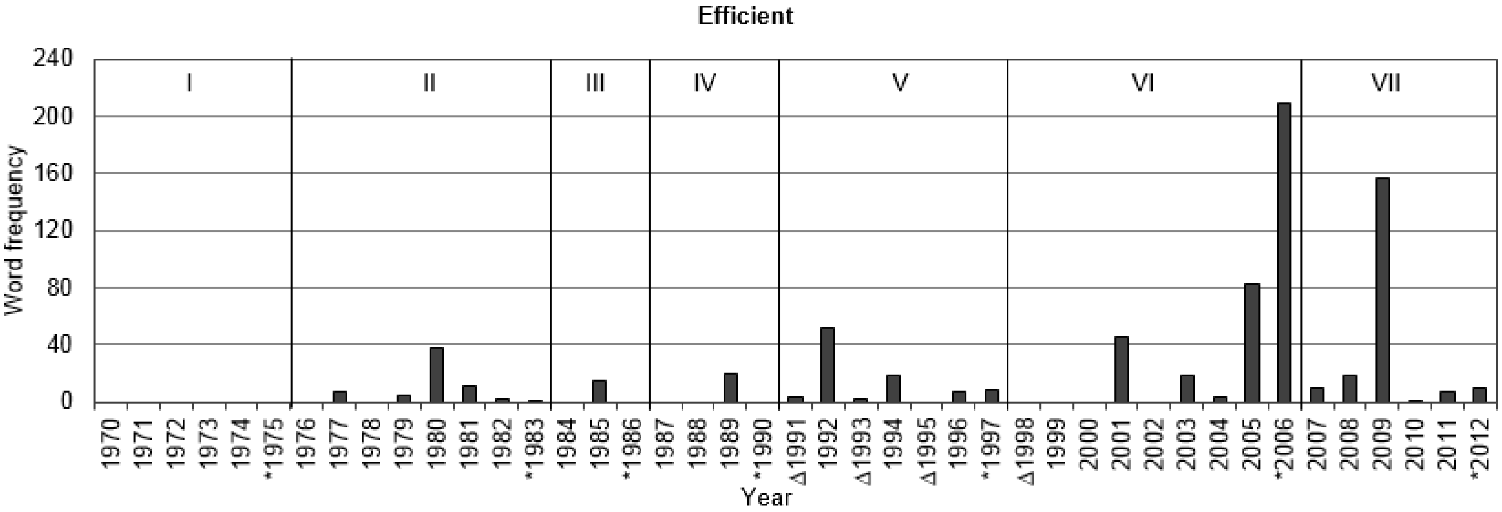


Figure 4.9: Word frequency of ‘efficient’.

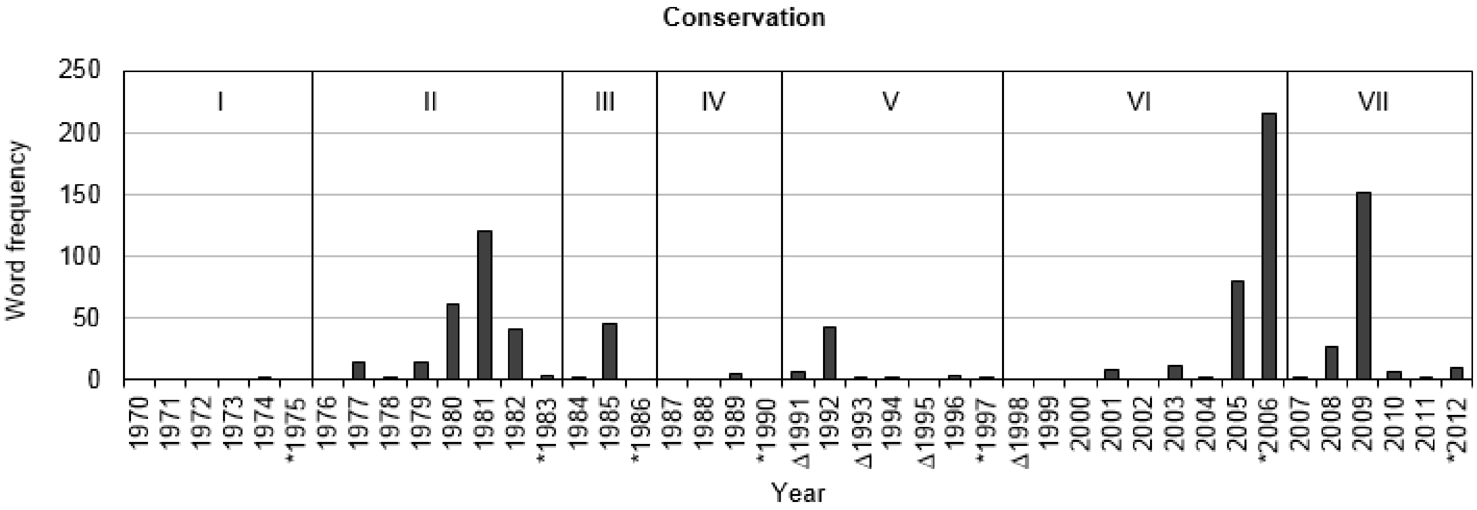


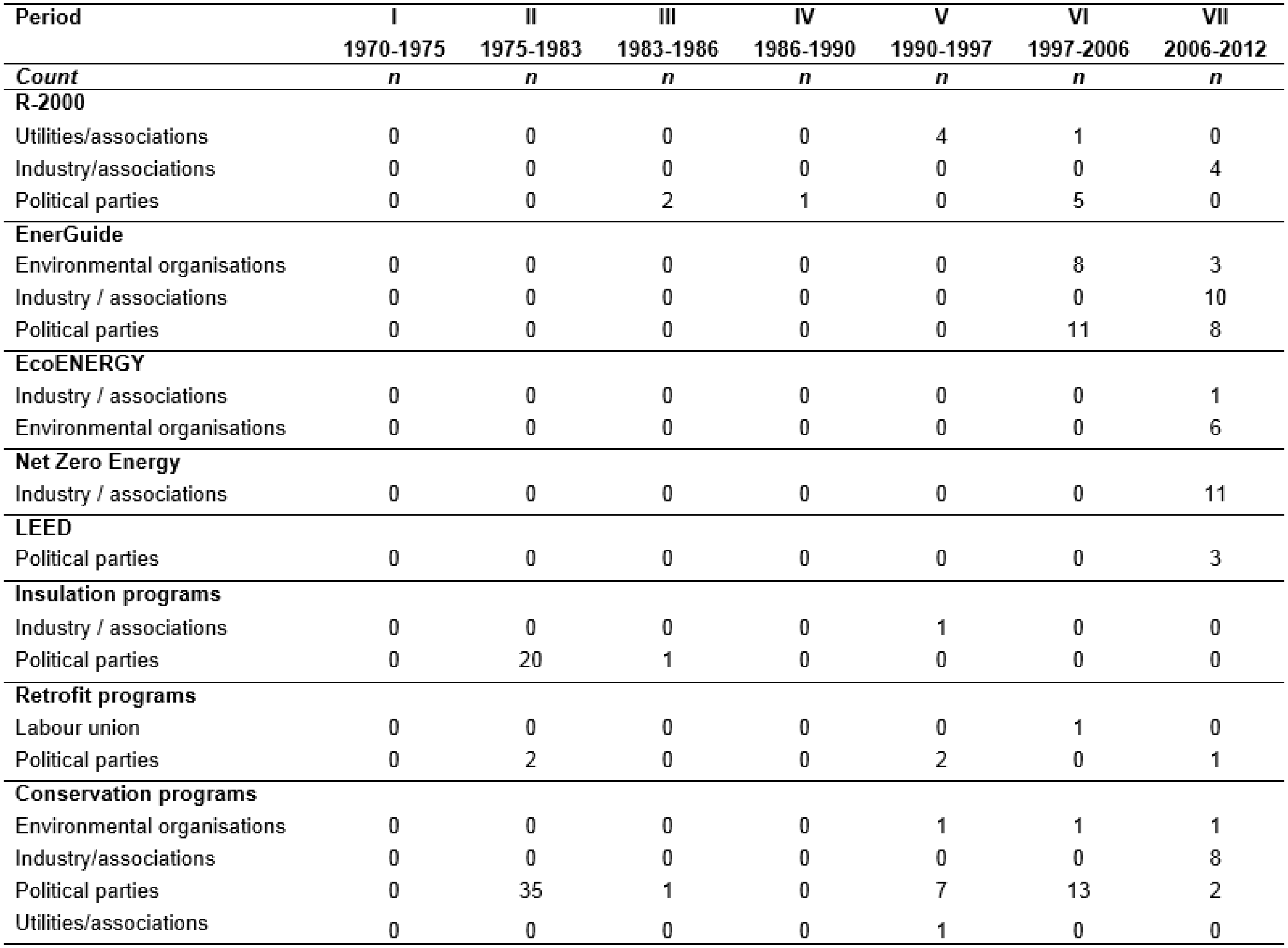
Figure 4.21: Word frequency of ‘conservation’.

Table 4.4: List of programs identified in the Ontario Legislative Assembly documents

1977	Capital Expansion Program of Ontario Hydro Federal/Ontario Home Insulation program
1979	Canadian Home Insulation Program Construction program
1980	Heat Save Energy Conservation Program Canada-Ontario Bilateral Energy Demonstration Program Ontario Home Renewal Program Energy from Waste Program
1982	Big Energy Saving Team Program Alternative Energy Program
1985	HeatSave Program Enersearch Program
1992	Canada Fuel/Oil Substitution Program EnerMark Program Bienergy Program R-2000 Program Off-electric Program Ontario New Home Warranty Program
2003	Efficiency Ontario
2005	Power Smart Program Canadian Building Improvement Program (CBIP) Energy Star Program
2006	EnerGuide for Houses Program EnerStar PST Rebate Program Solar PV Roof Program
2009	Ontario Home Energy Audit Program ecoENERGY Ontario Energy Conservation Program Home Retrofit Program

Source: Legislative Assembly of Ontario, 1972-2012.

Table 4.5: Discussions on different standards and programs



Period	I	II	III	IV	V	VI	VII
	1970-1975	1975-1983	1983-1986	1986-1990	1990-1997	1997-2006	2006-2012
Count	*n*	*n*	*n*	*n*	*n*	*n*	*n*
R-2000							
Utilities/associations	0	0	0	0	4	1	0
Industry/associations	0	0	0	0	0	0	4
Political parties	0	0	2	1	0	5	0
EnerGuide							
Environmental organisations	0	0	0	0	0	8	3
Industry / associations	0	0	0	0	0	0	10
Political parties	0	0	0	0	0	11	8
EcoENERGY							
Industry / associations	0	0	0	0	0	0	1
Environmental organisations	0	0	0	0	0	0	6
Net Zero Energy							
Industry / associations	0	0	0	0	0	0	11
LEED							
Political parties	0	0	0	0	0	0	3
Insulation programs							
Industry / associations	0	0	0	0	1	0	0
Political parties	0	20	1	0	0	0	0
Retrofit programs							
Labour union	0	0	0	0	0	1	0
Political parties	0	2	0	0	2	0	1
Conservation programs							
Environmental organisations	0	0	0	0	1	1	1
Industry/associations	0	0	0	0	0	0	8
Political parties	0	35	1	0	7	13	2
Utilities/associations	0	0	0	0	1	0	0

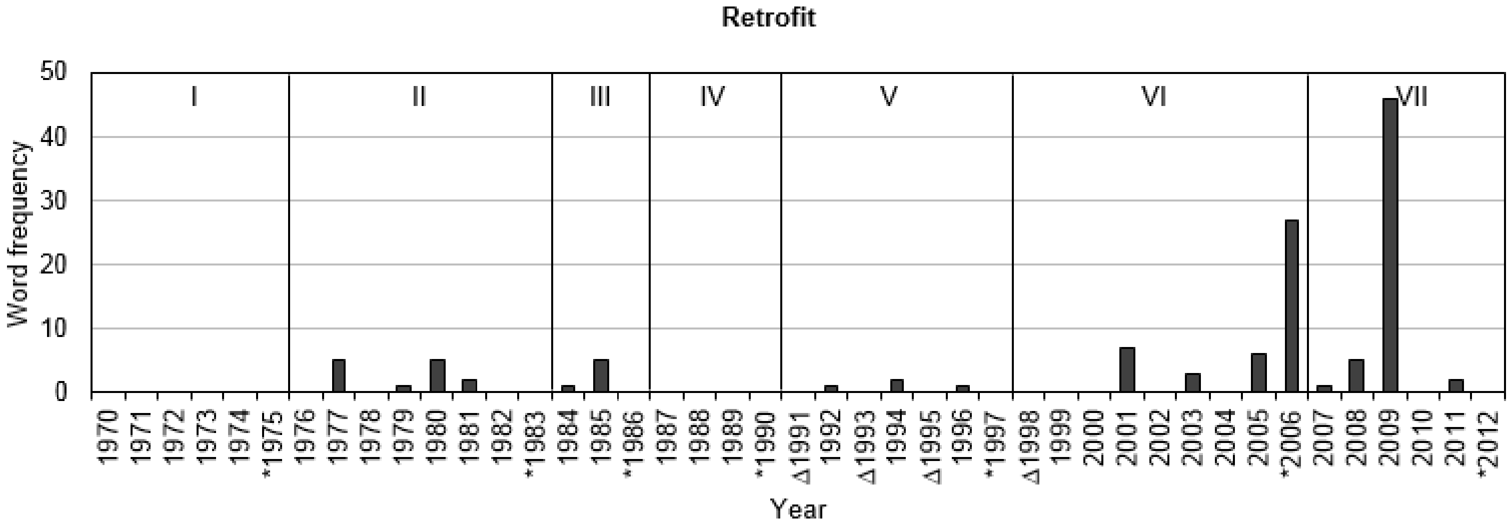
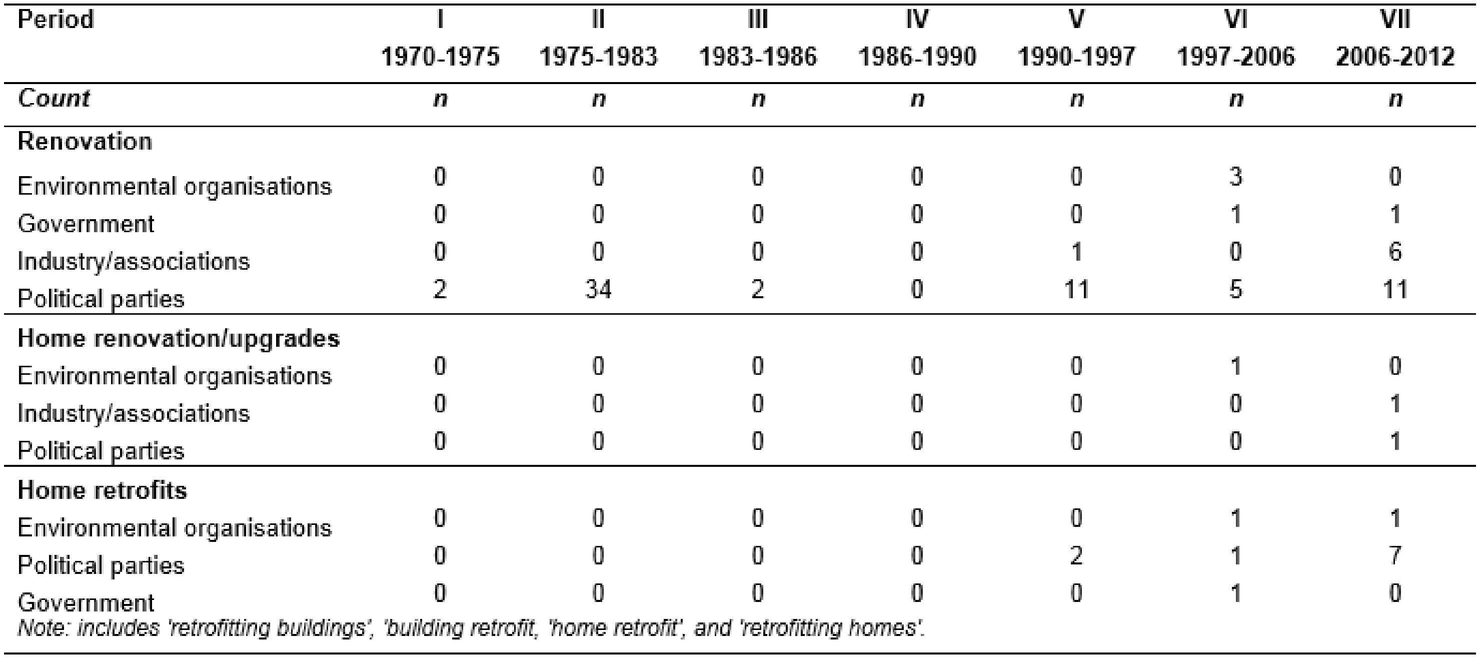


Figure 4.22: Word frequency of 'retrofit'. *Note: includes variations of the word retrofit (i.e.,retrofit,retrofits, retrofitting).*

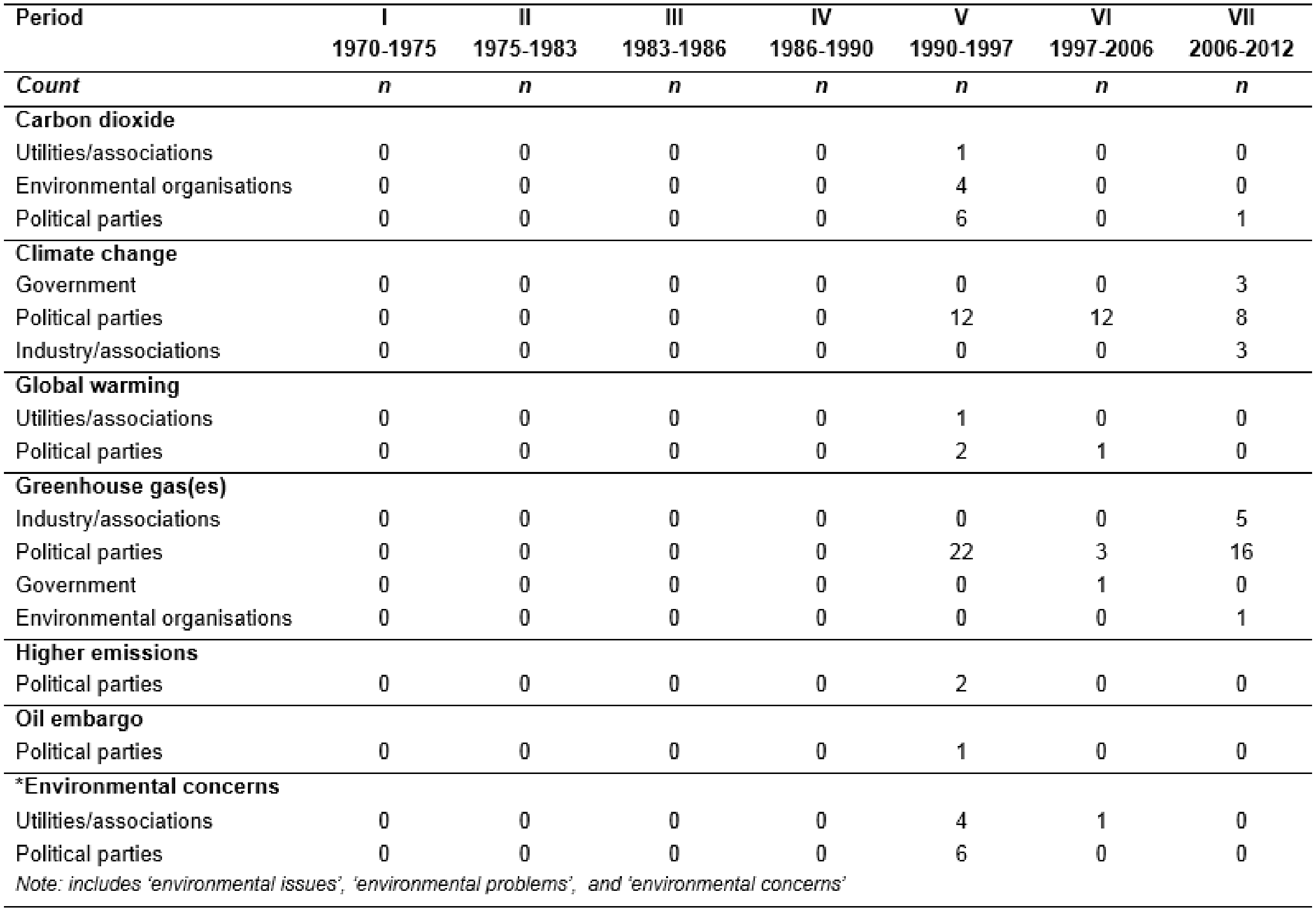
Table 4.6: Discussions on renovation and retrofits in homes and buildings by stakeholders



Period	I 1970-1975	II 1975-1983	III 1983-1986	IV 1986-1990	V 1990-1997	VI 1997-2006	VII 2006-2012
Count	*n*	*n*	*n*	*n*	*n*	*n*	*n*
Renovation							
Environmental organisations	0	0	0	0	0	3	0
Government	0	0	0	0	0	1	1
Industry/associations	0	0	0	0	1	0	6
Political parties	2	34	2	0	11	5	11
Home renovation/upgrades							
Environmental organisations	0	0	0	0	0	1	0
Industry/associations	0	0	0	0	0	0	1
Political parties	0	0	0	0	0	0	1
Home retrofits							
Environmental organisations	0	0	0	0	0	1	1
Political parties	0	0	0	0	2	1	7
Government	0	0	0	0	0	1	0

Note: includes 'retrofitting buildings', 'building retrofit, 'home retrofit', and 'retrofitting homes'.

Table 4.7: Legislative discussions on potential drivers for improved OBCs related to climate change, emissions, and environmental concerns by stakeholders



Period	I 1970-1975	II 1975-1983	III 1983-1986	IV 1986-1990	V 1990-1997	VI 1997-2006	VII 2006-2012
Count	*n*	*n*	*n*	*n*	*n*	*n*	*n*
Carbon dioxide							
Utilities/associations	0	0	0	0	1	0	0
Environmental organisations	0	0	0	0	4	0	0
Political parties	0	0	0	0	6	0	1
Climate change							
Government	0	0	0	0	0	0	3
Political parties	0	0	0	0	12	12	8
Industry/associations	0	0	0	0	0	0	3
Global warming							
Utilities/associations	0	0	0	0	1	0	0
Political parties	0	0	0	0	2	1	0
Greenhouse gas(es)							
Industry/associations	0	0	0	0	0	0	5
Political parties	0	0	0	0	22	3	16
Government	0	0	0	0	0	1	0
Environmental organisations	0	0	0	0	0	0	1
Higher emissions							
Political parties	0	0	0	0	2	0	0
Oil embargo							
Political parties	0	0	0	0	1	0	0
***Environmental concerns**							
Utilities/associations	0	0	0	0	4	1	0
Political parties	0	0	0	0	6	0	0

Note: includes 'environmental issues', 'environmental problems', and 'environmental concerns'

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