The Path to Mass Market Adoption of Net-Zero Energy Homes in Canada

A Major Project submitted to the Faculty of Environmental Studies in partial fulfillment of the requirements for the degree of Masters in Environmental Studies, York University, Toronto Ontario, Canada

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Foreword

This major project relates directly to my plan of study as it directly addresses the three key components of renewable energy, urban planning, and affordability of energy efficient housing. The focus of my plan of study was to understand how the three components intersect. The topic of my major paper explores the intersection of the three components by exploring how Net-Zero Energy housing will become a reality in Canada, and specifically the costs associated with constructing solar photovoltaic equipped Net-Zero Energy housing now and over time.

Introduction

The pursuit of Net-Zero Energy has been long and tireless. It has been a worthwhile pursuit, as it is no longer a question of if Net-Zero Energy will become a reality, but a question of when. The later, will be much faster than most of us expect. The reward for decades of effort will be outstanding not only for the vast improvement in housing, but for the major reduction in greenhouse gases that will significantly reduce the impact humanity has on earth for future generations.

Abstract

The purpose of this Major Paper is to demonstrate how Net-Zero Energy will become the next best practice for energy efficiency among Canadian production home builders. A combination of ambitious climate change targets, falling solar photovoltaic prices, Provincial Building Code changes, and flexible electricity rates have created the a situation where Net-Zero Energy is no longer a far out goal but a fast approaching reality. Through examining a carefully chosen collection of relevant sources on the topic this paper will demonstrate why, how, and when Net-Zero Energy will become reality in Canada.

Chapter 1: Canadian Energy Efficiency Programs

1.1 Energy Efficient Mass Production Homes Today

In Canada, energy efficiency programs have been the catalyst by which the vast majority of energy efficient homes have been constructed. Currently, the most prevalent energy efficiency program in Canada is ENERGY STAR. As of 2014, over 32 percent of new construction homes in Ontario were ENERGY STAR certified (EnerQuality, 2016, What's ENERGY STAR for New Homes?). Energy efficiency programs in Canada, like ENERGY STAR, set to achieve a higher level of energy efficiency then mandated by Canadian building codes. ENERGY STAR qualified homes consume 20 percent less energy than a home constructed to building code standards of energy efficiency (Natural Resources Canada, 2016, What is an ENERGY STAR home?).

1.2 Energy Efficient Home Certification

Construction of an energy efficient home certified under an energy efficiency program, similar to ENERGY STAR, involves two major requirements. First, the home must be constructed by home builders who are licensed by the Government of Canada, and that have been trained by service organizations certified by the Government of Canada (Natural Resources Canada, 2016, What sets an ENERGY STAR home apart?). Second, the home must meet the required level of energy efficiency set out by the energy efficiency program; which is verified by the service organizations certified by the Government of Canada (Natural Resources Canada, 2016, What sets an ENERGY STAR home apart?). Once the home is verified to have met the above requirements it is given a label and issued a certificate by the Government of Canada (Natural Resources Canada, 2016, What sets an ENERGY STAR home apart?).

1.3 History of Energy Efficient Homes in Canada

Energy efficiency programs in Canada began in the mid 1970's with the R-2000 level of energy efficiency (Canadian Home Builders Association, 2016, A Brief History of R-2000). The first R-2000 homes were built in Saskatchewan, with a goal of constructing a home that would use less energy than a conventional home, while not compromising on health and comfort (Canadian Home Builders Association, 2016, A Brief History of R-2000). The first R-2000 homes built is Saskatchewan resulted in the "house as a system" concept which noted how all components of the R-2000 home functioned together, and how a change in one component of the home may disturb another (Canadian Home Builders Association, 2016, A Brief History of R-2000). Based on the research conducted on the Saskatchewan homes, R-2000 was officially created and formalized in 1981 as a partnership between the Canadian Home Builders' Association and Natural Resources Canada (Canadian Home Builders Association, 2016, A Brief History of R-2000). Since 1981, R-2000 has remained the most ambitious energy efficiency standard to achieve, through periodical updates to the standard ensuring that R-2000 remains at the forefront of energy efficient construction technology (Canadian Home Builders Association, 2016, A Brief History of R-2000).

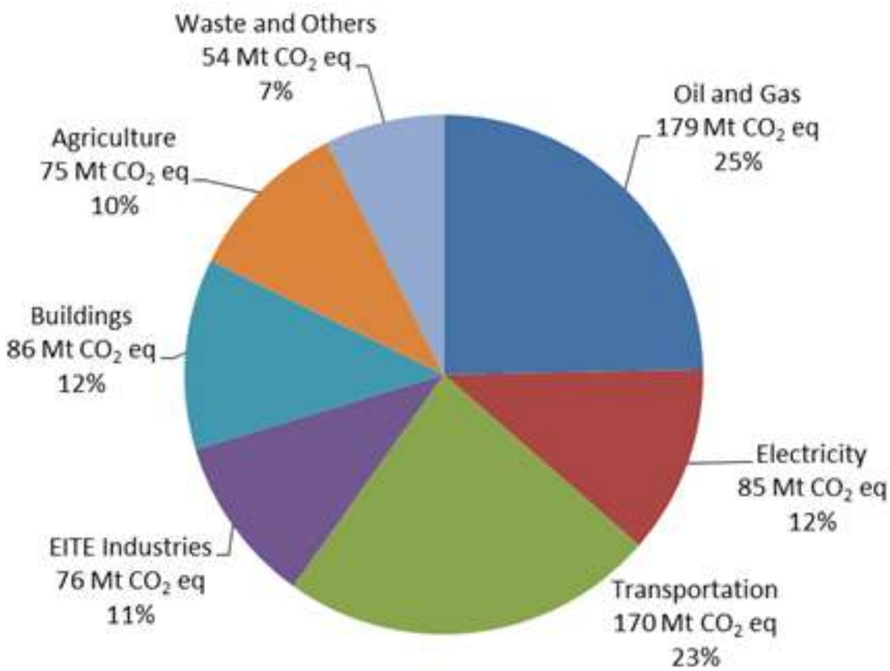
1.4 Success of Energy Efficiency Labelling in Canada

While R-2000 has and continues to be a leader in the research and labelling of energy efficiency homes, it has failed to be adopted by mass production home builders. Since 2013, 14,500 R-2000 homes have been built, which amounts to 0.5% percent of homes constructed since that time (Oding, 2015). While the numbers are not insignificant, they are not market transformative. It is widely agreed upon that this is due to the high costs associated with constructing a home to R-2000 standards. In 2005 ENERGY STAR was unveiled as a low cost energy efficiency program that would appeal to mass production home builders (Natural Resources Canada, 2016, What is ENERGY STAR?). Since 2005, the percentage of new homes constructed in Canada built to the ENERGY STAR standard continues to grow and as of 2014, 32 percent of new homes constructed in Ontario are ENERGY STAR certified (EnerQuality, 2016, What's ENERGY STAR for New Homes?). The success of ENERGY STAR highlights the market demand for affordable energy efficient homes among mass production builders and home buyers.

Chapter 2: A Look into the Future

2.1 Housing and Climate Change in Canada

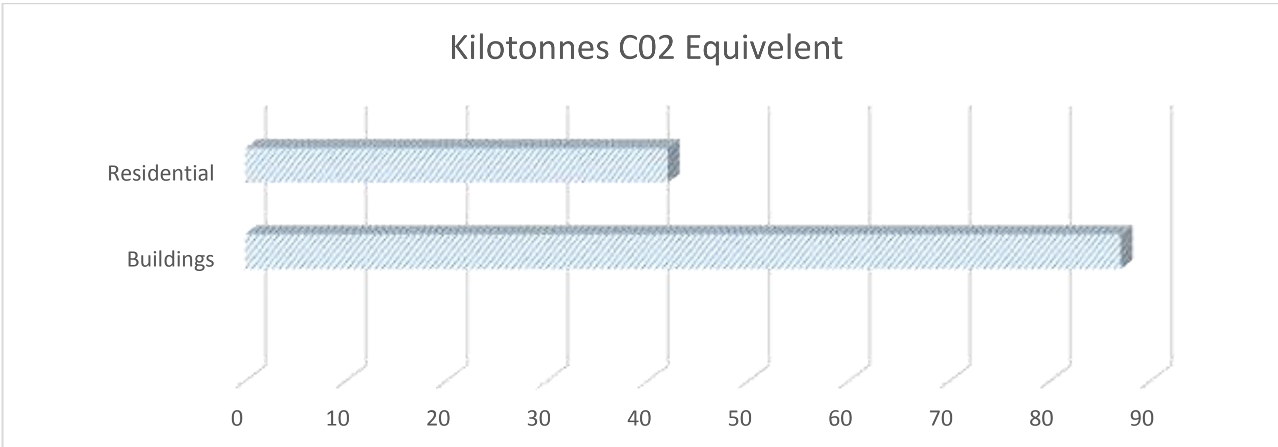
While energy efficiency programs have gone a long way to decrease the energy consumption of Canadian homes, housing in Canada remains a significant contributor to climate change. In Canada, 12 percent of carbon emissions or 86 Mt CO2 was generated from buildings in 2013 (Environment and Climate Change Canada, 2016, Table 5-2: Detailed Emission Projections by Economic Sector – 2005 Base Year).



(Environment and Climate Change Canada, 2016, Figure 2-2: Canada's 2013 Emissions Breakdown by Economic Sector)

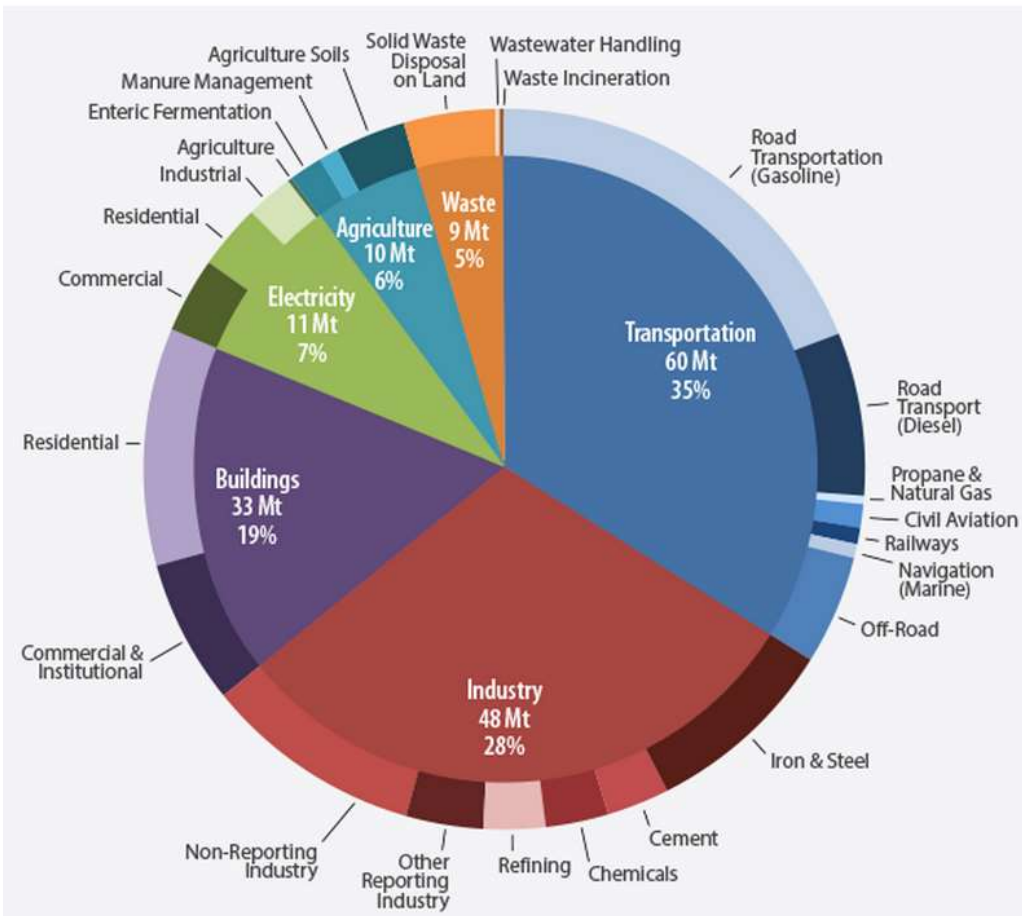
In 2005 residential housing contributed 42 Mt CO2 of the 87 Mt CO2 emitted from buildings or 48 percent (Statistics Canada, 2016, Table 1.3 Canada's greenhouse gas emissions).

Thus, it can be concluded that in 2005, 5.76 percent of total carbon emissions in Canada was generated from residential sources.



2.2 Housing and Climate Change in Ontario

Ontario has recognized the need to participate in the national effort to reduce carbon emissions in effort to, “avoid a 2°C rise in average global temperatures. If the world does not take strong action within the next decade, we are on track to see a 4°C rise, at which point the damage from climate change would be irreversible” (Ontario, 2016, Global Priority). As a result, Ontario has set a long term target to reduce greenhouse gas emissions by 80 percent below 1990 levels by 2050 (Ontario, 2016, Ontario's Climate Change Strategy). In addition, Ontario has created a mid-term target to reduce greenhouse gas emissions by 37 per cent below 1990 levels by 2030 (Ontario, 2016, Reaching 37 Percent by 2030). In Ontario, buildings contribute more to climate change than the national average. Ontario’s buildings represent it’s third-largest source of emissions totaling 19 percent of the province’s total greenhouse gas emissions or 24 percent if electricity used by equipment and appliances in buildings is included (Ontario, 2016, Reducing Greenhouse Gas Emissions Across Key Sectors). As a result Ontario's action plan has set aside between $180,000,000 and $220,000,000 for, "individuals who purchase or build their own near net zero carbon emission homes, with energy efficiency performance that sufficiently exceeds the requirements of the Building Code." (Ontario, 2016, Climate Change Strategy)



(Ontario, 2016, Reducing Greenhouse Gas Emissions Across Key Sectors).

2.3 Ontario's Building Code and Climate Change

Updates to the Ontario Building Code reflect the provinces goal to reduce greenhouse gas emissions from the buildings sector and have subsequently set ambitious targets for energy efficiency to be implemented in the year 2017. Reed notes, “As a result of the Code’s evolution, new houses constructed in 2017 will, according to the Ministry of Municipal Affairs and Housing, consume 50% less energy than homes built before 2006, and large buildings will only consume 65% of what they did before 2006” (Reed, 2014).

2.4 The Case for Net-Zero Energy Homes

As a result of the 2017 updates to the Ontario Building code, energy efficiency programs in Ontario will need to adapt. The 20 percent better than code level of efficiency that ENERGY STAR is designed upon will need to be extensively restructured, and it is very possible a 20 percent improvement on 2017 building codes will no longer be economically feasible for mass market home builders. The more stringent R-2000 level of energy efficiency is fast approaching building code, demonstrating the need for Net-Zero Energy.

The combination of Ontario’s ambitious climate change targets, and specifically targeted reductions from Net-Zero Energy buildings in combination with Ontario’s 2017 building code enhancements will unquestionably be transformative for energy efficiency programs and energy efficiency construction in both Ontario and Canada (Ontario, 2016, Ontario's Climate Change Strategy/ Reed, 2014). A Net-Zero Energy level of energy efficiency is no longer lofty goal for mass market production homes, it is now a fast approaching reality.

Chapter 3: What makes a Net-Zero Energy House?

3.1 Defining Net-Zero Energy

In order to define what makes a Net-Zero Energy house, it is useful to first explore the myriad of definitions that exist, and reach a consensus on the definition of the term.

The word net has multiple definitions, however for the purposes of this paper it is defined only as, "an amount remaining after a deduction"; and the word zero is defined as, "no quantity or number; naught; the figure 0; or a point on a scale or instrument from which a positive or negative quantity is reckoned" (Oxford Dictionary, 2016). Taken together the term Net-Zero is defined for the purpose of this paper as equaling nothing.

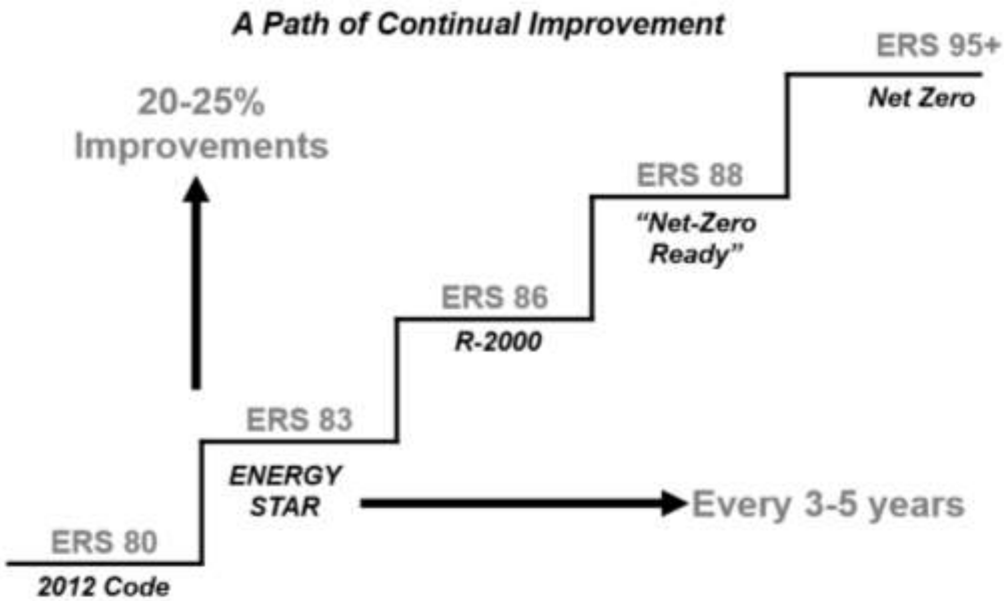
The term Net-Zero is widely used to describe energy efficient buildings built to various standards. Further, the terms Net-Zero, Net-Zero Energy, and Net-Zero Carbon are often used interchangeably, when in fact they each have very different meanings. When the word Net-Zero is combined with Energy to create the term Net-Zero Energy, the word is defined as, "an energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy" (Office of Energy Efficiency and Renewable Energy, 2016). The term Net-Zero Energy should not be confused with Net-Zero Carbon or any variation of the term, as it may either refer to the building emitting no carbon over a period of time or no carbon being emitted in the construction of the building, which is much more expensive and environmentally responsible standard to achieve.

The term Net-Zero Energy can be further complicated as various institutions may attach conditions to the definition. For the remainder of this paper the definition and conditions of Net-Zero Energy offered by The Canadian Home Building Association Net-Zero Council will be used. Net-Zero Energy for the remainder of this paper is defined as, “a home that is designed, modeled, and constructed to use as much energy as it consumes on an annual basis” (Oding, 2015). The definition contains the following four conditions (Oding, 2015):

1) The home is not Net-Zero Energy “as operated” but uses assumptions for occupant consumption (Plug/occupant loads are between 1/2 to 2/3 of total energy use)
2) The energy produced is generated on-site and renewable
3) Net-Zero Energy can be achieved via net-metering and/or battery storage
4) It includes all forms of energy (i.e. passive and thermal) including acknowledgement of gas and base loads.

3.2 EnerGuide Ratings and Net-Zero Energy

In Canada, in order for an energy efficient home to be certified under an energy efficiency program, it must meet the required EnerGuide rating. Currently, building code mandates a minimum EnerGuide rating of 80 (Oding, 2015). In order for a house to be certified Net-Zero Energy it must meet a minimum EnerGuide rating of 95 (Oding, 2015). The difference in the rating is made up of a variety of improved building materials, methods, and designs.



(Oding, 2015)

It is important to note that as of 2017 the Energy Rating System will use GJ rather than the EnerGuide ratings to measure energy efficiency. The 2017 GJ requirements have not yet been released, thus this paper has chosen to use the existing EnerGuide rating system.

3.3 Net-Zero Dwelling Types

It is possible to adapt the Net-Zero Energy level of energy efficiency to not only conventional homes, but a variety of dwelling types. It is likely that the Net-Zero Energy program will be designed for all standard residential buildings listed included in Part 9 of the national building code (Oding, 2015). These buildings include (Oding, 2015):

1) Detached houses; including houses with secondary suites
2) Attached houses, including semi-detached houses, row houses, and attached houses with secondary suites

3) Multi-unit residential buildings (MURB's) up to 4 stories in height, which include stacked townhouses, duplexes, triplexes, and apartment buildings (have other special compliance requirements)

Despite not knowing with certainty if or when Net-Zero Energy labelling for high-rise buildings will be brought to market at the time of writing, the private sector has shown tremendous interest. Tridel in partnership with the MaRs institute have developed the first Canadian Net-Zero Energy high-rise dwelling unit which has been named netZED (Net-Zero Energy Dwelling) (netZED, 2016). Although the unit has not been developed with the purpose of achieving Net-Zero Energy requirements set out by the Canadian Homebuilders Association, it is likely that once the requirements are officially released netZED will surpass them. Once the Canadian Homebuilders Association does release the requirements for Net-Zero Energy labelling, Tridel will be well equipped to bring Net-Zero Energy high-rise units to the mass market.

3.4 Net-Zero Energy Home Components

In order to achieve the level of energy efficiency required for Net-Zero Energy, improvements over building code are required to most or all of the following elements of the home (Oding, 2015):

1) Electrical baseloads including lights and appliances
2) Domestic hot water
3) Windows

4) Air Barriers

5) Walls and opaque assemblies

6) Mechanicals including heating and cooling

7) Ventilation

8) Renewables

9) Energy Storage

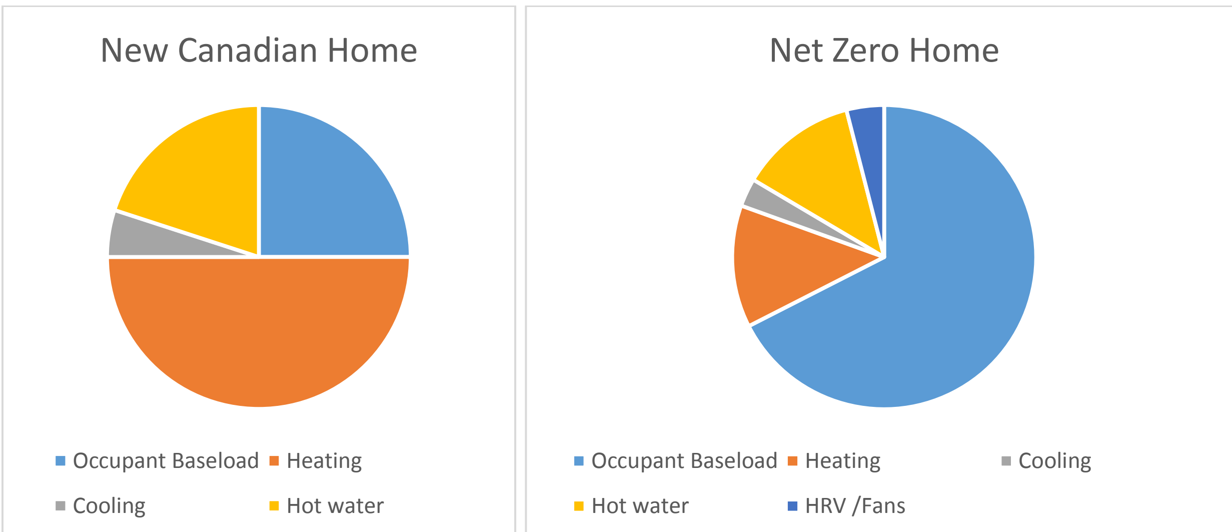
In addition to the elements listed above, in order for a home to be cetrified Net-Zero Energy it will be required to have a dashboard (Oding, 2015). A dashboard, as it pertains to Net-Zero Energy homes, is an electrical device that displays real time energy consumption and if applicable, energy production of the home (Oding, 2015). It is likely that that Net-Zero Energy homes will either come equiped with a dashboard, or an app will be available allowing the homeowneers existing electronic devices to function as the dashboard, or both options will be available. As noted by Oding, “the ability to compare with neighbours or other users has proven very effective in altering behaviour” (Oding, 2015)

3.5 Home Energy Use

Combined, improvements to the aformentioned 9 elements transform the energy consumption of the home. Compared to a code built house, the energy use breakdown is far different (Oding, 2015).

New Canadian Home		Net-Zero Home	
Occupant Baseload	25%	Occupant Baseload	68%
Heating	50%	Heating	13%
Cooling	5%	Cooling	3%
Hot water	20%	Hot water	13%
HRV /Fans	0%	HRV /Fans	4%

(Oding, 2015)



(Oding, 2015).

3.6 Electrical Base Loads

Electrical baseloads including lights and appliances are crucial to achieving a Net-Zero Energy home (Oding, 2015/ Net-Zero Initiative, 2016). To achieve Net-Zero Energy electrical baseloads must be dramatically reduced compared to a code built house. The energy savings from electrical baseloads in Net-Zero Energy homes will be the result two parts. The first is the Net-Zero Energy home itself, which will make use of LED lighting and efficient ENERGY STAR appliances (Oding, 2015). The second is the homeowner, and their awareness of the energy use of the various components, appliances, and devices within their home. This awareness will increase over time and alter homeowner's energy use as the homeowner becomes familiar with the home's dashboard and the effects using specific components, appliances, and devices has to the energy consumption displayed on the dashboard (Oding, 2015).

3.7 Domestic Hot Water

Domestic hot water is vital component of a Net-Zero Energy home (Oding, 2015/ Net-Zero Initiative, 2016). Traditional domestic how water consumes a significant portion of a home's energy (see page 12) (Oding, 2015). In order for a home to achieve Net-Zero Energy the energy required for domestic hot water must be reduced substantially (Oding, 2015). This is made possible through the use of either a condensing tank type of hot water heater with 80% or above efficiency or a tankless (instantaneous) hot water heater (Oding, 2015). These hot water heating systems may be used in conjunction with a solar water heater or a drain water heat recovery system which heats water entering the home with the water exiting the home (Oding, 2015).

3.8 Windows

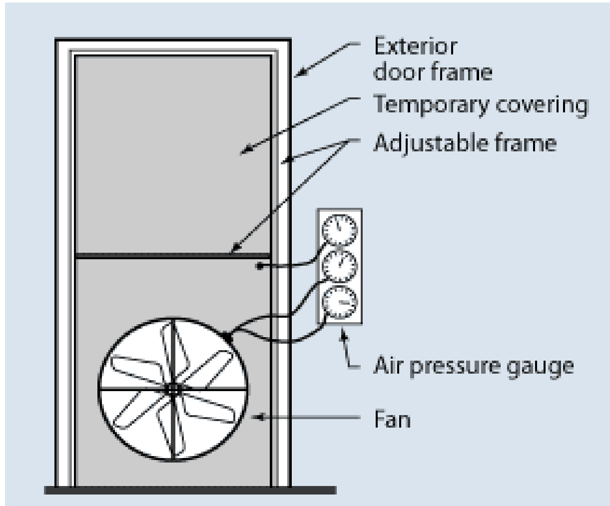
Windows are a central element of a Net-Zero Energy home (Oding, 2015/ Net-Zero Initiative, 2016). Windows are often one of most inefficient parts of a home and are a major contributor to heat loss and excess energy consumption (Oding, 2015). Thus, in order to achieve Net-Zero Energy windows must be highly efficient. Current research on window efficiency outlines 9 components of an energy efficient window.

1. Gas Filled
2. Low-Emissivity
3. Multiple Glazing's
4. Insulated Frames
5. Integrated Blinds
6. Super Insulated Spaces
7. Vacuum Glazing
8. Composite Frames
9. Electrochromic Glazing's

Although the Canadian Homebuilders Association has not yet released Net-Zero Energy home window requirements at the time of writing, it is likely that they will require windows to include the components listed above (Oding, 2015).

3.8 Air Barriers

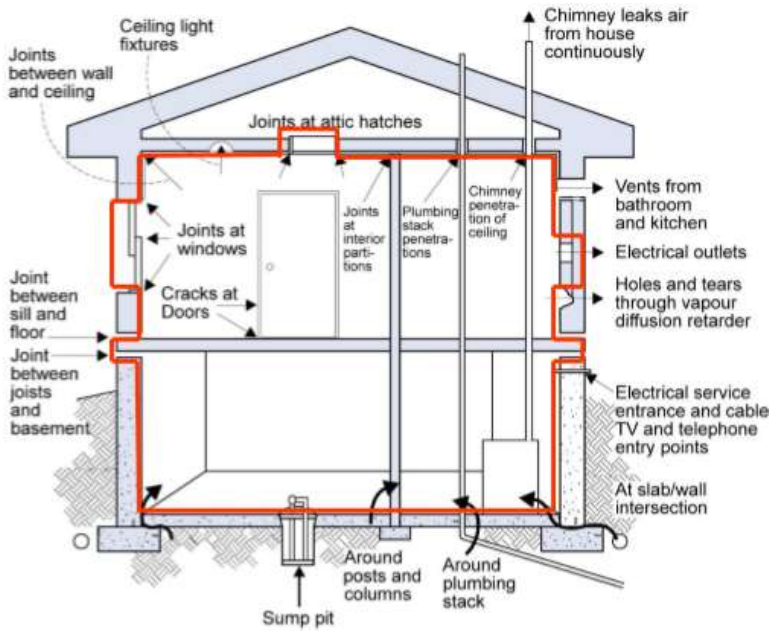
Air Barriers are the fourth integral component of a Net-Zero Energy house (Oding, 2015/ Net-Zero Initiative, 2016). A Net-Zero Energy home's air barriers are tested through air leakage which is measured by a blower door test (Oding, 2015/ Energy Saver). A blower door test uses a fan to draw air out of the front door of the house and measure the subsequent pressure within the home (Energy Saver, 2016).



(Energy Saver, 2016)

A typical home has air leakage of between 15% and 20% (Oding, 2015). Although the Canadian Homebuilders Association has not yet released Net-Zero Energy home air tightness requirements at the time of writing, it is likely that the requirement will be an air tightness of 1% (Oding, 2015). It is important to note that under the new Net-Zero Energy guidelines air leakage may be measured in air changes rather than in percentage.

There is no single best method for constructing air barriers in homes, however four common approaches can be identified: the sealed polyethylene approach, the airtight drywall approach, the exterior insulation approach, and the house wrap approach (Oding, 2015). Each of these approaches are often used in conjunction with one another and each has benefits and drawbacks (Oding, 2015). Regardless if one or multiple air barrier approaches are used, the system as a whole must perform in four specific area's including continuity, durability, strength, and air impermeability (Oding, 2015). A key principle in each of the approaches is to reduce and better insulate the number of interior and exterior intersections (places where two or more materials meet) in the home as can be observed below (Oding, 2015).



(Oding, 2015)

3.9 Walls and Opaque Assemblies

Walls and opaque assemblies are a critical component to Net-Zero Energy homes (Oding, 2015/ Net-Zero Initiative, 2016). Wall and opaque assemblies are measured on their R value, which measures insulation properties (Canadian Mortgage and Housing Corporation, 2016). According to the Canadian Mortgage and Housing Corporation, “R values and their metric equivalent, RSI values, are a way of labelling the effectiveness of insulating materials. The higher the R value or RSI value, the more resistance the material has to the movement of heat” (Canadian Mortgage and Housing Corporation, 2016). A homes R value is not assessed in its entirety, specific components of the home must be constructed to meet specific R values including: attic, windows, walls, below grade walls, and below grade slab (Oding, 2015). Although the Canadian Homebuilders Association has not yet released Net-Zero Energy R value requirements at the time of writing, it is likely that they will require above existing R-2000 standards.

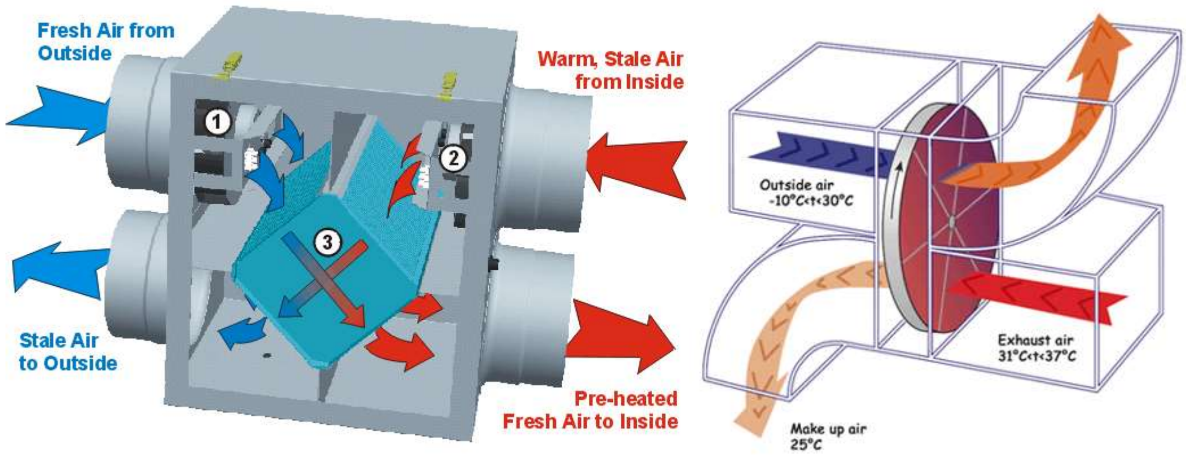
3.10 Mechanicals

Mechanicals including heating and cooling are an important element to a Net-Zero Energy Home (Oding, 2015/ Net-Zero Initiative, 2016). Research has shown that a variety of high efficiency heating and cooling systems work well in Net-Zero Energy homes in either gas or electric configurations (Oding, 2015). Further, the same research has demonstrated that gas and electric combination systems perform well (Oding, 2015). Findings have shown that the system design is far more important in increasing efficiency than choice of the heating/cooling unit (Oding, 2015). Distribution of heating and cooling must be taken into account when designing the home and choosing the right unit (Oding, 2015). Research has shown that floor register ducts are highly inefficient at heating/cooling rooms, as they result in a large portion of the room to remain with stagnant air flow (Oding, 2015). High wall ducts and low wall air returns have proven to be a much more efficient method at heating/cooling rooms resulting in less load on the system and increased efficiency (Oding, 2015). Additionally the high efficiency heating/cooling system must be accompanied with a smart control system or be available on the homes dashboard allowing the homeowner to view consumption and cost of consumption (Oding, 2015). This will allow the homeowner to adjust the thermostat to adjust the temperature to either increase or decrease (depending on outside temperature) when they are not home for an extended period of time to further increase efficiency (Oding, 2015).

3.11 Ventilation

Ventilation is a critical component to Net-Zero Energy homes (Oding, 2015/ Net-Zero Initiative). Natural ventilation is an inadequate form of ventilation for Net-Zero Energy homes (Oding, 2015). Net-Zero homes are designed to minimize natural ventilation in order to increase efficiency (Oding, 2015). The main purpose of minimizing natural ventilation is too limit heat loss (Oding, 2015/ Dodoo, Gustavsson, & Sathrae, 2011). Another reason for limiting natural ventilation is that it will not be provided unless pressure differences are at work (Oding, 2015). Further, natural ventilation is unable to remove high moisture and contaminant loads from the home (Oding, 2015). Additionally, natural ventilation often produces cold drafts and subsequent discomfort during winter months (Oding, 2015). Lastly, with natural ventilation is not evenly distributed resulting in a home where some areas are poorly ventilated and other areas are over ventilated (Oding, 2015).

As an alternative to natural ventilation Net-Zero Energy homes use either Heat Recovery Ventilators or Energy Recovery Ventilators (Oding, 2015). The terms Heat Recovery Ventilator and Energy Recovery Ventilator are often used interchangeably, however the two systems do not work in the same way (Healthy House Institute, 2016). Heat Recovery Ventilators exchange only heat whereas Energy Recovery Ventilators exchange heat and moisture (Healthy House Institute, 2016).



Heat Recovery Ventilator Diagram (Left) Retrieved from: http://www.prostar-mechanical.com/HRV/Greentek%20HRV.htm
Energy Recovery Ventilator Diagram (Right) Retrieved from: http://tomsptpassivehouse.blogspot.ca/2011/06/energy-recovery-ventilator.html

The better system for a Net-Zero Energy home depends on climate and home design (Oding, 2015). Research has shown that recovery ventilator systems can reduce the total energy for space heating by 20 to 50%, depending on building type and airtightness (Dodoo, Gustavsson, & Sathrae, 2011). When combined with efficient heating/cooling systems and well-insulated air-tight and insulated homes, Heat Recovery Ventilators and Energy Recovery Ventilators can significantly improve the energy efficiency of a home (Oding, 2015/ Dodoo, Gustavsson, & Sathrae, 2011).

3.12 Renewables and Energy Storage

Renewables are a core component of Net-Zero Energy Homes (Oding, 2015). Without renewables a home could not achieve Net-Zero Energy, as renewables are needed to offset the energy consumption of the home over a yearly basis. Solar is by far the most common renewable energy for residential applications (Oding, 2015/ Natural Resources Canada, 2016, Solar Photovoltaic Energy in Buildings). Electricity generated from solar is sold back to the grid through either Net-Metering or the MicroFIT program (Oding, 2015).

Under the MicroFIT program a homeowner is paid a guaranteed price for the electricity they produce and deliver back into the electricity grid for a 20 year period (Power Authority, 2016). The program is designed for projects under 10 Kw and intended to cover the cost of the installation and provide the homeowner with a reasonable rate of return on their investment (Power Authority, 2016, about microFIT). Thus, the rates paid to homeowner change periodically to reflect ever decreasing costs of solar photovoltaic systems and increasing electricity rates (Power Authority, 2016, Version 1/4 Generation Payments). During Version 1 of the microFIT program, homeowners were paid $0.802 cents per Kwh generated, currently microFIT is at Version 4 and pays homeowners $0.313 per Kwh generated (Power Authority, 2016, Version 1/4 Generation Payments). Unfortunately, the microFIT program is not suitable for mass production homes and is geared to one off residential or commercial applications (Power Authority, 2016, Who Can Apply).

Net-Metering is the most feasible option for mass production Net-Zero Homes (Oding, 2015). Net-Metering allows homeowners to sell excess electricity that they generate back into the electricity grid for a credit towards energy costs (Ontario Energy Board, 2016). Essentially energy supplied is traded for energy consumed (Ontario Energy Board, 2016). If the homeowner consumes more electricity than produced they pay the difference (Ontario Energy Board, 2016). If a homeowner produces more than they consume they can carry credits forward for 12 months towards future bills in months where their solar photovoltaic system is not as efficient (Ontario Energy Board, 2016).

The issue of whether net-metering is a positive or negative for local distribution companies is a hotly contested issue. In a Wall Street Journal article published May of 2015 titled *The Hole in the Rooftop Solar-Panel Craze*, Potts argues that “the roof-top solar craze” is wasting billions of dollars per year that could be spent on greener initiatives (Potts, 2015). It is further noted that Net-Metering will lead to increased electricity rates, forcing many to adopt photovoltaic solar technology in order to maintain affordable electricity rates (Potts, 2015). This, Potts argues will leave low-income home owners unable to afford high electricity rates or solar photovoltaic systems for their homes (Potts, 2015).

The aforementioned article has been widely contested. Shah criticizes Potts for providing an over simplistic analysis of the cost-benefit analysis Net-Metering (shah, 2015). As an alternative Shah recommends a 2012 article by Farrell for a more accurate representation (Shah, 2015). Farrell argues that Net-Metering is a benefit for utility companies and is actually profitable for them, citing a study conducted in New Mexico where by Net-Metering the local utility received a net benefit of 7.8 cents per kWh (Farrell, 2012). Shah argues that Farrell provides much more accurate data, and that his findings will likely hold true in other jurisdictions (Shah, 2015).

In a 2015 article titled *The Hole in Brian Potts' WSJ Critique of the "Solar-Panel Craze."*, Farrell directly criticizes the earlier Potts article (Farrell, 2015). Farrell argues that solar photovoltaic systems have a myriad of environmental benefits which are continually becoming a better investment as the price of solar photovoltaic continues to fall over time (Farrell, 2015). Further, it is noted that Net-Metering may actually reduce electricity rates citing a Palo Alto California case study demonstrating how two years after signing large and low cost solar contracts electricity rates fell by 13 percent (Farrell, 2015). Most notably, Farrell argues that roof-top solar photovoltaic has an immense benefit in its capacity to spawn an entrepreneurial generation of electricity producers (Farrell, 2015).

In Ontario local distribution companies have created programs incising homeowners to install solar photovoltaic Net-Metering systems in their homes (Hydro One, 2016/Power Stream 2016). In addition to the aforementioned benefits of Net-Metering, the direct financial benefits to the local distribution company and Province of Ontario can be observed by analyzing the Net-Metering bill below. A Net-Metering home owner must pay the following charges which are shared between the Province of Ontario and the Local Distribution Company (Sunfish Solar, 2016):

- HST on all purchased power
- Delivery charge
- Regulatory charge
- Debt retirement charge
- Standard supply admin charge

- Distribution service charge

hydro one

Service address:

Your account number: ill Cycle 18

Billing date: October 21, 2014

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Note: This is information regarding your Generation Credits that maybe included in the calculation of your bill. As stipulated in O. Reg. 541/05, accrued generation credits will not be carried forward for more than 11 months.

Generation Credit Details

Your service type is Residential - Urban High Density

Generation for this billing period
Statement of Detail for Bill Period September 11, 2014 to October 09, 2014

Current generation reading	010678
Previous generation reading	- 010005
Difference in generation readings	000673
Generation quantity in kilowatt-hours (673 x 1) = 673 kWh	

Generation: 600 kWh @ 8.6000 ¢	$51.60 CR
73 kWh @ 10.1000 ¢	$7.37 CR
Delivery	$25.67 CR
Regulatory Charges	$3.83 CR
Debt Retirement Charge	$4.71 CR
Total of your generation credits	**$93.18 CR**

	Total of your electricity charges	$184.25
	Less HST	$21.20
Less Fixed Charges:	Standard Supply Service Admin Charge	$0.25
	Distribution Service Charge	$17.43
		$145.37
	Total generation credits earned	$93.18 CR
	Less HST credit	$0.00
		$93.18 CR
	Plus accrued credits carried forward from previous bill	$0.00
	Less generation credit applied to this bill	$93.18
	Excess generation credit carried forward to next bill	$93.18
	Total banked credit	$0.00

(Sunfish Solar, 2016)

From analyzing the above bill we can see that the Province of Ontario and Local Distribution Company do not miss out on any of the standard charges. The Local Distribution Company is able to buy electricity from the homeowner less HST and with no line losses or having to upgrade or increase electricity supply infrastructure. Thus, we can see the tangible benefit of

Net-Metering to all of the parties involved including the Net-Zero Energy homeowner, the Local Distribution Company, and the Province of Ontario.

Solar photovoltaic Net-Metering systems can be further enhanced with battery storage (Oding, 2015). Battery storage allows a Net-Zero Energy home to store the electricity that they produce, allowing the home to be more independent from the electricity grid (Oding, 2015/ Tesla 2016). Battery storage reduces the amount of energy the home buys from the electricity grid and allows any power that needs to be purchased from the grid to be purchased at off peak rates (Oding 2015/ Tesla, 2016) This subsequently reduces electricity costs to the homeowner (Oding, 2015). Further, battery storage systems allow the home to operate during a power outage (Panasonic, 2016). Additionally, battery storage allows for a higher percentage of the homes energy use to be renewable (Panasonic, 2016).

Home battery storage becomes increasingly beneficial when combined with an electric vehicle. The ability of the home to store its own generated power and cheaper off peak purchased power substantially reduces the operating costs and environmental impact of an electric vehicle by allowing it to run off clean and cheap electricity. Further, automotive manufactures are researching “second-life” batteries, which are electric vehicle batteries that no longer have the capacity to power an electric vehicle, but may be more than adequate to power a home (Green Car Reports, 2016). This eliminates the environmental impact of dismantling and recycling the battery and allows the battery to seamlessly transition from one use to another, ideally with the same owner (Green car Reports, 2016). The integration of car and home opens up the possibility of the electric vehicle to power the home in case of emergency electrical outage, or when the electric vehicle is able to charge at no cost, further reducing costs and increasing benefits to the homeowner (Energy Storage Association, 2016/Green Car Reports, 2016).

Despite the benefits of battery storage there has been three constant negative aspects outlined by critics. The first is regulatory. Although it is highly likely incentives will become available for battery storage in Ontario, they are not yet clear (Dodge, D. & Kinney, D., 2016). Thus, innovators and early adopters may not benefit from incentives (Dodge, D. & Kinney, D., 2016). The second has to do with the technology being unproven. Since the technology is relatively new, case studies and research are not yet available on how home battery storage preforms in the long term (Dodge, D. & Kinney, D., 2016). The final negative aspect is cost. Due to the high cost of battery storage systems and unclear incentives, it is not possible to estimate a rate of return on the investment (Dodge, D. & Kinney, D., 2016)

Chapter 4: Net-Zero Energy Community Energy Case Studies

4.1 Community Net-Zero Energy

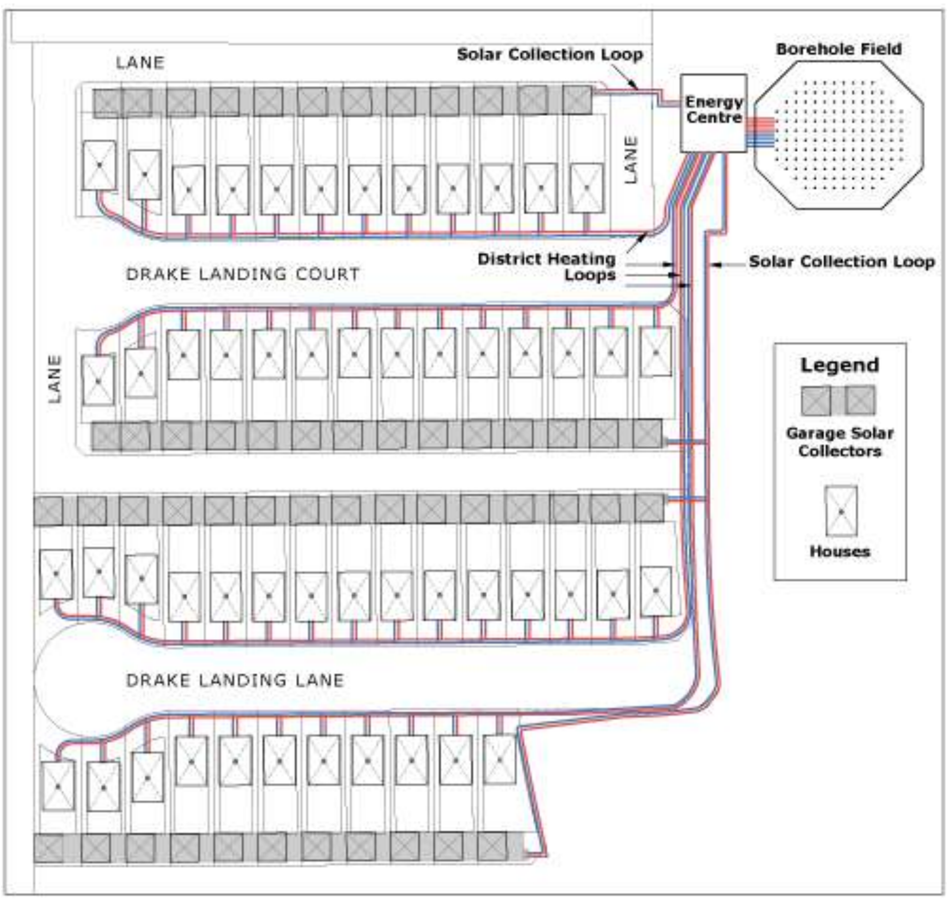
The efficiency and resiliency of Net-Zero Energy homes can be improved by creating a Net-Zero Energy community, whereby energy is created and stored at the community level. Although the Canadian Homebuilders Association has not announced its intension to release guidelines or programs for Net-Zero Energy communities, it is a worthwhile subject to explore. Net-Zero Energy homes combined with community battery storage may result in a community less reliant on the electricity grid, resulting in less of a need for standby power and subsequent carbon generation from non-renewable sources.

4.2 Community Energy Case Study – Single Detached

With regards to Canadian community energy examples, The Drake Landing Solar Community stands out from the rest. The Drake Landing Solar Community is located in Okotoks Alberta, 30 kilometers south of Calgary (Drake Landing Solar Community, 2016/ Cornford 2008).

(Drake Landing Solar Community, 2016)

The community is made up of 52 single detached R-2000 homes, and is the largest R-2000 community in existence (Drake Landing Solar Community, 2016/ Cornford, 2008). Solar energy is captured through 800 thermal solar collectors located on the rooftops of rear lane garages (Drake Landing Solar Community, 2016/ Cornford, 2008). A glycol solution is pumped through the solar collectors into a either the short term community storage tank or the long term borehole heat storage system, and re-circulated into the homes for space heating (Drake Landing Solar Community, 2016). The system is able to provide 90% of the entire community's space heating requirements on a yearly basis (Drake Landing Solar Community, 2016/ Cornford 2008).



(Drake Landing Solar Community, 2016)

The Drake Landing Solar Community reduces greenhouse gases by 5 tones per house on an annual basis (Drake Landing Solar Community, 2016/ Cornford 2008). Since opening in 2007, the total greenhouse gas reduction for the entire community is 2340 tones (Drake Landing Solar Community, 2016/ Cornford 2008).

4.3 Community Energy Efficient Design Case Study – Multi Unit Residential Building

One of the best practice case studies of energy efficient multi-unit residential unit buildings is the Elmpark development (OCSC, 2016/Design Build Network, 2016). Elmpark is a 15 acre site located in a suburban neighborhood of Dublin, Ireland (OCSC, 2016/Design Build Network, 2016). The mixed use development has a density of six times the surrounding area and includes offices, a healthcare center, market-rate and afford-able housing, a daycare center, a conference center, a restaurant, and a fitness center (OCSC, 2016/Design Build Network, 2016). According to the builder, Elmpark is seen as a model to combat sprawl (OCSC, 2016/Design Build Network, 2016).

Elmpark hosts numerous innovative environmental features (OCSC, 2016/Design Build Network, 2016). Most notable is the sites use of the local microclimate for ventilation (OCSC, 2016/Design Build Network, 2016). The buildings narrow design allows for each suite to have front and back windows, allowing for cross ventilation (OCSC, 2016/Design Build Network, 2016). The building’s design also anticipates windless days, “Wind blowing over vents on the top of the buildings pulls air in through openings on the east facades, over to thin atriums on the west facades, where it moves up and out of the buildings. These same atriums create thermal chimneys to maintain cross-ventilation on the few sunny, windless days each year." (OCSC, 2016/Design Build Network, 2016). The buildings innovative ventilation also contributes to the functioning of the sites combined heat and power plant, "Incoming air flows over hot-water pipes located near the east facades, fed by the project's combined heat-and-power plant, to heat the building in cold weather." (OCSC, 2016/Design Build Network, 2016). The residential buildings are designed with the bedrooms on the east to get morning sun while living areas get afternoon light (OCSC, 2016/Design Build Network, 2016). The buildings have been oriented to allow sunlight deep within each dwelling (OCSC, 2016/Design Build Network, 2016).

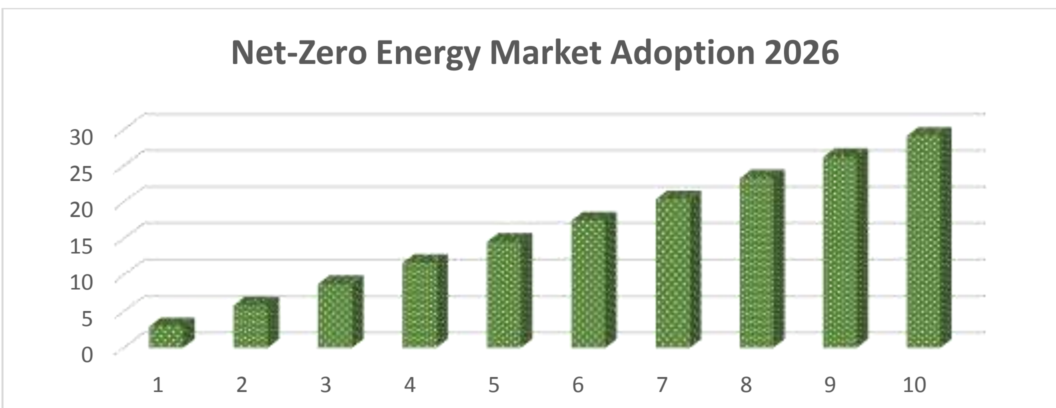
(Design Build Network, 2016)

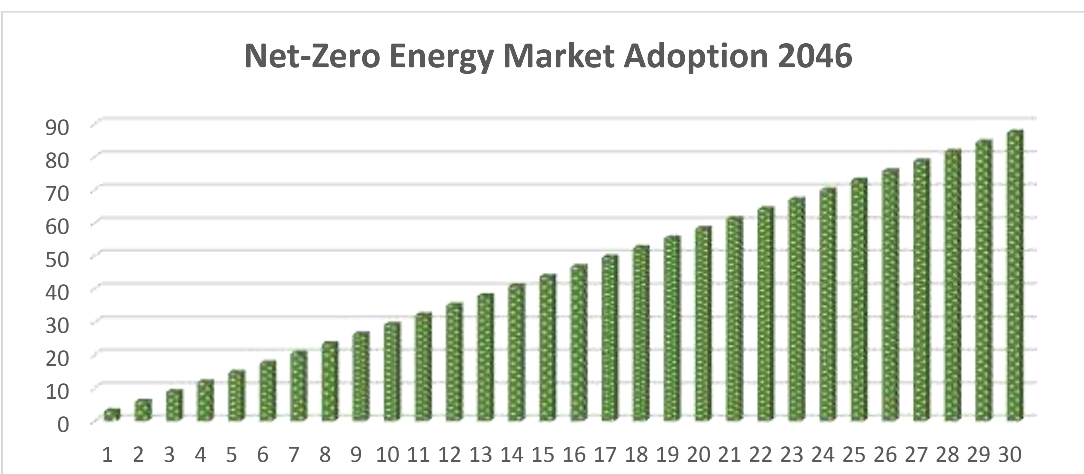
Although the site is connected to Dublin by transit, many individuals choose to drive (OCSC, 2016/Design Build Network, 2016). Thus, a large underground parking facility was constructed (OCSC, 2016/Design Build Network, 2016). The underground parking incorporates large lightwells which open up the underground structure, bringing daylight and ventilation to the space and providing entrances to various buildings (OCSC, 2016/Design Build Network, 2016).

Chapter 5: Our Net-Zero Energy Future

5.1 Net-Zero Energy Market Adoption

While it is certain Net-Zero Homes will soon be brought to market by mass production homebuilders, it is less certain how fast they will be adopted by new home buyers and how much market share they will take, and at what rate. If the success of ENERGY STAR is any indication, it can be extrapolated that in a federally-supported and provincially incented ecosystem, cost effective Net-Zero Energy homes may consume the equivalent of 2.9 percent of market share per year. At this rate, in 10 years or by 2026, nearly 30 percent of all new homes will be Net-Zero Energy. In 30 years, or by 2046, nearly 90 percent of all new homes will be Net-Zero Energy.





It is important to note that the growth of Net-Zero Energy homes to a 30 percent market penetration may not be linear as depicted above, and may gain more or less than 2.9 percent per year.

5.2 Net-Zero Energy and Planning

Net-Zero Energy will be equally transformative to planning as it will be to the housing industry. In order for Net-Zero Energy homes to efficiently produce their own energy, they must have south facing roofs (Edge at al, 2006). This requires a complete re-thinking of how homes and communities are designed (Edge at al, 2006). For a community of Net-Zero Energy homes to produce energy from solar photovoltaics efficiently, planners will have to take into account building orientation, grading, and elevation to ensure that each home has a south facing roof with no shading (Edge at al, 2006). This will undoubtedly change the look and feel of the communities many Canadians are accustomed to. According to Edge et al, the most efficient community designs will incorporate grid patterns with one way streets in order to maximize sun exposure and housing density, similar to the Drake Landing Solar Community (Edge at al, 2006).

5.3 Net-Zero Energy Affordability

My understanding of affordability is from a building/construction cost standpoint. The intent of this section is to explore how energy efficient homes can be built affordably, to be feasible for mass market, being constructed by production homebuilders.

The financial costs associated with building a Net-Zero Energy house are significant. According to Natural Resources Canada the cost of building a Net-Zero Energy home today adds between $90,000 and $120,000 to the price of a new home (Natural Resources Canada, 2016, Affordable Net-Zero Energy Homes). According to Delisle, the cost of building a Net-Zero Energy home today adds between $65,000 and $125,000 depending on technologies, house location, and typology (Delisle, 2016). Taking the low and high cost from each of the above estimates results in an average cost of $95,000. Currently, the average price of a Canadian home is $503,000 (Canadian Real Estate Association, 2016). Thus, Net-Zero Energy will increase the purchase price of the average Canadian home by an average of 18%.

Based solely on energy costs, the return on investment for a Net-Zero Energy home may be perceived as not worthwhile to many homebuyers. Estimating a Net-Zero Energy home to add $80,000 - $91,000 to the cost of a home would result in a payback period of 40 to 45 years (Delisle, 2016). As a result, those marketing Net-Zero Energy homes during the next 10 years will likely focus on many of the other benefits of owning a Net-Zero Energy Home. However, as time progresses the cost to build a Net-Zero Energy home will reduce. Delisle notes that by 2030 the added cost to build a Net-Zero Energy home will be between $39,000 and $50,000 (Delisle, 2016). At the 2030 prediction, the payback period to build a Net-Zero Energy home drops to 13 -16 years (Delisle, 2016). By 2030 the payback period of Net-Zero Energy will likely be irresistible or at the very least palatable to most new home buyers.

Innovative financing mechanisms, as seen in Germany and the U.S, may lessen the financial burden to Net-Zero Energy home buyers (PWC, 2016). Financing mechanisms in both Germany and the U.S allowing home owners to either finance or lease rooftop solar panels are commonplace (PWC, 2016). There is a strong potential for partnership between Net-Zero Energy home builders and financial institutions offering innovative financing mechanisms for rooftop solar. This may result in Net-Zero Energy home builders offering leasing or financing options to Net-Zero Energy home buyers.

5.4 Net-Zero Energy and Greenhouse Gas Production

Net-Zero Energy homes will have a significant impact on Canadian greenhouse gas production. Residential building emissions account for 5.76 percent of building greenhouse gas emissions or 41.28 Mt C02 (Environment and Climate Change Canada, 2016, Figure 2-2: Canada's 2013 Emissions Breakdown by Economic Sector). If Net-Zero Energy homes are as successful as ENERGY STAR, and in 10 years 30 percent of new construction homes are Net-Zero Energy, residential building emissions will be substantially reduced. Assuming an average of 200,000 housing starts per year and a 30 percent Net-Zero Energy housing market penetration, Net-Zero Energy has the capacity to take the electricity demand and greenhouse gas emissions of 60,000 homes offline per year (Statistics Canada, 2016, Housing Starts by Province). Over time this will reduce the percentage of greenhouse gases emitted from residential buildings in Canada and Ontario.

In Canada buildings account for 12 percent or 86 Mt C02 of Canadian greenhouse gas production, oil and gas accounts for 25 percent or 179 Mt C02, and transportation 23 percent or 170 Mt C02 (Environment and Climate Change Canada, 2016, Figure 2-2: Canada's 2013 Emissions Breakdown by Economic Sector). Net-Zero Energy homes combined with electric vehicles, electric vehicle charges, home batteries, and the possibility of community energy generation and storage have the capacity to greatly reduce greenhouse gases emitted from the 3 sources listed above.

5.5 Net-Zero Energy Indoor Air Quality

Occupant health is a paramount consideration in Net-Zero Energy Homes. Although Net-Zero Energy Home indoor air quality requirements have not yet been released by the Canadian Homebuilders Association, indoor air quality requirements will be based off and likely exceed current R-2000 home requirements (Oding, 2015). Current R-2000 indoor air quality requirements allow the home builder to choose a minimum of 3 indoor air features from the list below (Oding, 2015):

- Reduced carpet area or use of Green Label Carpet
- Improved air filtration
- Low-VOC paints and varnishes
- Low VOC flooring and adhesives
- Cabinets: solid wood, low-emission wood products or sealed surfaces
- Vinyl flooring shall be either linoleum or synthetic vinyl tile
- Low VOC composite wood materials for floor underlay or sealed surfaces, or pre-finished
- Sub-slab depressurization
- Indoor moisture control

It is important to note that although only 3 of the above indoor air quality features are required for current R2000 homes, many of these features are often included in Net-Zero Energy Pilot homes (Net-Zero Initiative, 2016). Further, as outlined in 3.11 Heat Recovery Ventilators or Energy Recovery Ventilators will be a requirement in Net-Zero Energy homes which will further reduce indoor air quality by improving air circulation within the home (Oding, 2015). The features listed above will allow for a home that is far healthier to live in than a home built to standard building code requirements.

5.6 Net-Zero Energy Water Conservation

Water conservation is an important requirement in Net-Zero Energy homes. Although Net-Zero Energy home water conservation requirements have not yet been released by the Canadian Homebuilders Association, water conservation requirements will be based off and likely exceed current R-2000 home requirements (Oding, 2015). Currently, R2000 homes require plumbing fixtures that meet the following criteria (Oding, 2015):

- Toilets: Water-saver or ultra-low flush units using 4.8 liters per flush or less
- Showers: Low-flow showerheads using 7.6 liters per minute or less when tested at 551 kPa (80 psi)
- Faucets: Lavatory faucets using 5.7 liters per minute or less when tested at 413 kPa (60 psi)

Combined the features listed above reduce water use substantially over a house built to standard building code requirements.

5.7 Net-Zero Energy Environmental Requirements

Environmental features are an important consideration in Net-Zero Energy homes. Although Net-Zero Energy home environmental features have not yet been released by the Canadian Homebuilders Association, environmental features will be based off and likely exceed current R-2000 home requirements (Oding, 2015). Current R-2000 environmental features allow the home builder to choose a minimum of 2 features from the list below (Oding, 2015):

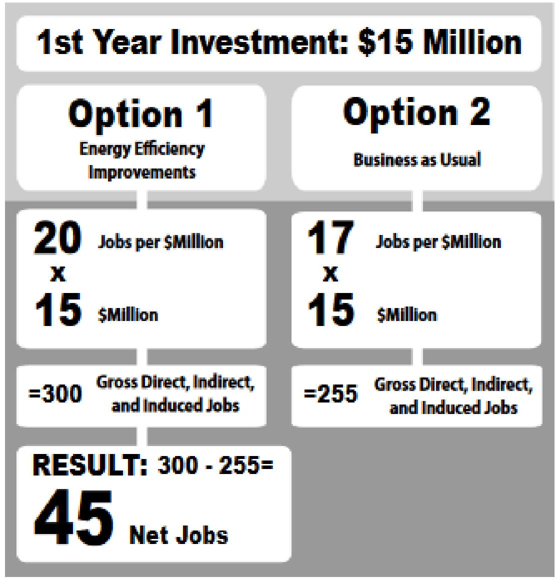
- Insulation meets or exceeds the requirements of the EcoLogo program
- Sheathing/Drywall/Siding made must be from recycled materials
- Steel studs must be made from 23% recycled material
- Studs and trim must be manufactured from sawmill cut-offs and waste and be urea-formaldehyde free
- Mixture of crushed rock with recycled glass for foundation and/or under-slab drainage
- Appliances must be ENERGY STAR rated or top 33% on the EnerGuide list
- Reduction in energy use including:
  - The cooling system shall be ENERGY STAR qualified
  - The house air distribution system shall be equipped with an energy-efficient motor

It is important to note that although only 2 of the above indoor air quality features are required for current R2000 homes it is likely that several of the above features will be standard features in Net-Zero Energy homes. Overall the features listed above will reduce environmental impact substantially over a house built to standard building code requirements.

5.8 Jobs and Economy

The creation of a Net-Zero Energy efficiency program will undoubtedly lead to the creation of jobs and a stronger economy as a result. Creation of a Net-Zero Energy program will have a trickle-down effect and create jobs at the federal level, at Natural Resources Canada and with the private sector, at service organizations who train Net-Zero Energy builders and process Net Zero Energy applications. Further, a Net-Zero Energy program will generate jobs for trained Net-Zero Energy advisors, building science consultants, and solar photovoltaic consultants. Additionally, homebuilders will need to hire trained tradespeople to who have been trained to preform work unique to Net-Zero Energy homes. Lastly, companies who produce energy efficient products required by Net-Zero Energy homes will generate more revenues.

In a U.S based study completed by the American Council for an Energy Efficient Economy it was found that investments in energy efficiency produce more jobs than business as usual investments (American Council for an Energy Efficient Economy, 2016). The study found that 17 jobs were created per 1 million dollars spent through business as usual investments (American Council for an Energy Efficient Economy, 2016). In comparison 20 jobs were created per 1 million dollars spend on Energy Efficiency based investments (American Council for an Energy Efficient Economy, 2016). This amounts to 15 percent more jobs created or 3 additional jobs created per 1 million dollar investment (American Council for an Energy Efficient Economy, 2016).

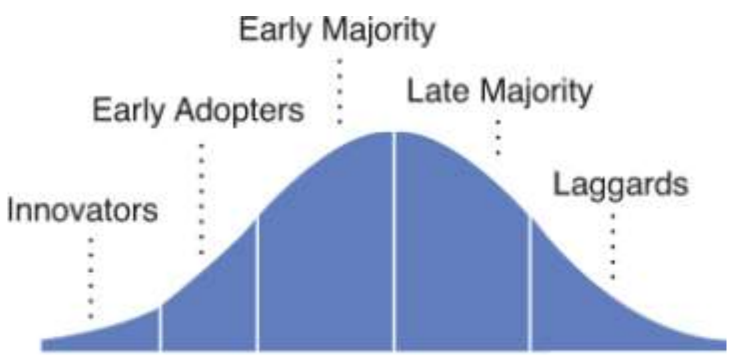


Further, the study concluded that money saved on energy bills through the lifespan of the home would result in more money for the homeowner to spend in other areas further benefiting the economy (American Council for an Energy Efficient Economy, 2016).

Chapter 6: A Roadmap to achieving Net-Zero Energy

Below is a possible roadmap outlining a predicted timeline of the path Net-Zero Energy homes will take to become the leader in energy efficient new construction homes in Canada. This roadmap takes into account a best case scenario outcome. It assumes government incentives and climate change targets will come into effect on time. Further it assumes consumer demand will be equivalent to Energy Star for new homes.

The market adoption of Net-Zero Energy homes has been adapted to the standard innovation adoption lifecycle framework as outlined below.



(http://agilehope.blogspot.ca/2015/08/technology-adoption-life-cycle.html)

(Fall 2016) The Canadian Homebuilders Association Canada Officially Releases the Net-Zero Energy program.

↓

(Fall/Winter 2016) Home builders decide to begin the voluntary process of becoming Net-Zero Energy certified.

↓

(Spring 2017) Home builders enroll in Net-Zero Energy builder training through service organizations appointed by Natural Resources Canada.

(Early 2017) Ontario Building Code changes take effect.

(Summer 2017) Net-Zero Energy home marketing begins.

(Fall 2017) Net-Zero Energy certified home builders begin to enroll homes through certified service organizations.

(Spring 2018) Provinces and Government of Canada unveil incentives for Net-Zero Energy home owners including Net-Metering and 10kw rooftop solar photovoltaic systems.

(Spring 2018) Municipalities, Provinces, and the Government of Canada and/or private companies partner with home builders and unveil financing mechanisms for 10kw rooftop solar photovoltaic systems.

(Spring 2018) Net-Zero Energy certified home builders offer the first ever post pilot Net-Zero Energy certified homes for sale in Canada. They are purchased by "innovators" or home

buyers that recognize the benefits of Net-Zero Energy home ownership and are willing to pay the financial premium for a Net-Zero Energy home.

(Summer 2019) The first Net-Zero Energy certified homes are delivered to homeowners.

(Summer 2021) The benefits of Net-Zero Energy home ownership are now well established. The payoff to Net-Zero Energy home owners from provincial and federal incentives and rooftop solar photovoltaic systems is well understood by home buyers.

(Summer 2021) The “early adopters” are now purchasing Net-Zero Energy homes.

(Fall 2021) Net-Zero Energy homes now account for 15% of all new construction homes sold in Ontario.

(2024-2025) The “early majority” are now purchasing Net-Zero Energy Homes.

(2026) Net-Zero Energy homes now account for 30% of all new construction homes sold in Ontario.

(2026) Net-Zero Energy homes reduce C02 emissions at the rate of taking the equivalent of the C02 production of 60,000 homes offline per year.

(2030) The financial premium to buy a Net-Zero Energy home has fallen by over 50 percent.

(2030) The “late majority” is now buying Net-Zero Energy homes.

(2030) Net-Zero Energy homes are now the leader in energy efficient new homes.

(2050) The last of the “laggards” are now buying Net-Zero Energy homes.

(2050) Net-Zero Energy is now the standard in new home construction.

It is possible that Net-Zero Energy homes will not come to market as quickly as the roadmap suggests. The inability for Net-Zero Energy homes to achieve the above targets will depend on four major factors. These factors include government incentives, government climate change target commitments, consumer demand, and ability to train tradespeople.

Chapter 7: We Can Choose Our Energy Future

Not all things go according to plan. This chapter will explore three possible scenarios for the adoption of Net-Zero Energy homes in both 2030 and 2050 in the case of aggressive market transformation, business as usual market transformation, and regressive market transformation. The three possible scenarios will explore the effect the scenarios may have on the number of Net-Zero Energy homes built, the number of jobs created, energy demand, and greenhouse gas generation.

7.1 Aggressive Market Transformation

The 2030 aggressive market transformation prediction for homes built estimates that by 2030, or 14 years from today (2016), 41 percent of all new construction homes will be Net-Zero Energy certified. The aggressive market transformation model applies the success Energy Star has had in Ontario on a national scale. Using an estimate of 200,000 housing starts per year, this amounts to 82,000 Net-Zero Energy homes built in Canada in the year 2030 (Statistics Canada, 2016, Housing Starts by Province).

Job creation is calculated according to a national average home price of $503,000 ($500,000 will be used for simplicity of calculation) and an estimated average of 200,000 housing starts per year (The Canadian Real Estate Association, 2016/ Statistics Canada, 2016, Housing Starts by Province). It is estimated that the additional investment of a Net-Zero Energy home is $100,000. Taking into account the numbers above, in the year 2030 or 14 years from today, 164,000 additional jobs will be created in the year 2030. (American Council for an Energy Efficient Economy, 2016).

The average Canadian household uses 106 gigajoules of energy per year (Statistics Canada, 2016, Households and the Environment: Energy Use). Using conservative estimates, this calculation estimates a Net-Zero Energy home will use 65% of the energy of a typical home. If 2030 homes built predictions are correct, and in the year 2030 82,000 Net-Zero Energy homes are built, energy savings will amount to 5,674,118 gigajoules of energy saved in the year 2030. Additionally, greenhouse gas production will be reduced by over 41 percent or 131,908 kt for new construction homes in the year 2030 (Statistics Canada, 2016, Greenhouse Gas Emissions: A focus on Canadian Households.).

The 2050 aggressive market transformation prediction for homes built estimates that by 2050, or 34 years from today (2016), 100 percent or of all new construction homes will be Net-Zero Energy certified for a total of 200,000 homes per year. (Statistics Canada, 2016, Housing Starts by Province). According to this model 400,000 additional jobs will be created assuming 100 percent of new construction homes are Net-Zero Energy (The Canadian Real Estate Association, 2016/ American Council for an Energy Efficient Economy, 2016/ Statistics Canada, 2016, Housing Starts by Province).

If 2050 homes built predictions are correct, and in the year 2050 or 34 years from today 200,000 Net-Zero Energy homes are built, energy savings will amount to 13,780,000 gigajoules of energy saved in the year 2050 (Statistics Canada, 2016, Housing Starts by Province/ Statistics Canada, 2016, Households and the Environment: Energy Use). Additionally, greenhouse gas production will cease from new construction homes in the year 2050 (Statistics Canada, 2016, Greenhouse Gas Emissions: A focus on Canadian Households.).

7.2 Business as Usual Market Transformation

The 2030 business as usual market transformation prediction for homes built estimates that by 2030, or 14 years from today (2016), 30 percent of all new construction homes will be Net-Zero Energy certified. This model adapts the success Energy Star has had in Ontario over the past 10 years as a business as usual case for the success of Net-Zero Energy on the National level over 14 years. Using an estimate of 200,000 housing starts per year, this amounts to 60,000 Net-Zero Energy homes built in Canada in the year 2030 (Statistics Canada, 2016, Housing Starts by Province).

According to this model 120,000 additional jobs will be created per year. (The Canadian Real Estate Association, 2016/ American Council for an Energy Efficient Economy, 2016/ Statistics Canada, 2016, Housing Starts by Province). If 2030 homes built predictions are correct, and in the year 2030 60,000 Net-Zero Energy homes are built, energy savings will amount to 4,255,588 gigajoules of energy saved in the year 2030 (Statistics Canada, 2016, Housing Starts by Province/ Statistics Canada, 2016, Households and the Environment: Energy Use). Additionally, greenhouse gas production will be reduced by over 30 percent or 96,518 kt for new construction homes in the year 2030 (Statistics Canada, 2016, Greenhouse Gas Emissions: A focus on Canadian Households.).

The 2050 business as usual market transformation prediction for homes built estimates that by 2050, or 34 years from today (2016), 75 percent or of all new construction homes will be Net-Zero Energy certified for a total of 150,000 homes per year. (Statistics Canada, 2016, Housing Starts by Province). According to this model 300,000 additional jobs will be created per year (The Canadian Real Estate Association, 2016/ American Council for an Energy Efficient Economy, 2016/ Statistics Canada, 2016, Housing Starts by Province). If 2050 homes built predictions are correct, and in the year 2050 150,000 Net-Zero Energy homes are built, energy savings will amount to 10,335,000 gigajoules of energy saved in the year 2050 (Statistics Canada, 2016, Housing Starts by Province/ Statistics Canada, 2016, Households and the Environment: Energy Use). Additionally greenhouse gas production will be reduced by 75 percent or 241,295 kt from new construction homes in the year 2050 (Statistics Canada, 2016, Greenhouse Gas Emissions: A focus on Canadian Households.).

7.3 Regressive Market Transformation

The 2030 regressive market transformation prediction for homes built estimates that by 2030, or 14 years from today (2016), 20 percent of all new construction homes will be Net-Zero Energy certified. The regressive market transformation model uses a figure one-third less than the business as usual model. Using an estimate of 200,000 housing starts per year, this amounts to 40,000 Net-Zero Energy homes built in Canada in the year 2030 (Statistics Canada, 2016, Housing Starts by Province). According to this model in the year 2030 an additional 80,000 jobs will be created (The Canadian Real Estate Association, 2016/ American Council for an Energy

Efficient Economy, 2016/ Statistics Canada, 2016, Housing Starts by Province). If 2030 homes built predictions are correct, and in the year 2030 40,000 Net-Zero Energy homes are built, energy savings will amount to 2,837,059 gigajoules of energy saved in the year 2030 (Statistics Canada, 2016, Housing Starts by Province/ Statistics Canada, 2016, Households and the Environment: Energy Use). Additionally, greenhouse gas production will be reduced by over 20 percent or 64,345 kt for new construction homes in the year 2030 (Statistics Canada, 2016, Greenhouse Gas Emissions: A focus on Canadian Households.).

The 2050 regressive market transformation prediction for homes built estimates that by 2050, or 34 years from today (2016), 50 percent or of all new construction homes will be Net-Zero Energy certified for a total of 100,000 homes per year (Statistics Canada, 2016, Housing Starts by Province). According to this model in the year 2050 an additional 200,000 jobs will be created per year (The Canadian Real Estate Association, 2016/ American Council for an Energy Efficient Economy, 2016/ Statistics Canada, 2016, Housing Starts by Province). If 2050 homes built predictions are correct, and in the year 2050 100,000 Net-Zero Energy homes are built, energy savings will amount to 6,890,000 gigajoules of energy saved in the year 2050 (Statistics Canada, 2016, Housing Starts by Province/ Statistics Canada, 2016, Households and the Environment: Energy Use). Additionally greenhouse gas production will be reduced by 50 percent or 160,863 kt from new construction homes in the year 2050 (Statistics Canada, 2016, Greenhouse Gas Emissions: A focus on Canadian Households.).

Model Summary

The summary table below outlines the findings in chapter 7. To calculate the percentage of Net-Zero Energy homes built in each scenario, the success of Energy Star over the past 10 years in Ontario was used as a baseline for Aggressive Market Transformation at a national level. For the business as usual model, the success of Energy Star in Ontario over the past 10 years was used on a national scale over the next 14 years. The regressive market transformation used a figure one-third less than the business as usual model. (EnerQuality, 2016, What's ENERGY STAR for New Homes?). To calculate jobs a figure of 20 additional jobs per $1,000,000 additional investment was used (The Canadian Real Estate Association, 2016/ American Council for an Energy Efficient Economy, 2016/ Statistics Canada, 2016, Housing Starts by Province). Energy Savings calculates the decreased demand for electricity in GJ that will result for the corresponding number of Net-Zero Energy homes built over code built homes (Statistics Canada, 2016, Housing Starts by Province/ Statistics Canada, 2016, Households and the Environment: Energy Use). GHG reduction from residential sources calculates the reduction the corresponding percentage of Net-Zero Energy homes has in GHG from residential sources on a national level (Statistics Canada, 2016, Housing Starts by Province/ Environment and Climate Change Canada, 2016, Figure 2-2: Canada's 2013 Emissions Breakdown by Economic Sector).

	Homes Built		Jobs Created (3 per million and 20 per million)		Energy Savings (Gj)		GHG Reduction from Residential (kt)	
	2030	**2050**	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**
Aggressive Market Transformation	41%	100%	164,000	400,000	5,674,118	13,780,000	131,908 kt	321,727 kt
Business as Usual	30%	75%	120,000	300,000	4,255,588	10,355,000	96,518 kt	241,295 kt
Regressive Market Transformation	20%	50%	80,000	200,000	2,833,059	6,890,000	64,345 kt	160,838 kt

Conclusion

This paper has demonstrated how Net-Zero Energy homes can become the next best practice in energy efficiency amongst home builders. It has outlined the history of energy efficiency programs in Canada and explained the success of present day energy efficiency programs. The need to adapt due to climate change has been reviewed both at a national and provincial level, along with fast approaching changes to building codes. The construction and components of Net-Zero energy homes have been explored, and case studies on energy efficient communities have been provided. The impact Net-Zero Energy will have on planning has been discussed, along with a discussion on affordability, market adoption, health, water conservation, environmental requirements, and jobs creation. Chapter 6 offers a roadmap outlining the possible success of Net-Zero energy homes according to a best case scenario from 2016 to 2050. It is important to note that the success depicted in the roadmap is highly dependent on four key barriers including government incentives, government climate change target commitments, consumer demand, and ability to train tradespeople. Chapter 7 finds that in an aggressive market transformation scenario, by 2030 41% of new homes will be Net-Zero Energy. This would result in substantial job creation and reduction in electricity demand and GHG production.

It is without question that Net-Zero Energy is no longer a far out goal but a fast approaching reality. Through examining a carefully chosen collection of relevant sources on the topic this paper has concluded that Net-Zero Energy can and should become the next best practice for energy efficiency among Ontario production home builders. While Net-Zero Energy may seem overly ambitious to some of us, one stands firmly in the belief that in the not too distant future Net-Zero Energy will no longer be an option, but a necessity.

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