CCEMC-FUNDED PROJECT REPORT

NETZERO (READY) HOME DESIGN AND DEMONSTRATION FOR PRODUCTION HOUSING

NON-CONFIDENTIAL FINAL REPORT

LANDMARK GROUP OF BUILDERS
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FINAL REPORT

NETZERO (READY) HOME DESIGN AND DEMONSTRATION FOR PRODUCTION HOUSING

PROJECT INFORMATION

CCEMC Project number: F110159

Project title: NetZero (Ready) Home Design and Demonstration for Production Housing

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Project completion date: October 31st, 2015

Total CCEMC fund: $499,200

TABLE OF CONTENTS

EXECUTIVE SUMMARY

NetZero Energy Homes combine highly energy-efficient house designs and on-site energy producing technologies to achieve zero energy consumption on an annual basis. The goal of the CCEMC-funded Landmark NetZero housing demonstration project is to develop, validate and demonstrate cost effective NetZero Energy Home (NZEH) designs for mainstream housing production. The project officially started in September 2012 and was completed on October 31st, 2015. During the course of the project, Landmark completed all 11 tasks that were outlined in the project proposal and constructed in total 19 NetZero Energy and 37 NetZero Carbon Ready homes.

Through the project implementation, two major barriers for large market penetration of NZEHs were identified, namely lack of customer awareness and high upgrade costs. Although NetZero concept has been widely recognized as the most promising mean for the housing industry to address climate change, the vast majority of average homebuyers is not aware of the true value of NZEHs and has no motivation to invest in energy efficiency due to historically low energy prices. In order to make NZEHs an attractive option to mainstream homebuyers, the NZEHs must be affordable and a collective effort is needed to build the public awareness and understanding of the excellent features of NZEHs for energy efficiency, comfort, health, quality and durability.

A major focus of the CCEMC NetZero demonstration project is to reduce the incremental costs of NZEHs. Design optimization via energy modelling and the adoption of NetZero Carbon Ready Home (NZCRH) concept were two key measures to improve the affordability. As direct results of the project, Landmark launched eco-upgrade package for all its low-rise housing product lines in late 2016 and the first affordable NetZero Energy show home in early 2017. Landmark's goal is to make NZEHs and NZCRHs attractive and affordable to customers at all incomes levels.

Depend on the house characteristics, each NZEH will reduce GHG emissions by 7 – 12 tonnes of CO2e from its operations and each NZCRH reduce 3-6 tonnes of CO2e. The direct GHG emission reduction of the project is 303 tonnes of CO2e per year and 15.2 kilotonnes of CO2e during the life time of the houses (50 years). Historically 32,200 new homes start construction every year in Alberta, and the market penetration of NZEHs today is less than 0.1%. Landmark has been actively involved in the industry's efforts on improving the energy efficiency of new homes and promoting NZEHs. We hope that Landmark's NetZero initiative and the project results will provide other production builders the guidance on the construction and marketing of NZEHs and lead the housing industry in Alberta move to building homes substantially more energy efficient.

Keywords: NetZero Energy Homes, Energy-efficient homes, Production housing, Energy conservation, Solar PV Microgeneration

PROJECT DESCRIPTION

NetZero Energy Homes (NZEHs) combine highly energy-efficient house designs and on-site energy producing technologies to achieve zero energy consumption or zero GHG emissions in house operations on an annual basis. In the past decade, some demonstration NetZero projects by leading-edge builders have proven that NZEHs are technically feasible in Canadian cold climate, but these homes were complex, custom and expensive, not regarded by the customers and the industry as economically viable. Landmark believes that NZEHs can be affordable and require no lifestyle change of homeowners. The goal of the CCEMC-funded Landmark NetZero (Ready) Home project is to develop, validate and demonstrate cost-effective NZEH solution for mainstream housing production.

During the course of the project, we completed the following 11 tasks that were outlined in the project proposal and constructed in total 19 NetZero Energy and 37 NetZero Carbon Ready homes.

1. Conducting a research on local, national and international best practices for NetZero Homes
2. Evaluating the applicability of energy conservation technologies and products in terms of product availability, customer acceptance, code compliance and constructability.
3. Designing 10 NetZero Ready and 5 NetZero Homes with different house models, orientations and in various geographic regions.
4. Constructing the 15 NetZero or NetZero Ready Homes designed in Task 3 as a field trial.
5. Measuring the energy performance of selected NetZero and NetZero Ready homes.
6. Modelling the energy performance and conducting cost trade-off analysis and building system optimization using actual cost and performance data.
7. Improving NetZero home system design based on the experiences from 15 NetZero and NetZero Ready Homes.
8. Developing green marketing strategies for NetZero and NetZero Ready Homes.
9. Developing generic NZEH designs for different types of homes based on the improved NZEH design and testing them in 35 NetZero and NetZero Ready homes.
10. Constructing 35 NetZero and NetZero Ready Homes.
11. Summarizing the findings and reporting.

PROJECT OUTCOMES AND LEARNINGS

The project started with a comprehensive literature review on the existing R&D efforts of highly energy efficient housing. Working with two graduate students at the University of Alberta, the project team collected the technical information of 25 R&D projects conducted by five Canadian and three international research institutes and organizations and detailed reports of 20 NZEHs or Passive Houses around world. The focus of the study was on the Energy Efficiency Measures

(EEMs) adopted by these initiatives and the impacts of these technologies on whole-building energy performance.

In the literature review, a number of innovative building energy conservation technologies and products were identified as promising technologies that can be used for NZEHs in cold climate region. Then the project team conducted a detailed energy performance and cost analysis for each identified technology and investigated their applicability in terms of product availability, customer acceptance, code compliance, constructability and product durability.

Based on the analysis results and the experience gained from the first Landmark NetZero Energy Show Home in Calgary, five single-family NetZero Ready homes and a 14-unit NetZero townhome project were designed and built in the first year of the project. Three NetZero Energy approaches had been developed for three types of homes with different building and energy consumption characteristics to achieve the optimal balance point of construction costs and energy performance and of energy conservation and renewable energy generation.

Single-family NZEHs with detached garages consume significant amount of energy for space heating. In order to achieve net zero energy, they need superior building envelope consisting of 2x8 wall with 5-inch close-cell sprayed foam in the cavity and exterior rigid insulation. Double layer frost wall in the basement, under slab insulation, and high performance windows, along with exceptional air-tightness help to reduce the heat loss through the building envelop by over 50%. High efficiency heat recovery ventilator (HRV) and drain water heat recovery (DWHR) can recover over 70% of heat from air or water going out of the house. Air-source heat pump space heating and water heating systems further cut the total energy consumption to less than 40% compared to the consumption of a same house built to the Alberta Building Code. At last, a 12 - 14 kW solar PV system was installed on the roof to offset the energy use of the building.

The NZEHs built following this approach exhibited excellent energy performance, but their costs were quite high, about $65 – 90K higher (including $35 – 40K for solar PV system) than the costs of a same home built to Landmark's standard specification. To enlarge the customer base for NZEHs, we also provided an option called NetZero Energy Ready, which has all the advance features of building envelope and heat recovery, but use high efficient furnace and tankless hot water heater as heating devices. A 3-kW solar roof-top PV system was installed on each house to show solar readiness and to maximize the on-site use of solar power. Although using natural gas would consume more energy[1], it could avoid the high operation costs caused by using electricity as energy

[1] High efficiency furnace and tankless water heater can achieve energy efficiency of 97-98%, but the average coefficient of performance (COP) of air source heat pump is about 2.0.

source for space and water heating[2]. The total construction costs of a NetZero Energy Ready package were about $30K for a typical 2,000 Sq.Ft. single-family home.

The design of NetZero Energy townhomes was different because the space heating loads of a townhome unit are much smaller than that of a single-family home. Based on energy modelling, the design team simplified the exterior wall design by eliminating the exterior insulation and used electrical baseboards for space heating. Under-slab insulation, high performance windows, high efficiency HRV, DWHR and air-source heat pump water heater were standard features for both NetZero Energy townhomes and single-family homes. A 10-kW solar PV system was installed on the roof of each dwelling unit to offset the overall energy use of the household. The average incremental costs of the 9 NetZero Energy townhomes built in the first year of the project were $41,000 per unit. Figure 1 shows the NetZero Energy townhomes in Edmonton's Larch Park community.

Figure 1: NetZero Energy townhomes (9-plex)

The project successfully achieved all planned objectives in the 1st year and the costs were control very well. Compared to other NZEH demonstration projects, the increment costs of 15 NZEHs built in the 1st year of the project was about 25% lower. However, there was still a long way to go to achieve cost neutral, i.e. no extra cost to NZEH customers when energy savings are taken into consideration. According an analysis of house total operation costs, the incremental costs of NZEH, including costs of solar PV, needed to be reduced by another 25-30% in order to achieve "cost neutral".

[2] The price of electricity is around 5 ¢/kWh and the price of natural gas is $5.5/GJ, which is equal to 2 ¢/kWh. Electricity is 2.5 times more expensive than natural gas in terms of energy content

Table 1: Specifications of NZEHs Built in the 1st Year

Item	Single-Family NZEHs	NetZero Energy Ready Homes – Single Family	NetZero Energy Townhomes
Framing Wall	2x8 wall w/ 5" 2-lb SPF in cavity and 2" exterior XPS (R40)	2x4 stagger wall w/ 2" of 2-lb SPF and 5-1/4" ½-lb SPF (R-32)	2x8 wall w/ 6.25" 2-lb SPF (R38)
Attic Insulation	R-80 loose fill insulation w/ 12" heel height	R-80 loose fill insulation w/ 12" heel height	R-80 loose fill insulation w/ 12" heel height
Exposed Floors over Garage	8" 2-lb SPF (R-42)	4.5" 2-lb SPF (R-28)	8" 2-lb SPF (R-42)
Windows	South-facing: Tripane w/ single Low E and Argon; Others: Tripane w/ two Sunstop coating and Argon	Tripane w/ two Low E coating and Argon	South-facing: Tripane w/ single Low E and Argon; Others: Tripane w/ two Sunstop coating and Argon
Basement Wall Insulation	5.5" Rock Wool & 2x4 frost wall w/ R12 batt (R-32)	5.5" Rock Wool & 2x4 frost wall w/ R12 batt (R-32)	3.5" 2-lb SPF on concrete & 2x4 frost wall w/ R12 batt (R-32)
Basement Floor	4" Type II EPS Rigid Insulation under slab (R16)	None	4" Type II EPS Rigid Insulation under slab (R16)
Furnace/Heating Source	Cold Climate Air Source Heat Pump backuped w/ Mitsubishi 12.5kW electric resistant heater.	Natural Gas 95% efficiency furnace	Electrical Baseboard (EE 100%)
Primary Ventilation	80% efficiency Energy Recovery Ventilator (ERV)	75% Heat Recovery Ventilator (HRV)	80% efficiency HRV
Domestic Hot Water	Air source heat pump hot water tank (60 Gal)	Natural Gas tankless water heater (EE: 97%)	Air source heat pump hot water tank (50 Gal)
Waste water heat recovery	72" Drain water heat recovery system (DWHR)	72" DWHR	72" DWHR
Lighting	LED bulbs	CFL bulbs	LED bulbs

In the 2nd year of the project, 21 NetZero and NetZero Ready Homes were built, including five single-family NZEHs and a NetZero Energy 5-plex townhomes. The designs of these NZEHs were similar to the design of NZEHs built in the first year and the focus was on fine-turning the design and selecting best products and contractors to reduce the costs. Figure 2a shows three single-family NZEHs that Landmark built in Calgary's neighborhood of Cranston and Figure 2b shows a row of NetZero Energy Ready solar homes in the same neighborhood. Partially funded by this project, Landmark built in total three NZEHs and 24 NetZero Energy Ready solar homes in the neighborhood, making Cranston, Calgary the first NetZero housing community in Canada.

a) Three Single-Family NZEHs

b) Three Consecutive NetZero Energy Ready Solar Homes

Figure 2: NetZero Energy and NetZero Energy Ready Solar Homes in Cranston, Calgary

A new design concept was introduced into the planning of NetZero Ready Solar homes. Instead of pursuing net zero on-site energy, the design goal of these homes was to minimize the carbon footprint of on-site energy consumption. As fossil fuel-fired plants accounted for over 80% of Alberta's electricity generation, the carbon emission factor of grid electricity is 0.85 tonnes of CO2e per MWh, almost 5 times more than the GHG emissions from burning natural gas on site to obtain the same amount of energy. Although the space and water heating devices used in NZEHs, such as air source heat pumps, have higher COP, they use electricity as energy source and the house has approximately the same carbon footprint compared to a code compliance house does, if renewable energy generation is not considered. The ultimate goal of NZEH initiatives is to achieve carbon neutral in house operations. For homes in a region where electricity is predominantly generated by coal-fired power plants, the most cost effective approach to achieve this goal is to use relatively clean energy, natural gas, to heat the house and export on-site renewable energy to the grid to offset the carbon emissions caused by on-site fossil fuel use.

Based on this understanding, 16 NetZero Carbon Ready homes (NZCRH) were designed and built in the year 2. They were equipped with superior building envelope, high efficiency furnace, tankless condensing water heater, high efficiency HRV and DWHR systems. The problem is that in Alberta

the Micro-Generation Regulation does not allow the house export electricity more than the amount that the house uses. Therefore, a smaller solar PV system, in the range of 2 – 4 kW capacity, was installed to each NECRH to provide visual identity of NetZero and to offset a portion of the electricity use of the house, thus minimizing the carbon footprints of home operations. In future, additional solar PV panels can be easily added on the roof top to make the home carbon neutral.

At the beginning of the 3rd year of the project, the project team and Landmark senior management evaluated the impacts of the CCEMC NetZero project to Landmark's operations and worked together to formulate a long-term NZEH strategy. Based on the knowledge and experience gained from the design, construction and sales of over 40 NREHs and NRCRHs (among them 36 homes were funded by the CCEMC), the project team was suggested to focus on the following two key areas in the last year of the project.

- Reducing incremental costs of NetZero upgrades and bringing the overall selling price of NZEHs to affordable level.
- Reviewing the designs and energy performance of all Landmark products and developing a system so that the houses built to Landmark's standard specifications can be seamlessly upgraded to NECRHs and NZEHs.

The efforts to reduce the incremental costs started with a thorough analysis of the actual costs of the NZEHs and NZCRHs that were completed. Roof top solar PV, building envelop and space heating system were the top three items that accounted for over 80% of the total incremental costs and had the largest impacts to house energy performance. They are also inter-related. A better building envelop (more expensive) can reduce the heating loads, allowing the adoption of alternative heating systems and a smaller solar PV system. Heating system with high COPs like air source heat pump can minimize the site energy use and reduce the size of solar PV system, while occurs higher costs. A research team at the University of Alberta, the research partner of the project, developed an energy performance and cost trade-off simulation model to examine a wide variety of energy-efficient building alternatives – including building envelope and space heating – to identify the most cost-effective design and optimal balance point between high R-value walls, more efficient heating system and power generation.

The results of the research were applied in the design of 19 NZCRHs built in the 3rd year, including 13 single-family, one duplex and one 4-plex townhouse. After considering all factors and limitations in prefabrication, material/product supply and the sales of energy upgrades, the project team finalized the generic designs of NZEHs and NZCRHs for all Landmark product lines and developed an energy upgrade system that allow the homebuyers to upgrade their homes to NZCRHs or NZEHs by simply purchase the Eco-Upgrade and NZEH packages.

The project successfully completed all its planned tasks on the amended project end date of October 31st. As shown in Table 2, 56 NZEHs and NZCRHs were constructed and sold to the customers. At the beginning of the project, the project team focused on the design and construction of NZEHs and tried to increase the market penetration of NZEHs by providing homebuyers a NZEH product at cost neutral. After a year and half into the project, we found that the key factor in the marketing

of NZEHs was the affordability. Over 80% of Landmark customers were either couples or growing family with kids, buying houses as their main residence, and 60-70% of them took mortgage loan more than 80% of the house purchasing price. They simply could not afford any increases in the house price, no matter whether it would save utility costs in the future.

Table 2: Project Results – NZEHs and NZCRHs

Milestone	No. of NetZero Energy Homes Completed	No. of NetZero Carbon Ready Homes Completed	Solar PV Installed (kW)	Actual Completion Date
2 & 3	11	4	124	Dec 15, 2013
5 & 6	7	5	95	May 31, 2014
7	1	8	35	Sep 15, 2014
8		5	16	Dec 31, 2014
9		8	8	Apr 30, 2015
10		6	17	Jun 30, 2015
Total	19	37	294	

At the same time, we realized that in a power environment like Alberta, NetZero site energy might not be the best way to achieve the ultimate goal of zero emissions in house operations. This conclusion was based on two facts: 1) as 80% of electricity in Alberta was generated from coal-fired power plant, using electricity would emit 5 times more GHG than obtaining energy from natural gas; and 2) electricity was about 3 times more expensive than natural gas in terms of the energy content. Starting from the 2nd year, the project changed the focuses to 1) improving the overall affordability of NZEHs through design optimization; 2) minimizing the carbon footprint of the homes built to Landmark standard specifications, and 3) developing an energy upgrade system to enable homebuyers to select house energy performance level based on their financial capacity.

As the direct results of the CCEMC project, Landmark Group has decided to adopt exterior rigid insulation in all its products in early 2016. This is the fourth energy conservation technology that Landmark as production builder first adopted in its standard specification. The other three, HRV, tankless hot water heater and triple-pane 2 low-e windows, have gradually become the industry standard after Landmark's move. In late 2016 and early 2017, Landmark Homes, Landmark Legacy and Landmark Communities officially launched the energy eco-Upgrade and NZEH packages for all single-family, duplexes and townhome product lines (see Table 3 for details). The first affordable NetZero Energy show home opened to public in March 2017. The 1260 SqFt single-family home in southeast Edmonton has a starting price under $400k, which includes the lot, home, garage, net zero upgrades and GST. This price is very much in line with February's median selling price of $391,000 for a new single-family home in Edmonton.

Table 3: Landmark Standard Specification and Energy Upgrades (Single-Family Homes)

Item	Landmark Standard Specification (25% better than Code)	Single-Family Home w/ Detached Garage		Single-Family Home w/ Attached Garage	
		Eco-Upgrade (40% better than Code)	NZEH (EnerGuide 0 GJ)	Eco-Upgrade (40% better than Code)	NZEH (EnerGuide 0 GJ)
Framing Wall	2x6 wall w/ R20 Batt in cavity and 1" exterior XPS (R21 effective)	2x6 wall w/ R22 Batt in cavity and 1" exterior XPS (R22e)	2x6 wall w/ R22 Batt in cavity and 1" exterior XPS (R22e)	2x6 wall w/ R22 Batt in cavity and 1" exterior XPS (R22e)	2x6 wall w/ R24 Batt in cavity and 1.5" exterior XPS (R26e)
Attic Insulation	R-50 loose fill insulation	R-60 loose fill insulation	R-80 loose fill insulation	R-60 loose fill insulation	R-80 loose fill insulation
Exposed Floors over Garage	5" 2-lb SPF (R-30e)	5" 2-lb SPF (R-30e)	7" 2-lb SPF (R-40e)	5" 2-lb SPF (R-30e)	7" 2-lb SPF (R-40e)
Windows	Tripane w/ two Low e & Argon	Tripane w/ two Low e & Argon	Tripane w/ two Low e & Argon	Tripane w/ two Low e & Argon	Tripane w/ two Low e & Argon
Basement Wall Insulation	2x4 frost wall w/ R24 batt (R-17e)	3.5" Rock Wool & 2x6 frost wall w/ R24 batt (R-30e)	3.5" Rock Wool & 2x6 frost wall w/ R24 batt (R-30e)	3.5" Rock Wool & 2x6 frost wall w/ R24 batt (R-30e)	3.5" Rock Wool & 2x6 frost wall w/ R24 batt (R-30e)
Basement Floor	-	2" Type II EPS Rigid Insulation under slab (R8)	2" Type II EPS Rigid Insulation under slab (R8)	2" Type II EPS Rigid Insulation under slab (R8)	2" Type II EPS Rigid Insulation under slab (R8)
Furnace/Heating Source	Natural Gas 95% efficiency furnace	Natural Gas 95% efficiency furnace	Air source heat pump & electrical furnace or resistant heater	Natural Gas 95% efficiency furnace	Air source heat pump & electrical furnace or resistant heater
Primary Ventilation	63% efficiency HRV	75% efficiency HRV	75% efficiency HRV	75% efficiency HRV	75% efficiency HRV

Item	Landmark Standard Specification (25% better than Code)	Single-Family Home w/ Detached Garage		Single-Family Home w/ Attached Garage	
		Eco-Upgrade (40% better than Code)	NZEH (EnerGuide 0 GJ)	Eco-Upgrade (40% better than Code)	NZEH (EnerGuide 0 GJ)
Domestic Hot Water	Natural Gas tankless water heater (EE: 97%)	Natural Gas tankless water heater (EE: 97%)	Air source heat pump hot water tank (50 Gal)	Air source heat pump hot water tank (50 Gal)	Air source heat pump hot water tank (50 Gal)
Waste water heat recovery	-	72" DWHR	72" DWHR	72" DWHR	72" DWHR
Lighting	CFL bulbs	>75% LED bulbs	>75% LED bulbs	>75% LED bulbs	>75% LED bulbs
Plumbing	-	-	Low flow showerheads and faucets	-	Low flow showerheads and faucets

GREENHOUSE GAS AND NON-GHG IMPACTS

The GHG benefits resulting from the completed project include direct benefits from 56 NZEHs and NZCRHs built in this project and potential future impacts that the project has to the market acceptance and implementation of NZEHs in Alberta. Starting on the day when the home is occupied and continuing for the life of the house, NZEHs and NZCRHs save energy and reduce GHG emissions from their operations. Building energy performance is affected by many factors. Weather, the number of people in the household and occupants' lifestyle are three biggest factors influencing how much power the home will use, and thus how much GHG will be emitted from house operations. To have a common standard of evaluating homes' energy performance, Natural Resources Canada (NECan) developed an EnerGuide Rating System (ERS) as a part of Canadian government's efforts to reduce GHG emissions and address climate change. ERS and associated energy simulation software HOT 2000™ are nationally recognized tools used in many energy efficiency programs across Canada and by the Alberta Building Code 2014.

The EnerGuide Rating of a home is based on the energy performance model that calculates the annual net energy consumption of the house, including both energy use and renewable energy production. 30 years average climatic data (from 1970 to 2000) collected in the weather region that

the building is located are used in the energy modeling and the household energy loads are calculated using standard operating conditions[3].

All NZEHs and NZCRHs built in the project were modelled in HOT 2000™ software by third-party energy advisors and had EnerGuide Rating. To calculate the direct GHG emission reductions from the project, a typical new house reference point was identified to reflect the industry common practice. Table 4 provides the technical details of the reference house and the building code requirements during the time of project implementation[4].

Table 4: Technical Details of Alberta Building Code and Industry Common Practice

Item	Alberta Building Code (ERS Rating ~70)	Industry Common Practice (ERS Rating ~75)
Exterior Wall (above grade)	2x4 Stud @ 16 c/c w/ R-12 batt	2x6 stud @24 c/c w/ R-20 batt
Ceiling Insulation	R-34 blown-in	R-40 blown-in
Exposed floors (cantilevers)	R-20 batt	R-28 batt
Windows	Dual Pane Clear Glass	Dual Pane, low-e film, Argon
Rim Boards	R-12	R-20
Basement Wall Insulation	R-8 batt to 600mm below grade	2x4 frost wall w/ R-12 batt
Air tightness	No Requirement	3.5 – 4.0 ACH @ 50 Pa
Primary Ventilation	Fans without Heat Recovery (Bath fans)	Heat Recovery Ventilator (Bath or inline fans)
Heating	NG Furnace 90% AFUE	NG Furnace 92% AFUE
Domestic Hot Water	NG hot water tank	NG hot water tank (EE 60%)
Lighting	No Requirement	75% CFLs

NZEHs use only electricity as energy source and all energy consumption of the house shall be offset by the on-site renewable energy generation. NZCRHs use natural gas for space and domestic hot water heating and electricity for ventilation, appliances and lighting. As natural gas and electricity have different GHG emission factors in terms of energy content, the energy savings were calculated separately by energy sources, as shown in Table 5. Detailed energy modelling result of each house is

[3] Detailed description of ERS and standard operating conditions can be found in EnerGuide Rating System Standard published by Natural Resources Canada.

[4] The construction of 56 NZEHs and NZCRHs in the project was completed in 2014 and 2015. The mandatory application date for Section 9.36 Alberta Building Code 2014 was November 1, 2016, a year after the project end date.

included in Appendix A. The total energy saving of the project is estimated to be 4,095 GJ of natural gas and 205.5 MWh of electricity per year. The direct GHG emission reduction of the project is 303 tonnes of CO2e per year[5] and 15.2 kilotonnes of CO2 during the life time of the houses (50 years).

Table 5: Expected Annual GHG Benefits and Total Direct GHG Reductions of the Project

City	Job Category	No. of Unit	Energy Savings		GHG Reduction (tonne CO2e)
			Natural Gas (GJ)	Electricity (MWh)	
Calgary	NetZero Energy	2	215	12.3	18.8
	NetZero Carbon Ready	22	1,403	96.9	96.4
Edmonton	NetZero Energy	17	1,808	66.1	134.5
	NetZero Carbon Ready	15	669	30.2	53.4
Annual Total			4,095	205.5	303.2
Project Total (50 years)					15,161.3

Housing accounts for 17% of Canada's secondary energy use and 15% of GHG emissions. With growth in the housing stock, the energy consumption and GHG emissions from this sector are expected to continue to grow in the next decade if the housing industry does not substantially improve the energy efficiency of its products. NZEHs employ enhanced energy conservative strategies and renewable energy technologies, providing an effective mean for the housing industry to contribute to GHG emission reductions.

On national level, two government funded NZEH initiatives, namely CMHC's EQuilibrium Project[6] and eco-EII's NetZero Energy Housing Initiative[7], demonstrated the feasibility of building NZEHs

[5] The Alberta provincial government released a Carbon Offset Emission Factors Handbook in March 2015. The GHG reduction estimates in the table reflect this recent updates.

[6] EQuilibrium™ is a national sustainable housing demonstration initiative, led by Canada Mortgage and Housing Corporation (CMHC). 15 NZEHs or near-NZEHs were constructed across Canada during 2008 – 2010 to demonstrate the feasibility of NZEHs and benefits on highly energy efficient homes in terms of health and sustainability, quality. The total funding provided was $0.9 million.

[7] The project of Integrating Renewables and Conservation Measures in a Net-Zero Energy Low-Rise Residential Subdivision was funded by Natural Resources Canada (NRCan) funded under the ecoENERGY Innovation Initiative (eco EII). Five builders across Canada participated in the project (footnote continued)

in various climate zones and showcased the technologies that can be used in the NZEHs. The unique contribution of CCEMC project is to demonstrate and provide a complete solution of building affordable NZEHs and NZCRHs in cold climate regions like Alberta. This will significantly reduce the costs and associated risk of research and development (R&D) of other homebuilders, particularly builders in Alberta, in adopting NZEH approach and facilitate the market penetration of highly energy efficient homes.

Historically, 32,240 new homes start construction every year in Alberta[8]. Today, the market penetration of NZEHs is less than 1%. Using the experience and knowledge gained from the project, Landmark has released the eco-Upgrade and affordable NZEH packages for single-family, semidetached and row house product lines in late 2016 and early 2017. We hope Landmark's initiative and the disseminated project results will provide other production builders the guidance on the construction and marketing of NZEHs and lead the housing industry in Alberta move to building homes substantially more efficient. A small but growing fraction of homebuilders have already follow Landmark's example, starting to provide near- and NZEHs to mainstream housing market. This trend is expected to continue. Every 1% of new homes achieving NZEH or carbon neutral standards will lead to 2.25 kilotonnes of GHG emission reductions per year during the life of the houses (50 years or more).

OVERALL CONCLUSIONS

The concept of NetZero Energy Homes has been introduced to the North America housing industry for over 10 years. Although some demonstrational and customized NetZero Energy or near-NetZero Energy homes were built in the US and Canada, they are never an option for average homebuyers. In early 2013, the U.S. Department of Energy (DOE) launched Zero Energy Ready Home (ZERH) program and a few large production homebuilders such as Meritage Homes, KB Homes, Shea Homes/Trilogy and Nexus Energy Homes started to market ZERHs to mainstream homebuyers. At the end of 2016, DOE's ZERH program reached 1,000 certified home milestone. Considering the size of U.S. new home market (600,000 units per year), the market acceptance of ZERHs was quite low, but the DOE expects that the market penetration of ZERHs will speed up in the next five years as American homebuyers learn more about the superior homeowner experience that comes with the high performance homes.

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and constructed 25 NZEHs in five communities, including one (5 NZEHs) in Calgary. The project started in early 2014 and completed in late 2016. The total contribution from NRCan was $1.96 million.

[8] CMHC (2017) Housing Now Tables: Prairie Region

The CCEMC NZEH demonstration project started at almost the same time when U.S. ZERH program was launched. In three years, Landmark constructed over 60 NZEHs and NZCRHs, including 56 homes funded by the project. As the only production homebuilder in Canada that was promoting high energy efficient home to mainstream housing market, Landmark has helped Canadian Home Builders' Association (CHBA) to develop and launched CHBA NetZero Home Labelling program. The knowledge and experience gained from the project were shared with the Canadian housing industry and inspired/supported many builders in Alberta and nationally to take similar actions.

Through the project implementation, two major barriers for wide-adoption of NZEHs were identified, namely lack of customer awareness and high incremental costs. Although NetZero concept has been a hot spot in the housing industry and among environmentalists, the vast majority of average homebuyers is not aware of the true value of NZEHs and has no motivation to invest in energy saving upgrades due to historically low energy prices. In order to make NZEHs an attractive option to mainstream homebuyers, the NZEHs must be affordable and a collective effort is needed to build the public awareness and understanding of the excellent features of NZEHs for energy efficiency, comfort, health, quality and durability.

Reducing the incremental costs of NZEHs was a major focus of the project. Design optimization via energy modelling and the adoption of NetZero Carbon Ready concept were two key measures to improve the affordability. Landmark's Eco-upgrade package and affordable NetZero Energy show home(s) were the direct results of these efforts. Landmark's goal is to make NZEHs and NZCRHs attractive and affordable to customers at all incomes levels.

Sales and marketing was another crucial area having great influence on the market penetration of NZEHs. Since the first Landmark NetZero Energy show home opened to public in the fall of 2012, over 1,500 people had toured two Landmark NetZero Energy show homes in Calgary and Edmonton. About 1,000 people visited four Landmark single-family NZEHs and the NetZero Energy townhouses at 2013, 2014, 2015 and 2016 Eco-Solar Tours. National and regional media such as CBC, the Globe and Mail, Calgary Herald, Green Energy Futures, Alberta Venture and Yahoo News have reported Landmark's NetZero initiatives. Although NZEHs represents only a very small percentage of the real estate market and awareness of NZEHs and NZCHs is still very low, Landmark, as a leader in energy efficient homes, would like to take the challenge and help the industry get started to explore this uncharted territory.

SCIENTIFIC ACHIEVEMENTS

To support the design optimization and evaluate the actual performance of NZEHs, a research team led by Dr. Mohamed Al-Hussein and Dr. Mustafa Gul at the University of Alberta has been work closely with Landmark in the past five years. Two Ph.D. and three M.Sc. students conducted their research based on works related to the project. The research works were conducted mainly in the

following four areas: 1) the evaluation of hygrothermal performance of different wood frame wall assemblies based on long-term site monitoring; 2) building energy modelling and optimization; 3) actual building energy performance monitoring and analysis; and 4) life-cycle analysis of NZEHs. Up to date, the research team has published three journal papers and five conference papers. One Ph.D. student and one M.Sc. students completed their programs based on their work conducted during the project. One Ph.D. and two M.Sc. students are still working on the project and are expected to finish their program this year.

Journal Papers

- *Automated Energy Simulation and Analysis for NetZero Energy Home (NZEH) Design*, Building Simulation, 2017
- *An Energy Performance Monitoring, Analysis and Modelling Framework for NetZero Energy Homes (NZEHs)*, Energy and Buildings, 2016.
- *Towards Energy-Efficient Homes: Evaluating the Hygrothermal Performance of Different Wall Assemblies Through Long-term Field Monitoring*, Energy and Buildings, 2016.

Conference Papers

- *An Experimental Framework for Investigating the Hygrothermal Properties of Multi-functional Wood Fibre and XPS Panels for Residential Building*, Modular and Offsite Construction (MOC) Summit, 2016, Canada.
- *Energy Simulation of Building Envelope for NetZero Energy Home (NZEH) Design*, International Conference on Construction and Real Estate Management (ICCREM), 2015, Sweden.
- *An Empirical Study on the Sustainability of Panelized Residential Building Construction in Canada*, International Construction Specialty Conference, 2015, Canada.
- *Energy Performance Monitoring and Analysis of NetZero Energy Homes (NZEHs)*, 2015 Modular and Offsite Construction (MOC) Summit and 1st International Conference on the Industrialization of Construction (ICIC), 2015, Canada.
- *Carbon Footprint of Panelized Construction: An Empirical and Comparative Study*, Construction Research Congress, 2014, USA.

Student Thesis

- *Analysis of NetZero Energy Homes (NZEHs): Stakeholders, Design, and Performance*, Ph.D. Theses, Hong Xian Li, 2016.
- *Carbon Footprint Assessment of the Pre-panelized Construction Process,* M.Sc. Theses, Mehrdad Naseri Esfahani, 2014.

NEXT STEPS

Landmark constructed its first NZEH in 2012 in Calgary's neighborhood of Cranston (see Figure 3a), followed by three NetZero Energy Ready solar homes in the same subdivision. The CCEMC project enables Landmark to build an additional 19 NZEHs and 37 NZCRHs in 2013 – 2015 cross Alberta. Using the knowledges and experience learned from the project, Landmark constructed ten NZCRHs in 2016 in Edmonton's Laurel Green neighborhood. On March 17, 2017, Landmark proudly introduced Canada's first affordable NZEH to the Edmonton new home market with a grand opening of the NetZero Energy show home in Edmonton's southeast neighborhood of Maple Crest (See Figure 3b). This latest NZEH project of Landmark have a starting price of $399,737, which includes the lot, home, garage, NetZero upgrades and GST. This price is very much in line with February's median selling price of $391,000 for a single family home in Edmonton. "For ten years we've been diligently working to drive down the cost of NetZero Energy Homes," said Reza Nasseri, CEO and founder of Landmark Group. "Big things have small beginnings and the NetZero homes we're building in Maple Crest today will lay down the groundwork for the mass adoption of this type of housing in the coming years."

The homes we're designing today are highly replicable, affordable and scalable," said Mike Haupt, general manager of Landmark Group's single-family division. "We saw an opportunity to rethink what's possible and use forward-looking planning to create an ultra-energy efficient home that is attainable by the majority of single-family homebuyers in Edmonton. I believe we've reached a tipping point in the industry."

a) The 1st Landmark NetZero Energy Show Home in Cranston, Calgary (2012)

b) Grand Opening of the 1st Landmark Affordable NetZero Energy Show Home in Maple Crest, Edmonton (2017)

Figure 3: The 1st and 3rd Landmark NetZero Energy Show Homes