Now House Windsor 5

Testing different approaches to energy reduction in five 1 ½-storey post-war houses

INTRODUCTION

The Now House Project set out to test the feasibility of retrofitting older homes to reach zero energy use. They started with the 1½ storey post-war house — a unique Canadian housing type that brands many communities in Canada.

Most of these houses have passed their sixtieth birthdays and are among the many older houses in Canada contributing to the residential sector's growing demand for energy and increased greenhouse gas emissions.

The first Now House® was completed in 2008, and was one of the 12 winning projects in Canada Mortgage and Housing Corporation's EQuilibrium Sustainable Housing Initiative. Since then the team has retrofitted eight additional houses in Ontario, including five homes in the city of Windsor, Ontario, which are the subject of this report.

PROJECT OBJECTIVES

In 2009, The Now House Project and Windsor Essex Community Housing Corporation (CHC) embarked on the Now House Windsor 5 project. Five 1½ storey post-war homes would undergo deep energy retrofits to reduce energy costs to zero, save carbon and create homes that are comfortable and healthy to live in. The team also planned to identify the most cost-effective retrofit model for the improvement of 125 similar houses in the CHC portfolio.

The Now House team wanted the project to include opportunities for education and community engagement. They applied for and received funding from the Ontario Power Authority's (OPA) Conservation Fund to extend the benefits of the project through communications, a demonstration house open to the public, knowledge transfer to local trades and post-retrofit performance evaluation.

FIVE HOUSES PRE-RETROFIT

The five 1½-storey homes are among 325 similar houses built in the Bridgeview area of Windsor in the early 1950s to provide housing in a city, typical of many in Canada, suffering from a housing shortage following WWII. Today, the community is a diverse neighbourhood with a mix of private ownership and community housing rentals and includes young families, students and a few of the original residents.

HOME CONDITIONS

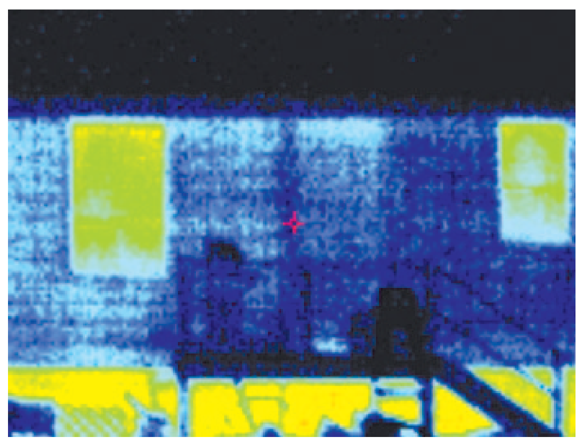
The five houses are located on Rankin Avenue, situated side-by-side with an east-west orientation. A review of pre-retrofit home conditions is summarized below:

- Roof constructed of 2 x 6 roof rafters and 1 x 8 roof boards with asphalt shingles in good condition
- Attic and crawl spaces insulated with cellulose with some deterioration showing
- Aluminum windows with fixed panes in the upper portion and opening sliders in the lower portion
- Walls constructed of 2 x 4 stud framing and clad in old vinyl siding except for one house which is of brick construction
- Basic plumbing was in good condition
- Basement walls constructed of hollow concrete block with evidence of deterioration in some cases
- Each house had a forced air gas furnace approximately 19 years old and a gas hot water heater
- The electrical boxes had been upgraded to breakers
- A grey water heat recovery pipe had been installed in each house
- Some houses had window air conditioners with no surrounding insulation
- All houses had old appliances supplied by the residents.

PRE-RETROFIT ENERGY AUDITS

The pre-retrofit energy audits were consistent with the ecoENERGY Retrofit Program administered by Natural Resources Canada. The EnerGuide for Houses (EGH) energy efficiency value produces a score from 1 to 100 with a higher score indicating higher efficiency levels. EGH ratings established by the energy audits were:

Model 1: EGH 18
Model 2: EGH 35
Model 3: EGH 28
Model 4: EGH 55
Model 5: EGH 55.



Typical EGH ratings for Canadian homes built before 1970 is 50 EGH or less.

FIVE RETROFIT MODELS

At the retrofit design stage, the Now House team used a version of the Hot2000 energy-modeling tool that had been modified by NRCan for the CMHC EQuilibrium design competition. The modified tool included some changes to reflect the objective of reaching zero energy consumption and reduced the number of standardized assumptions built into the tool used by the ecoEnergy auditors.

The team used Hot2000 for energy modeling to explore options between energy reduction and cost of various retrofit elements. Using a median EGH of 35 to represent the basic home condition, they designed a variety of potential retrofit models and reviewed them with Windsor Essex CHC.

As the option to apply a near zero energy retrofit model to all five houses was not feasible within the budget, CHC selected five approaches that ranged from basic insulation and air sealing to a model predicted to achieve near zero energy (See Table 1). These retrofit models enabled the Now House team to test the cost-effectiveness of different approaches, and provided CHC with the possibility to add changes in the future to upgrade all houses to near zero energy.

Table 1: Now House Windsor 5: Testing different approaches to deep energy reduction and zero energy use in five 1½-storey homes to determine the best approach for 125 similar houses in Windsor Essex Community Housing portfolio.

THIS BASE MODEL WAS APPLIED TO EACH HOME:

- Air sealing and insulation
- CFL and LED lights
- Low flow fixtures (shower head, toilet, aerators)
- ENERGY STAR refrigerator and front-loading washer
- Gas range and dryer
- New doors.

MODEL ONE

- Base Model +
- High efficiency hydronic heating system
- High efficiency central A/C
- Heat Recovery Ventilator
- Tankless water heater

Cost: $41,686

MODEL TWO

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

Cost: $41,126

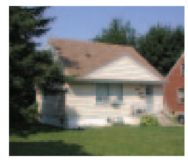
Cost with 2.1 KW solar PV: $66,126

MODEL THREE

- Base Model +
- High efficiency hydronic heating system
- High efficiency central A/C
- Heat Recovery Ventilator
- ENERGY STAR windows
- Tankless water heater
- Solar thermal system
- 2.1 kW solar photovoltaic system

Cost: $56,172

Cost with 2.1 kW solar PV: $81,172



MODEL FOUR

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

Cost: $41,126

MODEL FIVE

- Base Model without new appliances

Cost: $31,260

Note: A high efficiency forced air gas furnace and air conditioner were included in the budget but not installed until June 2010.

KEY CHANGES

- Each of the five retrofit models included a base package of air sealing and insulation, low flow water fixtures, energy efficient appliances, doors and lighting.
- Two houses (Model 2 and 4) received standard upgrades of an energy efficient forced air gas furnace, a tankless water heater, a heat recovery ventilator (HRT), and central air conditioning.
- Two houses were converted to a hydronic heating system; Model 1 is solar ready while Model 3 received a solar thermal system, which provides hot water used for domestic hot water and home heating. Model 3 was the only one to receive new energy efficient windows.
- Two homes (Models 2 and 3) have grid-tied solar photovoltaic systems, and were approved under Ontario's Feed-in-Tariff earning 80.2 cents per kilowatt-hour of generation for the contracted period of 20 years.

The team expected electricity savings to come from components in the base model including: CFL lighting, an ENERGY STAR® rated refrigerator and front-loading washer, and by replacing the electric range and dryer with new gas appliances. The solar photovoltaic panels added to Models 2 and 3 would make these houses energy producers as well as consumers. The PV panels would be grid-tied with all generation sold to the local utility and no impact on the actual electricity consumption of these two homes.

Gas savings were expected from improvements in the home envelope through air sealing and insulation, use of an on-demand, tankless water heater and new, high efficiency heating systems. The use of a solar thermal system in Model 3 to support domestic hot water and home heating was expected to further increase gas savings in that home.

The retrofit process began in June 2009 and was completed in September. Now House provided design, project management and general contracting, as well as, all communications and educational deliverables. Over 15 Windsor companies were employed in the retrofit and building materials and products were purchased from local suppliers and manufacturers where possible. Following the completion of the retrofits, the energy and water use of the five houses was monitored for twelve months for comparison to baseline data.

POST-RETROFIT ENERGY AND COST ANALYSIS

ENERGY AUDITS

Post-retrofit ecoEnergy audits showed significant improvements in all five 60-year old houses (See Chart 2). Houses with low EGH scores at the outset such as Model 1, 2 and 3, have post-retrofit energy efficiency scores in the high 70s. Two of these houses are just one point short of achieving EGH 80, which is the standard set for new ENERGY STAR® houses. Model 4 achieved EGH 81 exceeding building code for new houses in Ontario that will not be in effect until 2012. Model 5, which received the base package changes only (minus new appliances which were declined by the occupants) achieved an EGH of 74 well above the energy efficiency level of houses this old.

CHART 2: EGH SCORES PRE AND POST RETROFIT

	EGH Pre-Retrofit	EGH Post-Retrofit
Model 1:	18	77
Model 2:	35	79
Model 3:	28	79
Model 4:	55	81
Model 5:	55	74

New ENERGY STAR houses = EGH 80

ENERGY PERFORMANCE EVALUATION

CDML Ontario was appointed to provide third-party energy analysis of the five properties. They report finding considerable savings from a utility, economic and emissions perspective when comparing current energy usage patterns to pre-retrofit usage. The analysis looked at the pre-retrofit period of November 2007 – May 2008 against the same post-retrofit period in 2009/2010 (See Table 3).

Model 3 is excluded from the analysis as it was used as the project demonstration house and was unoccupied during the evaluation period. The methodology used for the energy analysis involved the use of regression models with historical utility billing data to calculate annual energy savings. Regression modeling identified and accounted for the warmer winter and warmer summer in the post-retrofit period.

After 12 months of monitoring, electricity savings among the houses range from 17% to 42%, gas savings 43% to 60% and water savings -17% to 63% (See Table 3). Solar PV generated for the measurement period represented three months only. When solar data are included for 12 months, Model 2 and 3 are expected to earn more from solar generation sales than the remaining post-retrofit energy cost, therefore achieving an annual energy cost of zero.

TABLE 3: NOW HOUSE WINDSOR 5 ENERGY ANALYSIS

Model	Electrical Reduction	Electrical Savings	**PV Electrical Generation	**PV Earnings	Gas Reduction	Gas Savings	Water Reduction	GHG Reduction (KgCO2e)
1	19.5 %	$131.56	n/a	n/a	43.2 %	$405.25	52.2 %	2725.01
2	42.7 %	$363.63	655.99kWh	$526.10	60.1 %	$749.09	63.8 %	5530.60
3*	-	-	552 kWh	$463.70	-	-	-	-
4	28.2 %	$155.18	n/a	n/a	55.6 %	$589.76	-17.1 %#	3756.28
5	17.4 %	$228.55	n/a	n/a	47.9 %	$420.25	27.7 %	3069.37

* Savings have been influence by the absence of occupants due to the house functioning as a demonstration house.

** The PV generation & earnings represents three months of data only.

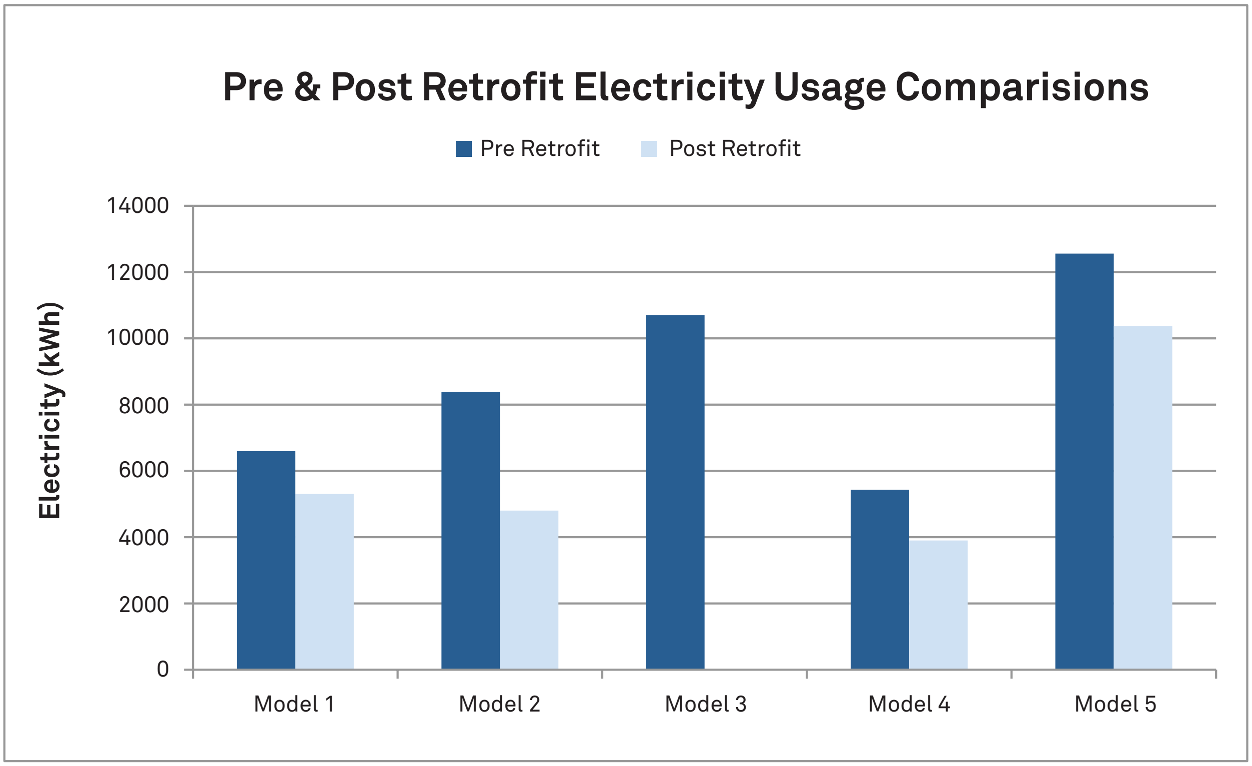
Negative value represents an increase in usage.

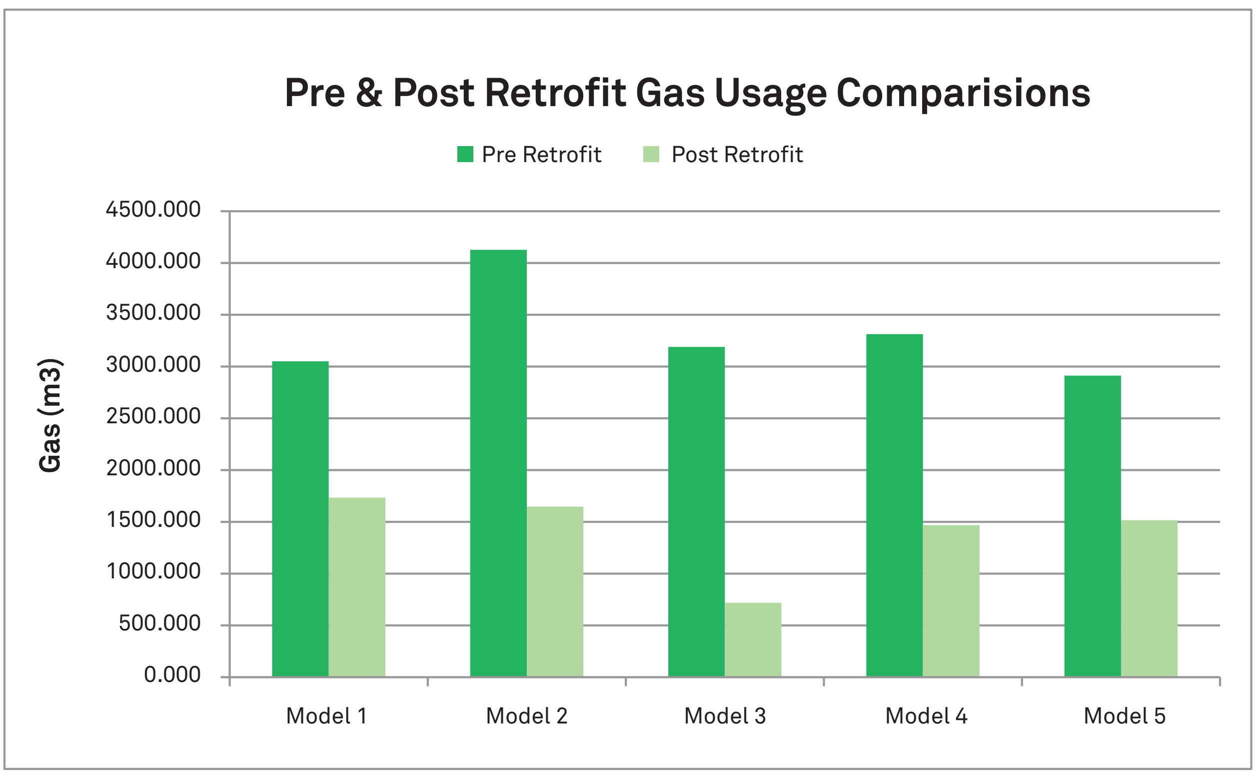
Charts 4,5, and 6 provide pre and post-retrofit usage comparisons. It is worth noting that the electricity usage prior to the retrofits is low by Ontario standards possibly due to the age and small size of the homes, and in one case due to the known conservation practices of the occupants.

In the post-retrofit evaluation period, the daily electricity use averaged over the four households is 16 kWh per day. While well below electricity used by most households in Ontario, this is less than the team's expected electricity savings. The extraordinarily hot summer of 2010 and the newly installed air conditioning may account for this outcome.

The charts also highlight the differences in occupant behaviour with some households using significantly fewer resources than others. CDML Ontario noted that residents of the five houses spend more hours at home than average and don't benefit from opportunities to set back their thermostats in winter or summer.

Although the heating evaluation period was also warmer than the pre-retrofit period, and aggression analysis applied, the gas saving still averaged 50% over the four houses measured.


Pre & Post Retrofit Electricity Usage Comparisions
Pre Retrofit
Post Retrofit
Electricity (kWh)
14000
12000
10000
8000
6000
4000
2000
0
Model 1
Model 2
Model 3
Model 4
Model 5


Pre & Post Retrofit Gas Usage Comparisions
Pre Retrofit
Post Retrofit
Gas (m3)
4500.000
4000.000
3500.000
3000.000
2500.000
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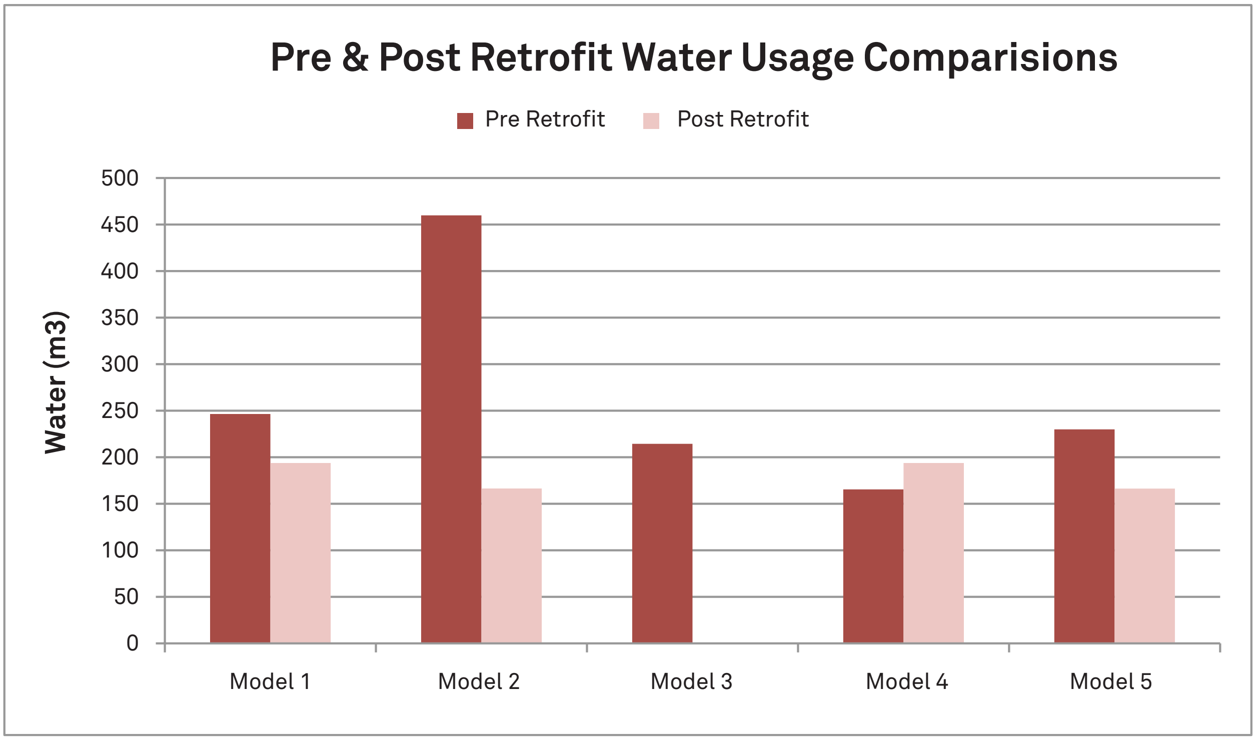
Model 1
Model 2
Model 3
Model 4
Model 5



MOST COST-EFFECTIVE MODEL

One of the primary objectives of the project was to achieve a retrofit model that would provide a cost effective approach for the retrofit of an additional 125 homes in the Windsor Essex CHC portfolio.

The Now House team considered the following four variables in evaluating cost effectiveness:

- EGH improved (cost to gain 0.1 EGH index point)
- Operating costs saved (cost to save $1 energy operating cost)
- Energy saved (cost to save 0.1 million BTUs)
- CO2 emissions reduced. (Cost to reduce 1 kg CO2 emissions)

The importance of each of these factors depends on the priorities of the people and organization undertaking the energy retrofits process.

From the perspective of the client, Windsor Essex Community Housing Corporation, the priorities for measuring cost effectiveness were ranked in this order:

1. Energy saved (cost to save 0.1 million BTUs)
2. Operating costs saved (cost to save $1 energy operating cost)
3. EGH improved (cost to gain 0.1 EGH index point)
4. CO2 emissions reduced (cost to reduce 1 kg. CO2 emissions)

From the cost analysis of the four houses (no reliable data for Model 3 which was unoccupied) the most cost-effective model is Model 2 (See Table 7 and Chart 8).

Model 2 has the lowest cost overall and is significantly lower for energy saving, operating cost saving and CO2 reduction. The addition of solar photovoltaic panels in Model 2A ($25K), which was part of the retrofit, but not included in the energy analysis, is the most cost effective model if evaluated on total operating costs saved, and is predicted to achieve a net zero energy cost.

Model 3, which will be occupied in early 2011 is also expected to achieve zero energy cost on an annual basis.

TABLE 7: NOW HOUSE WINDSOR 5 RETROFIT COST EFFECTIVENESS ANALYSIS

Factors	Analysis	Model 1	Model 2	Model 2A (Note 1)	Model 3 (Note 2)	Model 4	Model 5 (Note 3)
Inputs	Capital Costs	$41,686	$41,127	$66,127	$56,172	$41,127	$31,260
EGH improvements	Pre-retrofit	18	35	35	28	55	55
	Post-retrofit	77	79	79	79	81	74
	EGH index points gained	59	44	44	51	26	19
	Cost to gain 0.1 EGH index points	$70.65	$93.47	$150.29	$110.14	$158.18	$164.53
	Normalized EGH cost effectiveness (Note 4)	1.00	1.32	2.13	1.56	2.24	2.33
Operating Cost Savings	Saved operating cost - electricity	$132	$363	$2,287		$155	$229
	Saved operating cost - natural gas	$405	$749	$749		$590	$420
	Total operating costs saved	$537	$1,112	$3,037		$745	$649
	Cost to save $1 energy operating cost	$77.66	$36.99	$21.78		$55.21	$48.18
	Normalized operating cost effectiveness	3.57	1.70	1.00		2.54	2.21
Energy Savings	Saved energy - electricity (kWh)	1289	3580	5980		1532	2184
	Saved energy - natural gas (m^3)	1317	2480	2480		1844	1396
	Total energy saved (million BTUs) (Note 5)	52	102	110		72	58
	Cost to save 0.1 million BTUs	$79.86	$40.22	$59.87		$56.98	$53.76
	Normalized energy saving cost effectiveness	1.99	1.00	1.49		1.42	1.34
CO2 Reduction	Reduced emissions - electricity ($kgCO_2e$)	284	788	1316		337	480
	Reduced emissions - natural gas ($kgCO_2e$)	2441	4599	4600		3419	2589
	Total emissions reduced ($kgCO_2e$) (Note 6)	2725	5386	5915		3756	3069
	Cost to reduce 1 kg CO_2 emissions	$15.30	$7.64	$11.18		$10.95	$10.18
	Normalized emission reduction cost effectiveness	2.00	1.00	1.46		1.43	1.33
	Cost Effectiveness Index Totals	8.55	5.02	6.08	N/A	7.62	7.21

NOTES

(1) Same as Model 2 but including the costs and predicted benefits of solar photovoltaics

(2) Model 3 was unoccupied during the test period and only EGH improvements were measured

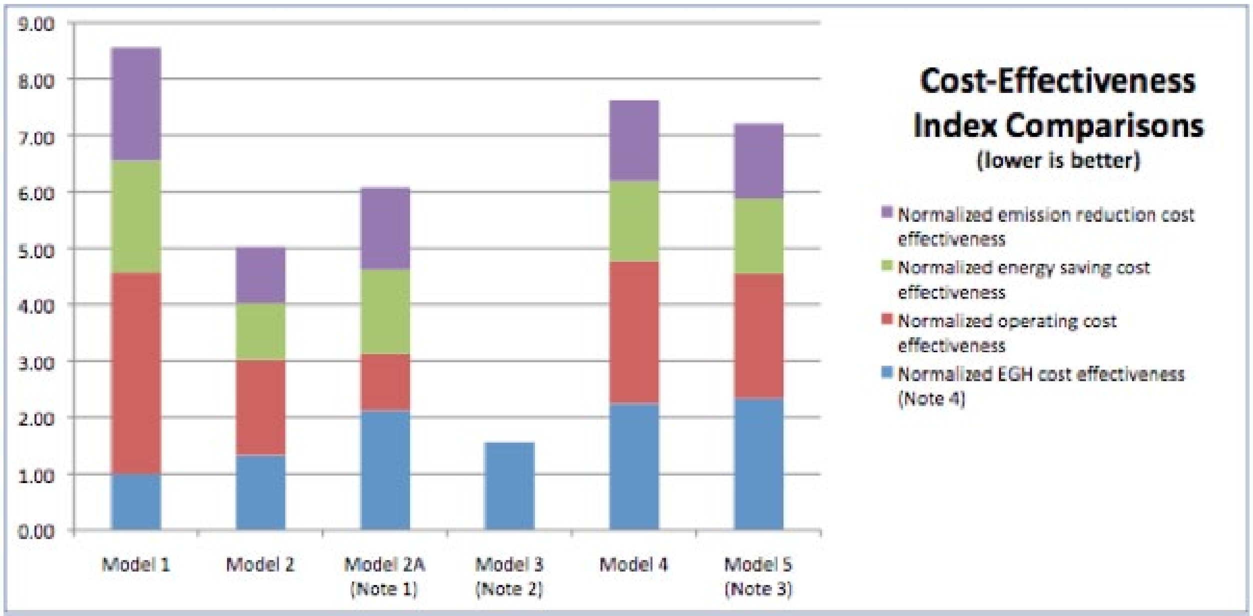
(3) High efficiency gas furnace and air conditioning were not installed in Model 5 until June, 6 months through the test period

(4) Divisors for each factor were chosen to normalize comparisons in the chart; the importance of each factor depends on the user's priorities.

(5) Energy savings were converted to BTU using conversion factors: 1 kWh=3412.3 BTU; 1 m3 = 35.3146667 ft3; 1 ft3 natural gas = 1028 BTU

(6) Energy savings were converted to emissions saved using conversion factors: 1 kWh = 0.22 kgCO2 emitted; natural gas = 49.84 kgCO2 emitted per gigajoule

CHART 8: NOW HOUSE WINDSOR 5 POST-RETROFIT PERFORMANCE COMPARISON



NOTES:

In each of the four categories, the house with the best performance was set as the baseline or index and the performance of the other houses was rated in proportion to the index in each category. The performance of Model 2 is the most cost effective overall. Model 2 without PV is the most cost effective in reducing energy use and CO 2 and with the addition of solar PV is the most effective in reducing operating cost. Model 1 is the most cost effective in EGH improvement. Model 3 was evaluated for EGH only as it was unoccupied during the test period.

COMMUNITY EVENTS AND OPEN HOUSES

Starting well before the retrofits began the Now House and CHC team held events to engage the community, the residents of the houses and the local media. When the retrofits were completed, a well-attended launch event provided the first opportunity to visit the demonstration house, which featured exhibitions detailing the changes to each of the five houses.

The demonstration house was open for several months and attracted hundreds of visitors from the community, the province and from outside Canada. Visitor feedback reports provided demographic information about visitors, and their level of interest in home energy improvements including factors influencing their past and future retrofits choices.

The families living in the newly renovated houses received a resident's handbook and attended an orientation session. By showing residents what specific changes had been made to their homes and providing tips on saving energy and money the Now House and CHC teams hoped to increase the potential for environmentally friendly life styles.

CONCLUSIONS

The Now House Windsor 5 is a unique project providing a comparison of energy efficiency improvements among five 1½ storey post-war homes situated side-by-side on the same street in Windsor, Ontario. The five houses underwent five different energy retrofits and were monitored for 12 months following their completion and evaluated against baseline data for a similar period.

Post-retrofit electricity, gas and water savings reached a high of 42%, 60% and 63% respectively. Pre and post energy audits show a significant improvement in all houses, and in one case achieving EGH 81 or the equivalent standard for a new ENERGY STAR® home. The retrofit of these homes is expected to extend their lifespan by another sixty years.

Of the five retrofit models one model emerged as a clear winner in the cost effectiveness analysis. Model 2, at a retrofit cost of $41,000 showed the best performance overall and specifically in two categories: energy saved and CO2 emissions reduced. With the addition of solar PV to Model 2 (raising the cost to $65,000) it became the most effective in reducing operating cost. This home is predicted to achieve an annual energy cost of zero over the twenty years of the Feed-In-Tariff contract. Model 3 is expected to do the same.

Model 1, also at a cost of $41,000, was the most cost effective in gaining EGH points. This house started at a low energy efficiency level, EGH 18, and post-retrofit had gained 59 points. At the same cost as three of the other retrofits, and with a significant savings in energy and water use, Model 1 presents a compelling argument for the careful retrofit of older homes in poor condition.

The Now House Windsor 5 project demonstrates the benefit of retrofitting older homes. It establishes a process for achievable energy savings and sets new energy usage targets. If applied to Canada's older homes, it would significantly reduce the impact of the residential sector on energy use and greenhouse gas emissions.

For more information see: **www.nowhouseproject.com** and **www.wechc.com** **www.cmhc-schl.gc.ca**