RESEARCH HIGHLIGHT

December 2011 Technical Series 11-102

Testing different approaches to energy reduction in five 1½-storey post-war houses

INTRODUCTION

The Now House Project[1] set out to test the feasibility of retrofitting older homes to reach net-zero annual energy use. The Now House Project team started with the 1½-storey post-war house—a unique Canadian housing type that brands many communities in Canada.

Most of these houses are over 60 years old 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 Demonstration 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, to reduce emissions, and to 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 a post-retrofit performance evaluation.

THE 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 the Second World War. 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 (Figures 1-5) 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 knee wall floors 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

[1] Now House® is a registered trade-mark of The Now House Project Inc. For more information see: www.nowhouseproject.com and www.wechc.com and www.cmhc-schl.gc.ca

- 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 panels had been upgraded to breaker type panels
- 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.

Figure 1 House 1 – EGH 18

Figure 2 House 2 – EGH 35

Figure 3 House 3 – EGH 28

Figure 4 House 4 – EGH 55

Figure 5 House 5 EGH 55

Pre-Retrofit Energy Audits

The pre-retrofit energy audits were performed in accordance with the ecoENERGY Retrofit Program administered by Natural Resources Canada, which does not include electricity usage. The EnerGuide for Houses (EGH) energy rating system produces a score from 1 to 100 with a higher score indicating higher efficiency levels. EGH ratings established by the energy audits ranged from EGH 18 to 55.

In comparison, typical EGH ratings for Canadian homes are listed in Table 1[2]:

Table 1 Typical EGH ratings of houses of different characteristics

House Characteristics	Typical Rating
Older house not upgraded	0 to 50
Upgraded older house	51 to 65
Energy-efficient upgraded older house or typical new house	66 to 74
Energy-efficient new house	75 to 79
Highly energy-efficient new house	80 to 90
House requiring little or no purchased energy	91 to 100

THE FIVE RETROFIT MODELS

The team used HOT2000 for energy modeling to explore the benefits of various retrofit elements by comparing estimated costs and energy reductions. 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 net-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 net-zero energy (see Table 2). 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 net-zero energy.

Key changes

- Each of the five retrofit models included a base package of air sealing and additional insulation in attic, exterior walls and basement, low-flow water fixtures, energy-efficient appliances, doors and lighting. The insulation costs for the base package was just over $18,000 and included three types of insulation: Polyurethane spray foam in the wall cavities by drilling access holes in the drywall (Figure 6); Polyurethane foam was used in the rafters of the sloped portion of the attic space (Figure 7), and cellulose insulation was installed on the horizontal surfaces in the attics.

Table 2 Retrofit Strategies and Costs

Base model applied to each home:	House 1	House 2	House 3	House 4	House 5
▪ Air sealing and insulation ▪ CFL lights ▪ Low-flow fixtures (shower head, toilet, aerators) ▪ ENERGY STAR® refrigerator and front-loading washer ▪ Gas range and dryer ▪ New doors ▪ New siding Cost: $25,627	Base model + ▪ High efficiency hydronic heating system ▪ High efficiency central A/C ▪ Heat Recovery Ventilator ▪ Tankless water heater Cost: $41,686	Base model + ▪ High efficiency forced-air gas furnace ▪ High efficiency central A/C ▪ Heat Recovery Ventilator ▪ Tankless water heater Cost: $41,126 Cost with 2.1 kW solar PV: $66,126	Base model + ▪ High efficiency hydronic heating system ▪ High efficiency A/C ▪ Heat Recovery Ventilator ▪ ENERGY STAR® windows ▪ Tankless water heater ▪ Solar DHW system Cost: $56,172 Cost with 2.1 kW solar PV: $81,172	Base model + ▪ High efficiency forced-air gas furnace ▪ High efficiency central A/C ▪ Heat Recovery Ventilator ▪ Tankless water heater Cost: $41,126	Base model without new appliances and siding ▪ High efficiency forced-air gas furnace ▪ High efficiency central A/C ▪ Heat Recovery Ventilator ▪ Tankless water heater Cost: $31,260

[2] http://oee.nrcan.gc.ca/residential/personal/home-improvement/service/rating.cfm

Figure 6 Access holes used to apply polyurethane foam

Figure 7 Polyurethane foam used in the rafters

- Two houses (Houses 2 and 4) received standard upgrades of an energy-efficient forced-air gas furnace, a tankless water heater, a heat recovery ventilator (HRV), and central air conditioning. House 5 also included these high efficiency HVAC systems, however, they were installed after the post-retrofit energy efficiency analysis presented later in this report.
- Two houses were converted to a hydronic heating system; House 1 is solar ready while House 3 received a solar thermal system, which provides hot water used for domestic hot water and home heating. House 3 was the only one to receive new energy-efficient windows.
- Two homes (Houses 2 and 3) have grid-tied solar photovoltaic systems, and were approved under Ontario's Feed-in-Tariff, which provides 80.2 cents per kilowatt-hour of generation for the contracted period of 20 years to CHC.

The team expected electricity savings to come from components in the base model including: compact fluorescent 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 systems added to Houses 2 and 3 make these houses energy producers as well as consumers. The PV systems are grid-tied with all generation sold to the local utility and therefore have no impact on the actual electricity consumption of these two homes.

Gas savings were expected from improvements in the building 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 House 3 was used to further reduce natural gas use for both domestic hot water and space heating.

The retrofit process began in June 2009 and was completed in September 2009. The Now House Project team 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 Table 3). Houses with low EGH scores at the outset such as Houses 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 expected to correspond to the energy performance of new ENERGY STAR® houses, whereas House 4 surpassed the standard achieving an EGH of 81. House 5, which had yet to install upgraded mechanicals and received the base package changes only (minus new appliances which were declined by the occupants) achieved an EGH of 74 well above the energy performance level of houses of this vintage.

Table 3 EGH Scores Pre- and Post-Retrofit

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

Note: Electrical energy savings and PV electricity generation are not included in reported EGH scores.

Energy Performance Evaluation

CDML Ontario was hired to provide third-party energy analysis of the five properties. It reported 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 4).

House 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 per cent to 42 per cent, gas savings 43 per cent to 60 per cent and water savings -17 per cent to 63 per cent (see Table 4). Solar PV generated for the measurement period represented three months only. When solar data are included for 12 months, Houses 2 and 3 are expected to earn more from solar electricity generation sales than the post-retrofit energy cost, therefore achieving an annual net-energy cost of zero.

Figures 8, 9, and 10 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.

Table 4 Now House Windsor 5 Energy Analysis

House	Electrical Reduction	Electrical Savings	**PV Electrical Generation	**PV Earnings	Gas Reduction	Gas Savings	Water Reduction	GHG Reduction ($KgCO_2e$)
1	19.5 %	$131.56	n/a	n/a	43.2 %	$405.25	52.2 %	2725
2	42.7 %	$363.63	655.99 kWh	$526.10	60.1 %	$749.09	63.8 %	5531
3*	-	-	552 kWh	$463.70	-	-	-	-
4	28.2 %	$155.18	n/a	n/a	55.6 %	$589.76	-17.1 %#	3756
5	17.4 %	$228.55	n/a	n/a	47.9 %	$420.25	27.7 %	3069

* Savings have been influenced by the absence of occupants due to the house functioning as a demonstration house and therefore was not included in the analysis.
** The PV generation and earnings represent three months of data only.
# Negative value represents an increase in usage.

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 more than what the team expected for electricity usage.

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

The post-retrofit heating evaluation period was warmer than the pre-retrofit period and regression analysis was used to eliminate the distortion in space heating energy caused by the temperature differences. The mean gas saving averaged 50 per cent over the four monitored houses. The savings are more remarkable considering that the number of gas appliances in the houses actually increased during the retrofit.

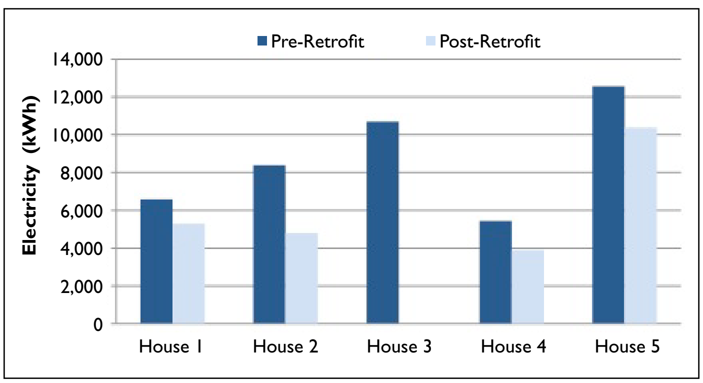


Figure 8 Pre- and Post-Retrofit Electricity Usage Comparisons

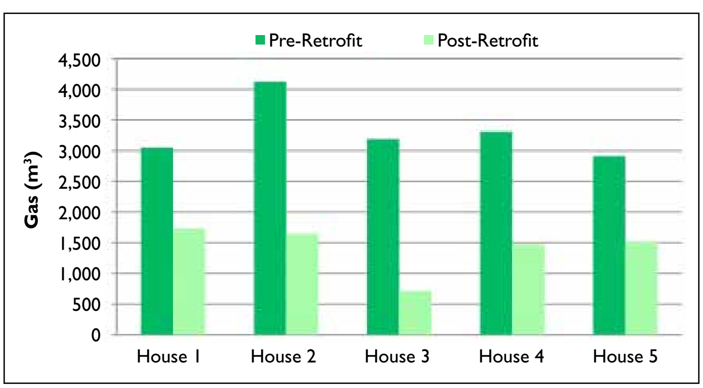


Figure 9 Pre- and Post-Retrofit Gas Usage Comparisons

FINDINGS—MOST COST-EFFECTIVE MODEL

One of the primary objectives of the project was to develop 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 in energy operating cost)
- Energy saved (cost to save 0.1 million BTUs)
- CO_2 emissions reduced. (Cost to reduce 1 kg of CO_2 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 in energy operating cost)
3. EGH improved (cost to gain 0.1 EGH index point)
4. CO_2 emissions reduced (cost to reduce 1 kg of CO_2 emissions)

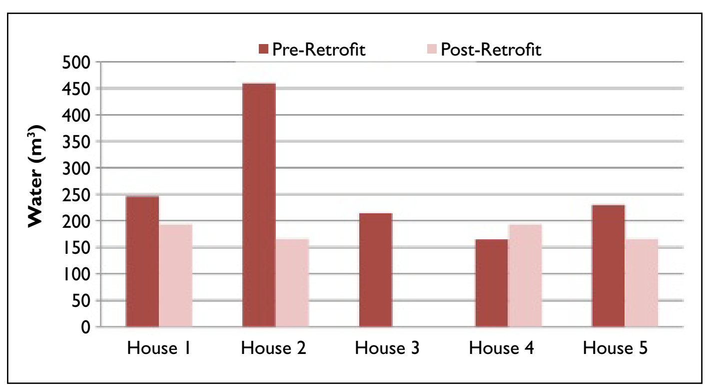


Figure 10 Pre- and Post-Retrofit Water Usage Comparisons

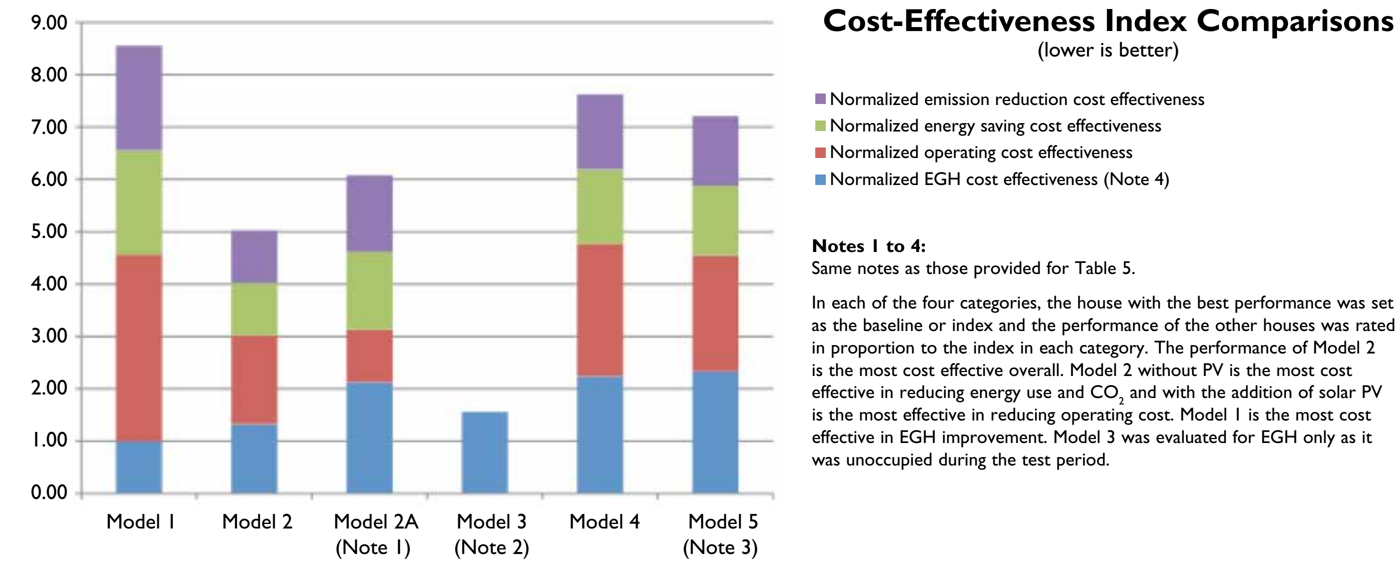
Table 5 Now House Windsor 5 Retrofit Cost Effectiveness Analysis

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 in 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)	52	102	110		72	58
	Cost to save 0.1 million BTUs	$79.86	$40.22	$59.87		$56.98	$53.76
	Normalized energy saving cost effectiveness	1.99	**1.00**	149		1.42	1.34
CO_2 Reduction	Reduced emissions - electricity ($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 1kg of CO_2 emissions	$15.30	$7.64	$11.18		$10.95	$10.18
	Normalized emission reduction cost effectivness	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 House 2 but including the costs and predicted benefits of solar photovoltaics
(2) House 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 House 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 m^3 = 35.3146667 ft^3; 1 ft^3 of natural gas = 1028 BTU
(6) Energy savings were converted to emissions saved using conversion factors: 1 kWh = 0.22 $kgCO_2$ emitted; natural gas = 49.84 $kgCO_2$ emitted per gigajoule

From the cost analysis of the four houses (no reliable data for House 3 which was unoccupied) the most cost-effective model is House 2 (see Table 5 and Figure 11). House 2 has the lowest cost overall and performs well in energy saving, operating cost saving and CO_2 reduction. The addition of solar photovoltaic panels in House 2A ($25,000), 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.

House 3, which was expected to be occupied in early 2011, is also expected to achieve net-zero energy cost on an annual basis.



Notes 1 to 4:
Same notes as those provided for Table 5.

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.

Figure 11 Now House Windsor 5 Post-Retrofit Performance Comparison

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 community 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 retrofit 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 team hoped to increase the potential for environmentally friendly lifestyles.

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 per cent, 60 per cent and 63 per cent respectively. Pre- and post-retrofit energy audits show a significant improvement in all houses, and in one case achieved an EGH of 81, which exceeds the 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. House 2, at a retrofit cost of $41,000, showed the best performance overall and specifically in two categories: energy saved and CO_2 emissions reduced. With the addition of solar PV to House 2 (raising the total retrofit cost to $65,000) it became the most effective in reducing operating cost. This home is predicted to achieve an annual net energy cost of zero over the twenty years of the Feed-in-Tariff contract. House 3 is expected to do the same.

House 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 significant savings in energy and water use, House 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.

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Housing Research at CMHC

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Printed in Canada
Produced by CMHC 14-12-11

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