RESEARCH HIGHLIGHT

June 2008 Technical Series 08-104

Approaching Net-Zero Energy in Existing Housing

INTRODUCTION

CMHC defines "net-zero energy housing" as a home that produces as much energy as it consumes annually. This is accomplished by a variety of means, including :

- reducing energy loads through a high-performance building envelope and energy-efficient appliances and lights;
- increased use of passive-solar cooling and heating techniques;
- high-efficiency mechanical systems that match the lower energy requirements of the home;
- space and water heating assisted by commercially available, solar thermal systems and heat pumps;
- electrical use offset by grid-connected, commercially available photovoltaic (PV) systems.

It is easier to build a new home to stringent energy specifications than it is to retrofit an existing house, yet new construction accounts for only two per cent of the housing stock annually. With residential uses accounting for 17 per cent of Canada's energy requirements and 16 per cent of our greenhouse gas (GHG) emissions, cost-effective ways to retrofit the millions of existing houses to meet net-zero energy targets are key elements to energy security and climate change mitigation.

Current energy-efficiency programs for existing homes aim for overall energy reductions of 20 to 30 per cent. Net-zero retrofits would require reductions in overall energy use of between 70 and 90 per cent.

There is a history of practical experience in energy retrofitting in Canada that stretches back to the 1970s. One of the 12 EQuilibrium initiative projects, the Now House™ is exploring the net-zero retrofit concept. This 60-year-old wartime house, in an established neighbourhood in Toronto, represents hundreds of thousands of homes in Canada.

Table 1 Benefits and barriers to net-zero energy retrofits

Benefits	Barriers
Radically reduces or eliminates energy costs	Initial cost / financing
Energy security	Knowledge and experience of building industry
National security	Knowledge and experience of building inspectors
Reduced air pollution	Knowledge and experience of financial institutions
Reduce or eliminate green house gas emissions and impact on climate change	Regulations
Increased thermal comfort	Minimum setbacks at property lines and adjacent buildings
Enhanced indoor air quality and occupant health	No guarantee of long-term solar access
Local job generation	Limitations on wind tower height and use of wind energy systems (WES) in urban areas
Reduces or eliminates peak electrical demand	Lack of detailed local wind energy data for WES and passive cooling
	Poor utility adoption of power buyback policies
	Lack of consumer interest

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RESEARCH PROGRAM

Houses of various ages and styles pose different challenges for energy-efficiency retrofits. Older homes can have uninsulated, damp basements and structural issues. There are variations in regional and historical construction practices and materials choices. In older homes, the street facade and the appearance of character-defining elements, such as windows and doors, have to be accommodated. In newer homes with current insulation levels and recently installed durable materials, the retrofit options will be limited.

The house types shown in Table 2 were modelled in HOT2000 for typical energy usage in six cities. In general, the modelled upgrades emphasized energy efficiency first, then add-on renewable energy systems. This meant improving the building envelope, then upgrading and updating HVAC equipment, appliances and lighting. High-efficiency heat pumps were modelled in houses where heritage value or other constraints meant the envelope could not be changed to meet the upgrade targets. PV and solar thermal were added after all energy reduction measures possible were modelled.

Table 2 Housing types and ages

House type	Year of Construction For Simulation
Pre-WW II 2½-storey	1922
Post-war 1½-storey	1952
2-storey	1988
	2000
Bungalow	1969
	2000
Split level	1985
Split entry	1980
Duplex (up and down)	1965
Row house	1965

UPGRADES TO ENVELOPE, MECHANICAL SYSTEMS AND BASELOADS

Typical building envelope characteristics and mechanical systems were determined through the EnerGuide for Houses database and archetype library.

The envelope upgrades were determined through comparison to other existing standards and initiatives. Space- and water-heating appliances were upgraded but not changed (for example, a mid-efficiency gas furnace was replaced with a high-efficiency condensing gas furnace).

Base loads were reduced by 60 per cent through a range of measures. The output of a standard 6 m^2 (64.5 sq. ft.) flat-plate, solar, thermal system and two PV systems were modelled for the various roof slopes of each house type (6 to 10 GJ/yr. [1,700 to 2,800 kWh/yr.]).

The first PV system was sized to fit on the roof of the house and the second system was sized to accommodate the initial electrical baseload. Table 3 shows the envelope targets for all houses in each of the six cities. All doors were updated to insulated metal units and all windows were upgraded to triple-pane units with low-e coatings, argon fill and insulating spacers.

AN EXAMPLE OF APPROACHING NET-ZERO ENERGY

The main upgrades are summarized below for a 1969 bungalow, located in Vancouver. The table shows their impact on energy use.

- The building envelope was improved with higher insulation levels, high-performance windows and good air-sealing work. An HRV was added to maintain high indoor air quality.
- The envelope improvements allowed the mid-efficiency furnace to be replaced with 4 kW of baseboard heaters.
- A high-efficiency hot-water system was coupled with a drainwater heat recovery unit and a drop in overall hot water use.
- A solar hot-water system was installed.
- Baseloads were reduced
- A rooftop PV system with the potential to contribute 21 GJ (5,800 kWh) annually was installed.
- The size of the PV system was increased to provide 31.5 GJ (8,750 kWh) annually.

Table 3 Modelled envelope upgrades for all house types, shown as RSI (R)

	Ceiling	Main walls	Exposed floors	Below-grade walls	Slab
Vancouver	8.8 (50)	4.6 (26)	4.6 (26)	4.6 (26)	1.8 (10)
Calgary	14.4 (80)	10.6 (60)	10.6 (60)	7 (40)	1.8 (10)
Toronto	10.6 (60)	7 (40)	7 (40)	7 (40)	1.8 (10)
Montréal	14.4 (80)	10.6 (60)	10.6 (60)	7 (40)	1.8 (10)
Halifax	10.6 (60)	7 (40)	7 (40)	7 (40)	1.8 (10)
Whitehorse	14.4 (80)	10.6 (60)	10.6 (60)	7 (40)	1.8 (10)

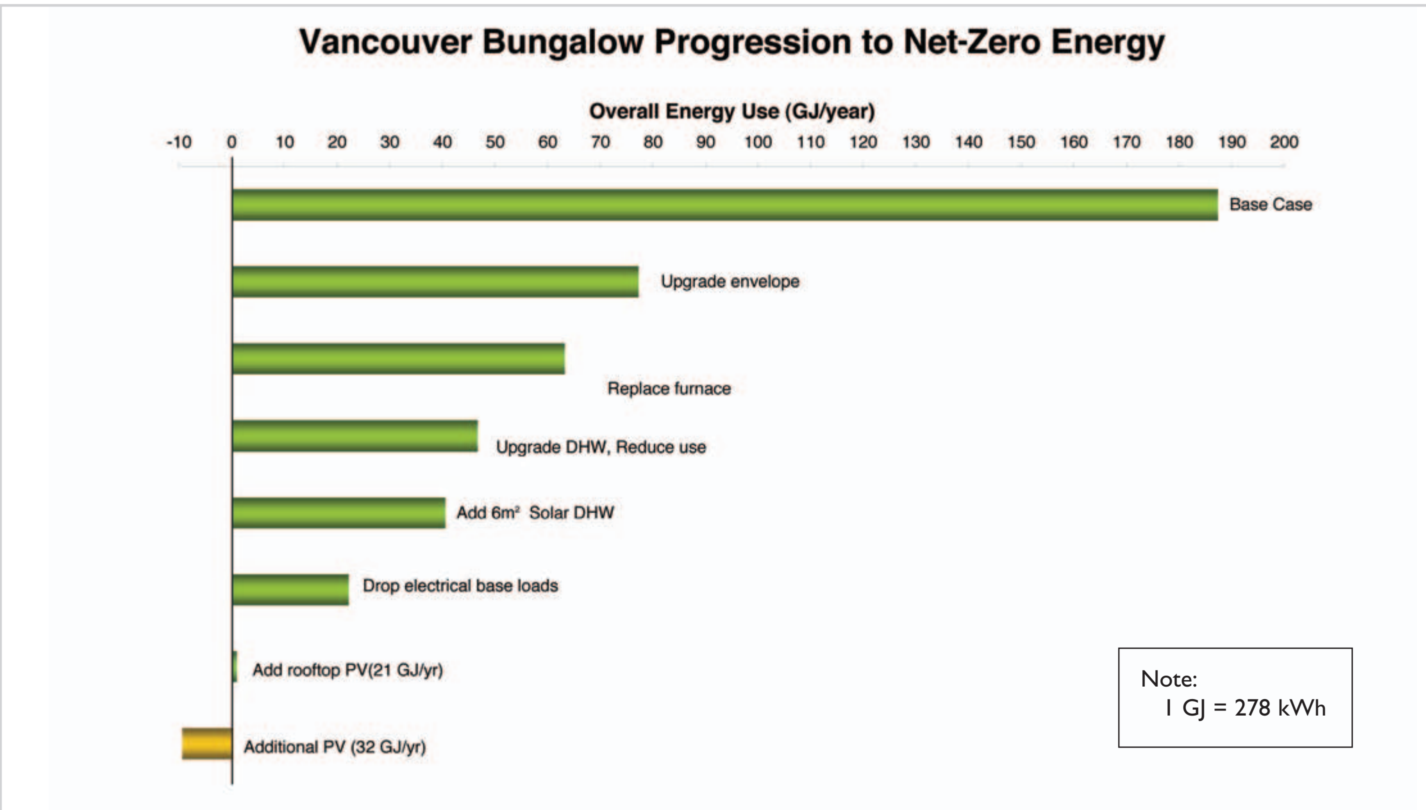

Figure 1

FINDINGS

As could be expected, there were differences between climatic regions that influenced the challenge of approaching net-zero energy in existing houses. The region where retrofits were most likely to come close to net-zero energy mainly through building envelope improvements was Vancouver.

The design heat loss indicates how much heat the house will require to maintain a comfortable inside temperature in the most severe winter conditions for a given location. In most cases, where envelope characteristics did not restrict the level of insulation improvements, the design heat loss was reduced by more than half, in some cases by up to three-quarters.

Table 4 Simulation Results

House type	City	Overall energy use (GJ)		Optimal rooftop SDHW contribution (GJ)	Optimal rooftop PV contribution (GJ)	Energy deficit (GJ)
		Base	Upgrade			
Pre-WWII w/brick veneer	Toronto	248.3	51.1	8.3	18.2	24.6
$1^1/_2$ - storey Post-WWII	Halifax	174.6	49.4	8.3	23.5	17.6
1969 bungalow	Vancouver	187.2	28.2	6.1	21.2	0.9
	Whitehorse	177.3	83.3	6.9	20.9	55.5
2000 two-storey	Calgary	161.3	49.3	8.8	33.3	7.2
	Whitehorse	263.4	87.7	6.9	26.1	54.7
Up/down duplex	Montréal	145.4	31.3	7.9	12.7	10.7

The heating load is the amount of energy (in GJ) that the house consumes annually. In general, there were significant reductions in heating loads in all house types, and in all cities, for an average reduction of 81 per cent. The overall range of reductions was from 56 per cent to 96 per cent. House type and age; typical construction patterns; and climatic differences between cities caused the variations in reductions.

Table 4 shows examples of the potential reductions in overall energy use. Of note is the 1969 bungalow: the energy usage in the initial house is nearly the same in Vancouver and Whitehorse, but the bungalow in Vancouver is one of the few house types to actually reach net-zero energy with a rooftop PV system.

The Whitehorse bungalow, with a massive improvement in the building envelope and a high-efficiency furnace, still requires over 55 GJ (15,000 kWh) of energy with a rooftop PV system installed. This changes, however, when the oil-fired, forced-air system is replaced with a high-efficiency, ground-source heat pump: the Whitehorse bungalow with a rooftop PV system requires less than 10 GJ (2,800 kWh) of energy. The likelihood of this scenario is low, however, because of the cost of improving the envelope and installing a high-efficiency, ground-source heat pump.

Upgraded older homes can achieve lower overall energy use than newer homes because there is more potential for upgrades. A new house, such as a two-storey house built in 2000, is more likely to have decent insulation levels and perhaps a higher-efficiency heating system. However, a homeowner is less likely to carry out a “deep” energy retrofit, as the siding, windows and mechanical equipment do not need replacing.

Looking at Table 4 further, the variation in the amount of the PV contribution, based on the available roof area, impacts heavily on the final energy “deficit.”

For example, the duplex in Montréal shows slightly more than half the PV contribution available to the $1^1/_2$-storey house in Halifax, and well under half of that of the two-storey home in Whitehorse, yet the two houses located in Whitehorse have only a 6 GJ (1,700 kWh) difference. While PV contributions vary from city to city, it can be seen that house types with larger roof areas, and thus higher potential PV contributions, have a definite advantage in terms approaching net-zero.

The house type that would most easily be retrofitted to net-zero energy is the bungalow, where the simple form of the building allows for better results from air sealing and insulation. In addition, the long axis of the house results in a larger, unobstructed or shaded roof face than other house types. This gives the potential for the largest possible roof-mounted PV array and solar domestic hot water system (SDHW), even if the 4/12 roof typically is not at optimum slope for these technologies in most Canadian regions.

THE COST OF NET-ZERO ENERGY RETROFITS

It was shown in the report that energy conservation retrofits in the $30,000 and $50,000 range were cost effective when refinancing a mortgage. In many cases, the monthly energy savings outweighed the incremental increase in a mortgage payment. However, a full “net-zero” retrofit would cost more than this. Canadian statistics show that the “average” major renovation figure costs about $12,000.It has been the project team’s experience that homeowners are willing to pay more for what they want, witness the number of $20,000 to $100,000 kitchen renovations. One aspect of whole house energy efficiency retrofits not currently addressed is the value of associated “non-energy benefits” (NEBs). Recent studies show comfort and aesthetic benefits far outweigh energy concerns, and very few homeowners assess the economic benefits of their investments by monitoring energy bills or calculating payback times.

IMPLICATIONS FOR HOMEOWNERS AND RENOVATORS

This project demonstrates the technical feasibility of approaching net-zero energy in existing homes. The technologies to retrofit a house to net-zero energy consumption are available. Solar heating and photovoltaic electricity generation can complete the energy balance, making a house very close to net-zero consumption. While it is possible, such major retrofits have not yet been taking place. Barriers to actually getting to net-zero energy in existing homes include the challenge of coordinating the timing of a retrofit. Making a project cost-effective depends on some planning—for example, if the siding is to be replaced on a home, that is the time to insulate the exterior and upgrade windows. Mechanical equipment is usually replaced under emergency situations, so a change-out to a higher-efficiency, smaller output unit that coordinates with an envelope upgrade requires a clear plan and timely financing. Other barriers are based in the logistics of finding contractors willing and able to do the work required.

The technology and materials are available to reduce energy loads significantly, in existing houses, by a factor of 7 to 9. However, getting to net-zero energy in existing houses is completely dependent on the cost of the add-on renewable systems that take the house to net-zero energy. Solar thermal systems are market ready with a reasonable payback period, and are a more readily accepted option by homeowners. If there were financial incentives and mechanisms in place, roof-mounted solar thermal systems would become a much more commonplace sight in Canada. PV systems are currently very expensive, with long payback periods for small systems. Until there are reasonable incentives to purchase and operate these systems (tax rebates, purchase incentives, “green power” premiums for grid-connected systems), homeowners will be best served by investing in envelope and mechanical systems upgrades, making their houses ‘net-zero ready’. Pre-planing for PV or other on-site options will make the transition from energy consuming house to net-zero house more cost-effective.

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Housing Research at CMHC

Under Part IX of the ***National Housing Act***, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

This fact sheet is one of a series intended to inform you of the nature and scope of CMHC's research.

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Printed in Canada
Produced by CMHC 25-03-09
Revised: 2009

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