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Exceeding the Ontario Building Code for low-rise residential buildings: Economic and environmental implications

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ABSTRACT

The residential sector accounts for approximately one fifth of Canada's secondary energy use and greenhouse gas emissions. Thus, addressing the energy efficiency of residential buildings has a significant role to play in reducing the nation's overall greenhouse gas emissions. The Ontario Building Code has recently been updated to reflect a more stringent energy performance standard. A home built to the prescribed minimum requirements will perform at a relatively high standard with respect to energy use when compared to homes built less than a decade ago. This paper explores three energy efficiency upgrade options which improve upon the energy efficiency of the 2012 Ontario Building Code. The "controlled ventilation" upgrade involved tightening up the building envelope and adding heat recovery to waste air streams, and two additional upgrade options were developed to meet the high performance targets of the R-2000 standard. While the upgrades explored did not show financial benefit for individual homeowners at current utility rates, if the benefits to society are considered, the upgrades are an economically efficient method of reducing greenhouse gas emissions owed to energy consumption. In addition to highlighting the need for a broader approach to the cost-benefit analyses associated with these types of upgrades, this finding also warrants a discussion about how to transform the current housing market so that energy efficient homes are more appropriately valued.

1. Introduction

Climate change is one of the most pressing issues currently facing the global community. Climate scientists are largely in agreement that greenhouse gas (GHG) emissions are responsible for climate change and government bodies around the world are recognizing this and implementing measures to reduce their emissions. The Province of Ontario has summarized their emissions targets as well as plans to reduce atmospheric carbon in Ontario's Climate Change Action Plan [1]. Ontario's Climate Change Action Plan has set out targets to reduce GHG emissions to 15% below 1990 levels by 2020. Current investments in green energy, energy efficiency, and other programs are expected to bring Ontario 60% of the way towards the 2020 target [2]. In order for Ontario to reach the 2020 target, additional programs must be introduced across all sectors within the province.

The building sector is often cited as one of the most cost-effective areas to reduce energy use and GHG emissions [3,4]. With the vast majority of Ontario's building stock in the form of residential housing, there exists significant potential in the residential sector to reduce carbon emissions province-wide. The residential sector accounts for 17% of Canada's secondary energy use, 80% of which is used for space and domestic hot water (DHW) heating [5]. GHG emissions from Canadian homes are closely tied to energy use from the residential sector; 16% of the nation's carbon emissions are from residential buildings [5]. With the continued growth of the residential sector, new Ontario housing has an important role to play in meeting Ontario's future greenhouse gas emission targets.

Ontario is currently experiencing significant growth with over 65,000 housing starts estimated in 2012 [6]. The large number of housing starts in Ontario will lead to significant growth in the demand for energy use, which correlates with a growth in GHG emissions. While more homes will require more energy, the rapid development of communities within Ontario represents an immense opportunity for energy conservation. As these homes will be occupied for decades to come, we must evaluate how design decisions that we make today will perform in the future.

Ontario has been progressively improving energy efficiency requirements for new homes over the past several decades, where the most recent changes to the Ontario Building Code (OBC) have significantly improved the standard for the energy efficiency of

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Table 1
Summary of the homes modeled in HOT2000.

	Model I: standard OBC home	Model II: OBC w/controlled ventilation	Model III: R-2000 (fuel-fired)	Model IV: R-2000 (electric-powered)
Roof effective thermal resistance	8.16 m^2 K/W (R46)		11 m^2 K/W (R62)	
Wall effective thermal resistance	4.49 m^2 K/W (R26)		6.10 m^2 K/W (R35)	
Below grade wall effective thermal resistance	2.57 m^2 K/W (R15) Interior + 0.88 m^2 K/W (R5) exterior to 0.6 m below grade		4.33 m^2 K/W (R25) Interior + 3.52 m^2 K/W (R20) exterior to 0.6 m below grade	
Windows	Double-glazed, low-e, argon fill		Krypton fill with 2 suspended reflective films	
Natural air infiltration	2.5 ACH_{50}		1.5 ACH_{50}	
Forced ventilation	No heat recovery	HRV, 65% sensible efficiency		
Space heating	Natural gas furnace, 95% AFUE	Air-source heat pump, 8.5 HSPF		
Space cooling	Conventional AC, 13 SEER			Air-source heat pump, 15 SEER
Domestic hot water heating	40 gallon tank, 0.62 EF			Tankless water heater, 0.94 EF

housing starts in the province. The changes came into effect January 21st 2012, effectively improving home energy efficiency by 40% when compared to housing starts in 2006 [1]. The revised code requires homes that are occupied continuously over the winter months to have a performance rating of at least 80 on the EnerGuide rating system, which is a home energy performance rating system on a scale from 0 to 100 developed by Natural Resources Canada, or be in conformance with the prescriptive path for energy efficiency outlined in Supplementary Standard SB-12, Energy Efficiency for Housing of the OBC [7].

The prescriptive path for energy efficiency outlines several equivalent compliance packages for energy efficiency. Each compliance package bundles energy efficiency measures in the form of prescriptive requirements for the building envelope and mechanical equipment. These compliance packages were partially developed from the recommendations put forth in a report by Lio & Associates [8] which were made on the basis of energy savings, GHG emissions, environmental impacts and costs, as well as barriers to adoption.

Since the implementation of the 2012 OBC, Dembo et al. [9] explored least-cost upgrade solutions that could be used to increase energy efficiency in new Canadian residential construction. A baseline model home was developed using the minimum energy efficiency requirements of the 2006 OBC which preceded the latest 2012 updates. From this baseline home located in Toronto, energy modeling was used to identify least-cost upgrade solutions. The least-cost upgrades from the 2006 OBC included improved thermal resistance of the building envelope and installation of high efficiency HVAC equipment.

Most of the remaining literature on the reduction of energy use and GHG emissions in the residential building sector focuses on improving the performance of existing homes through energy retrofits. Dowson et al. [10] reviewed the barriers to significantly reducing carbon related emissions by retrofitting the United Kingdom's (UK) existing housing stock. The major barriers identified included "hard-to-treat" solid walls, the large expense of replacing windows, and the high embodied energy in retrofit materials. Gamtessa [11] gave an overview of the residential energy efficiency retrofit behavior in Canada in conjunction with government incentives, and found that retrofits are more likely to be carried out in older less efficient homes, and that the likelihood of undertaking an energy retrofit was directly related to the expected cost savings and upfront financial incentives. Galvin [3] took a critical view of the generosity of Germany's financial incentives for single residential retrofits, citing the declining economic efficiency with more aggressive energy retrofits as the reason.

The focus of this paper is on the merits of energy efficiency in new construction. Building upon and updating the work previously mentioned by Dembo et al. [9], this study explores the economic and carbon implications of building more energy efficient homes than required by the 2012 OBC. To develop this case, a model of a typical single-family detached home that would just meet the energy efficiency requirements of the 2012 OBC was developed as the baseline. Three separate energy efficiency upgrade options were developed and modeled using home energy simulation software to compare both energy savings and carbon reductions. The most basic upgrade entailed tightening up the building envelope and adding heat recovery to the ventilation system. The two remaining upgrades included increased levels of insulation and high performance windows which meet the R-2000 energy target. R-2000 is a voluntary home performance standard administered by Natural Resources Canada, and is based on such metrics as energy efficiency, indoor air quality, and environmental responsibility. The R-2000 energy target was recently updated to reflect improvements in building codes across the country and subsequent advances of industry standards [12]. It is this updated target upon which the upgrade options have been based. The difference between the two R-2000 models was the fuel source used for space and water heating—the more typical model used natural gas for heating while the less carbon-intensive model was powered and heated exclusively by electricity. These measures showed more significant reductions in energy use and GHG emissions.

2. The model homes

To obtain energy simulation inputs, four model homes were developed that would be representative of new homes being built in Ontario in both size and fenestration ratios. The baseline model was generated based on the OBC and two of the three energy efficiency upgrade options were designed to qualify for R-2000 certification.

The overall dimensions and placement of windows and doors were held constant to enable a comparison amongst the baseline model and the different upgrades. These parameters were selected to best reflect the average new home being built in Ontario. The average home size of a new single-detached home in Ontario is 177 square meters [6]. The model home was designed to capture this with a square building footprint measuring 10 m by 10 m over two stories. The model includes a basement which extends 1.86 m below ground. The Canadian Single-Detached and Double/Row Housing Database (CSDDRD) was consulted in selecting window-to-wall ratios for accurate representation of newly constructed homes; the average glazing area of homes built since the 1980s has remained steady at about 15% of the wall area, and the average south facing window area is currently about 5% of the