SUMMARY[1]
ALTERNATIVE ENERGY EFFICIENT DESIGNS (CANADA) FOR SINGLE WYTHE MASONRY STRUCTURES - PHASE 2

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In most climates in Canada, the prescriptive-based building envelope provisions in the National Energy Code for Buildings (NECB-2011) require that exterior walls be sufficiently insulated to provide maximum thermal transmittance values varying from 0.210 to 0.315 W/m^2K, depending upon climate zone. This requirement significantly impacts the cost of single wythe concrete block masonry wall systems where they are commonly used in warehousing, industrial, and some commercial buildings. Because masonry walls have a relatively high thermal transmittance, surface insulation must be applied to the wall system to meet the low wall thermal transmittances required by the code. This also requires that the insulation be protected (from fire, mechanical damage, and moisture), often with coverings that have lower durability than masonry (which otherwise may have simply been exposed), resulting in higher maintenance costs. In addition, prescriptive insulation requirements lead designers to assume that a building envelope having a high thermal resistance (low thermal transmittance) is needed for a building to be considered "energy efficient", even though increasing envelope insulation levels may have only a minimal effect on the overall energy performance, especially for walls with a high thermal mass. In fact, studies on annual energy use of buildings have shown that the efficiencies of lighting systems, and heating and cooling systems can have a much more significant and positive effect on energy consumption than simply increasing envelope thermal resistance, depending on the building occupancy, its operating schedules, and the climate zone in which it is located.

To develop more cost effective design alternatives to the simple prescriptive solutions offered by the energy code, the University of Louisville conducted a two phase investigation on the energy used by a number of building archetypes commonly constructed with single wythe masonry exterior wall systems. For each archetype, and most climate zones identified in the NECB-11, various (code-compliant) alternative construction configurations were examined for energy efficiencies and construction costs. These alternative configurations did not use externally applied insulation.

The first phase of the study examined a warehouse archetype. In the second phase, two archetypes were investigated; a prototype supermarket building detailed as shown in Figure 1 and a low-rise (box) retail building (described later). These building occupancies were chosen because they commonly use single wythe exterior masonry wall systems and have substantially different energy use patterns than the warehouse archetype evaluated in Phase 1. The supermarket archetype is also one of 16 reference buildings used for the evaluation of energy analysis software by the Department of Energy (DOE) (http://www.nrel.gov/docs/fy11osti/46861.pdf).

Using the DOE EnergyPlus energy simulation program, and for the cities and climate zones shown in Table 1, whole building energy analyses were conducted in accordance with Part 8 of NECB-11 to establish annual energy costs for the prototype supermarket configured using code prescriptive minimum requirements (termed building "baseline or reference configurations"). Using this process

[1]From: "An Investigation of Alternative Energy Efficient Designs for Medium Sized Single Wythe Masonry Buildings Phase 2 – Supermarket and Low-Rise (Box) Retail", W. Mark McGinley ,J B School of Engineering, University of Louisville, July 2014.

to verify code compliance requires that the alternative building designs use no more energy on a yearly basis than equivalent buildings prescriptively configured when modelled in the same cities, with the same set points, schedules, etc. The exterior walls of the baseline configurations were modelled as single wythe 20 cm concrete block masonry. To meet the NECB building envelope thermal transmittance requirements, the thickness of extruded polystyrene interior face insulation (see Figure 2) required for the exterior masonry walls in the baseline building configurations varied from 76 to 127 mm (3 to 5 inches), depending upon climate zone.

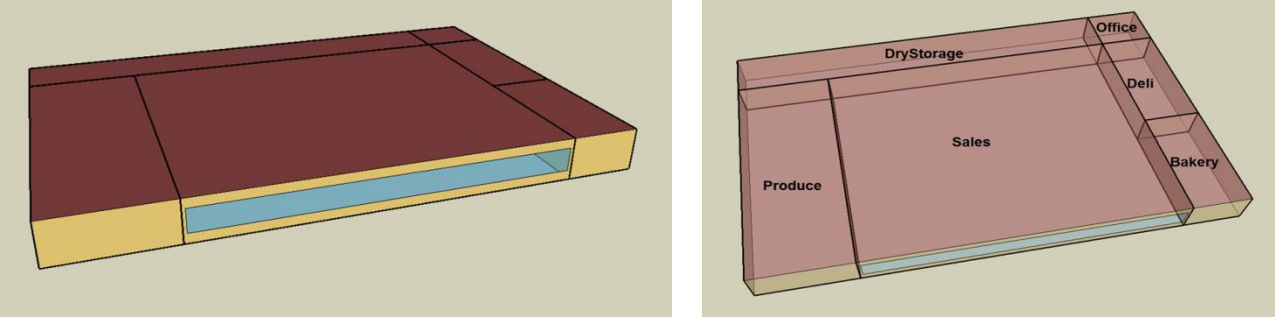


Figure 1: Prototype Supermarket Configuration for the Energy Model 4180 m^2 (45000 ft^2) Prototype (From DOE Prototype buildings).

Table 1. Evaluated Climate Zones and Cities in Canada.

City	Climate Zone	HDD
Victoria, BC	4 (<3000 HDD)	2650
Windsor, ON	5 (3000 to 3999)	3400
Montreal (City Hall), QC	6 (4000 to 4999)	4200
Edmonton, AB	7A (5000 to 5999)	5120
Ft. McMurray, AB	7B (6000 to 6999)	6250

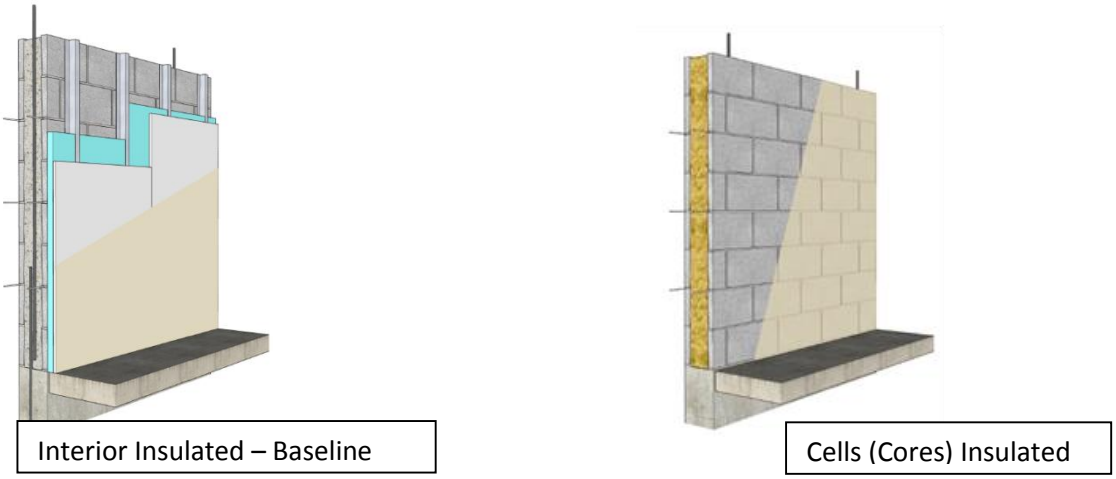


Figure 2. Exterior Masonry Walls, Interior Insulated and Cell Insulated.

When using the whole building analysis compliance path, the NECB has a provision that allows the fenestration+door area to gross wall area ratio (FDWR) of the reference building to be increased under certain conditions. The FDWR of the reference building is not required to "track" the FDWR of the proposed building where the FDWR of the proposed building is below a prescribed maximum value. Thus, for the purposes of proving compliance, the reference building may be assigned the maximum FDWR permissible, even though the proposed building uses its design FDWR. The FDWR limit varies

from 20% to 40%, depending on heating degree days (HDD). Because fenestration and doors typically have higher U-values than opaque envelope components, this code provision aids in qualifying buildings (having a higher opaque wall thermal transmittance than that prescribed by the code) where the FDWR is low, such as a supermarket (the prototype supermarket design FDWR was less than 11%). These provisions also allow the reference building to be assigned a total skylight area of 5% of the gross roof area, and like FDWR, may be used where the proposed building has less than a 5% skylight area, however this effect is much smaller. In this study, the FDWRs of the "baseline configuration" buildings (the reference buildings) were adjusted as permitted by the NECB, but skylight area adjustments were not used.

Supermarkets have large freezers and these freezers so dominate the yearly building energy use that the effects on energy consumption by the other building systems are largely overshadowed. The energy analyses on the building model were conducted with and without refrigeration but only the energy use without refrigeration was used to better assess the effects of changes in the other building systems on the overall energy consumption of the building. The net change in energy use is the same, even if the refrigeration energy is accounted for.

Yearly building energy use predicted by the EnergyPlus simulations for each reference baseline configuration is shown in Table 2 (identified as "Reference Baseline-Max FDWR") and expressed using an Energy Usage Intensity (EUI). EUI is the annual energy used per square meter (or square foot) of building foot print, and is a convenient way to display energy use in a building that allows for easy comparisons.

In order to evaluate the cost-effectiveness of the various design alternatives to externally insulated masonry walls (examining both energy costs and construction costs), a variety of alternative building configurations were explored in the study. For each city, whole building energy analyses were also conducted on otherwise identical supermarket configurations having exterior single wythe 20 cm concrete block masonry walls without external (surface applied) insulation. For these configurations, core (cell) insulation, roof insulation, lighting systems, and HVAC efficiencies were adjusted until the energy analysis showed code compliance using equivalent energy performance method described in Part 8 of the NECB-11.

One of the alternative building configurations investigated used 20 cm exterior concrete block masonry walls (grouted and reinforced vertically at 1.2 m centres to simulate structural requirements), foam insulation injected into the ungrouted CMU cells (see Figure 2), and LED lighting instead of much lower efficiency T8 fluorescent lights (the latter meeting the prescribed lighting energy performance under the NECB). Table 2 shows that this building configuration (designated "20 CMU LED") was code compliant in all but Climate Zone 7B, with yearly energy use (expressed as EUI) less than the reference baseline configuration.

Also included in Table 2 is a proposed building configuration that also makes use of improved heating coil efficiencies [configuration: 20 cm (8 in.) foamed CMU wall, LED lighting, and 0.9 heating coil efficiencies]. This configuration was analyzed under only Climate Zone 7B conditions and the total yearly energy used by this configuration is less than the reference baseline and is thus code compliant.

Low-rise (box) retail entities such as Walgreens, CVS and Best Buy often use single wythe exterior masonry walls and were the second archetype evaluated by Phase 2 of this investigation. With the exception of the bakery and refrigeration, these entities have similar operating hours, occupancy schedules, equipment and configurations to those used for the supermarket prototype. A box retail

archetype with the same basic configuration as the supermarket archetype was evaluated using the analyses described for the supermarket and the results are also summarized in Table 2. Alternative box retail building configurations that used 20 cm exterior concrete block masonry walls, (grouted and reinforced vertically) with foam insulation injected into the ungrouted CMU cells and LED lighting were shown to be code compliant in all but Climate Zone 7B. In Climate Zone 7B, box retail configurations that used 20 cm foamed CMU walls, LED lighting, and 0.9 (increased) heating coil efficiencies were code compliant.

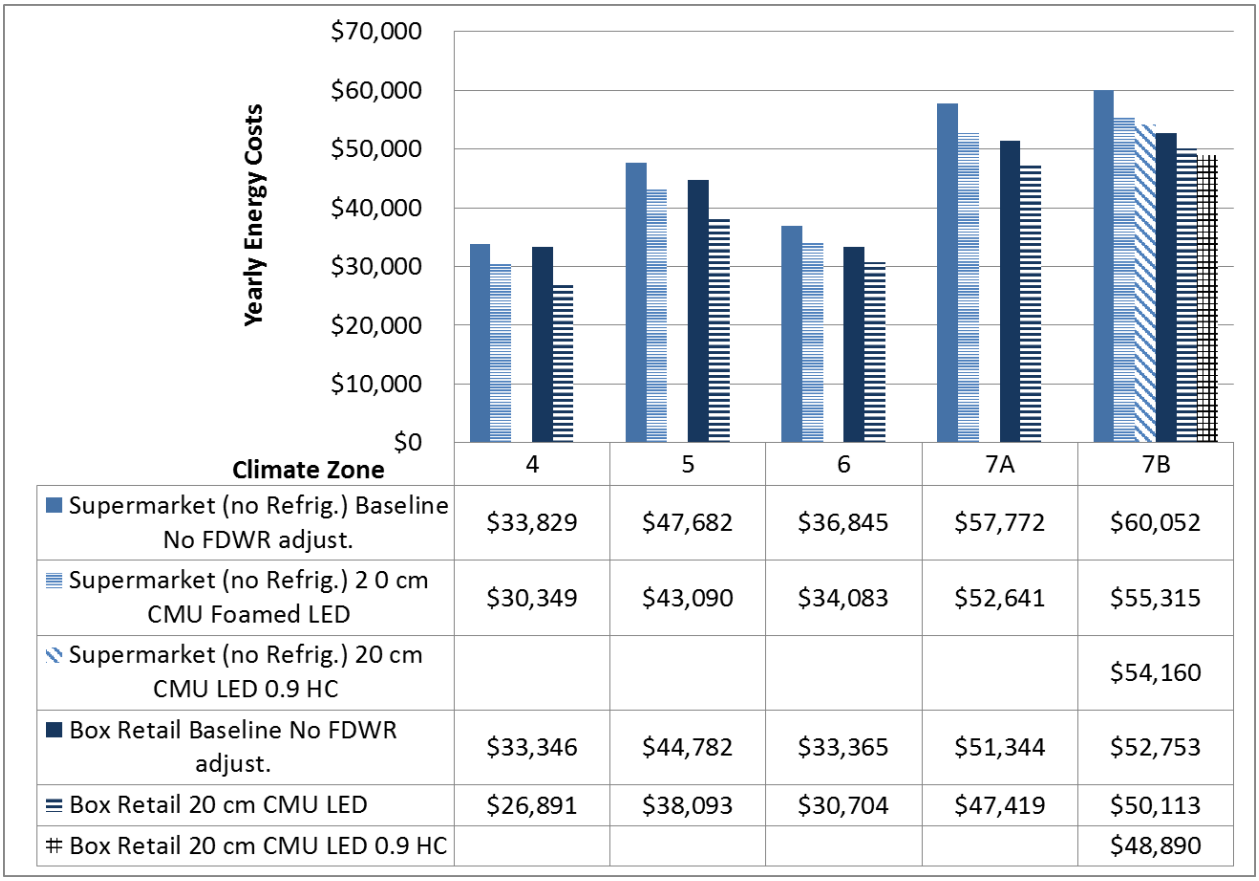
Table 2. Yearly Energy Consumption (EUI) Reference Baseline (Code Prescriptive Configurations) vs. Proposed Building Configurations (Foamed in Place 20 cm CMU Walls, and LED Lighting).

	EUI – GJ/m^2 (kBtu/ft^2)				
Location	**Victoria**	**Windsor**	**Montreal**	**Edmonton**	**Ft. McMurray**
Province	**BC**	**ON**	**QC**	**AB**	**AB**
Climate Zone	**4**	**5**	**6**	**7A**	**7B**
Supermarket (no refrigeration)					
Reference Baseline (Max FDWR)	0.732 (64.5)	0.809 (71.2)	0.937 (82.5)	0.966 (85.1)	1.06 (93.1)
20 cm CMU, LED	0.674 (59.4)	0.750 (66.0)	0.899 (79.2)	0.947 (83.4)	1.07 (94.1)
20 CMU, LED, 0.9 Heating Coil					0.990 (87.1)
Box Retail					
Reference Baseline (Max FDWR)	0.696 (61.3)	0.773 (68.1)	0.913 (80.4)	0.927 (81.6)	1.015 (89.4)
20 cm CMU, LED	0.635 (55.9)	0.709 (62.4)	0.872 (76.8)	0.921 (81.1)	1.046 (92.1)
20 cm CMU, LED, 0.9 Heating Coil.					0.961 (84.60)

Noncompliant

Independent from energy compliance required by NECB-11, for each climate zone, yearly energy costs for the proposed building configuration were calculated using natural gas prices from the Canadian Natural Gas Association (yearly average) and electricity rates for Canadian cities from hydroquebec.com. For each archetype, the yearly energy costs for the proposed supermarket and box retail building configurations (20 cm Foamed CMU and LED lighting) are listed in Figure 3 as "…20 CMU Foamed LED". Also calculated and shown in Figure 3 are the yearly energy costs for the baseline supermarket and box retail prototypes [the reference buildings without the increased FDWR (permitted by the NECB) are designated as "… Baseline"]. Yearly energy use predictions show significant energy cost savings for the proposed building configurations in all climate zones (including for Zone 7B even though it is not code compliant). In Zone 7B, the alternative building configuration with foamed CMU walls, LED lights and improved coil efficiencies had energy cost savings of nearly $5,900 compared to the baseline prototype configuration (without FDWR increases).

Although not required for energy compliance under NECB-11, an incremental construction cost estimate was also conducted on the baseline buildings (both Supermarket and Box Retail) and alternative designs. All costs were obtained using the RSMeans construction data base (2013). The incremental construction costs for the alternative building configurations (20 cm foamed CMU walls and LED lights, and with improved heating coil efficiency) relative to the code prescriptive baseline configurations (the reference building without increased FDWR) are summarized in Table 3. Note that the Supermarket and Box Retail building have the same differences in construction for each climate zone and thus have the same differential costs.



Climate Zone	4	5	6	7A	7B
Supermarket (no Refrig.) Baseline No FDWR adjust.	$33,829	$47,682	$36,845	$57,772	$60,052
Supermarket (no Refrig.) 2 0 cm CMU Foamed LED	$30,349	$43,090	$34,083	$52,641	$55,315
Supermarket (no Refrig.) 20 cm CMU LED 0.9 HC					$54,160
Box Retail Baseline No FDWR adjust.	$33,346	$44,782	$33,365	$51,344	$52,753
Box Retail 20 cm CMU LED	$26,891	$38,093	$30,704	$47,419	$50,113
Box Retail 20 cm CMU LED 0.9 HC					$48,890

Figure 3. Yearly Prototype and Baseline Energy Costs.

Table 3. Differential Construction Costs for Supermarket and Box Retail Archetypes: Proposed Buildings (20 cm Foam Filled Wall and LED Lighting) Compared to Code Prescriptive Configurations.

Location	Victoria	Windsor	Montreal	Edmonton	Ft. McMurray
Climate Zone	**4**	**5**	**6**	**7A**	**7B**
Supermarket and Box Retail Total Differential Construction Cost, Foamed CMU, LED Lights	($64,270)	($52,041)	($56,095)	($59,844)	($60,351)
+ 0.9 Heating coil					($20,351)

() indicates net cost savings Noncompliant

The differential construction cost analyses show that the code-compliant alternative designs for the Canadian prototype supermarket and box retail buildings are less costly to construct than those meeting the code prescriptive configurations, although in Climate Zone 7B, increasing the heating efficiency to achieve compliance will cost an additional $40,000. However, this cost increase is offset by a $60,351 construction cost savings (wall + lighting) resulting in a net construction cost savings of $20,351, along with a yearly energy cost savings of at least $5,900.

When compared to code prescriptive configurations, it is clear that alternative supermarket and box retail designs using single wythe concrete block masonry walls without external insulation and with more efficient lighting systems can be readily shown to be code compliant using whole building energy analysis. Furthermore, these alternative configurations produce substantial yearly energy costs savings at significantly lower construction costs.