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

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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^{2}K, 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 oftentimes falsely 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 find prudent design alternatives to the simple prescriptive solutions offered by the energy code, the University of Louisville conducted an 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.

In the first phase of this study, a prototype warehouse building was identified and detailed as shown in Figure 1. This prototype is 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 warehouse configured using code prescriptive minimum requirements (termed building "baseline or reference configurations"). The exterior walls of the baseline configurations were constructed "virtually" of single wythe 20 cm concrete block masonry. To meet the NECB building envelope thermal transmittance requirements, the required thickness of extruded polystyrene face (interior/exterior) insulation (see Figure 2) applied to the exterior masonry walls in the baseline building configurations varied from 76 to 127 mm (3 to 5 inches), depending upon climate zone.

[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.

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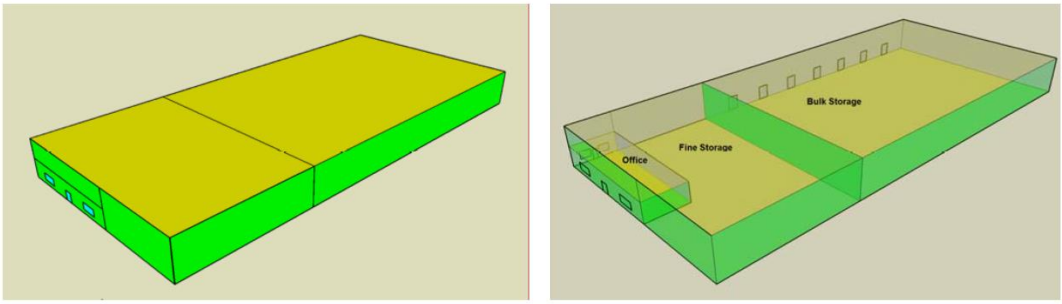


Figure 1. Prototype Warehouse Configuration for the Energy Model ≈4600 m^2 (50000 ft^2 warehouse From DOE Prototype buildings).

Table 1. Evaluated Climate Zones and Cities in Canada.

City	Climate Zone	HDD
Victoria,	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

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 analyses and 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 compared to 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 warehouse (the prototype warehouse design FDWR was about 7%). 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. For the analyses undertaken in this study, the FDWRs of the “baseline configuration” buildings (the reference buildings) were adjusted as permitted by the NECB, however, skylight area adjustments were not used.

The resulting 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 building configurations were explored in the study. For each city, whole building energy analyses were also conducted on otherwise identical warehouse configurations having exterior single wythe 20 cm concrete block masonry walls without external (surface applied) insulation. For these configurations, core insulation, roof insulation, lighting systems, and HVAC efficiencies were adjusted until the energy analysis showed code compliance using the equivalent energy performance method described in Part 8 of the NECB-11. Using whole building simulations to verify code compliance requires that the alternative building designs use no more energy on a yearly basis than equivalent prescriptive building configurations when modelled in the same cities, with the same set points, schedules, etc.

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**
20 CMU Foamed LED	0.198 (17.33)	0.271 (23.80)	0.304 (26.64)	0.407 (35.74)	0.521 (45.70)
Reference Baseline (Max FDWR)	0.235 (20.71)	0.318 (28.02)	0.348 (30.62)	0.452 (39.83)	0.554 (48.83)

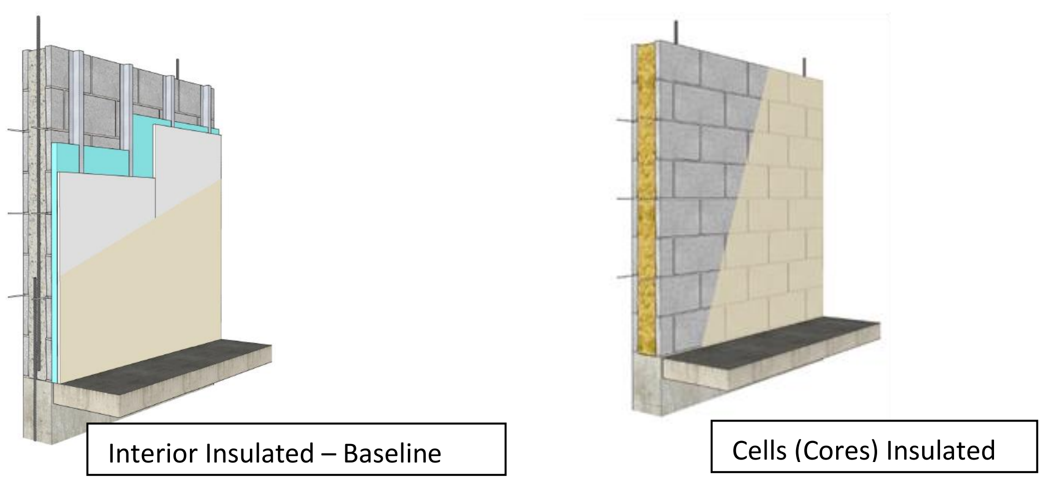
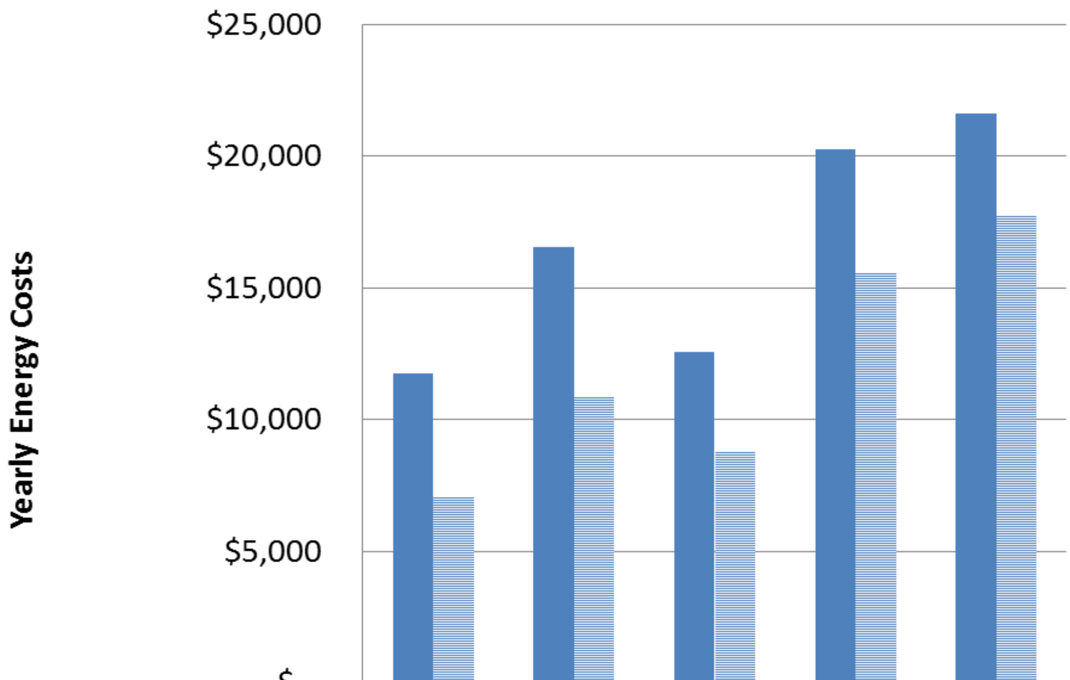


Figure 2. Exterior Masonry Walls, Interior Insulated and Cell Insulated.

Perhaps the most simple of the proposed alternative building configurations showing NECB compliance 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 T8 fluorescent lights (the latter meeting the prescribed lighting energy performance under the NECB). This lighting configuration produces significantly lower energy demand than that of the baseline. Table 2 shows that this building configuration (denoted as ”20 CMU Foamed LED”) was code compliant, with yearly energy use (expressed as EUI) less than the reference baseline configuration in all climate zones.

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. The yearly energy costs for the proposed building configurations 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 warehouse prototype (the reference building without increased FDWR permitted by the NECB, designated as “Baseline”).



Climate Zone	4	5	6	7A	7B
Baseline	$11,762	$16,531	$12,581	$20,262	$21,631
20 CMU Foamed LED	$7,052	$10,849	$8,788	$15,581	$17,710

Figure 3. Yearly Prototype Warehouse Energy Costs.

Although not required for energy compliance under NECB-11, an incremental construction cost estimate was also conducted on the baseline buildings 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) relative to the code prescriptive baseline configurations (the reference building without increased FDWR) are summarized in Table 3. The alternative building configurations were shown to be less costly to construct than the code prescriptive baseline configurations.

Table 3. Differential Construction Costs: Proposed Buildings (20 cm Foam Filled Wall and LED Lighting) - Code Prescriptive Configurations.

Location	**Victoria**	**Windsor**	**Montreal**	**Edmonton**	**Ft. McMurray**
Climate Zone	**4**	**5**	**6**	**7A**	**7B**
Total Differential Construction Cost	($54,971)	($41,848)	($45,300)	($45,113)	($46,723)

() indicates net cost savings

When compared to code prescriptive configurations, it is clear that alternative warehouse 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.