Revitalize!

2010 Heritage Canada Foundation Conference

Katarzyna Blaszak, M.A.Sc. Candidate

Ryerson University

TOWARDS SUSTAINABILITY:
PRIORITIZING RETROFIT OPTIONS FOR TORONTO'S SINGLE-FAMILY HOMES

WHAT ARE YOUR RETROFIT PRIORITIES?

Defining the Problem

The homeowner's dilemma:

I have house x,
should I do retrofit y or z?

Objectives:

1) Define: effects, retrofits, houses
2) Measure: environmental effects
3) Compare: develop a preliminary tool with which to rate retrofit options for the archetypes

Process

- Must define:
  - Environmental effects
  - Retrofit Options
  - House Archetypes

Eight Summary Measures

- Primary energy consumption
- Weighted resource use
- Global warming potential
- Acidification potential
- Human health respiratory effects
- Eutrophication potential
- Ozone depletion potential
- Smog potential

Process

- Must define:
  - Environmental effects
  - Retrofit Options
  - House Archetypes

- Insulation
  - Location
  - Amount
  - Type (fiberglass batt, blown-in cellulose, Icynene, polyurethane)
- Ventilation
  - Air leakage rate reductions
- Window replacement
  - Sealed, double-glazed units
  - Heat mirror units
- Door replacement

House Archetypes

Century

- Double-wythe brick walls
- L-shaped
- Finished attic

Wartime

- Light wood-framed walls
- rectangular
- Single-storey

70s OBC

- Light wood-framed walls
- rectangular
- Built to 1975 OBC

Modern

- Light wood-framed walls
- L-shaped
- Attached garage, walk-out basement

http://www.realtor.ca/index.aspx?cul=1

WHICH RETROFIT OPTIONS DO YOU THINK WILL BE BEST?

Process

- Measure:
  - Operational Effects
    - HOT2000
    - Find parameter with largest portion of heat loss, apply retrofit, iterate
    - Target 100kWh/m2
  - Embodied Effects
    - ATHENA Impact Estimator

Process

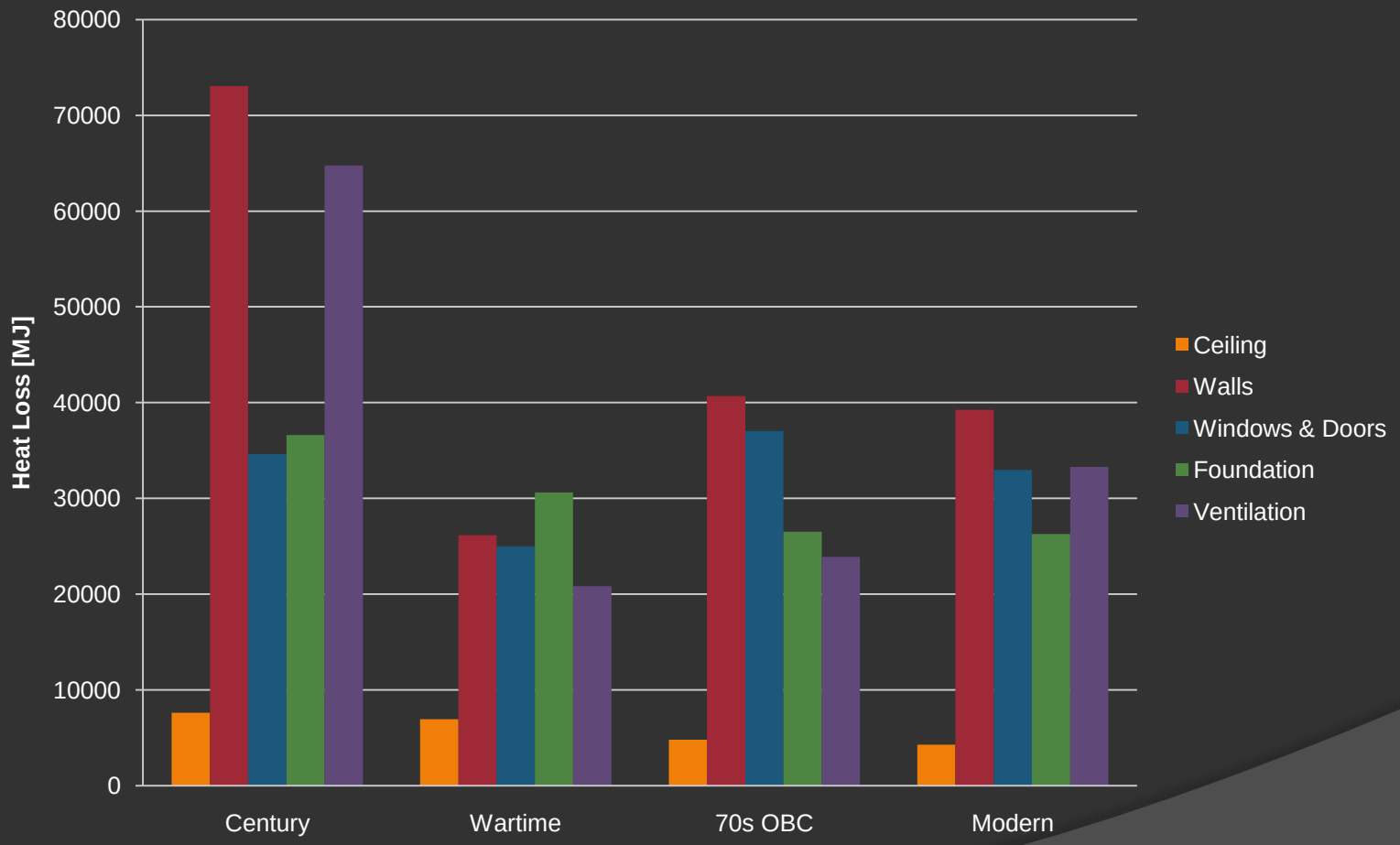
- Compare:
  - Develop preliminary ranking equation
  - Preliminary testing

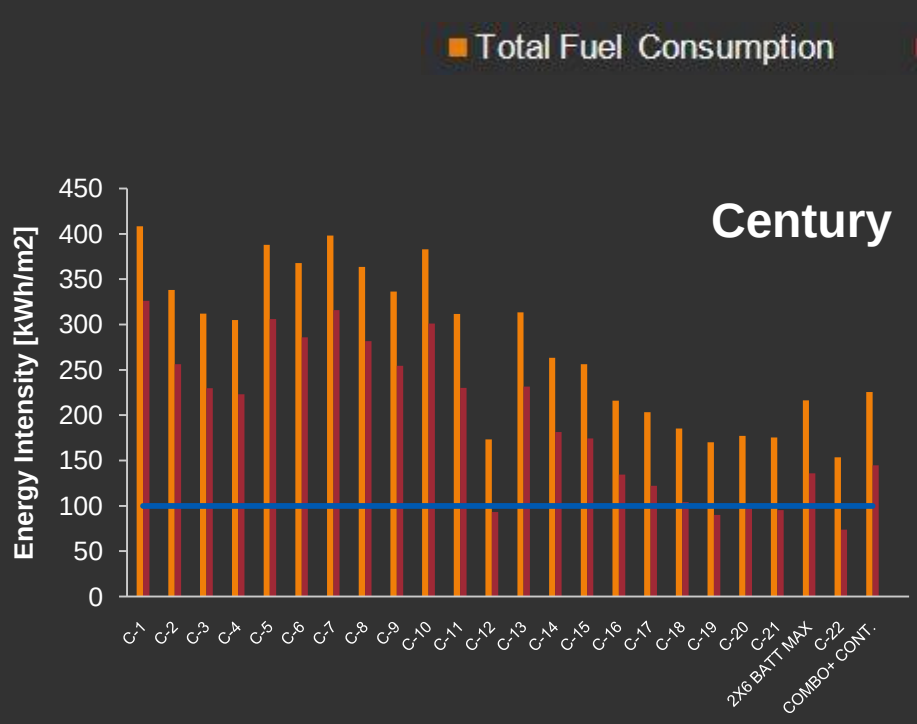
$$SM_{total} = Y \times \left(Electricty \times Factor_{electricity} + Natural\ Gas \times Factor_{natural\ gas}\right) + BSF \times SM_{embodied}$$

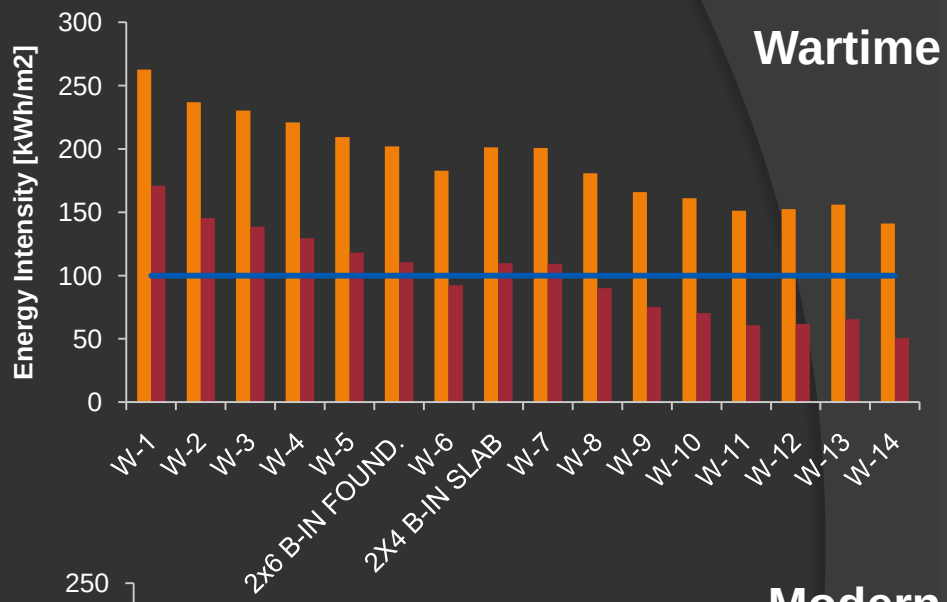
$$SM_{ratio} = Case\ 1 / Case\ B$$

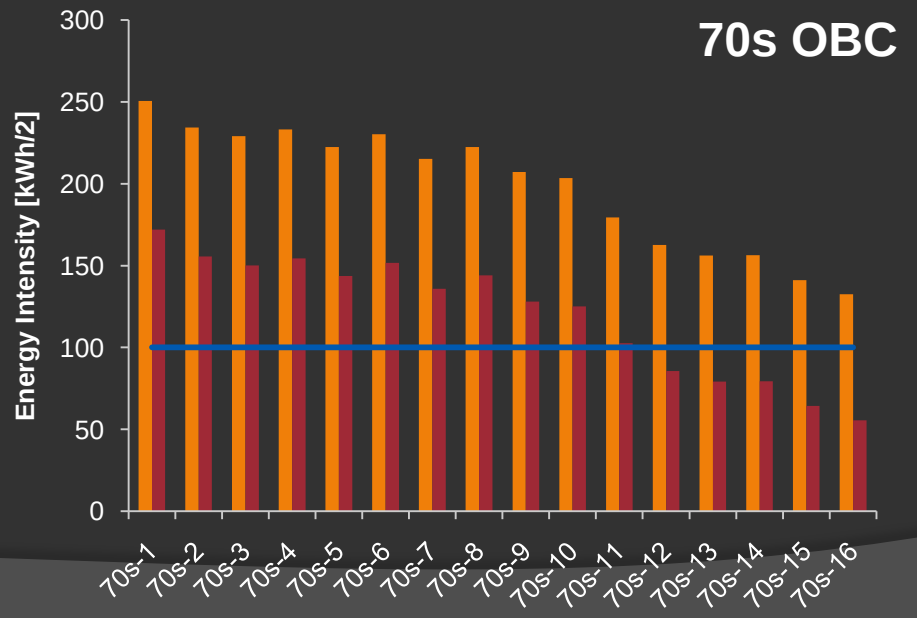
$$Retrofit\ Ranking = (W_{1\times} SM_1 + W_2 \times SM_2 + W_3 \times SM_3 + W_4 \times SM_4 + W_5 \times SM_5 + W_6 \times SM_6 + W_7 \times SM_7 + W_8 \times SM_8\ )/8$$

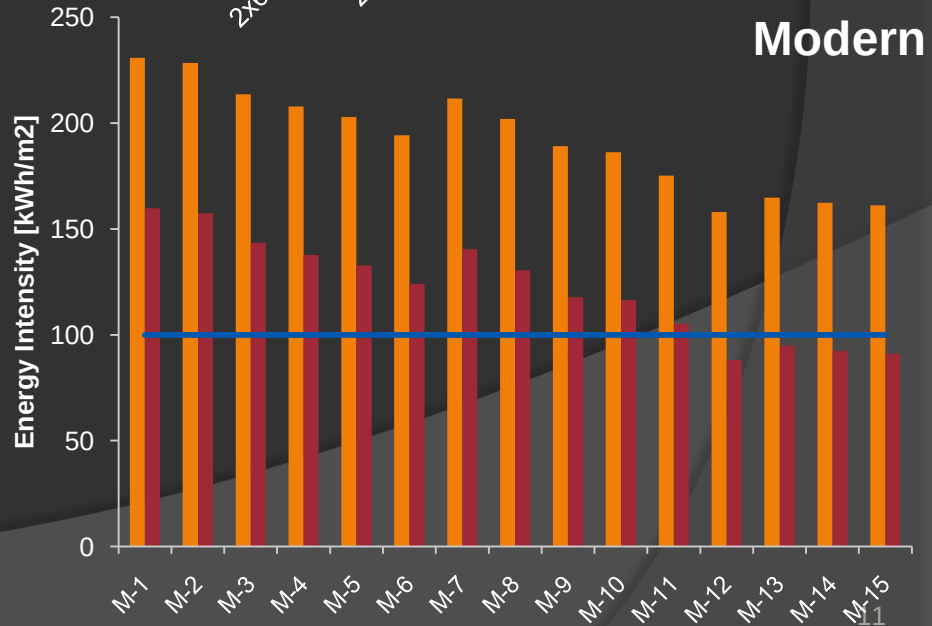
Results: Archetypes



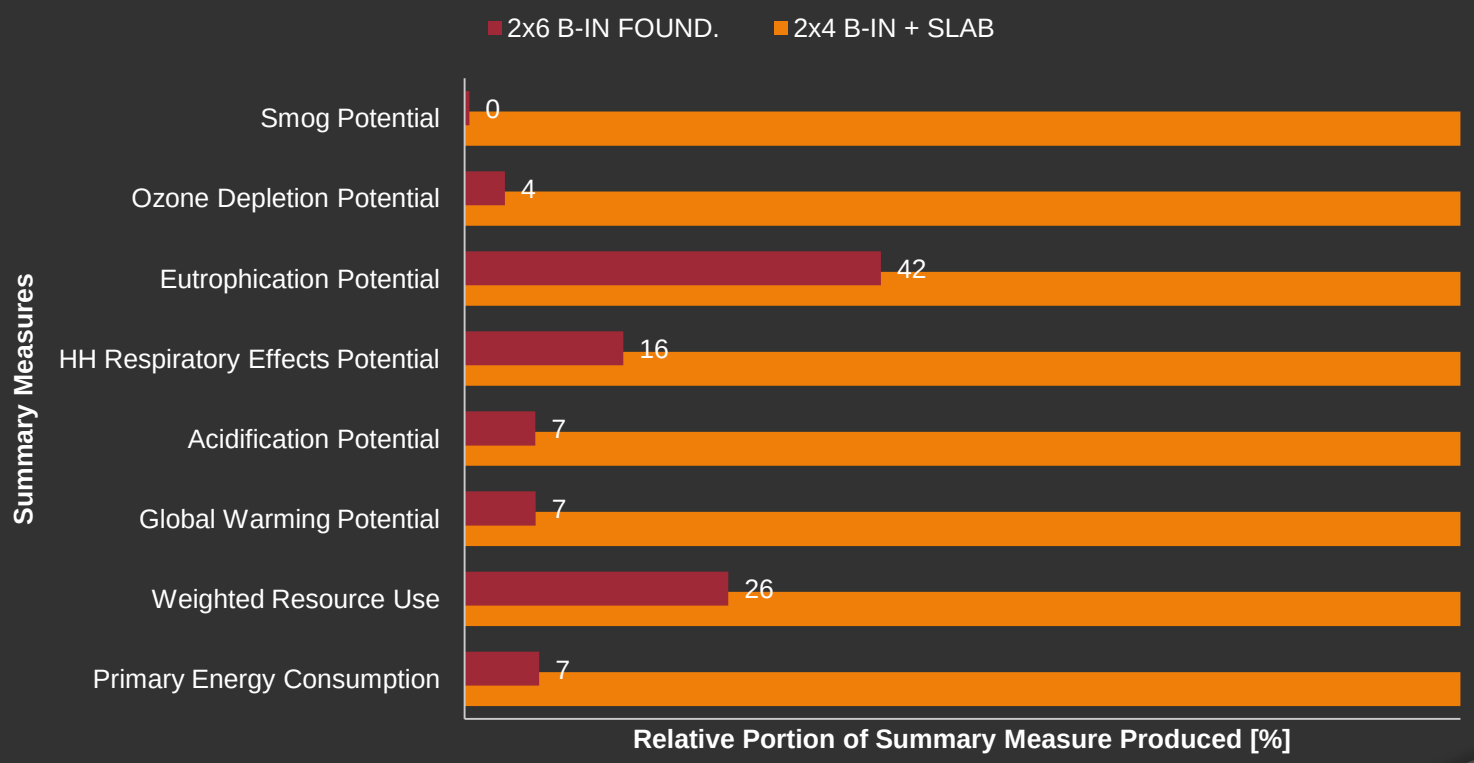

Total Fuel Consumption
Heating & Cooling Consumption
Century
Energy Intensity [kWh/m2]
450
400
350
300
250
200
150
100
50
0
C-1
C-2
C-3
C-4
C-5
C-6
C-7
C-8
C-9
C-10
C-11
C-12
C-13
C-14
C-15
C-16
C-17
C-18
C-19
C-20
C-21
2X6 BATT MAX
C-22
COMBO+ CONT.


Wartime
Energy Intensity [kWh/m2]
300
250
200
150
100
50
0
W-1
W-2
W-3
W-4
W-5
2x6 B-IN FOUND.
W-6
2X4 B-IN SLAB
W-7
W-8
W-9
W-10
W-11
W-12
W-13
W-14

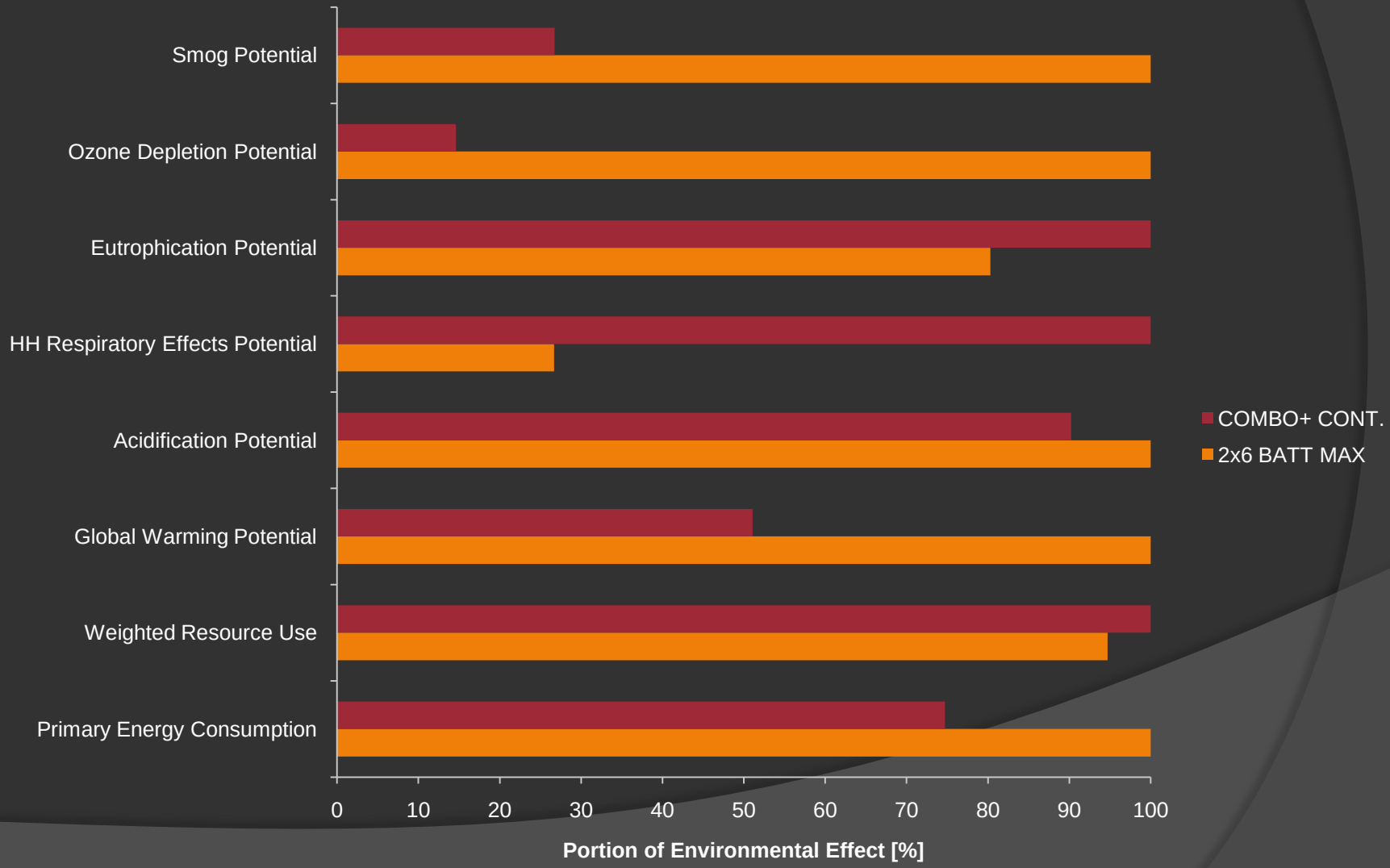

70s OBC
Energy Intensity [kWh/2]
300
250
200
150
100
50
0
70s-1
70s-2
70s-3
70s-4
70s-5
70s-6
70s-7
70s-8
70s-9
70s-10
70s-11
70s-12
70s-13
70s-14
70s-15
70s-16


Modern
Energy Intensity [kWh/m2]
250
200
150
100
50
0
M-1
M-2
M-3
M-4
M-5
M-6
M-7
M-8
M-9
M-10
M-11
M-12
M-13
M-14
M-15

Results: Operationally Equal



Results: Operationally Unequal



Example: Smog Potential

- Step 1
  - Total kg NOx eq. produced

	COMBO+ CONT.	2x6 BATT MAX
Natural Gas [m3]	3418.6	3251.1
Factor	5.94E-04	5.94E-04
Total =	2.0	1.9
Electricity [kWh]	11582.9	11394.8
Factor	1.06E-04	1.06E-04
Total =	1.2	1.2
Years Operating	60	60
Operational Eff. =	195.4	188.3
BSF	1	1
Embodied Eff. =	19.25	5.15
Total Effect =	**214.7**	**193.4**

$$SM_{total} = Y \times \left(Electricty \times Factor_{electricity} + Natural\ Gas \times Factor_{natural\ gas}\right) + BSF \times SM_{embodied}$$

Example: Smog Potential

- Step 2
  - Determine summary measure ratio

	COMBO+ CONT.	2x6 BATT MAX
Case 1	214.7	-
Case 2	-	193.4
Case B	214.7	214.7
Ratio =	**1.0**	**0.9**

$$SM_{ratio} = Case\,1 / Case\,B$$

Example: Ranked Retrofits

- Step 3
  - Repeat for all other summary measures
- Step 4
  - Combine summary measures

No. Years	COMBO+ CONT.	2x6 BATT MAX
1	0.95	0.77
10	0.99	0.83
20	1	0.84
60	1	0.85
80	1	0.86
100	1	0.86

$$Retrofit\ Ranking = (W_{1\times}SM_1 + W_2 \times SM_2 + W_3 \times SM_3 + W_4 \times SM_4 + W_5 \times SM_5 + W_6 \times SM_6 + W_7 \times SM_7 + W_8 \times SM_8\ )/8$$

Results: Retrofit Ranking

- Limitations:
  - High sensitivity to large differences in embodied effects
  - High sensitivity to weighting of embodied effects
  - Include more house styles and locations
  - Include more retrofit options and a wider variety of materials

Results: Retrofit Ranking

- Conclusions
  - Low-energy retrofits are possible
  - Recommended retrofit depends on house style
  - Some common retrofits have limited environmental returns

QUESTIONS?

More information at: www.ryerson.ca/richman/research

House Archetypes	Air Sealing Measures									
	Non-invasive: caulking, sealing baseboards, weatherstripping doors, attics, etc. Anything that doesn't involve damaging finishes		Semi- invasive: same as non-invasive plus removing some drywall to access sill plates, etc.		Exterior/Interior: rigid insulation on exterior taped and sealed somehow to remainder of air barrier, tyvek house wrap, poly etc.		Cellulose: dense-pack cellulose into all applicable cavities		Foam: full gut and application of Icynene with attention paid to air sealing	
					no additional air sealing	combined with semi-invasive	no additional air sealing	combined with semi-invasive	no additional air sealing	combined with semi-invasive
Century: double-wythe brick, 2 storey plus finished attic	10-33	20	30-50	40	30	45	33	50	n/a	2-3ACH
							30	3 (75%)	35	2
Wartime Bungalow: wood-framed, Wartime Housing Limited bungalow	10-25	15	22-40	30	33	33-42	25-35	33-48	n/a	2-3ACH
					30	40	30	3 (60%)	35	2
70's OBC: 2-storey, rectangular home built to 1975 OBC	10-20	12	15-28	24	33	40	19	30-40		
					20	35	20	3 (50%)	25	2
Modern: 3-storey, rectangular, attached garage, built to 2005 OBC	0	5	15-30	15	15-30	17-66				
					10	30	10	2.75 (10%)	15	2

Ceiling Heat Loss

- Surface area ratios
  - Wartime example
    - 1:1.3 ceilings to walls
    - 1:2.3 ceilings to foundation
- Insulation levels
  - Wartime example
    - Default is 3.7RSI
    - When lowered to match walls (1.5RSI) portion of heat loss through ceiling doubles to 12.4%

Icynene

- ASTM E2178
  - 2x6” wall assembly = 0.01 L/s*m2
  - Requires substrate removal
    - Damages closed-cell surface
- ASTM E283
  - 3.25” of foam = 0.0080 L/s*m2