Energy Consumptions of Office Buildings
Technical Analysis - Annex 61

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Outline

- OBEPM Tool
- Model buildings
  - Geometry
  - Climate
  - Retrofit Scenarios
- Energy model of office buildings
- Model results
- Concluding remarks

OBEPM Tool

Hybrid model - EnergyPlus, Mathematics, and Energy balance principles

1. Developed representative office buildings
   a) Geometry; shape and size
   b) Zones; Number, size, distribution
   c) Operation
   d) Building attributes
   e) ECMs
2. Monthly energy prediction model for a building
3. Yearly energy prediction model for a portfolio
4. Derive most effective ECM(s)
5. Decision tool

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Monthly end uses energy consumption Models

1. Lighting;
2. Equipment;
3. DHW;
4. Fans;
5. Pumps
   - Chilled water loop supply pumps (CWLSP);
   - Condenser water loop supply pumps (CNDWLSP);
   - Hot water loop supply pumps (HWLSP);
6. Chiller;
7. Boiler.

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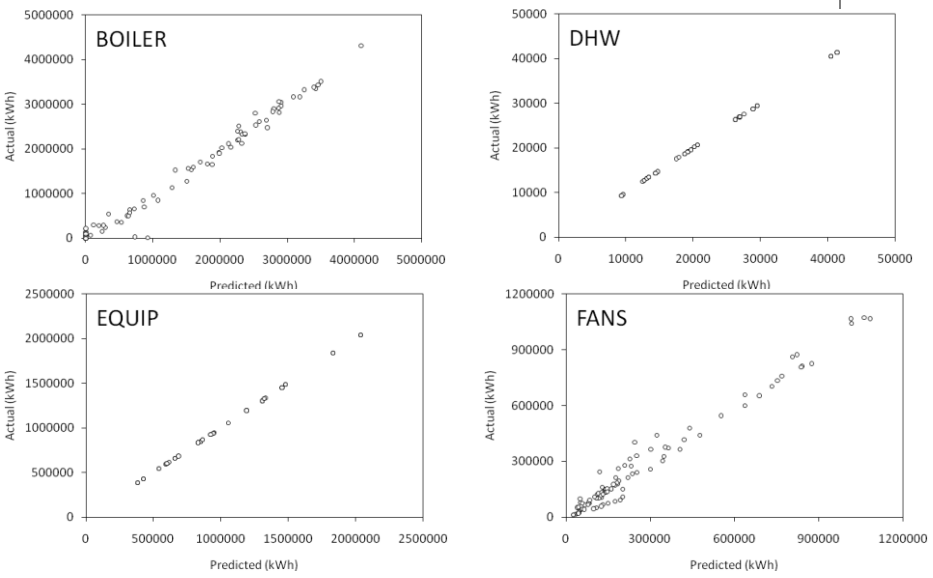
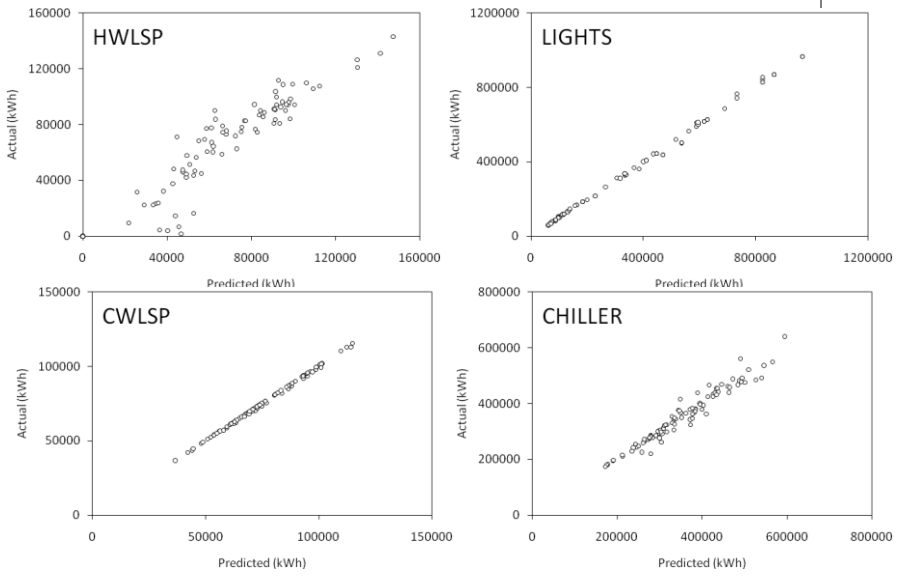
Model validation – Energy Plus



Model validation – Energy Plus



Model – Geographic Location

Canada is divided into five climate zones (ASHRAE, 2007)

Location	ASHRAE Climate Zone	Design Temperature (°C)		Degree Days (18.3°C base)	
		Heating DB 99%	Cooling DB 1%	HDD	CDD
Windsor	5A	-13.1	30.5	3444	434
Vancouver	5C	-3.3	24.4	2903	44
Ottawa	6A	-21.5	28.9	4523	238
Calgary	7	-25	26.6	5052	36
Iqaluit	8	-37.6	14.2	9924	0

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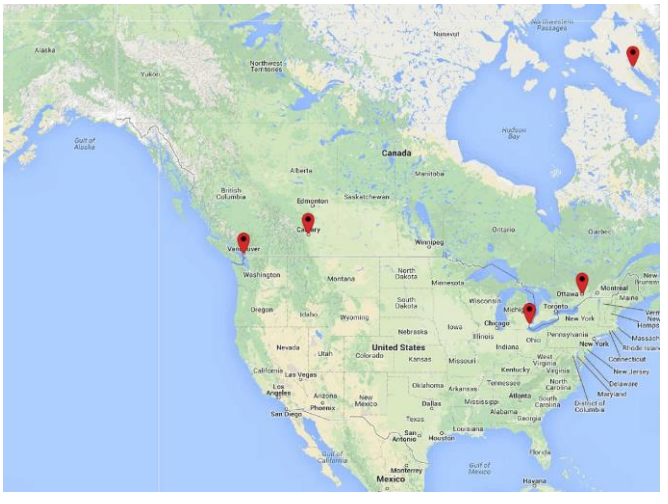
Model – Geographic Location

Canada is divided into five climate zones (ASHRAE, 2007)



Source: http://multiplottr.com/

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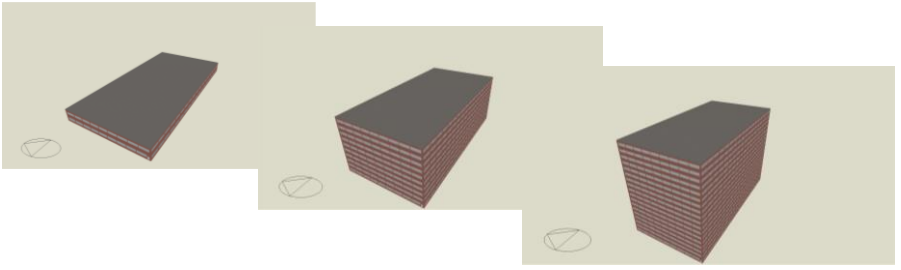
Model – Geometry & Size

Building Type	Number of Storeys	Total Floor Area (m^2)
Low Rise	2	9,000
Medium Rise	10	45,000
High Rise	18	81,000



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Model – Retrofit Scenarios

- Pre-1980 Standard
- Baseline: Current Building Energy Standard in Canada (NECB 2011)
- 50% Energy Use Intensity Reduction or greater from Baseline (National Dream)

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Energy Models of the buildings

- Floors area = 4,500 m²
- Aspect/orientation is 2:1 rectangular building with the long side facing north-south
- No basement floors
- Occupancy density of each model = 25 m²/person
- Occupancy schedule = 10 hours per day with no weekend occupancy
- Fan pressure rise is 300 Pa, 900 Pa, and 1,500 Pa for the small, medium and large office buildings, respectively
- Solar Heat Gain Coefficient was assumed to be 0.68 for all fenestration
- Equipment load will be maintained at 20 W/m²
- No gas process load

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Energy Models of the buildings

$$PVS_{NG} = \left(\frac{(N.G.\ Savings) * (N.G.unit\ cost)}{N.G.MARR - N.G.Growth}\right)\left(1 - \left(\frac{1 + N.G.Growth}{1 + N.G.MARR}\right)^{payback\ period}\right)$$

Description	Value	References
Annual electricity unit cost ($/kW·h) – *Elect. unit cost*	0.0923	(Hydro One Inc. , 2014)
Electrical annual growth rate – *Elect. unit cost*	2.54%	(Ontario Ministry of Energy , 2014)
Electrical Minimum Acceptable Rate of Return – *Elect. MARR*	6.00%	
Annual natural gas unit cost ($/kW·h) – *N.G. unit cost*	0.2454	(Ontario Energy Board, 2014a)
Natural gas annual growth rate – *N.G. Growth*	1.00%	(Ontario Energy Board, 2014b)
Natural gas Minimum Acceptable Rate of Return – *N.G. MARR*	6.00%	
Payback Period (Years)	40	

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Energy Models – Scenario 1

Building Envelope

Equivalent fenestration U-Value = 4.5 W/m²·K with a 40% fenestration
Wall U-Value = 1.21 W/m²·K
Roof U-Value = 0.74 W/m²·K
Roof solar absorptance = 0.8
Infiltration rate = 1 ACH

Lighting

Lighting load = 17.8 W/m² with no daylighting.

HVAC

CAV system with no heating setback
No economizer or heat recovery unit
Boiler efficiency = 75%
Chiller coefficient of performance (COP) = 2.5

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Energy Models – Scenario 2 - NCEB

Building Envelope

Roof solar absorptance = 0.7
Infiltration rate = 0.2 ACH

City	Overall Thermal Transmittance (W/m²·K)			Fenestration
	Walls	Roofs	Fenestration	(%)
Vancouver	0.315	0.227	2.4	40.0
Windsor	0.278	0.183	2.2	40.0
Ottawa	0.247	0.183	2.2	36.3
Calgary	0.210	0.162	2.2	32.4
Iqaluit	0.183	0.142	1.6	20.0

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Energy Models – Scenario 2 - NCEB

Lighting

Lighting power density (LPD) in the NECB = 9.7 W/m².
Daylighting is implemented

HVAC

Boiler thermal efficiency = 83%
Chiller COP = 6.1 at full load.
HVAC system includes an economizer, heat recovery system, and heating setback.
Low rise office building type has a CAV system
Medium and High rise office building types use a Variable Air Volume (VAV) system with a turndown ratio of 0.5.

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Energy Models – Scenario 3 – 50% below

Building Envelope

Building Parameter	Value	Reference
Equivalent Fenestration U	1.03 W/m²·K	(ASHRAE, 2013)
Fenestration	40%	
Wall U	0.183 W/m²·K	(NECB, 2011)
Roof U	0.142 W/m²·K	(NECB, 2011)
Roof Solar Absorptance	0.8	
Infiltration Rate	0.2 ACH	(NECB, 2011)

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Energy Models – Scenario 3 – 50% below NCEB

Lighting

Lighting power density (LPD) in the NECB = 5.0 W/m².
Daylighting is implemented

HVAC

Building Parameter	Value
Heating Setback	1 (Yes)
Economizer	1 (Yes)
Heat Recovery	1 (Yes)
VAV	0.3
Chiller COP	7.3
Boiler Efficiency	96%

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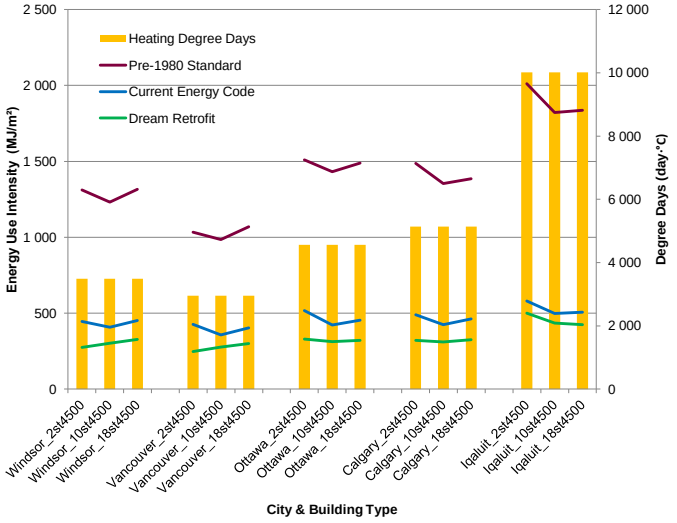
Energy Use Intensity



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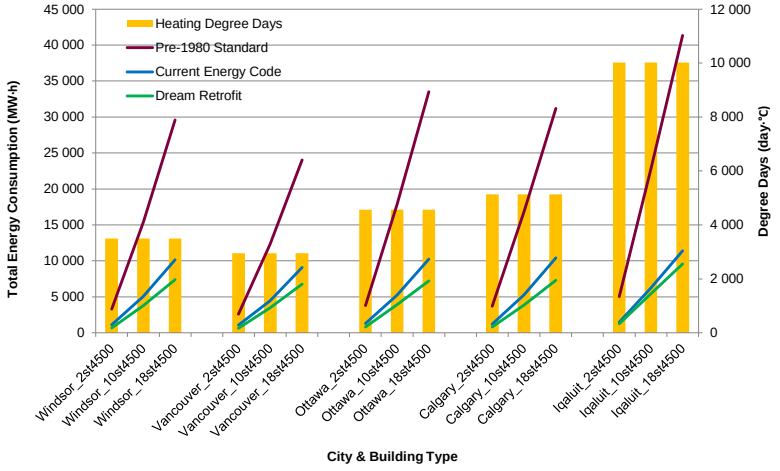
Total Energy Consumption



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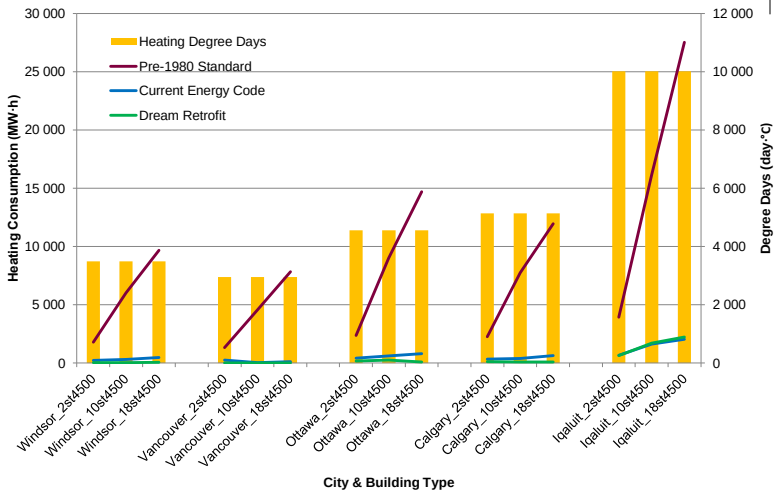
Total Energy Consumption



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Buildings Energy Consumptions – Current Energy Code (NECB 2011)

Energy Model	Consumption (MW·h)			EUI (MJ/m²)	Below Pre-1980
	Natural Gas	Electrical	Total		
Windsor_SC2_2st4500	233	880	1,113	445	66.1%
Windsor_SC2_10st4500	302	4,784	5,086	407	67.0%
Windsor_SC2_18st4500	485	9,681	10,166	452	65.6%
Vancouver_SC2_2st4500	246	821	1,066	427	58.8%
Vancouver_SC2_10st4500	38	4,425	4,463	357	63.8%
Vancouver_SC2_18st4500	104	8,967	9,071	403	62.3%
Ottawa_SC2_2st4500	425	870	1,295	518	65.7%
Ottawa_SC2_10st4500	612	4,664	5,276	422	70.5%
Ottawa_SC2_18st4500	816	9,418	10,234	455	69.5%
Calgary_SC2_2st4500	347	880	1,227	491	67.0%
Calgary_SC2_10st4500	394	4,919	5,313	425	68.6%
Calgary_SC2_18st4500	641	9,765	10,406	462	66.6%
Iqaluit_SC2_2st4500	656	796	1,451	581	71.2%
Iqaluit_SC2_10st4500	1,628	4,592	6,220	498	72.7%
Iqaluit_SC2_18st4500	2,042	9,336	11,378	506	72.5%

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Buildings Energy Consumptions – Dream Retrofit

Energy Model	Consumption (MW·h)			EUI (MJ/m²)	Below Baseline	Present Value Analysis
	Natural Gas	Electrical	Total			
Windsor_SC4_2st4500	24	663	687	275	-38.2%	$916
Windsor_SC4_10st4500	27	3,748	3,775	302	-25.8%	$2,178
Windsor_SC4_18st4500	54	7,330	7,384	328	-27.4%	$4,354
Vancouver_SC4_2st4500	0	617	617	247	-42.2%	$1,011
Vancouver_SC4_10st4500	0	3,460	3,460	277	-22.5%	$1,365
Vancouver_SC4_18st4500	0	6,776	6,776	301	-25.3%	$3,151
Ottawa_SC4_2st4500	171	653	824	329	-36.4%	$1,054
Ottawa_SC4_10st4500	261	3,658	3,920	314	-25.7%	$2,367
Ottawa_SC4_18st4500	104	7,123	7,226	321	-29.4%	$5,136
Calgary_SC4_2st4500	122	683	805	322	-34.4%	$939
Calgary_SC4_10st4500	89	3,805	3,894	312	-26.7%	$2,368
Calgary_SC4_18st4500	103	7,216	7,319	325	-29.7%	$4,933
Iqaluit_SC4_2st4500	626	622	1,249	499	-14.0%	$313
Iqaluit_SC4_10st4500	1,699	3,736	5,435	435	-12.6%	$892
Iqaluit_SC4_18st4500	2,234	7,319	9,553	425	-16.0%	$2,026

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Concluding Remarks

- 60 to 70% energy savings for Pre-1980 office buildings that have not conformed to current standard
- Up to 40% energy saving is still possible with dream retrofit for office buildings meeting NECB 2011.
- 50% reduction in energy consumption is not possible with current technology for office buildings that meet NECB 2011 requirements.
- Present value savings are too low to justify the implementation of dream retrofit.