5th Experts Meeting, Annex 46

"Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings, EnERGo"

Lyon, France

September 5, 2007

Screening Governments Buildings for Energy Efficiency Retrofit Opportunities

S.E. Chidiac & E. Catania

Department of Civil Engineering

McMaster University

E. Morofsky & S. Foo

Public Works Government Services Canada

Outline

1. Description of the methodology for screening for energy retrofits
2. NLMV Regression analyses
3. Cost / Benefit analysis
4. Case studies

Description of Methodology

- Either collect energy consumption data of existing government office buildings or generate data using “reliable” software
- Define representative government office buildings: construction date, size, location
- Evaluate energy consumption and effectiveness of energy conservation measures, ECMs (Non-linear multi-variables regression analyses)
- Rank buildings using a cost benefit analysis: effectiveness of ECMs vs. implementation cost

Representative Gov.Office Buildings

- Construction date / Energy standard/best practice
- Pre 1950 / ASHVE (1939)
- 1950 – 1975 / ASHVE (1939) & ASHRAE (1961)
- Post 1975 / ASHRAE (1977) & MNECB (1997)
- Size of building
- 24150 m^2 (260,000 ft^2), Floor height = 3.5 m
- 4,200 m^2 (45,000 ft^2), Floor height = 3.5 m
- Location - weather
- Ottawa
- Edmonton
- Vancouver

Regression Analysis (1/8)

- Equations were developed from database of Energy Consumption for representative buildings
- Eight equations per building type: Large – Concrete, Large – Curtain and Small
- Energy Consumption was broken down in components:

  - Lighting
  - Equipment
  - Pumps
  - Fans
  - DHW
  - Chiller
  - Total Electrical
  - Secondary Fuel

Regression Analysis (2/8)

- Variables considered & Ranges

Lighting load	10 to 26 W/m^2
Equipment load	15 to 65 W/m^2
Occupancy	18 to 30 m^2/person
Fenestration %	85% - 100% (Large Curtain-wall) 30% - 50% (Large concrete building) 30% - 50% (Small building)
Fenestration U-value	1.8 to 6.42
Wall U-value	0.37 (Large curtain wall building) 0.25 – 1.21 (Large concrete building) 0.55 – 1.21 (Small building)

Regression Analysis (3/8)

Roof U-value	0.47 – 0.74 (Large curtain wall) 0.28 – 1.41 (Large concrete building) 0.55 – 1.36 (Small building)
Infiltration rate (ach)	1.0 to 0.1
Heating efficiency	0.6 to 0.95
Cooling cop	1.7 to 5.2
Blinds?	Yes / No
Turndown ratio	Yes / No
Daylighting?	Yes / No
Heat recovery eff.	0% to 60%
Gas pre-heat w/econ	Yes / No

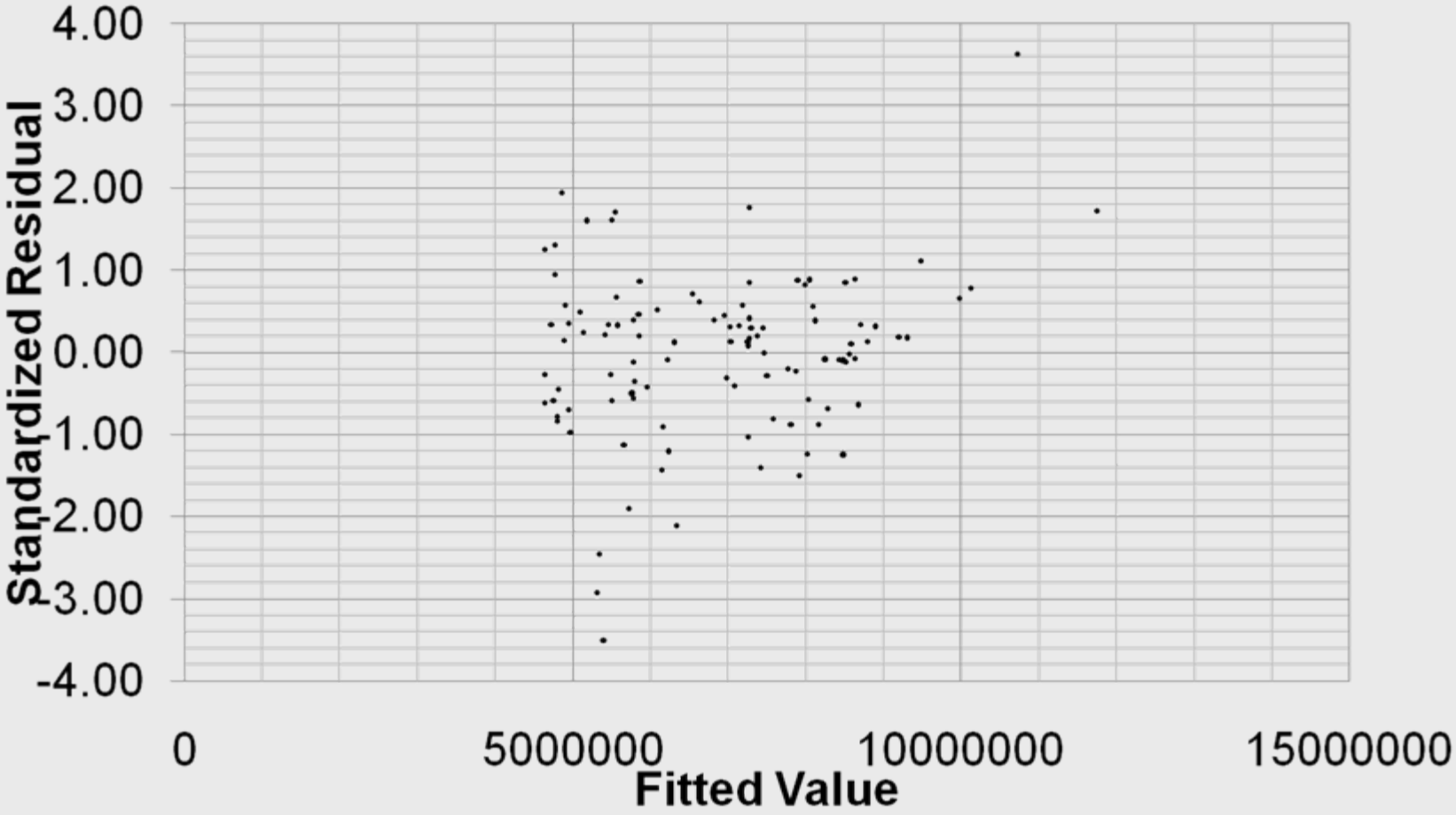
Regression Analysis (4/8)

- Accuracy of Model - Building #1 – Ottawa

Function	*R^2*	*F-Value*	*P-Value*	*MS*
'Lights'	0.994	6094	0	1,023,655,208
'Equipment'	1.000	7.69E+29	0	
'Pumps'	0.953	114	0	4,224,974
'Fans'	0.985	352	0	22,280,155,636
'DHW'	1.000	4221363	0	1,287
'Chiller'	0.991	570	0	1,970,002,008
'Total Electrical'	0.988	365	0	35,176,590,091
'Natural Gas'	0.982	331	0	13,860,970,769

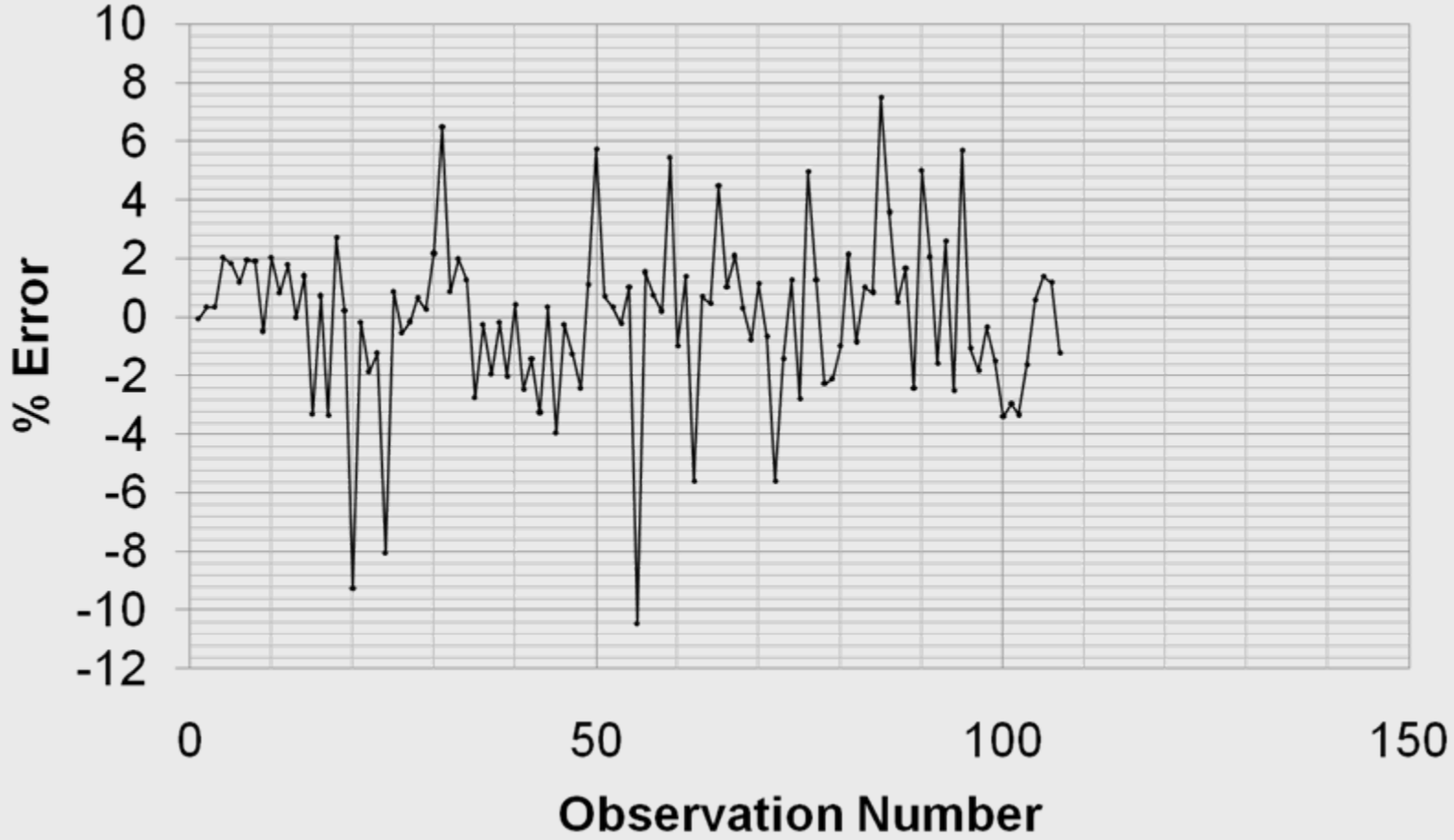
Regression Analysis (5/8)

- Residual vs. Fitted Values - Electricity



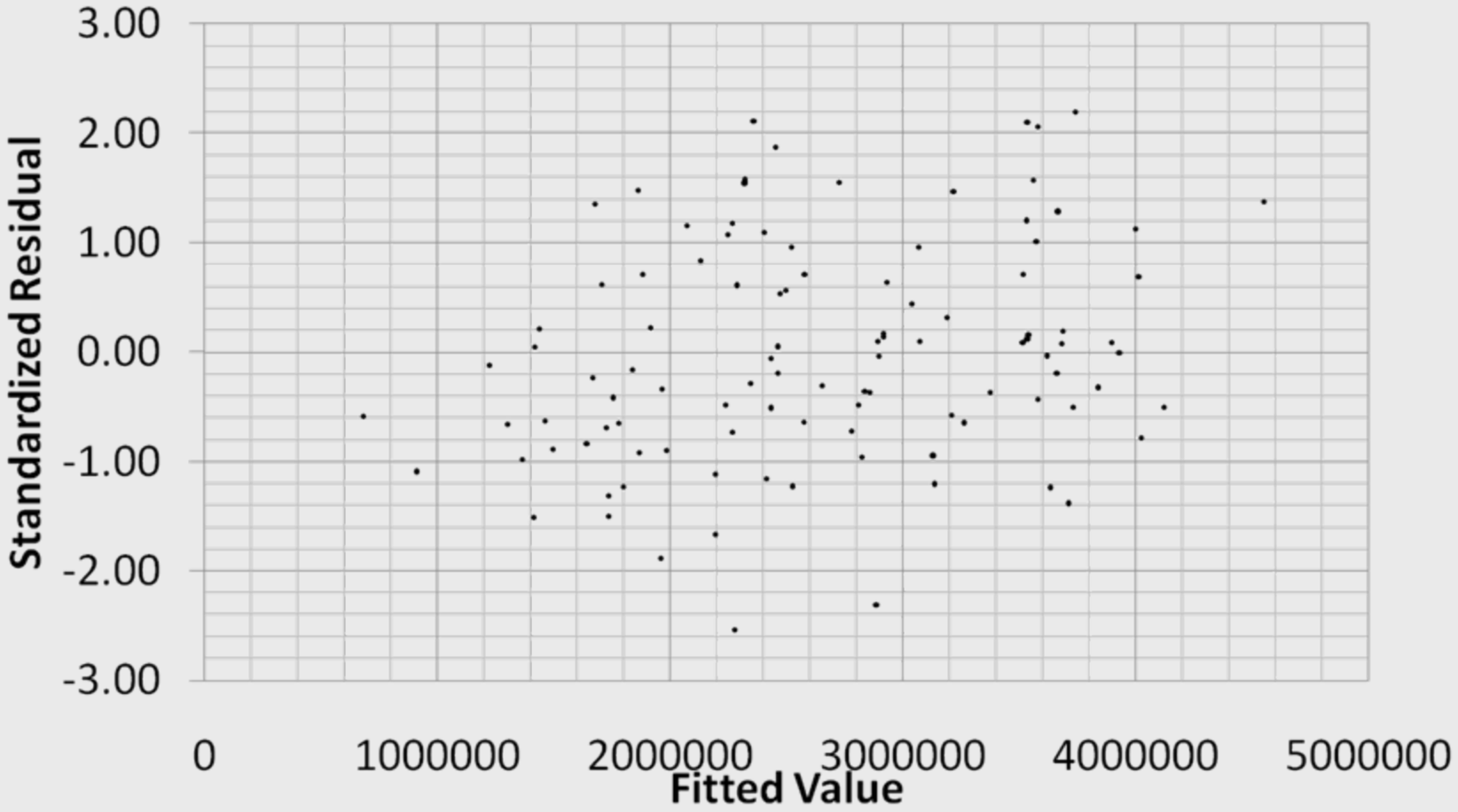
Regression Analysis (6/8)

- % Error vs. Observation- Electricity



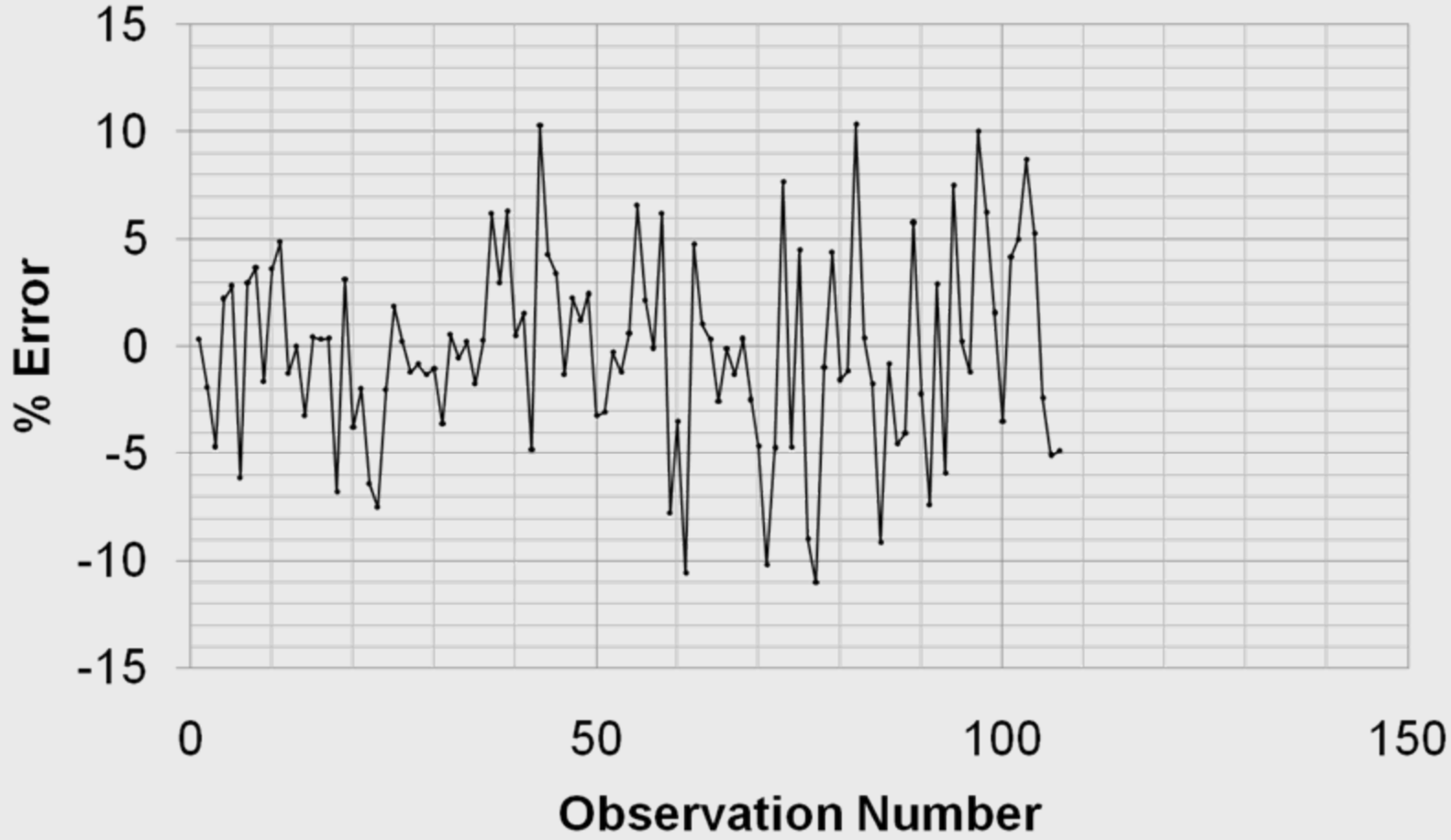
Regression Analysis (7/8)

- Residual vs. Fitted Values –Natural Gas



Regression Analysis (8/8)

- % Error vs. Observation- Natural gas



Cost Estimation (1/5)

- Determine payback period using Present Value (PV) analysis
- PV (Costs) – PV (Savings) = 0
- Factors included
  - Inflation rate
  - Interest rate
  - Growth rate for fuel cost
  - Minimum acceptable rate of return

Cost Estimation (2/5)

Costs include:

- Maintenance
- Installation/Labour
- Materials and Equipment
- Fuel
- Loss of Production

Cost Estimation (3/5)

PV (Costs) = *L*(A/P, i, N_L)* (P/A, f, N_L)*

L = Load Amount (known)

N_L = Agreed upon number of payments to payback loan

i = Interest rate associated with the loan (Estimated: Bank of Canada)

f = Inflation rate (Estimated: Bank of Canada)

Cost Estimation (4/5)

- $(A/P, i, N_L)$ – Capital Recovery Factor

$$= \quad i(1 + i)^N/[(1 + i)^N - 1]$$

- $(P/A, f, N_L) = 1/ (A/P, i, N_L)$

Cost Estimation (5/5)

$$PV(savings) = (AMD) * (P/A, i_f, N) + AFC_B * SE * (P/A, i_{fe}^{\circ}, N) * (1/(1+g_e)) + AFC_B * SS * (P/A, i_{fg}^{\circ}, N) * (1/(1+g_s))$$

AMD	=	Difference in the annual maintenance costs
SE, SS	=	Fuel Savings (kWh)
AFC_e, AFC_g	=	Annual fuel costs for base year
g_e, g_s and	=	Growth rate expected on fuel costs, electrical secondary fuel source
i_f adjusted for	=	The Minimum Acceptable Rate of Return Inflation (MARR).
i_{fe}°, i_{fg}° based on	=	growth adjusted interest rate for electricity Inflation and MARR
N	=	Number of years (to be calculated)

Case Study 1 – Upgrade Lighting System

Factors assumed:

- MARR = 10%
- Interest rate = 4.5%
- Inflation rate = 2.2%
- Growth rate for fuel cost (Electricity and Natural Gas: 2.13% and 2.05%)
- Initial Fuel Cost (Electricity and Natural Gas: $0.07 and $0.04 per kWh)

Case Study 1 – Upgrade Lighting System

- Upgrade Lighting System from T12 to T8 Lamps on Pre-1950's Large Concrete Building
- Initial Lighting Load: 17.8 W/m^2
- Retrofit Lighting Load: 14.24 W/m^2
- Costs of Replacing 2704 Fixtures: C$599,501.13 (RSMeans)

Case Study 1 – Upgrade Lighting System

Use the regression equations to calculate the effects on Consumption

Initial Annual Consumption (kWh):

9,377,483 Electricity

3,266,819 Natural Gas

Post Retrofit Annual Consumption (kWh):

7,377,997 Electricity

3,772,190 Natural Gas

Set: PV(Costs) = PV (Savings): Solve for N

N = 6.47 Years

Case Study 2 – Upgrade Building Envelope

- Install Exterior Insulation Finish System (EIFS), using 1" EPS insulation
- Initial Wall U-Value: 1.21 W/m^2*C
- Retrofit Wall U-Value: 0.61 W/m^2*C
- Cost of adding EIFS to 51,522.32 ft^2 of Exterior Wall: C$475,035.79 (RSMeans)

Case Study 2 – Upgrade Building Envelope

Use the regression formulation to determine the effects on Consumption

Initial Annual Consumption (kWh):

9,377,483 Electricity

3,266,819 Natural Gas

Post Retrofit Annual Consumption (kWh):

9,259,297 Electricity

3,110,937 Natural Gas

Set: PV(Costs) = PV (Savings): Solve for N

N > 200 Years (Infeasible)

Concluding Remarks

1. Proposed screening methodology provides a ranking to Government Office Buildings on the basis of expected energy consumption, cost of ERM, inflation rate and interest rate.
2. Energy consumption is not linearly proportion to the volume,infiltration rate and building aspect ratio (No of floors/floor area). – Need to be incorporated
3. Validation and calibration of the screening tool using metered energy data will be carried out this coming year.
4. Need to consider other ECMs.

Acknowledgements

This study forms a part of ongoing research at The McMaster Centre for Effective Design of Structures funded through the Ontario Research and Development Challenge Fund.

This research was also funded through grants from:

- Public Works & Government Services Canada
- Center for Effective Design of Structures, McMaster University
- Department of Civil Engineering, McMaster University

Questions?