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The Effect of Occupant Behaviour on Electricity Consumption in Canadian Schools

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Overview

- Introduction
- Background
- Objectives
- Methodology
- Results
- Conclusions



Introduction

- Research on buildings' performance
 - Energy benchmarking
 - Green buildings performance
- State of the art
 - Focused on commercial
 - Why study schools?
 - “performance gap” in green buildings
 - Factors influencing performance
 - Role of occupants



Background

- Research on Canadian school buildings
 - Robertson and Higgins 2012 (Alberquerque, NM – 4 schools)
 - Issa et al. 2011 (Toronto, ON – 33 schools)

School Category	Number of Buildings	Mean Equivalent Annual Values				
		Quantities		Costs (2009\$/m ² /year)		
		Electricity (kwh/m ² / year)	Gas (m ³ /m ² / year)	Electricity	Gas	Energy
Conventional	10	68.6	25.3	6.4	9.5	15.9
Energy-Retrofitted	20	93.7	18.9	8.8	7.1	15.9
Green	3	92.4	11.1	8.3	4.0	12.3
Savings (Green – Conventional)		- 23.8	14.2	- 1.9	5.5	3.6

Savings percentages:

- Electricity: 34.6% (Red)
- Gas: 56% (Green)
- Energy: 28% (Green)



Objectives

- Benchmark historical energy consumption in Manitoba school buildings
- Analyze their real-time electricity consumption
- Investigate effect of energy-related occupant behaviour on their energy consumption



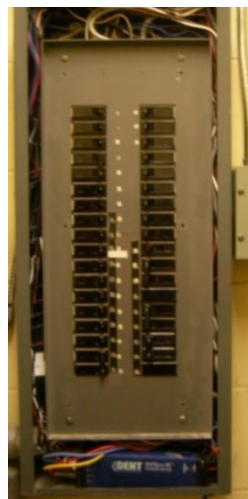
Data Collection

- Preliminary data
 - Floor area, number of occupants, school type
- Sampling
 - 4 school divisions (126 schools)
 - 30 schools randomly selected (Neyman's)
 - Categories
 - Old (<1959) | Middle Aged (1960 -1989) | New (>1990)
- Historical data
 - Energy retrofit history, historical utility bills



Data Collection

- 3 case-study schools selected
- Real-time electricity consumption (Feb – Jun 2015)
 - Total Building
 - Classroom Light and Plug loads (Classroom, gym)



Data Collection

- Real-time occupancy (Feb – Jun 2015)

Classroom and Gymnasium

- Point-in-time observations (2 researchers, 2 weeks)

Classroom

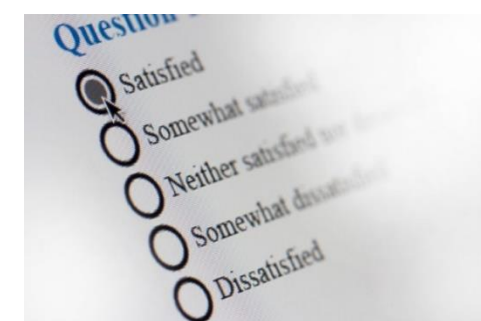
- Daily surveys (2 weeks)
- Occupancy and light sensors

Gymnasium

- After-school bookings

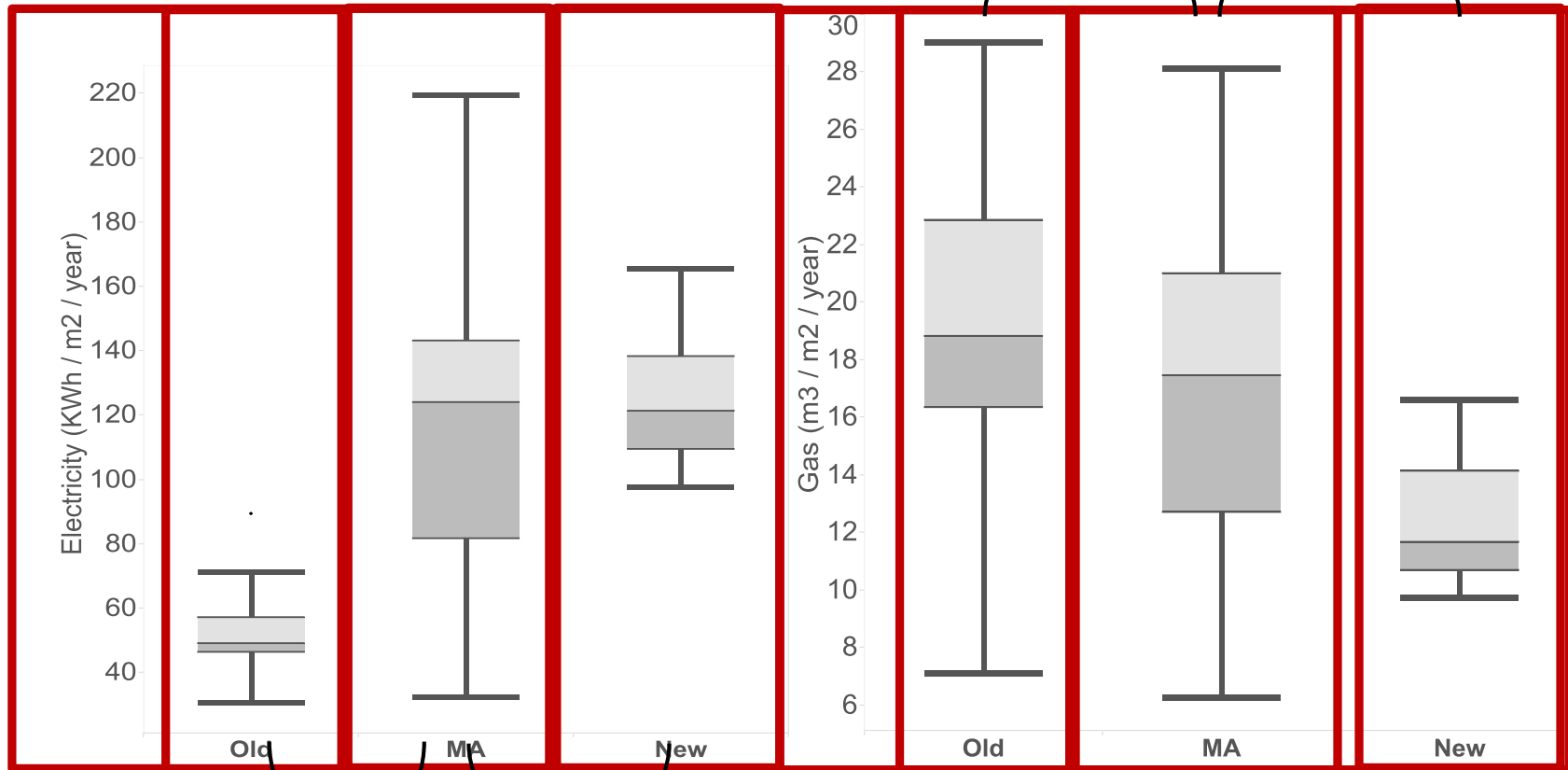
Overall School

- General behavioural survey (Teachers - Response rate: 65%)



Results

- Historical Energy Consumption in 30 schools



105.5%

8.6%

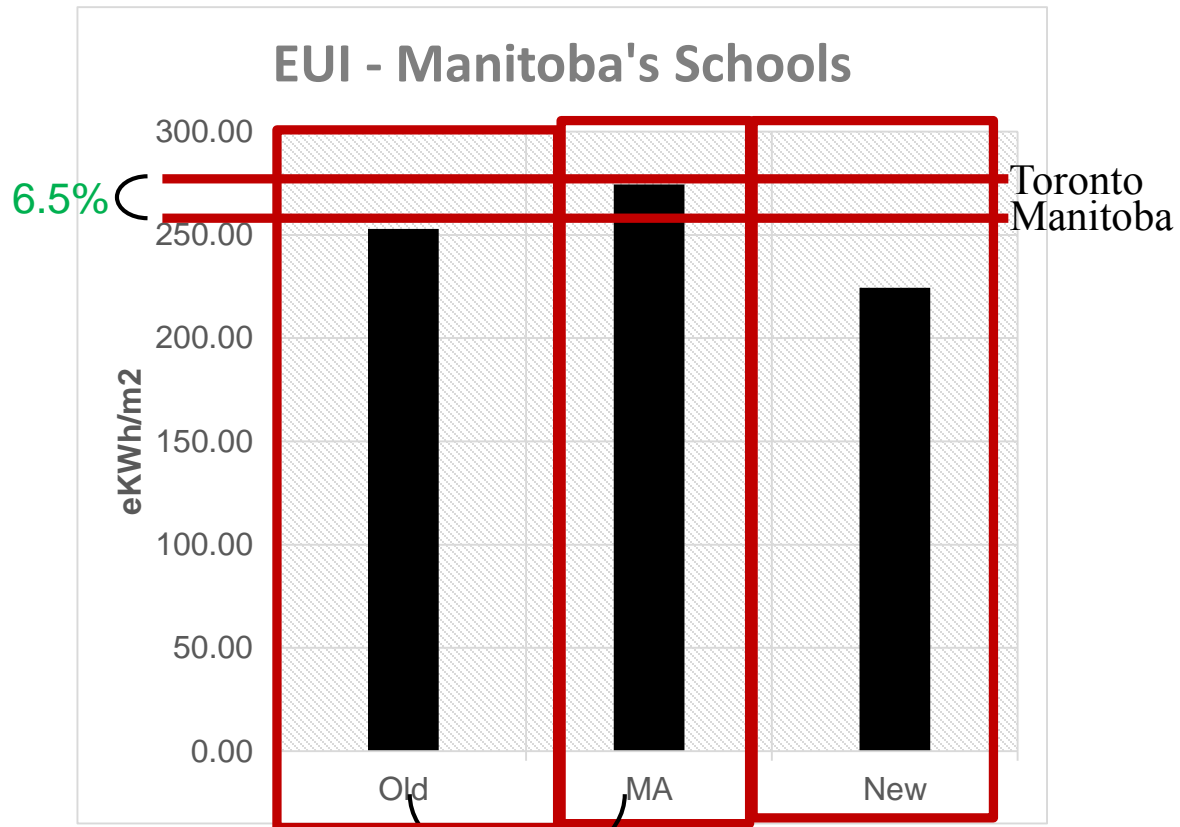
19.5%

23.6%



Results

- Historical Energy Consumption in 30 schools



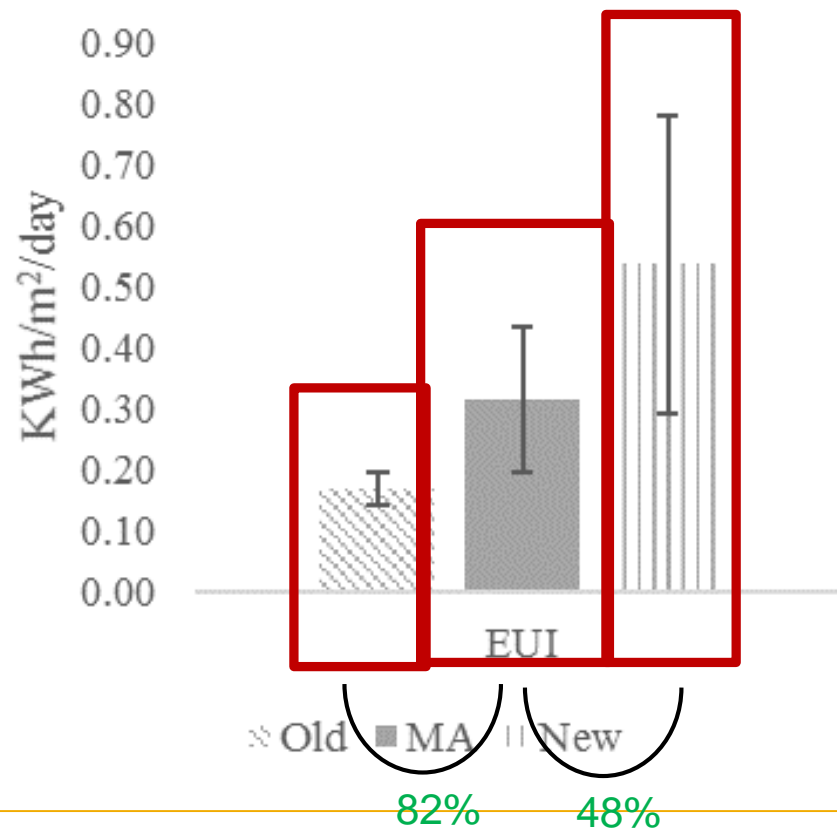
8.5%

18.2%



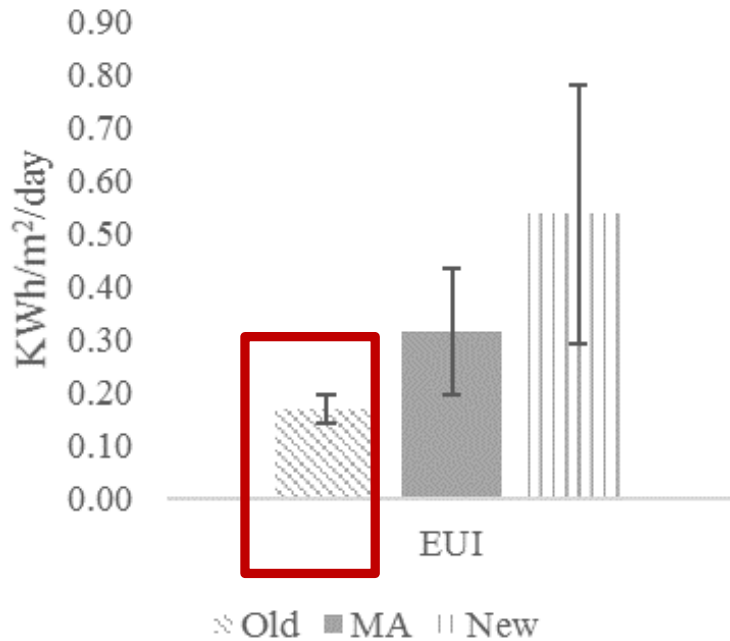
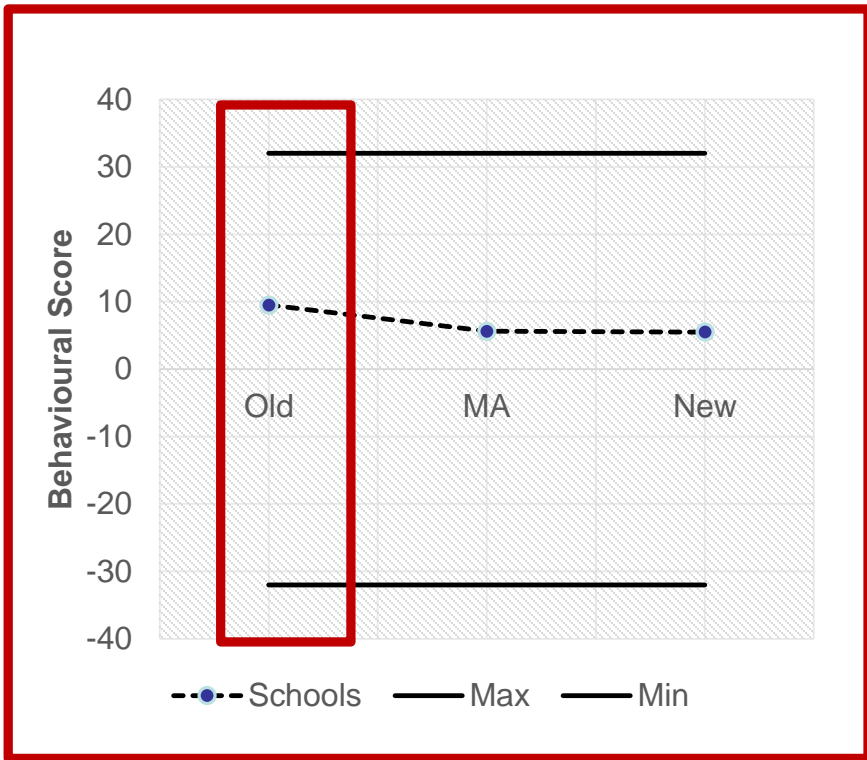
Results

- Real-Time Electricity Consumption in 3 schools



Results

- Effect of energy-related occupant behaviour on real-time electricity consumption in 3 schools



Results

- Effect of energy-related occupant behaviour on real-time electricity consumption in 3 schools
- Statistically significant positive correlations between recorded light use durations and electricity consumption for lighting during school day in all three classrooms
 - ($r = 0.826$, $r = 0.411$, $r = 0.785$, $P < 0.005$ for the old, middle-aged and new schools' classrooms respectively).
- Recorded light use durations explained 68.2%, 16.9% and 61.6% of variation in electricity consumption for lighting in old, middle-aged and new school classrooms, respectively.



Results

- Effect of energy-related occupant behaviour on real-time electricity consumption in 3 schools

School space	Spearman Correlation Coefficient (r_s)	P (Sig. 2-tailed)
Old Gymnasium	0.176	0.049
MA Gymnasium	0.478	<0.0005*
New Gymnasium	0.182	0.041
Old Classroom	0.489	<0.0005*
MA Classroom	-0.097	0.212
New Classroom	0.509	<0.0005*

- Weak to moderate positive correlations between half-hourly number of equipment in use and electricity consumption for plug loads in some school spaces
- Number of equipment in use explained 11 to 26% of variability in electricity consumption for plug loads



Conclusions

- Research provides empirical evidence on effect of energy-related occupant behaviour on energy consumption
- Future research directions
 - Increasing sample size and large-scale deployment
 - Development of data-driven occupancy models for energy modeling
 - Research on occupant engagement in existing buildings



For more information

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Ouf, M. and Issa M.H. (2017). “Energy Consumption Analysis of School Buildings in Manitoba”, *International Journal of Sustainable Built Environment*, fully accepted, in press.

Ouf, M., Issa M.H. and Merkel P. (2016). “Analysis of Real-Time Electricity Consumption in Canadian School Buildings”, *Energy and Buildings*, 128, 530-539.



EXPLORER INNOVATOR ADV

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INNOVATOR CHALLENGER REBEL VISIONARY

REBEL PIONEER CREATOR EXPLORER TRAILBLAZER INNOVATOR

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