



# **A Methodology to Evaluate the Effects of School Buildings' Occupancy and Usage on their Energy Consumption**

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# Outline

- Introduction
- Goal, Objectives and Scope
- Literature Review
- Methods
- Conclusion

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# Introduction

- Buildings account for 20-40% of energy use globally
- Green buildings offer potential for decreasing buildings' energy use by 25-30%
- Research on green buildings' energy performance (e.g. Menassa et al. 2012, Thiers and Peuportier 2012) shows mixed results
- Limited research on:
  - Schools (e.g. Issa et al. 2011, Robertson and Higgins 2012)
  - Schools' occupancy and usage (e.g. Ridley et al. 2014, Guerra-Santin et al. 2013)





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# Goal, Objectives and Scope

## Goal and Objectives

- Evaluate schools' energy consumption in relation to their usage and occupancy
  - Develop and validate methodology to evaluate schools' energy consumption
  - Develop and validate methodology to evaluate schools' occupancy and usage
  - Investigate relationship between schools' energy consumption and their usage and occupancy

## Scope:

- Manitoba schools
- Evaluation at building level and space level

# Literature Review

## Method

## Drawbacks

Surveys and interviews (e.g. Chen et al. 2013, Ridley et al. 2014; Durand-Daubin 2013)

Subjective

Visual observations/ monitoring of equipment use (Klein et al. 2012)

Labour-intensive

Video monitoring of occupants (Zhou et al. 2008)

Privacy concerns

Monitoring of WiFi connections (Zeiler et al. 2014)

Use of radio-frequency identification technology (Spataru & Gillott 2011)

Use of infra-red motion detectors (Yun and Lee 2014)

Only account for number of occupants

# Methods

Total: 112 schools from 4 participating school divisions

Old (before 1959), middle-aged (1960 – 1989), new buildings (after 1990)

Building level (31 schools)

Neyman's allocation method

Confidence level: 90 %

Historical analysis of energy  
use and occupancy

Space level (3 schools)

Real-time analysis of electricity  
use (lighting and appliances)

Real-time analysis of usage  
patterns

# Methods

## Building-Level Analysis (31 schools)

### Energy

Energy data collection  
(historical)

Historical utility bills

Electricity and gas consumption

Energy costs

### Occupancy

Occupancy Data Collection  
(historical)

Historical occupancy figures

Number of students,  
teachers and staff



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# Methods

## Occupancy Building-Level Analysis

School Name
School Address
Building Key Site manager Contact name and Information*
Building Type
Building climate zone
Number of Floors

	Circular
	L-Shaped
	U-Shaped
	I-Shaped
	V-Shaped
	Other (Specify)
Surroundings (Check all that apply)	Attached to another building one side
	Attached to another building from two sides
	Attached to another building from three sides
	Attached to underground parking garage
	Attached to indoor above ground parking garage



# Methods

Space-Level Analysis (**3 schools**)  
(1 classroom, 1 gym, 1 multi-purpose room)

## Electricity

Electricity Data Collection  
(real time)

Power meters

Plug monitors

## Usage

Usage Data Collection  
(real time)

Occupancy sensors

Document analysis (room schedules)

Surveys (general and daily)

Observations

# Methods

## Electricity Space-Level Analysis (3 schools)

### ELITEPRO XC ANATOMY



# Methods

Space-Level Analysis (**3 schools**)  
(1 classroom, 1 gym, 1 multi-purpose room)

## Electricity

Electricity Data Collection  
(real time)

Power meters

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# Methods

## Usage Space-Level Analysis (General survey)

### Schools Energy Consumption Survey

#### Personal strategies to increase energy efficiency

Please indicate the extent to which you agree or disagree with the following statements

**17. I use less energy than other teachers/staff members at the school**

☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

**18. In my primary work location (e.g. classroom, gym, music room), I know the potential reasons for energy waste**

#### Personal strategies to increase energy efficiency

Please indicate the extent to which you agree or disagree with the following statements

**17. I use less energy than other teachers/staff members at the school**

☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

**18. In my primary work location (e.g. classroom, gym, music room), I know the potential reasons for energy waste**

☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

☐ Teacher in classroom  
☐ Teacher in gymnasium  
☐ Teacher in music room  
☐ Staff member





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# Methods

## Usage Space-Level Analysis (Daily survey)

Please estimate the duration of active use for each of the following devices today  
("active use" denotes times of direct interaction between a user and a device)

Your laptop/computer

Other laptops or computers (Leave blank if not applicable)

The projector

The stereo

Electric Sharpener

Device charging (e.g. cell phones or ipads or camera charger)

Other (Leave blank if not applicable) Please specify:

Other (Leave blank if not applicable) Please specify:

For how long were the lights switched off today?

# Methods

## Usage Space-Level Analysis (Observations)

- Period and type
  - two weeks per school
  - Point-in-time (half-hour intervals)
- Data type
  - (States 1,2,3)
- Issues
  - Subject reactivity
  - Inter-observer reliability





# Methods

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## Usage Space-Level Analysis (Observations)

Classroom		Date:	Time:
Observation	State	Definition (0 = Not visible in room OR around it) / blank = cannot be observed	for any reason beyond observer control)
Weather		1 <b>Completely Clear</b> = No clouds at all in sight	2 <b>Partial Clouds</b> = One or more clouds in sight, <b>Partial</b> = Blind is down but not covering the entire window, <b>Full</b> = Blind is covering the entire window
by students side		<b>Off</b> = Blind is completely up (window completely cleared)	<b>Partial</b> = Blind is down but not covering the entire window, <b>Full</b> = Blind is covering the entire window
Blind by students side		<b>Off</b> = Blind is completely up (window completely cleared)	<b>Partial</b> = Blind is down but not covering the entire window, <b>Full</b> = Blind is covering the entire window
by teacher side (closer to the door)		<b>Off</b> = Blind is completely up (window completely cleared)	<b>Partial</b> = Blind is down but not covering the entire window, <b>Full</b> = Blind is covering the entire window
		<b>Off</b> = Blind is completely up (window completely cleared)	<b>Partial</b> = Blind is down but not covering the entire window, <b>Full</b> = Blind is covering the entire window
		<b>No</b> = Projector is not being used and is unplugged	<b>Idle</b> = Projector is plugged in and on-standby but not projecting anything at the moment <b>Yes</b> = Projector is being used to project something on the board
		<b>No</b> = speaker is unplugged	<b>Idle</b> = speaker is plugged in but not being used <b>Yes</b> = Speaker is being actively used
		<b>No</b> = No chargers are plugged in	<b>Idle</b> = 1 or more devices chargers are plugged in but not connected to a device <b>Yes</b> = 1 or more devices are being charged
		<b>No</b> = No other devices are plugged in (definition can be readjusted according to device)	<b>Idle</b> = 1 or more devices are plugged in but not being used (definition can be readjusted according to device) <b>Yes</b> = 1 or more devices are actively being used (definition can be readjusted according to device)
		<b>No</b> = Laptop is not being used and/or is unplugged	<b>Idle</b> = Laptop is on standby or sleep mode, screensaver or blank screen is on but laptop is plugged in <b>Yes</b> = Laptop is being actively used or projector screen is on
		<b>No</b> = Laptop is not being used and/or is unplugged	<b>Idle</b> = Laptop is on standby or sleep mode, screensaver or blank screen is on but laptop is plugged in <b>Yes</b> = Laptop is being actively used or projector screen is on
		<b>No</b> = Stereo is unplugged	<b>Idle</b> = Stereo is plugged in but not being used <b>Yes</b> = Stereo station is being actively used
		<b>No</b> = Electric sharpener is unplugged	<b>Idle</b> = Electric sharpener is plugged but not being used <b>Yes</b> = Electric sharpener is plugged in and being used
		<b>Off</b> = All Classroom lights are off except emergency lights	<b>Dimmed</b> = Some classroom lights are on and some are off (as long as at least one light bulb is switched off not due to malfunction but using a specific light switch) <b>On</b> = All classroom lights are on
		<b>No</b> = No one in present	<b>Partial</b> = 3 or less people are present <b>Yes</b> = More than 3 people are present
General Comments			

Teacher's laptop or computer in use  
(also check the charger alone)

**No** = Laptop is not being used and/or is unplugged

**Idle** = Laptop is on standby or sleep mode, screensaver or blank screen is on but laptop is plugged in

**Yes** = Laptop is being actively used or projector screen is on



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# Conclusion

## Research Contributions

- New methodology to quantify school occupancy and usage in relation to energy consumption
- Tool for use in schools in particular to:
  - Improve energy efficient occupancy and usage of existing schools
  - Design new schools that optimize energy-efficient occupancy and usage
- Recommendations/ best practices to improve energy-efficient occupancy and usage of new and existing schools

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# Questions



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