

'Portfolio Analysis-Methodology for school buildings audit and upgrades'

An Energy Audit Study

By

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Prepared for:

- **Union Gas**
- **HWDSB**
- **HWCDSD**



Agenda

- Introduction: Scope
- Variation in Building Characteristics
- What is Archotyping?
- Archotyping: Our Approach
 - Step 1: Building Stock
 - Step 2: Determine Building Characteristics
 - Step 3: Construct Flowcharts
 - Step 4: Display Grouping Results
- Conclusions

Introduction

- Using the record provided by Hamilton-Wenworth Distric School Board (HWDSB) and Hamilton-Wenworth Catholic School Board (HWCDSB) each school was analyzed based on their energy efficiency
- This presentation is organized in order to get a better understanding of
- Benchmarking for Statistical Analysis
- Energy Conservation Measures
- Justify Rationale for the Set of archotyping for the schools

Introduction: Scope

- This presentation addresses high school buildings. The current strategy does not include schools with portables, pools, fields, and stadiums.
- Secondary schools have different building characteristics than elementary schools
- Secondary schools tend to have:
 - Larger building volume
 - Larger gross area
 - Higher enrolment
- Elementary schools usually do not contain:
 - Auditoriums
 - Multiple Gymnasiums
 - Wood shop, Auto shop, metal shop, cooking classes, etc.
 - Cafeteria
 - Recreation centre/pool/stadium
- Overall, secondary schools are complex compared to elementary schools

Variation in Building Characteristics

- Building characteristics:
 - Building envelope performance
 - HVAC System
 - Energy Consumption
 - Building Automation System
 - Gross Area of the building
 - Volume of the building
 - Occupancy
 - Etc.
- Since there are several variables involved in describing a building's characteristics, no two schools can be exactly the same

Variation in Building Characteristics

- However, with such a large building stock, finding similarities between certain schools can be of extreme value
- Some reasons are:
 - Benchmarking
 - Providing reasonable assumptions to missing information
 - Similar Energy Conservation Measures implementation
 - Determining which buildings to perform energy audits on

What is Archotyping?

- *Archotyping* is a process of grouping the buildings according to similar characteristics
- A building within one of these groups can then be used to represent a typical building for that group based on their similarities

What is Archotyping?

- Generally, the archotyping of a building stock begins by selecting a building characteristic and then determining a method of separation
- For example, construction age of a building can be broken down into several categories
 - Pre-1950
 - 1950-1975
 - 1976-1996
 - Post-1996
- Once broken down by one building characteristic, the groups can then be further evaluated for another building characteristic for that particular group

What is Archotyping?

- Building Characteristic ideas for categorizing building stock:

Building Age

Energy Consumption

Area

Building's Future

Number of Storeys

Enrolment

Portables

Pools/Stadiums

Gym

Basement

Renovations

Windows

Cooling System

Heating System

Heat recovery

Occupancy Sensors

Building Automation System

Archotyping: Our Approach

Step 1: Building Stock

Step 2: Determine Building Characteristics

Step 3: Construct Flowcharts

Step 4: Display Grouping Results

Step 1: Building Stock

- Include all buildings that have potential for an energy audit
 - HWDSB:
 - 18 secondary
 - 92 elementary
 - HWCDSB:
 - 6 secondary
 - 42 elementary
 - Grand total of 159 schools

Step 2: Determine Building Characteristics

- Determine a set of building characteristics to utilize for archotyping the building stock
- The characteristics chosen for the secondary schools were:
 - Building Construction Age
 - Building Envelope Performance
 - HVAC System
 - Energy Consumption

Step 2: Determine Building Characteristics

- Building Construction Age
 - Pre-1950
 - 1950-1975
 - 1976-1996
 - Post-1996
- Building Envelope Performance
 - The UA-Value
 - Broken down into groups by observing UA-Value vs. Secondary School (in chronological order of building age)
 - A new UA group was started when a significant change in percentage difference in UA-Value between schools was observed
- An example to clarify UA-Value:
 - A building which was constructed in the 1960s may have a UA-Value which is better represented by the Pre-1950 grouping

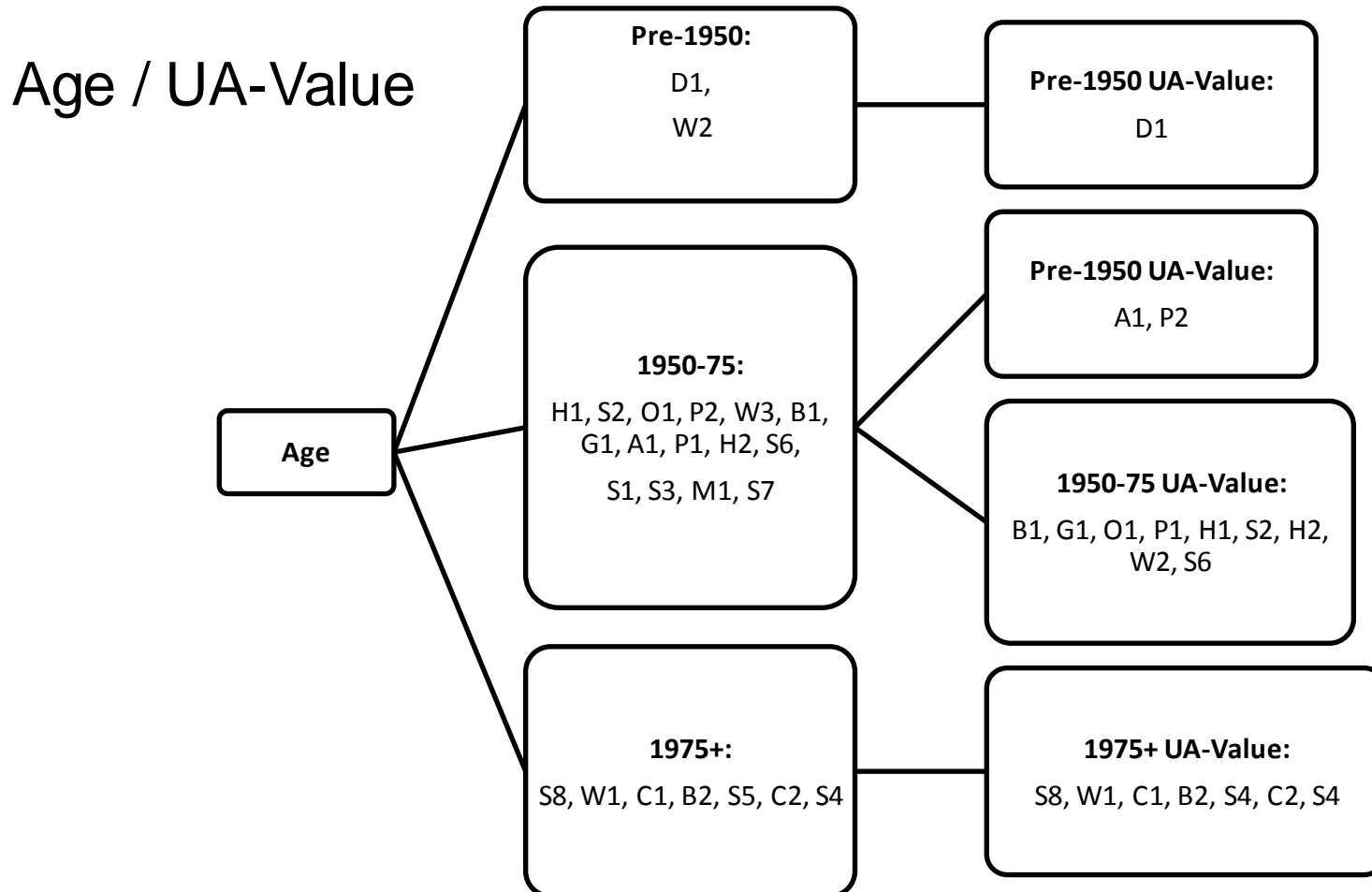
Step 2: Determine Building Characteristics

School	Age	UA Values	School	Age	UA Values
A1	1959	44605	S1	1996	10725
B1	1960	21359	S2	1969	N/A
B2	2004	14925	S3	1967	24800
C1	1999	14966	S4	1969	N/A
C2	1995	13508	S5	1995	17500
D1	1924	54301	S6	1992	17309
G1	1960	22766	S7	1963	25756
H1	1968	32464	S8	1967	N/A
H2	1954	39157	W1	1992	9896
M1	1968	N/A	W2	1930	N/A
O1	1965	36151	W3	1961	28799
P1	1959	24963			
P2	1962	41567			

Step 2: Determine Building Characteristics

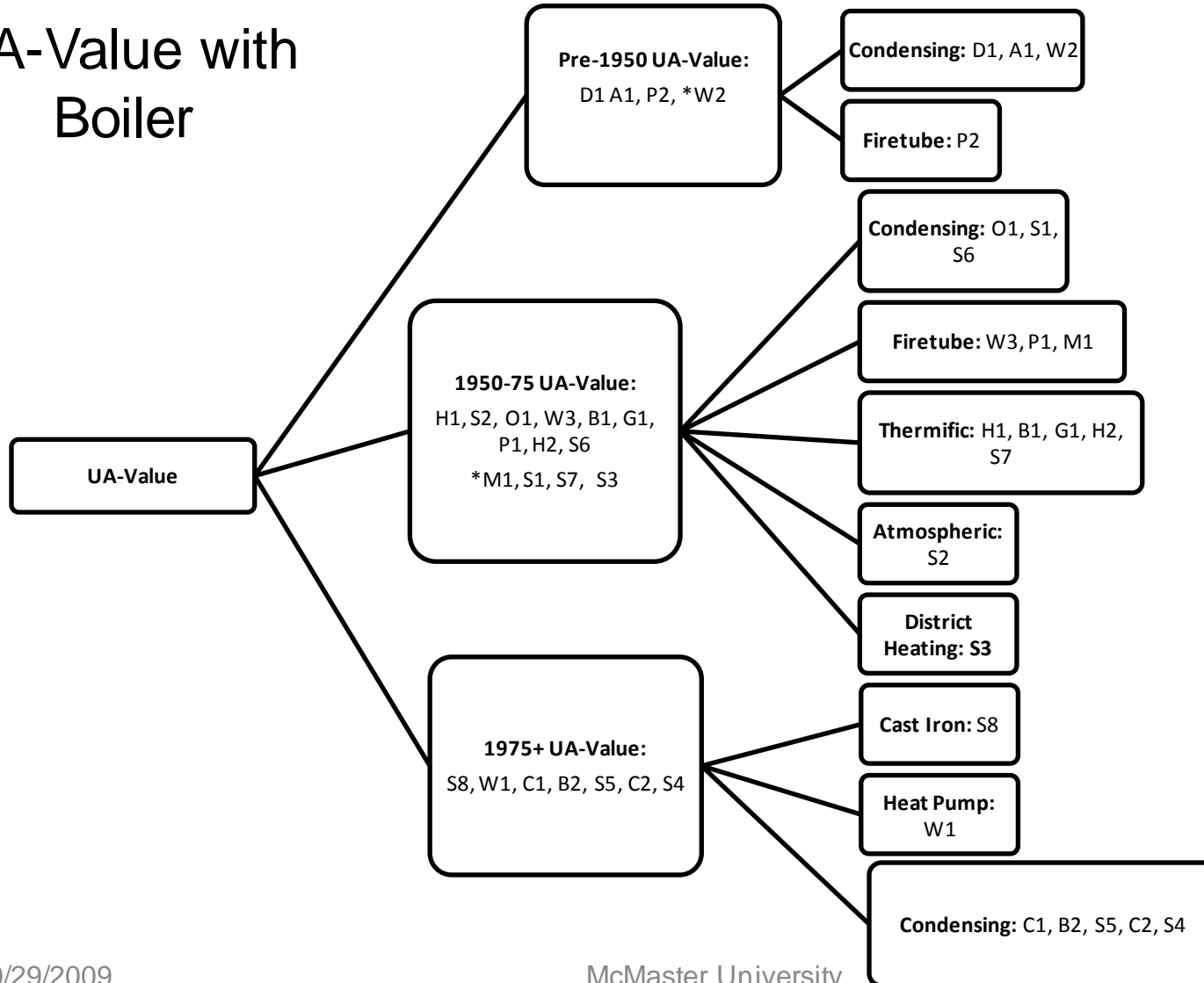
- HVAC System
 - Boiler type
- Energy Consumption
 - Natural Gas Consumption per building volume (m^3/m^3)

Step 3: Construct Flowcharts



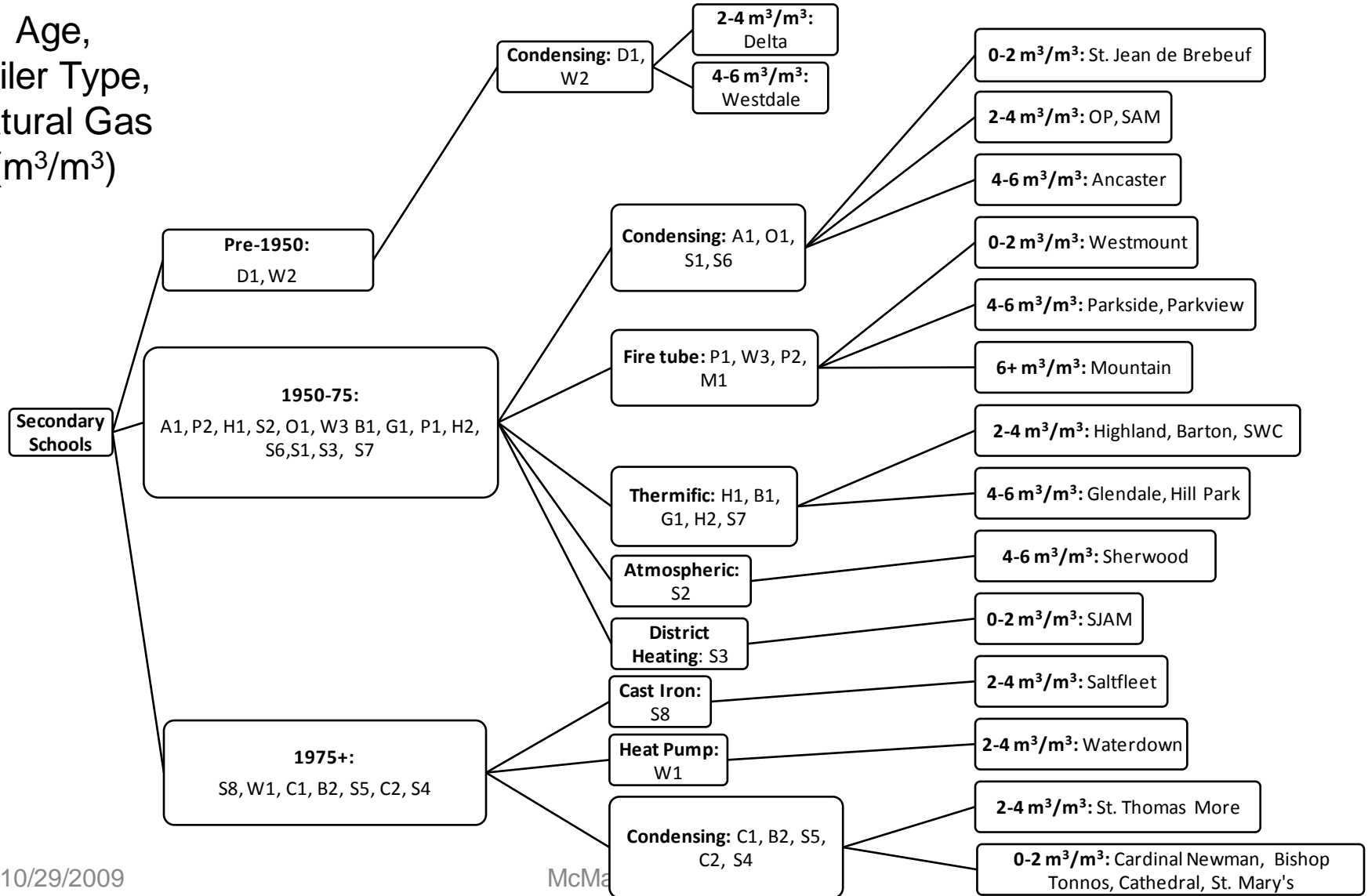
Step 3: Construct Flowcharts

UA-Value with Boiler



Step 3: Construct Flowcharts

Age,
Boiler Type,
Natural Gas
(m³/m³)



Step 4: Display Grouping Results

Group #1	C2	S8	S4	S5	W1
Year Built	1995	1996	1995	1992	1992
UA Value¹	13508	10725	17500	17309	9896
Heating Type	Condensing	Cast Iron	Condensing	Condensing	Heat Pump
Heat Pumps	Y	Y	Y	Y	Y
Natural Gas² (m³/m³)	0.9	4	0.5	3.6	2.9
Cooling System	Rooftop	Pumps	Rooftop	Rooftop	Pumps
Heat Recovery	N	Y	N	Y	N
Portables	2	10	3	12	19
Volume³ (m³)	65062	62239	84316	65259	56311
Students	1287	1268	1000	1806	1274
Window Type	Double	Mixed ⁴	Double	Double	Double

Step 4: Display Grouping Results

Group One

- Reasons for this grouping:
 - Built between 1992 and 1996
 - UA values in range from 10000 to 17500 (BTU/hr·°F)
 - Have heat pumps
 - Have portables
 - Have high enrolment
 - Double glazed windows, few areas single glazed
 - All have 3 gymnasiums

Step 4: Display Grouping Results

Group #2	M1	P1	S2	W3
Year Built	1968	1959	1967	1961
UA Value¹	n/a	24963	24800	28799
Heating Type	Firetube	Firetube	Atmospheric	Firetube
Heat Pumps	N	Y	N	N
Natural Gas² (m³/m³)	7.3	4.8	5.6	2
Cooling System	Window	Window	Chiller	Window
Heat Recovery	N	N	Y	N
Portables	0	0	0	0
Volume³ (m³)	26681	37845	40069	60560
Students	271	636	1155	1322
Window Type	Mixed ⁴	Single	Mixed	Single

Step 4: Display Grouping Results

Group Two

- Reasons for this grouping:
 - Built between 1959 and 1968
 - UA values in range from 18000 to 27000 (BTU/hr·°F)
[M1 data not available]
 - Firetube boilers for all schools but S2, which has an Atmospheric boiler
 - Window A/C units for all schools except S2
 - No heat recovery units except for S2, which has an economizer
 - No portables

Step 4: Display Grouping Results

Group #3	A1	D1	P2	W2
Year Built	1959	1924	1962	1930
UA Value¹	44605	54301	41567	n/a
Heating Type	Condensing	Condensing	Firetube	Condensing
Heat Pumps	N	N	N	N
Natural Gas² (m³/m³)	4.1	3.4	5.4	4.1
Cooling System	Window	Window	Window	Rooftop
Heat Recovery	N	N	N	N
Portables	1	0	0	0
Volume³ (m³)	83939	99392	31224	103651
Students	1028	926	282	1456
Window Type	Mixed ⁴	Mixed	Mixed	Double

Step 4: Display Grouping Results

Group Three

- Reasons for this grouping:
 - UA values in range from 36000 to 45000 (BTU/hr·°F) [W2 data not available]
 - Condensing boilers for all schools but P1, which has a Fire tube boiler
 - No heat pumps
 - Adjusted natural gas consumption, in m³ per school volume, from 3.4 to 5.4
 - Only specific areas of the schools are cooled
 - No heat exchangers or economizers
 - None have stadiums, pools

Step 4: Display Grouping Results

Group #4	B1	G1	H1	H2	S7
Year Built	1960	1960	1968	1954	1967
UA Value¹	21359	22766	32464	39157	n/a
Heating Type	Thermific	Thermific	Thermific	Thermific	Thermific
Heat Pumps	N	N	N	N	N
Natural Gas² (m³/m³)	3.2	4	3.4	4.9	3.6
Cooling System	Rooftop	Rooftop	Chiller	Rooftop	Window
Heat Recovery	Y	Y	N	Y	N
Portables	0	0	0	1	0
Volume³ (m³)	57243	57212	53901	60967	66698
Students	944	967	864	962	1196
Window Type	Mixed ⁴	Mixed	Mixed	Mixed	Mixed

Step 4: Display Grouping Results

Group Four

- Reasons for this grouping:
 - Built between 1954 and 1968
 - UA values in range from 15000 to 23000 (BTU/hr·°F) [S4]
 - Thermific boilers for all schools
 - No heat pumps
 - Adjusted natural gas consumption in m³ per school volume ranges from 3.2 to 4.9
 - Volume ranges from 54000 m³ to 67000 m³
 - Mixed (single and double glazed) window types

Step 4: Display Grouping Results

Group # 5	O1	S1	S6
Year Built	1965	1969	1963
UA Value¹	36151	N/A	N/A
Heating Type	Condensing	Condensing	Condensing
Heat Pumps	Y	N	N
Natural Gas² (m³/m³)	3.2	3.1	2
Cooling System	Chiller	Chiller	Window
Heat Recovery	Y	Y	Y
Portables	0	0	12
Volume³ (m³)	70601	73856	79495
Students	1218	847	1772
Window Type	Mixed ⁴	Mixed	Mixed

Step 4: Display Grouping Results

Group Five

- Reasons for this grouping:
 - Built between 1963 and 1969
 - UA values not available for all schools (O1 Park UA is 36000 BTU/hr·°F)
 - Condensing boilers for all schools
 - Adjusted natural gas consumption in m³ per school volume ranges from 2.0 to 3.2
 - Volumes range from 71000 m³ to 80000 m³
 - Mixed (single and double glazed) window types
 - All have 3 gymnasiums

Step 4: Display Grouping Results

Group # 6	B2	C1
Year Built	2004	1999
UA Value¹	14925	14966
Heating Type	Condensing	Condensing
Heat Pumps	N	N
Natural Gas² (m³/m³)	1	1.6
Cooling System	Rooftop	Chiller
Heat Recovery	Y	N
Portables	0	0
Volume³ (m³)	79745	86619
Students	1434	1509
Window Type	Double	Double

Step 4: Display Grouping Results

Group Six

- Reasons for this grouping:
 - Built between 1999 and 2004 (new ASHRAE standards)
 - UA values in range from 14900 to 15000 (BTU/hr·°F)
 - Condensing boilers for both schools
 - No heat pumps
 - Adjusted natural gas consumption, in m³ per school volume, ranges from 1.0 to 1.6
 - No portables
 - Volumes range from 80000 m³ to 87000 m³
 - Occupancy is similar (1434 & 1509)
 - Double glazed windows

Step 4: Display Grouping Results

Other

S3

- Reasons:
 - District heating system
 - UA value unknown
 - Five storey building

Conclusions

- From the initial review & archotyping of available data, the following conclusions have been made:
 - The elementary and secondary schools must be analyzed separately
 - Within the secondary school grouping the age ranges of pre-1950, 1950 – 1974, 1975-1996, and post 1996 provide an appropriate division among the schools
 - Three archotyping strategies were made possible by using the building envelope performance (UA-Values), the primary heating system, and the normalized natural gas consumption
 - Several grouping strategies were utilized in order to incorporate all secondary schools into groups

DISCUSSION / QUESTIONS ???