



Choosing Windows for the North

MAY 7, 2015 - WHITEHORSE, YUKON
GRAHAM FINCH, MASC, PENG - PRINCIPAL, BUILDING SCIENCE RESEARCH SPECIALIST
RDH BUILDING ENGINEERING LTD. VANCOUVER, BC - GFINCH@RDH.COM



Afternoon Agenda

- Luncheon 12:00 to 1:00
 - Choosing Windows for the North - A Balancing Act
- Workshop - 1:00 to 3:00
 - Understanding Energy Use in Multi-Unit Residential Buildings (MURBs) & Opportunities for Deep Retrofits - Case Studies and Lessons Learned from BC
 - PNWER Net Zero Study Case Study Building Discussion

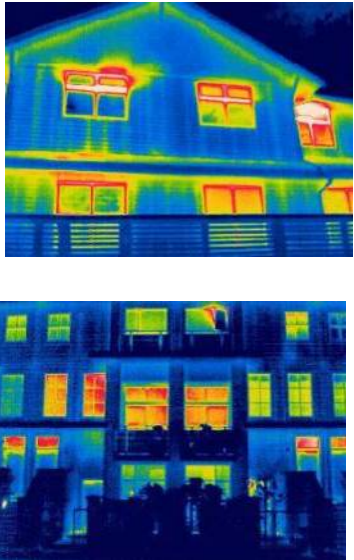
Contact Information & Resources **RDH**

- Presentation Slides will be made available by email
 - Fill out information sheet and/or email me

- Graham Finch
 - gfinch@rdh.com
 - 604-873-1181

Why The Focus on Windows? **RDH**

- Are a focal architectural and function part of our homes (views, daylighting, aesthetics)
- Can be one of the biggest components of heat loss in a building
- But they can also gain an appreciable amount of heat, which can be good to reduce space-heat loads – or it can also be bad and cause overheating and discomfort
- Picking windows is a learned experience of conflicting priorities and a fairly technical one at that!



The Engineer's Solutions to Windows!

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How Do YOU Pick a Window?

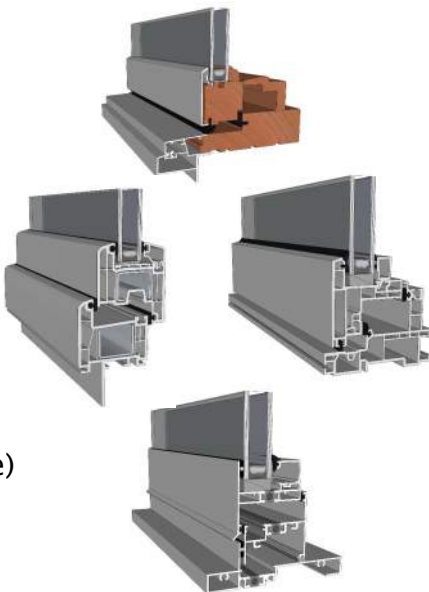
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- Frame & Glazing Considerations
- Aesthetics, Colour, Look & Feel?
- Materials?
- Hardware & Accessories?
- Technical Performance & Specifications?
 - Thermal
 - Air-tightness
 - Water-resistance
 - Security
 - Condensation Resistance
- Etc.




Picking Frames RDH

- Frame Material
 - Vinyl
 - Aluminium
 - Wood
 - Fiberglass
 - Hybrids
- Dimensions
- Structural Considerations
- Aesthetics
- Thermal Performance (U-value)
- Hardware Integration
- Installation Method



Picking Glazing RDH

- Insulated Glazing Units (IGUs)
 - Double/Triple/Quad Glazing
 - Inert Gas Fill (Air, Argon, Xenon, Krypton)
- Aesthetics
 - Colour (Clear, Green, Blue etc.)
 - Clarity (Visible Light Transmission, VLT)
 - Reflection
- Technical Specifications
 - U-value
 - Solar Heat Gain Coefficient (SHGC)
 - UV Resistance
- Spacer Bars/Edge Seals



Insulating Glazing Units (IGUs)

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IGU Components:

1. Surface 1 (exterior)
2. Surface 2 (interior side of exterior lite)
3. Surface 3 (exterior side of interior lite)
4. Surface 4
5. Low-e coating
6. Edge spacer (separate glass panes)
7. Desiccant (to dry air)
8. Primary edge seal (vapor)
9. Secondary edge seal (structure)

Airspace(s)

With triples - add in surfaces 5&6
With quads - add in surfaces 7&8

Wading through the Technical Specs of IGUs

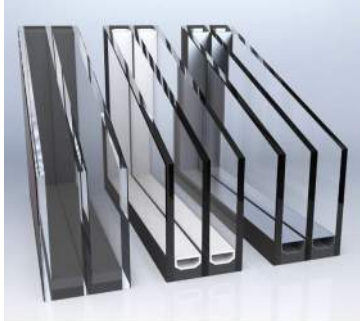
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	Visible Light			Center of Glass U-Factor (Btu/hr/ft ² /°F)				Indoor Glass Temp (F)		UV Trans	Tdw ISO/CIE
	Trans. %	Reflectance		SHGC	SC	U-Factor		Winter	Summer		
		% Out	% In			Air	Argon				
Clear IG	82%	15%	15%	0.78	0.89	0.48	0.46	45	90	58%	75%
LoE Products - Sputtered											
Cardinal LoE ² -272 #2 (e=.041)	72%	11%	12%	0.41	0.47	0.30	0.25	56	84	16%	55%
Cardinal LoE ² -272 #3 (e=.041)	72%	12%	11%	0.50	0.57	0.30	0.25	56	98	16%	55%
Cardinal LoE ² -270 #2 (e=.036)	70%	12%	13%	0.37	0.42	0.29	0.25	56	93	14%	53%
Cardinal LoE ² -270 #3 (e=.036)	70%	13%	12%	0.45	0.53	0.29	0.25	56	99	14%	53%
Cardinal LoE ³ -366 #2 (e=.022)	65%	11%	12%	0.27	0.31	0.29	0.24	56	83	5%	43%
Cardinal LoE ³ -366 #3 (e=.022)	65%	12%	11%	0.39	0.45	0.29	0.24	56	101	5%	43%
PPG SolarBan 60#2 (e=.043)	71%	12%	13%	0.39	0.45	0.30	0.25	56	95	16%	53%
Viracon VE-2000 #2(e=.040)	72%	11%	12%	0.38	0.44	0.26	0.25	56	84	11%	52%
Guardian Perf. Plus II #2(e=.044)	69%	19%	17%	0.41	0.47	0.30	0.25	56	65	20%	50%
AFG Comfort TIAC #2(e=.036)	62%	23%	29%	0.40	0.46	0.29	0.25	56	85	30%	51%
AFG Comfort TIR #2(e=.034)	71%	21%	19%	0.47	0.54	0.29	0.25	56	85	30%	57%
AFG Comfort TIPS #3(e=.047)	77%	13%	14%	0.60	0.69	0.30	0.25	56	94	33%	63%
LoE Products - Pyrolytic											
AFG Comfort E2 #3 (e=.204)	76%	16%	14%	0.73	0.85	0.35	0.31	53	101	44%	64%
Pilk/LOF Energy Adv. #3,(e=.153)	75%	18%	17%	0.72	0.82	0.33	0.29	54	100	45%	65%
Pilk/LOF Solar E #2(e=.153)	54%	10%	16%	0.48	0.55	0.33	0.29	54	91	40%	52%
PPG Sungate 500 #3,(e=.215)	76%	18%	17%	0.71	0.81	0.35	0.31	52	99	49%	66%
PPG Sungate 300 #3 (e=.324)	76%	18%	18%	0.71	0.82	0.38	0.34	51	96	56%	66%

Triples & Quads

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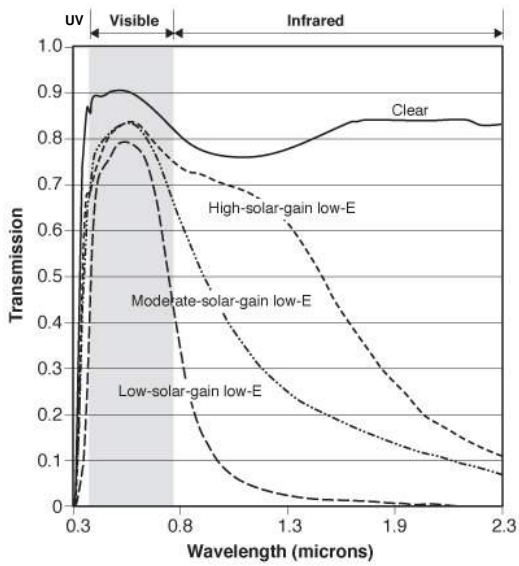
- More airspaces - lower (better) U-values
 - Argon consistently makes sense to incorporate and minimal cost to do so
- More glass - lower SHGC values
 - Fundamental law with stacking layers of glass together, even clear non-low-e, unless you use optically clear glass, \$\$
- Low-e coatings typically put on inner and outer panes of glass
- Concerns with glass breakage increases with more layers of glass - watch placement of low-e
- From experience - glass is better than thin suspended plastic films



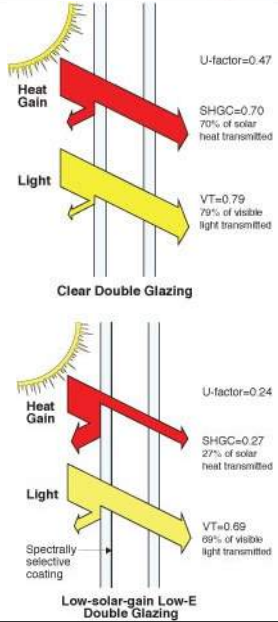
Free program by LBNL, called [WINDOW](#) allows you to design your own IGUs and get all of the optical properties

How Low-e Coatings Work

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Images from LBNL



Clear Double Glazing

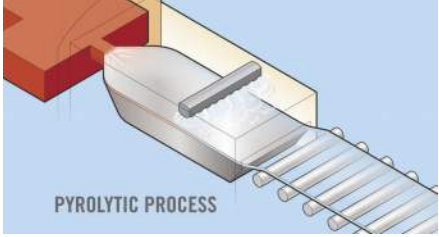
- U-factor=0.47
- SHGC=0.70 (70% of solar heat transmitted)
- VT=0.79 (79% of visible light transmitted)

Low-solar-gain Low-E Double Glazing

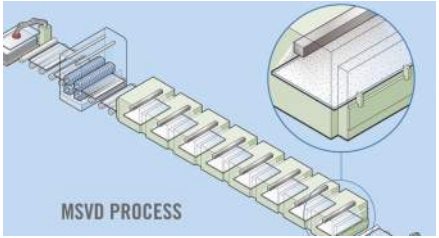
- U-factor=0.24
- SHGC=0.27 (27% of solar heat transmitted)
- VT=0.69 (69% of visible light transmitted)
- Spectrally selective coating

Hard Coat vs. Soft Coat Low-e Coatings RDH

- Both thin metal films (silver, tin, stainless steel etc.) & anti-reflective metal-oxide films applied to glass
- Hard coat (pyrolytic) applied during float process of making glass
 - Tends to result in higher SHGC but lower thermal performance (higher U-values)
- Soft coat (sputtered) applied to glass anytime
 - Tends to result in lower SHGC but better thermal performance
 - Newer coatings can get best of both worlds high SGHC, high thermal performance



PYROLYTIC PROCESS



MSVD PROCESS

Images from PPG

Aesthetics, Colour, & Reflection RDH



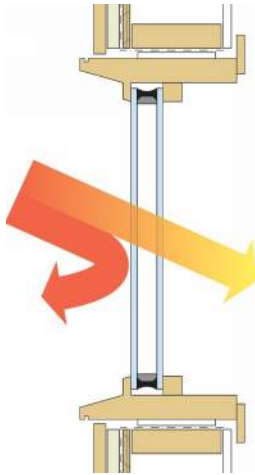
Visible Light Transmission RDH



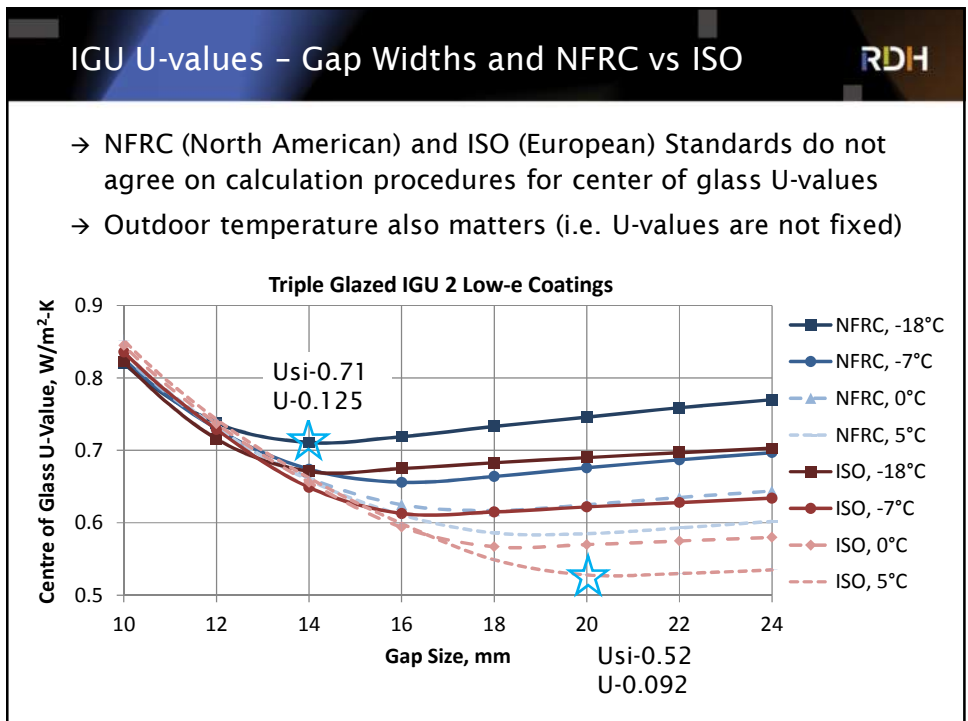
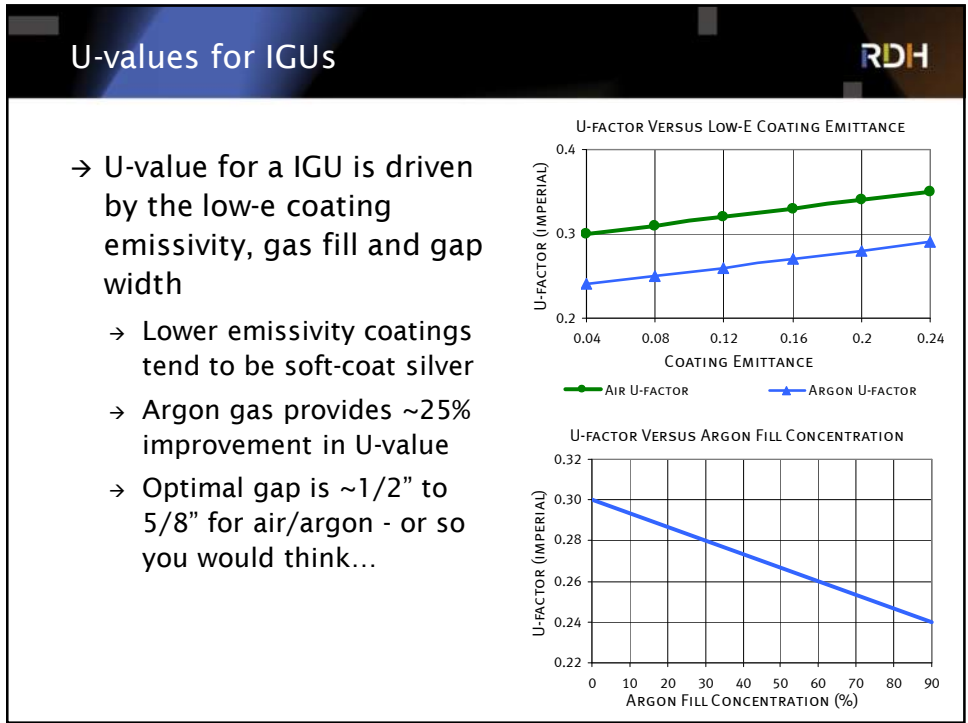
- Visible Light Transmission (VLT) is the visible light spectrum that is transmitted through the glazing unit
- Important in day-lighting and glare control
- Typical range of 30-70%, optimum depends on use of space and window to wall ratio

Solar Heat Gain Coefficient (SHGC) RDH

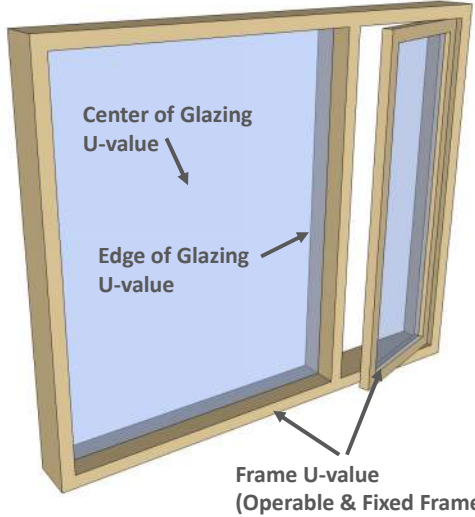
- SHGC is the percentage of total solar radiation transmitted as heat-gain through an IGU (window)
 - SHGC of 0.45 means 45% transferred to interior (directly by short wave radiation and indirectly by absorption and long-wave radiation)
 - Rest is reflected or absorbed and re-radiated back out
- Too high can cause over-heating with too much glass
- Too low can limit amount of “free” heat gain often beneficial in heating climates



SHGC for a window includes the frames, hence why operable windows have lower SHGCs overall



Overall Window U-values RDH



Window U-value =

$$\text{Frame U-value} \times \% \text{ Frame Area}$$

+

$$\text{Center of Glass U-value} \times \% \text{ Glass Area}$$

+

$$\text{Edge of Glass U-value} \times \% \text{ Edge of Glass Area}$$

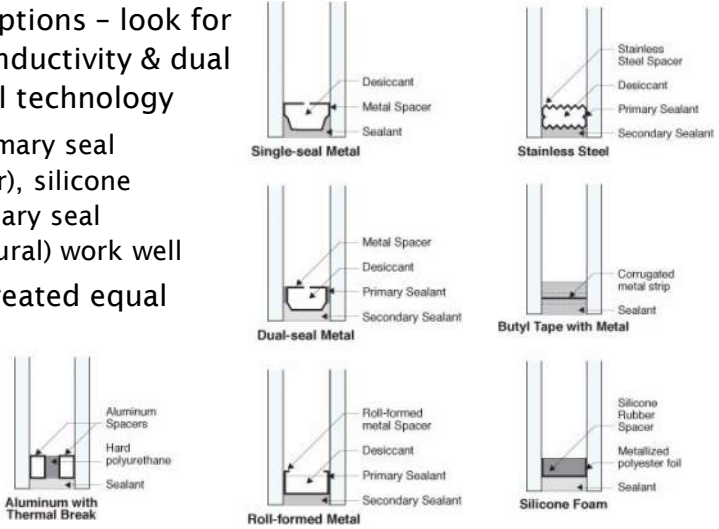
Overall R-value =
 $1/\text{U-value}$

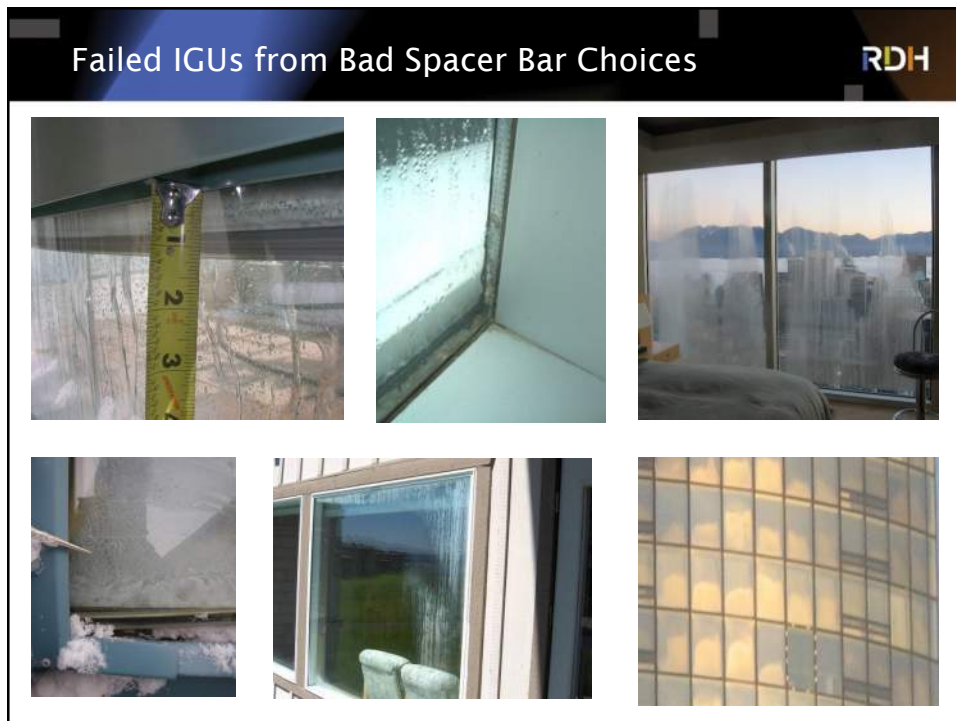
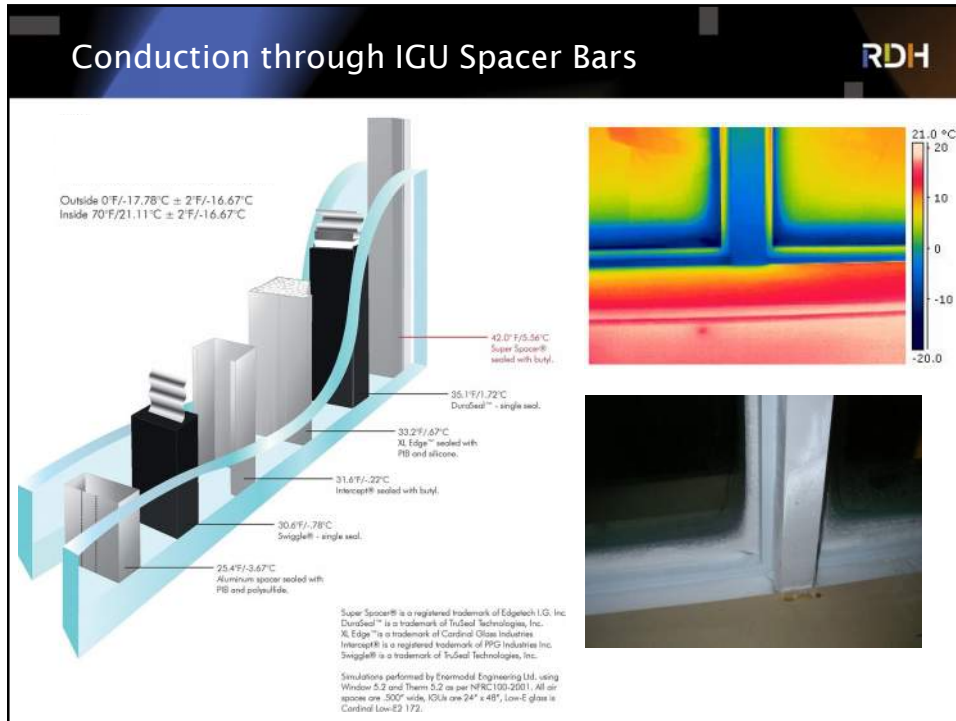
IGU Spacer Bars RDH

→ Lots of options - look for lower conductivity & dual edge seal technology

- PIB primary seal (vapour), silicone secondary seal (structural) work well


→ Not all created equal





Condensation & Frost Prevention RDH

- Condensation/frost occurs when the **surface temperature of the window drops below the dewpoint** temperature of the surrounding air
- Causes:
 - Inadequate window frames or IGU spacer bars for climate
 - Curtains/inadequate airflow at interior of glazing/frame
 - Poor installation of window frame and thermal bridging
 - Too high of an indoor dewpoint
 - Bad HVAC design, not enough heat or air



Condensation & Frost due to Hardware Problems RDH



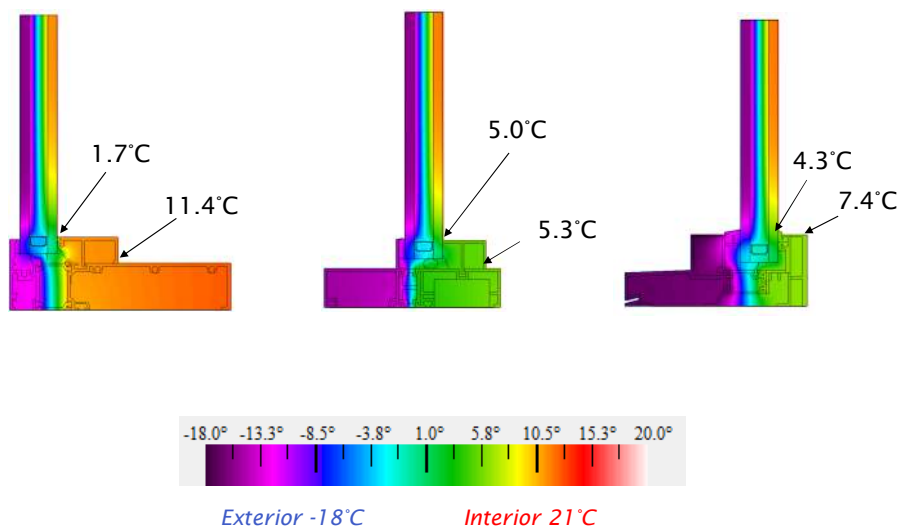
Window Frame Design & Condensation Risk

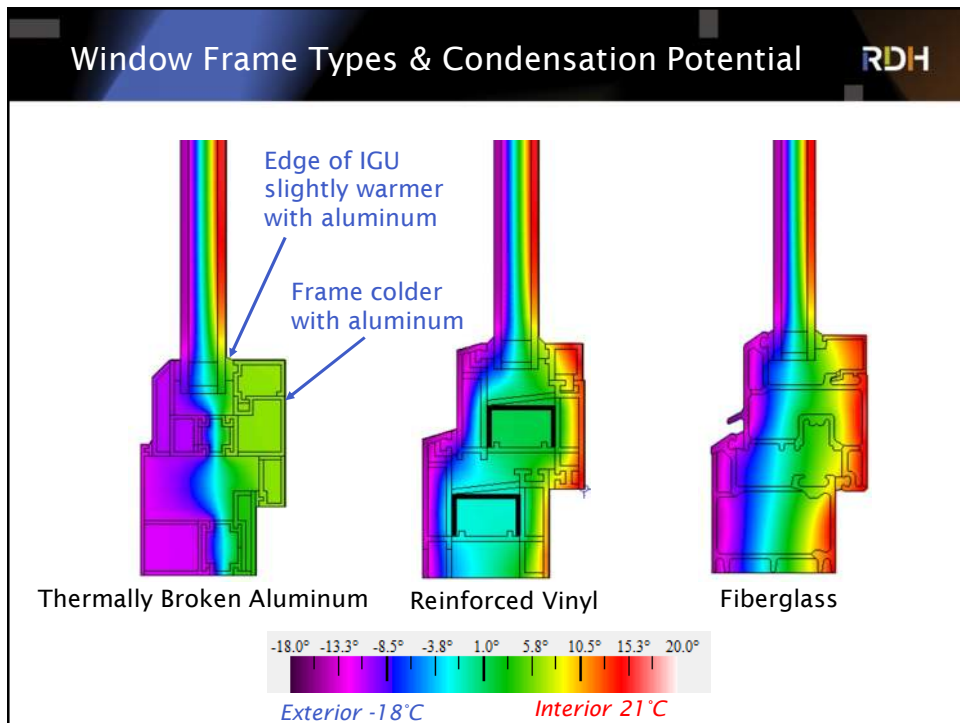
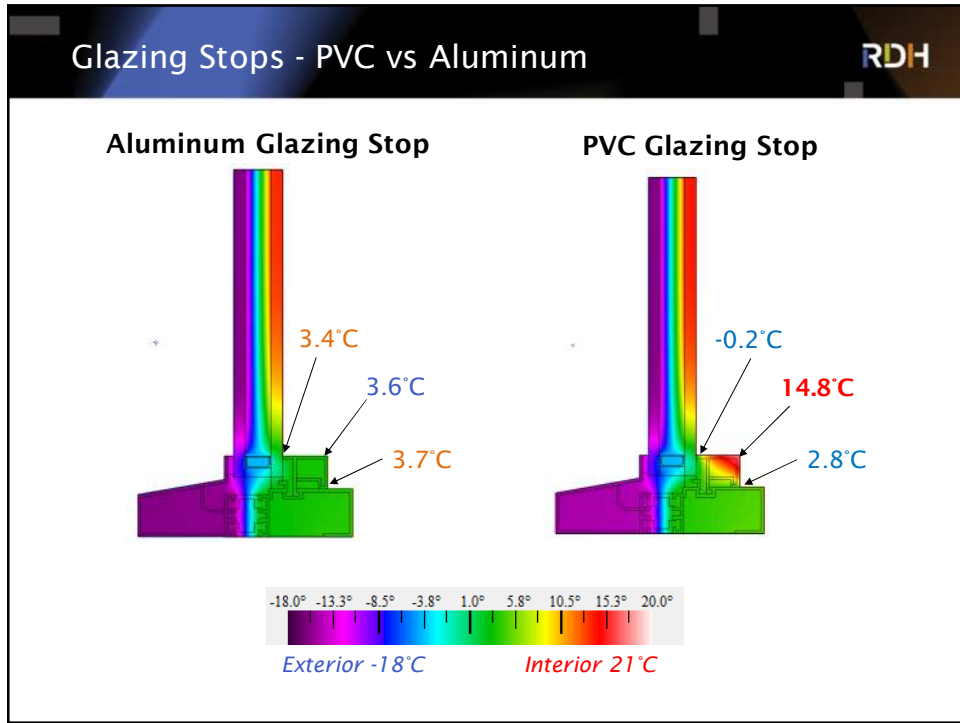
RDH

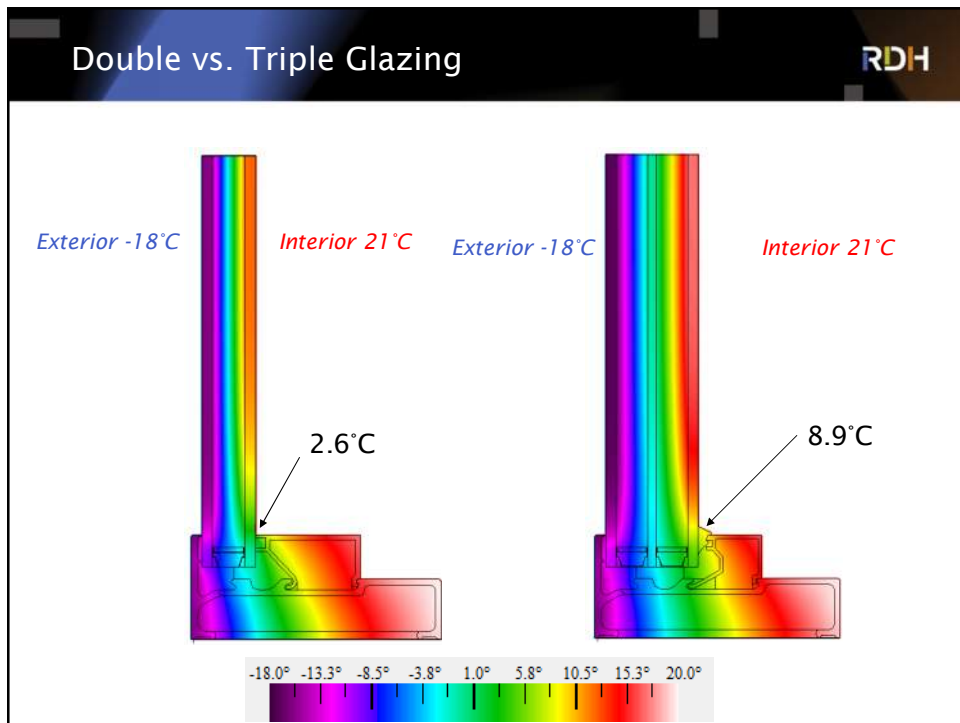
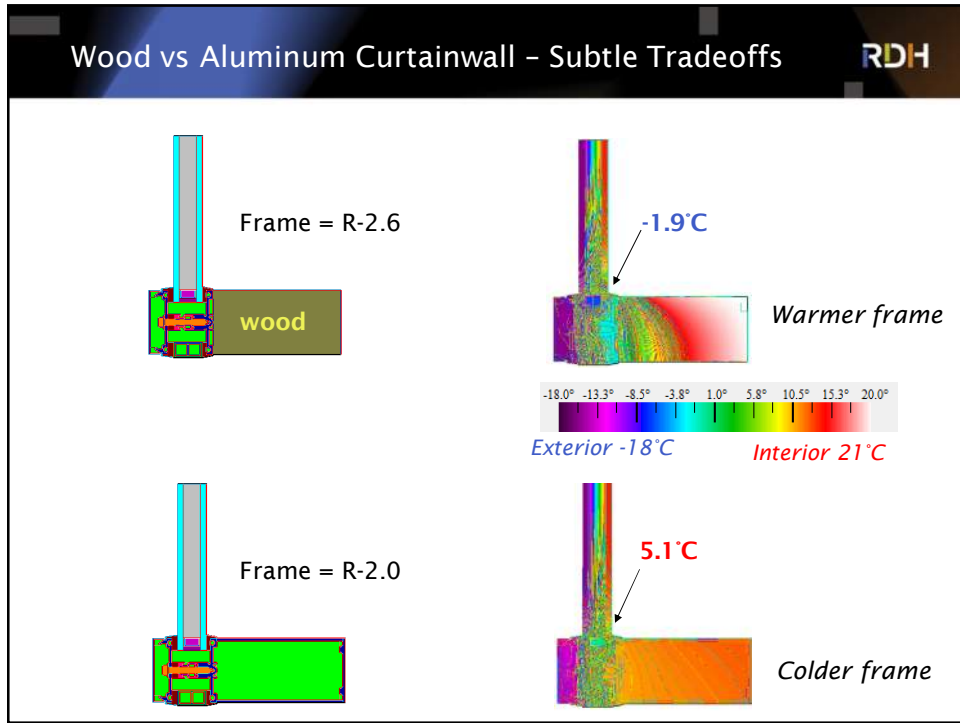
- Every window has a slightly different condensation potential & many factors involved
 - More conductive frame materials tend to be colder, but also bring heat from the frame to the edge glass
 - Massing of frame material inboard or outboard of thermal break or IGU matters
 - Operable units tend to perform worse than fixed units (frame profile & air leakage)
 - IGU spacer bars matter for edge of glass & frame temperatures
 - Glazing stop material also matters
 - Glazing matters - double vs triple glazing, low-e coating location, and interior surface low-e coatings
- Placement of window in rough opening can be as powerful of impact

Frame Profile/Massing & Condensation Potential

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Rating Condensation Resistance of Windows RDH

- Temperature Index (I-value) - CSA A440
 - Measured in Lab - coldest location
 - Is value that can also be checked in the field - preferred
- Condensation Resistance Factor (CRF) - AAMA
 - Measured in Lab - weighted cold location (relative metric)
- Condensation Resistance (CR) - NFRC
 - Simulated - weighted factor accounting for range of indoor RH levels (30,50,70%) and fixed outdoor conditions

- All factors are different and cannot be correlated
- In all cases a **higher number** means a **better product** with lower potential for condensation

Temperature Index (I-value) RDH

- Measure of a window's condensation resistance (higher better)
- **I-value** = $100 \times (T_F - T_O) / (T_I - T_O)$
 - T_F = Frame temperature (worst),
 - T_I and T_O = inside and outside temp.
- Can be used to help select windows based on exterior design conditions and interior RH expectations

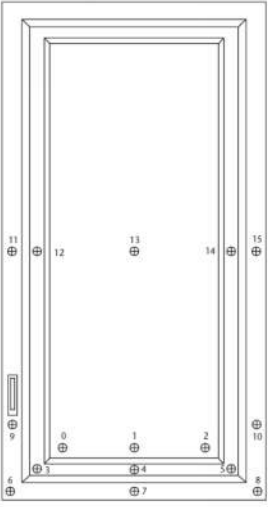
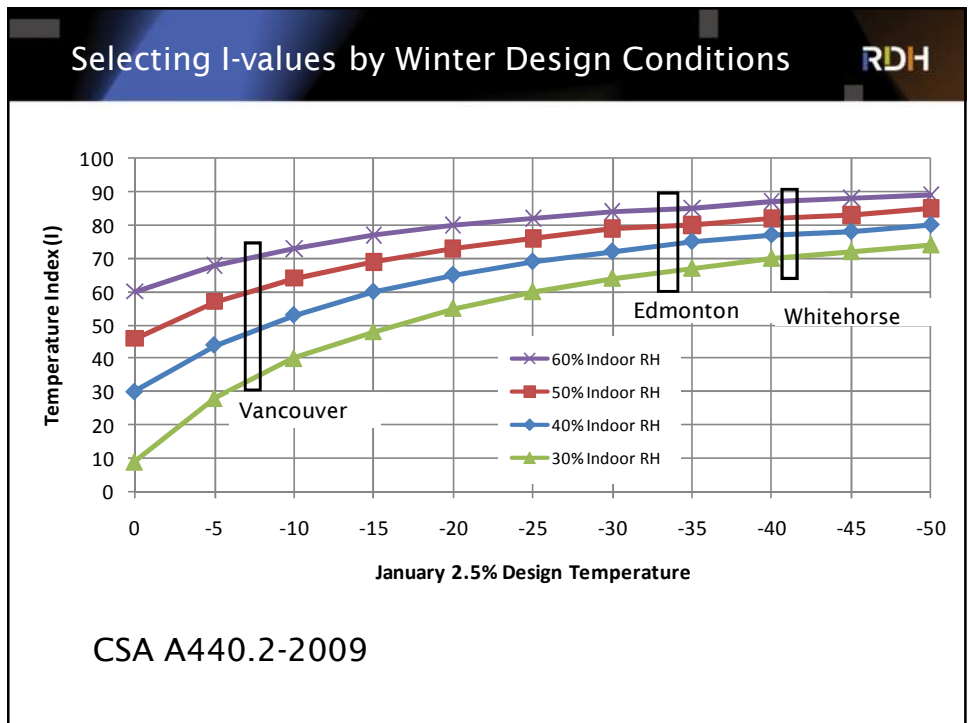


Figure A.1
Thermocouple locations for condensation resistance test for casement windows
(See Clause A.1.2.7.)



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Other Considerations - Window Air-Leakage Rates


- Leakage occurs at frame joints/glazing interfaces, gaskets & operable hardware
- Air leakage ratings in CSA A440-00 and NAFS-08

Window Rating	CSA A440-00		NAFS-08
	Max air leakage rate, m ³ /h/m	Max air leakage rate, converted to L/s/m ² (NFRC Standard Size Window)	Max air leakage rate for R Class, L/s/m ²
A1	2.79	1.86	n/a
A2	1.65	1.10	1.5
A3	0.55	0.37	0.5
Fixed	0.25	0.17	0.2

Window ER Study – Selecting Optimal Windows to Balance Energy Savings & Thermal Comfort

Window ER Study Research RDH

- Canada-wide study of the Energy Rating (ER) for windows
 - Single rating for a window based on U-value, solar heat gain coefficient, and air leakage
- Research study goals
 - Assess how well the ER rating as a single metric is at helping users pick the most energy efficient window for their home
 - Understand how comfort may be positively or negatively affected
 - Understand differences between Canadian & International standards



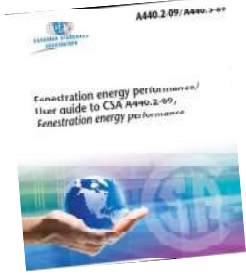
Download full report at www.rdh.com

What is the ER Calculation RDH

- Calculation given in CSA A440.2, for low-rise residential
- ER Equation:

$$ER = \frac{[SHGC_w \times F_{\theta} \times H_t \times R] - [(T_{bi} - T_{bo}) \times U_w] - [(T_{bi} - T_{bo}) \times (PF/20) \times L_{75} \times \rho C_p]}{DF} + SF$$

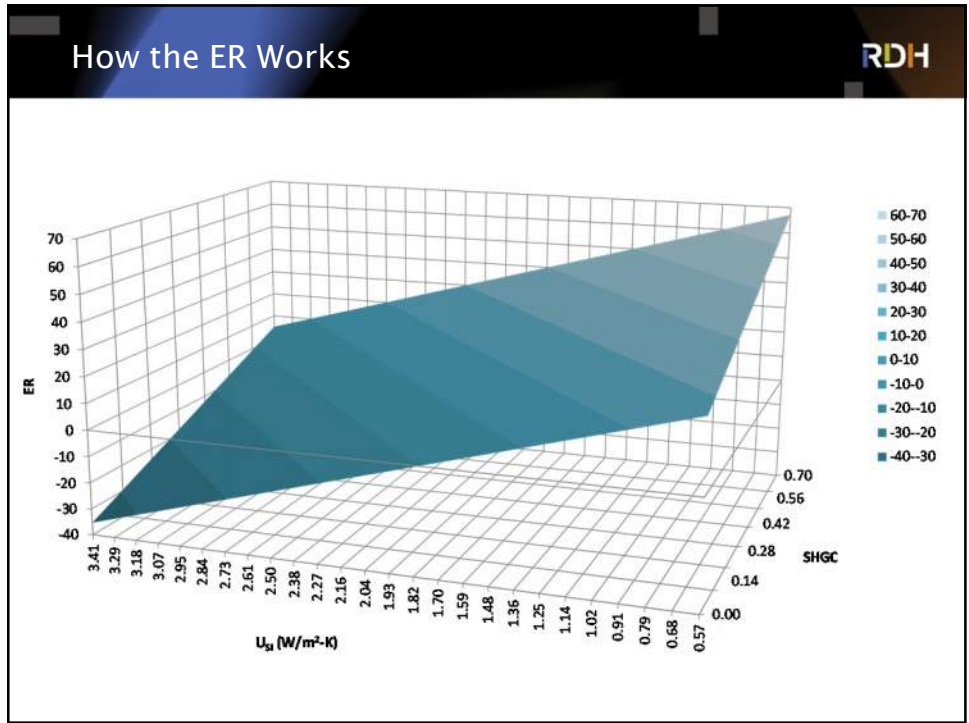
- Simplified Equation:



$$ER = (57.76 \times SHGC_w) - (21.90 \times U_w) - (1.97 \times L_{75}) + 40$$

Solar Heat Gain
Conduction
Air Leakage

$F_{\theta} \times H_t = 72.20 \text{ W/m}^2$
 $(T_{bi} - T_{bo}) = 21.90 \text{ K}$
 $PF = 1.5 \text{ m}^3/\text{s/m}^2$



The ER & Energy Star® Program

ENERGY STAR®

- ZONE 3
- ZONE 2
- ZONE 1

Windows and doors (effective February 1, 2015)				
Zone	Heating degree-day range	Minimum Energy Rating (unitless)	or	Maximum U-factor W/m ² ·K (Btu/h·sq. ft.·°F)
1	<3 500	25	or	1.60 (0.28)
2	3 500 to <6 000	29	or	1.40 (0.25)
3	≥6 000	34	or	1.20 (0.21)

The ER & The Building Code (Part 9.36) **RDH**

	Zone 4	Zone 5	Zone 6	Zone 7a	Zone 7b	Zone 8
HDD	<3000	3000 to 3999	4000 to 4999	5000 to 5999	6000 to 6999	≥7000
Max U-Value, Btu/h-ft²-F (W/m²-K)	0.32 (1.8)	0.32 (1.8)	0.28 (1.6)	0.28 (1.6)	0.25 (1.4)	0.25 (1.4)
Minimum ER	21	21	25	25	29	29

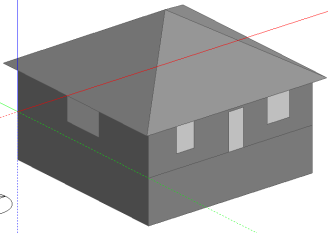
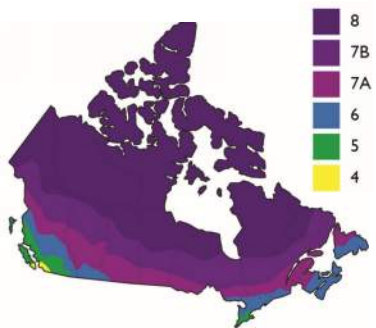
Window Selection for Energy & Thermal Comfort **RDH**

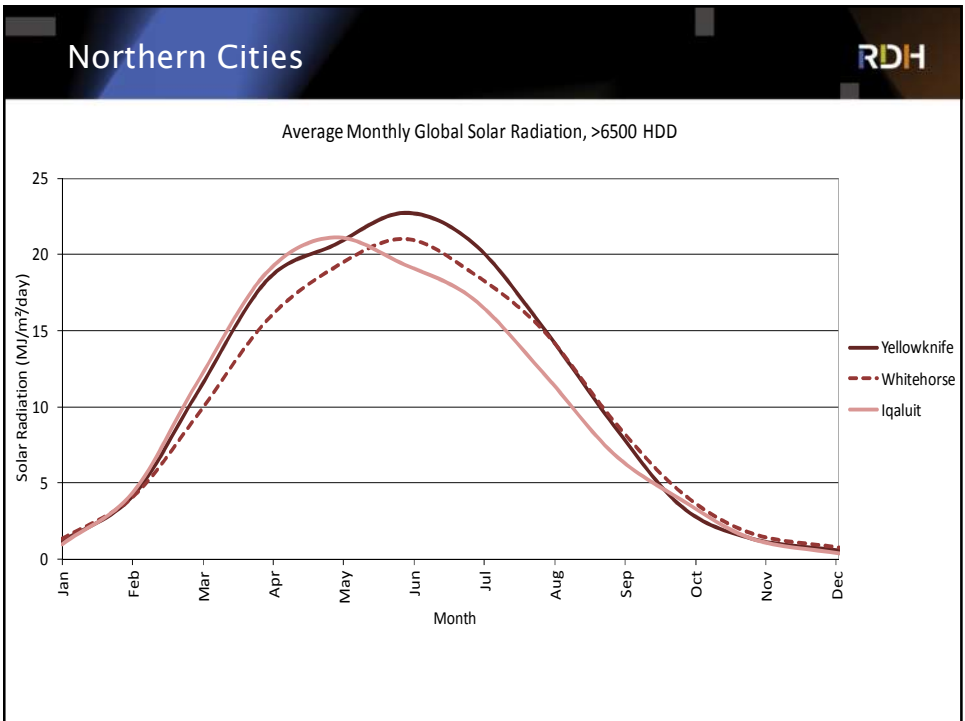
- Winter Goals
 - Minimize heating energy
 - Improve thermal comfort by reducing cold surfaces
 - Low U-values, High SHGC
- Summer & Swing Season Goals
 - Minimize overheating to prevent or reduce cooling needs
 - Improve thermal comfort by reducing surface temperatures and indoor gains
 - U-values not as important, Lower SHGC

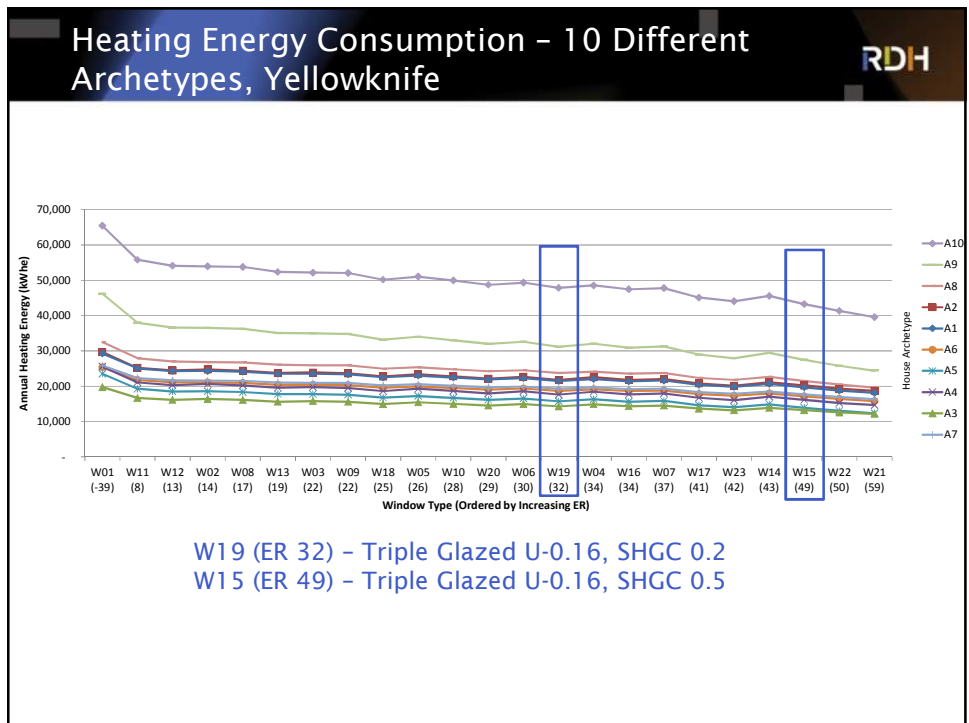
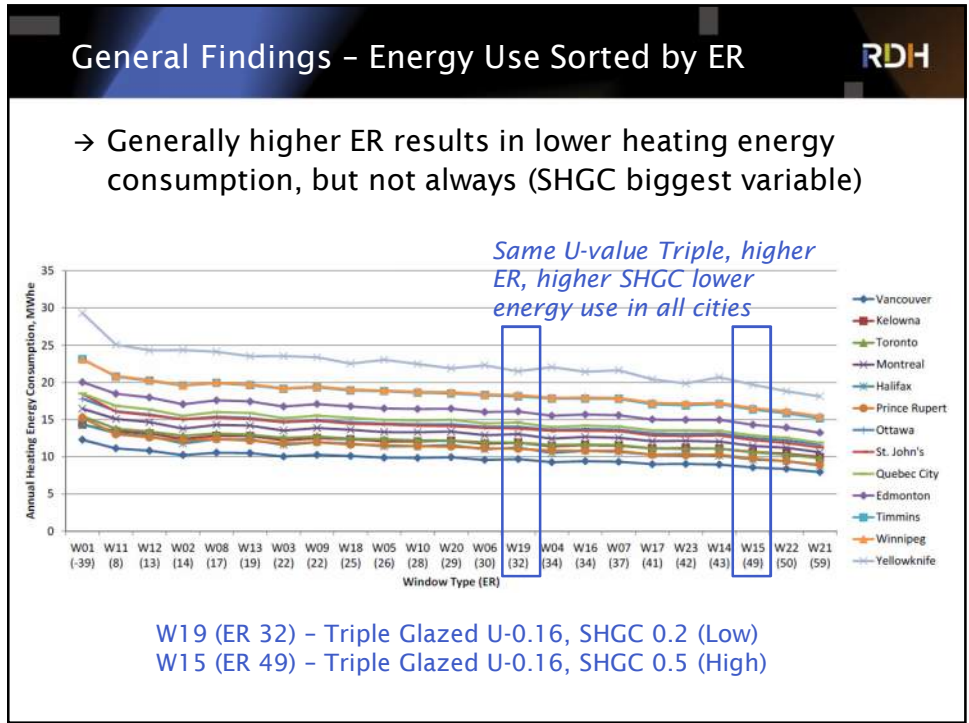


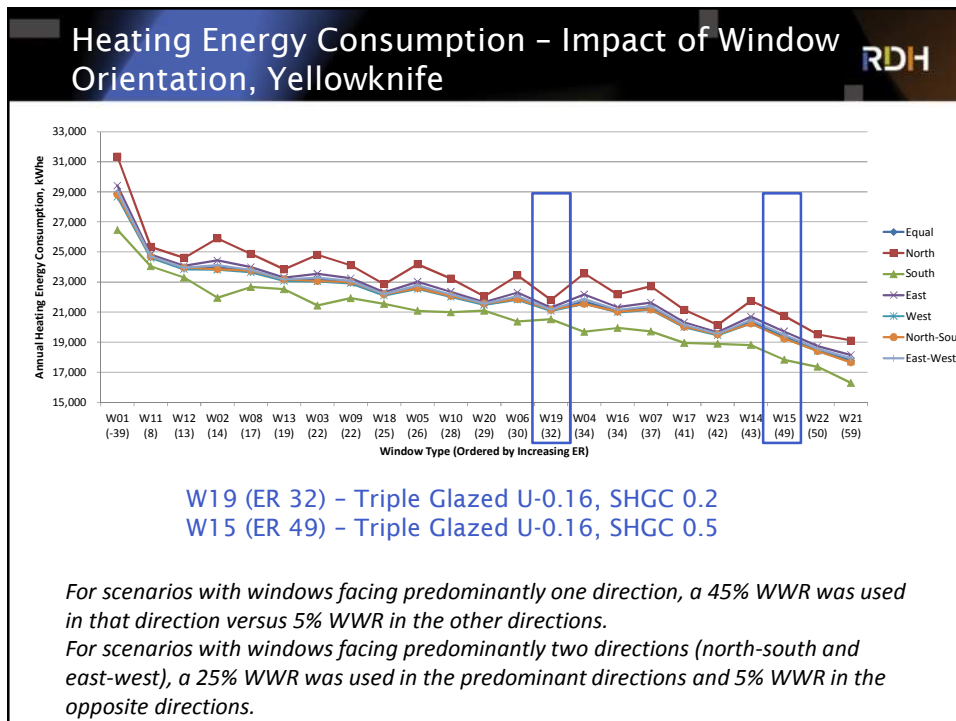
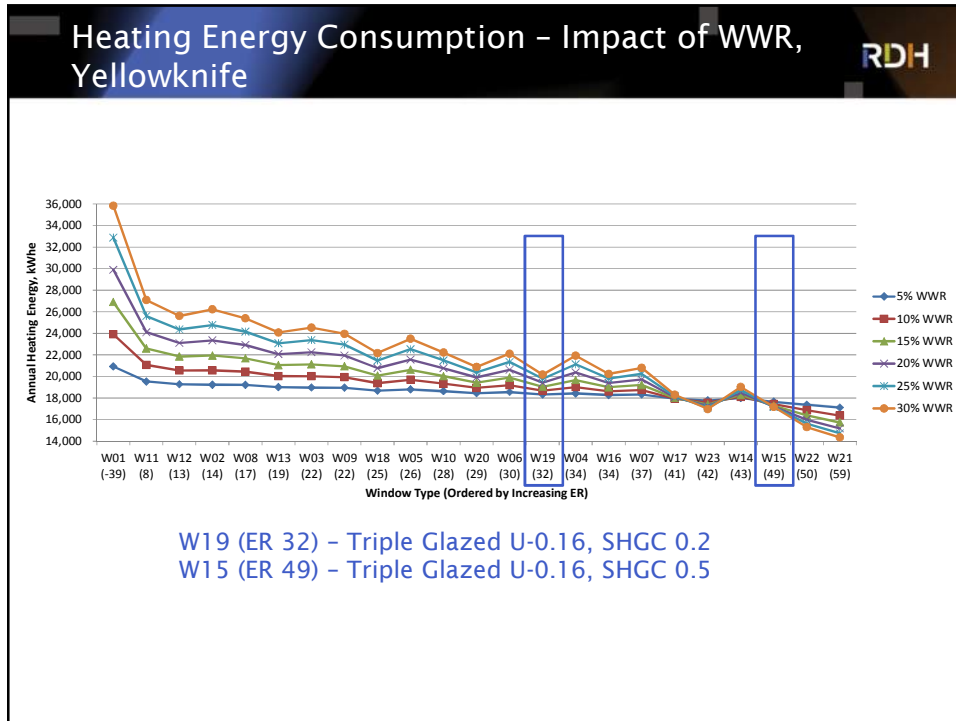

How to Optimize Window Selection – Modeling Tools RDH

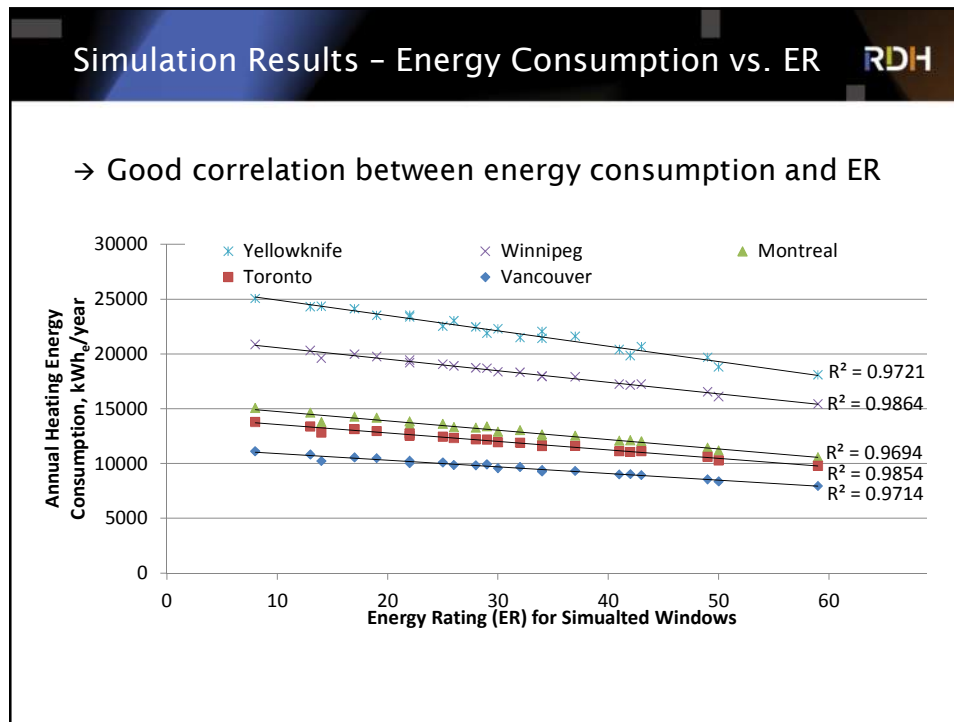
- Hourly energy simulations performed using the program DesignBuilder (EnergyPlus engine)
- 10 different archetype houses – sizes, enclosures, etc.
- Representative cities & climate zones across Canada
- 23 different window types selected - investigate wide range of different combinations of U-values and SHGCs (ER value)
- Orientation, WWR, Shades etc. all evaluated









Window Selection for Energy Efficiency RDH

- In a typical house, low U-value & high SHGC result in lowest heating and total energy consumption in houses
 - Cooling even if provided is low relative to heating and total energy
- ER is generally good indication of lower heating and total energy consumption – helps with understanding optimal selection
 - When comparing two similar windows with similar U-values and different SHGCs, it will help pick the better one.

Window Selection for Thermal Comfort RDH

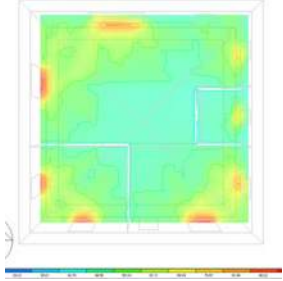
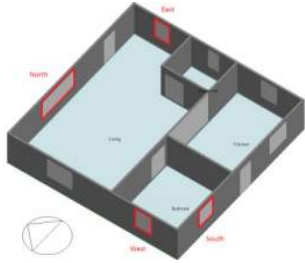
- How to “measure” thermal comfort?
- *ASHRAE Standard 55: Thermal Comfort Conditions for Human Occupancy*
- 6 Primary factors that affect thermal comfort:
 - Air temperature
 - Radiant Surface Temperature
 - Humidity
 - Air Speed
 - Metabolic Rate
 - Clothing Insulation

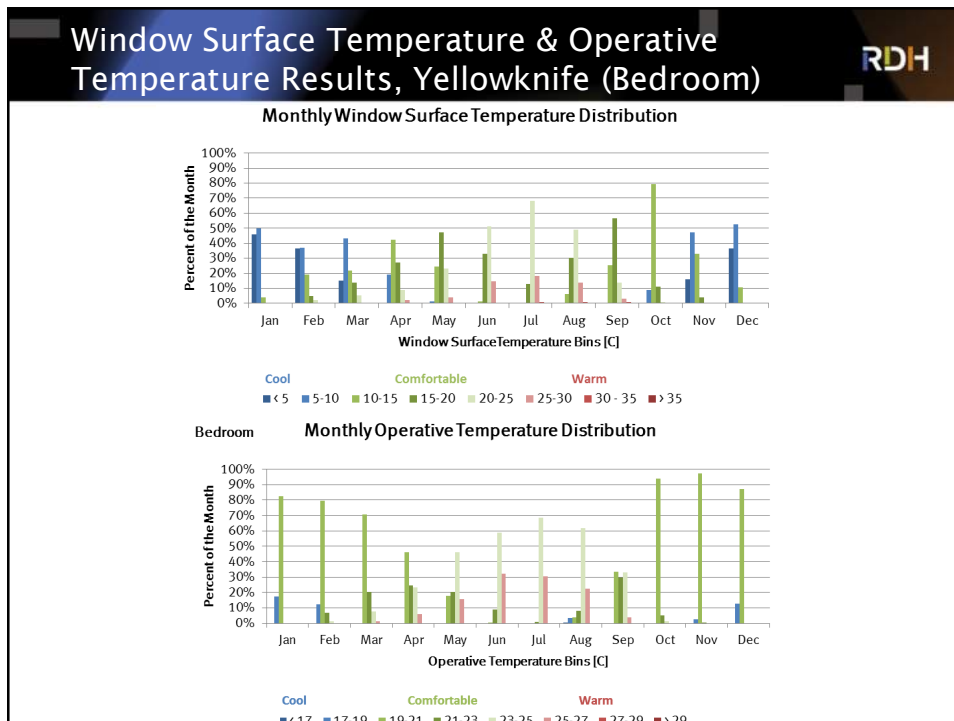
Window Selection for Thermal Comfort RDH

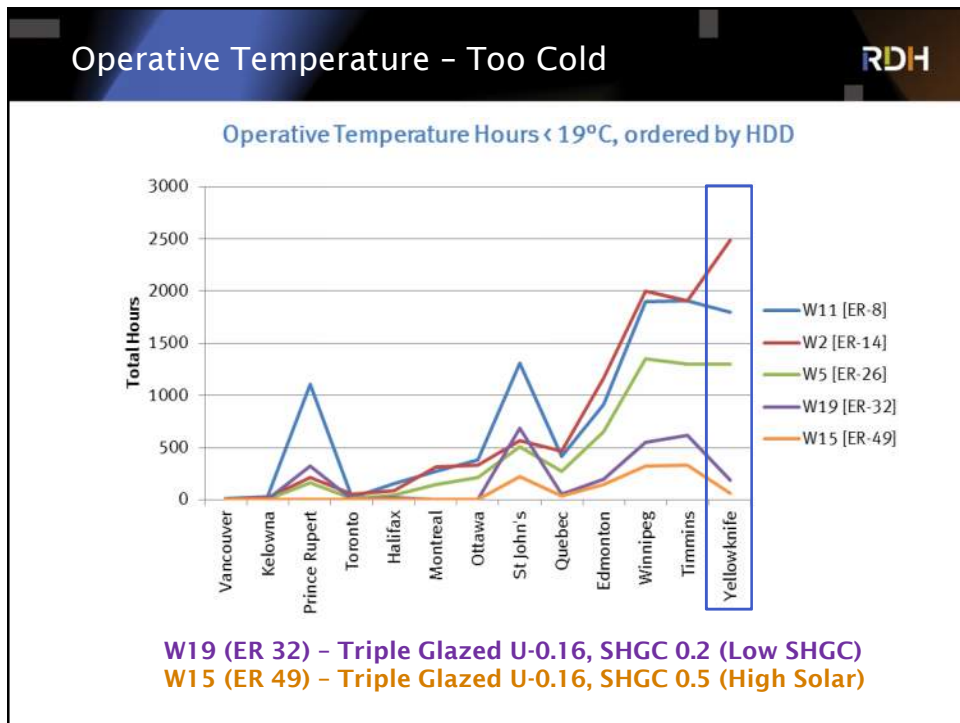
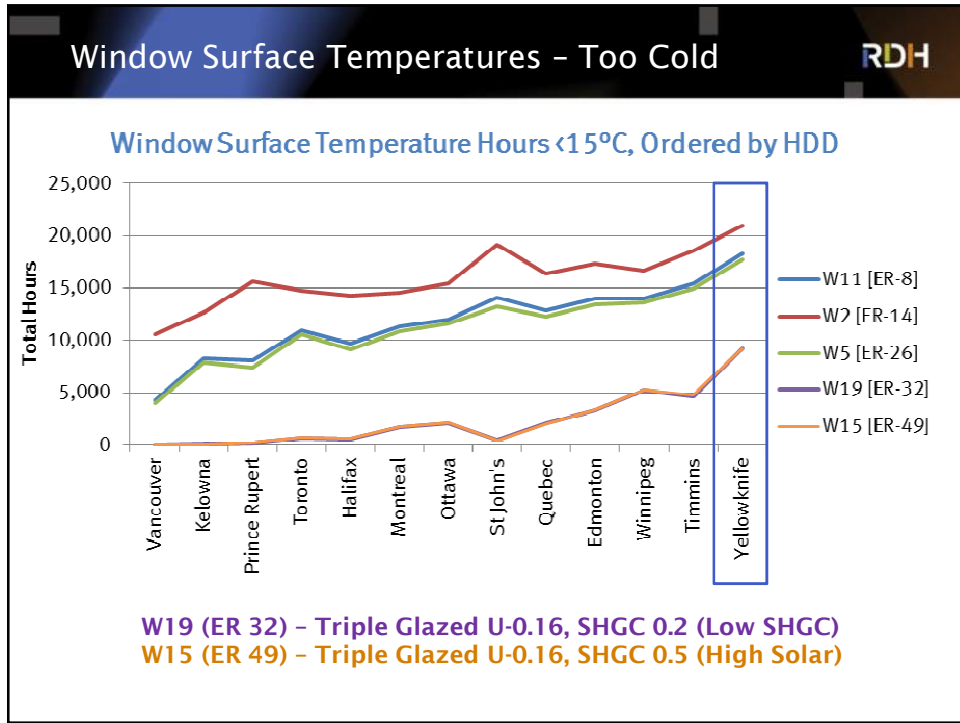
- **Operative Temperature: Balance of window surface temperature and air temperature**
- ASHRAE acceptable range of operative temperature based on research studies

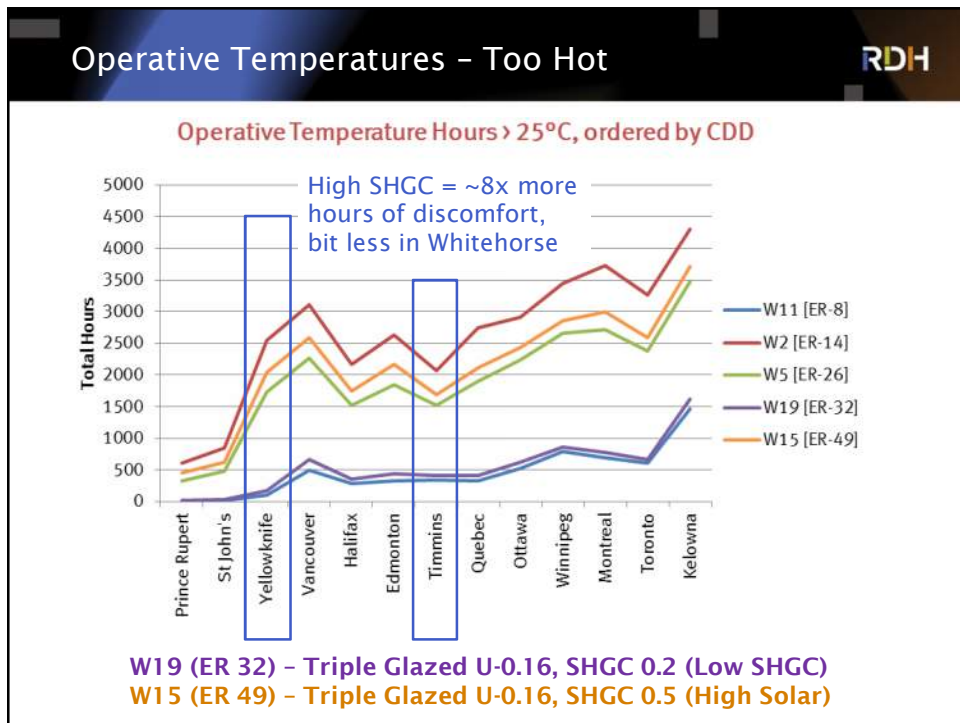
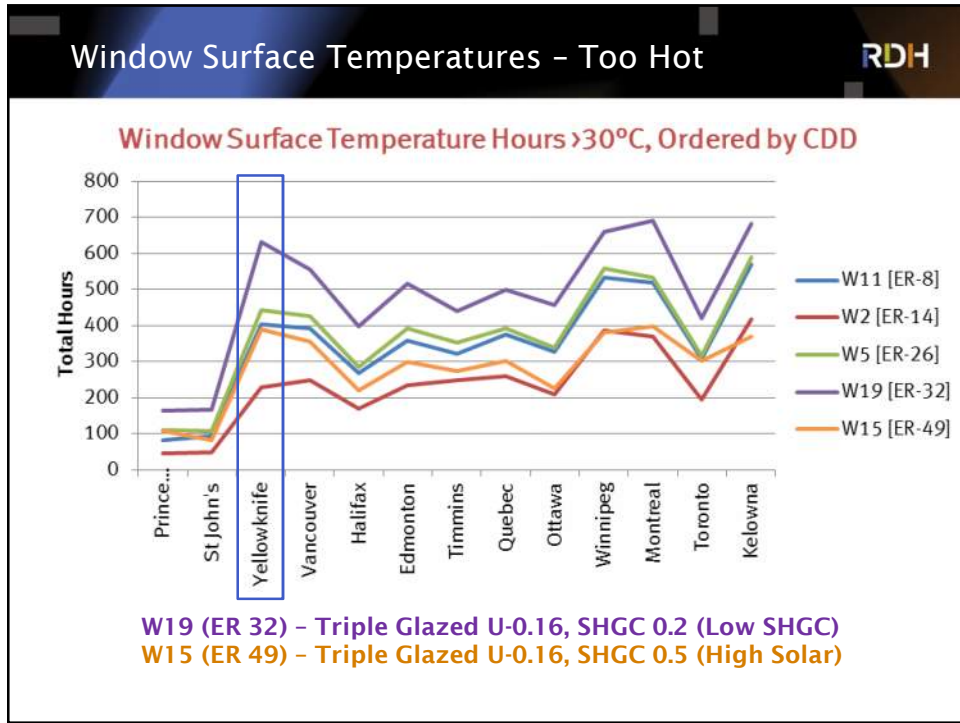
Window Selection for Thermal Comfort RDH

- Hourly Energy Simulations – extract window surface temperature, air temperature, operative temperatures
- Defined comfort parameters:
 - Operative temperature 19°C to 25°C
 - Surface temperature 15°C to 30°C
- Count number of hours outside this range (*4 orientations so maximum hours per year = 4*8760 = 35040*)







Choosing Windows for Thermal Comfort



- Low U-value improves surface temperatures, particularly in the winter
- Low SHGC reduces overheating
 - Consider whether overheating is a concern
- ER may or may not result in more overheating, better to review SHGC than rely on ER alone
- Also consider project-specific conditions
 - Exterior shading (trees, shades etc)
 - Orientation
 - Window to Wall Ratio


Overall Window Selection for Houses



- Always look for the lowest possible U-value
- Wide range of glazing available means large selection of low/high SHGC products with good U-values
- Evaluate an appropriate SHGC based on project specific conditions
 - If overheating is not a concern, use a high SHGC window (e.g. if there is good exterior shading)
 - If overheating may be a concern, consider a low SHGC window
- When in doubt – modeling is a very useful tool for window optimization – every project is unique

Upcoming Work RDH


- ER Study identified some issues with reliance on ER for selection of windows in the Far North – unique solar conditions
- Research underway to optimize window selection for more northern housing archetypes & and at higher latitudes
- Dial into optimal glazing packages balancing cost, energy savings and thermal comfort implications
- Research will be complete this summer



Understanding Energy Use in MURBs & Opportunities for Deep Retrofits

MAY 7, 2015 – WHITEHORSE, YUKON

GRAHAM FINCH, MASC, PENG – PRINCIPAL, BUILDING SCIENCE RESEARCH SPECIALIST
RDH BUILDING ENGINEERING LTD. VANCOUVER, BC - GFINCH@RDH.COM



Presentation Outline

- Energy use on Multi-Unit Residential Buildings
- Case Study:
 - Deep Energy Retrofit of a High-Rise MURB
 - Monitoring of Energy Savings
 - Monitoring of Indoor Environmental Conditions & understanding Airflow and Ventilation Problems within MURBs


Understanding Energy use in Multi-Unit Residential Buildings

Multi-Storey Multi-Unit Residential Buildings in Whitehorse




Maximum
20m, city
bylaw

Building Energy Use & GHGs



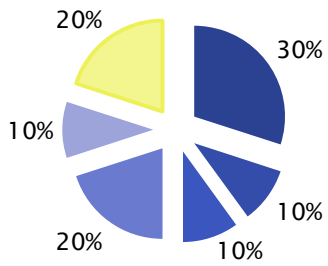
- **Buildings are substantial energy consumers**
 - Buildings use >30% of all energy in Canada, 40% in US
- **Buildings are large emitters of GHGs**
 - 25% of GHGs in Canada are from buildings
 - 55% of GHGs in Large Cities like Vancouver are from buildings
- **Energy retrofits of existing buildings are important**
 - 70 to 80% of buildings in 2030 already exist today



Why Multi-Unit Residential Buildings? RDH

→ Significant and Growing Proportion of the Housing Stock

- Many Important Challenges & Features
 - › Split Incentives (only 1/3 of energy bills paid directly by owners), mix of gas/electricity suites/common areas which no-one is looking at together
 - › Complicated Building Forms & poor thermal performance (Windows, balconies, height, etc)
 - › Utilities are Significant Portion of Operating Costs



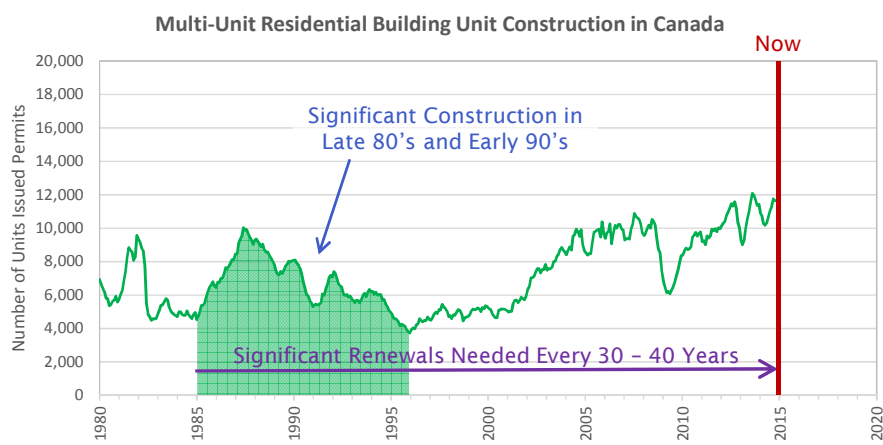
- Maintenance
- Repairs
- Capital Reserve
- Insurance & Admin
- Staffing & Misc
- Utilities

Why Now? RDH

→ Large opportunity to impact building stock is coming up


- Buildings from late 80's and early 90's will need renewals work

Multi-Unit Residential Building Unit Construction in Canada




Multi-Unit Residential Building Energy Study RDH


- Study looked at energy consumption of over 60 MURBs in BC
 - Constructed from 1974 -2002
 - 5 to 35 storeys in height
- Half of study buildings underwent a full building enclosure rehabilitation
- Assessed actual performance characteristics in each building
 - Decade of energy consumption
 - Effective R-values (design vs in-situ)
 - Airtightness of enclosure & interiors
 - Impact of building enclosure repairs and upgrades

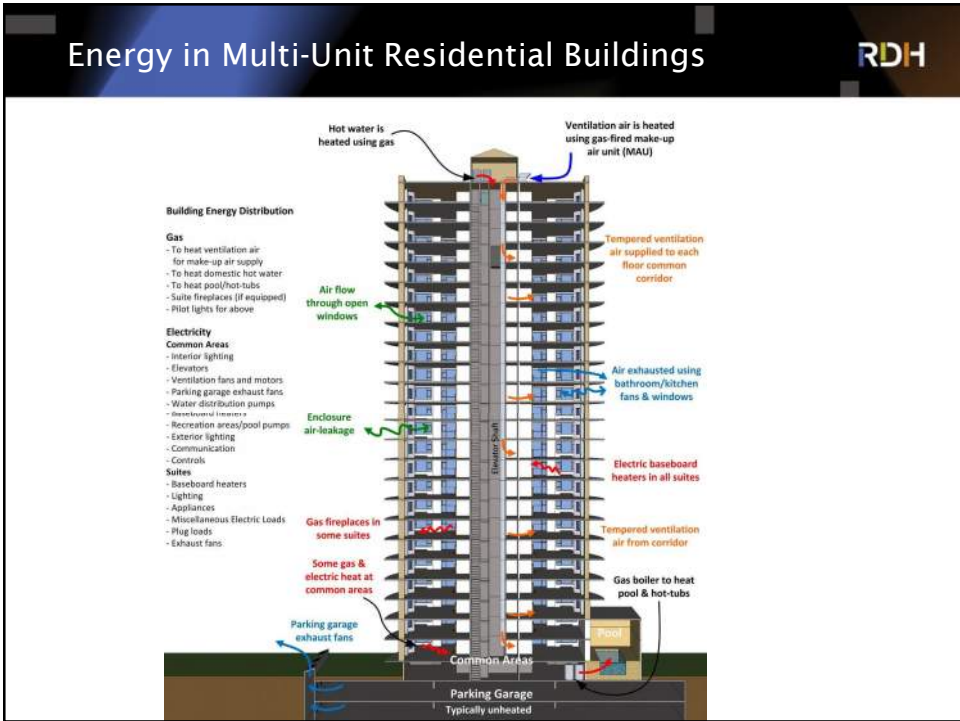


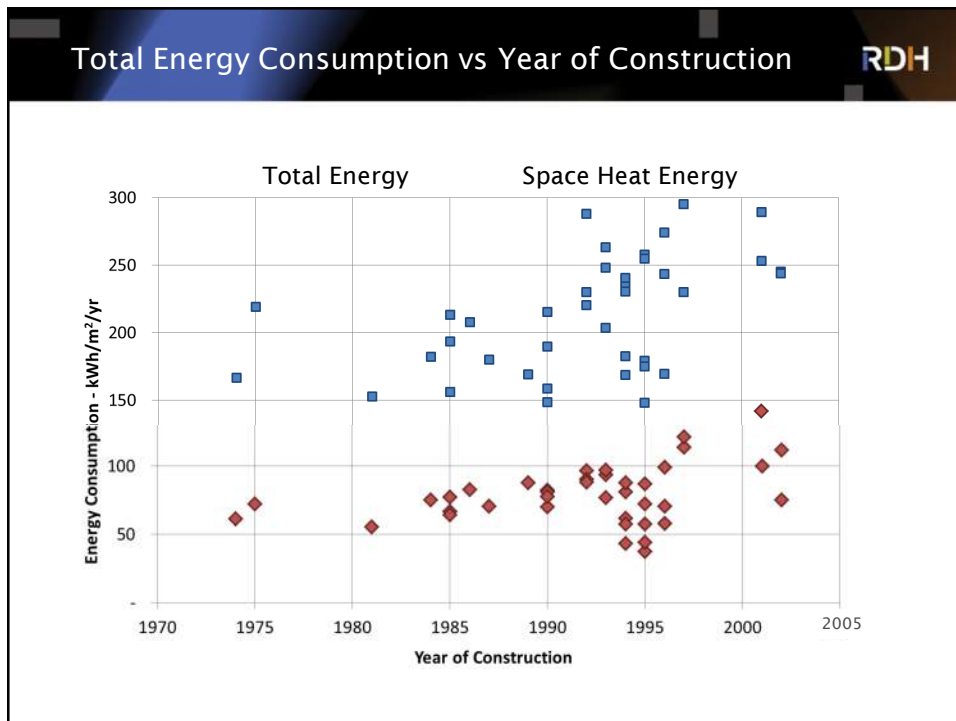
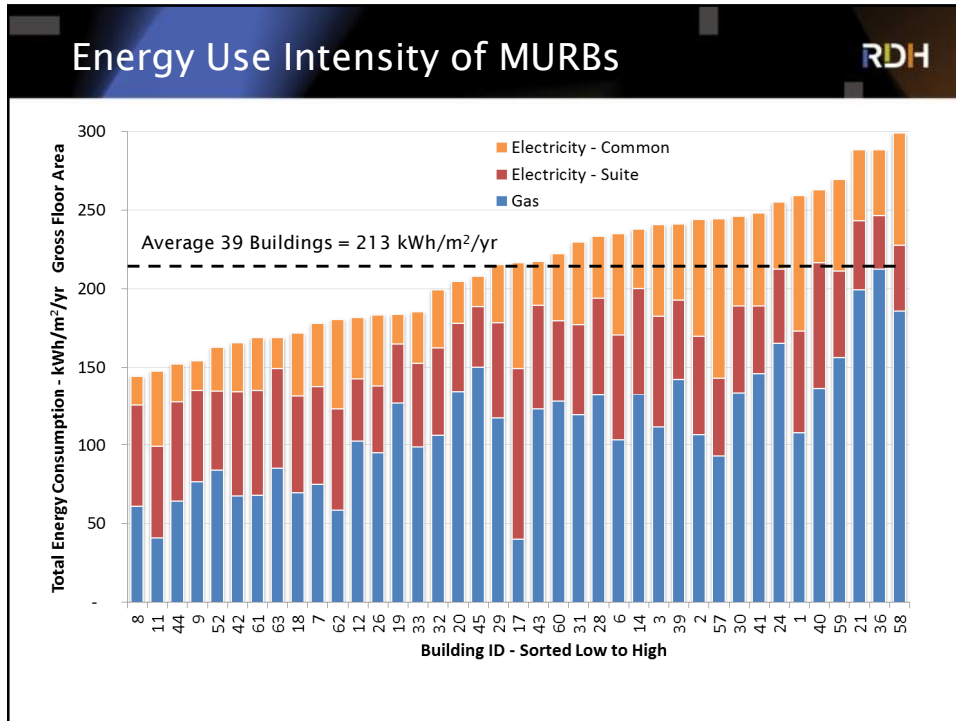
Energy Consumption and Conservation
in Mid- and High-Rise Residential Buildings
in British Columbia

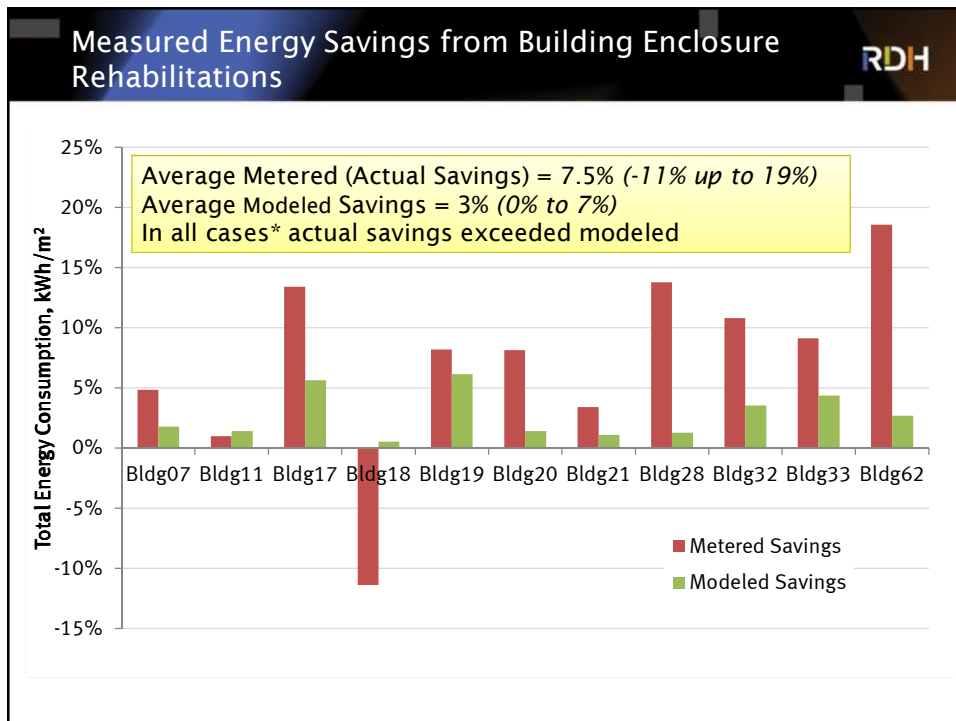
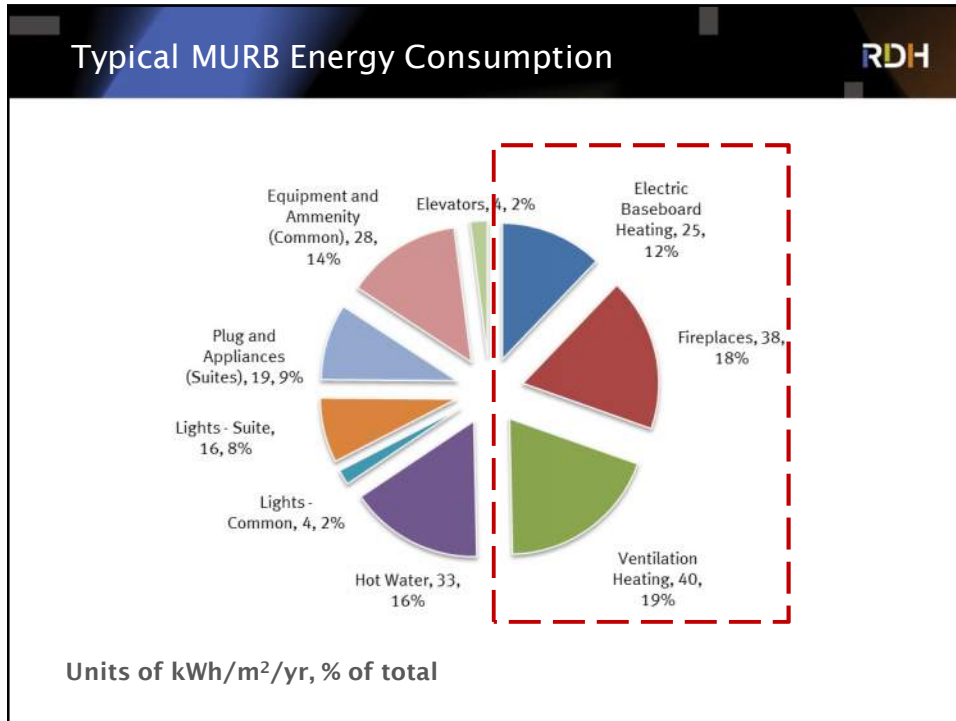


FINAL REPORT
ENERGY USE








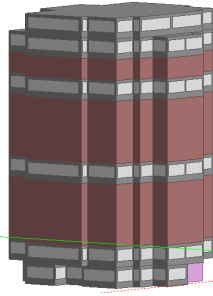


Calibration of Whole Building Energy Models RDH

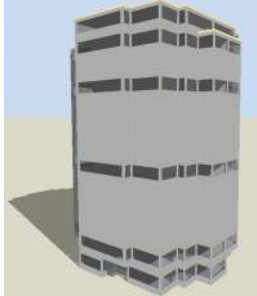
- Step 1: Gathering input data
- Step 2: Building the model
- Step 3: Checking the results
- Step 4: Assess potential Energy Efficiency Measures



SketchUp



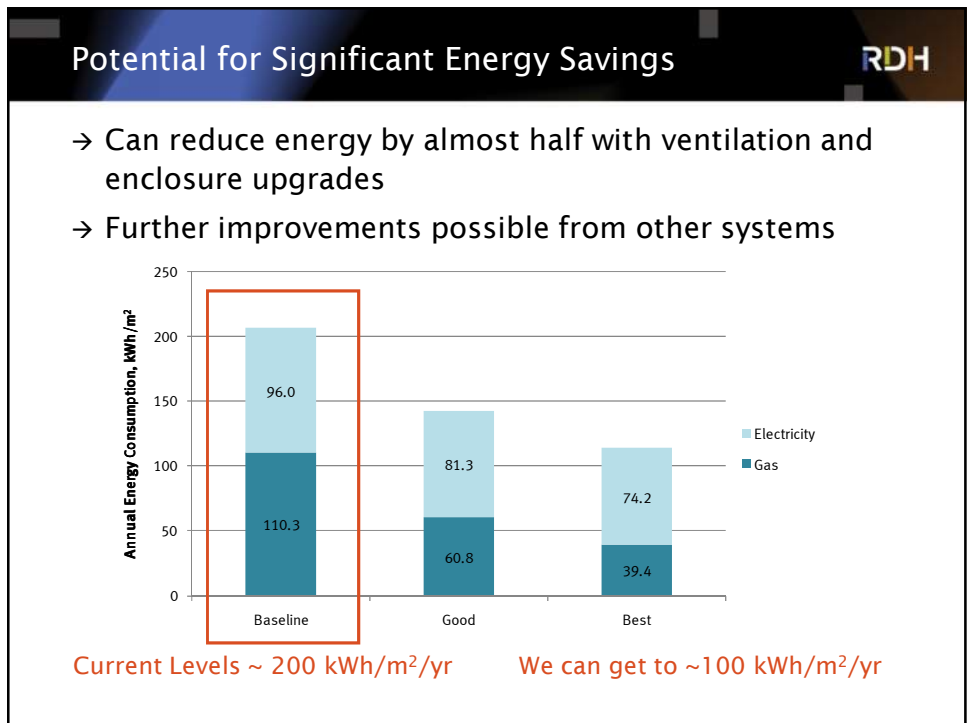
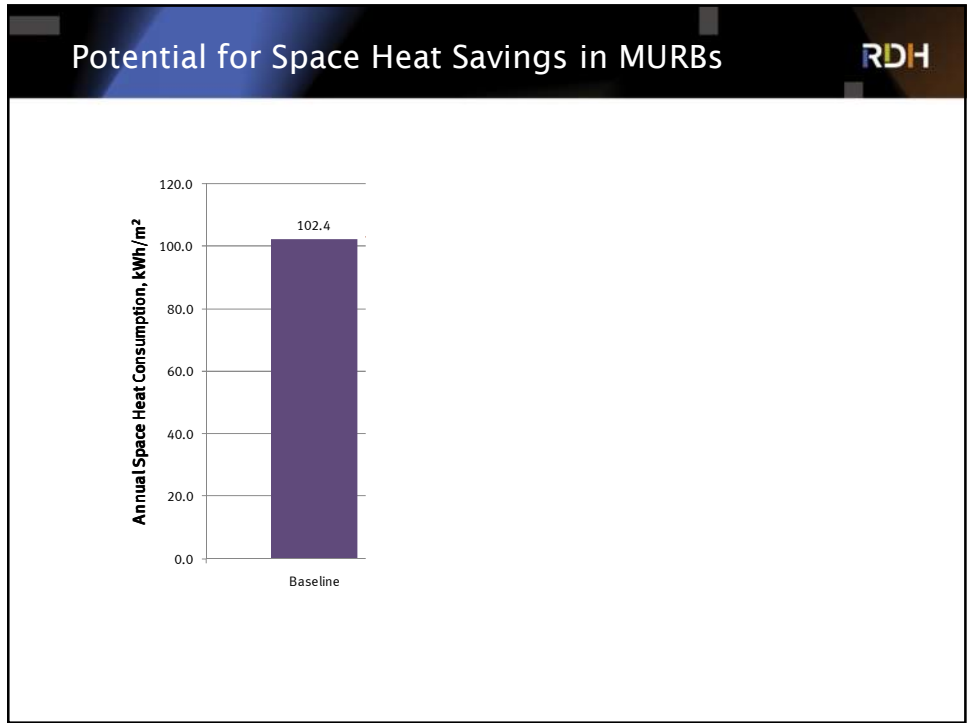
Energy Model
Geometry



Energy Model
Rendering

MURB Energy Simulations: The Potential RDH


Scenario	Simulation Inputs
Baseline:	<ul style="list-style-type: none"> • Walls effective R-3.6
Pre-Rehab	<ul style="list-style-type: none"> • Windows single glazed U = 0.7, SC = 0.67 • Air tightness "Tight – High Average", 0.15 cfm/ft² • Make-up air temperature set-point 68° F • No heat recovery
Good:	<ul style="list-style-type: none"> • Walls effective R-10
Target Performance	<ul style="list-style-type: none"> • Windows double glazed, argon fill, low-e, low conductive frame; U = 0.27, SC = 0.35 • Air tightness "Tight – Low Average", 0.05 cfm/ft² • Make-up air temperature set-point 64° F • No heat recovery • No Fireplaces
Best:	<ul style="list-style-type: none"> • Walls effective R-18.2
Green Design Performance	<ul style="list-style-type: none"> • Windows triple glazed, argon fill, low-e, low conductive frame; U = 0.17, SC = 0.23 • Air tightness "Very Tight", 0.02 cfm/ft² • Make-up air temperature set-point 60° F • 80% Heat Recovery • No Fireplaces



Deep Building Enclosure Retrofit - Applying the MURB Study Findings

Case Study: Deep Energy Retrofit RDH

- Started with a condition assessment
- Then, whole building energy modeling to assess options for renewals project






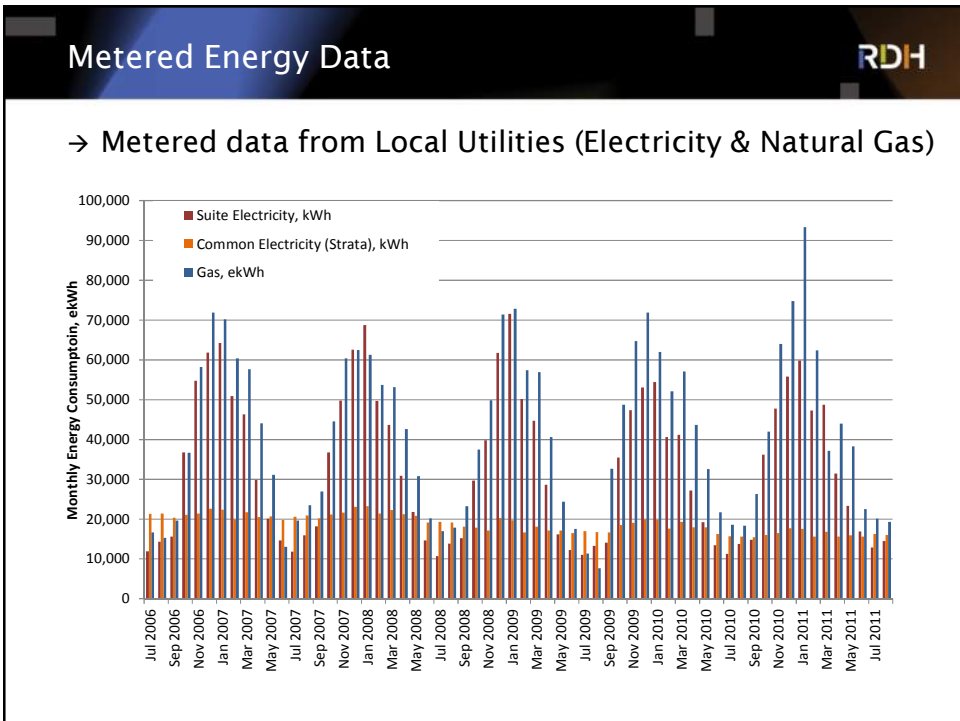
Pilot Timeline

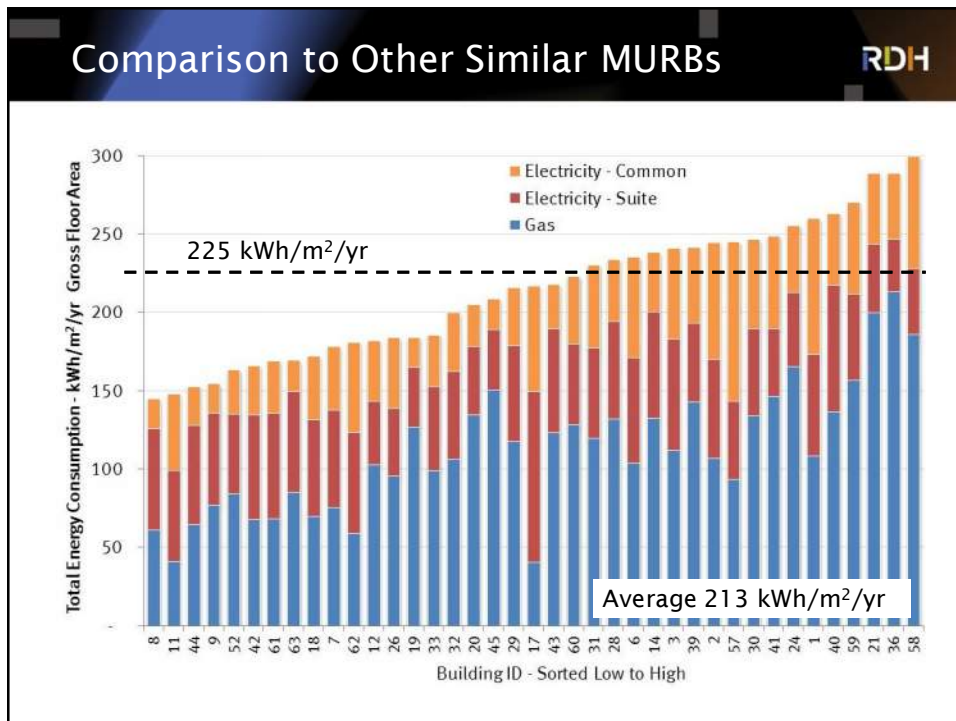
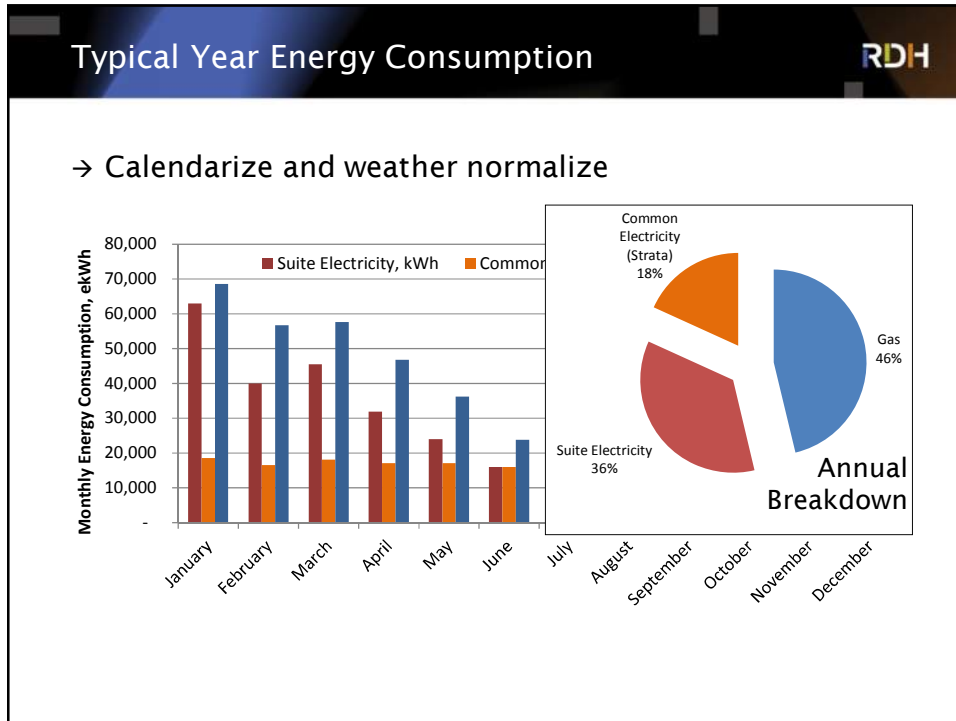
	Monitoring & Testing	BE Upgrades	1 year M&V	Mechanical upgrades	1 year M&V
Year	2011	2012	2013	2015	future

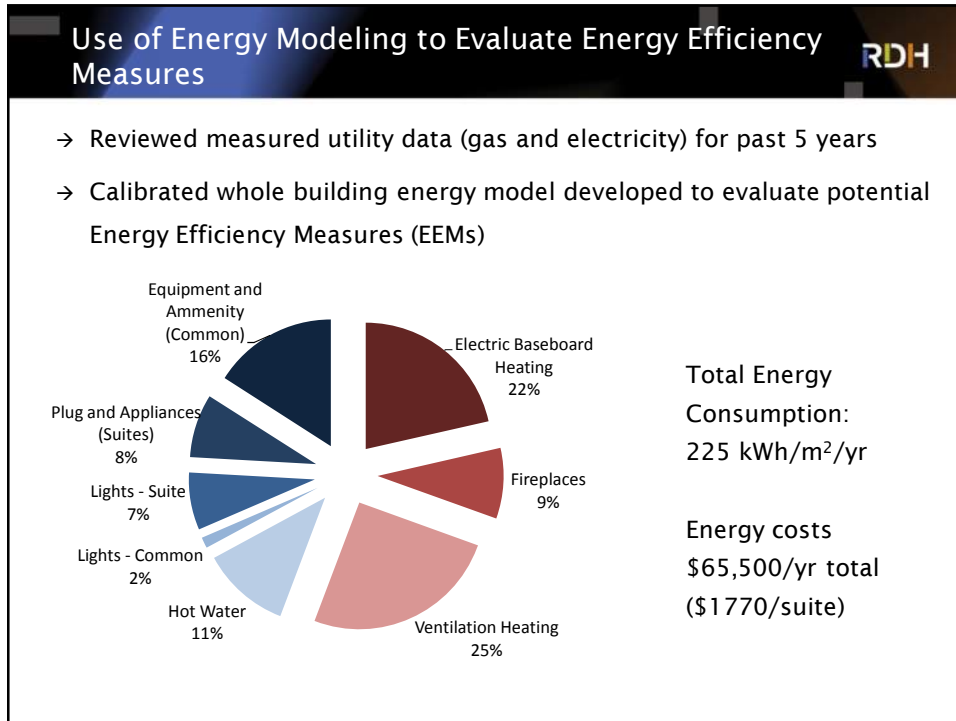
Existing Mechanical System Assessment RDH

- Original mechanical systems largely in place
- Electric baseboard heating
- Gas-heated make-up air for ventilation (to corridors)
- 14 decorative gas fireplaces at upper floor suites - some replaced by owners
- Hot-water boiler & tanks replaced few times before








Building Enclosure Renewal Design RDH

- Plan to renew building aesthetic to more modern appearance
 - Metal panels with color features
 - Stucco features
 - New windows
 - New skylights at penthouse
 - New entrance door
 - Enclosed balconies
 - New roof and decks
- Adds value

East Elevation - Colour Scheme 1

Potential Energy Efficiency Measures RDH


- Wall insulation with low conductivity cladding attachment
 - Reduced thermal bridging
- Windows
 - Double & triple glazed low-conductivity frames
- Airtightness improvement
- Roof insulation
- Heat recovery ventilation
- Fireplace upgrade
- Make-up air unit (ventilation)



Window Replacement Evaluation RDH

→ Alternatives:

- Double glazed, metal frame windows (minimum code requirement)
- Double glazed, fibreglass frame
- Triple glazed, fibreglass frame

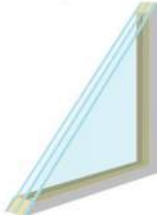


Window	Estimated Annual Energy Savings	Estimated % Savings
Double Glazed, Aluminum Frames	\$1,900	3%
Double Glazed, Fibreglass Frames	\$7,600	7%
Triple Glazed, Fibreglass Frames	\$11,000	10%

Window Replacement Payback Assessment RDH

→ Incremental Payback

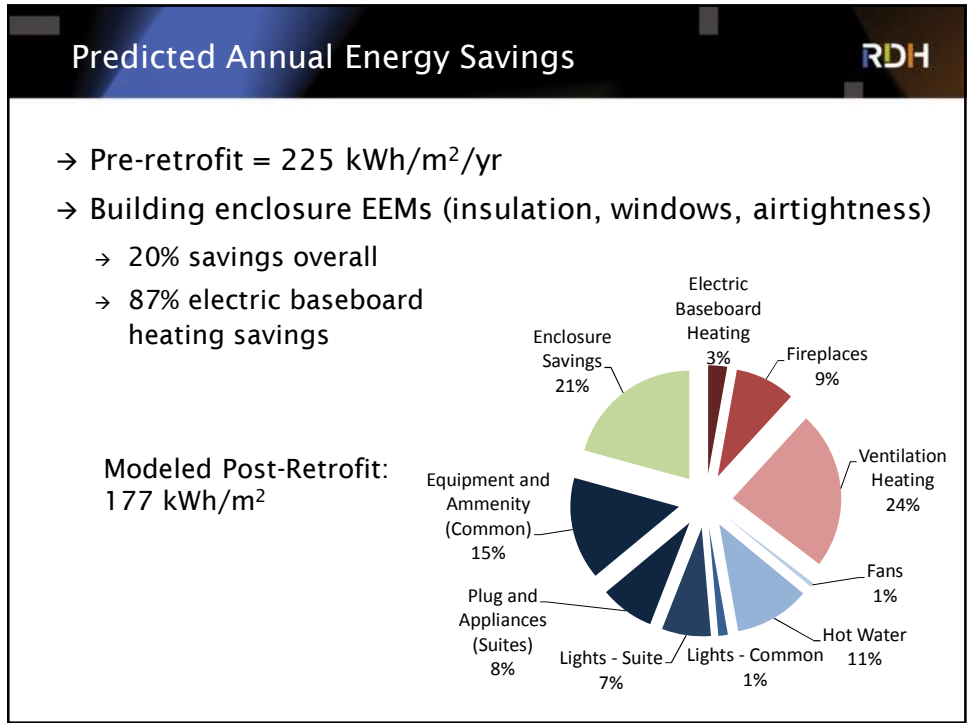
- Choosing a more energy efficient window will pay back in energy savings
- Double or triple glazed windows with fibreglass frames compared to code minimum
- Incentive programs help offset cost, improve payback



	Simple Payback	Simple Payback Including Incentives
Double Glazed, Fibreglass Frames	5 years	<1 year
Triple Glazed, Fibreglass Frames	14 years	6 years

Cost Payback Analysis of EEMs RDH

Energy Efficiency Measure / Incremental Upgrade	% Total Energy Savings (% Electrical Heat Savings)	\$ Savings per year	Incremental Cost with Utility Incentives	Simple Payback
Low Conductivity Cladding Attachment	4% (19%)	\$4,800	\$0	Immediate
Double Glazed Fibreglass Windows	7% (30%)	\$7,600	\$2,700	0.4 years
Triple Glazed Fibreglass Windows	10% (44%)	\$11,000	\$60,000	6 years
Airtightness	2% (7%)	\$1,800	\$0	Immediate
Fireplace Replacement	2% (8%)	\$2,100	\$14,000	7 years
In-Suite HRV Installation	6% (-32%)	-\$4,400	\$74,000	n/a
Make-up Air Unit Replacement	5% (0%)	\$1,600	\$23,500	15 years




Building Enclosure Renewals RDH

- \$3.6M renewals project, 7 month construction period
- Work primarily from exterior with access to suites for window installations

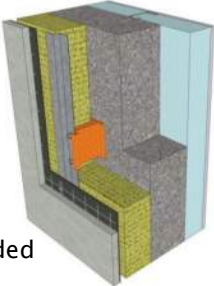


Building Enclosure Renewals Performed RDH

- Over clad and exterior insulate walls (R-16 effective walls)
- New R-6 tripled glazed fiberglass windows
- New roof and decks
- Improve air-tightness
- Overall new enclosure R-value **R-9.1 vs R-2.8 original**

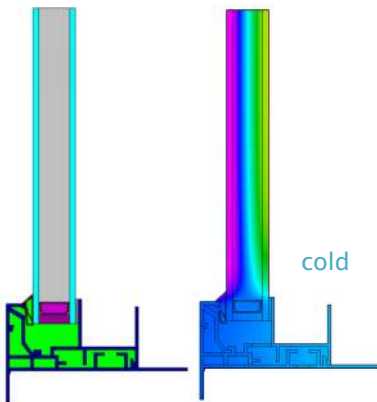


Existing

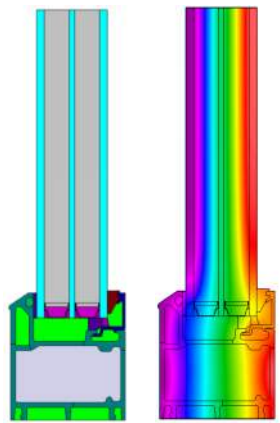


Upgraded

Upgraded Window Thermal Performance RDH



Existing Non Thermally Broken
Aluminium Frame = ~R-1
performance




Upgraded Fiberglass Frame
Triple Glazed = R-6 performance










Measurement & Verification RDH

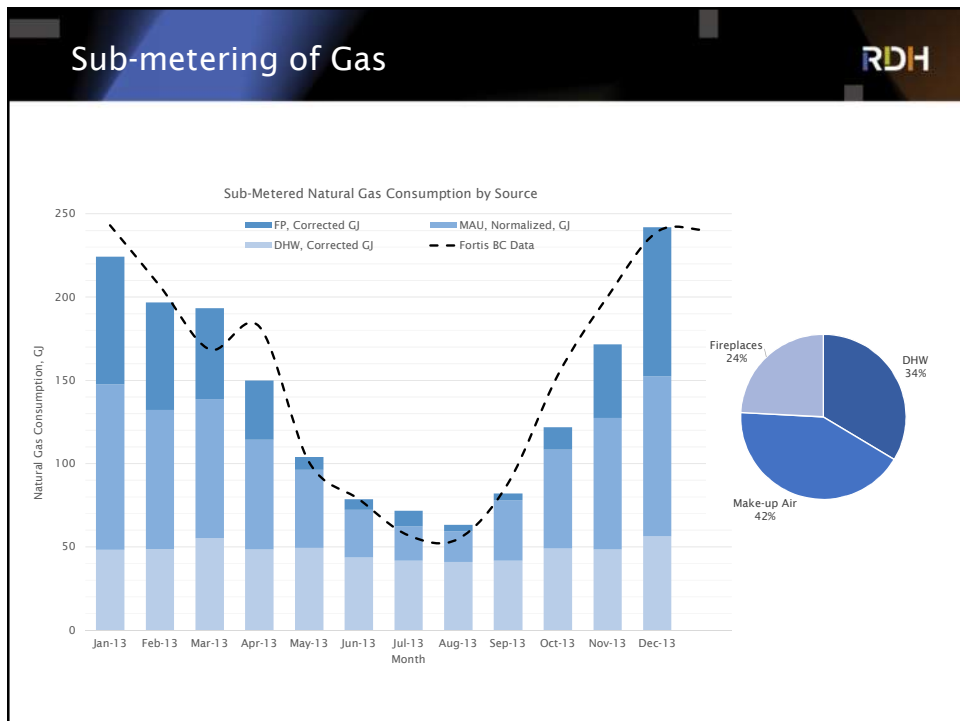
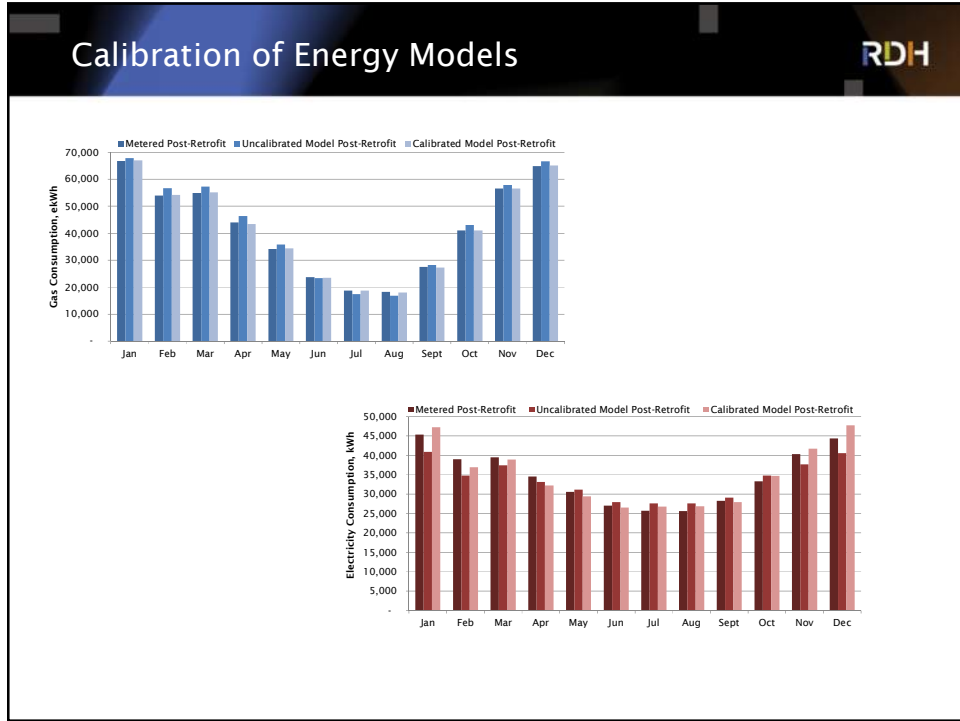
- Purpose: Confirm energy savings & ensure that energy efficiency measures are performing as designed
- Standard: International Performance Measurement and Verification Protocol (IPMVP)
 - Make a plan
 - Collect data - energy and other variables
 - Analyse results
 - Compare actual use vs predicted

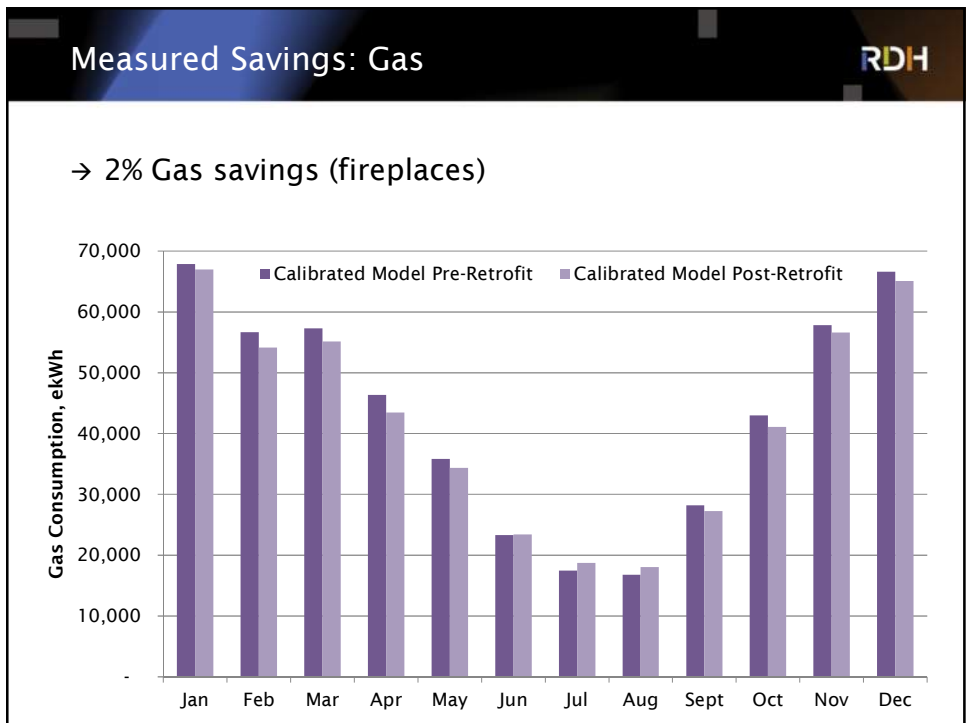
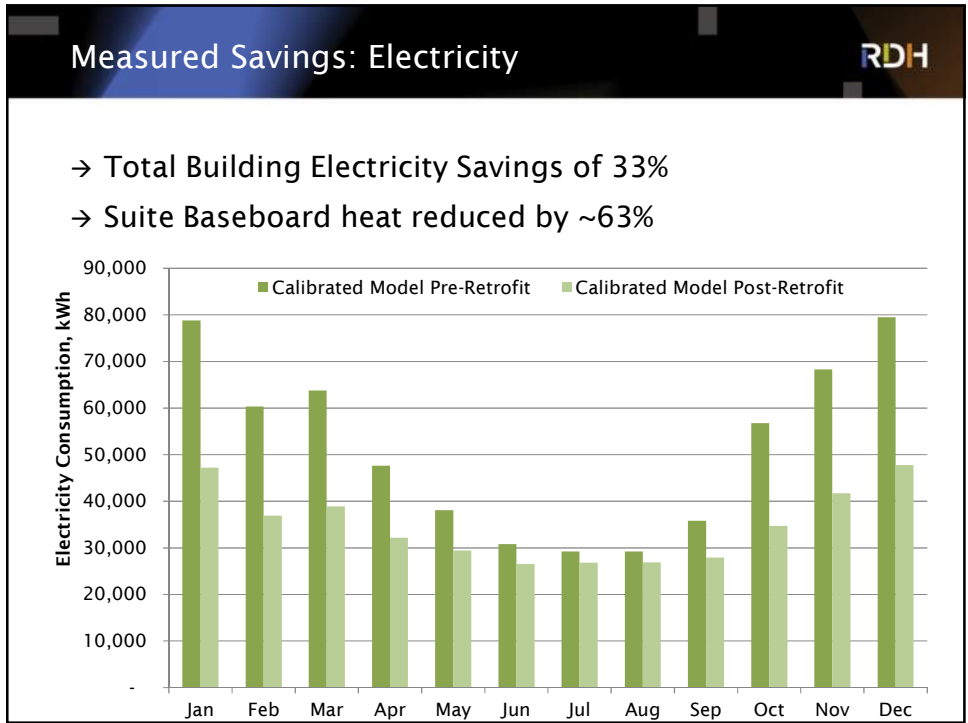


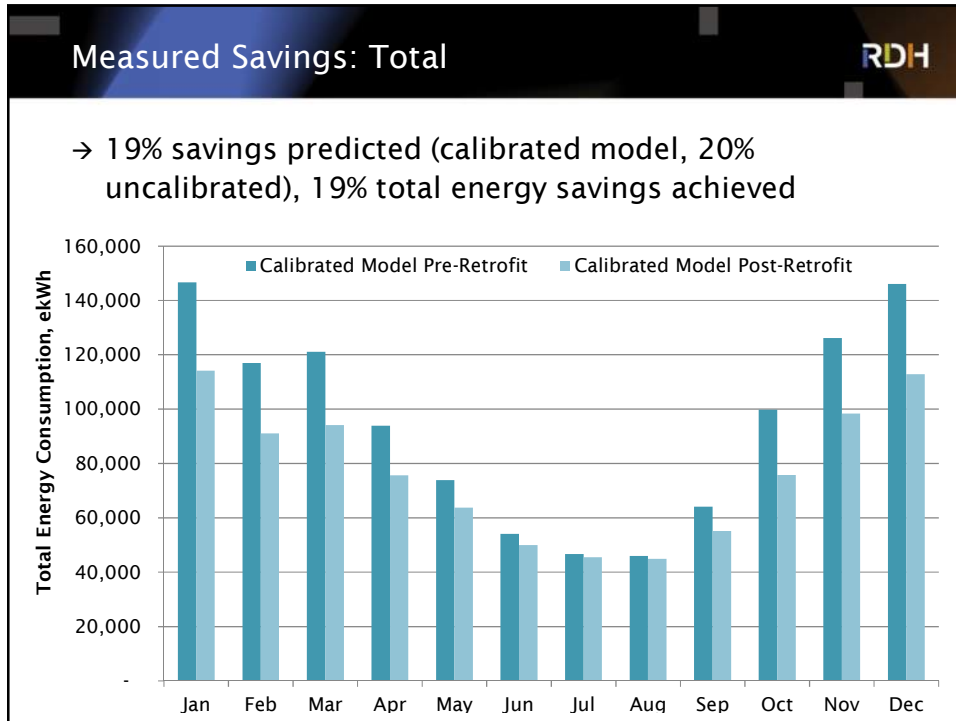
Case Study Building Testing & Monitoring Plan RDH

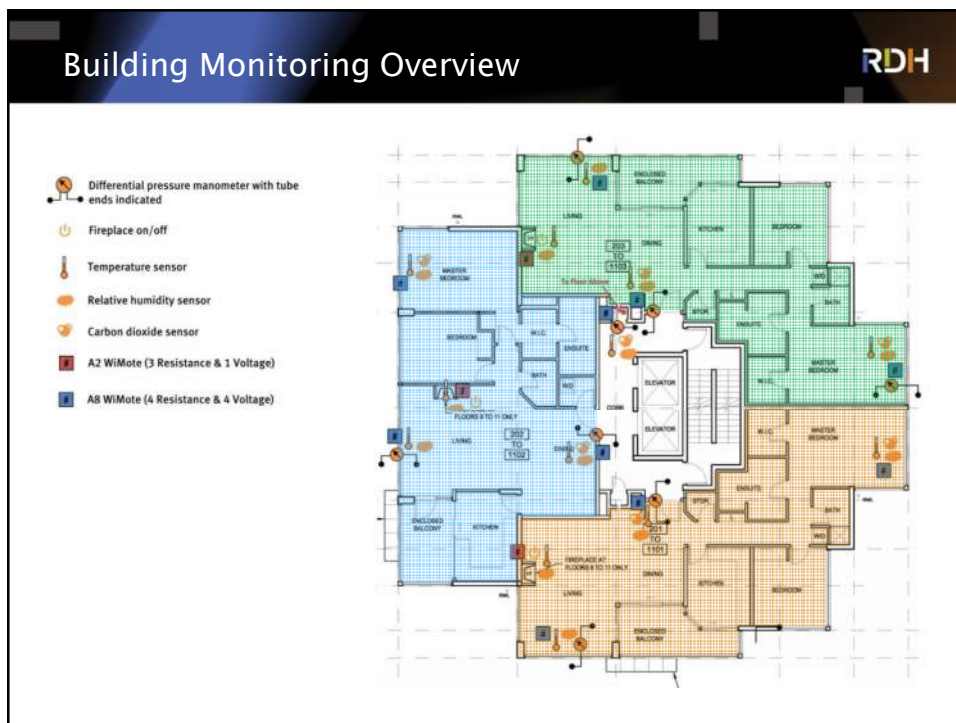
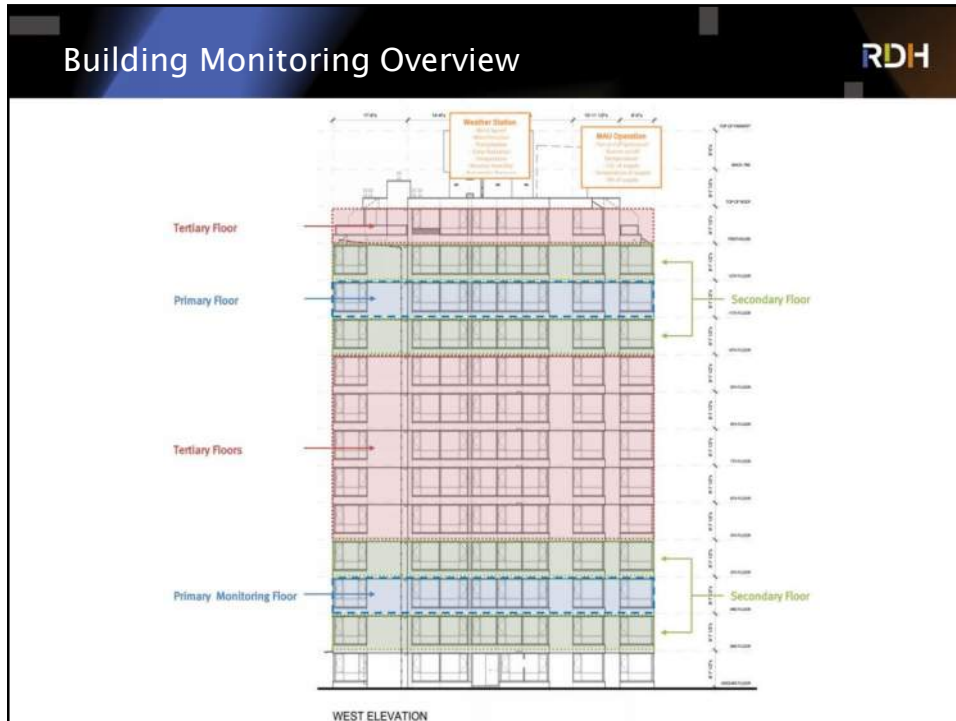
- 1+ year measurement period
- Energy savings metering primarily through utility meters (smart meters & sub-meters)
- Supplemental sensors installed to measure indoor conditions (T/RH/CO2), airflows, pressures, occupant comfort, fireplace use
- Air-tightness testing
- Tracer Gas Testing (PFT, Brookhaven Method)














Air Flow Testing Results RDH

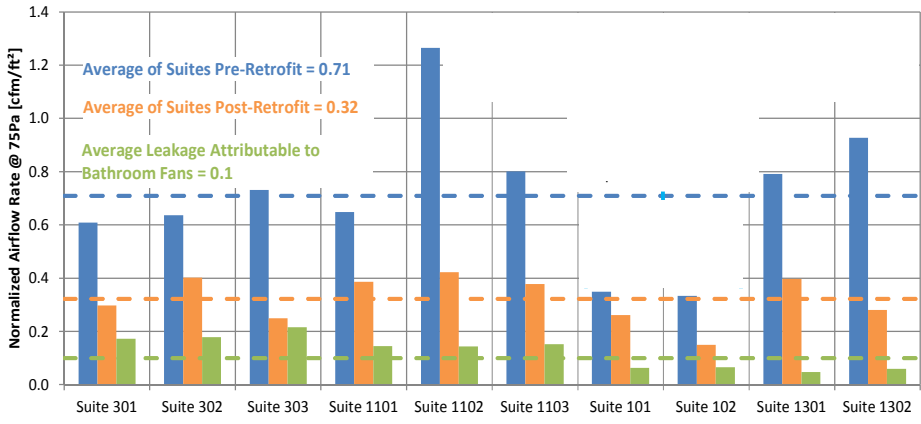
- Airtightness testing performed in 2013 – pre and post-building enclosure renewals
- Pressure neutralized approach to measure each surface (interior & exterior) individually – by suites & floors
- Determine enclosure airtightness and degree of internal compartmentalization

How Airtight is the Building Enclosure? RDH

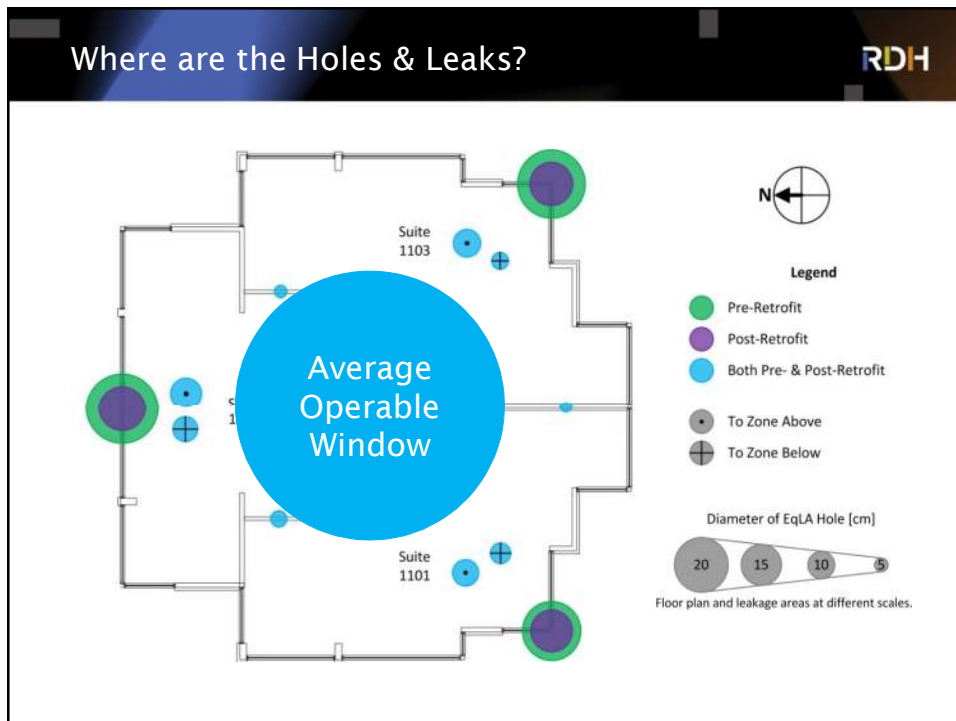
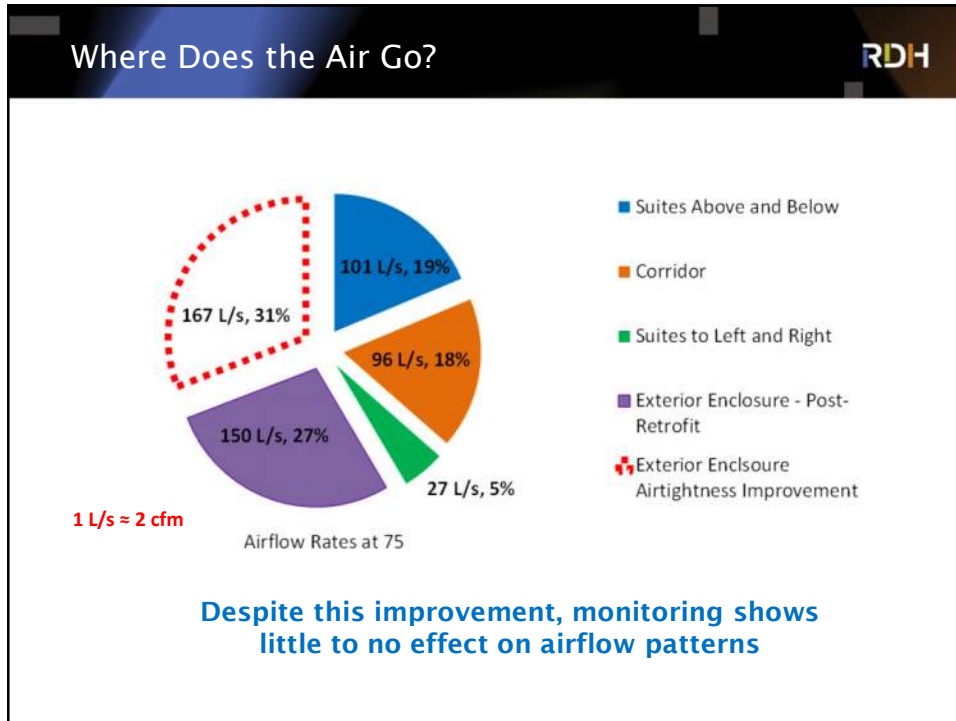
- Measured average enclosure airtightness improvement of approximately 55%
 - Estimated 50% prior to testing for pre-modeling

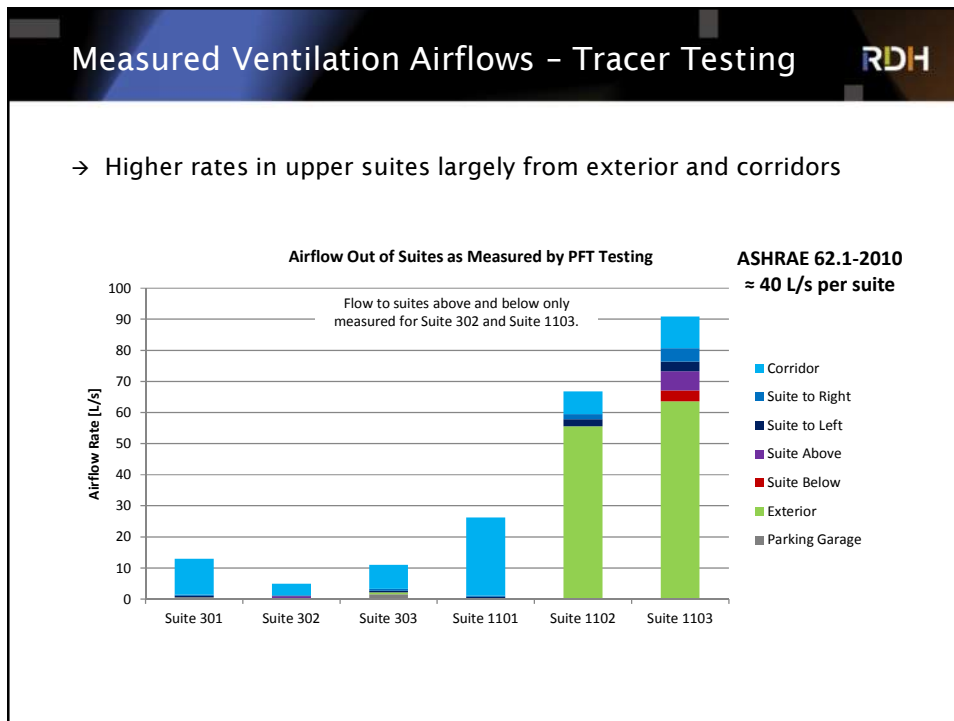
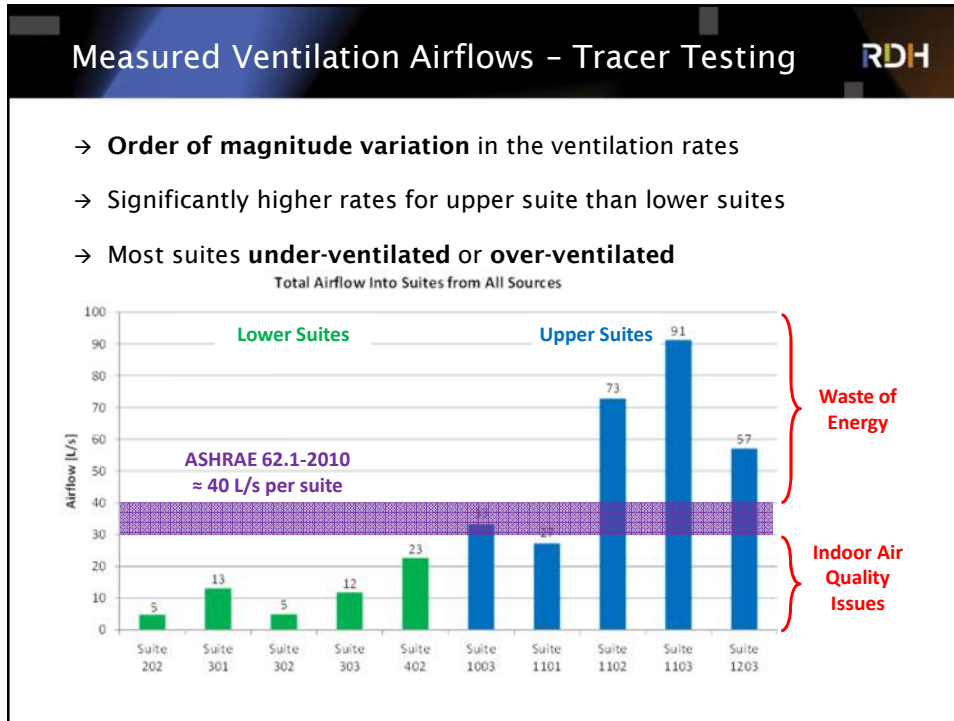
Enclosure Airtightnesses Pre- and Post-Retrofit with Bathroom Fan Air Leakage

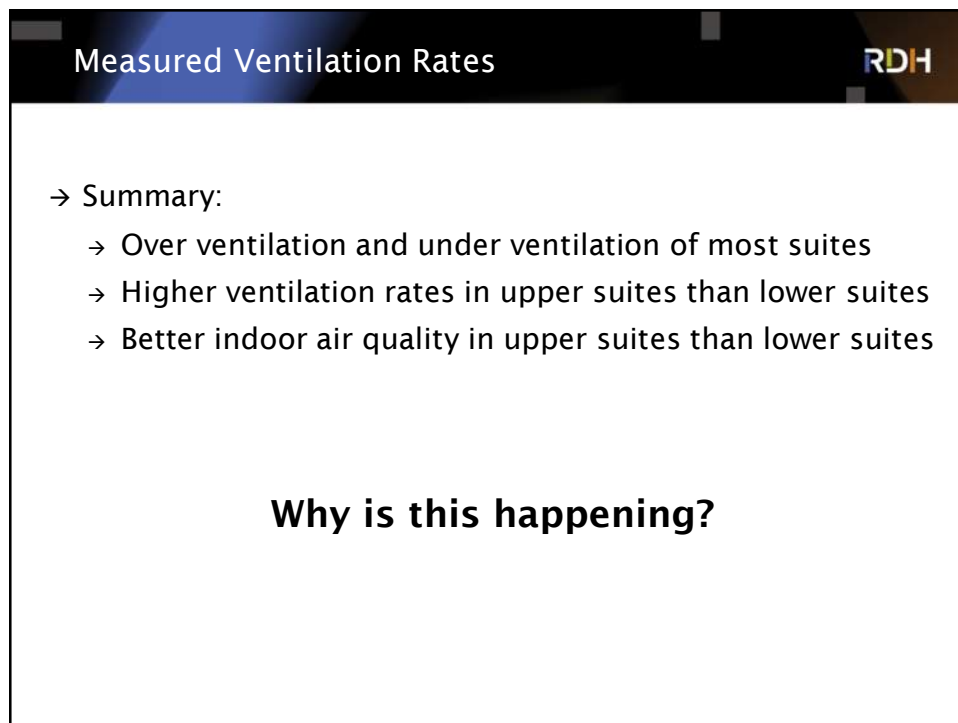
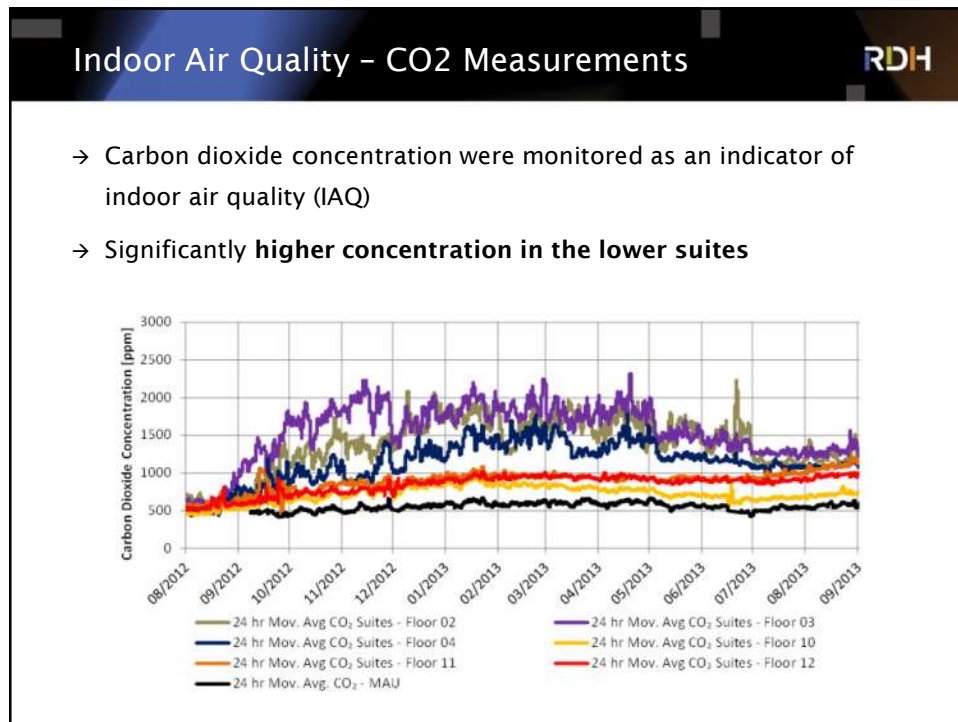


Suite	Pre-Retrofit	Post-Retrofit	Bathroom Fan Leakage
Suite 301	0.60	0.30	0.15
Suite 302	0.65	0.40	0.18
Suite 303	0.75	0.25	0.22
Suite 1101	0.65	0.38	0.15
Suite 1102	1.25	0.42	0.15
Suite 1103	0.80	0.38	0.15
Suite 101	0.35	0.28	0.10
Suite 102	0.32	0.15	0.10
Suite 1301	0.80	0.40	0.10
Suite 1302	0.95	0.28	0.10

Average of Suites Pre-Retrofit = 0.71
Average of Suites Post-Retrofit = 0.32
Average Leakage Attributable to Bathroom Fans = 0.1








Cause of Ventilation Rates RDH

Maybe the MAU isn't working correctly?


- Custom powered flow hood used to measure intake flow rate of the make-up air unit
- MAU airflow **approximately the same** as design flow rate of 1,560 L/s (3,300 cfm)



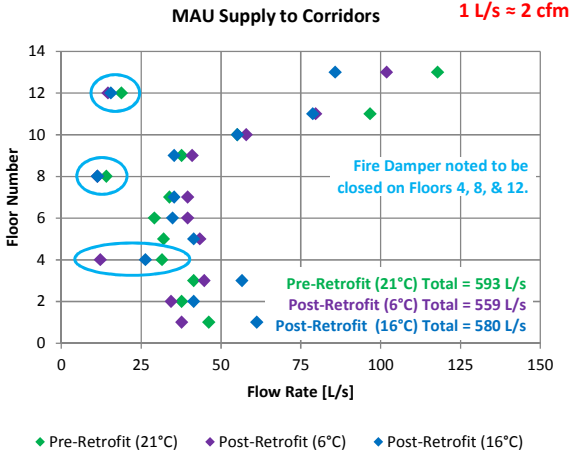
Cause of Ventilation Rates RDH

Maybe the ventilation air isn't reaching the corridors?

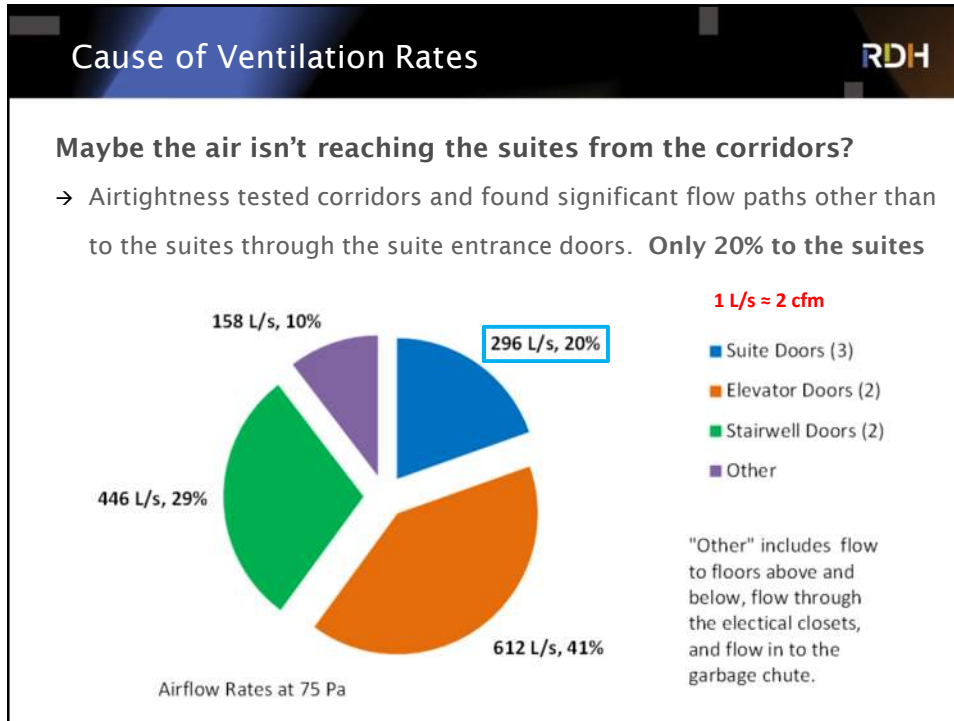
- Only 40% of intake flow reaches the corridors directly



MAU Supply to Corridors 1 L/s ≈ 2 cfm



Category	Total Flow Rate [L/s]
Pre-Retrofit (21°C)	593
Post-Retrofit (6°C)	559
Post-Retrofit (16°C)	580



Cause of Ventilation Rates RDH

→ If only 40% of the flow rate reaches the corridors
And, only 20% of that air reaches the suites...

40% × 20% = 8%

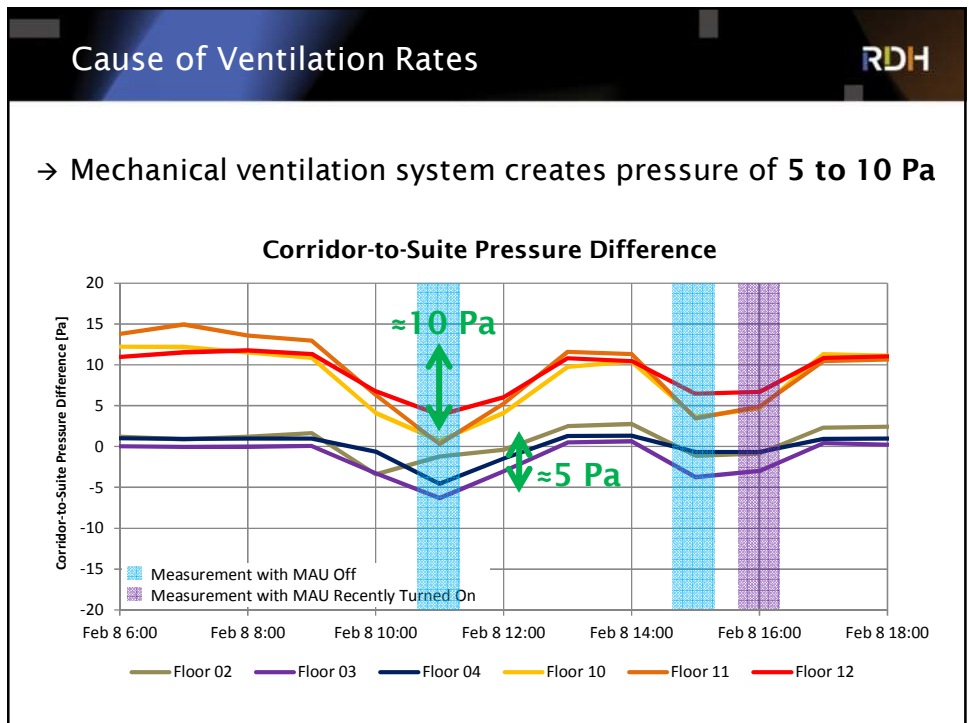
→ Theoretically, only **8%** of intended ventilation actually goes where it is supposed to! Waste of ventilation air, and the energy needed to move and condition it.

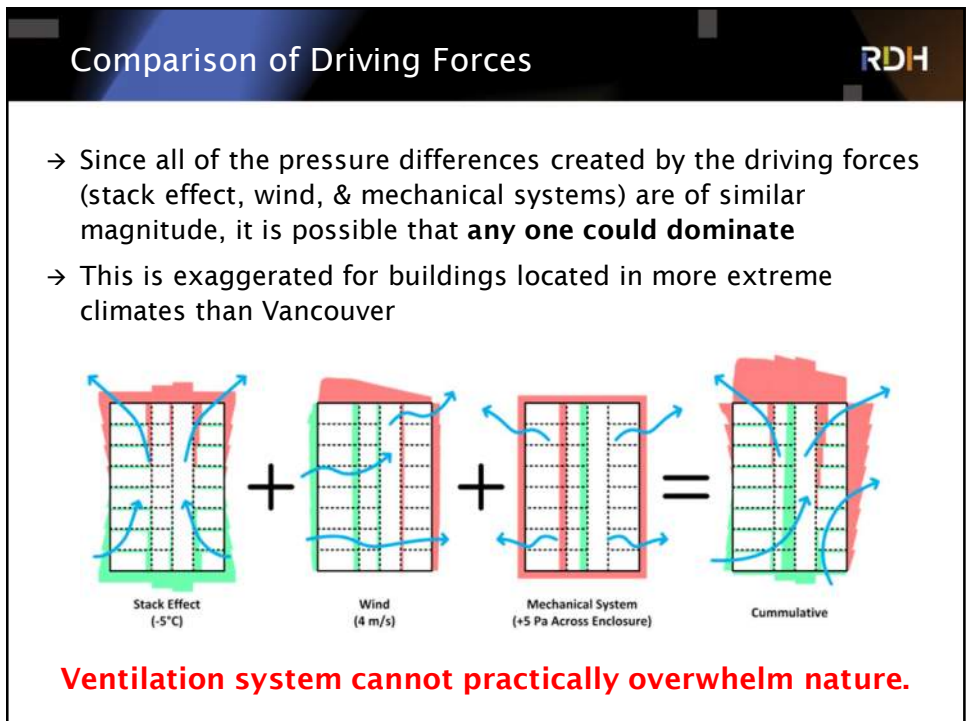
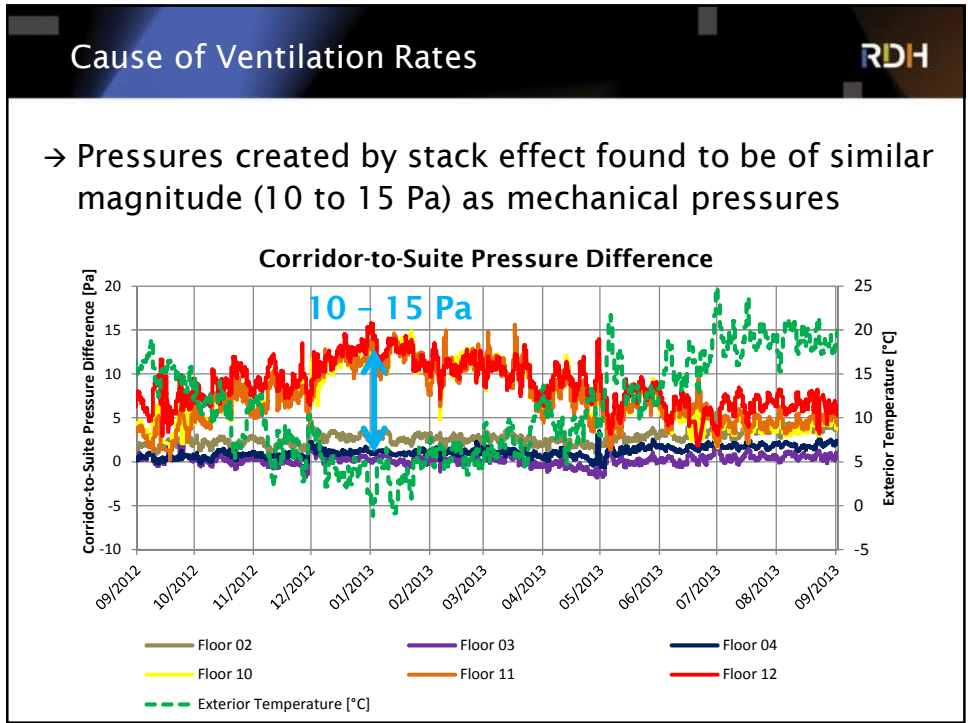
Leakage of air along ventilation flow path is a major issue.

Cause of Ventilation Rates RDH

Maybe pressure differences are an important factor?

- Pressure differences were monitored with a focus on an upper floor and a lower floor (Floors 11 & 3)
- Assessed relationship between exterior temperature (stack effect) and wind events using a weather station on the roof





Ventilation & IAQ - Summary

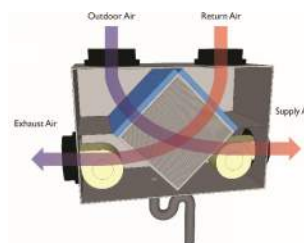
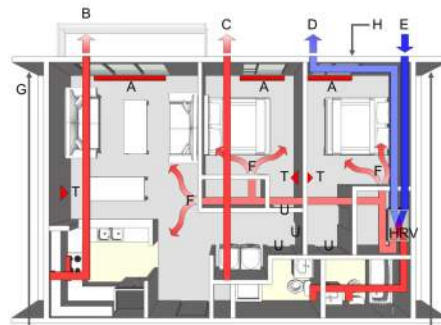
RDH

- Corridor pressurization **does not provide intended ventilation rates** to a large number of suites
 - Some significantly over ventilated while others significantly under ventilated
- Significant **leakage along the ventilation air flow path** from the duct and the corridor (wasted ventilation)
 - Uncontrolled airflow wastes energy and provides poor ventilation
- Stack effect and wind pressures are often similar or greater than mechanically-induced pressures
 - **Ventilation system can not practically overwhelm nature**

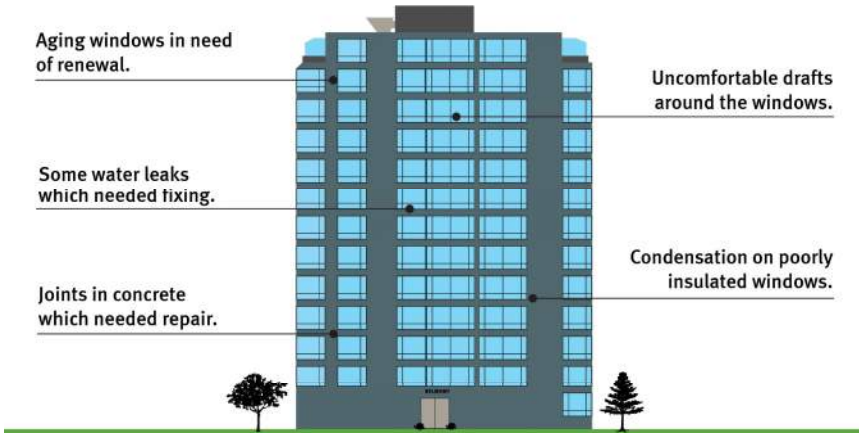
Next Steps

RDH

- Plan to upgrade mechanical ventilation system in building
- Most effective is to install in suite HRV or ERVs – challenges with retrofit & running ducts
- Will also perform air-sealing to compartmentalize the suites and corridors & reduce make-up air to just corridor flow rates/temperatures
- Measure ongoing energy savings
- Proposed installation late 2015



Summary RDH



Aging windows in need of renewal.

Some water leaks which needed fixing.

Joints in concrete which needed repair.

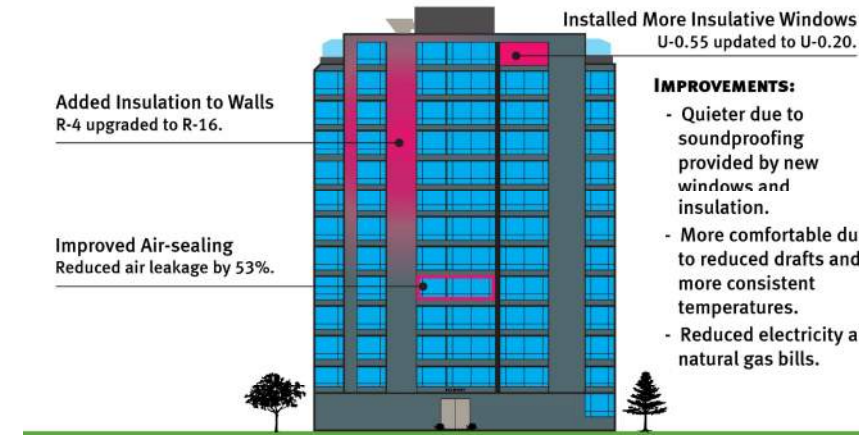
Uncomfortable drafts around the windows.

Condensation on poorly insulated windows.

Old Building that Needs Renewals

The diagram shows a cross-section of a multi-story building with several issues identified by red dots and lines pointing to text labels. The issues include aging windows, water leaks, concrete joint repairs, drafts, and condensation on windows.

Summary RDH



Added Insulation to Walls
R-4 upgraded to R-16.

Improved Air-sealing
Reduced air leakage by 53%.

Installed More Insulative Windows
U-0.55 updated to U-0.20.

IMPROVEMENTS:

- Quieter due to soundproofing provided by new windows and insulation.
- More comfortable due to reduced drafts and more consistent temperatures.
- Reduced electricity and natural gas bills.

19% Total Energy Savings!

The diagram shows the same building after several improvements: walls are insulated to R-16, air-sealing is improved (reducing leakage by 53%), and windows are updated to U-0.20. A list of improvements highlights that the building is now quieter, more comfortable, and has reduced energy bills. A large banner at the bottom states a total energy savings of 19%.

Summary RDH

- Significant opportunities exist to reduce energy consumption of MURBs
- Pilot project demonstrates the potential for simple and cost effective EEMs at time of retrofit work & new construction
- Total building energy savings of 19% for building enclosure improvements predicted and then measured & verified
- Ventilation assessment necessary at time of building enclosure renewals
- Replicating the success of this project is a huge opportunity for the entire industry




Some Thoughts for Whitehorse MURB Retrofits RDH

- Majority of MURBs here are wood-frame townhouse and <4 storey multi-storey
 - Will be easier to access and complete retrofits within a single spring-fall construction season
- Central ventilation systems (if present in older buildings, pre-HRV requirements) will be big consumers of energy - consider in-suite systems/HRVs
- Fireplaces if present will be another big consumer of energy - consider sub-metering
- Opportunities for thermal insulation upgrades to window, wall and roof assemblies & overall building air-tightness improvements - consider upgrades beyond code



Looking Ahead RDH

- Move towards improving resilience and energy efficiency of new and existing buildings
- Focus on GHGs and move towards “net-zero” emissions
- Pacific Northwest Economic Region (PNWER)
 - currently performing research & developing strategies & a roadmap to transform construction market in most cost-effective manner
- Working with all levels of government & private sector to develop roadmap with multiple goals



Roadmap to Resilient, Net Zero Energy Buildings and Deep Energy Retrofits

RDH

- Gathering & review of case study buildings of all types and in all PNWER regions with demonstrated low-energy use, net-zero energy, resilient construction etc.
- Technical & economic assessment, interviews with design teams & owners to determine key energy efficiency measures
- Verification of energy & financial performance
- Summarize key design and operation features of net zero buildings (existing & new) for potential replication across PNEWR region
- Forecast regional benefits and savings to existing & future building stock
- Review government policy and market mechanisms to facilitate net zero new construction and deep retrofits

How You Can Help

RDH

- Looking for Case Studies in Yukon and Northwest Territories
 - New Buildings of all types demonstrating net-zero energy and/or emissions
 - Deep energy retrofits with >30% reduction in energy use or GHG
 - Designers & owners willing to share success stories

