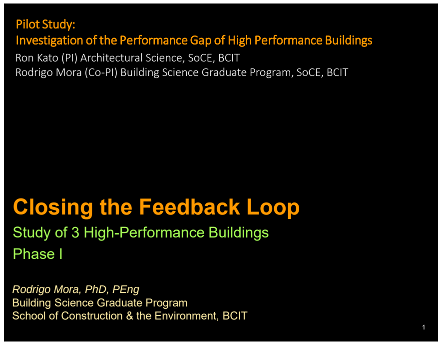
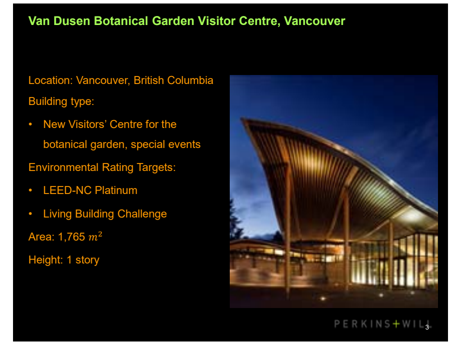
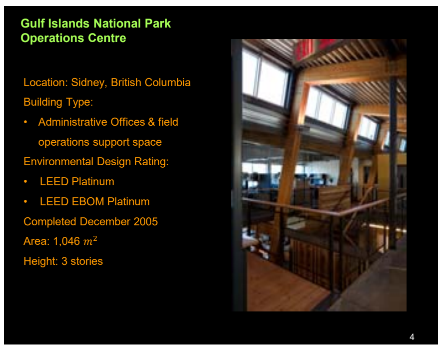
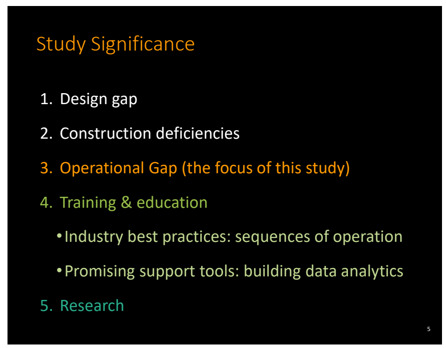
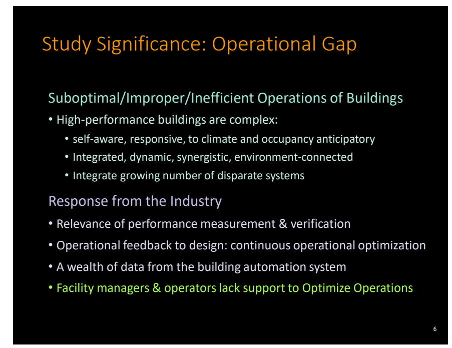

Pilot Study:
Investigation of the Performance Gap of High Performance Buildings
Ron Kato (PI) Architectural Science, SoCE, BCIT
Rodrigo Mora (Co-PI) Building Science Graduate Program, SoCE, BCIT
Closing the Feedback Loop
Study of 3 High-Performance Buildings
Phase I
Rodrigo Mora, PhD, PEng
Building Science Graduate Program
School of Construction & the Environment, BCIT
1

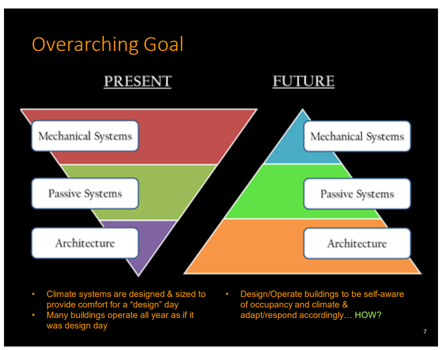

Vancouver Island University
Cowichan Campus
Location: Duncan, British Columbia
Building Type:
• Academic
• Administrative Offices
Environmental Rating Targets:
• LEED Gold Certified
Completed: June 2011
Building Area: 4, 364 m^2
Height: 3 stories
2


Van Dusen Botanical Garden Visitor Centre, Vancouver
Location: Vancouver, British Columbia
Building type:
• New Visitors' Centre for the botanical garden, special events
Environmental Rating Targets:
• LEED-NC Platinum
• Living Building Challenge
Area: 1,765 m^2
Height: 1 story
PERKINS+WILL
3

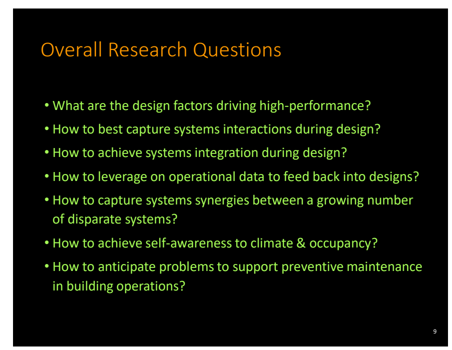

Gulf Islands National Park
Operations Centre
Location: Sidney, British Columbia
Building Type:
• Administrative Offices & field operations support space
Environmental Design Rating:
• LEED Platinum
• LEED EBOM Platinum
Completed December 2005
Area: 1,046 m^2
Height: 3 stories
4


Study Significance
1. Design gap
2. Construction deficiencies
3. Operational Gap (the focus of this study)
4. Training & education
• Industry best practices: sequences of operation
• Promising support tools: building data analytics
5. Research
5

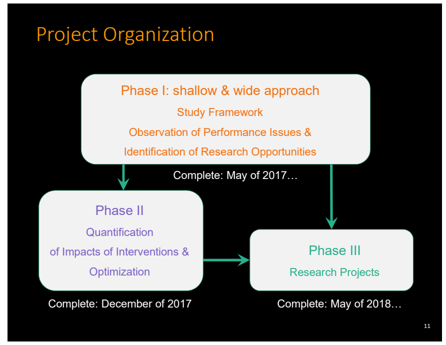

Study Significance: Operational Gap
Suboptimal/Improper/Inefficient Operations of Buildings
• High-performance buildings are complex:
• self-aware, responsive, to climate and occupancy anticipatory
• Integrated, dynamic, synergistic, environment-connected
• Integrate growing number of disparate systems
Response from the Industry
• Relevance of performance measurement & verification
• Operational feedback to design: continuous operational optimization
• A wealth of data from the building automation system
• Facility managers & operators lack support to Optimize Operations
6

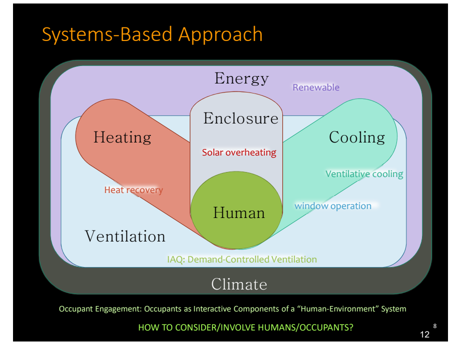

Overarching Goal
PRESENT
FUTURE
Mechanical Systems
Passive Systems
Architecture
Mechanical Systems
Passive Systems
Architecture
• Climate systems are designed & sized to provide comfort for a "design" day
• Many buildings operate all year as if it was design day
• Design/Operate buildings to be self-aware of occupancy and climate & adapt/respond accordingly… HOW?
7

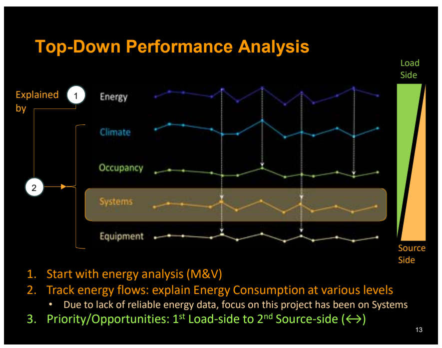

Overarching Goal
1. Awareness
• Complexities / Challenges / Opportunities
2. Understanding
• Assessment / Quantification / Interpretation / Impacts / Metrics
• Systems / Integration / Technologies / Dynamics / Behaviours
3. Implementation
• Optimization: Strategies / Tools / Methods / Best practices
4. Research & Innovation
• Develop industry relevant research projects
• Support innovative-technology integration in buildings
8

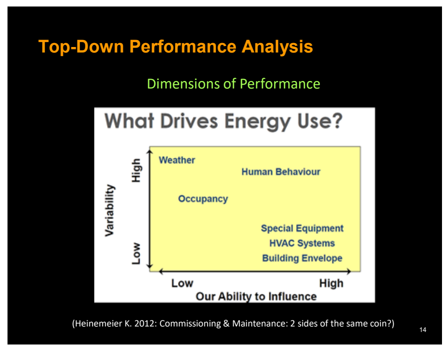

Overall Research Questions
• What are the design factors driving high-performance?
• How to best capture systems interactions during design?
• How to achieve systems integration during design?
• How to leverage on operational data to feed back into designs?
• How to capture systems synergies between a growing number of disparate systems?
• How to achieve self-awareness to climate & occupancy?
• How to anticipate problems to support preventive maintenance in building operations?
9

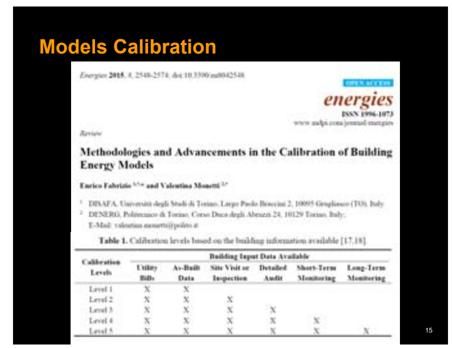

Research Objectives
1. Develop a methodological framework for training & research using real buildings
2. Develop ongoing capacity at BCIT to analyze high-performance buildings & learn from them
3. Develop ongoing capacity at BCIT to leverage on the wealth of data from buildings for training & research
4. Investigate tools & methods to analyze complex building systems
5. Develop tools & methods to provide feedback to the industry: designers, owners, operators
10

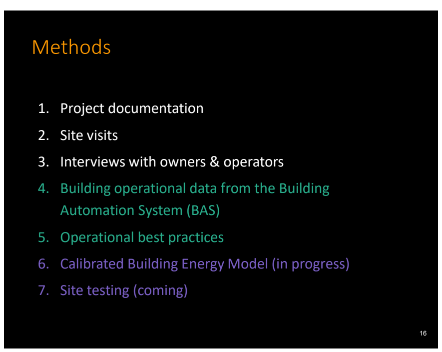

Project Organization
Phase I: shallow & wide approach
Study Framework
Observation of Performance Issues &
Identification of Research Opportunities
Complete: May of 2017…
Phase II
Quantification
of Impacts of Interventions &
Optimization
Complete: December of 2017
Phase III
Research Projects
Complete: May of 2018…
11

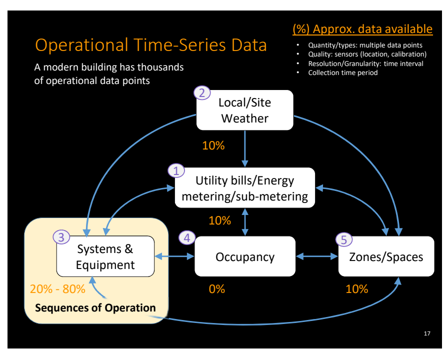

Systems-Based Approach
Energy
Renewable
Enclosure
Heating
Cooling
Solar overheating
Ventilative cooling
Heat recovery
Human
window operation
Ventilation
IAQ: Demand-Controlled Ventilation
Climate
Occupant Engagement: Occupants as Interactive Components of a "Human-Environment" System
HOW TO CONSIDER/INVOLVE HUMANS/OCCUPANTS?
12

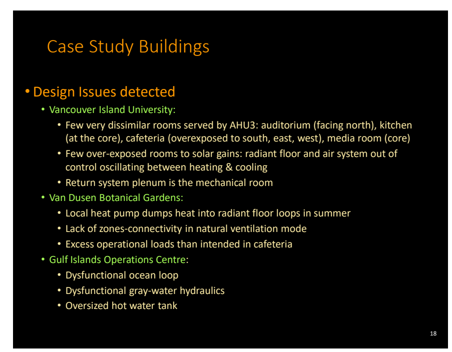

Top-Down Performance Analysis
Load Side
Explained by
1
Energy
Climate
Occupancy
2
Systems
Equipment
Source Side
1. Start with energy analysis (M&V)
2. Track energy flows: explain Energy Consumption at various levels
• Due to lack of reliable energy data, focus on this project has been on Systems
3. Priority/Opportunities: 1st Load-side to 2nd Source-side (<->)
13

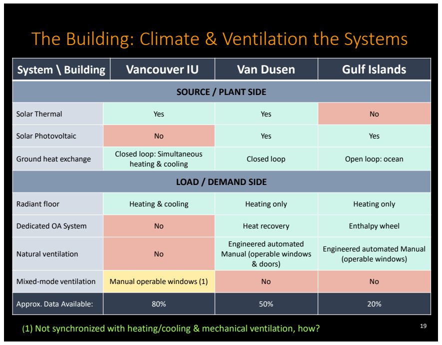

Top-Down Performance Analysis
Dimensions of Performance
What Drives Energy Use?
Variability
High
Low
Weather
Human Behaviour
Occupancy
Special Equipment
HVAC Systems
Building Envelope
Low
High
Our Ability to Influence
(Heinemeier K. 2012: Commissioning & Maintenance: 2 sides of the same coin?)
14


Models Calibration
energies
Methodologies and Advancements in the Calibration of Building Energy Models
15


Methods
1. Project documentation
2. Site visits
3. Interviews with owners & operators
4. Building operational data from the Building Automation System (BAS)
5. Operational best practices
6. Calibrated Building Energy Model (in progress)
7. Site testing (coming)
16


Operational Time-Series Data
A modern building has thousands of operational data points
(%) Approx. data available
• Quantity/types: multiple data points
• Quality: sensors (location, calibration)
• Resolution/Granularity: time interval
• Collection time period
2 Local/Site Weather
10%
1 Utility bills/Energy metering/sub-metering
10%
3 Systems & Equipment
4 Occupancy
5 Zones/Spaces
20% - 80%
0%
10%
Sequences of Operation
17


Case Study Buildings
• Design Issues detected
• Vancouver Island University:
• Few very dissimilar rooms served by AHU3: auditorium (facing north), kitchen (at the core), cafeteria (overexposed to south, east, west), media room (core)
• Few over-exposed rooms to solar gains: radiant floor and air system out of control oscillating between heating & cooling
• Return system plenum is the mechanical room
• Van Dusen Botanical Gardens:
• Local heat pump dumps heat into radiant floor loops in summer
• Lack of zones-connectivity in natural ventilation mode
• Excess operational loads than intended in cafeteria
• Gulf Islands Operations Centre:
• Dysfunctional ocean loop
• Dysfunctional gray-water hydraulics
• Oversized hot water tank
18

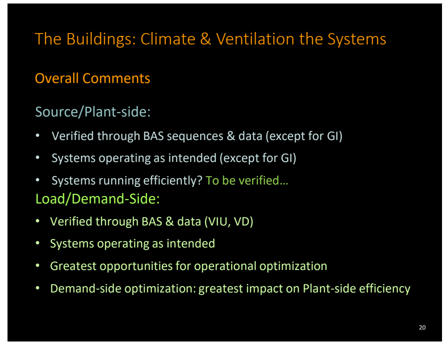


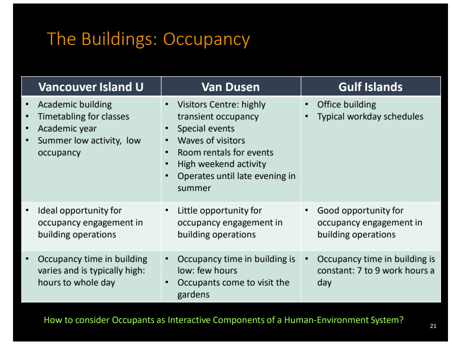
The Building: Climate & Ventilation the Systems

System \ Building	Vancouver IU	Van Dusen	Gulf Islands
SOURCE / PLANT SIDE			
Solar Thermal	Yes	Yes	No
Solar Photovoltaic	No	Yes	Yes
Ground heat exchange	Closed loop: Simultaneous heating & cooling	Closed loop	Open loop: ocean
LOAD / DEMAND SIDE			
Radiant floor	Heating & cooling	Heating only	Heating only
Dedicated OA System	No	Heat recovery	Enthalpy wheel
Natural ventilation	No	Engineered automated Manual (operable windows & doors)	Engineered automated Manual (operable windows)
Mixed-mode ventilation	Manual operable windows (1)	No	No
Approx. Data Available:	80%	50%	20%

(1) Not synchronized with heating/cooling & mechanical ventilation, how?

19



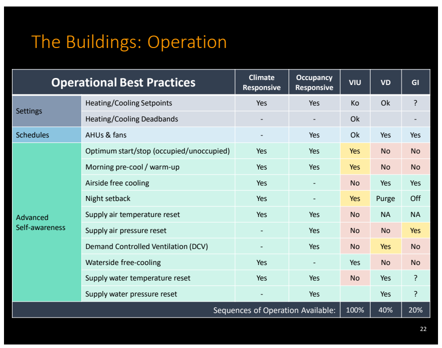


The Buildings: Occupancy

Vancouver Island U	Van Dusen	Gulf Islands
• Academic building • Timetabling for classes • Academic year • Summer low activity, low occupancy	• Visitors Centre: highly transient occupancy • Special events • Waves of visitors • Room rentals for events • High weekend activity • Operates until late evening in summer	• Office building • Typical workday schedules
• Ideal opportunity for occupancy engagement in building operations	• Little opportunity for occupancy engagement in building operations	• Good opportunity for occupancy engagement in building operations
• Occupancy time in building varies and is typically high: hours to whole day	• Occupancy time in building is low: few hours • Occupants come to visit the gardens	• Occupancy time in building is constant: 7 to 9 work hours a day

How to consider Occupants as Interactive Components of a Human-Environment System?

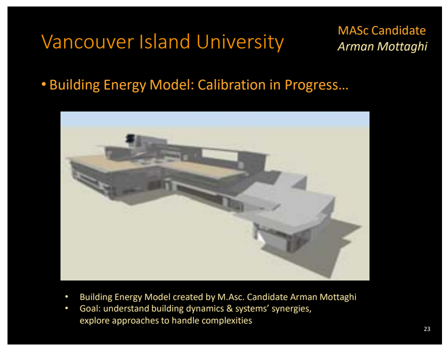
21

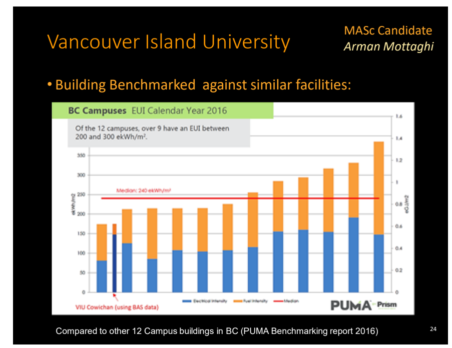


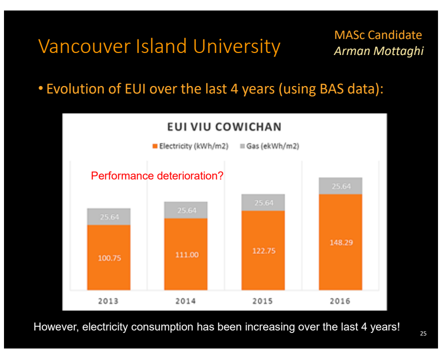
The Buildings: Operation

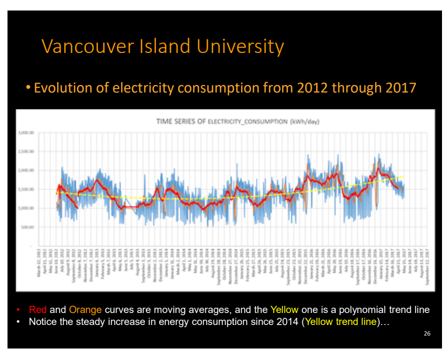
Operational Best Practices		Climate Responsive	Occupancy Responsive	VIU	VD	GI
Settings	Heating/Cooling Setpoints	Yes	Yes	Ko	Ok	?
	Heating/Cooling Deadbands	-	-	Ok		-
Schedules	AHUs & fans	-	Yes	Ok	Yes	Yes
Advanced Self-awareness	Optimum start/stop (occupied/unoccupied)	Yes	Yes	Yes	No	No
	Morning pre-cool / warm-up	Yes	Yes	Yes	No	No
	Airside free cooling	Yes	-	No	Yes	Yes
	Night setback	Yes	-	Yes	Purge	Off
	Supply air temperature reset	Yes	Yes	No	NA	NA
	Supply air pressure reset	-	Yes	No	No	Yes
	Demand Controlled Ventilation (DCV)	-	Yes	No	Yes	No
	Waterside free-cooling	Yes	-	Yes	No	No
	Supply water temperature reset	Yes	Yes	No	Yes	?
	Supply water pressure reset	-	Yes		Yes	?
			Sequences of Operation Available:	100%	40%	20%

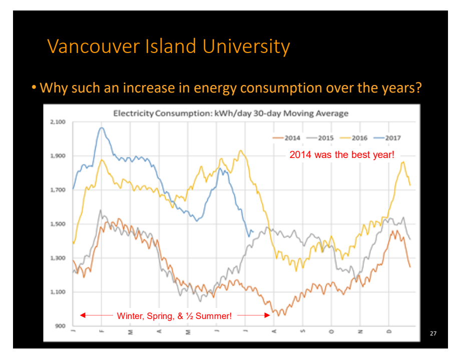
22









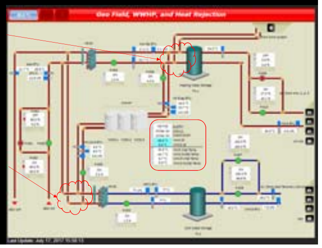


Vancouver Island University

• Heat Pump Control

Does not correspond to mechanical schematics
Header missing…

Does not correspond to mechanical schematics
Missing key valves…
Not accounted for in BAS…



Vancouver Island University

• Heat Pump Control

- Heat Pumps (WWHP) and solar are the primary means for heating. Boilers are backup for when WWHP & solar cannot meet heating needs.
- The heat pump staging (WWHP1 > WWHP2 > WWHP3) is controlled by heating water requirements in the winter & cooling water requirements in the summer (i.e. cooling or heating leaving set point temperatures)
- The BMS will determine the predominant load: heating or cooling in the different zones, and act accordingly
- Boilers are only enabled when the heat pumps and/or solar heating system are unable to achieve supply water temperature set points

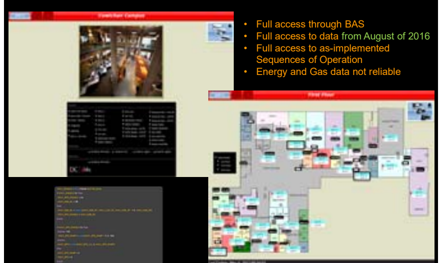
29

Vancouver Island University

How can we explain such an energy increase over the years?

Possible Causes	Proposed Solutions
1. Lack of systems operational optimization	Night setbacks, early pre-cool (purged), early warm-up, optimum start/stop, economizer control, set point resets
2. Excessive ventilation year-round: outdoor air damper 100% open	Modulate outdoor and mixed air dampers during occupied periods. Monitor/Verify building & mechanical room pressures
3. Excessive summer cooling	Relax indoor summer set point temperatures
4. Supply air temperature set point is fixed at the air handlers year-round	Implement supply air temperature set point reset logic
5. Supply air pressure set point is fixed at the air handlers year-round	Implement supply air pressure set point reset logic. Monitor/Verify building & mechanical room pressures
6. Room-level radiant & air temperature set point controls not harmonized	Individual fine-tuning of slab set point temperatures and resets based on outdoor temperature and indoor feedback
7. Local problems: Zone served by AHU3	Study local solutions

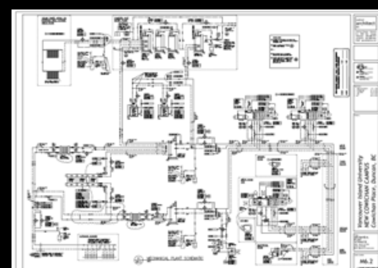
VIU: Access to BAS Data & Sequences of Operation



- Full access through BAS
- Full access to data from August of 2016
- Full access to as-implemented Sequences of Operation
- Energy and Gas data not reliable

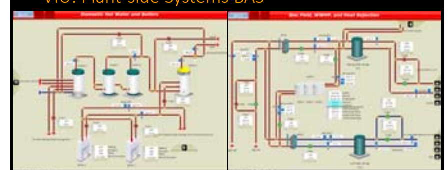
31

VIU: Plant-side Systems



32

VIU: Plant-side Systems BAS



3) Geo-Exchange Heat Pumps
- Are VFD pumps that vary speed to maintain constant temperatures of:
  - 10F° ΔT for Cooling
  - 7F° ΔT for Heating

GSHPs
Sequences of Operation

Has this been achieved?
How would this affect COP?

To achieve the optimum field size and payback we recommend that the field only be sized to 50-70% of the block heating load. This would be sufficient enough to meet the building heating requirements for over 90% of the year. As a backup we would recommend a small boiler to compliment the heating plant on the coldest winter days.

Geo-Exchange System Mechanical Schematic Design Report, AME Group August 2009

33

VIU: Plant-side Systems Modes of Operation

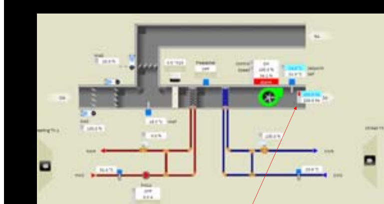
No	Modes of operation	HP	HE-1 cold	HE-2 hot	P-001 P-002	P-003 cold	P-004 hot	P-005 Evap.	P-006 Cond.	Tk1 hot	Tk2 cold
1	Cooling / Rejecting HE-1 heat to the ground / Storing heat in Tk1 (to set point)	ON	ON	OFF	High	ON	OFF	ON	ON	ON	ON
2	Cooling / Rejecting HE-1 heat to the ground / Tk1 reaches storage set point capacity Reject HE-2 heat to ground	ON	ON	ON	High	ON	ON	ON	ON	OFF	ON
3	Heating / Rejecting HP cold to the ground / (No need for cooling)	ON	OFF	OFF	High	OFF	OFF	ON	ON	ON	OFF
4	Heating / storing cold in Tk2 (to set point) / Rejecting excess HP cold to the ground	ON	ON	OFF	High	ON	OFF	ON	ON	ON	ON
5	Combined Heating & Cooling Cooling (zones n) & Heating (zones m) / Little heat rejection to the ground	ON	ON	OFF/ ON	OFF/ Low	ON	ON	ON	ON	ON	ON
6	Free cooling / reject little heat to the ground	OFF	ON	OFF	Medium	ON	OFF	OFF	OFF	OFF	ON
7	Free heating / reject little cold to the ground	OFF	OFF	ON	Medium	OFF	ON	OFF	OFF	ON	OFF

34

VIU: Systems

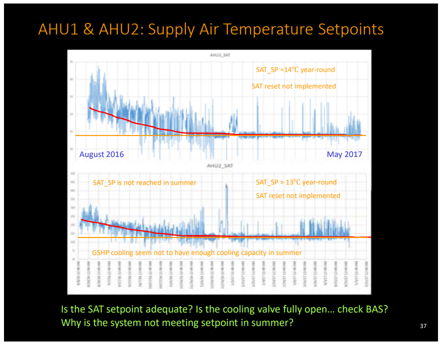
35

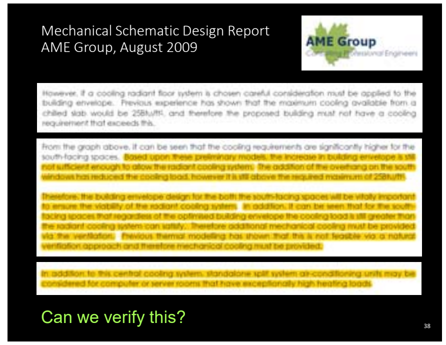
AHU1 & AHU2: System Static Pressure Differential



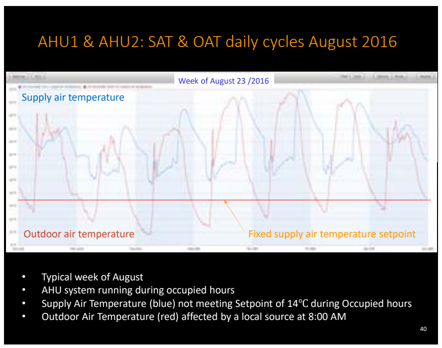
- VFD fan maintains fixed system static pressure during occupancy year-round…
- Not static pressure reset implemented (ASHRAE Guideline 36P)
- No direct feedback from VAV-boxes received
- Does the VFD fan need to consistently run at high speed?
- Do the VAV-boxes really need this much pressure to deliver the required flow?

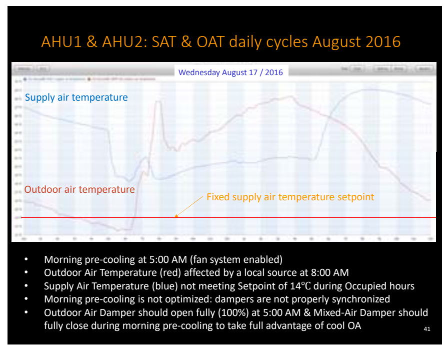
36

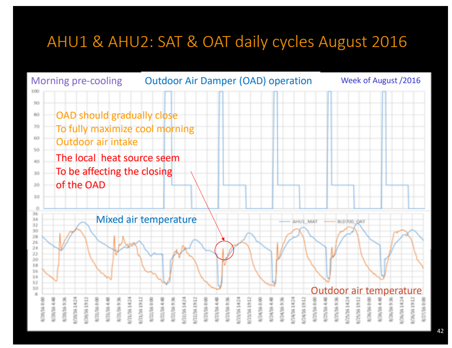

AHU1 & AHU2: Supply Air Temperature Setpoints
SAT_SP =14°C year-round
SAT reset not implemented
August 2016
May 2017
SAT_SP is not reached in summer
SAT_SP = 13°C year-round
SAT reset not implemented
GSHP cooling seem not to have enough cooling capacity in summer
Is the SAT setpoint adequate? Is the cooling valve fully open… check BAS?
Why is the system not meeting setpoint in summer?
37

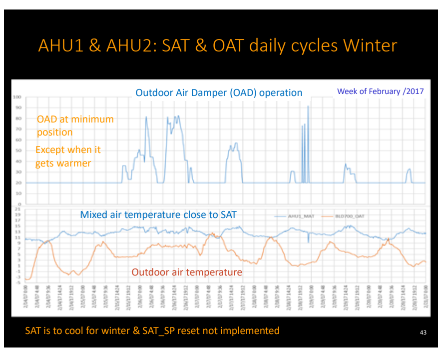

Mechanical Schematic Design Report
AME Group, August 2009
Can we verify this?
38

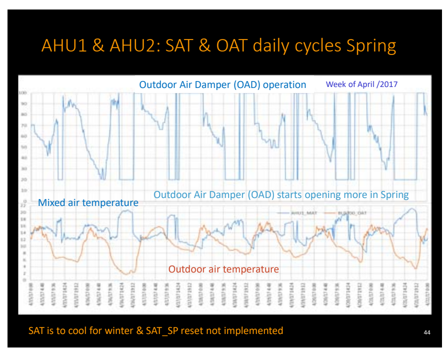

Mechanical Design Development Report
AME Group, October 2009
39

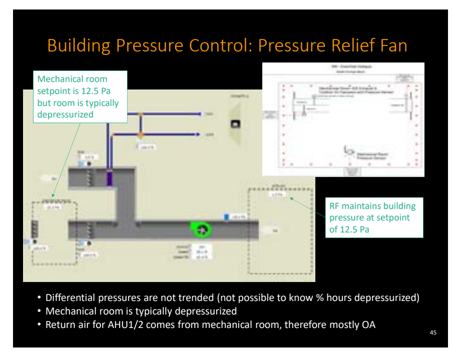

AHU1 & AHU2: SAT & OAT daily cycles August 2016
Week of August 23 /2016
Supply air temperature
Outdoor air temperature
Fixed supply air temperature setpoint
• Typical week of August
• AHU system running during occupied hours
• Supply Air Temperature (blue) not meeting Setpoint of 14°C during Occupied hours
• Outdoor Air Temperature (red) affected by a local source at 8:00 AM
40

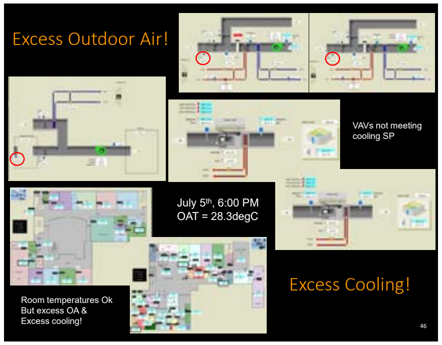

AHU1 & AHU2: SAT & OAT daily cycles August 2016
Wednesday August 17 / 2016
Supply air temperature
Outdoor air temperature
Fixed supply air temperature setpoint
• Morning pre-cooling at 5:00 AM (fan system enabled)
• Outdoor Air Temperature (red) affected by a local source at 8:00 AM
• Supply Air Temperature (blue) not meeting Setpoint of 14°C during Occupied hours
• Morning pre-cooling is not optimized: dampers are not properly synchronized
• Outdoor Air Damper should open fully (100%) at 5:00 AM & Mixed-Air Damper should fully close during morning pre-cooling to take full advantage of cool OA
41

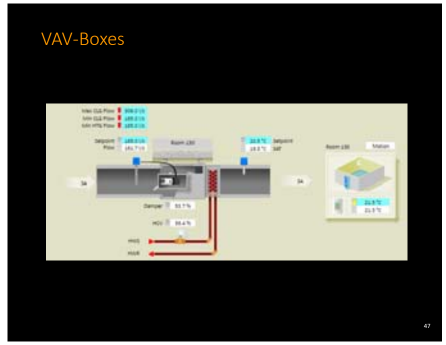

AHU1 & AHU2: SAT & OAT daily cycles August 2016
Morning pre-cooling
Outdoor Air Damper (OAD) operation
Week of August /2016
OAD should gradually close
To fully maximize cool morning
Outdoor air intake
The local heat source seem
To be affecting the closing
of the OAD
Mixed air temperature
Outdoor air temperature
42

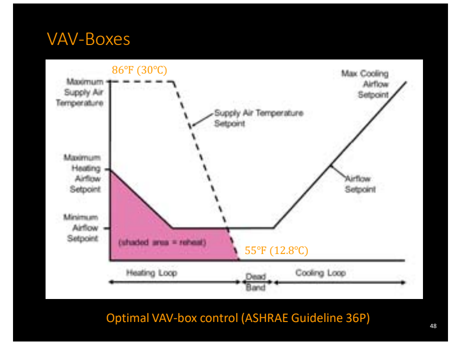

AHU1 & AHU2: SAT & OAT daily cycles Winter
Outdoor Air Damper (OAD) operation
Week of February /2017
OAD at minimum
position
Except when it
gets warmer
Mixed air temperature close to SAT
Outdoor air temperature
SAT is to cool for winter & SAT_SP reset not implemented
43

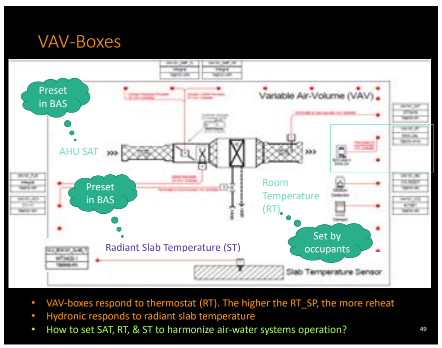

AHU1 & AHU2: SAT & OAT daily cycles Spring
Outdoor Air Damper (OAD) operation
Week of April /2017
Mixed air temperature
Outdoor Air Damper (OAD) starts opening more in Spring
Outdoor air temperature
SAT is to cool for winter & SAT_SP reset not implemented
44

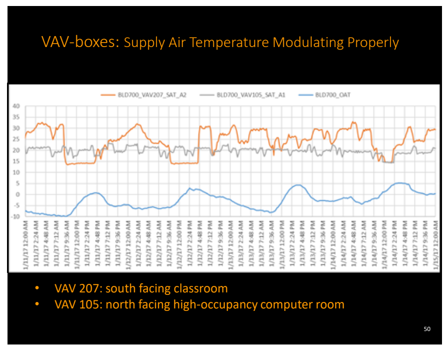

Building Pressure Control: Pressure Relief Fan
Mechanical room
setpoint is 12.5 Pa
but room is typically
depressurized
RF maintains building
pressure at setpoint
of 12.5 Pa
• Differential pressures are not trended (not possible to know % hours depressurized)
• Mechanical room is typically depressurized
• Return air for AHU1/2 comes from mechanical room, therefore mostly OA
45

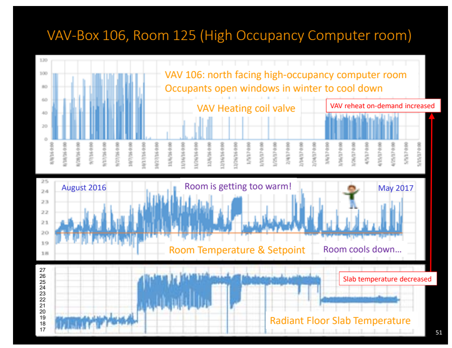

Excess Outdoor Air!
VAVs not meeting cooling SP
July 5th, 6:00 PM
OAT = 28.3degC
Excess Cooling!
Room temperatures Ok
But excess OA &
Excess cooling!
46

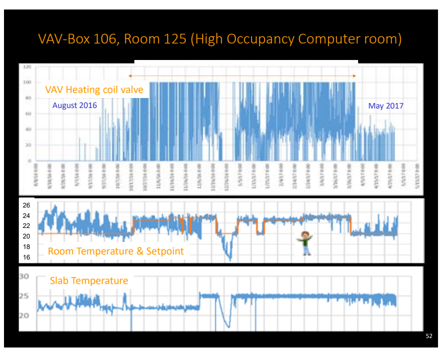

VAV-Boxes
47

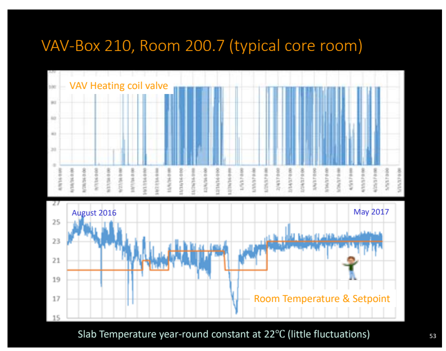

VAV-Boxes
86°F (30°C)
Maximum Supply Air Temperature
Supply Air Temperature Setpoint
Max Cooling Airflow Setpoint
Maximum Heating Airflow Setpoint
Airflow Setpoint
Minimum Airflow Setpoint
(shaded area = reheat)
55°F (12.8°C)
Heating Loop
Dead Band
Cooling Loop
Optimal VAV-box control (ASHRAE Guideline 36P)
48

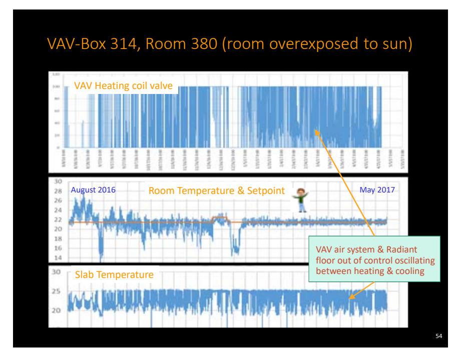

VAV-Boxes
Preset in BAS
Variable Air-Volume (VAV)
AHU SAT
Preset in BAS
Room Temperature (RT)
Set by occupants
Radiant Slab Temperature (ST)
Slab Temperature Sensor
VAV-boxes respond to thermostat (RT). The higher the RT_SP, the more reheat
Hydronic responds to radiant slab temperature
How to set SAT, RT, & ST to harmonize air-water systems operation?
49


VAV-boxes: Supply Air Temperature Modulating Properly
VAV 207: south facing classroom
VAV 105: north facing high-occupancy computer room
50

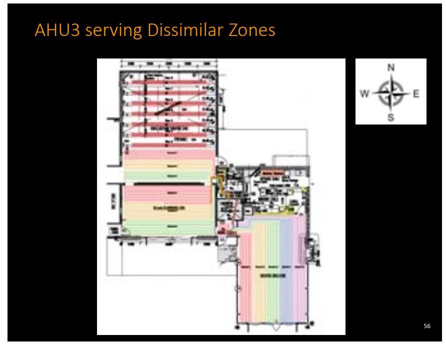

VAV-Box 106, Room 125 (High Occupancy Computer room)
VAV 106: north facing high-occupancy computer room
Occupants open windows in winter to cool down
VAV Heating coil valve
VAV reheat on-demand increased
August 2016
Room is getting too warm!
May 2017
Room Temperature & Setpoint
Room cools down...
Slab temperature decreased
Radiant Floor Slab Temperature
51

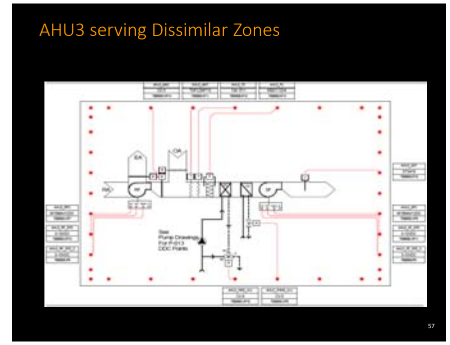

VAV-Box 106, Room 125 (High Occupancy Computer room)
VAV Heating coil valve
August 2016
May 2017
Room Temperature & Setpoint
Slab Temperature
52

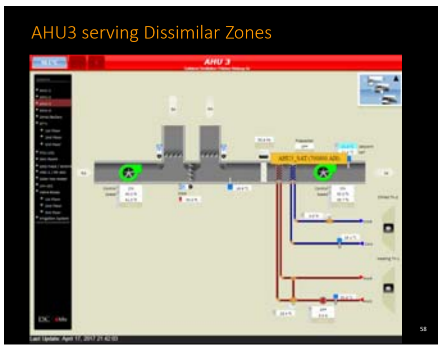

VAV-Box 210, Room 200.7 (typical core room)
VAV Heating coil valve
August 2016
May 2017
Room Temperature & Setpoint
Slab Temperature year-round constant at 22°C (little fluctuations)
53

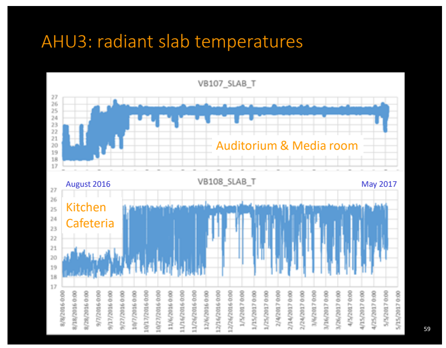

VAV-Box 314, Room 380 (room overexposed to sun)
VAV Heating coil valve
August 2016
Room Temperature & Setpoint
May 2017
VAV air system & Radiant floor out of control oscillating between heating & cooling
Slab Temperature
54

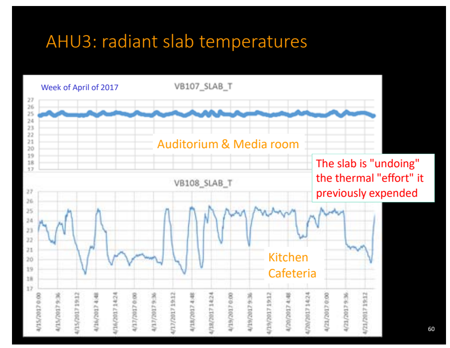

AHU3 serving Dissimilar Zones
Cafeteria: south/east/west exposed
Kitchen (core)
Auditorium (north facing)
Media room (core)
55

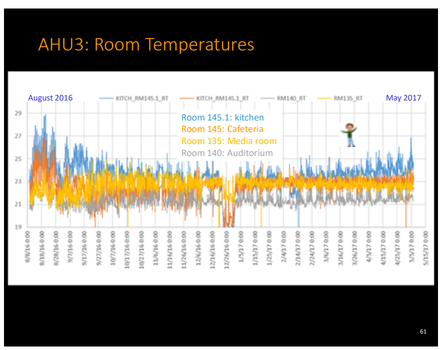

AHU3 serving Dissimilar Zones
N
W
E
S
56

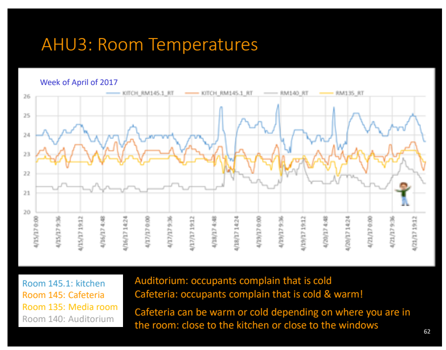

AHU3 serving Dissimilar Zones
57

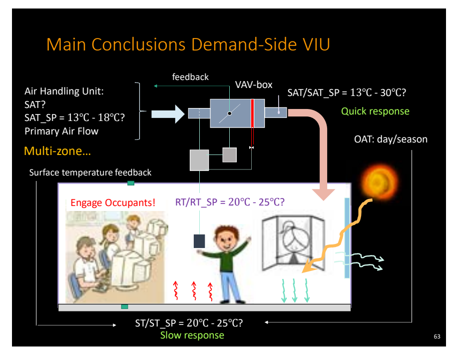

AHU3 serving Dissimilar Zones
AHU 3
58

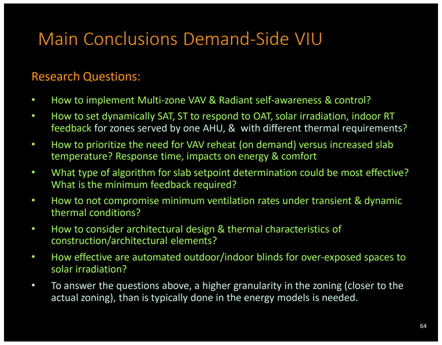

AHU3: radiant slab temperatures
VB107_SLAB_T
Auditorium & Media room
VB108_SLAB_T
August 2016
May 2017
Kitchen
Cafeteria
59

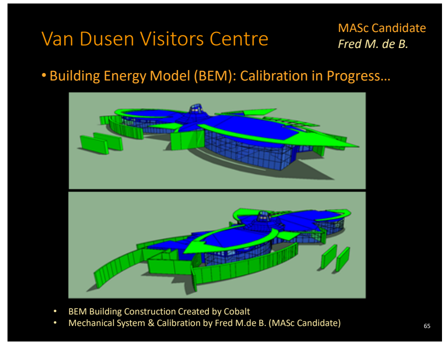

AHU3: radiant slab temperatures
Week of April of 2017
VB107_SLAB_T
Auditorium & Media room
The slab is "undoing" the thermal "effort" it previously expended
VB108_SLAB_T
Kitchen
Cafeteria
60

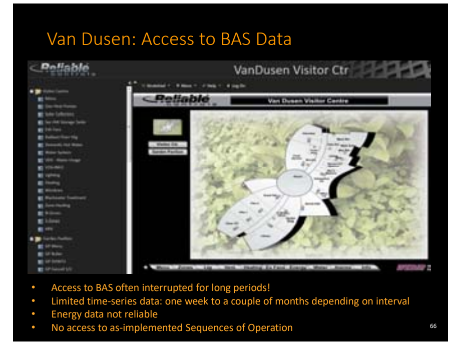

AHU3: Room Temperatures
August 2016
May 2017
Room 145.1: kitchen
Room 145: Cafeteria
Room 135: Media room
Room 140: Auditorium
61

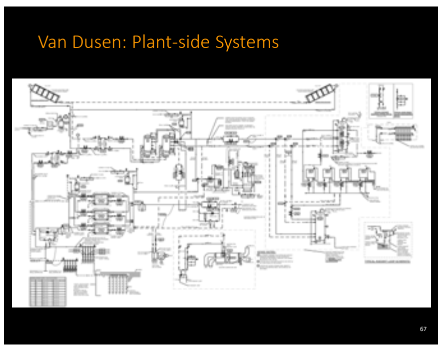

AHU3: Room Temperatures
Week of April of 2017
Room 145.1: kitchen
Room 145: Cafeteria
Room 135: Media room
Room 140: Auditorium
Auditorium: occupants complain that is cold
Cafeteria: occupants complain that is cold & warm!
Cafeteria can be warm or cold depending on where you are in the room: close to the kitchen or close to the windows
62

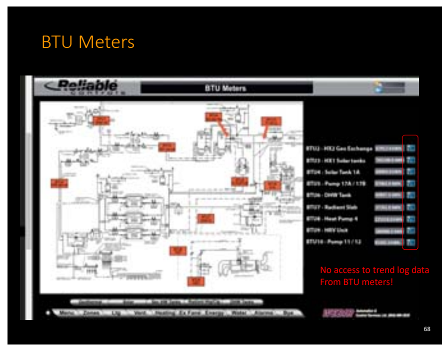

Main Conclusions Demand-Side VIU
feedback
VAV-box
Air Handling Unit:
SAT?
SAT_SP = 13°C - 18°C?
Primary Air Flow
SAT/SAT_SP = 13°C - 30°C?
Quick response
Multi-zone...
OAT: day/season
Surface temperature feedback
Engage Occupants!
RT/RT_SP = 20°C - 25°C?
ST/ST_SP = 20°C - 25°C?
Slow response
63

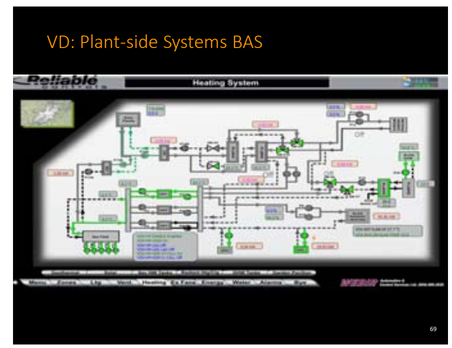

Main Conclusions Demand-Side VIU
Research Questions:
How to implement Multi-zone VAV & Radiant self-awareness & control?
How to set dynamically SAT, ST to respond to OAT, solar irradiation, indoor RT feedback for zones served by one AHU, & with different thermal requirements?
How to prioritize the need for VAV reheat (on demand) versus increased slab temperature? Response time, impacts on energy & comfort
What type of algorithm for slab setpoint determination could be most effective? What is the minimum feedback required?
How to not compromise minimum ventilation rates under transient & dynamic thermal conditions?
How to consider architectural design & thermal characteristics of construction/architectural elements?
How effective are automated outdoor/indoor blinds for over-exposed spaces to solar irradiation?
To answer the questions above, a higher granularity in the zoning (closer to the actual zoning), than is typically done in the energy models is needed.
64

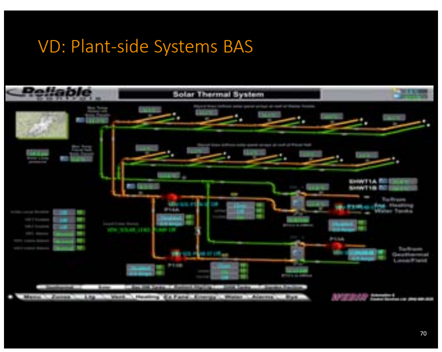

Van Dusen Visitors Centre
MASc Candidate
Fred M. de B.
Building Energy Model (BEM): Calibration in Progress...
BEM Building Construction Created by Cobalt
Mechanical System & Calibration by Fred M.de B. (MASc Candidate)
65

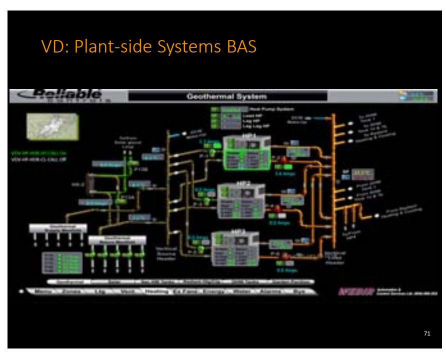

Van Dusen: Access to BAS Data
VanDusen Visitor Ctr
Access to BAS often interrupted for long periods!
Limited time-series data: one week to a couple of months depending on interval
Energy data not reliable
No access to as-implemented Sequences of Operation
66

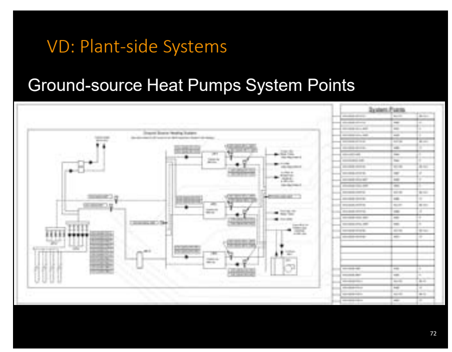

Van Dusen: Plant-side Systems
67

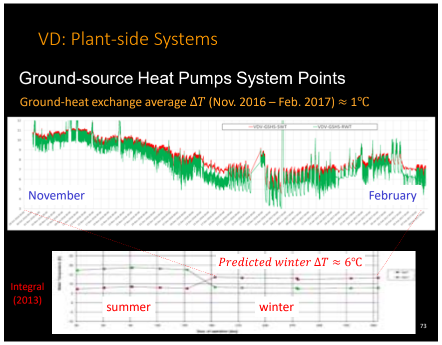

BTU Meters
BTU Meters
No access to trend log data
From BTU meters!
68

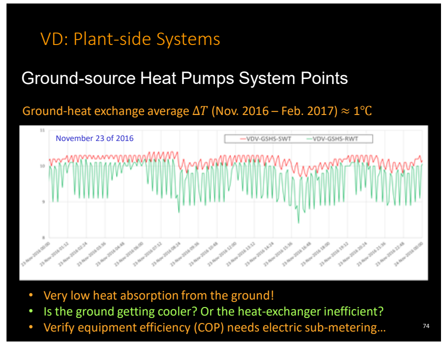

VD: Plant-side Systems BAS
Heating System
69

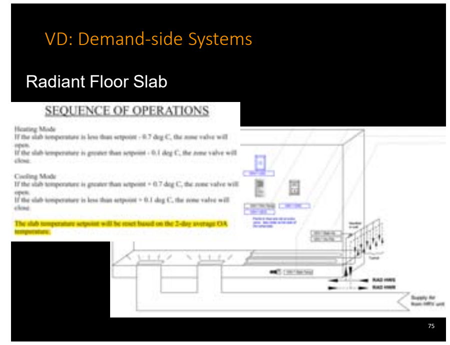

VD: Plant-side Systems BAS
Solar Thermal System
70

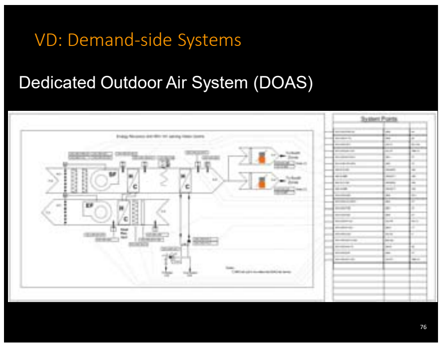

VD: Plant-side Systems BAS
Geothermal System
71

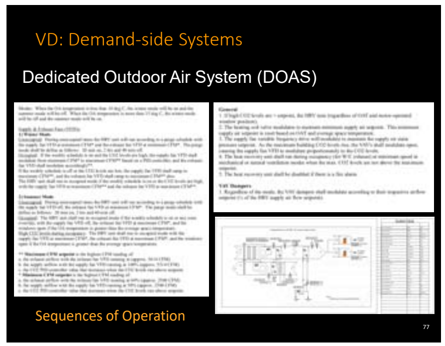

VD: Plant-side Systems
Ground-source Heat Pumps System Points
72

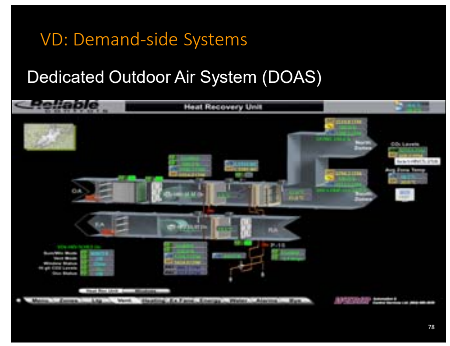

VD: Plant-side Systems
Ground-source Heat Pumps System Points
Ground-heat exchange average ΔT (Nov. 2016 – Feb. 2017) ≈ 1°C
November
February
Predicted winter ΔT ≈ 6°C
Integral (2013)
summer
winter
73

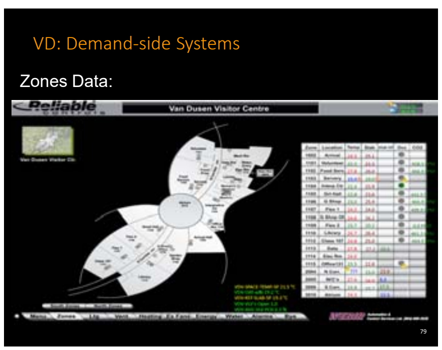

VD: Plant-side Systems
Ground-source Heat Pumps System Points
Ground-heat exchange average ΔT (Nov. 2016 – Feb. 2017) ≈ 1°C
November 23 of 2016
• Very low heat absorption from the ground!
• Is the ground getting cooler? Or the heat-exchanger inefficient?
• Verify equipment efficiency (COP) needs electric sub-metering…
74

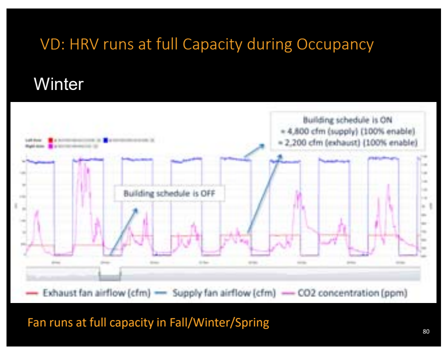

VD: Demand-side Systems
Radiant Floor Slab
SEQUENCE OF OPERATIONS
75

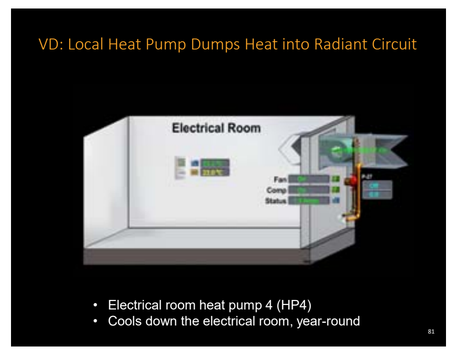

VD: Demand-side Systems
Dedicated Outdoor Air System (DOAS)
76


VD: Demand-side Systems
Dedicated Outdoor Air System (DOAS)
Sequences of Operation
77

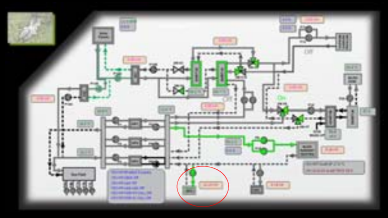

VD: Demand-side Systems
Dedicated Outdoor Air System (DOAS)
Reliable
Heat Recovery Unit
78


VD: Demand-side Systems
Zones Data:
Reliable
Van Dusen Visitor Centre
79


VD: HRV runs at full Capacity during Occupancy
Winter
Building schedule is ON
≈ 4,800 cfm (supply) (100% enable)
≈ 2,200 cfm (exhaust) (100% enable)
Building schedule is OFF
Exhaust fan airflow (cfm)
Supply fan airflow (cfm)
CO2 concentration (ppm)
Fan runs at full capacity in Fall/Winter/Spring
80


VD: Local Heat Pump Dumps Heat into Radiant Circuit
Electrical Room
Fan
Comp
Status
• Electrical room heat pump 4 (HP4)
• Cools down the electrical room, year-round
81

VD: Local Heat Pump Dumps Heat into Radiant Circuit

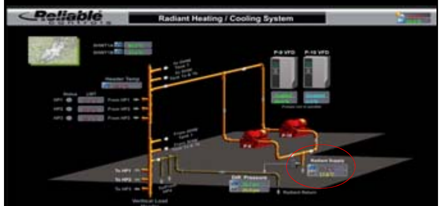


- Electrical room heat pump 4 (HP4)
- Cools down the electrical room, year-round

82

VD: Local Heat Pump Dumps Heat into Radiant Circuit

Summer



- Radiant floors dissipate heat-pump heat into the spaces in summer!

83

VD: Local Heat Pump Dumps Heat into Radiant Circuit

Summer

- Rooms in north zones become too hot!
- Probably, the HP4 is dissipating its heat into the north zones

- South zones are cooler!

84

VD: Natural Ventilation during Summer

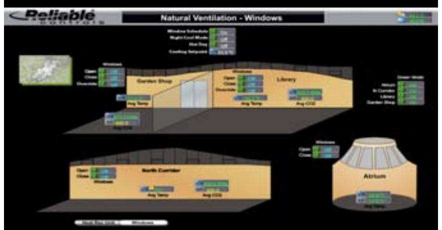
Lack of Connectivity Between Spaces & Chimney Bypass

(Cobalt, 2009)

How effective is natural ventilation in cooling?

85

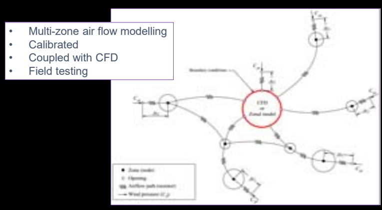
VD: Natural Ventilation during Summer



86

VD: Natural Ventilation during Summer

Lack of Connectivity Between Spaces & Chimney Bypass

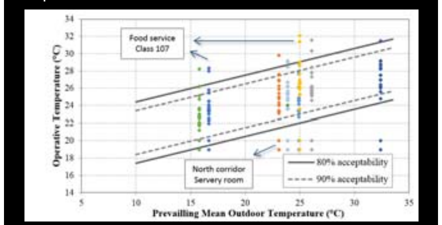


How effective is natural ventilation in cooling?

87

VD: Natural Ventilation during Summer

Spaces achieve Thermal Comfort



Adaptive Thermal Comfort Model (ASHRAE Standard 55-2013)

88

Possible Causes for Performance Deterioration & Opportunities for Operational Optimization

Possible Issues	Proposed Solutions
1. System design and operational anomalies	Fixing these anomalies should be a top priority
2. Lack of systems operational optimization	Night setbacks, early pre-cool, early warm-up, optimum start/stop, economizer control, set point resets
3. Inadequate ventilation year-round: either excessive or poor at the building & room levels.	Modulate the operation of the HRV-VFD fans, as well as the zone VAV dampers. Implement improve CO2-based demand-controlled ventilation
4. Inadequate room air distribution through displacement ventilation	Optimize the supply air temperature set point for the HRV to maintain a supply air temperature 3°C to 5°C below the average room temperature
5. Supply air temperature set point is not optimized to with outdoor and indoor feedback HRV year-round	Implement supply air temperature set point reset logic
6. Hydronic system operation may need fine tuning	Re-calibrate the BTU meters to verify the hydronic energy flows and optimize hydronic performance
7. Room-level radiant is not optimized	Individual fine-tuning of slab set point temperatures and resets based on outdoor temperature and indoor feedback

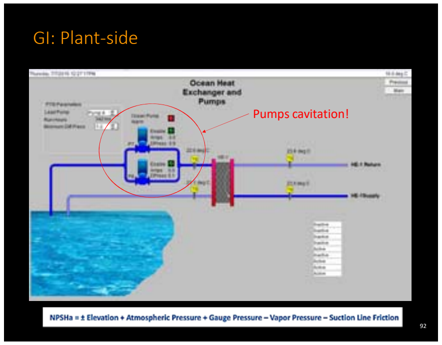
VD: Displacement Ventilation

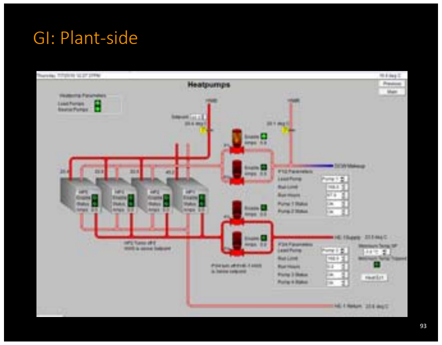
Warm Supply Air Temperature
for Displacement Ventilation

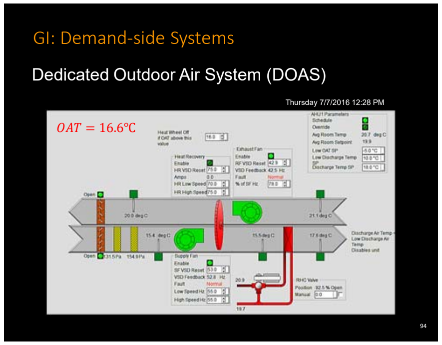
- Displacement Ventilation: Supply Air Temperature must be 3℃ to 5℃ cooler than air room temperature
- However, in Van Dusen SAT is often warmer than the room temperature in summer & in shoulder seasons (not in winter)
- Furthermore, radiant floor heating compounds to the problem by warming up faster the air at the floor level
- Consequences:
  - Reduced effectiveness of displacement ventilation… To be verified
  - Poor indoor air quality… To be verified

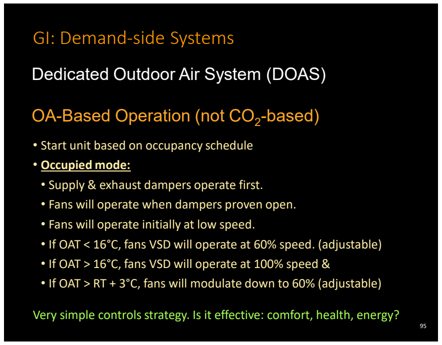
90

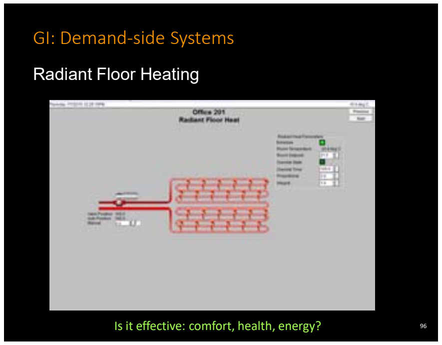

Gulf Islands:
Parks Canada Operations Centre
MEng Candidate
Armando
Supervised by: Bo Li
• Building Energy Model: Model Calibration in Progress...
91

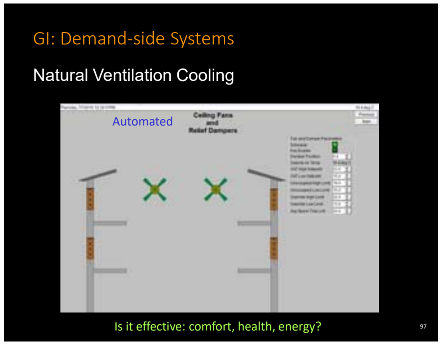

GI: Plant-side
Ocean Heat Exchanger and Pumps
Pumps cavitation!
NPSHa = ± Elevation + Atmospheric Pressure + Gauge Pressure – Vapor Pressure – Suction Line Friction
92

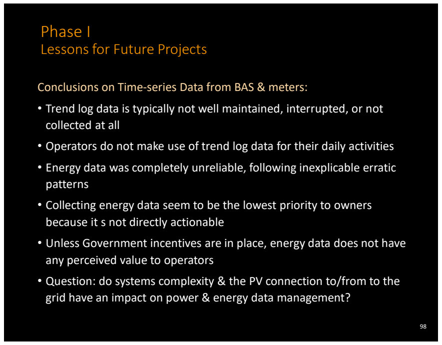

GI: Plant-side
Heatpumps
93

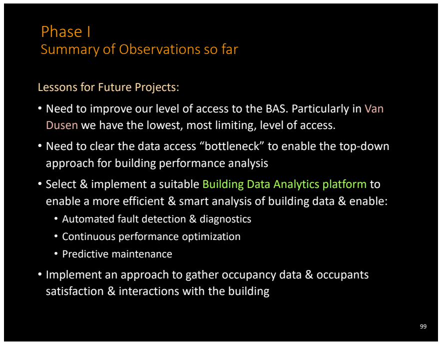

GI: Demand-side Systems
Dedicated Outdoor Air System (DOAS)
Thursday 7/7/2016 12:28 PM
OAT = 16.6°C
94

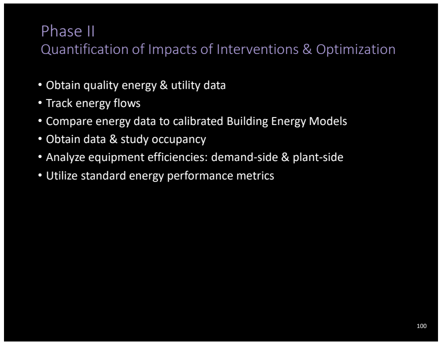

GI: Demand-side Systems
Dedicated Outdoor Air System (DOAS)
OA-Based Operation (not CO_2-based)
• Start unit based on occupancy schedule
• Occupied mode:
• Supply & exhaust dampers operate first.
• Fans will operate when dampers proven open.
• Fans will operate initially at low speed.
• If OAT < 16°C, fans VSD will operate at 60% speed. (adjustable)
• If OAT > 16°C, fans VSD will operate at 100% speed &
• If OAT > RT + 3°C, fans will modulate down to 60% (adjustable)
Very simple controls strategy. Is it effective: comfort, health, energy?
95

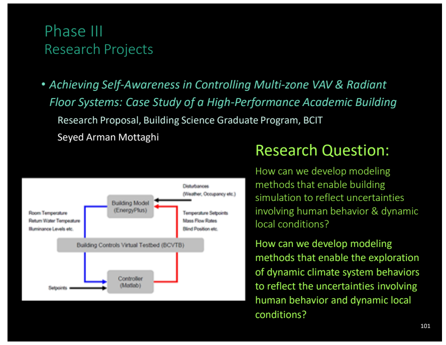

GI: Demand-side Systems
Radiant Floor Heating
Office 201
Radiant Floor Heat
Is it effective: comfort, health, energy?
96

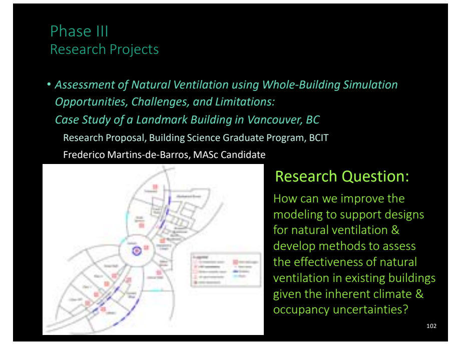

GI: Demand-side Systems
Natural Ventilation Cooling
Automated
Ceiling Fans and Relief Dampers
Is it effective: comfort, health, energy?
97


Phase I
Lessons for Future Projects
Conclusions on Time-series Data from BAS & meters:
• Trend log data is typically not well maintained, interrupted, or not collected at all
• Operators do not make use of trend log data for their daily activities
• Energy data was completely unreliable, following inexplicable erratic patterns
• Collecting energy data seem to be the lowest priority to owners because it s not directly actionable
• Unless Government incentives are in place, energy data does not have any perceived value to operators
• Question: do systems complexity & the PV connection to/from to the grid have an impact on power & energy data management?
98


Phase I
Summary of Observations so far
Lessons for Future Projects:
• Need to improve our level of access to the BAS. Particularly in Van Dusen we have the lowest, most limiting, level of access.
• Need to clear the data access “bottleneck” to enable the top-down approach for building performance analysis
• Select & implement a suitable Building Data Analytics platform to enable a more efficient & smart analysis of building data & enable:
• Automated fault detection & diagnostics
• Continuous performance optimization
• Predictive maintenance
• Implement an approach to gather occupancy data & occupants satisfaction & interactions with the building
99


Phase II
Quantification of Impacts of Interventions & Optimization
• Obtain quality energy & utility data
• Track energy flows
• Compare energy data to calibrated Building Energy Models
• Obtain data & study occupancy
• Analyze equipment efficiencies: demand-side & plant-side
• Utilize standard energy performance metrics
100


Phase III
Research Projects
• Achieving Self-Awareness in Controlling Multi-zone VAV & Radiant Floor Systems: Case Study of a High-Performance Academic Building
Research Proposal, Building Science Graduate Program, BCIT
Seyed Arman Mottaghi
Disturbances (Weather, Occupancy etc.)
Building Model (EnergyPlus)
Room Temperature
Return Water Tempeature
Illuminance Levels etc.
Temperature Setpoints
Mass Flow Rates
Blind Position etc.
Building Controls Virtual Testbed (BCVTB)
Controller (Matlab)
Setpoints
Research Question:
How can we develop modeling methods that enable building simulation to reflect uncertainties involving human behavior & dynamic local conditions?
How can we develop modeling methods that enable the exploration of dynamic climate system behaviors to reflect the uncertainties involving human behavior and dynamic local conditions?
101


Phase III
Research Projects
• Assessment of Natural Ventilation using Whole-Building Simulation Opportunities, Challenges, and Limitations: Case Study of a Landmark Building in Vancouver, BC
Research Proposal, Building Science Graduate Program, BCIT
Frederico Martins-de-Barros, MASc Candidate
Research Question:
How can we improve the modeling to support designs for natural ventilation & develop methods to assess the effectiveness of natural ventilation in existing buildings given the inherent climate & occupancy uncertainties?
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