Prism
ENGINEERING

Mining for Energy Efficiency – Unlocking the Power of Data

Peak Performance: An Express Summit Series on High Performance Buildings

BUILDEX Express

Thursday November 3rd, 2016 11:00 am to 12:00 pm

Introductions

Prism ENGINEERING 25 YEARS

saving you energy

Prism Engineering provides consulting services to address technical, behavioural and organizational aspects of Energy Management

We design and implement cost effective approaches to address comfort, efficiency and reliability.

Introduction to your Presenter

Robert Greenwald

25 years of energy management experience, including:

- developing **strategic energy plans**,
- determining **energy savings opportunities**, designing building upgrades, setting up energy monitoring programs,
- acting as an **Energy Coach**, and
- supporting **cultural change** through training and engagement programs.

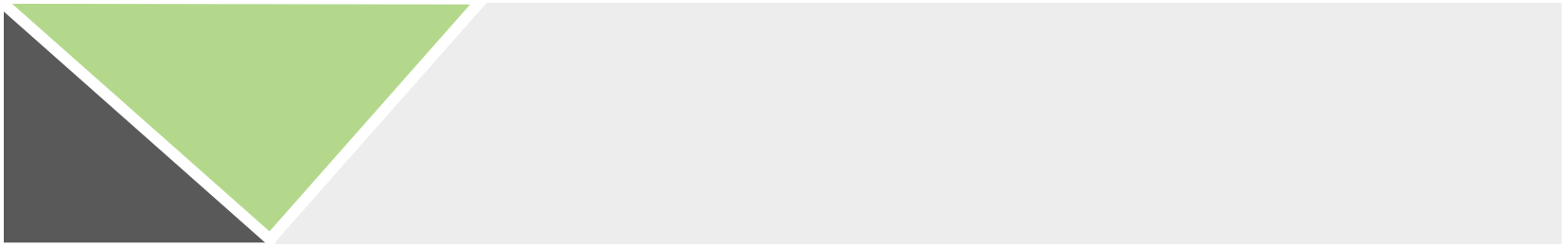
Robert has a genuine passion for training and has facilitated over 200 energy management workshops.

Objective

Optimize HVAC Operations

METHODOLOGY:

Use analytics on data available from our building control system (DDC) to drive action

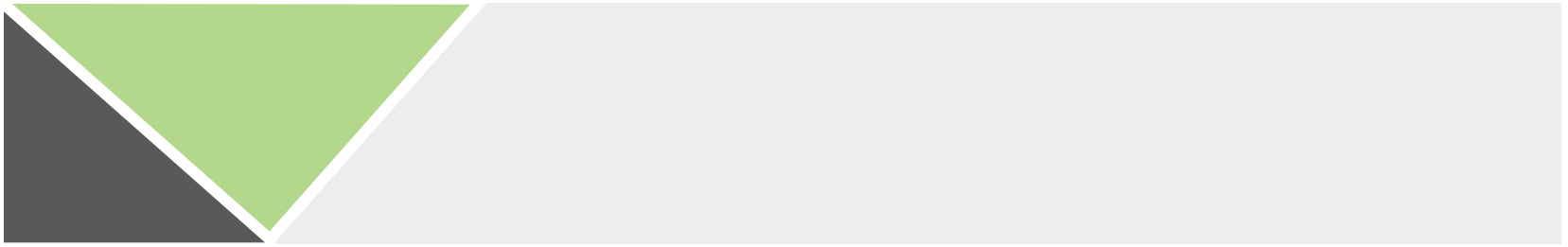


Agenda

1. Traditional Approach: Using Trend Logs
2. Enhanced Analytics to Understand Operations
    - Find savings
    - Commission new equipment
    - Identify O&M issues
3. Verify Equipment Efficiency
4. Use Energy Information to flag opportunities
5. Automated Fault Detection (FDD)

> **7 "Situations"** will be presented demonstrating these approaches

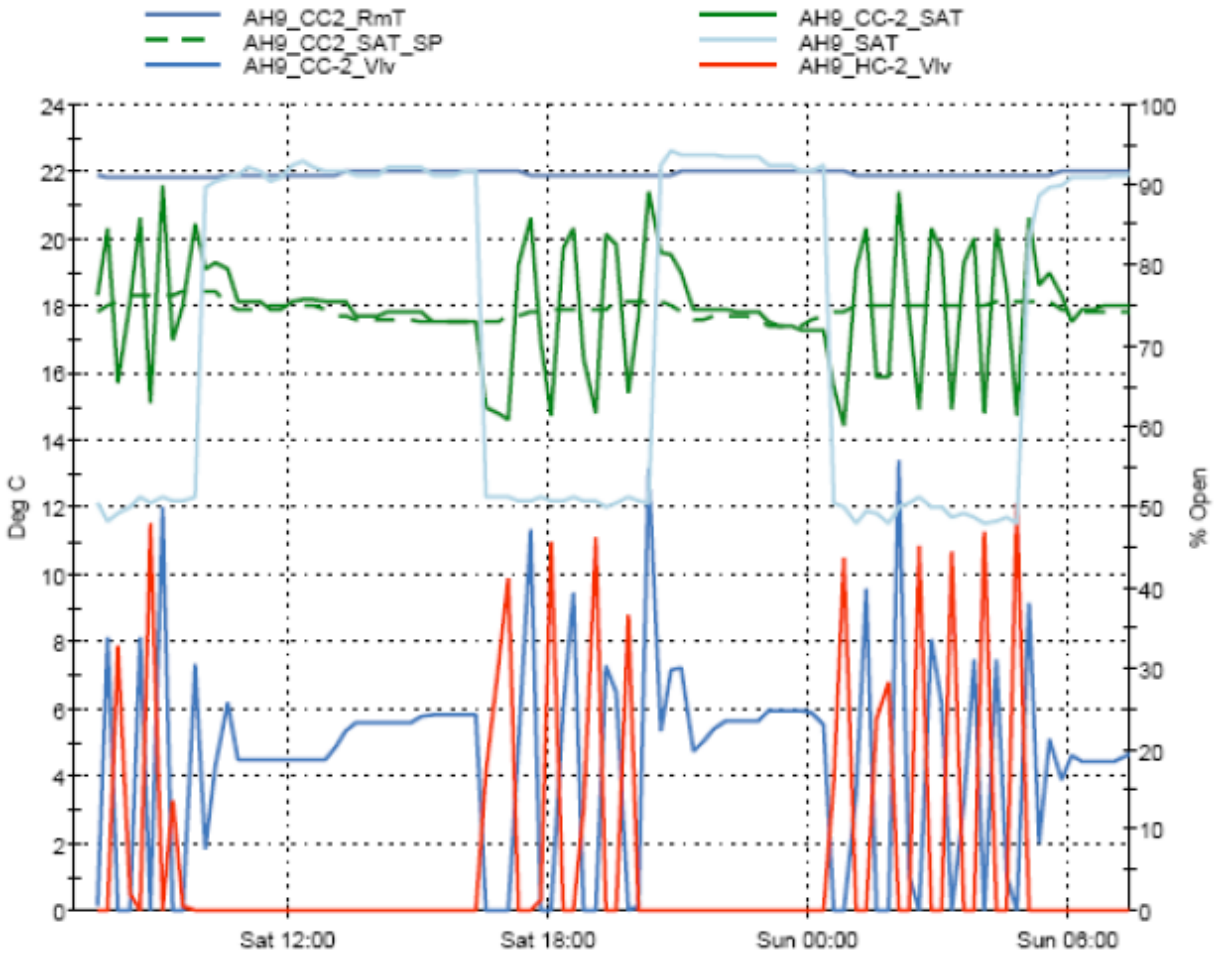
TRADITIONAL DATA ANALYTICS TO TROUBLESHOOT: TREND LOGS



Can be Applied to Most Sequence of Operations

- Feedback and Reset Temperatures
- Feedback and Reset Static Pressure
- Damper controls
- Simultaneous Heating and Cooling
- Shut down pumps
- Optimize VAV Operation

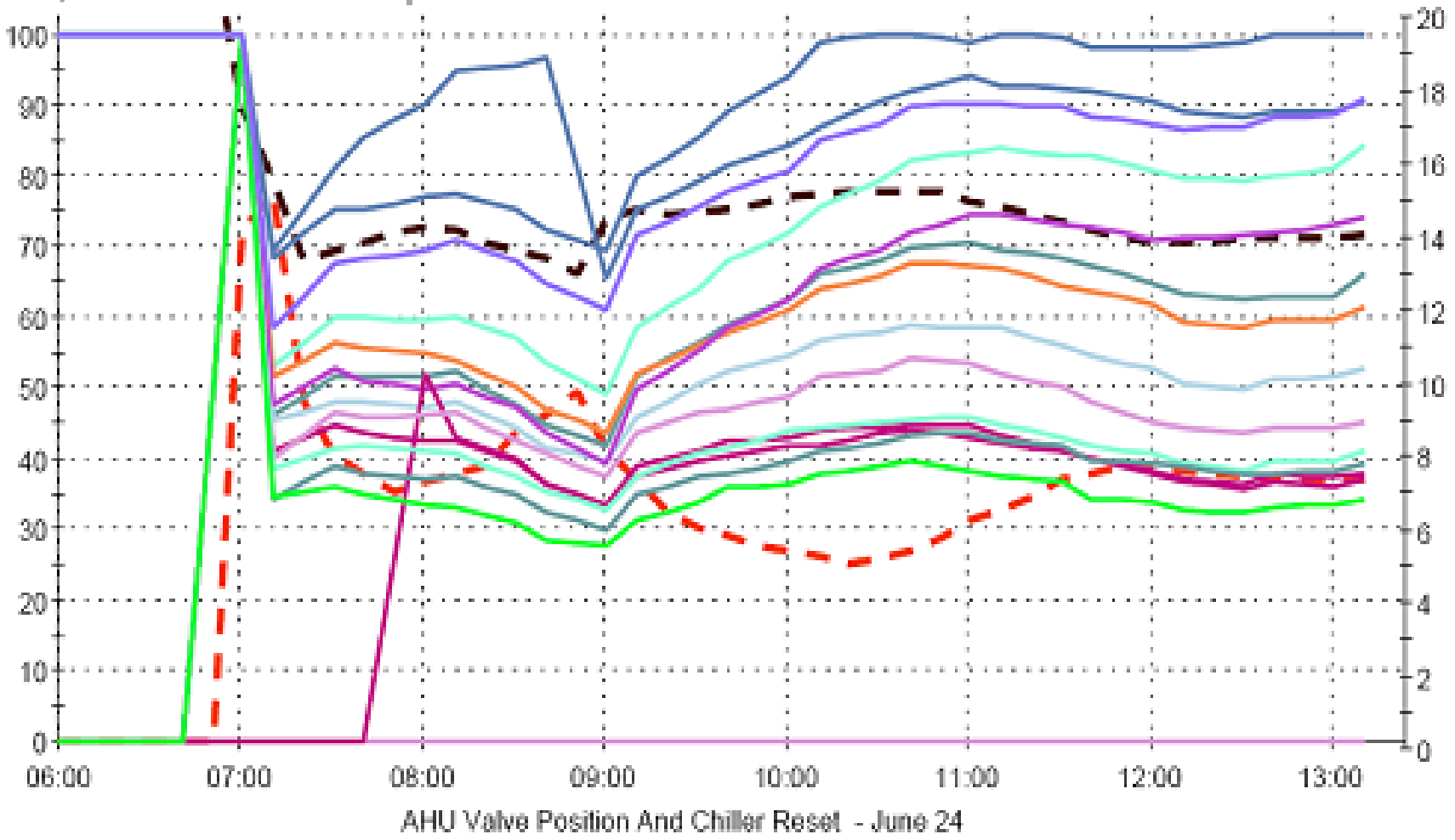
Valves Cycling



- Valves commanded based on a PID loop
- Improper settings of Proportional & Integral parameters results in valves cycling
- May result in comfort complaints & energy waste

Optimize Supply Water Temperature

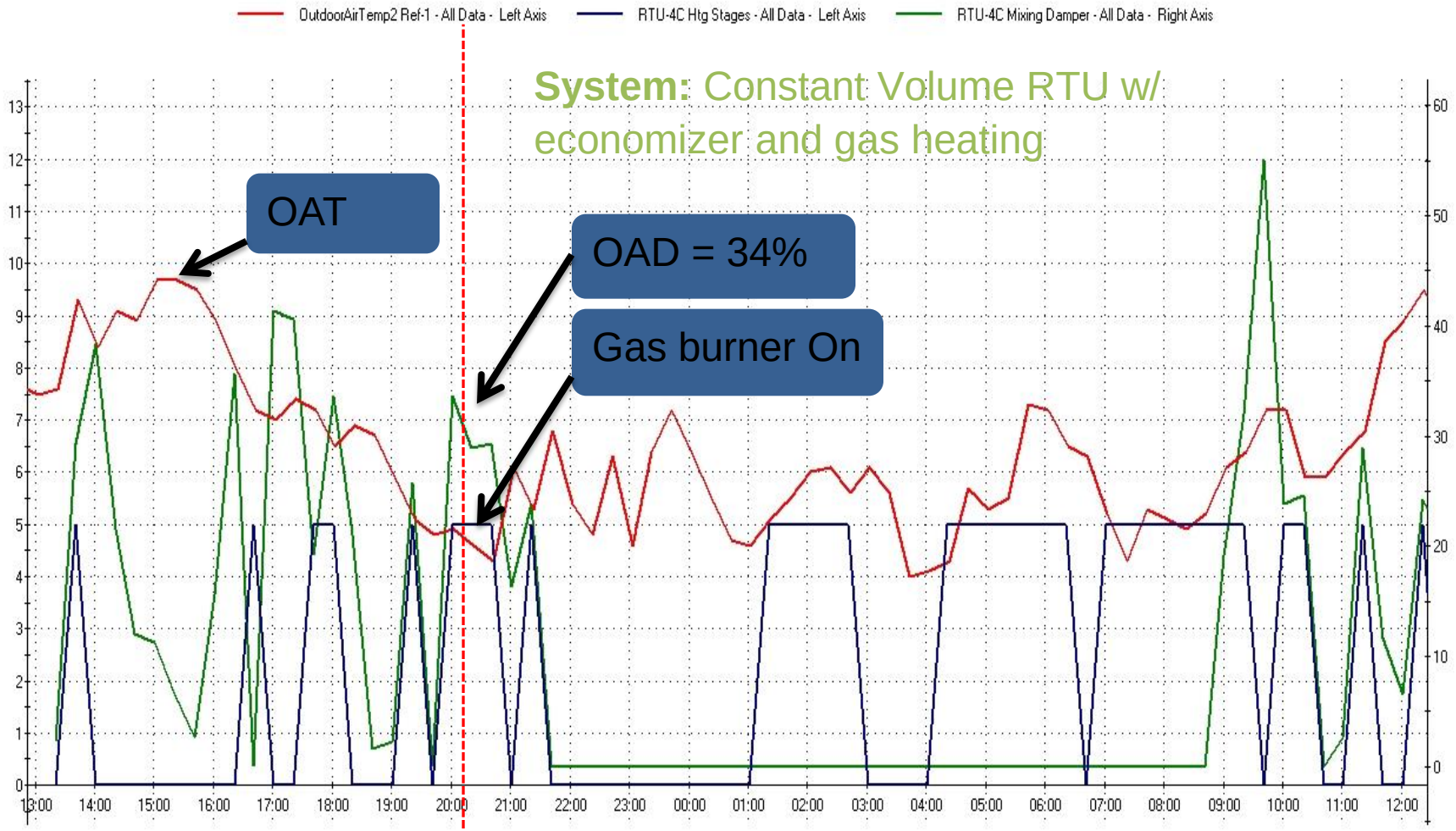
AHU cooling coil valves on each floor for a high rise building w/ central chiller plant



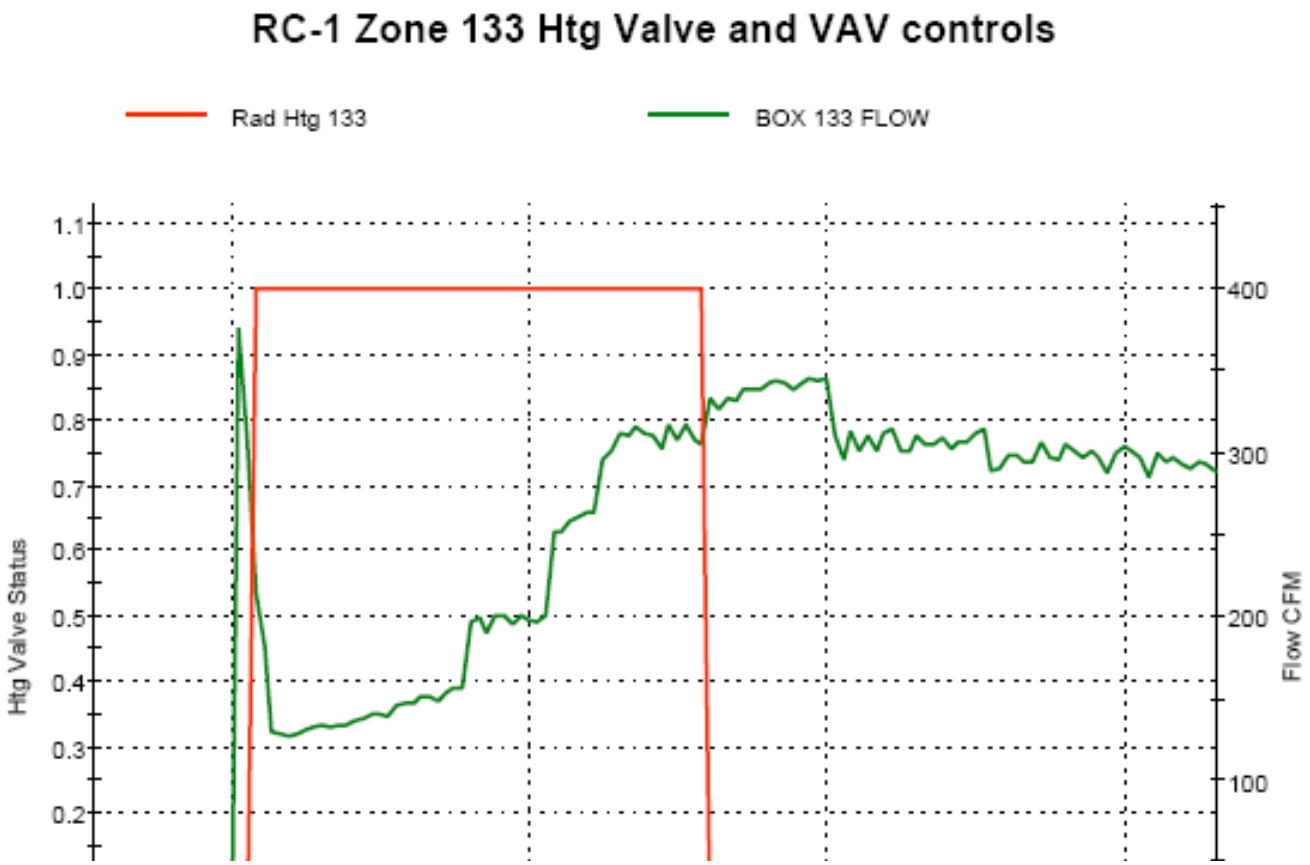
Problem: low chilled water supply temperature

Solution: reset based on CCV position

Minimum Damper Position in Heating



Zone Controls (VAV with Heating)



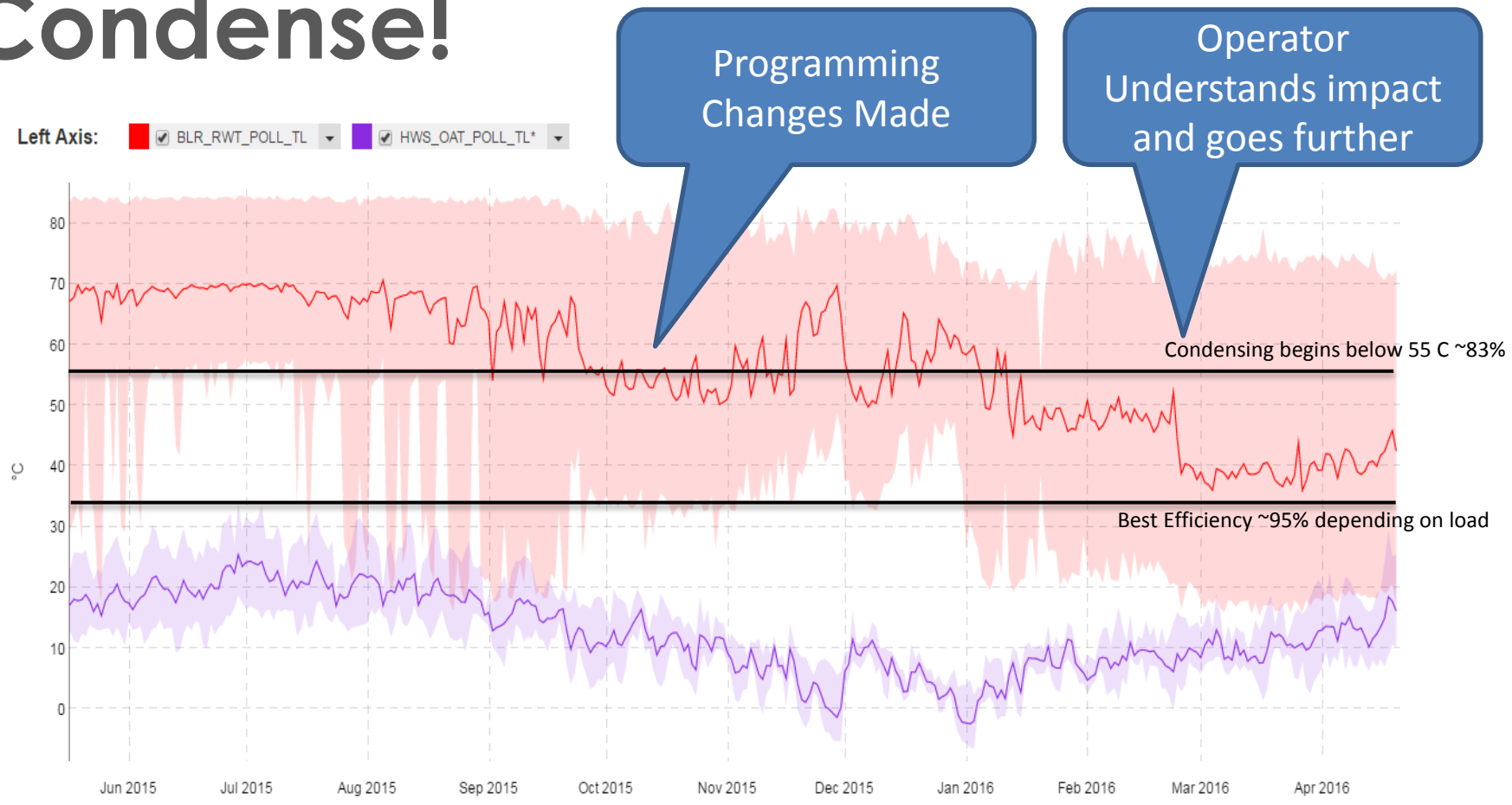
Problem:

Simultaneous heating and cooling during occupied periods

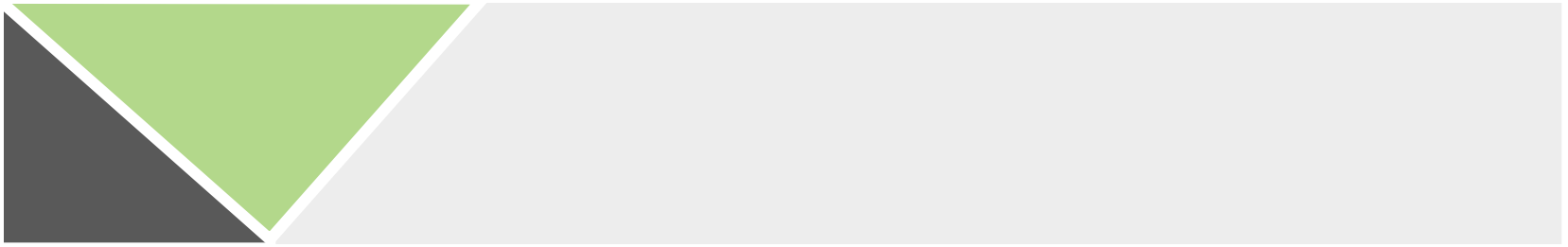
Solution:

Revise the code to modulate the VAV damper to the minimum position during occupied periods prior to cycling the radiant panel valve.

Get Condensing Boilers to Condense!



ENHANCED ANALYTICS:
The power of data in understanding operations and identifying savings

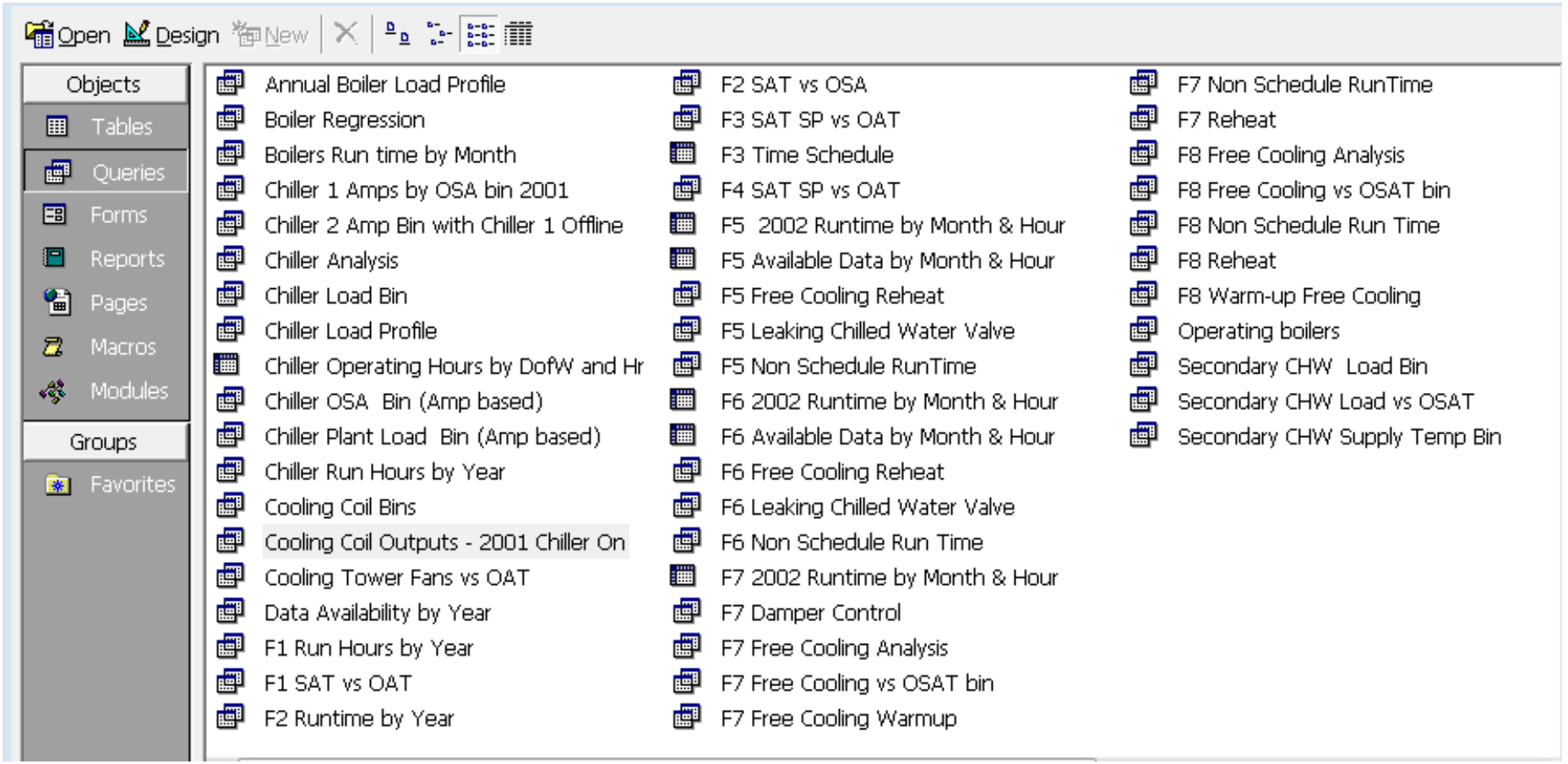


Situation 1:
Evaluating Savings Opportunities

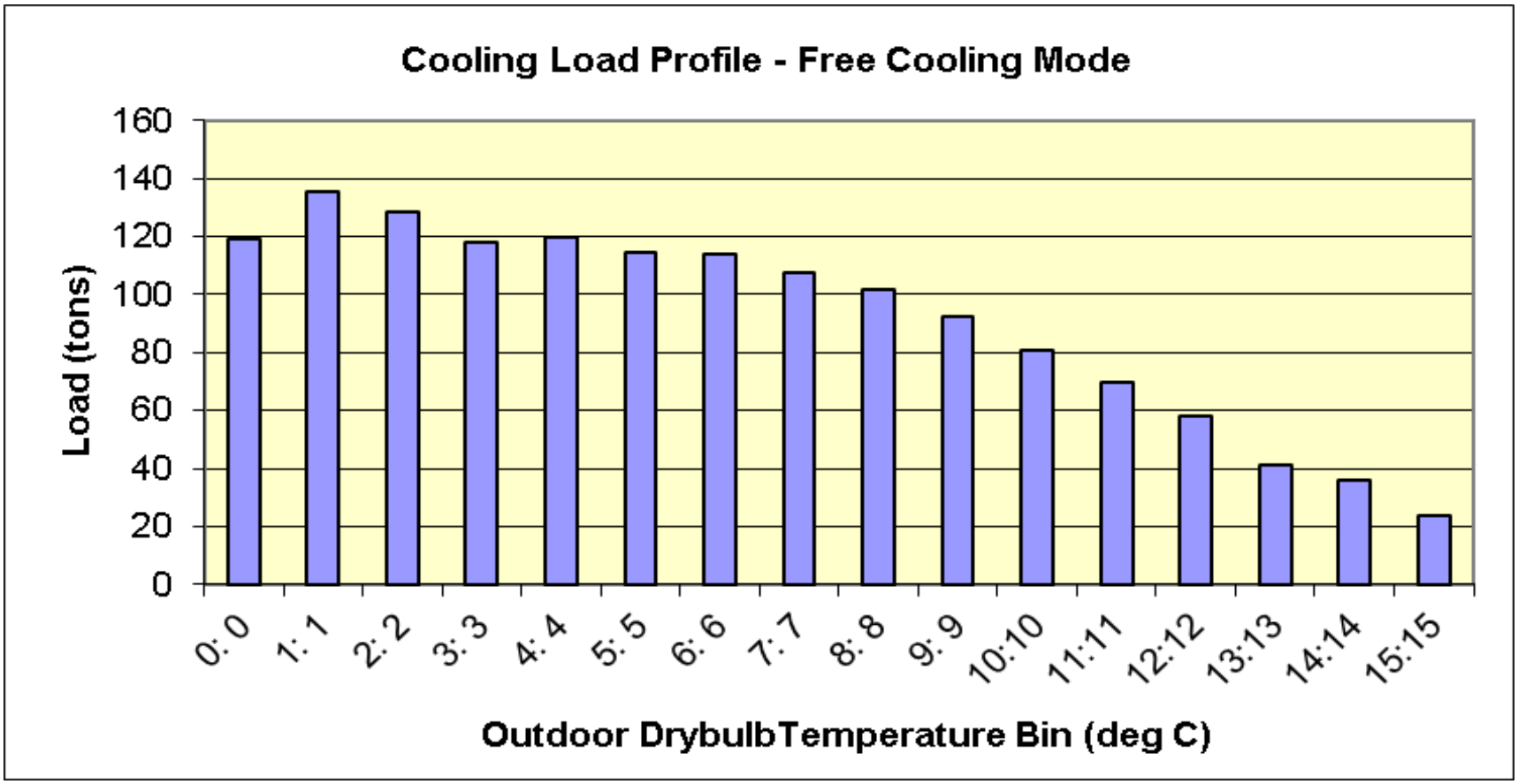
High Rise Office Tower in Vancouver

- Wanted to understand what was going on
- 3 years of 15 minute data available
- Imported data to relational database
  - Wrote queries
  - Carried out analytics

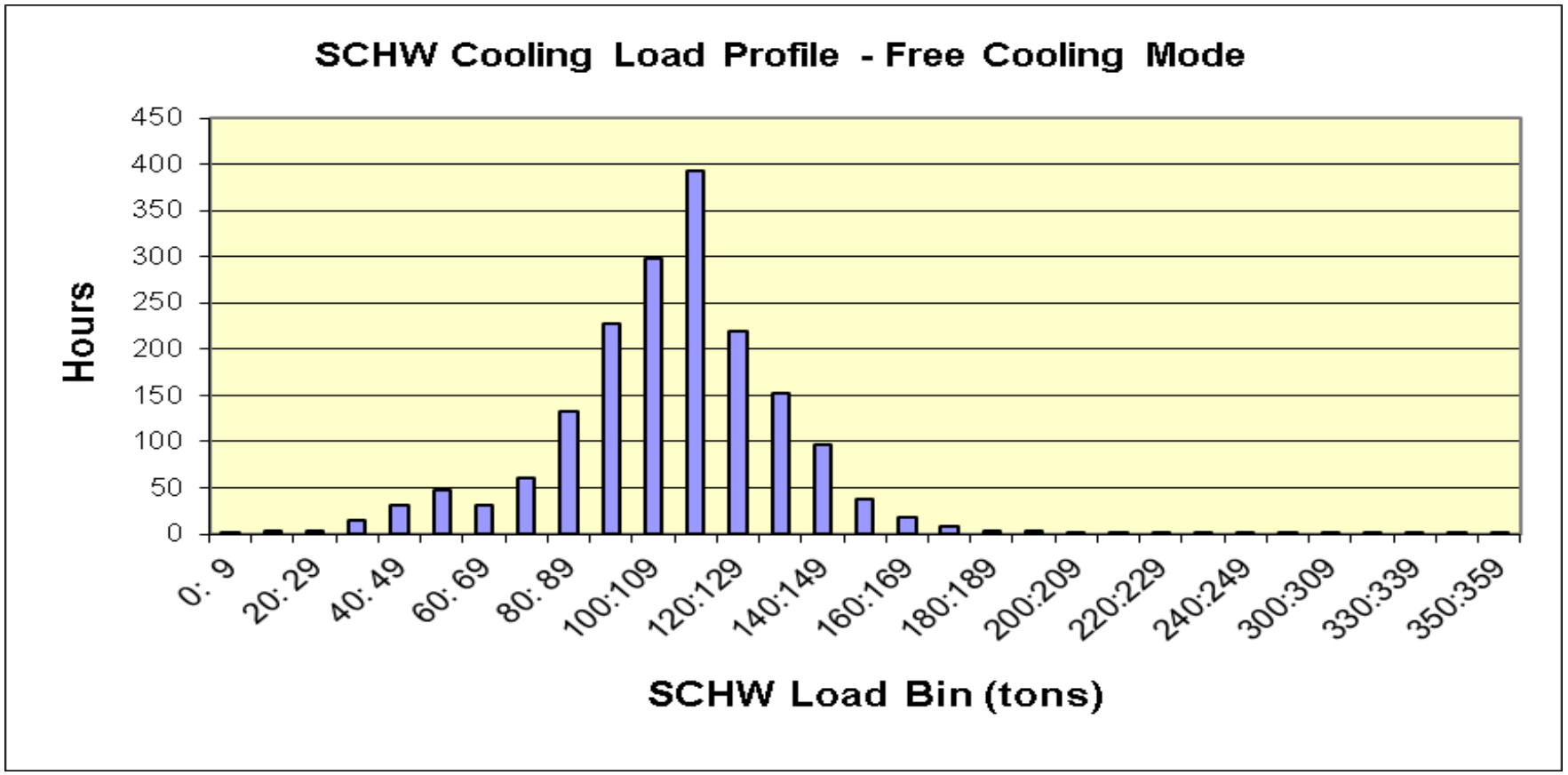
MS Access


Open
Design
New
Objects
Tables
Queries
Forms
Reports
Pages
Macros
Modules
Groups
Favorites
Annual Boiler Load Profile
Boiler Regression
Boilers Run time by Month
Chiller 1 Amps by OSA bin 2001
Chiller 2 Amp Bin with Chiller 1 Offline
Chiller Analysis
Chiller Load Bin
Chiller Load Profile
Chiller Operating Hours by DofW and Hr
Chiller OSA Bin (Amp based)
Chiller Plant Load Bin (Amp based)
Chiller Run Hours by Year
Cooling Coil Bins
Cooling Coil Outputs - 2001 Chiller On
Cooling Tower Fans vs OAT
Data Availability by Year
F1 Run Hours by Year
F1 SAT vs OAT
F2 Runtime by Year
F2 SAT vs OSA
F3 SAT SP vs OAT
F3 Time Schedule
F4 SAT SP vs OAT
F5 2002 Runtime by Month & Hour
F5 Available Data by Month & Hour
F5 Free Cooling Reheat
F5 Leaking Chilled Water Valve
F5 Non Schedule RunTime
F6 2002 Runtime by Month & Hour
F6 Available Data by Month & Hour
F6 Free Cooling Reheat
F6 Leaking Chilled Water Valve
F6 Non Schedule Run Time
F7 2002 Runtime by Month & Hour
F7 Damper Control
F7 Free Cooling Analysis
F7 Free Cooling vs OSAT bin
F7 Free Cooling Warmup
F7 Non Schedule RunTime
F7 Reheat
F8 Free Cooling Analysis
F8 Free Cooling vs OSAT bin
F8 Non Schedule Run Time
F8 Reheat
F8 Warm-up Free Cooling
Operating boilers
Secondary CHW Load Bin
Secondary CHW Load vs OSAT
Secondary CHW Supply Temp Bin

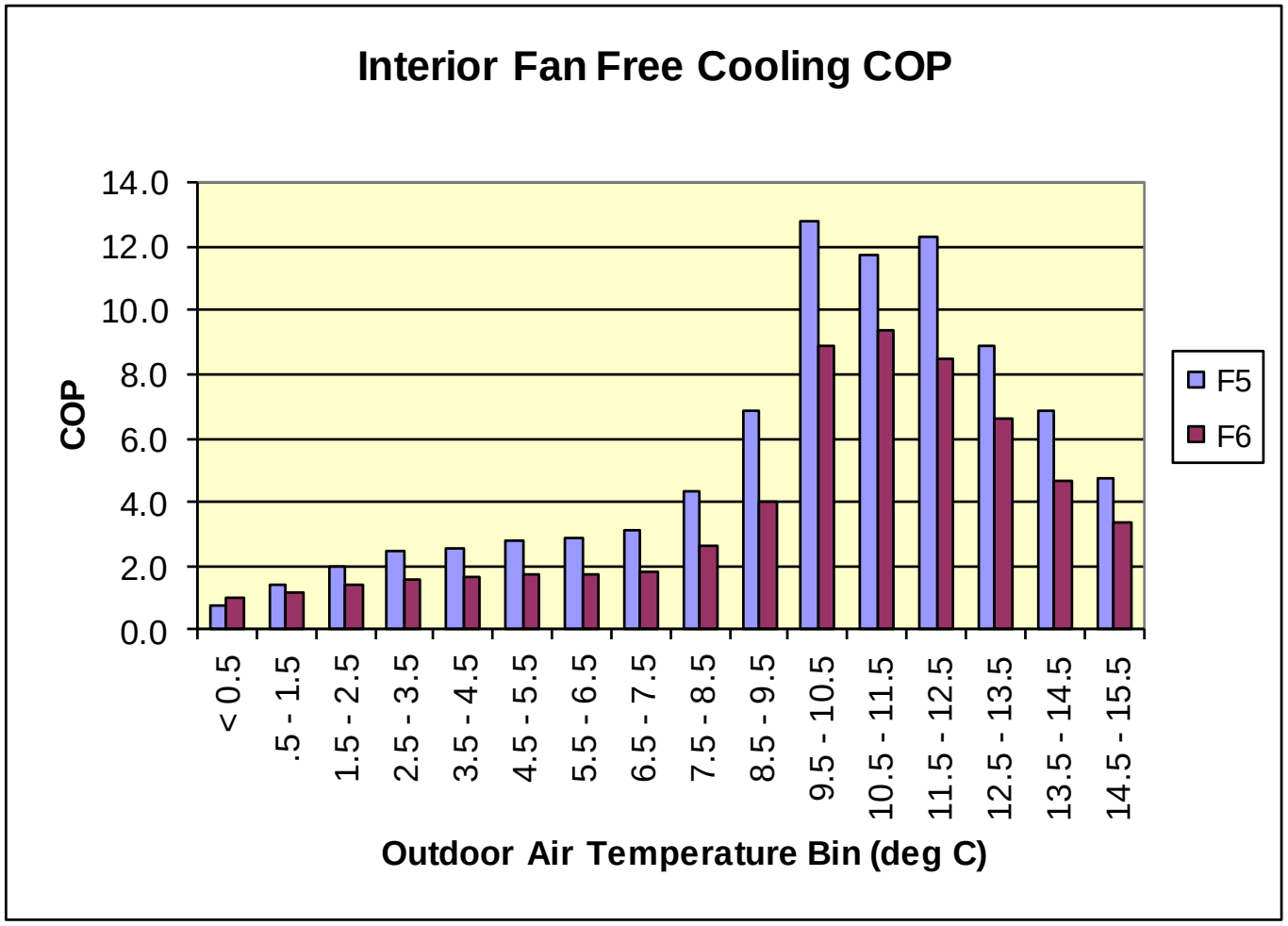
Overlap of Fan System Heating and Induction Cooling



Analytics Provides Actual Profile



“Efficiency” (COP) at Each Temperature Bin



Results

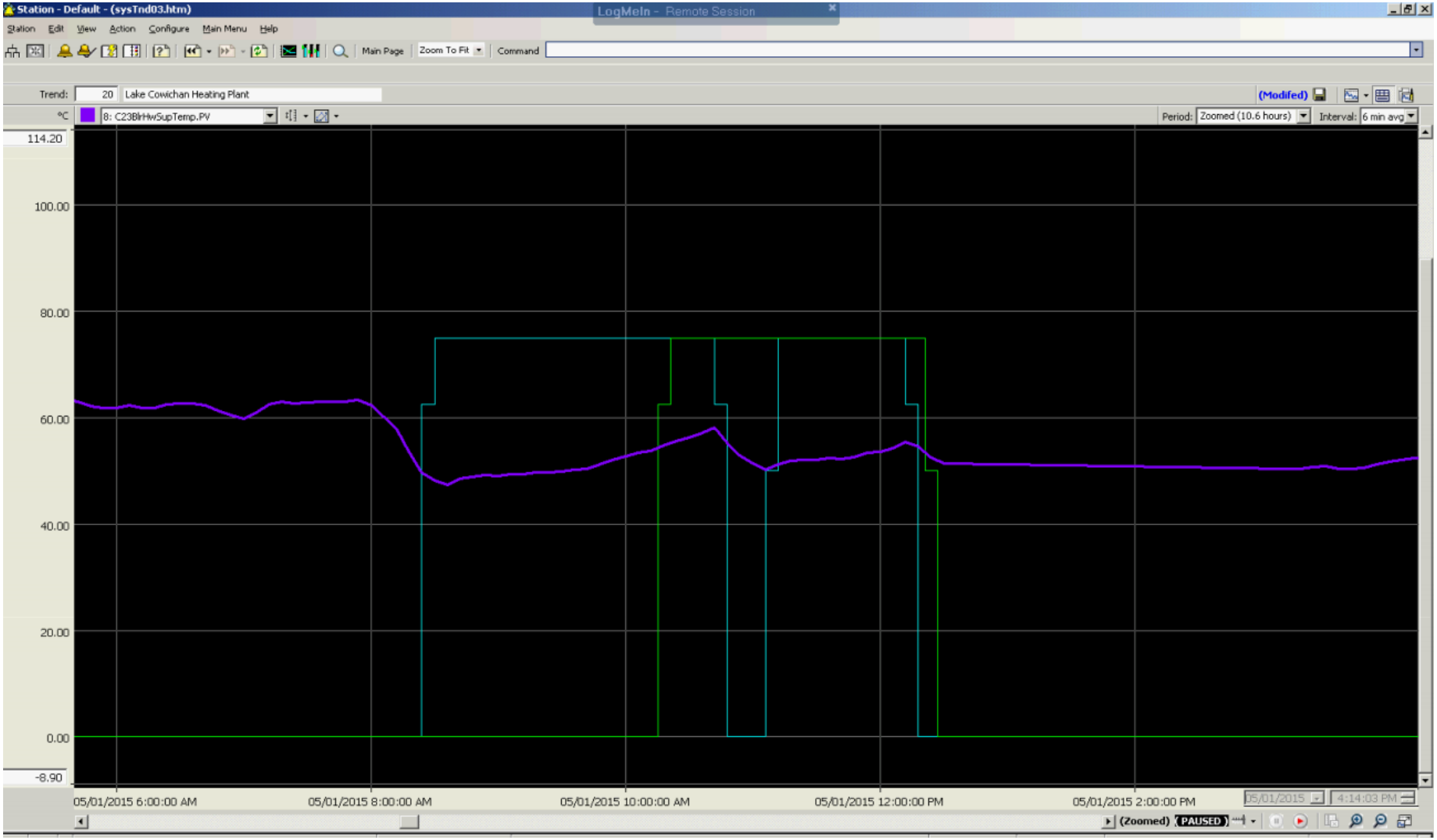
- Used this analysis to:
  - Revised sequences
    - modify the “free cooling” routines
    - refine supply air temperature control for perimeter system
  - Data analytics provided more accurate estimates of energy savings

Situation 2: Commissioning a New Equipment

New Biomass Installation

- Cx example
- Run the analytics and report on it to operators in a way they can use it.
- Example of how data is there but:
  - How can we use it?
  - How can use it more effectively?

Oil Boilers Status Trend

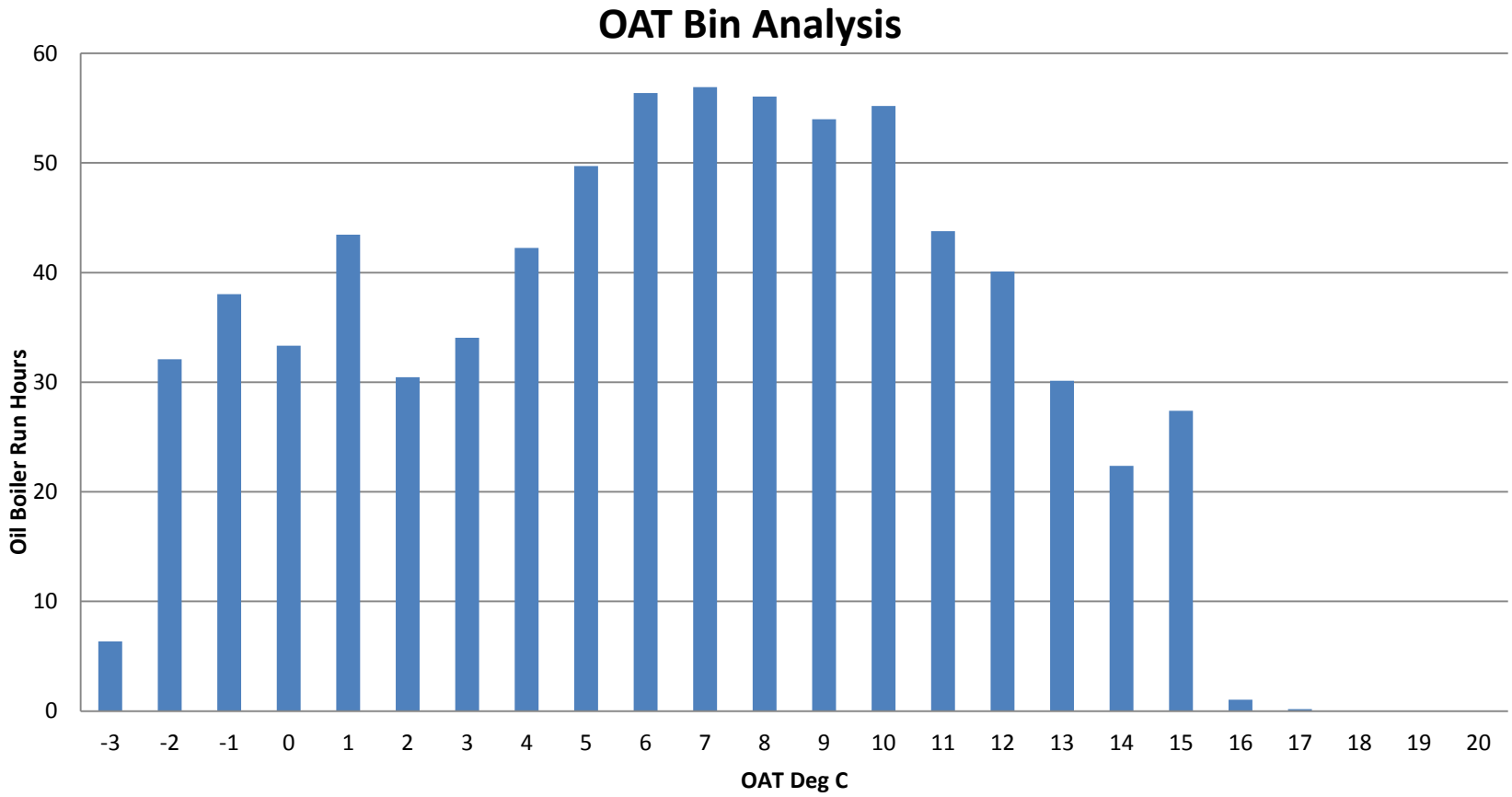


Hot water supply temperature (purple line) drops well below the supply temperature setpoint, causing the oil boilers to start during cold mornings instead of biomass

The Investigation Showed…

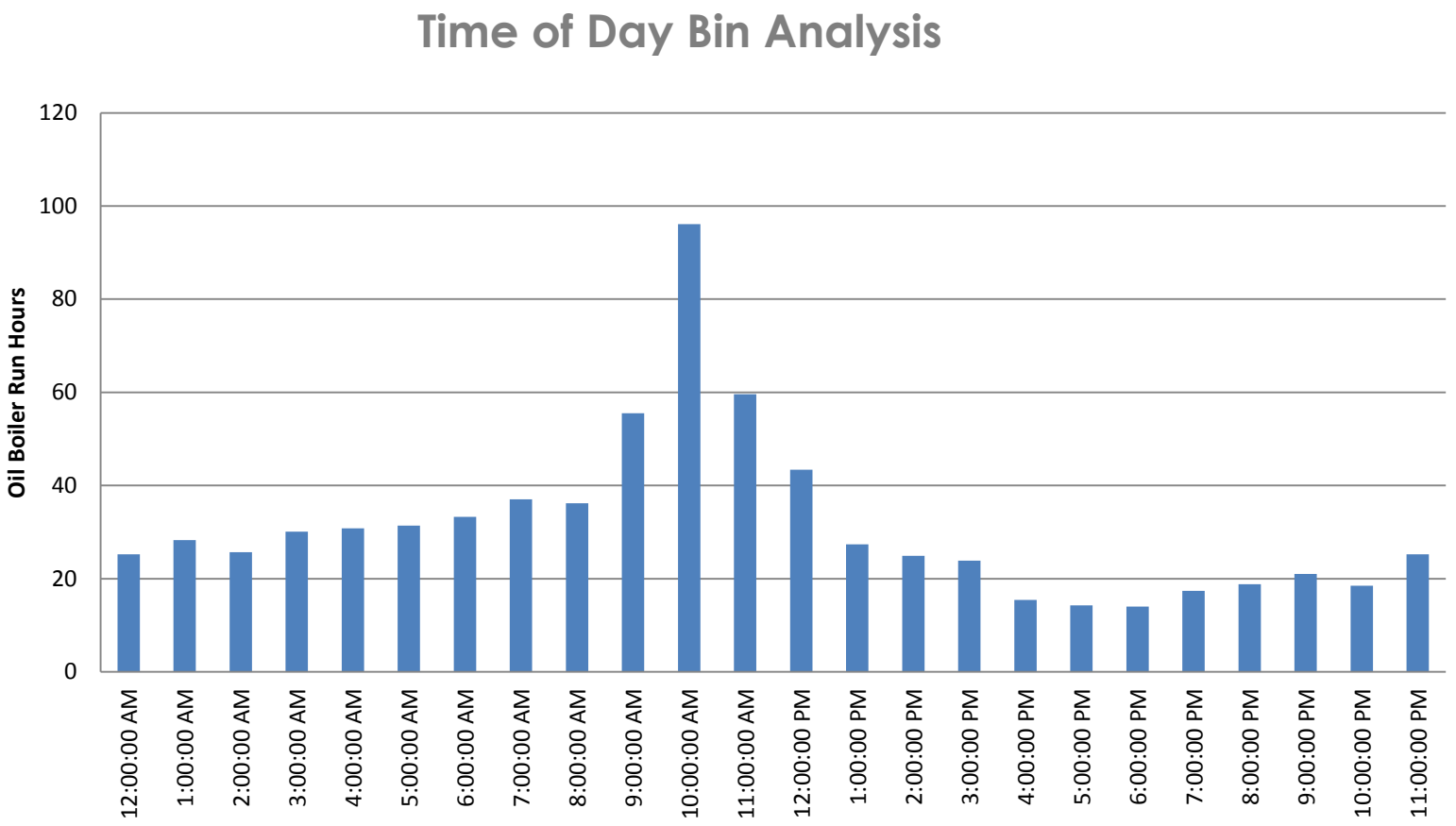
- During building warm-up, the biomass plant cannot respond fast enough to varying load
- Oil boilers take over

Analytics showed Oil Boiler Run Time



The slower response time by the biomass boiler prevented operation even during warmer periods

Understand Why



The majority of the load for the oil boilers is during warm up periods

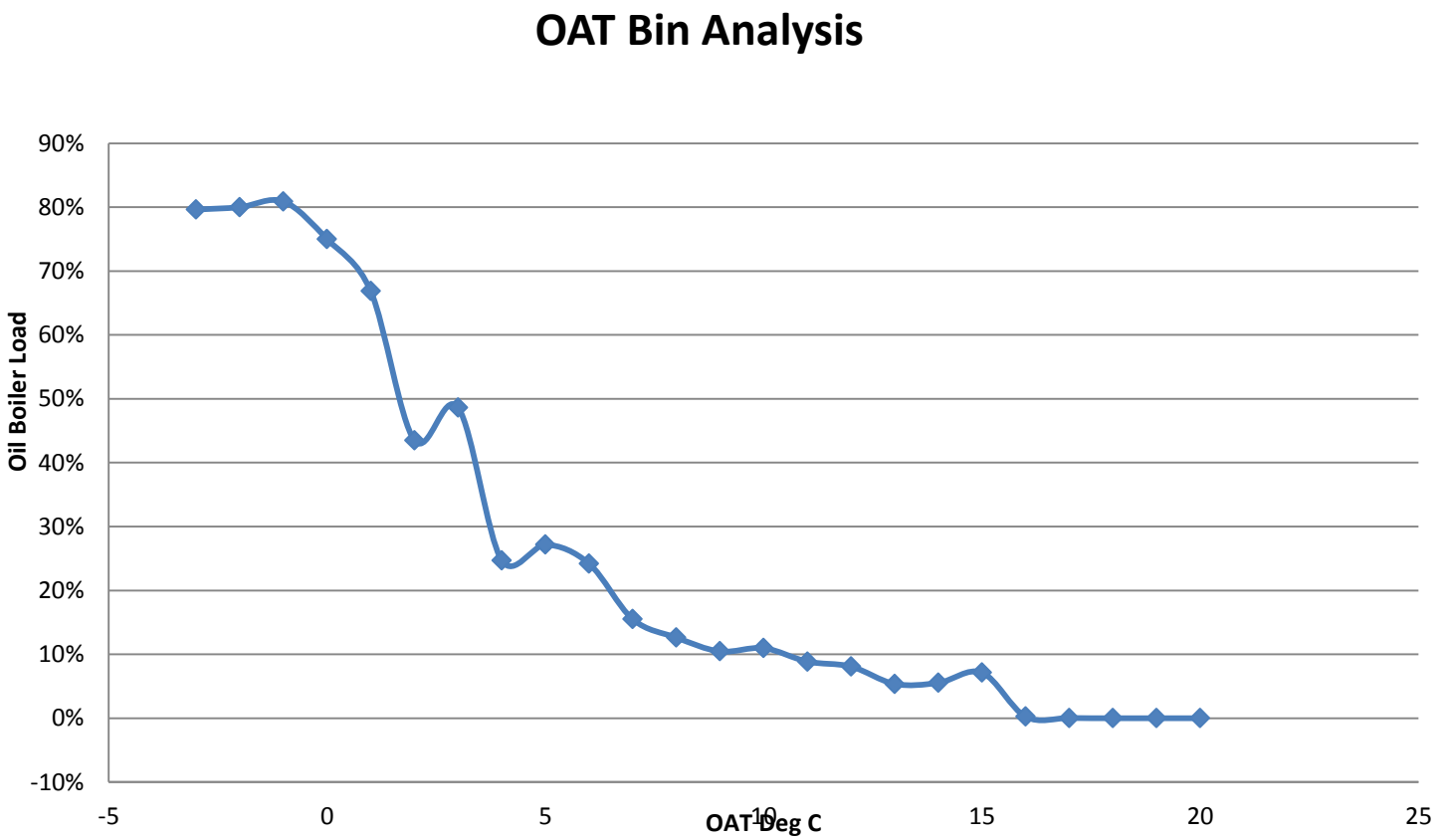
Analysis

- Used run time and rated boilers input to calculate how much oil is burned each morning

Sequencing New and Old

- Used building heat pump loop as heat storage
- Reset heat pump loop and buffer tank temperature setpoints before start-up

When we should expect the oil boilers to run by design



Impact

- **Result:** oil does not run anymore during warm up
  - Baseline 753 hours/year 556.6 GJ 28% oil
  - Proposed 337 hours/year 249.1 GJ 13% oil
  - Savings based on the # of hours when OAT > 5C

- **Update:** refining sequences to automate the process and reduce oil boiler run time even further

Situation 3: Finding O&M Issues and Opportunities

High Rise with VAV system with Reheat coils

- No feedback on operations of reheat valves
- **Step 1: Installed approx. 300 temperature sensors**
  - This installation allowed us to troubleshoot performance problems (comfort and energy)
  - Data collected could be used to determine appropriate (and unique) solutions to each problem

Finding the Problem

- **Step 2: Reheat coil analysis**
  - Used discharge temperature is an indicator of "passing valve alarm"
  - Got passing valve alarms for the majority !!!!
  - Found out that all the valves were retrofit and the wrong actuator installed
  - Replaced the faulty actuators

VAV Summary Table:
What can you see?

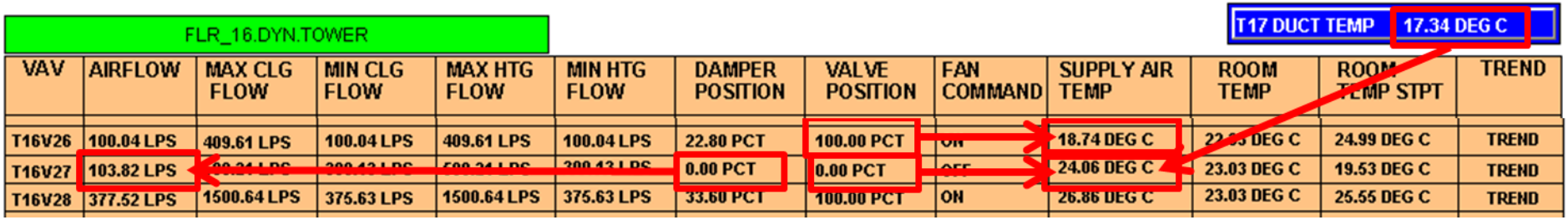
- Step 3 – Use DDC for O&M needs

FLR_21.DYN.TOWER

T20 DUCT TEMP 17.34 DEG C

VAV	AIRFLOW	MAX CLG FLOW	MIN CLG FLOW	MAX HTG FLOW	MIN HTG FLOW	DAMPER POSITION	VALVE POSITION	FAN COMMAND	SUPPLY AIR TEMP	ROOM TEMP	ROOM TEMP STPT	TREND
T21V01	124.58 LPS	239.73 LPS	54.74 LPS	239.73 LPS	124.58 LPS	32.00 PCT	80.00 PCT		35.82 DEG C	20.51 DEG C	24.57 DEG C	TREND
T21V02	47.19 LPS	200.09 LPS	49.08 LPS	200.09 LPS	49.08 LPS	28.00 PCT	100.00 PCT		44.50 DEG C	23.87 DEG C	24.57 DEG C	TREND
T21V03	105.71 LPS	439.81 LPS	105.71 LPS	439.81 LPS	105.71 LPS	6.80 PCT	96.80 PCT		38.34 DEG C	24.57 DEG C	24.57 DEG C	TREND
T21V04	381.30 LPS	377.52 LPS	94.38 LPS			50.00 PCT				22.61 DEG C	20.65 DEG C	TREND
T21V05	322.78 LPS	320.89 LPS	79.28 LPS			41.20 PCT				23.59 DEG C	20.51 DEG C	TREND
T21V06	83.05 LPS	390.73 LPS	130.24 LPS	349.21 LPS	84.94 LPS	23.60 PCT	0.00 PCT		19.02 DEG C	22.89 DEG C	22.75 DEG C	TREND
T21V07	47.19 LPS	186.87 LPS	47.19 LPS			46.80 PCT				23.03 DEG C	24.57 DEG C	TREND
T21V08	0.00 LPS	120.81 LPS	30.20 LPS			100.00 PCT				22.61 DEG C	20.51 DEG C	TREND
T21V09	66.07 LPS	184.98 LPS	45.30 LPS			29.60 PCT				24.71 DEG C	24.57 DEG C	TREND
T21V10	83.05 LPS	334.11 LPS	84.94 LPS	334.11 LPS	84.94 LPS	23.60 PCT	100.00 PCT		38.62 DEG C	23.73 DEG C	24.57 DEG C	TREND
T21V11	81.17 LPS	320.89 LPS	79.28 LPS			8.80 PCT				23.03 DEG C	24.57 DEG C	TREND
T21V12	101.93 LPS	320.89 LPS	79.28 LPS	320.89 LPS	79.28 LPS	44.80 PCT	0.00 PCT		18.18 DEG C	22.33 DEG C	22.33 DEG C	TREND
T21V13	39.64 LPS	160.45 LPS	39.64 LPS	160.45 LPS	39.64 LPS	13.20 PCT	100.00 PCT		40.02 DEG C	23.31 DEG C	23.87 DEG C	TREND
T21V14	100.04 LPS	209.52 LPS	100.04 LPS	209.52 LPS	100.04 LPS	35.20 PCT	74.00 PCT		39.46 DEG C	24.15 DEG C	24.43 DEG C	TREND
T21V15	160.45 LPS	234.06 LPS	58.52 LPS	234.06 LPS	79.28 LPS	41.20 PCT	0.00 PCT		17.90 DEG C	22.89 DEG C	23.03 DEG C	TREND
T21V16	205.75 LPS	200.09 LPS	49.08 LPS	200.09 LPS	49.08 LPS	43.60 PCT	0.00 PCT		17.90 DEG C	23.03 DEG C	20.51 DEG C	TREND
T21V17	100.04 LPS	243.50 LPS	100.04 LPS			33.60 PCT				23.17 DEG C	24.57 DEG C	TREND
T21V18	132.13 LPS	149.12 LPS	75.50 LPS			100.00 PCT				23.73 DEG C	21.07 DEG C	TREND
T21V19	60.40 LPS	179.32 LPS	54.74 LPS	179.32 LPS	60.40 LPS	62.00 PCT	8.80 PCT		21.82 DEG C	20.51 DEG C	20.51 DEG C	TREND

Problem: Reheat Valve Not Opening



FLR_16.DYN.TOWER

T17 DUCT TEMP 17.34 DEG C

VAV	AIRFLOW	MAX CLG FLOW	MIN CLG FLOW	MAX HTG FLOW	MIN HTG FLOW	DAMPER POSITION	VALVE POSITION	FAN COMMAND	SUPPLY AIR TEMP	ROOM TEMP	ROOM TEMP STPT	TREND
T16V26	100.04 LPS	409.61 LPS	100.04 LPS	409.61 LPS	100.04 LPS	22.80 PCT	100.00 PCT	ON	18.74 DEG C	22.3 DEG C	24.99 DEG C	TREND
T16V27	103.82 LPS	[illegible]	[illegible]	[illegible]	[illegible]	0.00 PCT	0.00 PCT	OFF	24.06 DEG C	23.03 DEG C	19.53 DEG C	TREND
T16V28	377.52 LPS	1500.64 LPS	375.63 LPS	1500.64 LPS	375.63 LPS	33.60 PCT	100.00 PCT	ON	26.86 DEG C	23.03 DEG C	25.55 DEG C	TREND

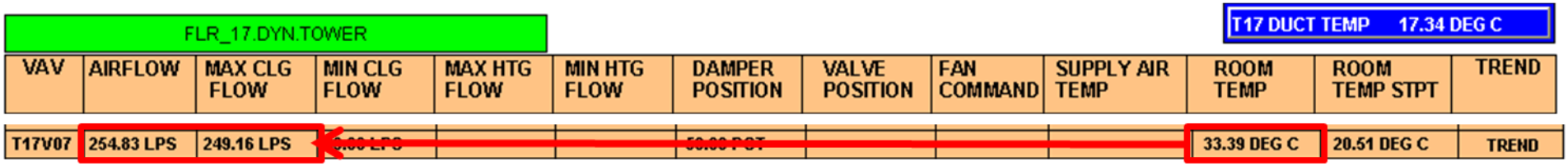
"Too Cold" Re-heat Valve not Opening:

- **VAV T16V26.** The reheat valve is showing as 100% open but supply air temperature is 18.7 C causing the room temperature to be cold (22.3 C for a 25 C setpoint).

"Too Hot" Passing Re-heat Valve and Damper:

- **VAV T16V27.** The room temperature is 23 C for a setpoint of 19.5 C. Both VAV damper and re-heat valve are showing fully closed (0%) but air flow is 103.8 l/s and supply air temperature is 24.1 C. The damper actuator of this VAV box should be investigated. It appears that it is not properly set at the damper shaft. The reheat valve appears to be passing.

Incorrect Room Temperature



VAV T17V07

- The room temperature sensor is reading 33.4°C driving the VAV box to maximum cooling flow.
- The temperature sensor location should be investigated and relocated or the sensor should be replaced/calibrated if required.

Damper commanded fully open and no airflow indication

FLR_21.DYN.TOWER

T20 DUCT TEMP 17.34 DEG C

VAV	AIRFLOW	MAX CLG FLOW	MIN CLG FLOW	MAX HTG FLOW	MIN HTG FLOW	DAMPER POSITION	VALVE POSITION	FAN COMMAND	SUPPLY AIR TEMP	ROOM TEMP	ROOM TEMP STPT	TREND
T21V07	47.19 LPS	186.87 LPS	47.19 LPS			46.80 PCT				23.03 DEG C	24.57 DEG C	TREND
T21V08	0.00 LPS	[illegible]	[illegible]			100.00 PCT				22.61 DEG C	20.51 DEG C	TREND
T21V09	66.07 LPS	184.98 LPS	45.30 LPS			29.60 PCT				24.71 DEG C	24.57 DEG C	TREND

T21V08

- The damper is fully open to maintain the flow setpoint.
- A defective flow sensor, or loose tubing could be causing this issue.

Summary of Identified Problems

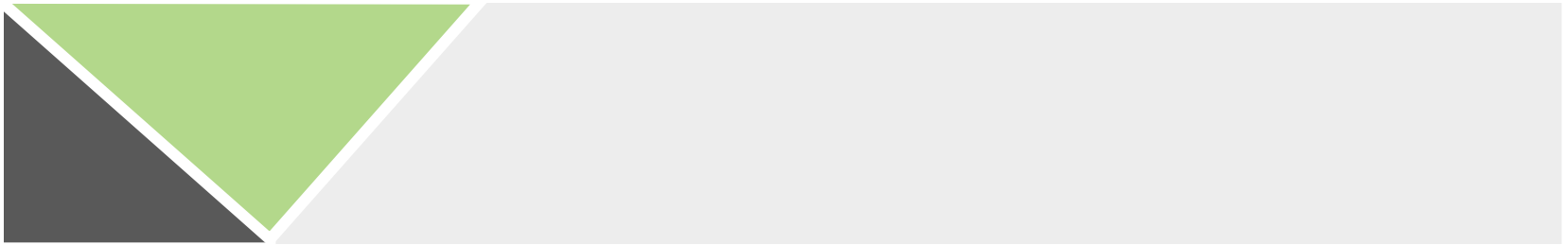
Example Presented:

- Re-heat Valve not Opening
- Passing Re-heat Valve and Damper
- Incorrect Room temperature
- Damper commanded fully open and no airflow indication

Other Problems identified:

- Damper fully open and not reaching the airflow setpoint
- Room temperature above setpoint & dampers not fully open
- High minimum heating airflow
- Cold interior zones served by cooling only boxes caused by higher than required minimum cooling air volume setpoints

ENHANCED ANALYTICS:
THE POWER OF DATA IN VERIFYING EQUIPMENT EFFICIENCY



Situation 4

Evaluate New Technology

- How is chiller performing compared to manufacturers claims?
- Use Database Analysis
  1. Performance data from manufacturer
  2. Actual site measurements

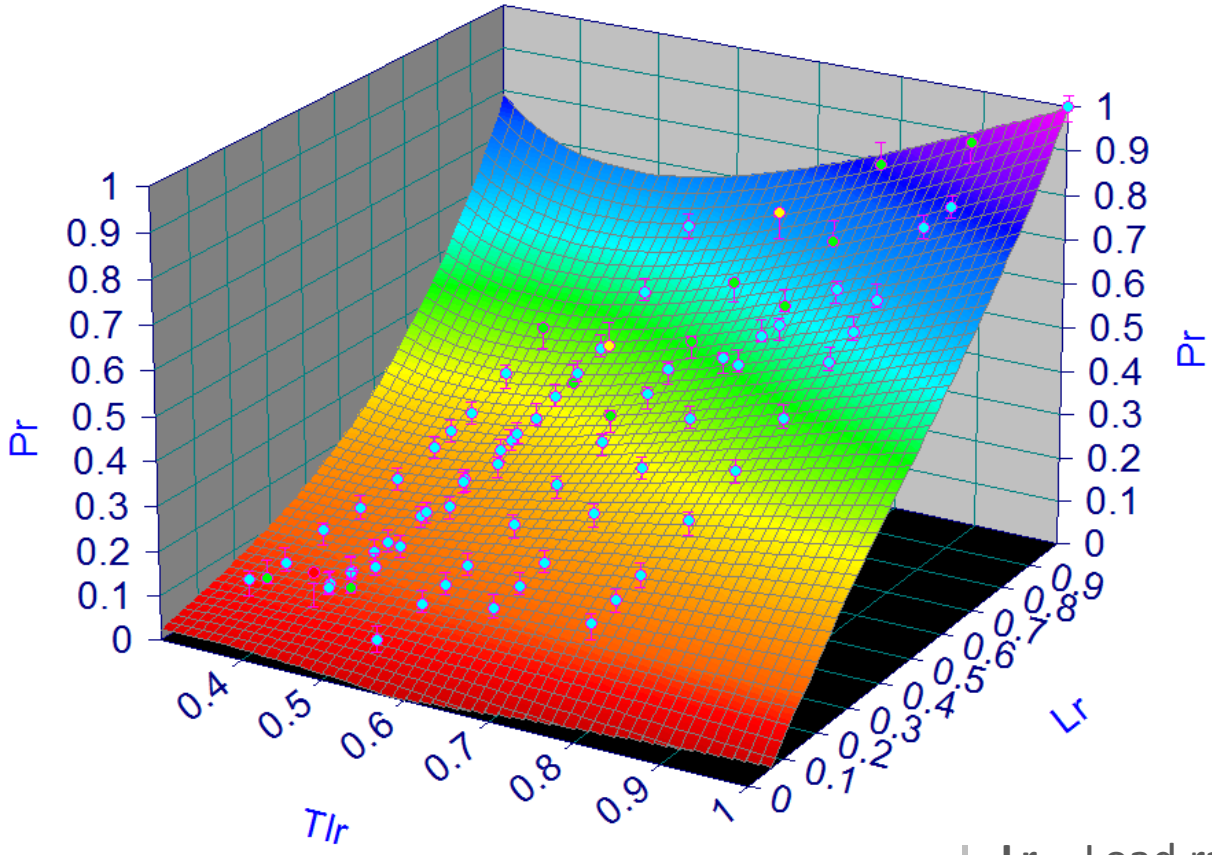
Manufacturers Data

- Used 3D Modelling Program
- Determined an empirical equation that models the manufacturers' performance data
- Compromise between best fit and equation complexity:

$$\mathbf{Pr} = a+b\cdot \ln Tlr+c\cdot Lr+d\cdot(\ln Tlr)^2+e\cdot Lr^2+f\cdot Lr\cdot \ln Tlr$$
$$+g\cdot(\ln Tlr)^3+h\cdot Lr^3+i\cdot Lr^2\cdot \ln Tlr+j\cdot Lr\cdot(\ln Tlr)^2$$

The regression coefficient (R^2) for the model is 0.9972

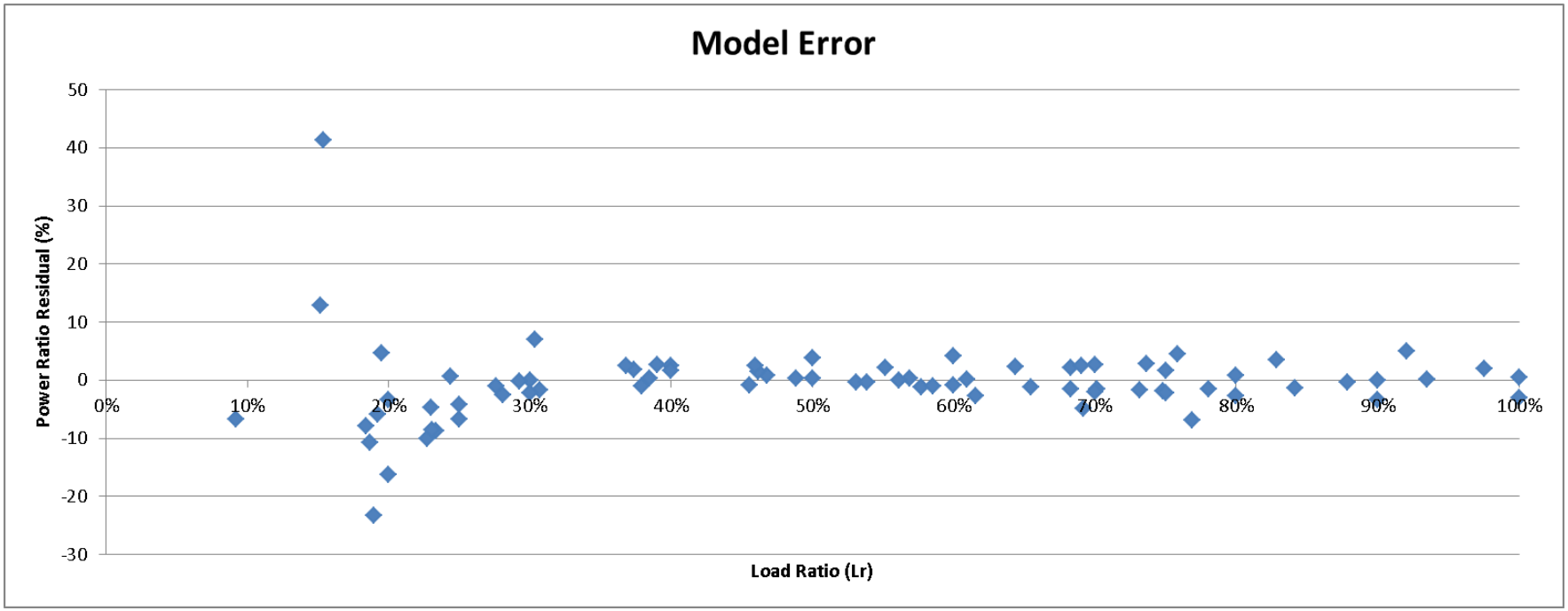
Graph of 3D Chiller Performance Curve for the Model



The data point in the upper right hand corner (Lr = Tlr = Pr = 1.0) represents the design condition.

Lr = Load ratio
Tlr = Leaving temperature ratio
Pr = Input power ratio

Accuracy of Model

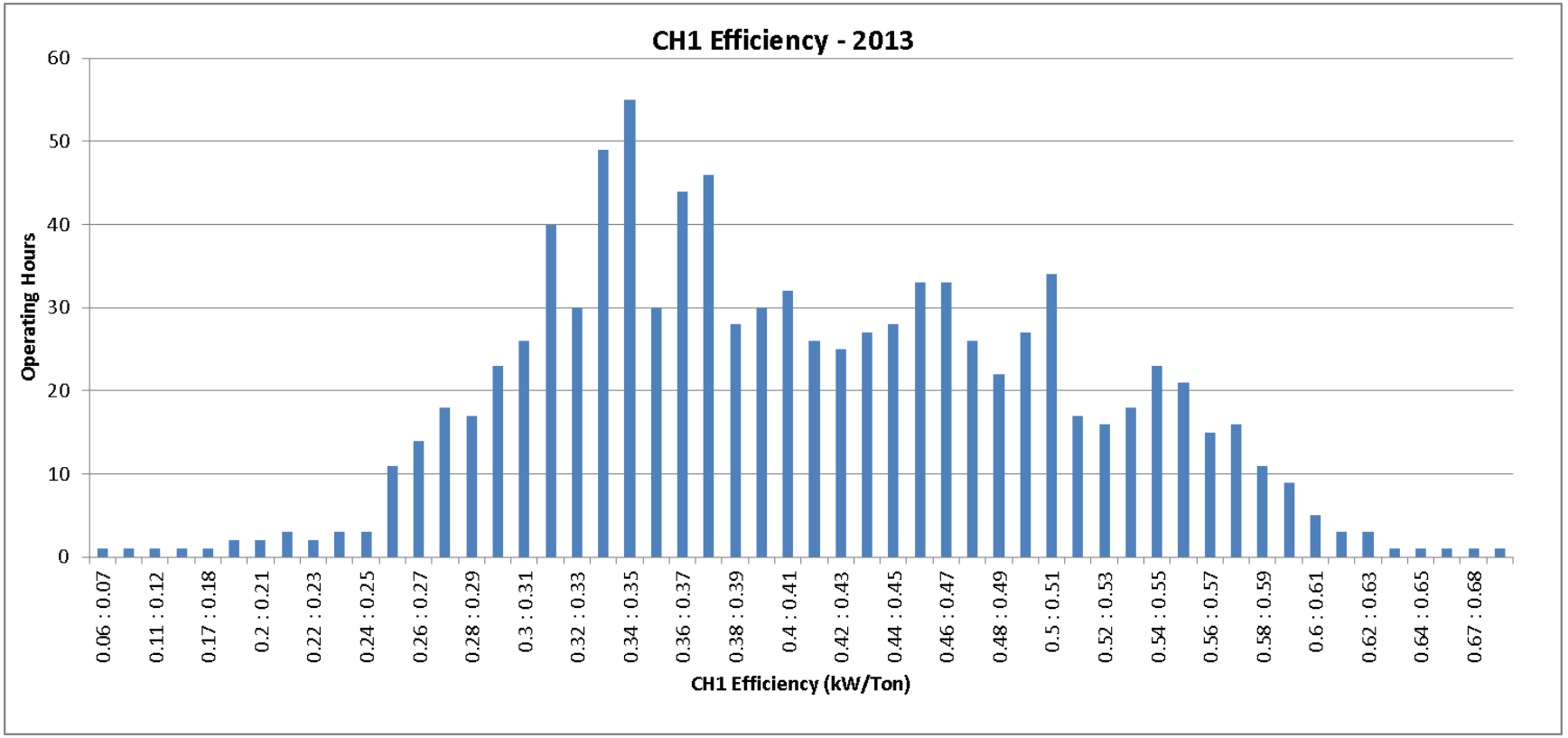


Y axis shows the error…below 20% model has significant error

Analysis

- Actual energy performance was compared to the performance model derived from the manufacturers' data sheets.

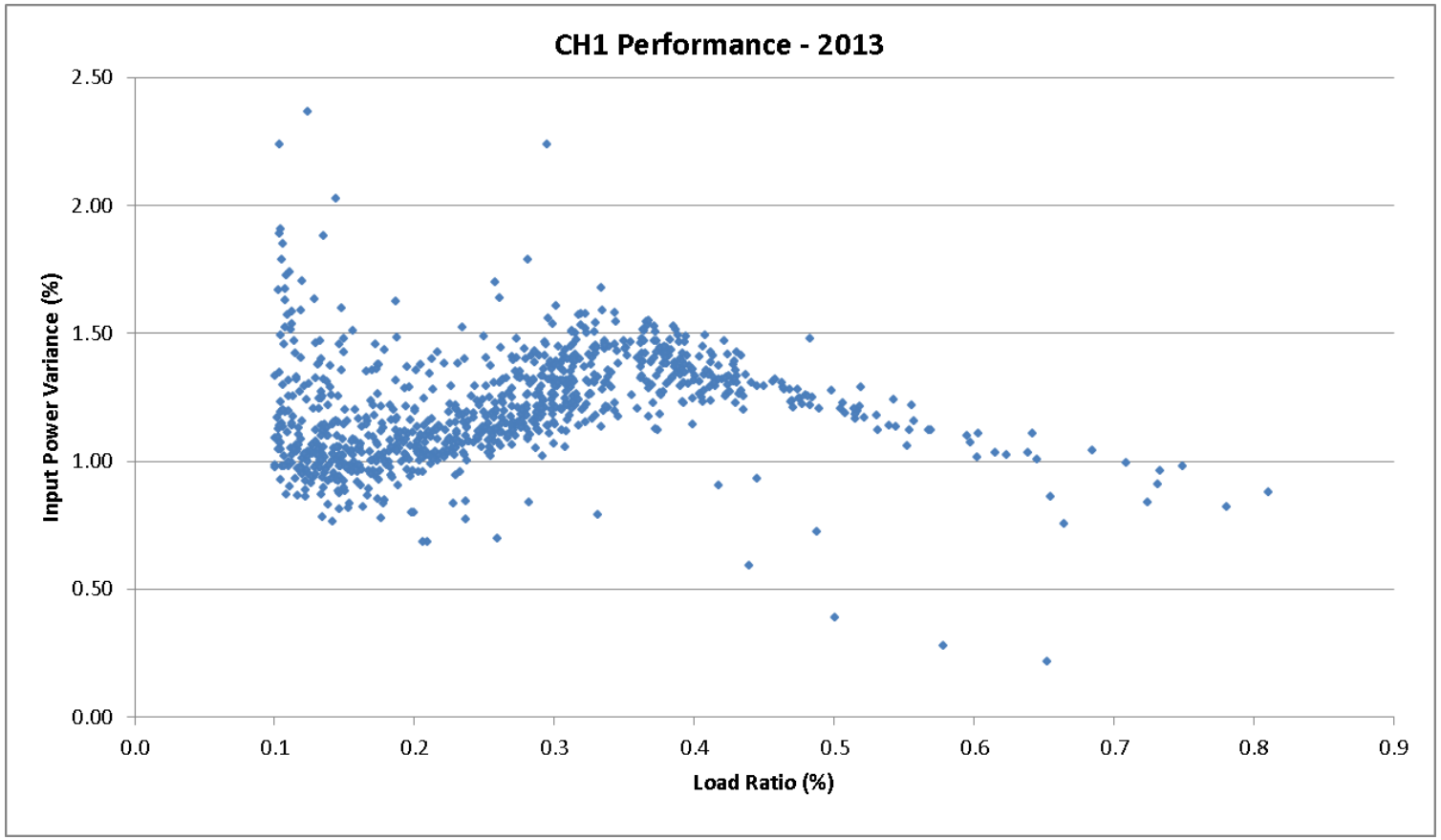
Site Measurement- Actual Efficiency kW/ton



Analysis

- The **input power variance** is the ratio of measured power to the predicted power at the prevailing operating conditions
  - An **input power variance** of 1.1 indicates measured power was 10% greater than would be expected
- Operating data for chilled water loads of less than 10% of rated load (177 tonsR) were not included due to chiller low load cycling.

Part Load Performance Critical

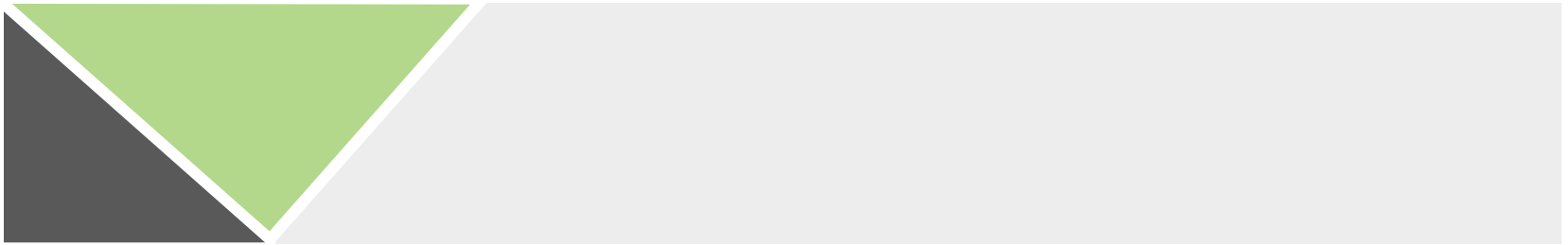


Each of the 956 data points represents one hour of chiller CH-1 operation.

Results

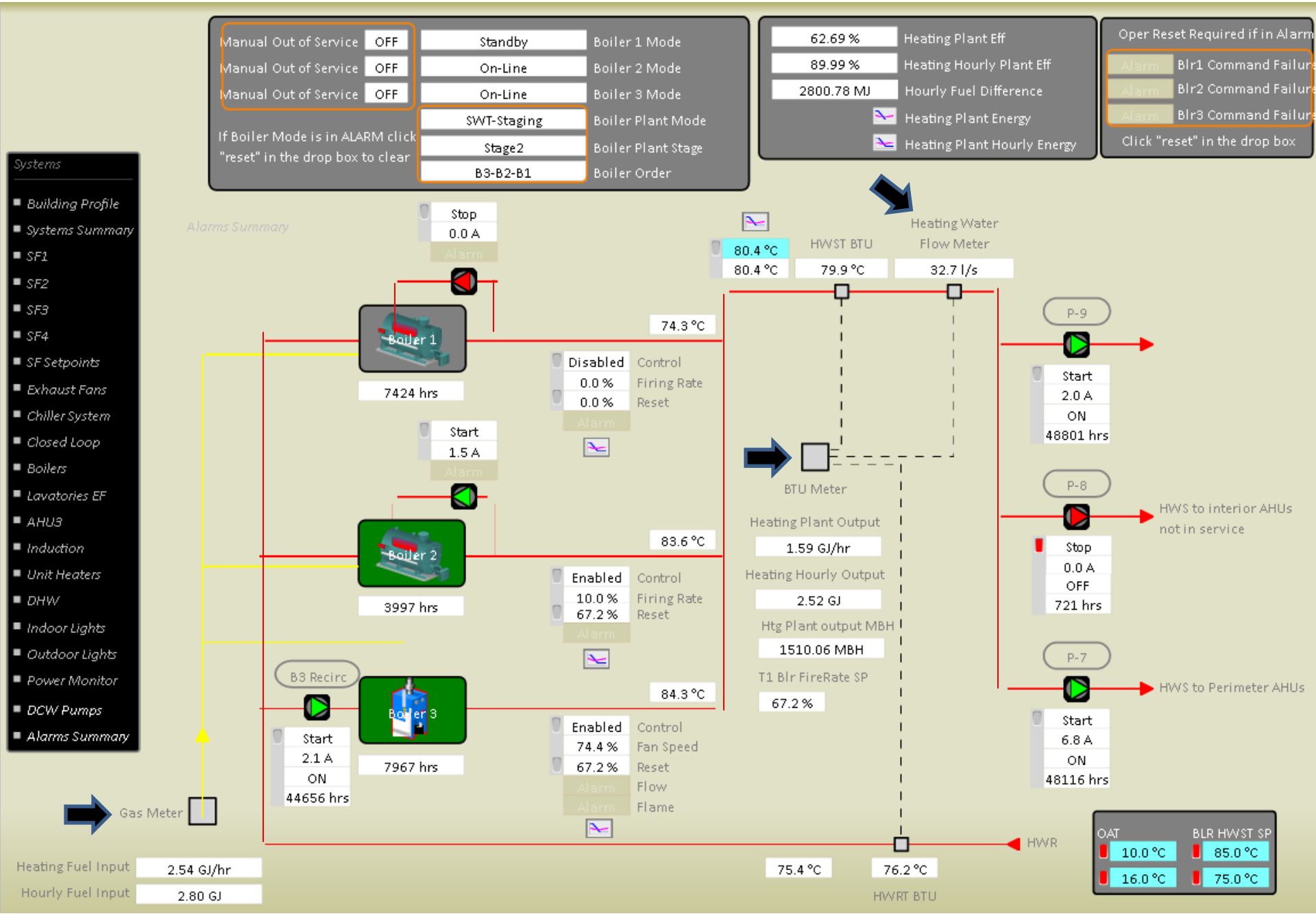
- Chiller does not achieve rated performance when 25% to 55% loaded
- Operation at less than about 25% load is reasonably consistent with manufacturer data
- Appears to perform close to predictions between 60% and 80% loading BUT…
- Insufficient chiller operation above 40% loading (low number of data samples) for high confidence level

ENHANCED ANALYTICS:
USING ENERGY INFORMATION TO IMPROVE OPERATING EFFICIENCIES



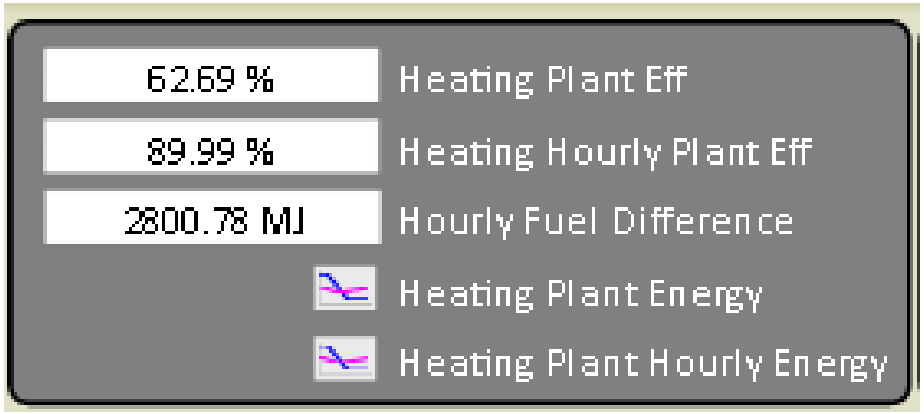
Situation 5

- **Use data for energy analysis**
  - We install new boilers but we want to know the actual performance and how can we improve it?
- **Recommendation:**
  - install meters during upgrades
  - calculating heating plant efficiencies with ACTUAL data: idle time lowers the efficiency so we can get real values
  - look at changes and track performance and changes over time


Systems
Building Profile
Systems Summary
SF1
SF2
SF3
SF4
SF Setpoints
Exhaust Fans
Chiller System
Closed Loop
Boilers
Lavatories EF
AHU3
Induction
Unit Heaters
DHW
Indoor Lights
Outdoor Lights
Power Monitor
DCW Pumps
Alarms Summary
Manual Out of Service OFF
Manual Out of Service OFF
Manual Out of Service OFF
If Boiler Mode is in ALARM click "reset" in the drop box to clear
Standby
On-Line
On-Line
SWT-Staging
Stage2
B3-B2-B1
Boiler 1 Mode
Boiler 2 Mode
Boiler 3 Mode
Boiler Plant Mode
Boiler Plant Stage
Boiler Order
62.69 %
89.99 %
2800.78 MJ
Heating Plant Eff
Heating Hourly Plant Eff
Hourly Fuel Difference
Heating Plant Energy
Heating Plant Hourly Energy
Oper Reset Required if in Alarm
Alarm
Blr1 Command Failure
Alarm
Blr2 Command Failure
Alarm
Blr3 Command Failure
Click "reset" in the drop box
Alarms Summary
Stop
0.0 A
Alarm
Boiler 1
7424 hrs
74.3 °C
Disabled
Control
0.0 %
Firing Rate
0.0 %
Reset
Alarm
Start
1.5 A
Alarm
Boiler 2
3997 hrs
83.6 °C
Enabled
Control
10.0 %
Firing Rate
67.2 %
Reset
Alarm
B3 Recirc
Start
2.1 A
ON
44656 hrs
Boiler 3
7967 hrs
84.3 °C
Enabled
Control
74.4 %
Fan Speed
67.2 %
Reset
Alarm
Flow
Alarm
Flame
Gas Meter
Heating Fuel Input
2.54 GJ/hr
Hourly Fuel Input
2.80 GJ
80.4 °C
80.4 °C
HWST BTU
79.9 °C
Heating Water Flow Meter
32.7 l/s
BTU Meter
Heating Plant Output
1.59 GJ/hr
Heating Hourly Output
2.52 GJ
Htg Plant output MBH
1510.06 MBH
T1 Blr FireRate SP
67.2 %
HWR
75.4 °C
76.2 °C
HWRT BTU
P-9
Start
2.0 A
ON
48801 hrs
P-8
Stop
0.0 A
OFF
721 hrs
HWS to interior AHUs not in service
P-7
Start
6.8 A
ON
48116 hrs
HWS to Perimeter AHUs
OAT
10.0 °C
16.0 °C
BLR HWST SP
85.0 °C
75.0 °C

Application

$$\frac{\text{Output 2.52 GJ}}{\text{Input 2.80 GJ}}$$



- Measure heating plant efficiency
- Track it over time
- Set thresholds for investigation and maintenance

Situation 6

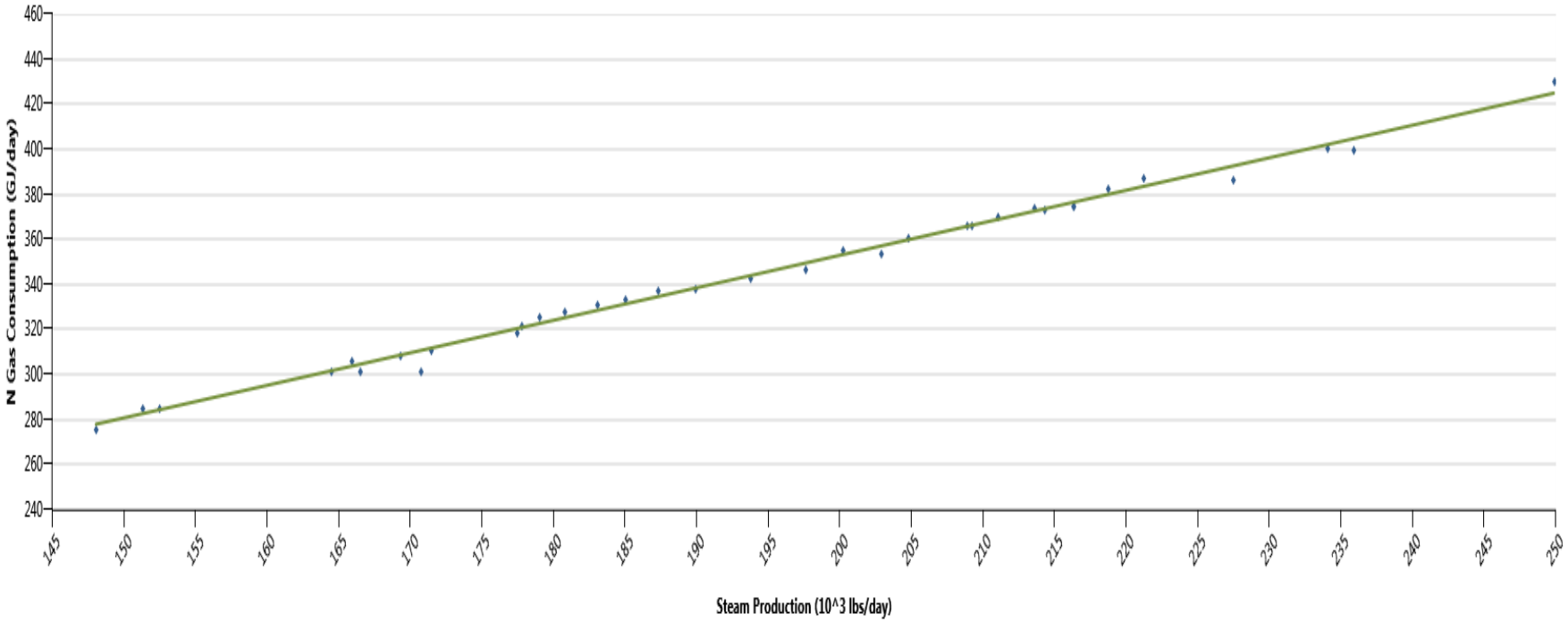
- Evaluate steam plant efficiency prior to retrofit
  - Two steam boilers (lead/lag)
  - One boiler recently replaced to improve efficiency and add capacity (new boiler has ~50% higher capacity)
- Evaluate new boiler efficiency
- Evaluate best operational sequence

Analysis

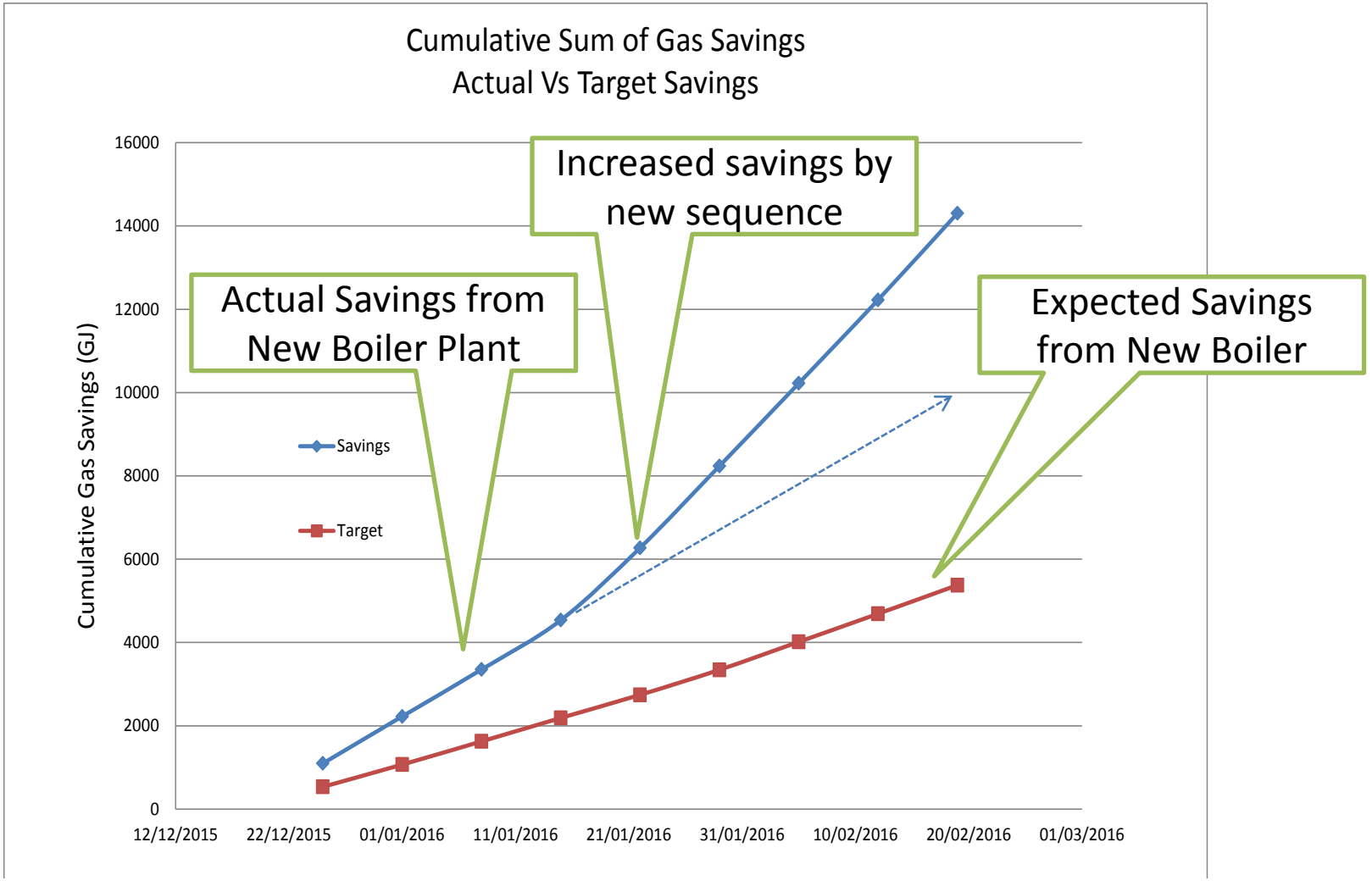
- Boiler level steam and gas metering
- Calculate boiler performance model
- Heating plant efficiencies with ACTUAL data:
  - Decide whether to switch to smaller boiler or potentially cycle new boiler at low load?
- Look at savings and track performance and compare to target

Overall Plant Performance Model (Baseline) based on actual data

$$Baseline\ NG\ Used = 64.4534 + 1.4427 \times Mst \quad (2)$$



Steam Plant Gas Savings

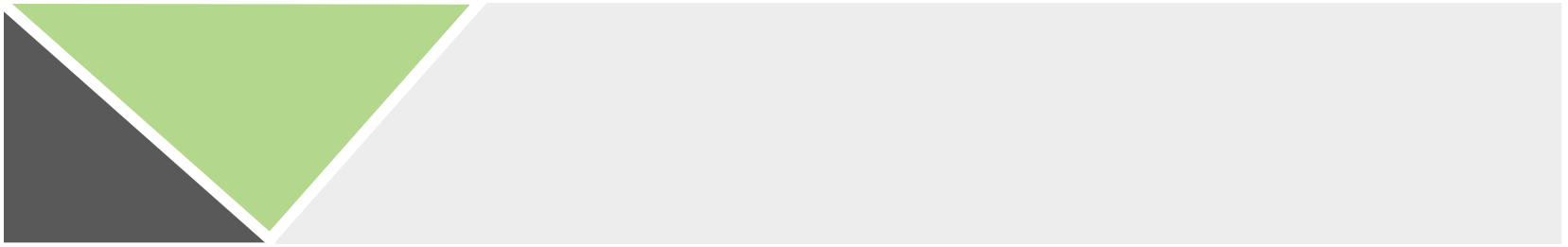


Weekly savings (based on daily data) shown for two months

Summary

- It's important to be able to **measure input and output energy** use from a system
- Analytics carried on the boiler plant showed the improvement in energy savings from **programming changes**
- New **targets** can be set based on optimized performance

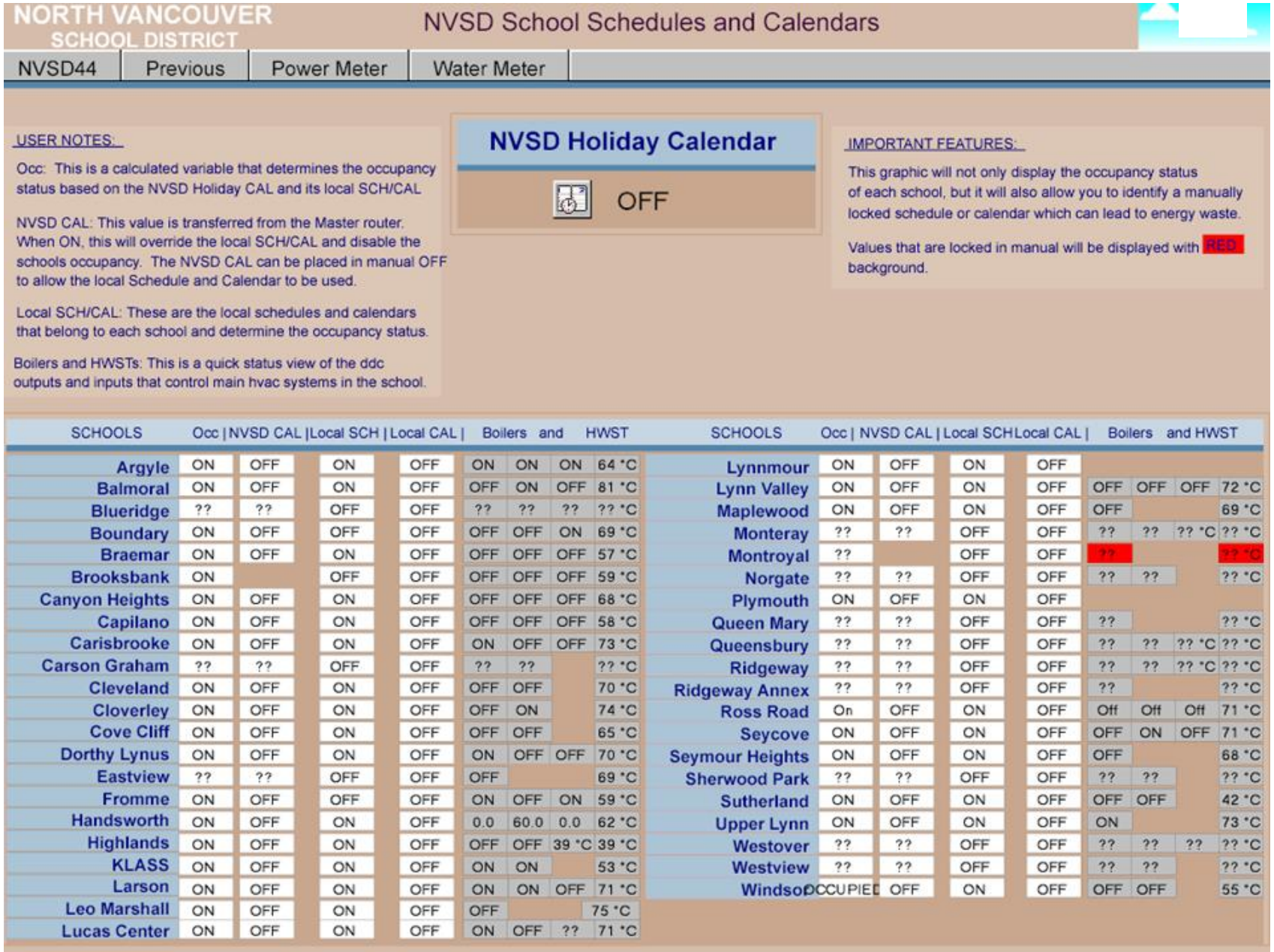
USE DDC FOR OPERATIONS AND MAINTENANCE: MAKING DATA VISIBLE



Develop Summary Graphics for Improving Operations

- **Understanding Building Operators**
  - don't have time
  - may be scared of the data
  - there may be too much data
  - not in the job description
- **Tabulation of data**
  - improves building operators ability to monitor systems performance
  - when you don’t have time to review every screen!

Multi Site Overview: Calender and Boiler Status



NORTH VANCOUVER SCHOOL DISTRICT

NVSD School Schedules and Calendars

NVSD44 | Previous | Power Meter | Water Meter

USER NOTES:

Occ: This is a calculated variable that determines the occupancy status based on the NVSD Holiday CAL and its local SCH/CAL

NVSD CAL: This value is transferred from the Master router. When ON, this will override the local SCH/CAL and disable the schools occupancy. The NVSD CAL can be placed in manual OFF to allow the local Schedule and Calendar to be used.

Local SCH/CAL: These are the local schedules and calendars that belong to each school and determine the occupancy status.

Boilers and HWSTs: This is a quick status view of the ddc outputs and inputs that control main hvac systems in the school.

NVSD Holiday Calendar

OFF

IMPORTANT FEATURES:

This graphic will not only display the occupancy status of each school, but it will also allow you to identify a manually locked schedule or calendar which can lead to energy waste.

Values that are locked in manual will be displayed with RED background.

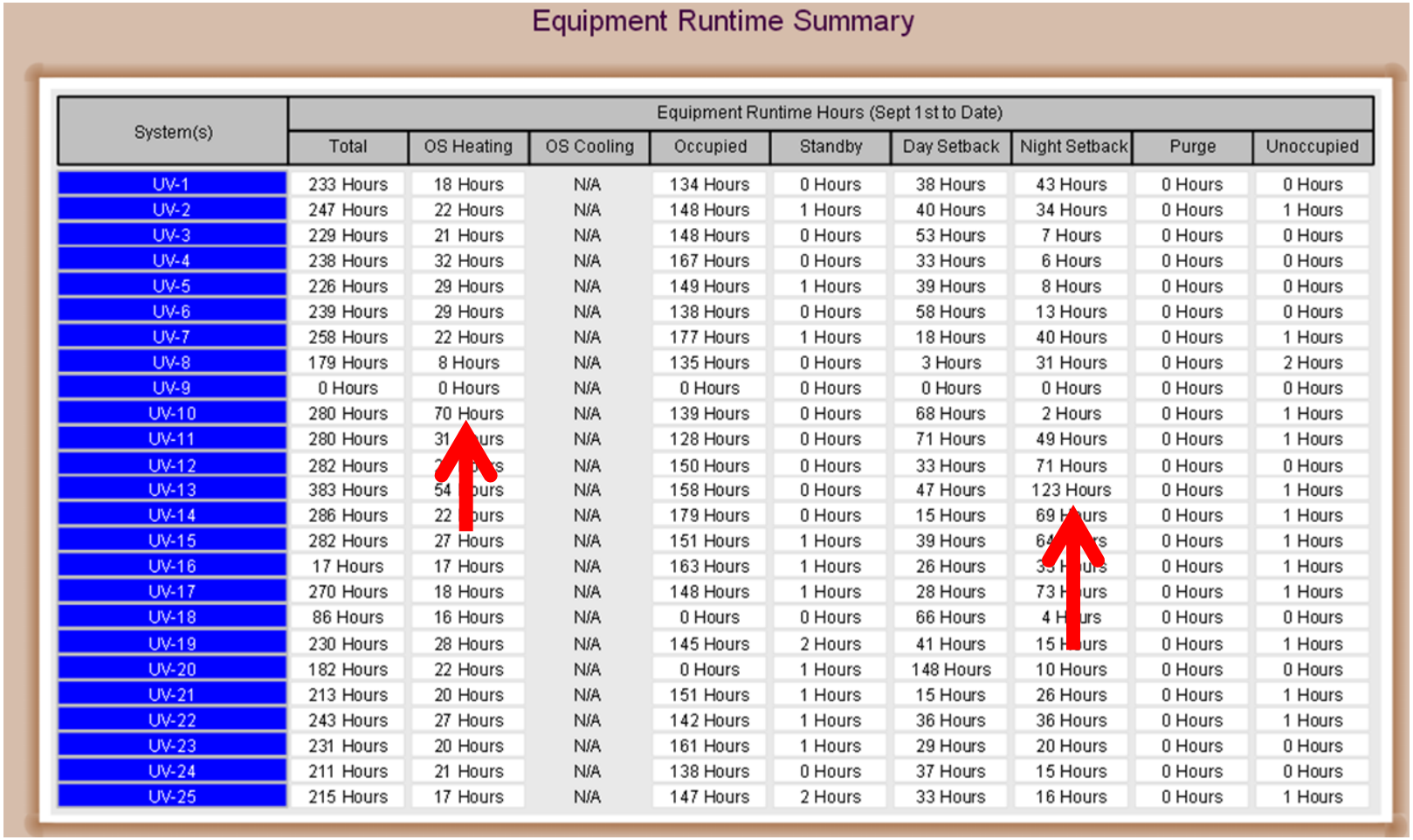
SCHOOLS	Occ	NVSD CAL	Local SCH	Local CAL	Boilers	and		HWST
Argyle	ON	OFF	ON	OFF	ON	ON	ON	64 °C
Balmoral	ON	OFF	ON	OFF	OFF	ON	OFF	81 °C
Blueridge	??	??	OFF	OFF	??	??	??	?? °C
Boundary	ON	OFF	OFF	OFF	OFF	OFF	ON	69 °C
Braemar	ON	OFF	ON	OFF	OFF	OFF	OFF	57 °C
Brooksbank	ON		OFF	OFF	OFF	OFF	OFF	59 °C
Canyon Heights	ON	OFF	ON	OFF	OFF	OFF	OFF	68 °C
Capilano	ON	OFF	ON	OFF	OFF	OFF	OFF	58 °C
Carisbrooke	ON	OFF	ON	OFF	ON	OFF	OFF	73 °C
Carson Graham	??	??	OFF	OFF	??	??		?? °C
Cleveland	ON	OFF	ON	OFF	OFF	OFF		70 °C
Cloverley	ON	OFF	ON	OFF	OFF	ON		74 °C
Cove Cliff	ON	OFF	ON	OFF	OFF	OFF		65 °C
Dorthy Lynus	ON	OFF	ON	OFF	ON	OFF	OFF	70 °C
Eastview	??	??	OFF	OFF	OFF			69 °C
Fromme	ON	OFF	OFF	OFF	ON	OFF	ON	59 °C
Handsworth	ON	OFF	ON	OFF	0.0	60.0	0.0	62 °C
Highlands	ON	OFF	ON	OFF	OFF	OFF	39 °C	39 °C
KLASS	ON	OFF	ON	OFF	ON	ON		53 °C
Larson	ON	OFF	ON	OFF	ON	ON	OFF	71 °C
Leo Marshall	ON	OFF	ON	OFF	OFF			75 °C
Lucas Center	ON	OFF	ON	OFF	ON	OFF	??	71 °C

SCHOOLS	Occ	NVSD CAL	Local SCH	Local CAL	Boilers	and		HWST
Lynnmour	ON	OFF	ON	OFF				
Lynn Valley	ON	OFF	ON	OFF	OFF	OFF	OFF	72 °C
Maplewood	ON	OFF	ON	OFF	OFF			69 °C
Monteray	??	??	OFF	OFF	??	??	?? °C	?? °C
Montroyal	??		OFF	OFF	??			?? °C
Norgate	??	??	OFF	OFF	??	??		?? °C
Plymouth	ON	OFF	ON	OFF				
Queen Mary	??	??	OFF	OFF	??			?? °C
Queensbury	??	??	OFF	OFF	??	??	?? °C	?? °C
Ridgeway	??	??	OFF	OFF	??	??	?? °C	?? °C
Ridgeway Annex	??	??	OFF	OFF	??			?? °C
Ross Road	On	OFF	ON	OFF	Off	Off	Off	71 °C
Seycove	ON	OFF	ON	OFF	OFF	ON	OFF	71 °C
Seymour Heights	ON	OFF	ON	OFF	OFF			68 °C
Sherwood Park	??	??	OFF	OFF	??	??		?? °C
Sutherland	ON	OFF	ON	OFF	OFF	OFF		42 °C
Upper Lynn	ON	OFF	ON	OFF	ON			73 °C
Westover	??	??	OFF	OFF	??	??	??	?? °C
Westview	??	??	OFF	OFF	??	??		?? °C
Windsor	OCCUPIED	OFF	ON	OFF	OFF	OFF		55 °C

Dashboards of Mode Running

- **Consolidate data into a graphic screen providing a summary**
  - Catch bad things
  - Investigate
  - Fix!

Summary of Site Run Time



Equipment Runtime Summary

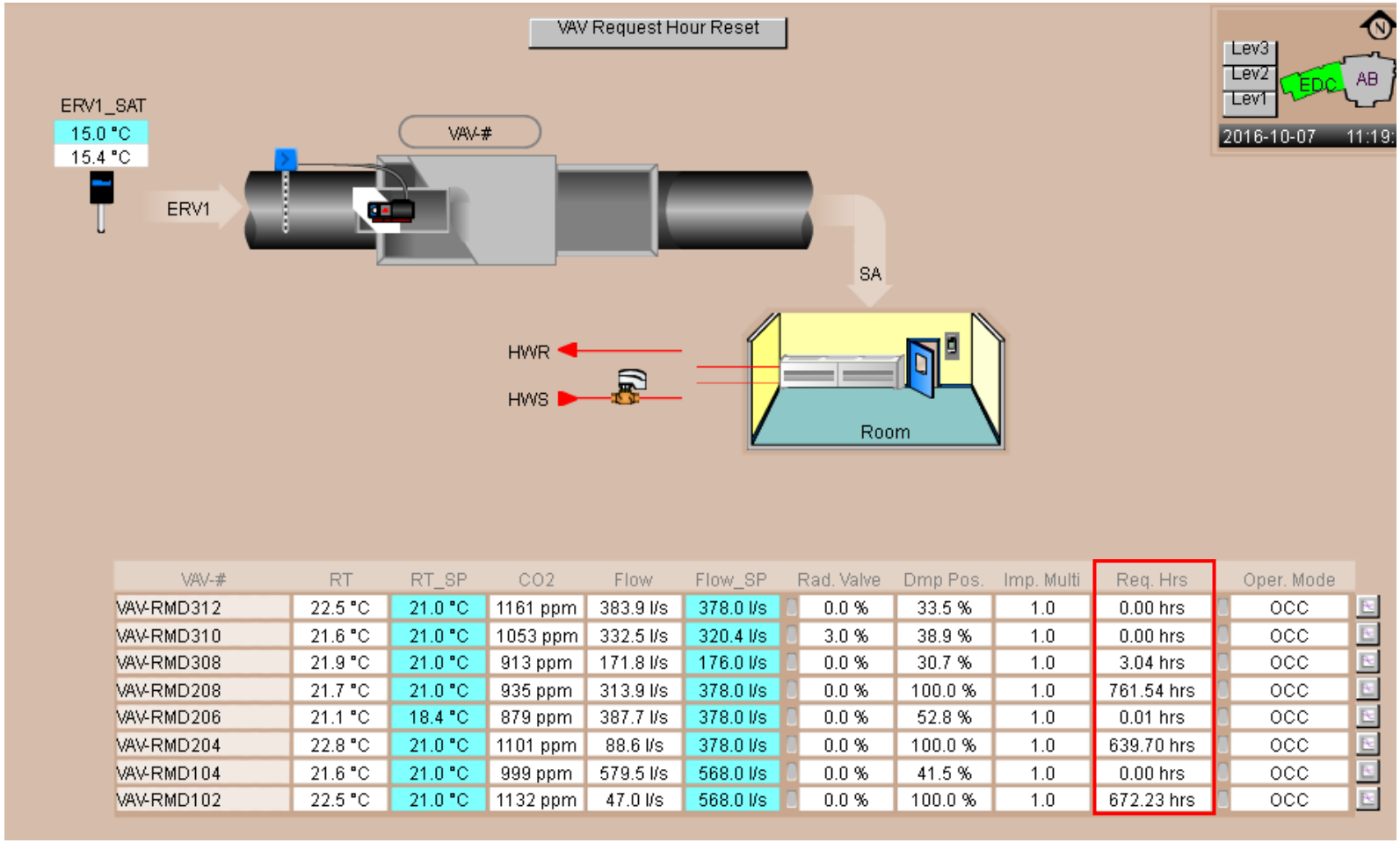
System(s)	Equipment Runtime Hours (Sept 1st to Date)								
	Total	OS Heating	OS Cooling	Occupied	Standby	Day Setback	Night Setback	Purge	Unoccupied
UV-1	233 Hours	18 Hours	N/A	134 Hours	0 Hours	38 Hours	43 Hours	0 Hours	0 Hours
UV-2	247 Hours	22 Hours	N/A	148 Hours	1 Hours	40 Hours	34 Hours	0 Hours	1 Hours
UV-3	229 Hours	21 Hours	N/A	148 Hours	0 Hours	53 Hours	7 Hours	0 Hours	0 Hours
UV-4	238 Hours	32 Hours	N/A	167 Hours	0 Hours	33 Hours	6 Hours	0 Hours	0 Hours
UV-5	226 Hours	29 Hours	N/A	149 Hours	1 Hours	39 Hours	8 Hours	0 Hours	0 Hours
UV-6	239 Hours	29 Hours	N/A	138 Hours	0 Hours	58 Hours	13 Hours	0 Hours	0 Hours
UV-7	258 Hours	22 Hours	N/A	177 Hours	1 Hours	18 Hours	40 Hours	0 Hours	1 Hours
UV-8	179 Hours	8 Hours	N/A	135 Hours	0 Hours	3 Hours	31 Hours	0 Hours	2 Hours
UV-9	0 Hours	0 Hours	N/A	0 Hours	0 Hours	0 Hours	0 Hours	0 Hours	0 Hours
UV-10	280 Hours	70 Hours	N/A	139 Hours	0 Hours	68 Hours	2 Hours	0 Hours	1 Hours
UV-11	280 Hours	31 [illegible]urs	N/A	128 Hours	0 Hours	71 Hours	49 Hours	0 Hours	1 Hours
UV-12	282 Hours	[illegible]	N/A	150 Hours	0 Hours	33 Hours	71 Hours	0 Hours	0 Hours
UV-13	383 Hours	54 [illegible]ours	N/A	158 Hours	0 Hours	47 Hours	123 Hours	0 Hours	1 Hours
UV-14	286 Hours	22 [illegible]ours	N/A	179 Hours	0 Hours	15 Hours	69 H[illegible]urs	0 Hours	1 Hours
UV-15	282 Hours	27 Hours	N/A	151 Hours	1 Hours	39 Hours	64 [illegible]rs	0 Hours	1 Hours
UV-16	17 Hours	17 Hours	N/A	163 Hours	1 Hours	26 Hours	35 H[illegible]urs	0 Hours	1 Hours
UV-17	270 Hours	18 Hours	N/A	148 Hours	1 Hours	28 Hours	73 H[illegible]urs	0 Hours	1 Hours
UV-18	86 Hours	16 Hours	N/A	0 Hours	0 Hours	66 Hours	4 H[illegible]urs	0 Hours	0 Hours
UV-19	230 Hours	28 Hours	N/A	145 Hours	2 Hours	41 Hours	15 H[illegible]urs	0 Hours	1 Hours
UV-20	182 Hours	22 Hours	N/A	0 Hours	1 Hours	148 Hours	10 Hours	0 Hours	0 Hours
UV-21	213 Hours	20 Hours	N/A	151 Hours	1 Hours	15 Hours	26 Hours	0 Hours	1 Hours
UV-22	243 Hours	27 Hours	N/A	142 Hours	1 Hours	36 Hours	36 Hours	0 Hours	1 Hours
UV-23	231 Hours	20 Hours	N/A	161 Hours	1 Hours	29 Hours	20 Hours	0 Hours	0 Hours
UV-24	211 Hours	21 Hours	N/A	138 Hours	0 Hours	37 Hours	15 Hours	0 Hours	0 Hours
UV-25	215 Hours	17 Hours	N/A	147 Hours	2 Hours	33 Hours	16 Hours	0 Hours	1 Hours

Maintenance Manager: “The most important screen we have” (May 2016)

Another Site…Where is the Problem?

System(s)	Equipment Runtime Hours (Sept 1st to Date)								
	Total	OS Heating	OS Cooling	Occupied	Standby	Day Setback	Night Setback	Purge	Unoccupied
AHU1EX - Gym	1196	88	N/A	794	40	32	65	0	177
AHU2EX - Gym	1658	104	N/A	1308	2	136	108	0	
AHU3EX - A Block	1754	24	N/A	1729	2	N/A	N/A	0	
AHU4EX - Drama	2533	135	N/A	2397	N/A	N/A	1	0	
AHU5EX - Music	2059	138	N/A	1908	N/A	N/A	12	0	
AHU6EX - Block E	2262	97	N/A	1957	N/A	N/A	207	0	
AHU9EX - Block H	2058	132	N/A	1887	N/A	N/A	39	0	0
AHU10EX - Block H	1918	130	N/A	1788	N/A	N/A	0	0	0
AHU101 - Art/Lib	2068	78	N/A	1977	N/A	N/A	11	0	2
AHU102 - Multi	2079	104	N/A	1966	N/A	N/A	8	0	0
AHU103 - Small Gym	1489	140	N/A	1066	0	0	153	0	1
FTU101 - Rm A320	3418	0	N/A	2198	N/A	N/A	0	N/A	1220
FTU102	2045	66	N/A	1979	N/A	N/A	0	N/A	
FTU103 - Rm 314	2304	57	N/A	2198	N/A	N/A	49	N/A	
FTU104 - Rm 316	2811	38	N/A	2710	N/A	N/A	63	N/A	
FTU105 - Rm 317	2717	3	N/A	2710	N/A	N/A	4	N/A	
UV101 - D418	2905	277	N/A	1228	0	626	775	0	
UV102 - D418	1937	240	N/A	1312	0	384	0	0	0
UV103 - D410/411	6885	134	N/A	1979	N/A	N/A	0	0	4773
UV104 - E206	3128	23	N/A	2824	0	281	0	0	
UV105 - E208	1366	32	N/A	1141	0	188	5	0	
UV106 - E209	0	0	N/A	0	0	0	0	0	
UV107 - E210	1033	50	N/A	982	1	0	0	0	
UV108 - B42	3217	68	N/A	3149	N/A	N/A	1	0	
DHW	554	N/A	N/A	553	N/A	N/A	N/A	N/A	0
EXFAN124	1375	N/A	N/A	1375	N/A	N/A	N/A	N/A	0

All Zones Showing Summary of VAV and Reheat



VAV-#	RT	RT_SP	CO2	Flow	Flow_SP	Rad. Valve	Dmp Pos.	Imp. Multi	Req. Hrs	Oper. Mode
VAV-RMD312	22.5 °C	21.0 °C	1161 ppm	383.9 l/s	378.0 l/s	0.0 %	33.5 %	1.0	0.00 hrs	OCC
VAV-RMD310	21.6 °C	21.0 °C	1053 ppm	332.5 l/s	320.4 l/s	3.0 %	38.9 %	1.0	0.00 hrs	OCC
VAV-RMD308	21.9 °C	21.0 °C	913 ppm	171.8 l/s	176.0 l/s	0.0 %	30.7 %	1.0	3.04 hrs	OCC
VAV-RMD208	21.7 °C	21.0 °C	935 ppm	313.9 l/s	378.0 l/s	0.0 %	100.0 %	1.0	761.54 hrs	OCC
VAV-RMD206	21.1 °C	18.4 °C	879 ppm	387.7 l/s	378.0 l/s	0.0 %	52.8 %	1.0	0.01 hrs	OCC
VAV-RMD204	22.8 °C	21.0 °C	1101 ppm	88.6 l/s	378.0 l/s	0.0 %	100.0 %	1.0	639.70 hrs	OCC
VAV-RMD104	21.6 °C	21.0 °C	999 ppm	579.5 l/s	568.0 l/s	0.0 %	41.5 %	1.0	0.00 hrs	OCC
VAV-RMD102	22.5 °C	21.0 °C	1132 ppm	47.0 l/s	568.0 l/s	0.0 %	100.0 %	1.0	672.23 hrs	OCC

Tabulation of request hrs for each VAV box served by a variable volume system

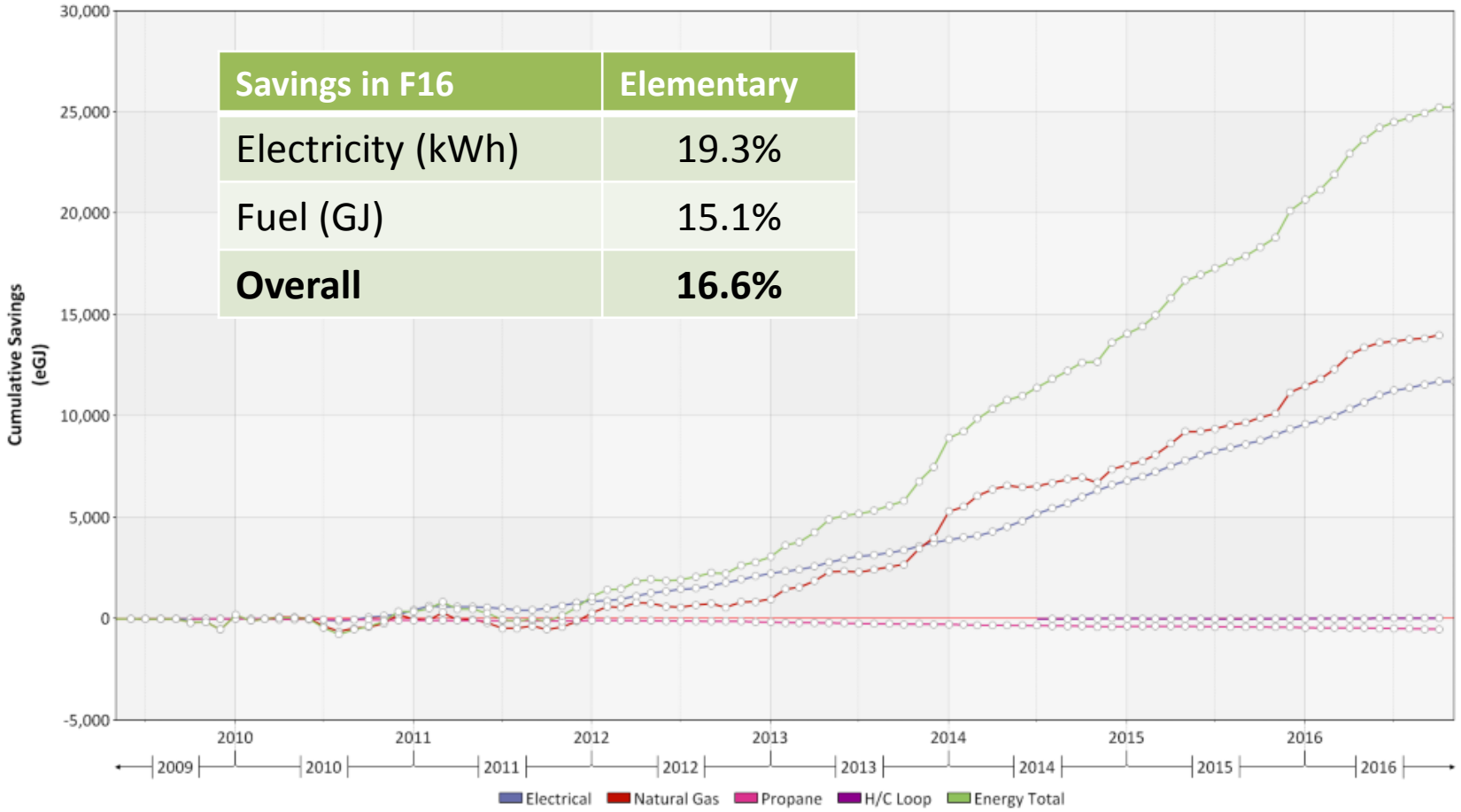
What this means

- **Data:** the number of hours that VAV box has been issuing a request for an increase in supply fan static pressure.
- **Analysis:** Allows for determination of which VAV zones are necessitating an increase in supply fan speed and energy use.
- **Action:** Rebalance, review room sensor locations, identify defective boxes and controls etc.

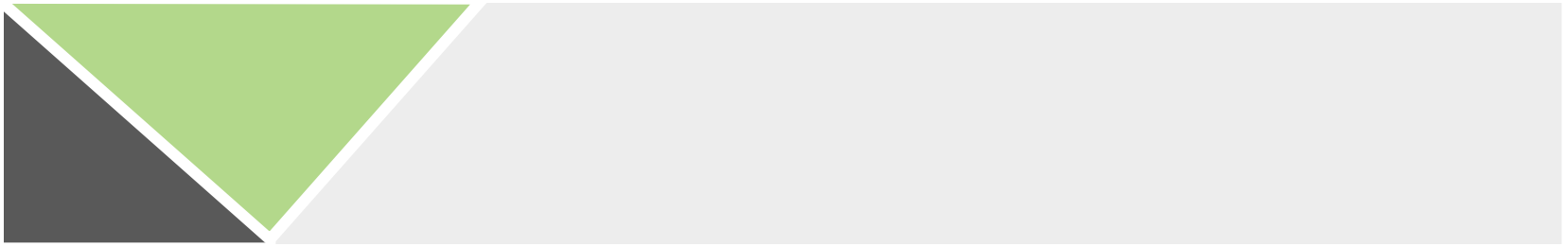
Results – Elementary Schools Only

- Primarily controls

Savings in F16	Elementary
Electricity (kWh)	19.3%
Fuel (GJ)	15.1%
Overall	**16.6%**

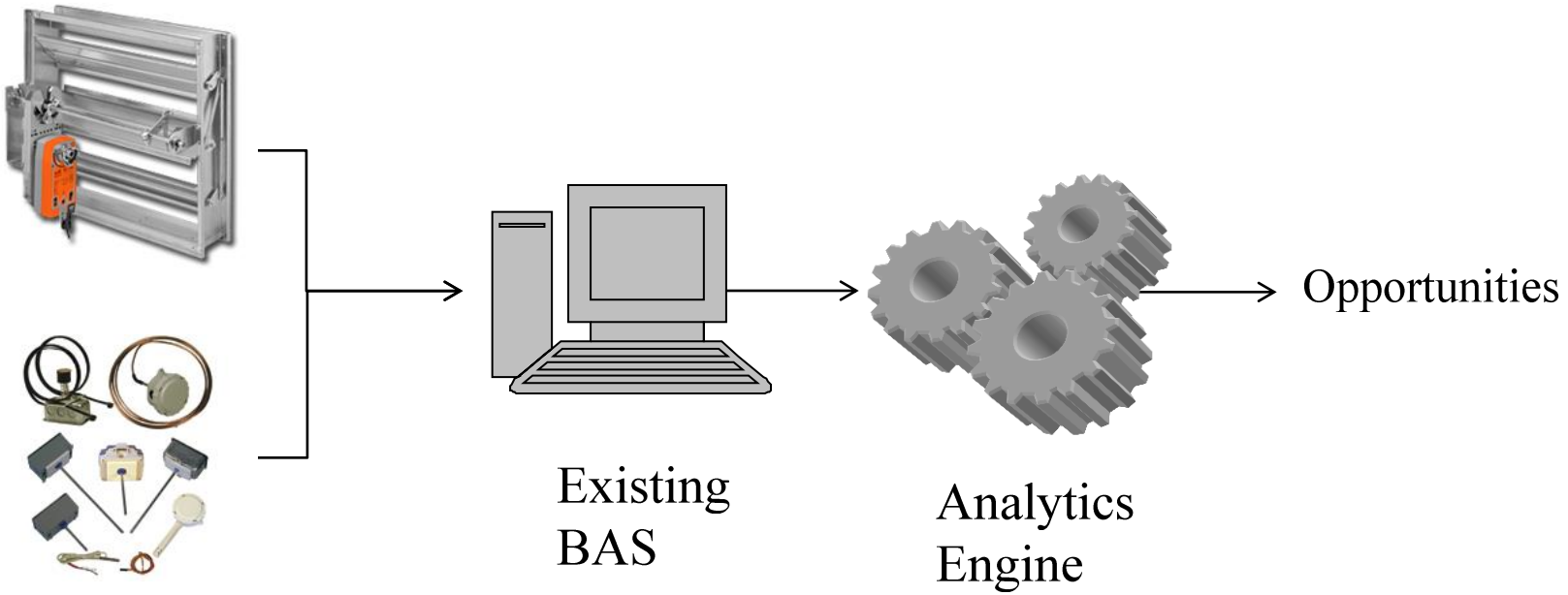


FAULT DETECTION & DIAGNOTICS (FDD)

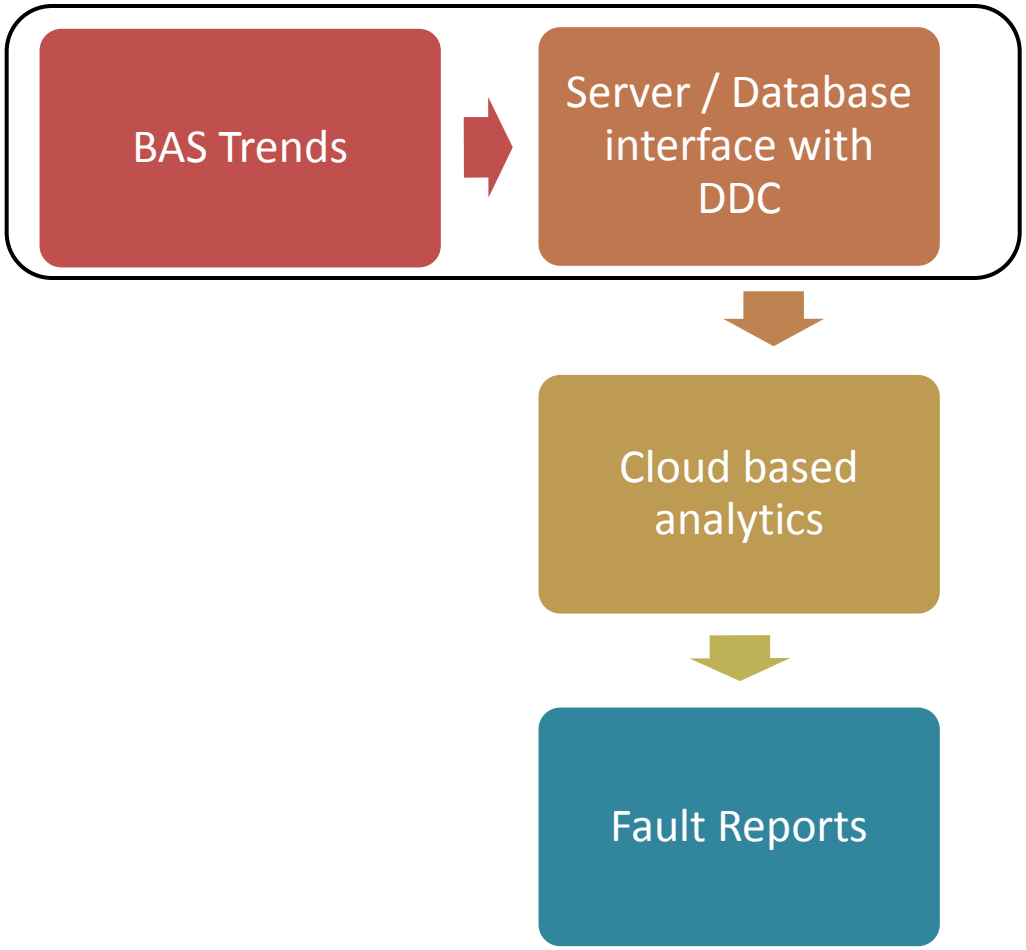


FDD Systems Overview

- Use information from the existing building automation system to identify faults / suboptimal operation of equipment
- Trend data from the DDC system is run through an analytics engine



Typical FDD System Architecture



Inside Building Network

FDD System Goals

- Increase energy efficiency
- Improve occupant comfort
- Reduce maintenance costs
- All the FDD systems in the marketplace have the same goals however systems vary in their approach and sophistication
  - objective is to generate and prioritize *actionable* tasks that can be addressed by the facilities team

Rules based approach

One of the main approaches used to identify faults is applying "If/Then" logic to appropriately mapped points

- Simple economizer rule example:
  - If a system is operating in 100% outside air and MAT is greater than OAT by 2˚C then trigger a fault recommending sensor calibration and verification of proper damper actuation.
- Equipment maintenance example:
  - If a heat pump cycles more than a maximum number of times per hour, trigger a fault recommending deadband revision.

Example Faults

- AHU with simultaneous heating and cooling
- Excessive ventilation air supply
- System not using free cooling
- System operating outside of schedules hours
- Manual overrides
- Excessive equipment cycling
- Equipment hunting due to inappropriate control loop tuning

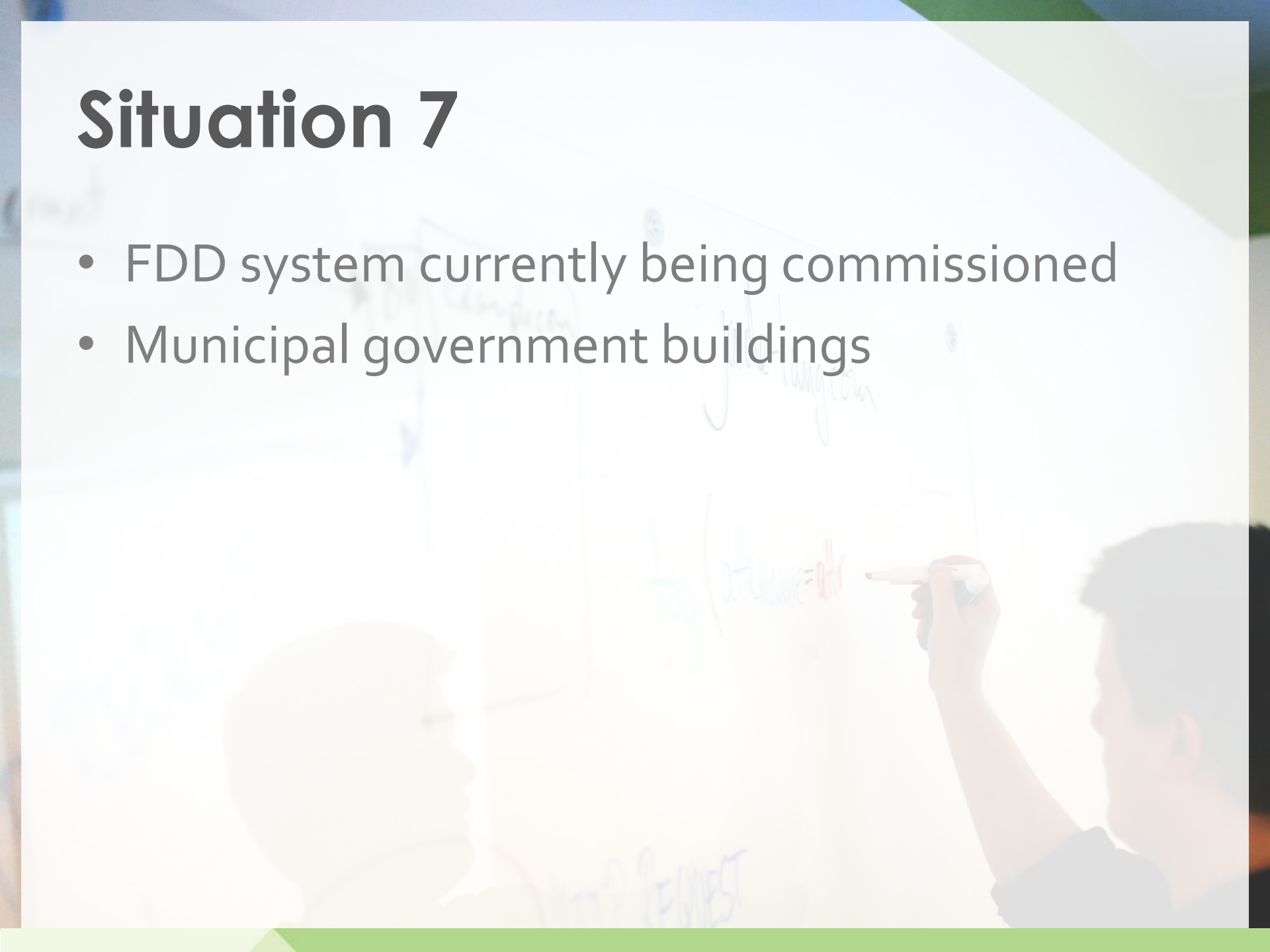
How will FDD be used?

- **Challenge:** how to turn a rule into a fix?

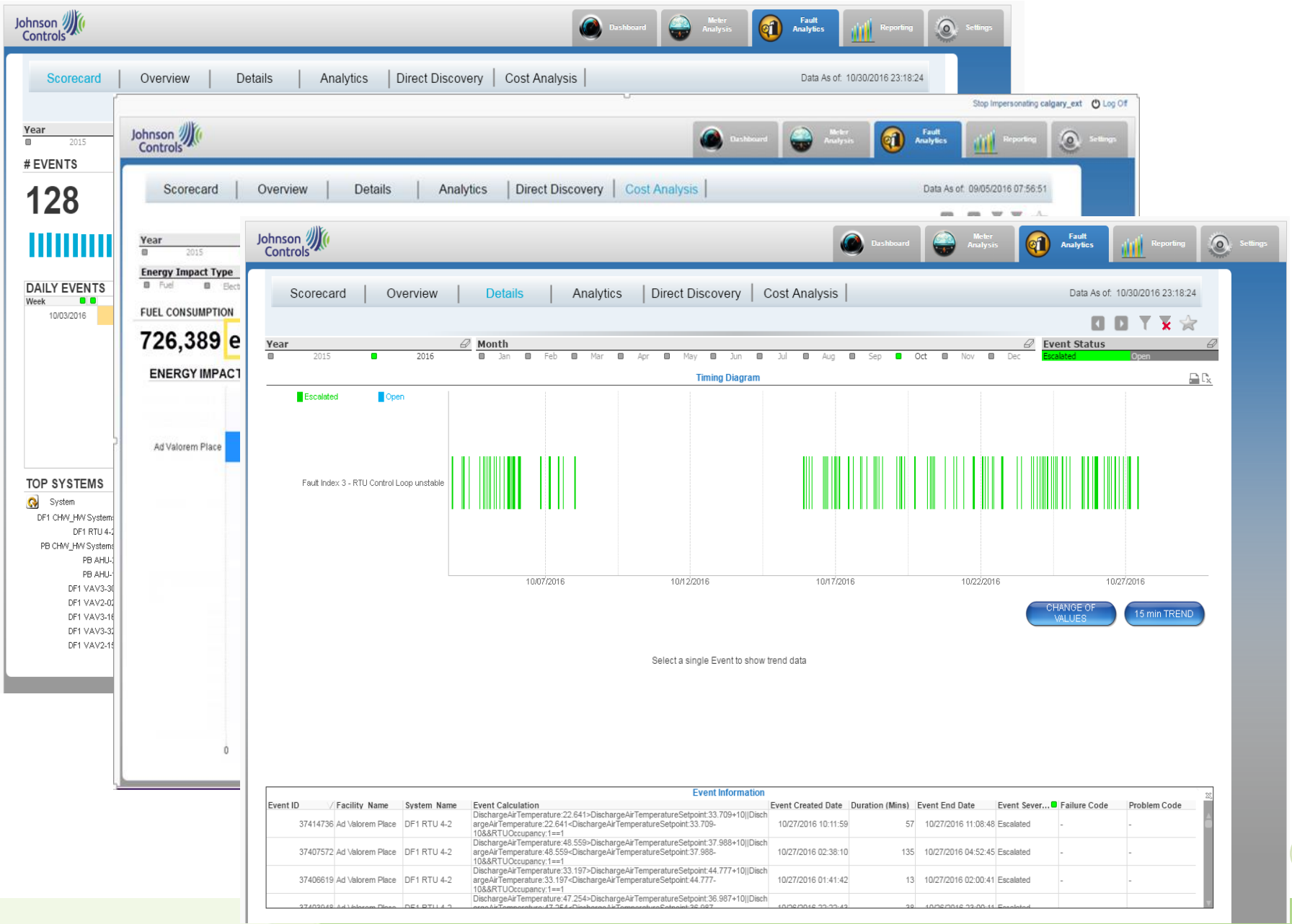
- Eventually FDD will be part of the DDC systems but the challenge remains:
  - how do you get it used?
  - Will it become like a list of "alarms" that go unchecked?
  - Or will operators adopt this?

Situation 7

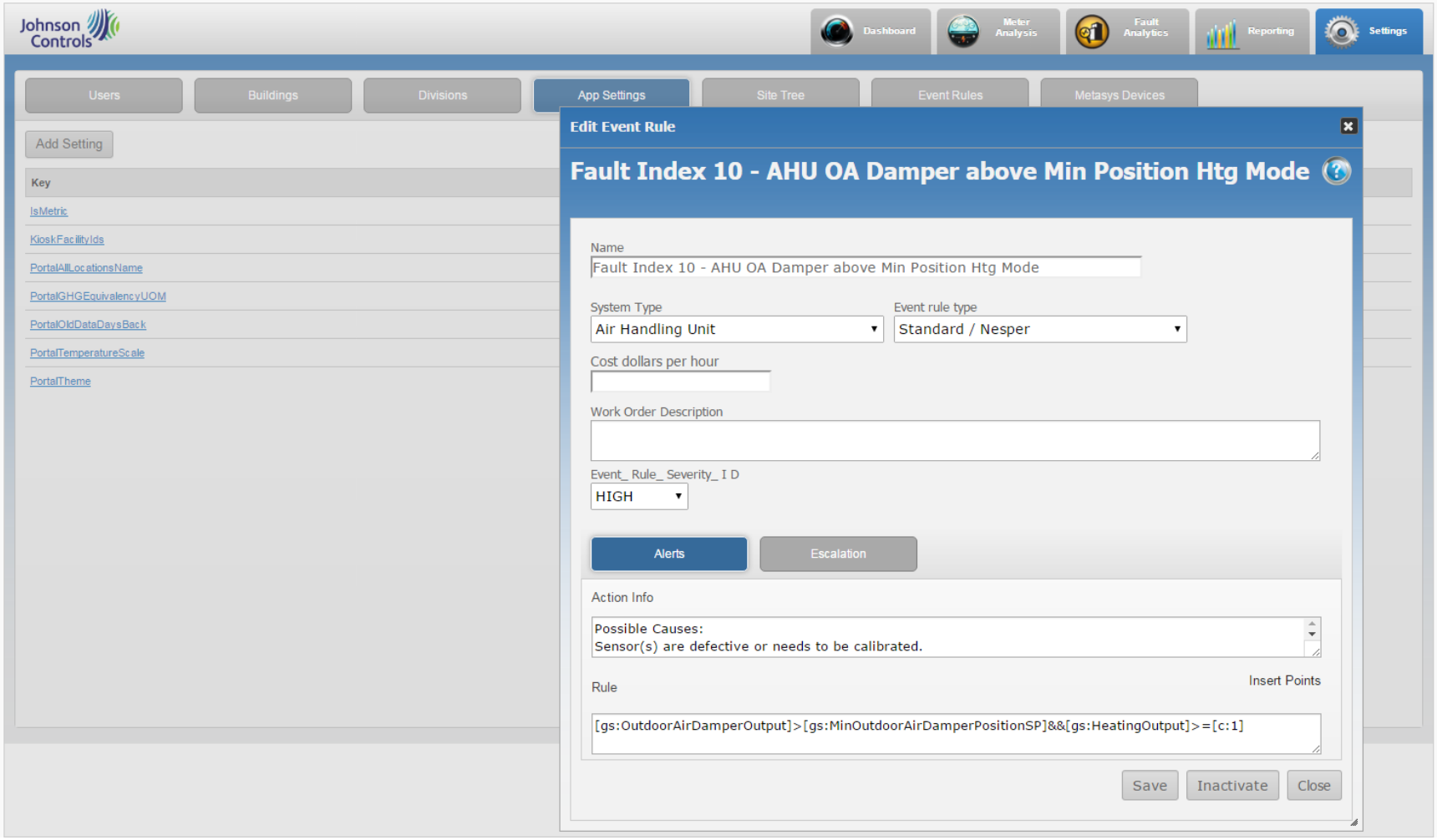
- FDD system currently being commissioned
- Municipal government buildings



Example


Johnson Controls
Dashboard
Meter Analysis
Fault Analytics
Reporting
Settings
Scorecard
Overview
Details
Analytics
Direct Discovery
Cost Analysis
Data As of: 10/30/2016 23:18:24
Stop Impersonating calgary_ext
Log Off
Year
2015
2016
Month
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Event Status
Escalated
Open
EVENTS
128
DAILY EVENTS
Week
10/03/2016
Energy Impact Type
Fuel
FUEL CONSUMPTION
726,389
ENERGY IMPACT
Ad Valorem Place
TOP SYSTEMS
System
Timing Diagram
Escalated
Open
Fault Index 3 - RTU Control Loop unstable
10/07/2016
10/12/2016
10/17/2016
10/22/2016
10/27/2016
CHANGE OF VALUES
15 min TREND
Select a single Event to show trend data
Event Information
Event ID
Facility Name
System Name
Event Calculation
Event Created Date
Duration (Mins)
Event End Date
Event Sever...
Failure Code
Problem Code
37414736 Ad Valorem Place DF1 RTU 4-2 DischargeAirTemperature:22.641>DischargeAirTemperatureSetpoint:33.709+10||DischargeAirTemperature:22.641<DischargeAirTemperatureSetpoint:33.709-10&&RTUOccupancy:1==1 10/27/2016 10:11:59 57 10/27/2016 11:08:48 Escalated
37407572 Ad Valorem Place DF1 RTU 4-2 DischargeAirTemperature:48.559>DischargeAirTemperatureSetpoint:37.988+10||DischargeAirTemperature:48.559<DischargeAirTemperatureSetpoint:37.988-10&&RTUOccupancy:1==1 10/27/2016 02:38:10 135 10/27/2016 04:52:45 Escalated
37406619 Ad Valorem Place DF1 RTU 4-2 DischargeAirTemperature:33.197>DischargeAirTemperatureSetpoint:44.777+10||DischargeAirTemperature:33.197<DischargeAirTemperatureSetpoint:44.777-10&&RTUOccupancy:1==1 10/27/2016 01:41:42 13 10/27/2016 02:00:41 Escalated
DischargeAirTemperature:47.254>DischargeAirTemperatureSetpoint:36.987+10||Disch

How Faults are Defined



Implementing Analytical Platforms and Processes

Do's

1. Expect to invest considerable time setting the system up
2. Ensure the rules implemented are applicable to your systems
3. Engage the DDC contractor in the rule selection & deployment
4. Consider DDC network performance impact
5. Ensure Building Operators are involved throughout implementation
6. Refine fault logic to remove nuisance triggers
7. Develop a plan for turning faults into remedial actions

Implementing Analytical Platforms and Processes

Don'ts

- Get sold on the abilities of software without considering how it will fit in to your operating processes
- Rely on "black box" results or treat it as "hands off": your operators will need to take action based on the opportunities identified

You could benefit from input and advice from your RCx consultant throughout the process.

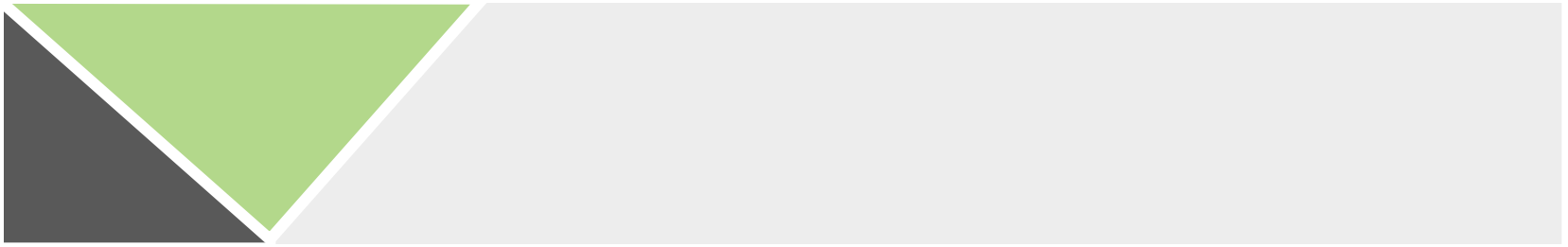
What we miss with FDD

- Opportunity to introduce improved sequence (there is an opportunity to do better)
- the ability to do queries on historical data
- not part of a package -- can not open up the "vault"

CopperTree: Identified Faults and Messages

Priority	System	Message	Type	Weekday	Occurred
Medium	N/A	SF6 West has taken longer than 2 hours per week to reach its Supply Air Temperature Set Point on initialization.		Wed	Jun 01, 2016 11:59 pm
Medium	N/A	When the unit is receiving 100% outdoor air, SF1's Mixed Air Temperature has been significantly different that the Outside Air Temperature. This is likely due to a leaking air damper, and should be looked at as a preventative measure.		Sun	Oct 30, 2016 11:59 pm
Medium	N/A	SF3 South's Supply Air Temperature has been significantly greater than the preceding air temperature over the course of a week. This is likely due to a leaking heating coil valve. Please review the system as a preventative measure.		Sun	Sep 11, 2016 11:59 pm
Medium	N/A	SF4 East's Supply Air Temperature has been significantly greater than the preceding air temperature over the course of a week. This is likely due to a leaking heating coil valve. Please review the system as a preventative measure.		Sun	Sep 11, 2016 11:59 pm
Medium	N/A	SF5 North's Supply Air Temperature has been significantly greater than the preceding air temperature over the course of a week. This is likely due to a leaking heating coil valve. Please review the system as a preventative measure.		Sun	Sep 11, 2016 11:59 pm
Medium	N/A	SF6 West's Supply Air Temperature has been significantly greater than the preceding air temperature over the course of a week. This is likely due to a leaking heating coil valve. Please review the system as a preventative measure.		Sun	Aug 14, 2016 11:59 pm
Medium	N/A	AHU1 has taken longer than 2 hours per week to reach its Supply Air Temperature Set Point on initialization.		Sat	Oct 29, 2016 11:59 pm
Medium	N/A	SF5 North has taken longer than 2 hours per week to reach its Supply Air Temperature Set Point on initialization.		Fri	May 13, 2016 11:59 pm
Medium	N/A	When the unit is receiving 100% outdoor air, SF3's Mixed Air Temperature has been significantly different that the Outside Air Temperature. This is likely due to a leaking air damper, and should be looked at as a preventative measure.		Sun	May 01, 2016 11:59 pm

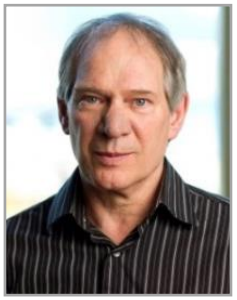
WRAP UP



Five Key Take Aways

1. Although "traditional", using trend logs effectively can help identify savings opportunities
2. Enhanced analytics using historical data can help us understand HVAC operations and can lead to
    - The identification of energy savings
    - More effective commissioning of new equipment
    - Identifying O&M issues and working with operators
3. Data analytics support the verification of actual equipment operating efficiency
4. Analytics on energy data can flag issues and opportunities
5. Automated Fault Detection (FDD) can be an effective tool when combined with operating processes and adequate support

Credit



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Q & A

Thank you.

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