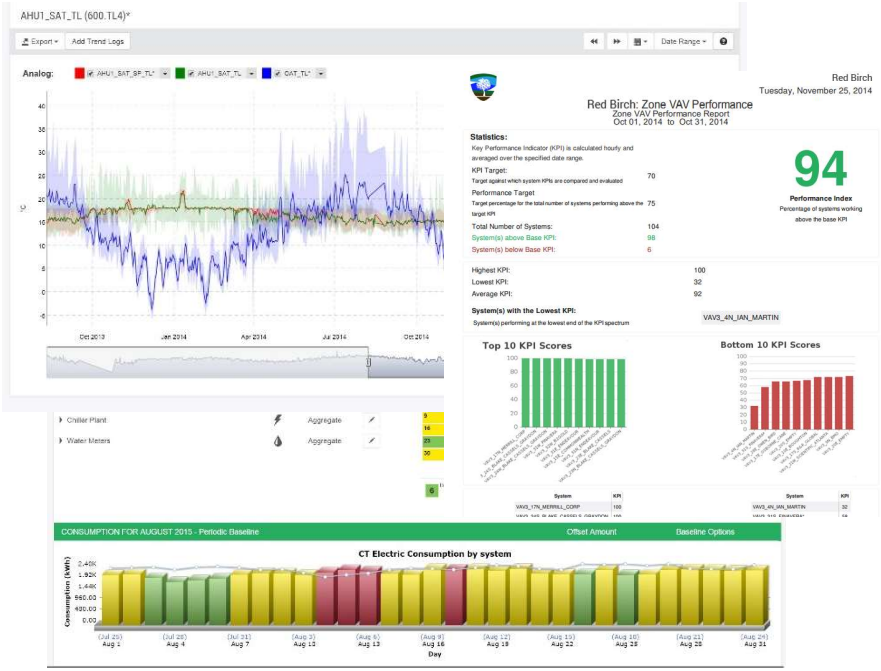
COPPERTREE
ANALYTICS

Analytics for a better building

www.coppertreeanalytics.com

Agenda



- CopperTree Background
- ~~How to acquire BAS data~~
- Data Driven Maintenance
- Data Driven Fault Detection & Diagnostics
- Data Driven Energy Management
- Live Demo

COPPERTREE ANALYTICS

Who is CopperTree Analytics?

What does CopperTree Analytics do?

Intelligent building technology is not fulfilling its potential

We provide a powerful tool which delivers actionable insights that help building managers.

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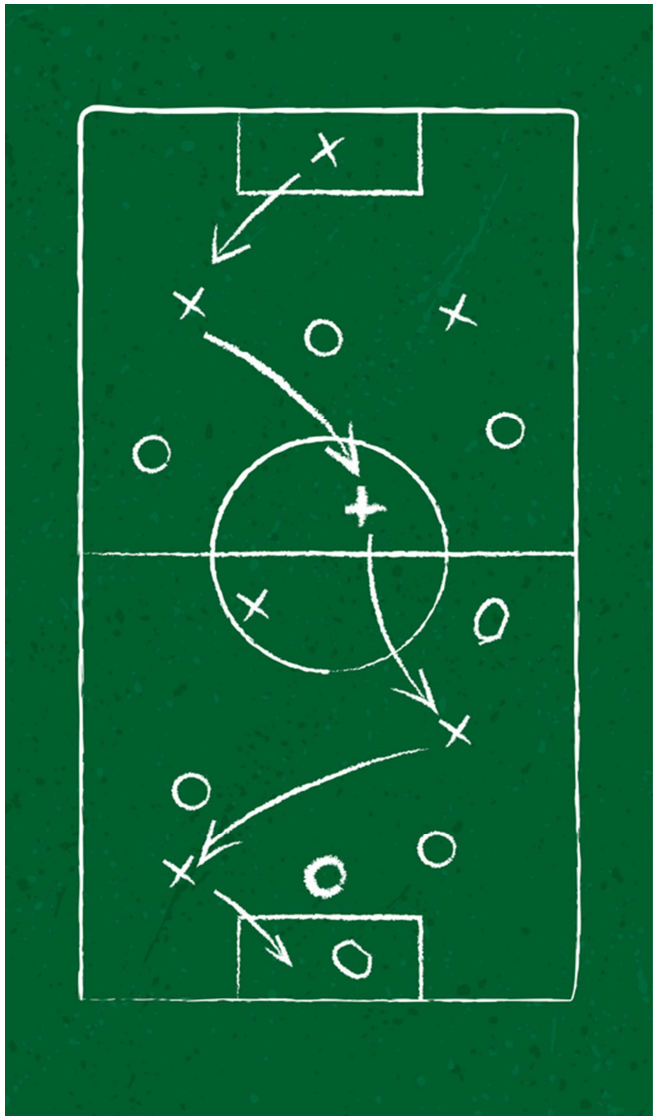
The “Why” - Building Analytics Goals

- ✓ Increase energy efficiency
- ✓ Improve tenant comfort
- ✓ Reduce maintenance costs
- ✓ Prolong equipment life



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Data Driven Maintenance using Key Performance Indicators (KPIs)

- Compare multiple systems or buildings to each other and find best and worst performers
- Prioritize Maintenance & Repair

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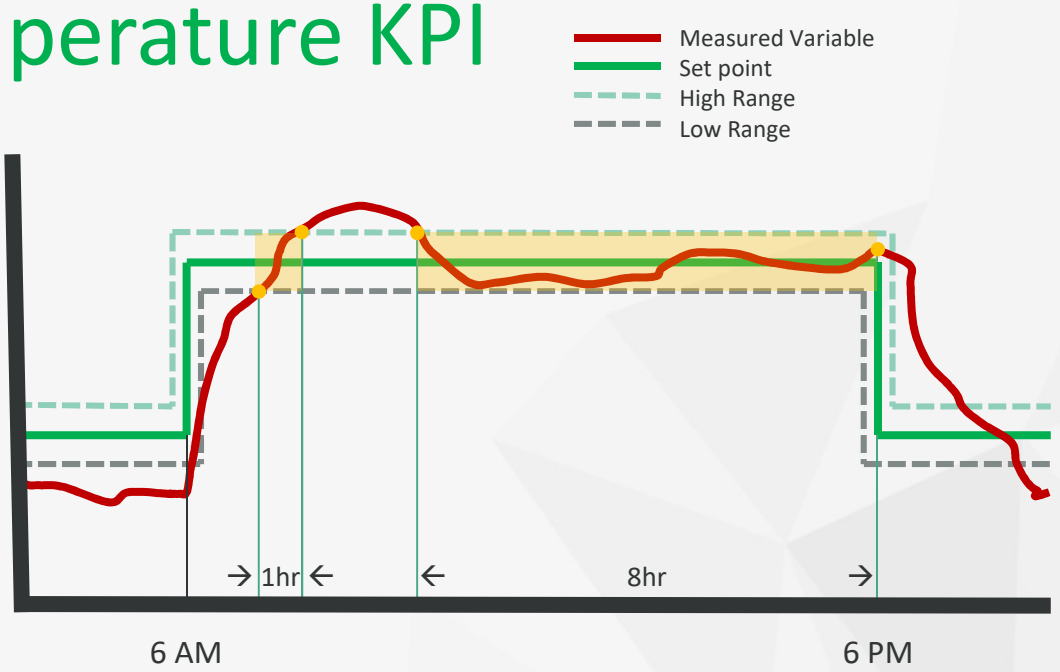
A KPI "Rule" Explained for 1 Zone/System

75% Temperature KPI



Target: KPI of 100 - *A KPI of 100 means that the measured variable has been within normal operating range during the occupied period.*

This Example - Total time within range: 9 hours (1 hour + 8 hours)
KPI = 9 hours / 12 hours = 0.75 = **75%**

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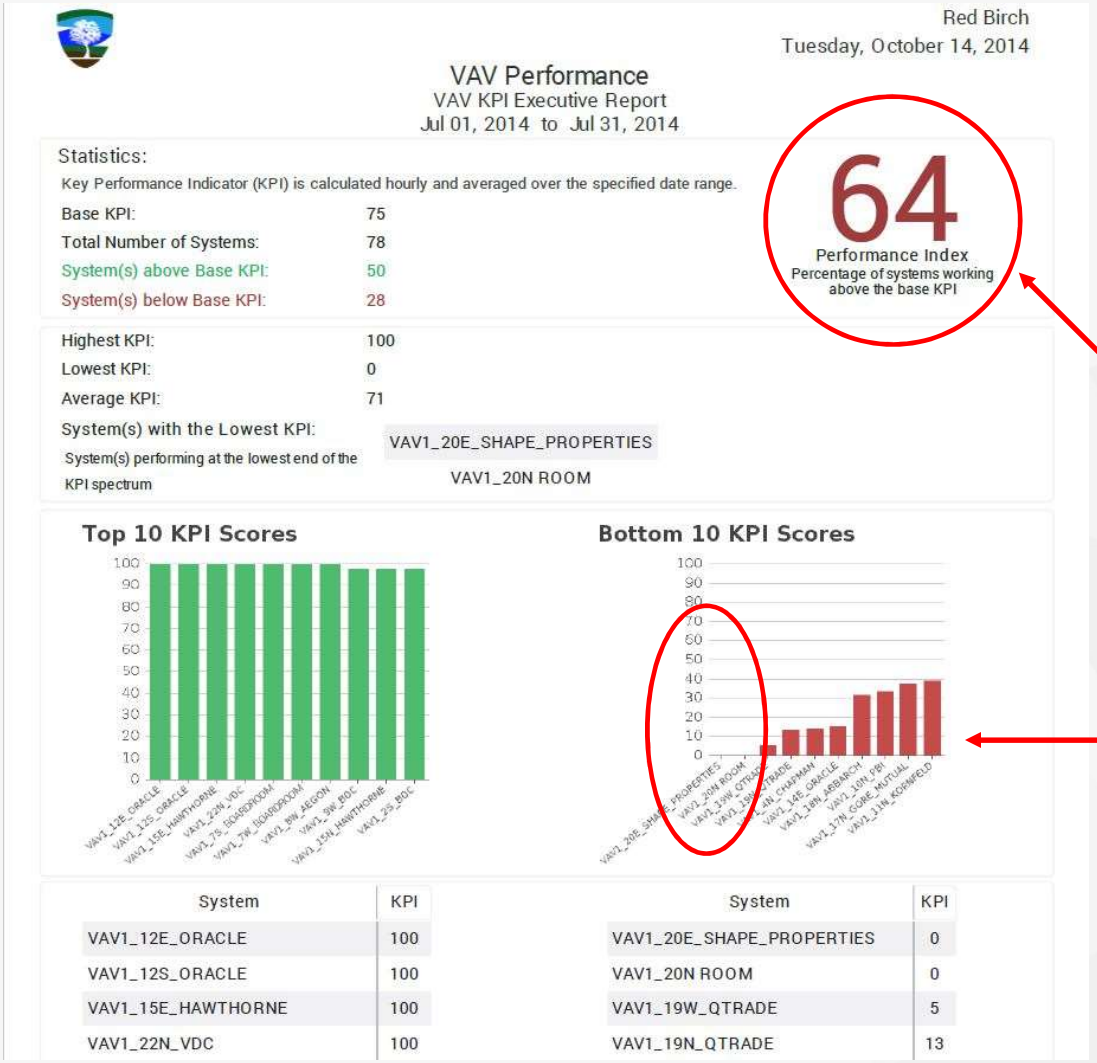
A KPI Report for a Whole Building



Red Birch
Tuesday, October 14, 2014

VAV Performance
VAV KPI Executive Report
Jul 01, 2014 to Jul 31, 2014

Statistics:

Key Performance Indicator (KPI) is calculated hourly and averaged over the specified date range.

Base KPI:	75
Total Number of Systems:	78
System(s) above Base KPI:	50
System(s) below Base KPI:	28

64
Performance Index
Percentage of systems working above the base KPI

Highest KPI:	100
Lowest KPI:	0
Average KPI:	71
System(s) with the Lowest KPI:	VAV1_20E_SHAPE_PROPERTIES
System(s) performing at the lowest end of the KPI spectrum	VAV1_20N ROOM

Top 10 KPI Scores

Bottom 10 KPI Scores

System	KPI
VAV1_12E_ORACLE	100
VAV1_12S_ORACLE	100
VAV1_15E_HAWTHORNE	100
VAV1_22N_VDC	100

System	KPI
VAV1_20E_SHAPE_PROPERTIES	0
VAV1_20N ROOM	0
VAV1_19W_QTRADE	5
VAV1_19N_QTRADE	13

- One measure for entire building's performance
- Find worst performers easily

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Case Study #1

Vancouver International Airport

- Terminal Link Building
- Systems of interest:
  - 4 AHUs
  - 170 VAV/FCU

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Challenges faced with conventional maintenance

- General areas difficult to access for manual zone maintenance with cubicles & storage cabinets all over
- Some offices require third party security to be hired for overnight to perform maintenance
- Clean up is critical

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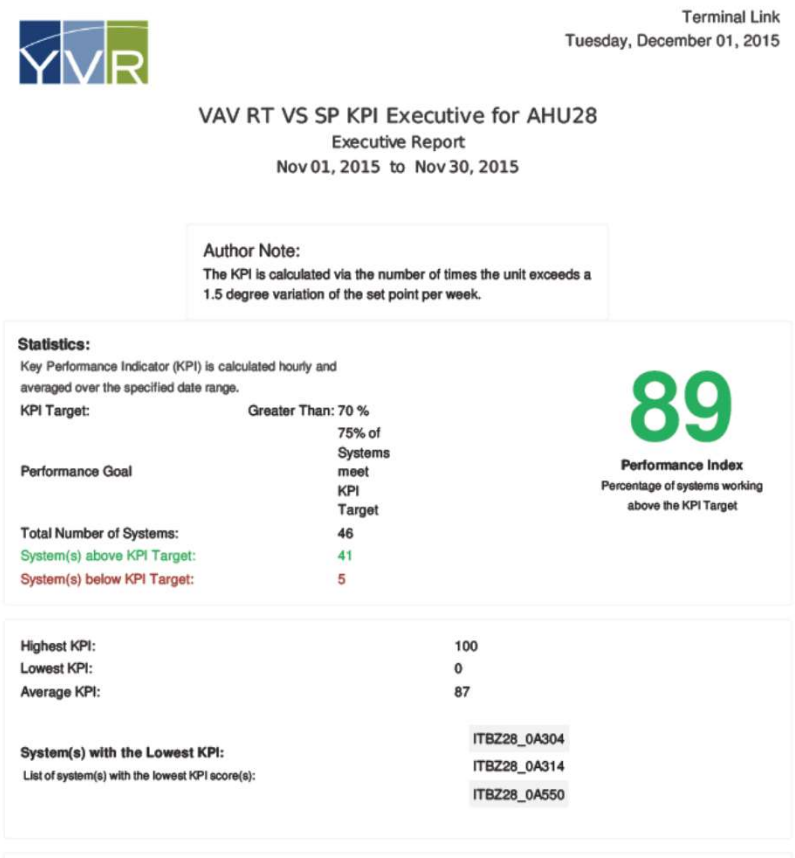
KPI Reports



Terminal Link
Tuesday, December 01, 2015

VAV RT VS SP KPI Executive for AHU28
Executive Report
Nov 01, 2015 to Nov 30, 2015

Author Note:
The KPI is calculated via the number of times the unit exceeds a 1.5 degree variation of the set point per week.

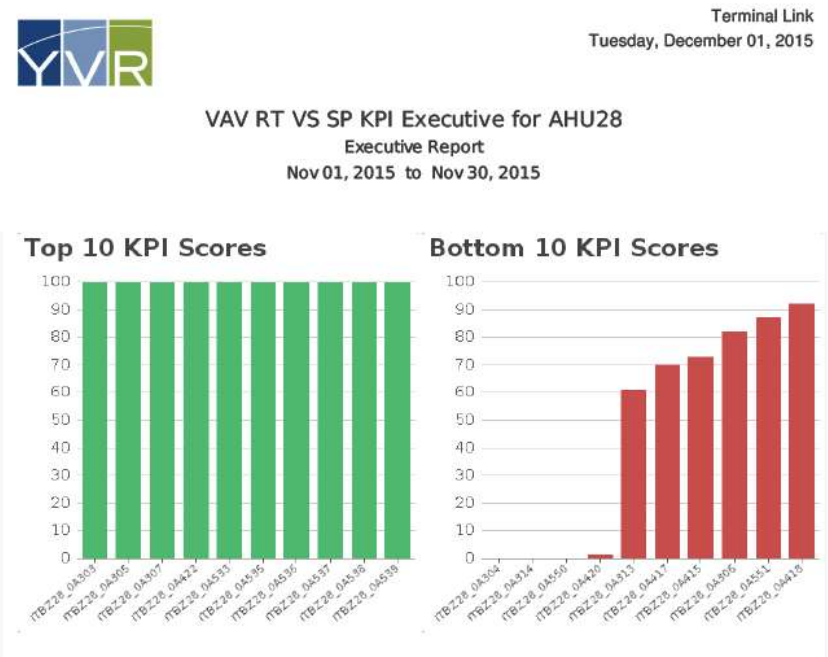
Statistics:
Key Performance Indicator (KPI) is calculated hourly and averaged over the specified date range.

KPI Target:	Greater Than: 70 %
Performance Goal	75% of Systems meet KPI Target
Total Number of Systems:	46
System(s) above KPI Target:	41
System(s) below KPI Target:	5

89
Performance Index
Percentage of systems working above the KPI Target

Highest KPI:	100
Lowest KPI:	0
Average KPI:	87

System(s) with the Lowest KPI:
List of system(s) with the lowest KPI score(s):
ITBZ28_0A304
ITBZ28_0A314
ITBZ28_0A550



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Nov 01, 2015 to Nov 30, 2015

Top 10 KPI Scores

Bottom 10 KPI Scores

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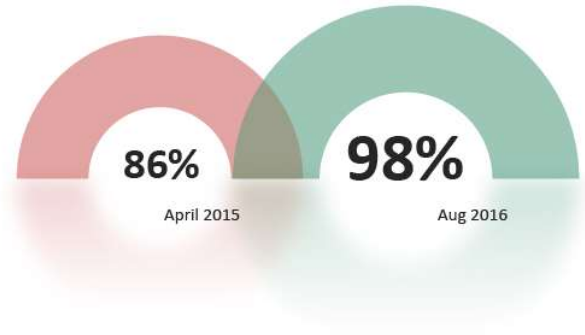
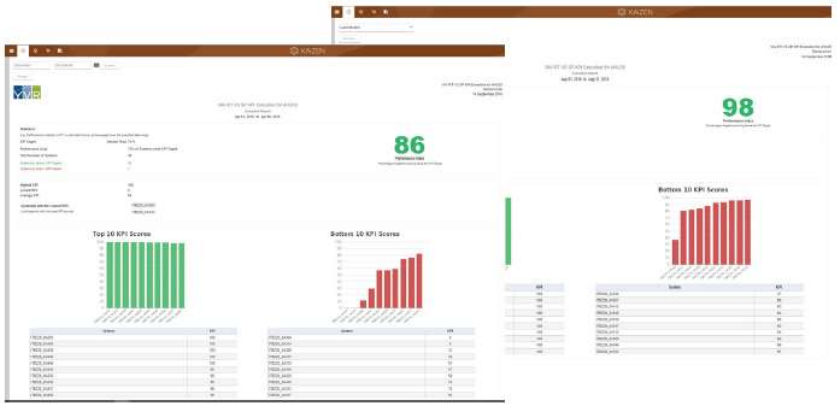
Results achieved

- Reduction in HVAC Maintenance $, while increasing # of systems repaired

- Improved Measured Passenger Comfort Performance from 86% to 98%



12% Improvement in Systems Maintaining Target



Kaizen KPI Reports clearly show ten worst and ten best performing units

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Case Study #2

University Medical Education Building

- Location: Southwestern USA
- Year Built: 2001
- Boiler & Plant Upgrades 2 Years Ago
- 72,000 Square Feet of:
  - Medical Classrooms
  - Meeting rooms
  - Administrative offices
  - Medical library

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KPIs in This Building: Temperature

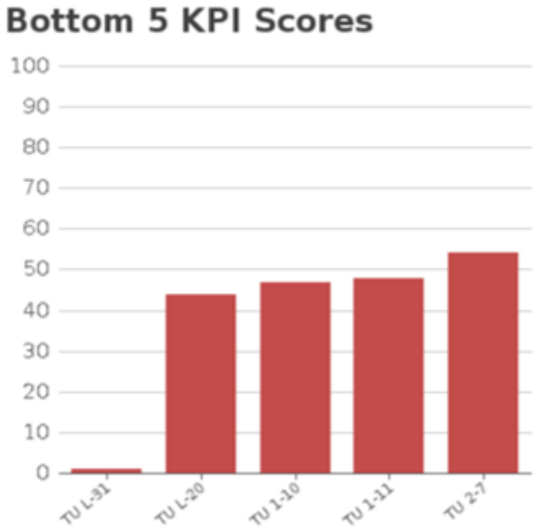
Zone Temperature Performance

Big Data! 770,000

Data points

KPI: 85%

Analysis showed 85% of zones maintained zone temperature within desired deadband (setpoint +/- 1.5 degrees F) during occupied hours



System	KPI
TU L-31	1
TU L-20	44
TU 1-10	47
TU 1-11	48
TU 2-7	54

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KPIs in This Building: Airflow

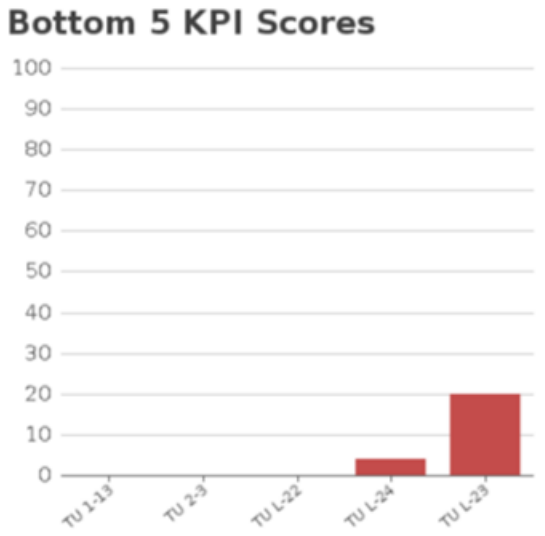
Zone Airflow Performance

Big Data! 770,000

Data points

KPI: 45%

Analysis showed 45% of zones maintained airflow within desired deadband (setpoint +/- 8%) during occupied hours



System	KPI
TU 1-13	0
TU 2-3	0
TU L-22	0
TU L-24	4
TU L-23	20

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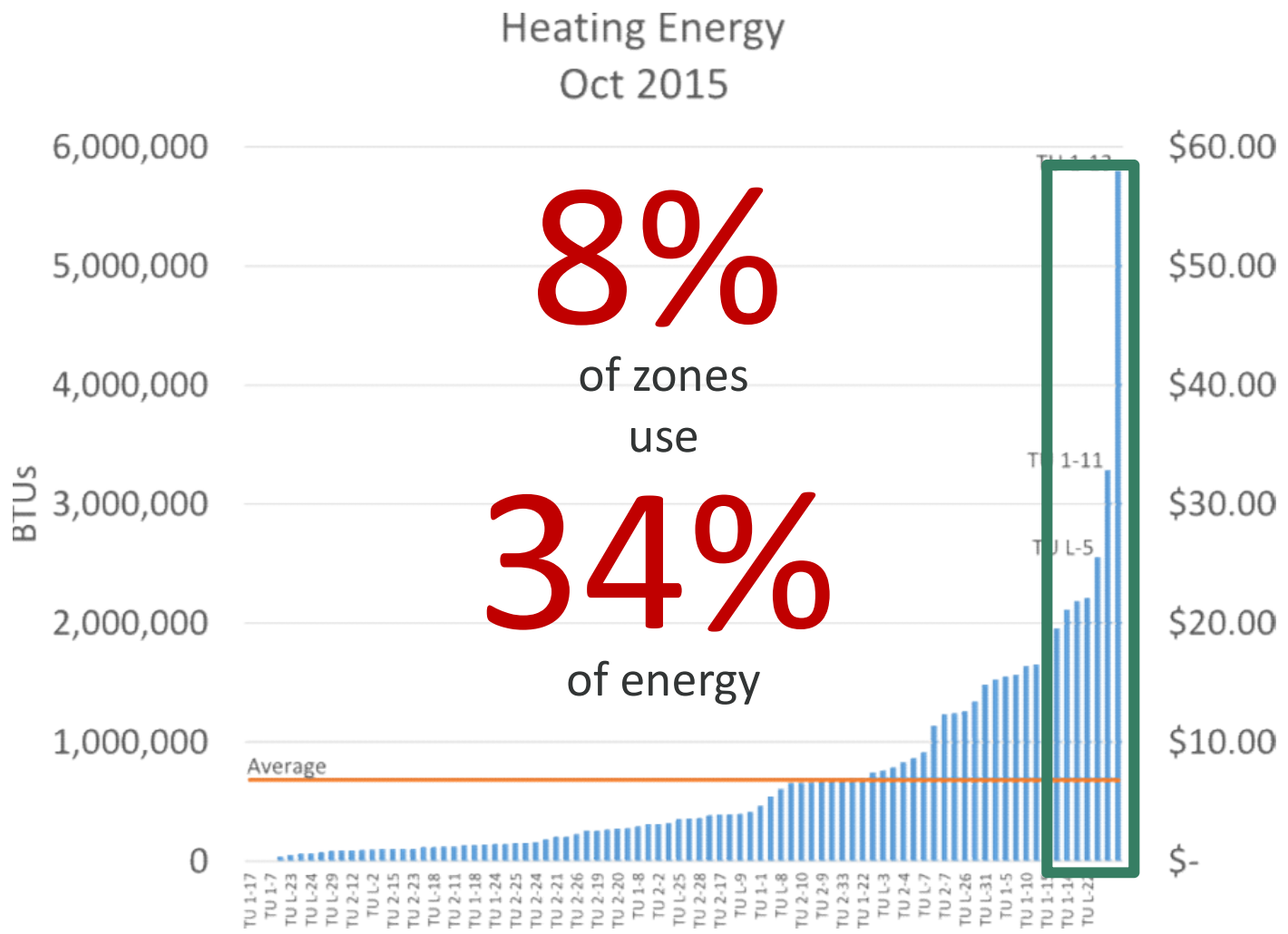
VAV Reheat Energy KPI



COPPERTREE ANALYTICS

Applying KPIs

Temperature KPI	
TU L-31	1
TU L-20	44
TU 1-10	47
TU 1-11	48
TU 2-7	54
TU 1-3	56
TU 1-2	70
TU L-7	71
TU 1-4	74
TU 1-5	77
TU 1-6	78
TU 2-29	79
TU 2-32	80
TU L-8	80
TU L-25	82
TU 1-16	84
TU 1-9	84
TU 2-27	86
TU 2-21	88
TU 1-12	89
TU L-28	90
TU L-26	95
TU L-27	95
TU 2-24	96
TU 2-30	96
TU 1-13	97

Reheat Energy	
TU 1-13	2,988,971
TU L-5	1,823,936
TU L-6	1,615,534
TU 1-15	1,140,873
TU 1-14	1,127,586
TU 1-11	977,038
TU 2-27	790,242
TU 1-10	688,504
TU L-31	687,599
TU L-28	618,168
TU L-13	593,248
TU 1-12	585,086
TU 2-30	580,148
TU 2-29	541,903
TU L-22	538,241
TU L-26	537,037
TU 1-2	528,713
TU 1-5	504,830
TU L-7	472,769
TU 2-32	464,877
TU 1-22	450,989
TU 2-7	428,750
TU 1-4	422,306
TU 1-1	388,135
TU 2-33	387,041
TU L-20	334,175

Airflow KPI	
TU 1-13	0
TU 2-3	0
TU L-22	0
TU L-24	4
TU L-23	20
TU L-18	36
TU 2-34	42
TU L-29	50
TU 2-7	52
TU 1-21	53
TU 1-5	54
TU L-6	64
TU 2-33	68
TU L-21	68
TU 2-24	70
TU 2-31	70
TU L-31	70
TU 2-22	71
TU 2-23	71
TU 2-27	71
TU 2-28	71
TU 2-29	71
TU 2-30	71
TU 2-32	71
TU 1-23	72
TU 1-8	72

3

Measures of Performance

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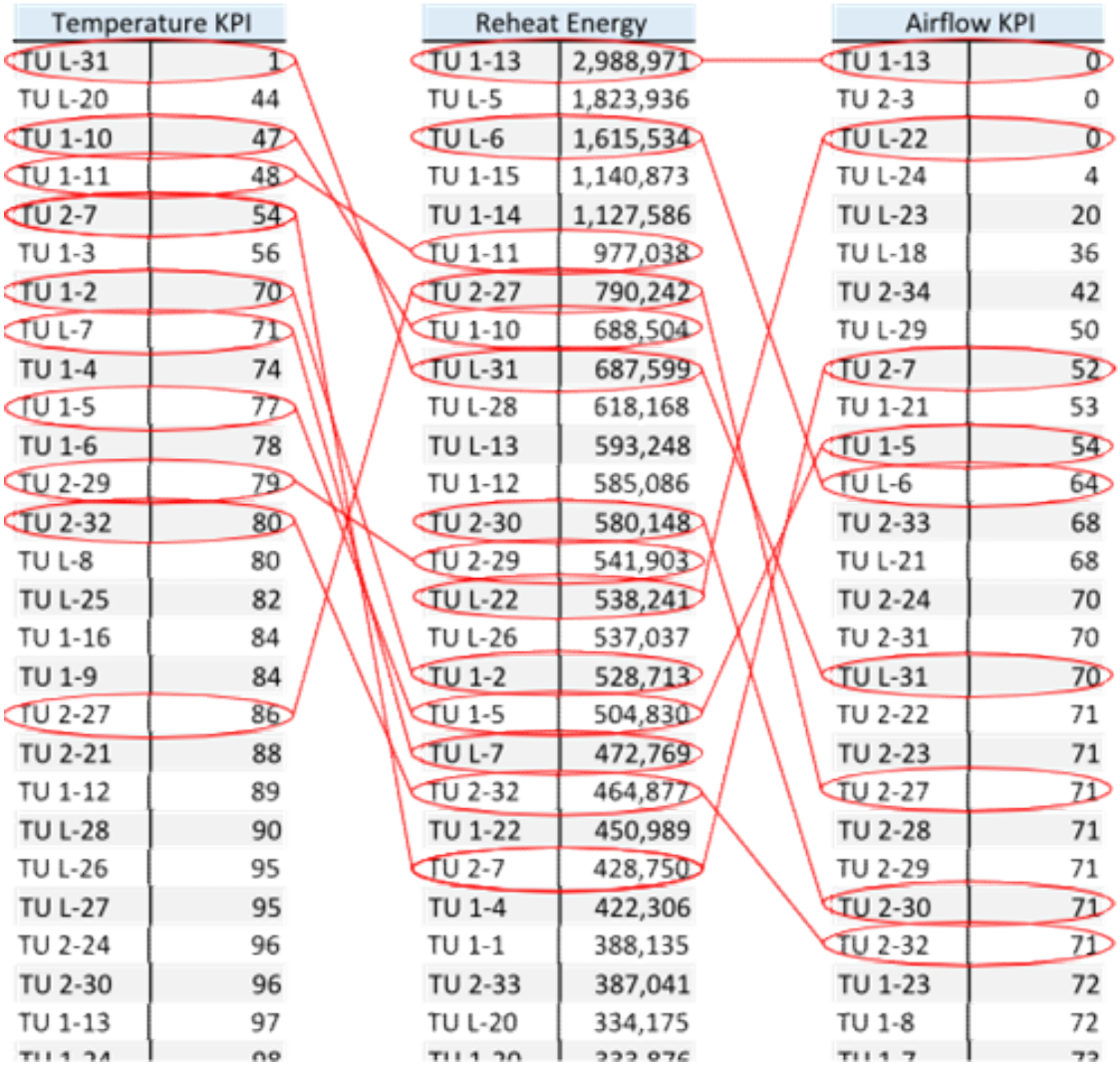
Findings Worst Performers Quickly & Easily



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TU 1-4	74
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TU 2-29	79
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TU 1-16	84
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TU 2-24	70
TU 2-31	70
TU L-31	70
TU 2-22	71
TU 2-23	71
TU 2-27	71
TU 2-28	71
TU 2-29	71
TU 2-30	71
TU 2-32	71
TU 1-23	72
TU 1-8	72

14

Zones (of 86) score poorly on multiple lists

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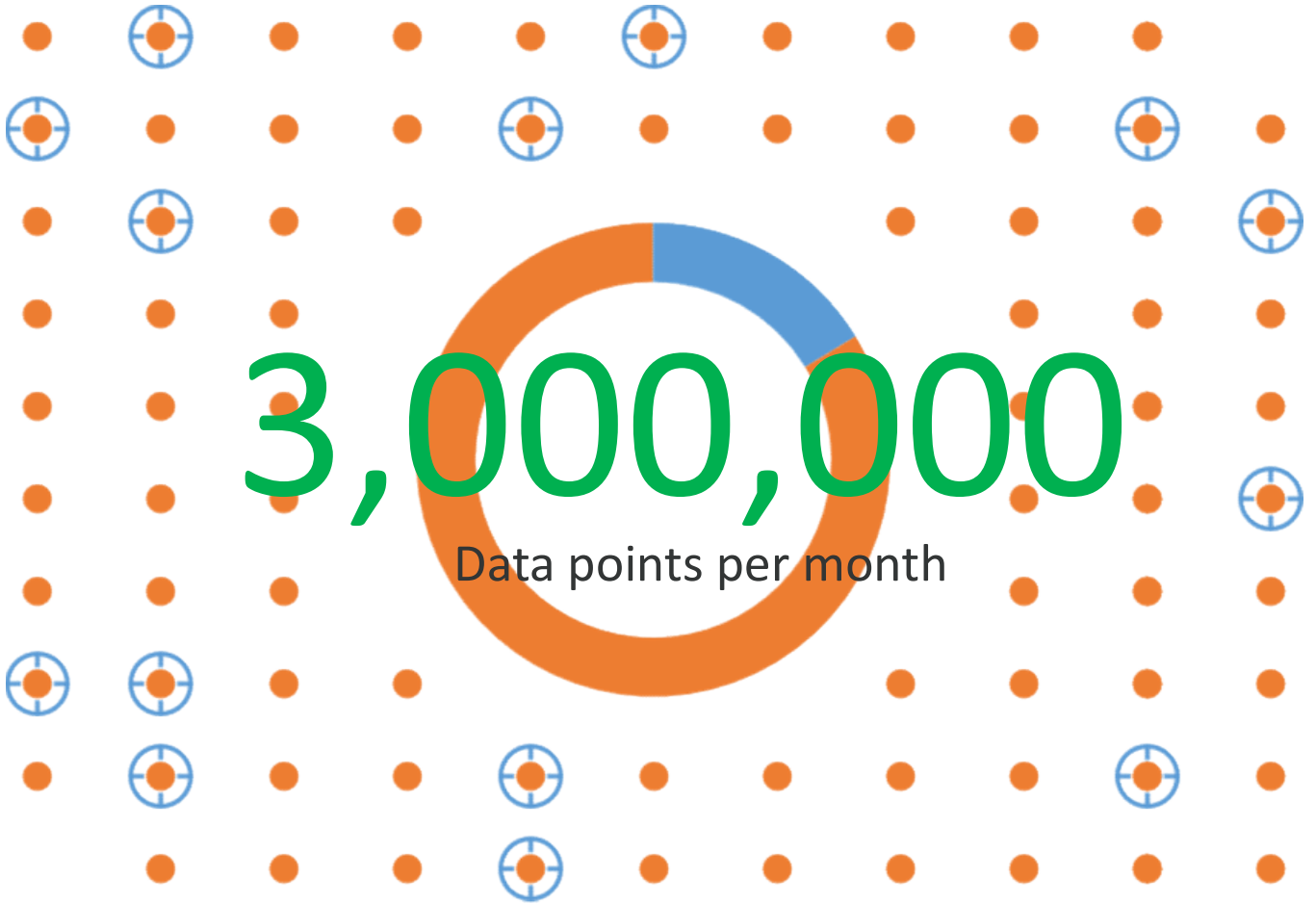
Targeting Worst for Repair



Big Data!

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Data Driven Maintenance vs. Traditional Maintenance

System	Time (minutes)		Difference
	Traditional Time	Using Analytics	
AHU	115	75	-34.8%
VAV	31	10	-67.7%
FCU	45	10	-77.8%
ACU	35	10	-71.4%
Chiller	40	20	-50.0%
Boiler	40	20	-50.0%
Average	**51**	**24**	**-60%**

On average:

- Found that performing data driven maintenance on the above systems was 60% more time effective!

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Data Driven Maintenance vs. Traditional Maintenance

- Analytics drastically reduces the manual maintenance tasks
- Unlike traditional maintenance, performance is being monitored 24/7/365 – catching issues immediately
- Maintenance staff & $ can be re-directed, driving improvements to the bottom line

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Data Driven Fault Detection & Diagnostics

Common Types of Faults

- Systems running outside intended schedule
- Manual overrides
- Improper sequencing
- Heating/Cooling simultaneously

- Valves & dampers leaking, hunting & PID tuning issues
- Temperature/Comfort issues in zones (temp/airflow/CO2)

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Case Study #2 continued

University Medical Education Building

- Location: Southwestern USA
- Year Built: 2001
- Boiler & Plant Upgrades 2 Years Ago
- 72,000 Square Feet of:
  - Medical Classrooms
  - Meeting rooms
  - Administrative offices
  - Medical library

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The Building Operator's Perspective

Room Temperature Avg. 15 Minute Trend

- BAS is not generating alarms - Avg. temps are within range
- Many occupant temperature complaints despite trend above
- No evidence there's anything wrong with the room temperatures or underlying mechanical equipment

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Supply Air Temperature Analysis

- Supply Air Temperature from Air Handler swinging wildly up to 25 degrees either way
- Occupants sitting under diffusers would definitely feel this, but average room temperatures are within range (when averaged over 15 minutes)

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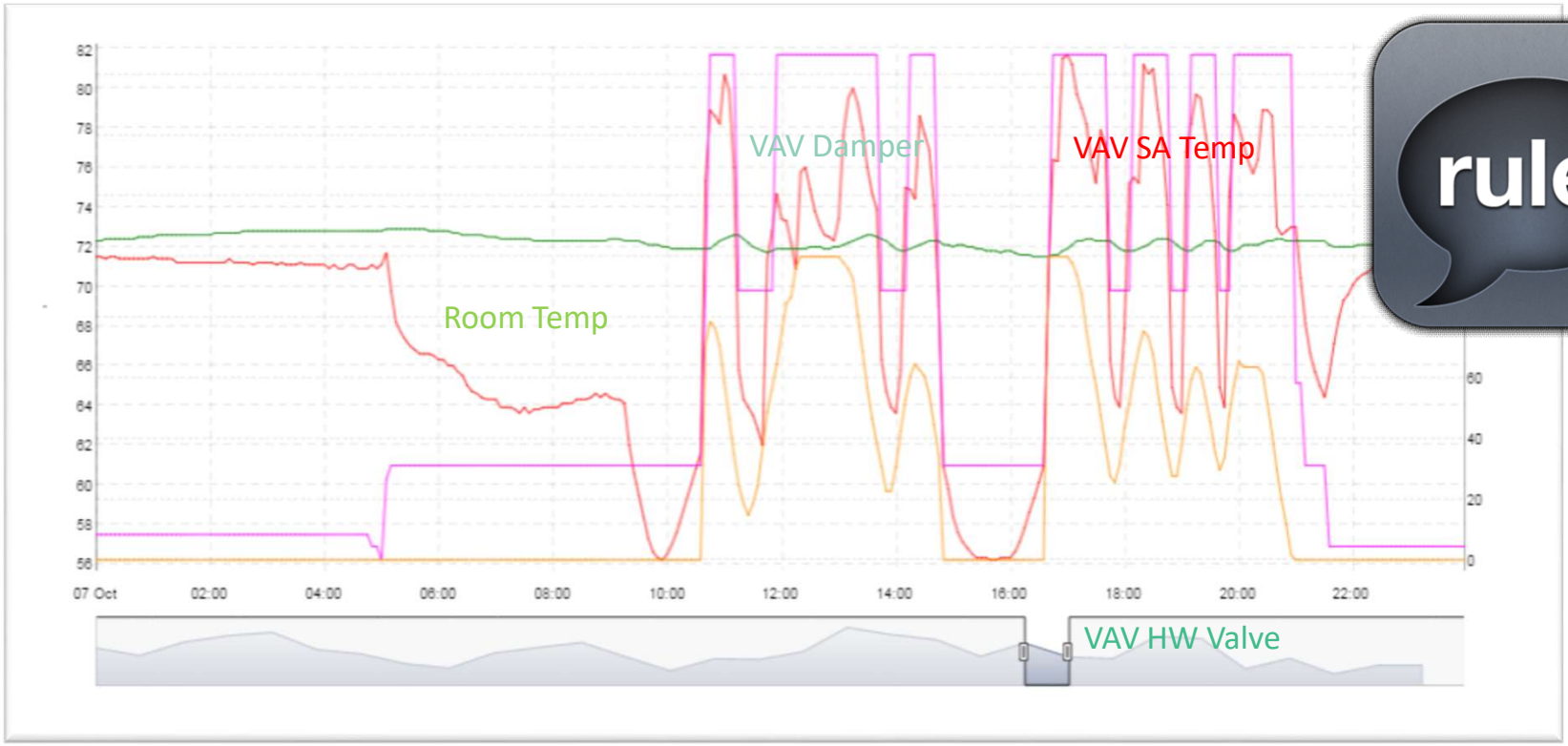
Zone System Mechanical Analysis



- VAV dampers are actuating and hunting wildly
- VAV Hot Water valves are hunting wildly
- Tremendous wear and tear on these systems!

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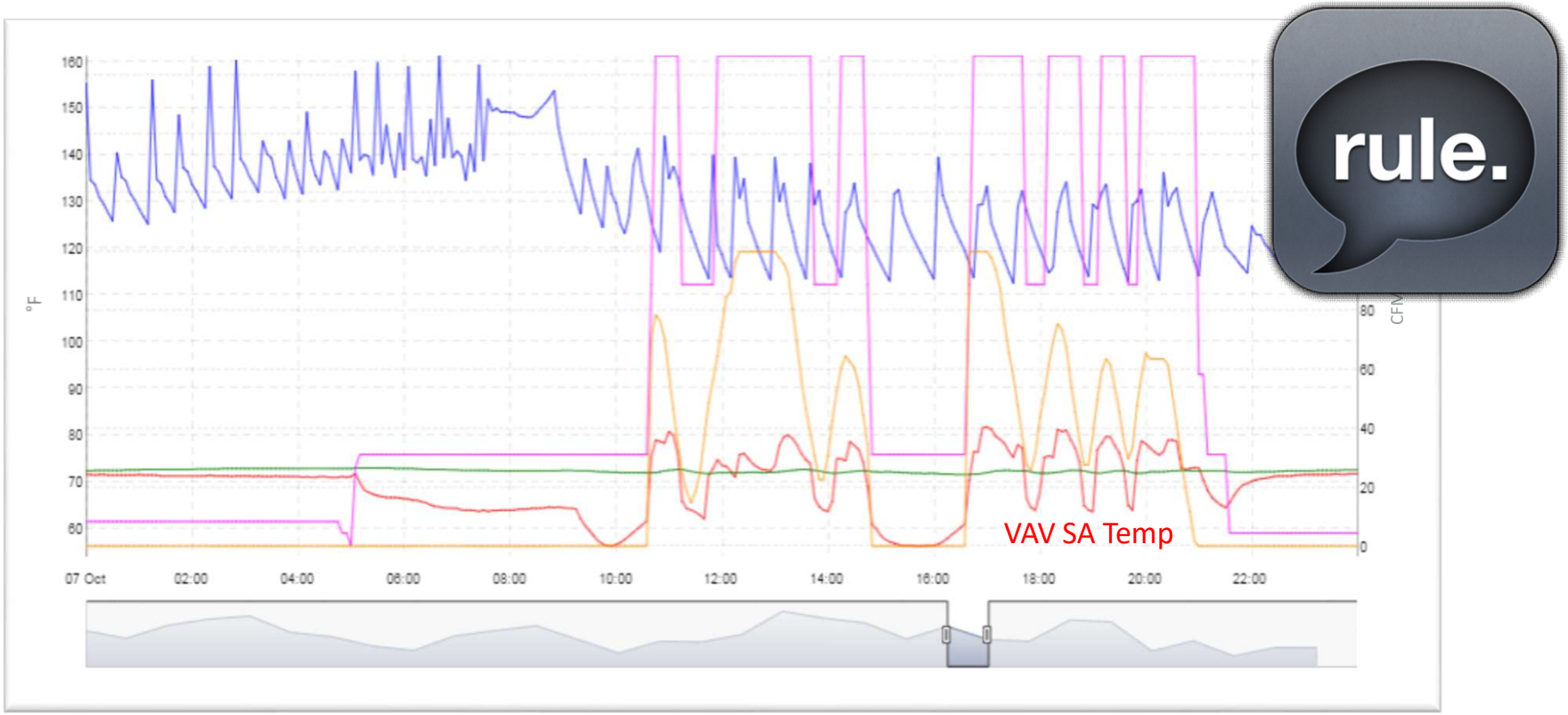
Hot Water Supply Analysis



- Hot Water Supply Temperature swinging wildly
- Hunting valves and dampers attributable to this inconsistent HWS temperature

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Hot Water Supply Analysis

It’s akin to driving down the highway perfectly at the speed limit with both the gas and the brakes on simultaneously.

- Hot Water Supply Temperature swinging wildly
- Hunting valves and dampers attributable to this inconsistent HWS temperature

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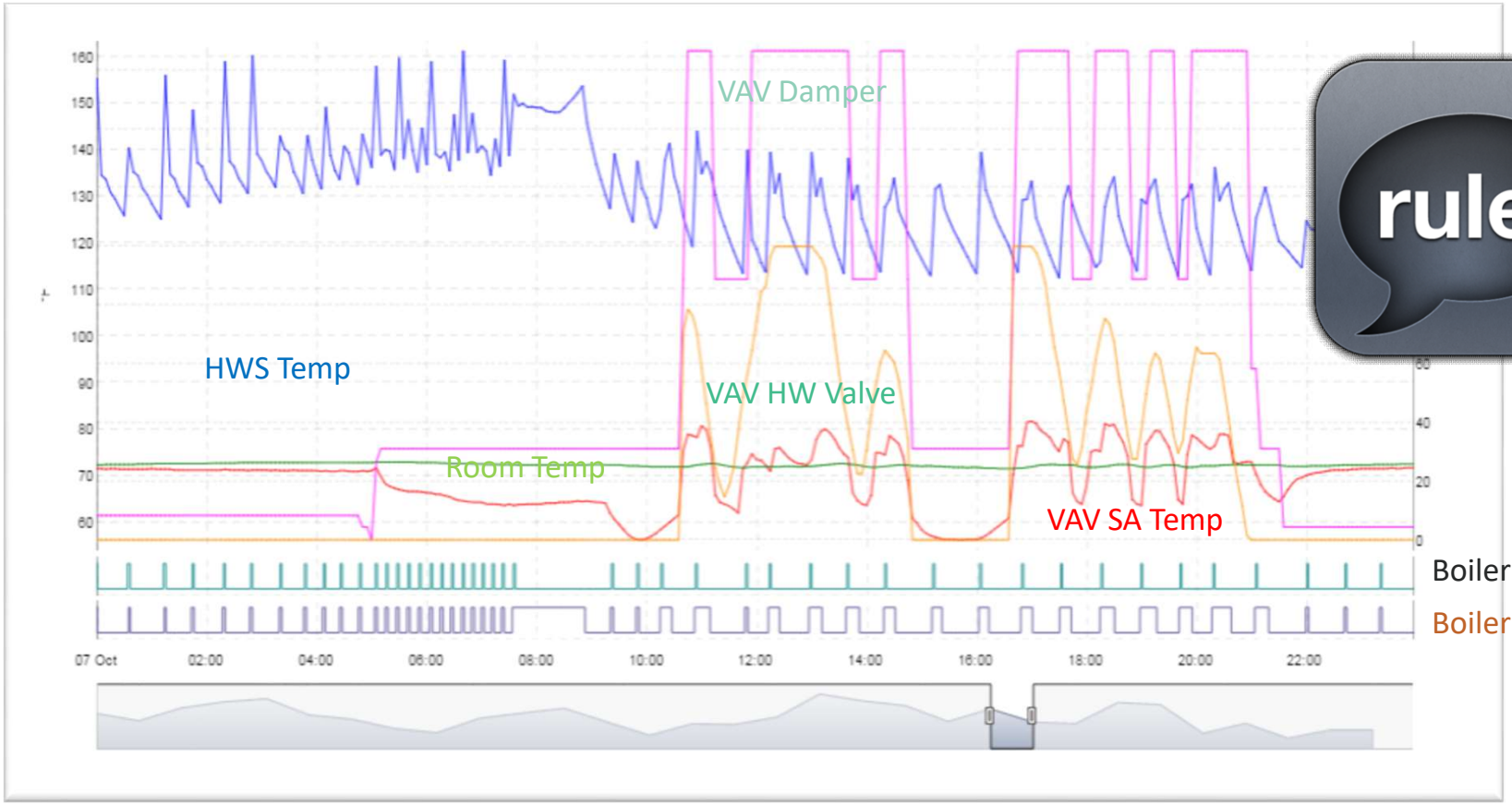
Root Cause: Boiler Sequence Analysis



- Boilers designed to be “lead/lag” sequenced
- Boiler control sequence analysis shows that is not the case: both are turning on and off together, overshooting HWS setpoints, then shutting off

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Boiler Over-cycling: Poor sequencing

- Dozens of cycles per day!
- Huge impact on boiler system operation and longevity

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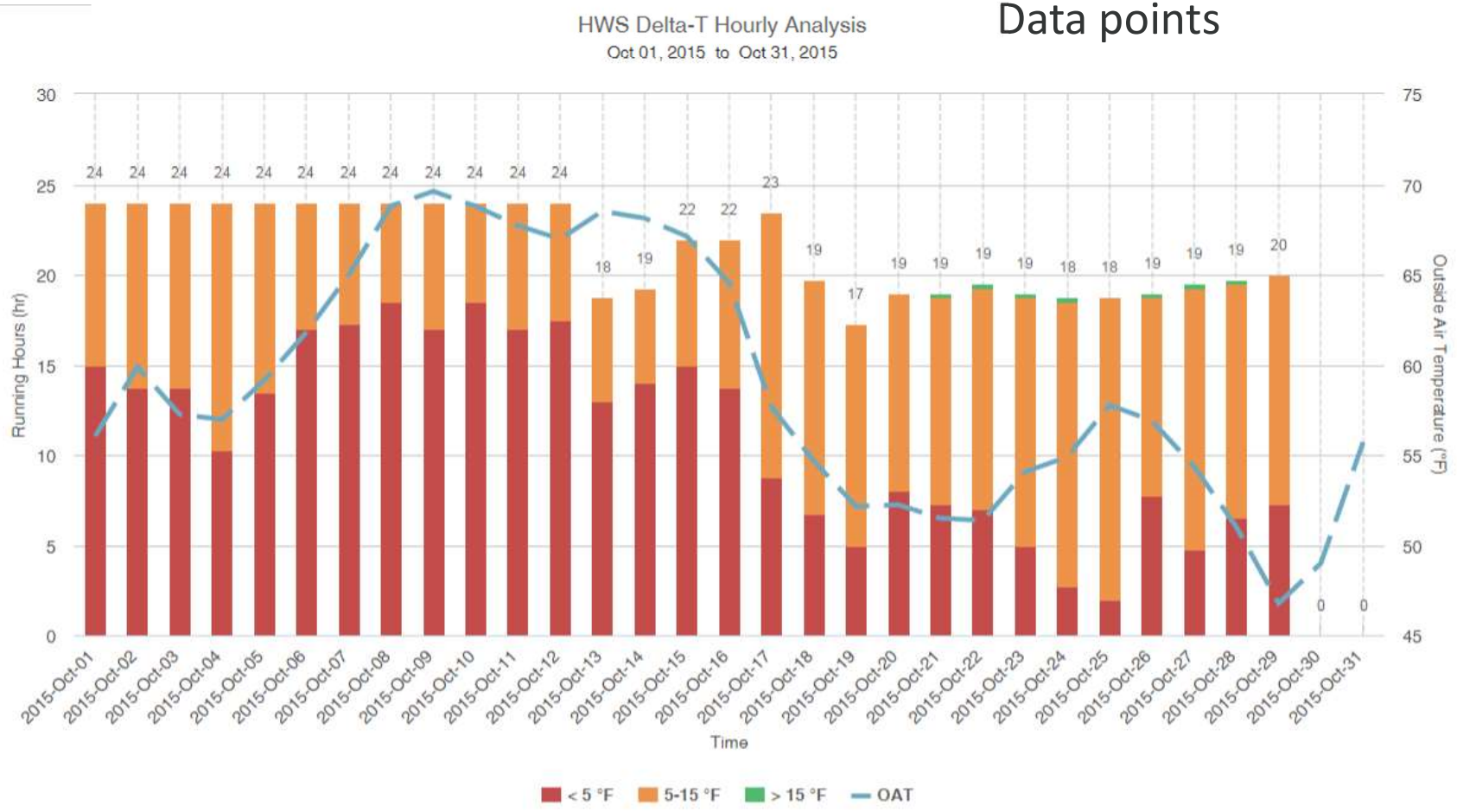
Hot Water System Temperature Delta

Big Data! 67,000
Data points



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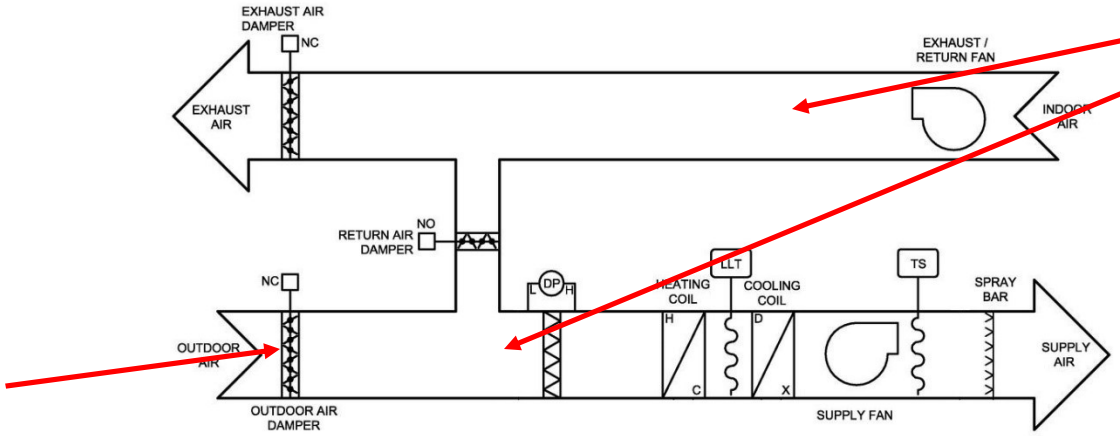
Example Fault & Analytics "Rule" to Find It

Insight Notification Triggers Only When All Parameters TRUE:

- Outside Air Damper says it is **closed (0%)**
- Mixed Air & Return Air Temperature Sensor **Delta T > 2 degrees**
- These conditions have all been true for **> 6 total occupied hours in a week.**

Once per week this data is analyzed and fault results (if any) sent to interested parties.

Delta T > 2 Degrees?



Damper Closed?

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Example Building Analytics Insight

- Delivered automatically to the people who need the information
- Explains what was analyzed to create the insight
- Shows the recipient the exact trended data used for analysis
- Even recommends remedial actions/repairs to solve the problem!

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How Do We Prevent This?

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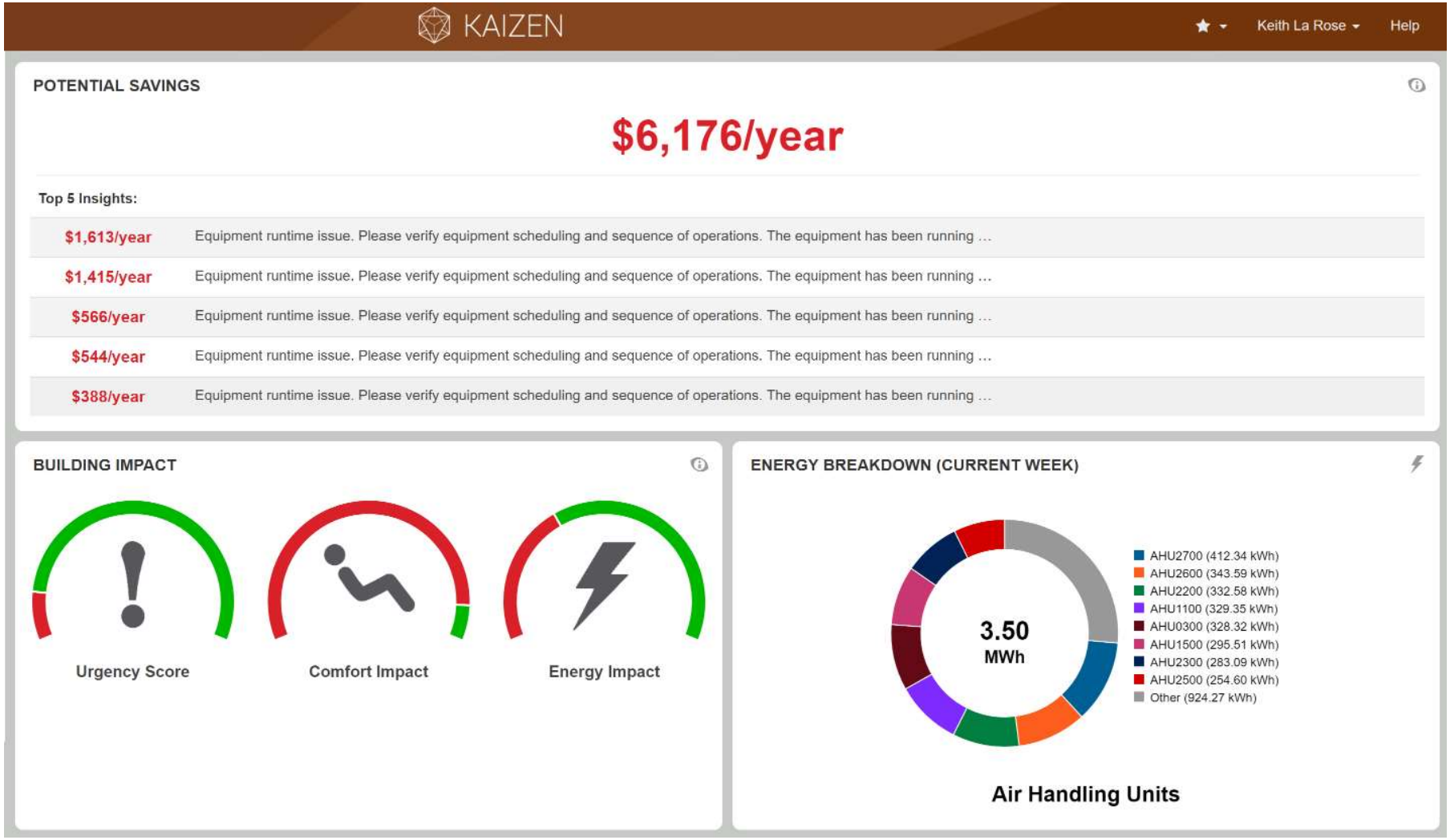
…by Turning Faults Into $ and Occupant Impact



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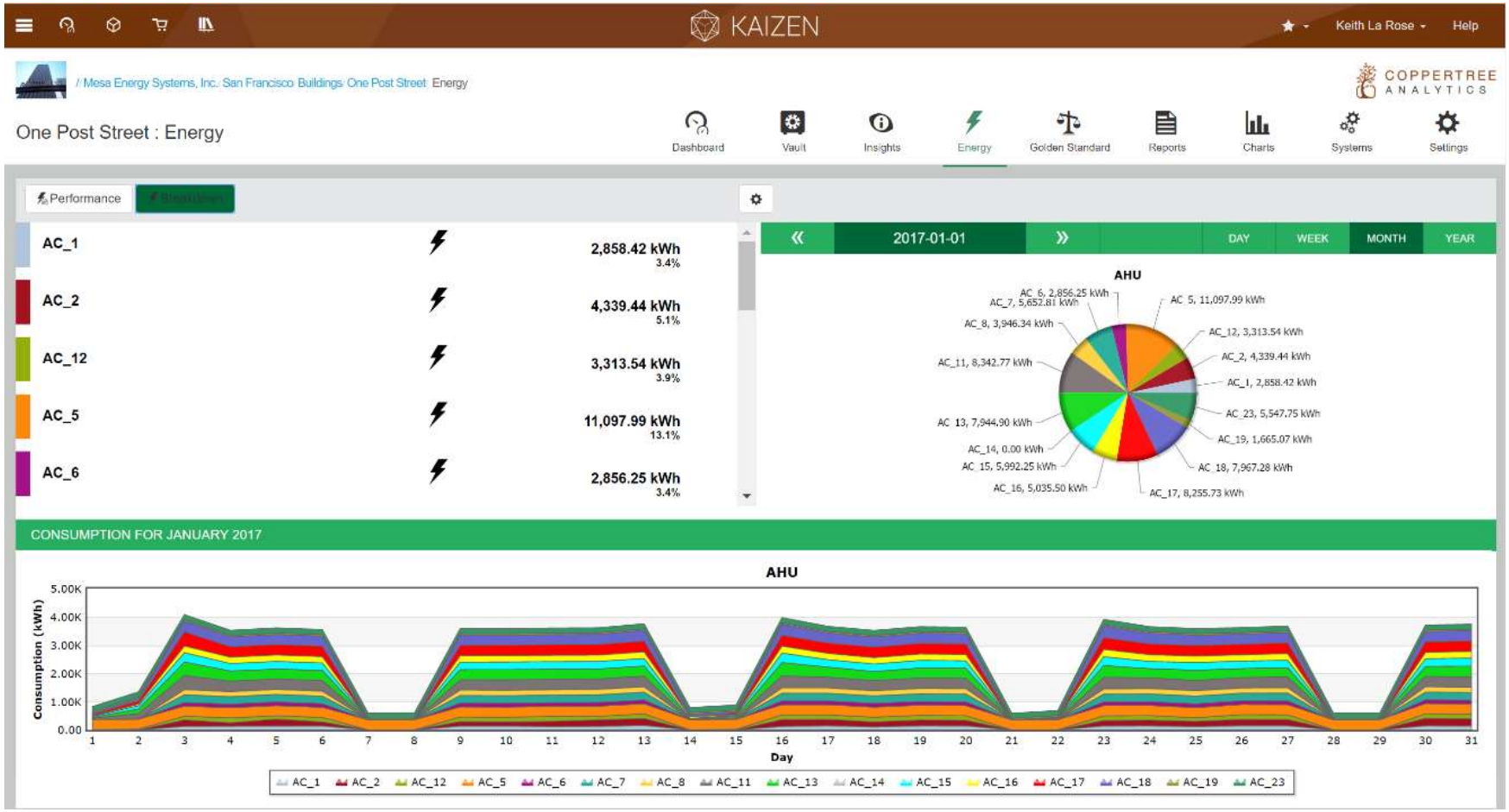
Data Driven Energy Management
What is a Virtual Meter?



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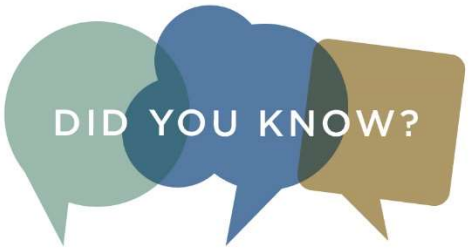
Analytics for Energy - What is a Virtual Meter?

- Energy meters created from existing sensor data
- Pinpoint energy issues
- Meter every single piece of equipment or zone!



Example Formulas:

Virtual BTU Meter for Airside System:
BTU/hr = Fan Volume *1.08 * (SAT-MAT)

Virtual Meter for Electrical Component:
kW/h = Amps * Voltage * runtime

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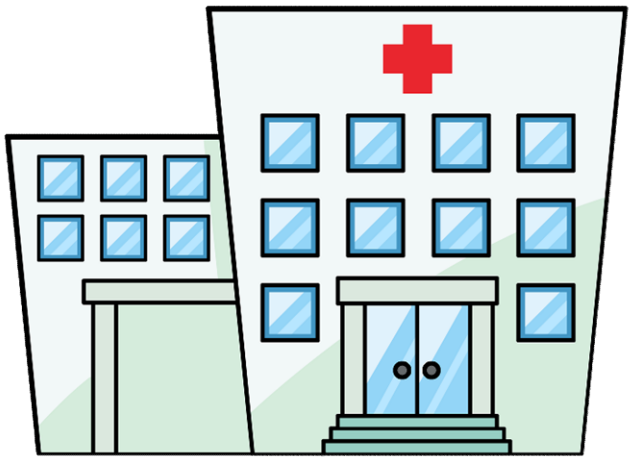
Case Study #3

Publicly Funded Hospital

- Location: British Columbia, Canada
- Year Built: 1980
- Boiler & BAS Upgrades 2 Years Ago



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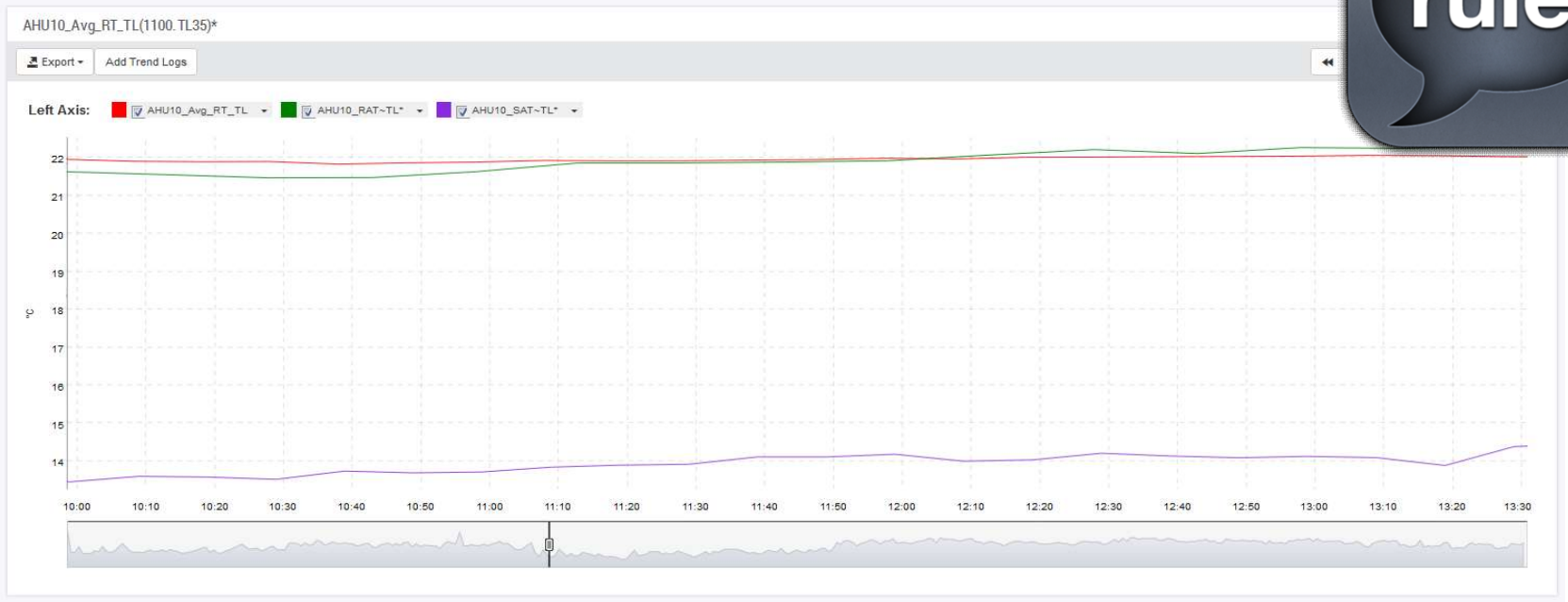
The Building Operator's Perspective

BAS Room Temperature Avg. 10 Minute Trend



- No complains from occupants/patients
- No evidence there's anything wrong with the room temperatures or underlying mechanical equipment

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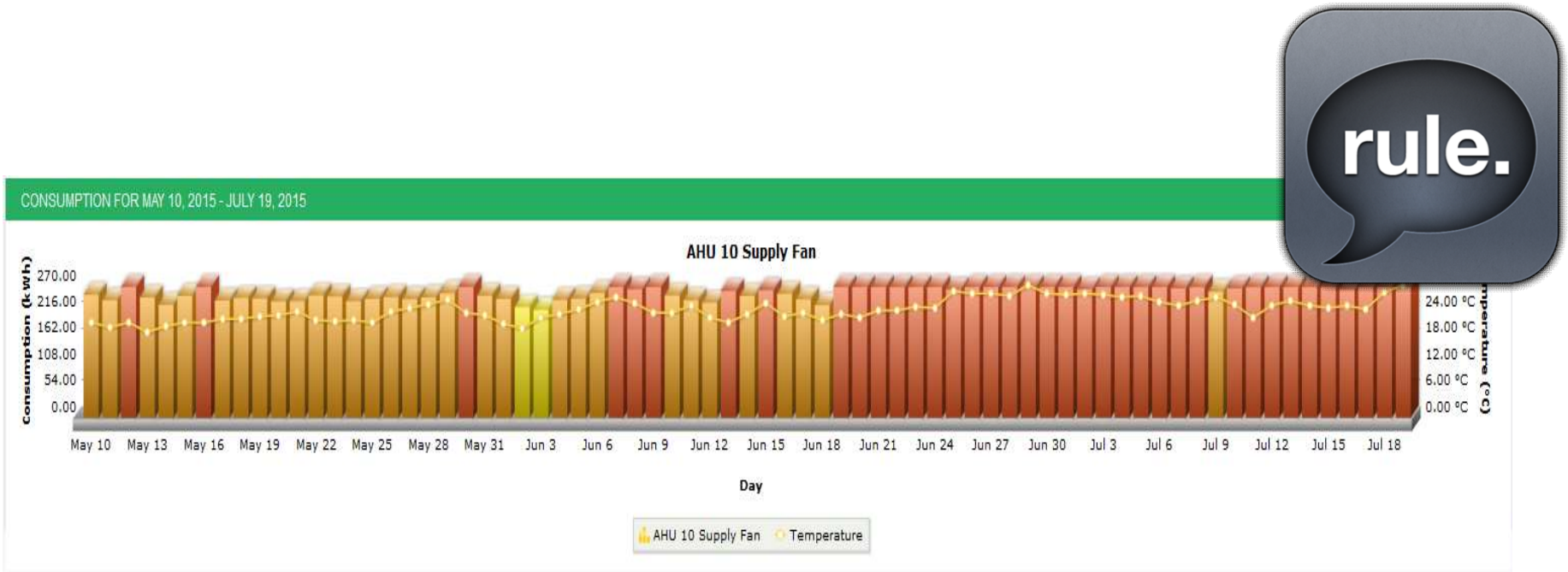
Supply Fan Energy Analysis



- The energy has increased after Jun 18th
- No occupant complaints. Operators unaware
- Discovered using Virtual Energy Meters and FDD Insights

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Automated Zone System Mechanical Analysis

Fault Detection and Diagnostics (FDD)

Insight messages crated by the rule:		
Description	**Weekday**	**Occurred**
VAV_10_1 Damper is fully open for more than 12 hours per week.	Mon	Jun 29, 2015 12:00 am
VAV_10_1 Damper is fully open for more than 12 hours per week.	Mon	Jun 22, 2015 12:00 am

- Analytics reported insights related to AHU subsystems
- The VAV dampers are open for atypical amounts of time
- FDD rules for this were reporting the condition

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Automated Zone System Mechanical Analysis

- VAV damper position trend log capture indicates transition change
- Change to damper saturation coincided (started same day) with increase in AHU supply fan energy increase

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Automated Zone System Mechanical Analysis

AHU 10 VAV Dampers are fully open excessively during occupancy

Rule template: Determine if the VAV Damper is fully open excessively during occupancy due to possible low static pressure or design issues. Check the amount of time the VAV Damper is in the fully open position during occupied hours. An insight is generated if the VAV Damper is fully open for more than 12 hours per week.

Priority
Low

Insight Type
Fault Detection

System
N/A

Insight ID
2864.30965

Working Rule
Determine if VAV is constantly at maximum flow

Description /Method
Determine if the VAV Damper is fully open excessively during occupancy .Check the amount of time the VAV Damper is in the fully open position during occupied hours.

Message
The VAV damper has been fully open for more than 12 hours per week.

Diagnosis /Recommended Action
1. Check the static pressure setpoint 2. Check if fan speed is 100% (or ductwork leaking) 3. Check the VAV boxes tuning, and overall operation 4. Check AHU filters heck duct static pressure control.

- Example of Insight notification sent to operators with recommended actions to resolve.

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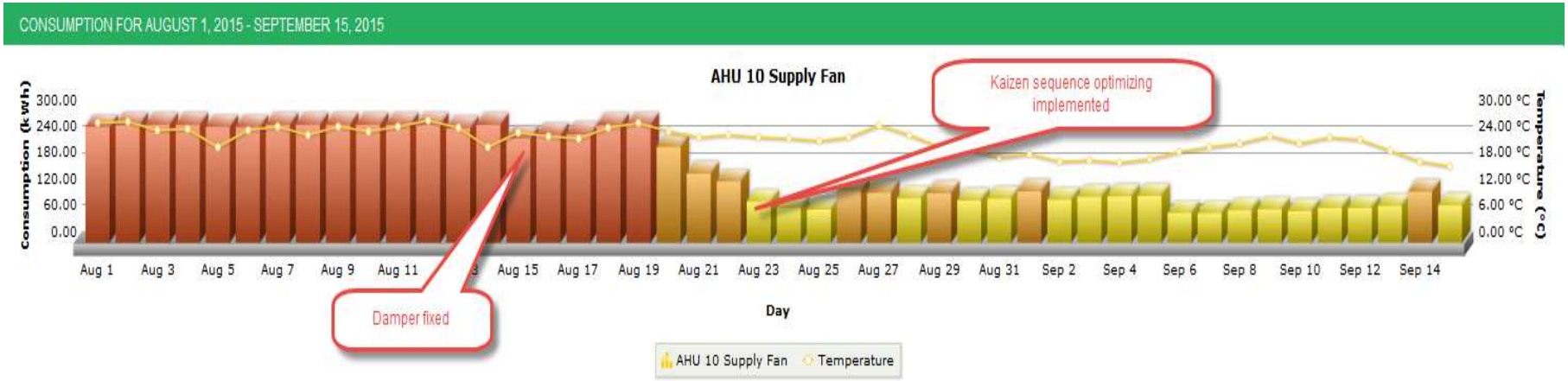
Automated Main System Mechanical Analysis

- AHU Damper command trend log capture indicates transition change
- Also Coincides with energy increase and VAV damper saturation (started same day)

COPPERTREE ANALYTICS

Results Driven by Fixes



- Identified issues used to direct action at the site
- Dampers fixed (electrical power issue)
- Analytics recommended sequence changes implemented
- Estimated savings $20,500 yearly for this problem alone
- Savings measured (M&V) for ongoing reporting & ROI calculation

COPPERTREE ANALYTICS

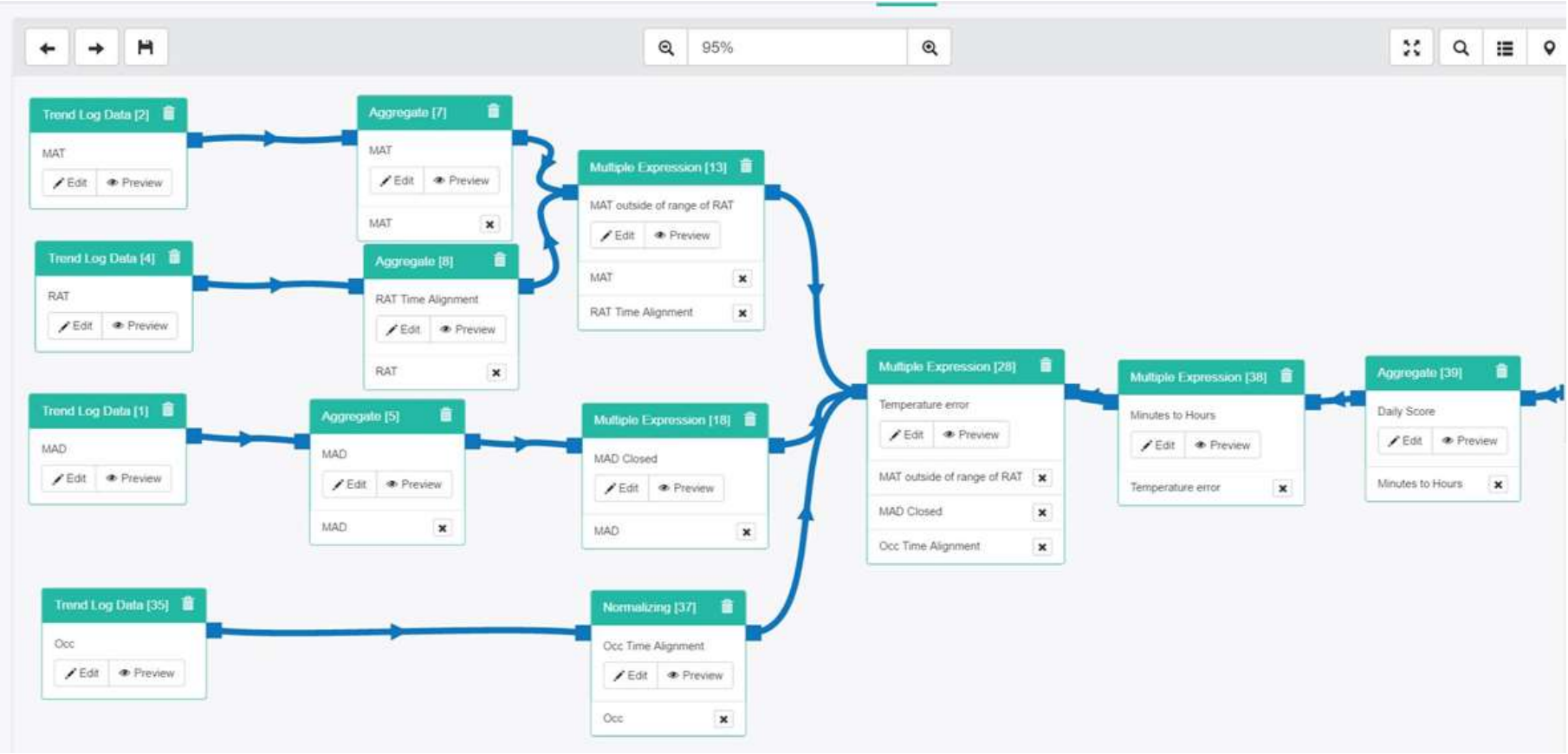
Typical Results Achieved

From hundreds of projects:

- ✓ ~15% total building energy reduction average
- ✓ ~60% HVAC maintenance labour savings
- ✓ We have never had a project not show positive ROI in less than 2 years – most are in weeks

COPPERTREE ANALYTICS

Play By Your Own Rules! Customizable Rules



- Leverage large existing library of rules which are customizable
- Write your own rules for your particular scenario/building

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Analytics Rules of Thumb

Realistic Savings Range for Projects

- Some as high as 50% energy savings
- **Averages in the range of 15-20% energy savings**
- Intangible savings – Maintenance efficiency, Equipment longevity and occupant comfort

Ideal Building Opportunity:

- BACnet DDC BAS
- **Engaged Operators & Owners**
- Extensive trending

Pilot Project Approach

- **Start small, prove it and show ROI**

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ANALYTICS
Realize building potential

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Thank you.

Sunny Sandhu, Sales Application Engineer
ssandhu@coppertreeanalytics.com
604-786-2403