AABC Commissioning Group

AIA Provider Number 50111116

Commissioning and Energy Management Bring Efficiency and Savings to School Campus: A Case Study

AIA Course Number CXENERGY1524

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B.E.S. Plus Tech

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Learning Objectives

At the end of the this course, participants will be able to:

1. Learn how to assess a large building portfolio in order to identify where to begin energy management and retro-commissioning efforts.

2. Understand how to overcome difficulties in implementing large HVAC renovation projects in educational facilities which can only be worked in during short summer seasons.

3. Learn how to integrate capital replacement and infrastructure renewal projects with commissioning and energy management to ensure the overall building performance is optimized.

4. Understand how to utilize on-going commissioning processes and tools to further optimize system performance and extend the persistence of energy savings following a retro-commissioning effort.

Copyright Materials

BUILDING ENERGY SCIENCES, LLC
Energy Consulting - Commissioning - Building Systems Analysis

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Case Study Description

Bailey Middle School, a 200,000 square foot facility constructed in 1994, had for quite some time been at the bottom of the school district's energy performance list based on any metric – energy usage intensity, dollars per square foot, and Energy Star score.

Over the years **minor changes were made to the HVAC systems to address comfort issues** but nothing to address the overall building performance; minor occupant comfort problems were addressed but performance still did not improve. As the **equipment neared the end of its life the District began to replace the HVAC equipment in phases** but still did not see expected building performance improvement as total energy consumption remained nearly constant despite all of the capital expenditures.

A **whole-building HVAC retro-commissioning effort** was undertaken to investigate and identify hidden system deficiencies affecting overall system performance. These deficiencies were then corrected in conjunction with the last phase of equipment replacement, new control sequences implemented, and the entire building was commissioned.

Following the corrections a **monitoring-based on-going commissioning effort has continued to decrease the utility consumption and ensure persistence of the savings.** Efforts at the campus have been an overwhelming success as in just over a two year period the energy usage intensity has dropped from a high of near 160 kBtu/gsf/year to below 50 kBtu/gsf/year. Even without accounting for utility rate increases the resulting annual utility cost savings are over $400,000 – **a nearly 60% reduction!**

Portfolio Assessment

How to assess a large portfolio in order to identify where to begin energy management and retro-commissioning efforts

Escambia County School District Facts:

- 56 K-12 School Campuses
  Total gross square footage
  of over 7,000,000 SF

- Large geographical area with
  campuses spread out over the
  entire county

- Largest campus > 300,000 SF
- Average campus of approx. 114,000 SF

Portfolio Assessment

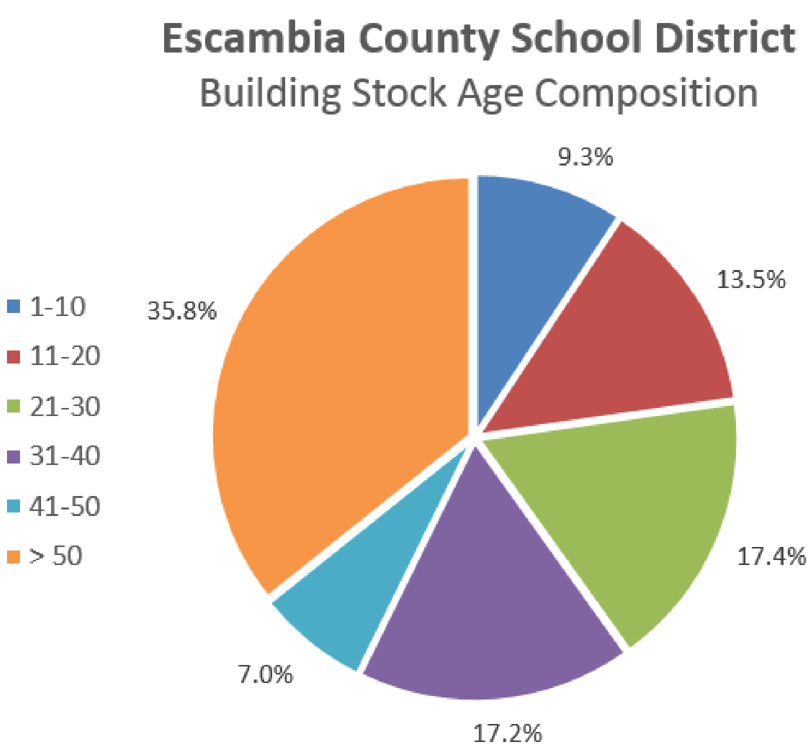
How to assess a large portfolio in order to identify where to begin energy management and retro-commissioning efforts

Escambia County School District Facts:

- Newest campus, opened 2015
- Average building, 37 years
- 36% of buildings > 50 yrs old

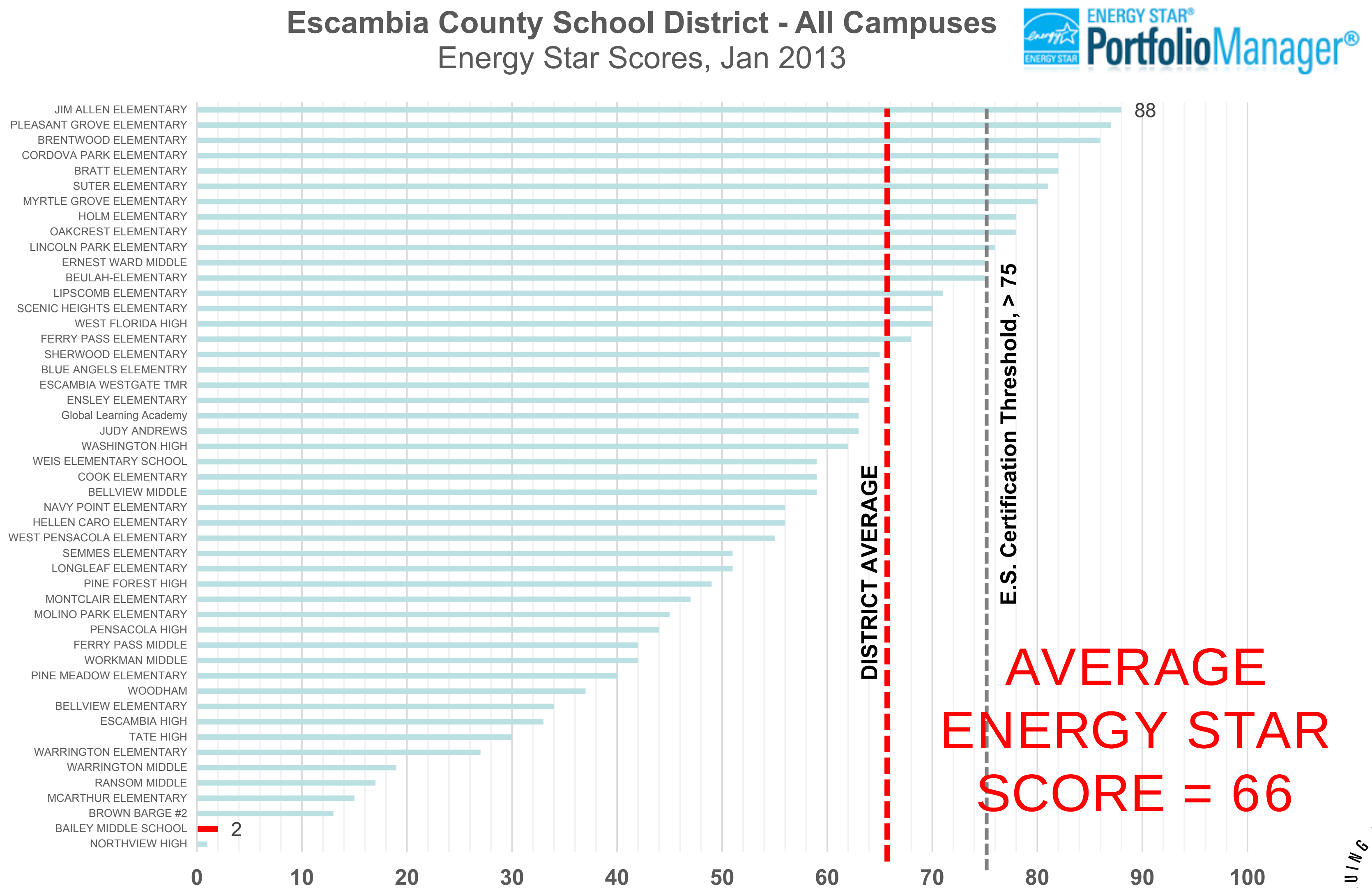
WHERE DO YOU START ???

Cannot address ALL facilities simultaneously so we must prioritize need based on some agreed upon performance metric



Portfolio Assessment

Energy Star Portfolio Manager is a very common methodology for benchmarking school facilities



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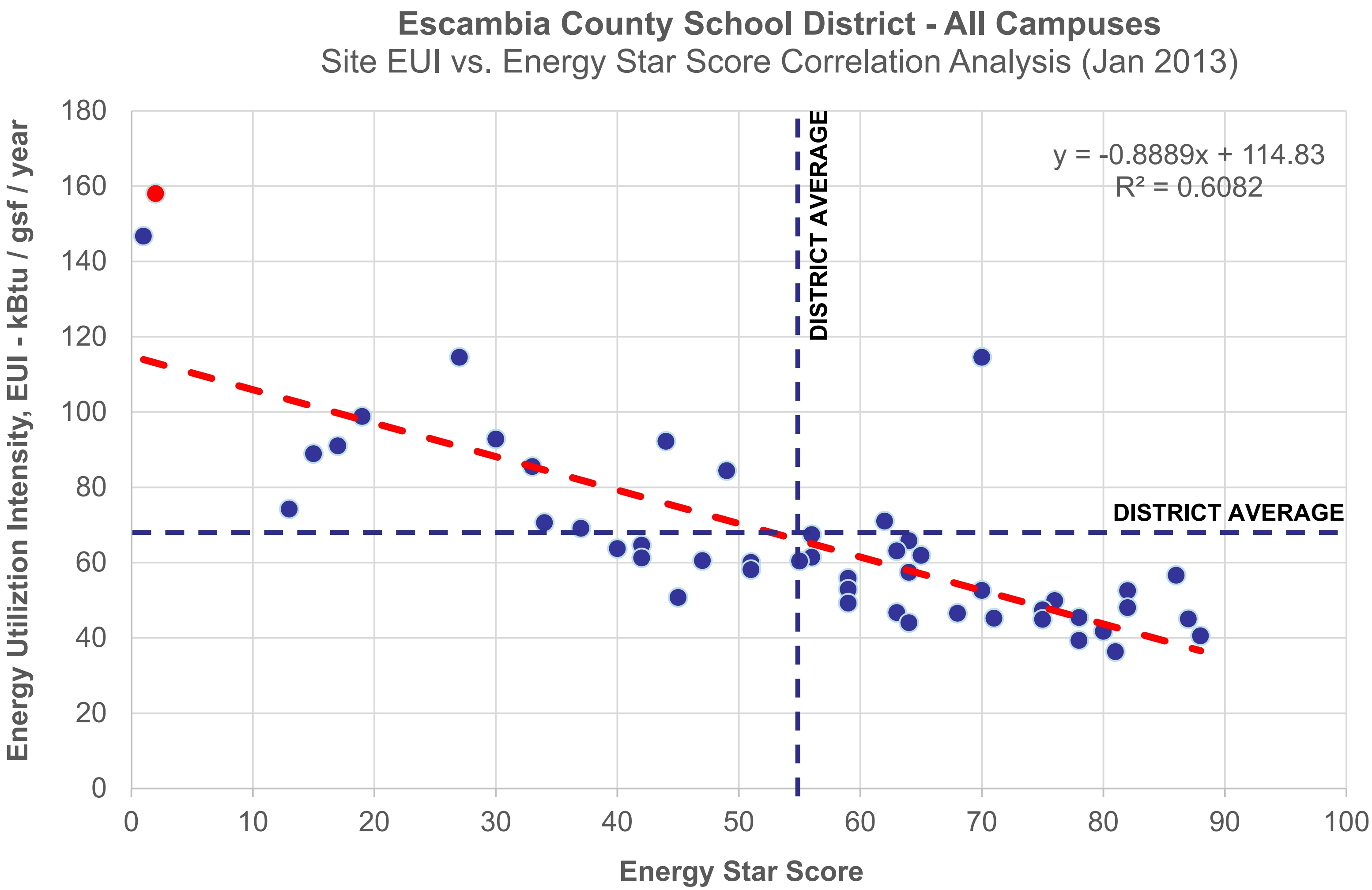
Portfolio Assessment

Relationship of Energy Star Score to Site Energy Intensity… correlation coefficient of 0.60 meaning that the variation in energy consumption explains 60% of the variation in Energy Star score.

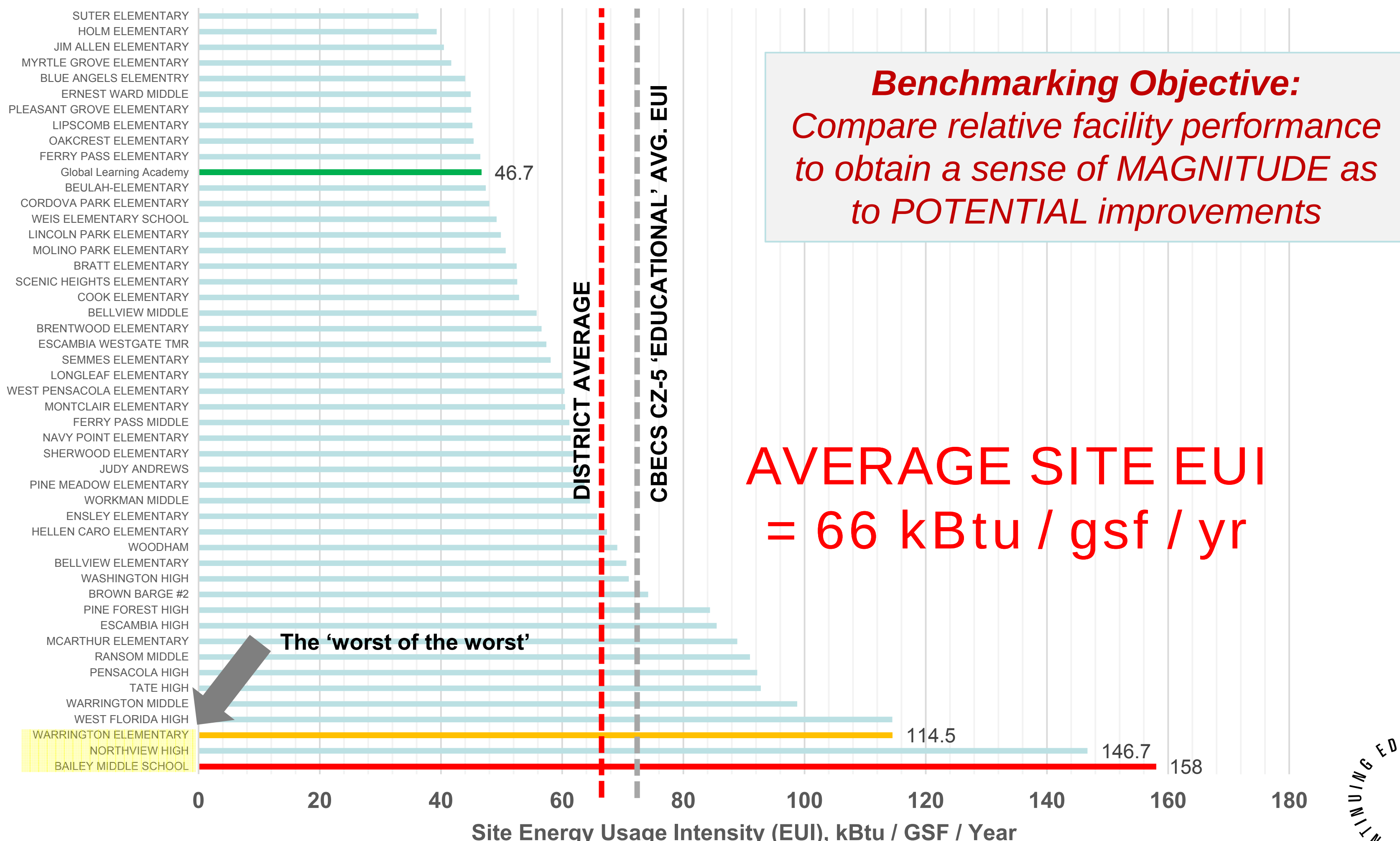


Portfolio Assessment

Site Energy Usage Intensity is even more helpful for a nominalized energy consumption perspective

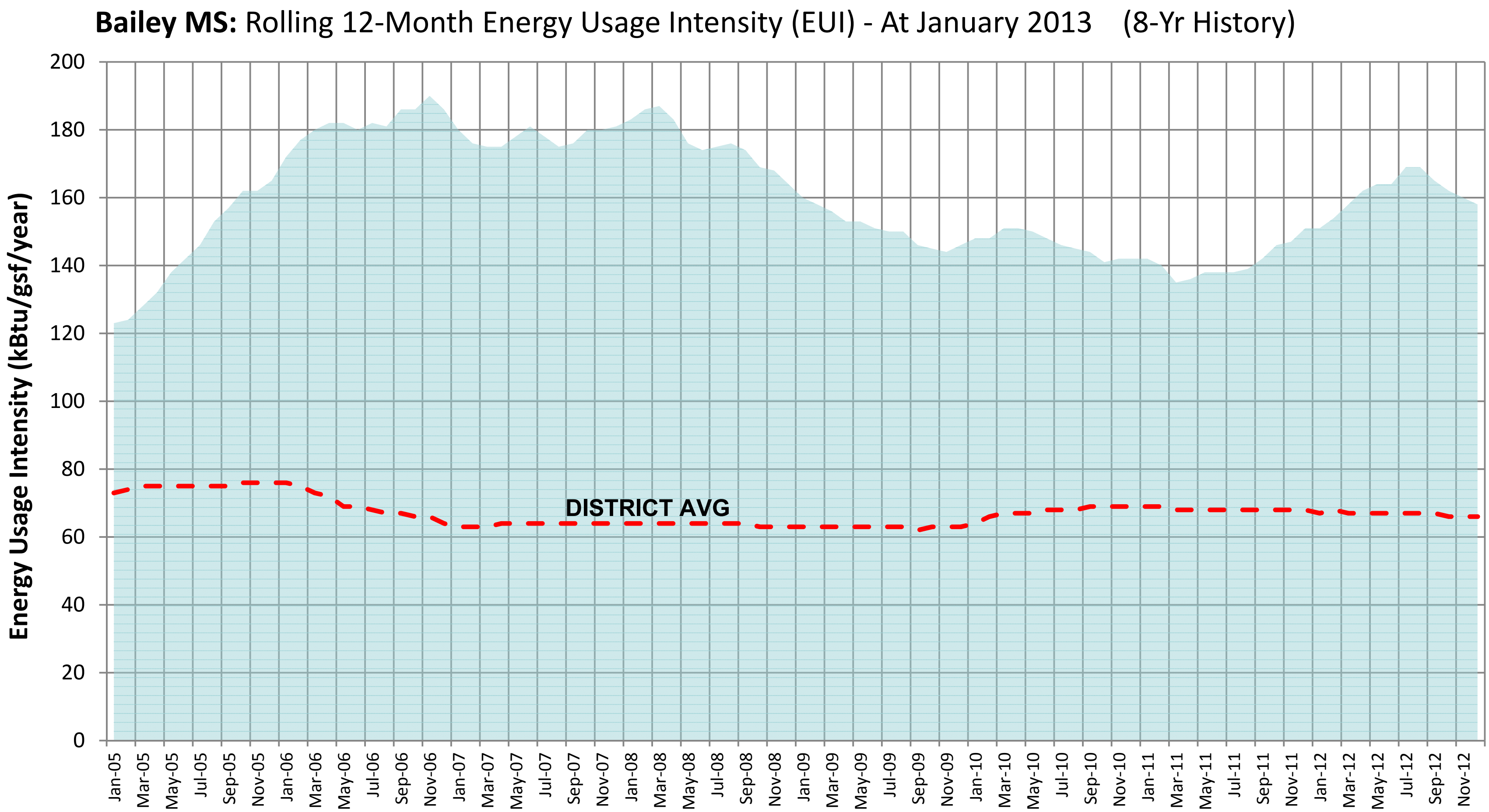
Escambia County School District - All Campuses

Site Energy Utilization Intensity (EUI), Jan 2013



Historical EUI – Bailey Middle School

At January 2013, the current EUI of the facility was 158 kBtu / gsf / year which was more than double the ‘average EUI’ of the District (66) and nearly three times the aggregate District EUI of 56.



LET’S START HERE!

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Facility Overview – Bailey Middle School

200,000 GSF middle school, constructed in 1994

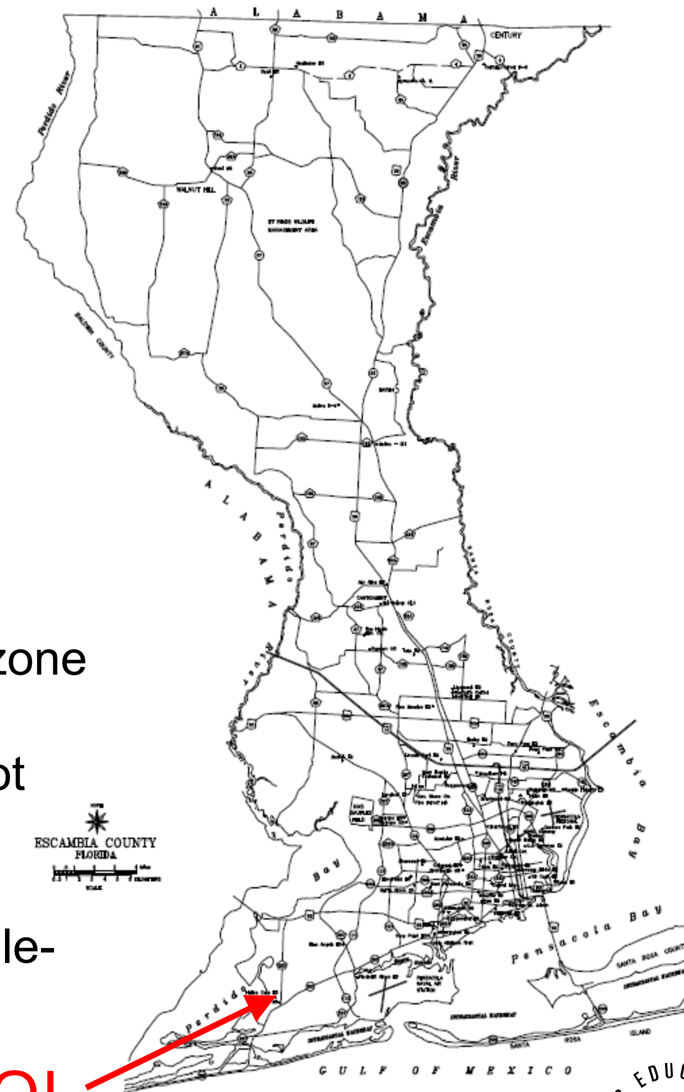
HVAC Systems:

<u>Primary Plant Systems</u>:

- Two air-cooled chillers, variable primary and variable secondary pumping
- Two gas-fired condensing boilers, variable primary-only pumping

<u>Air Handling Systems</u>:

- Ten Central Station Variable Air Volume multi-zone air handling units
- 150 Single-Duct VAV Air Terminal Units with hot water reheat coils
- Five Dedicated Outside Air Units (plate HX)
- Three Central Station Variable Air Volume single-zone air handling units

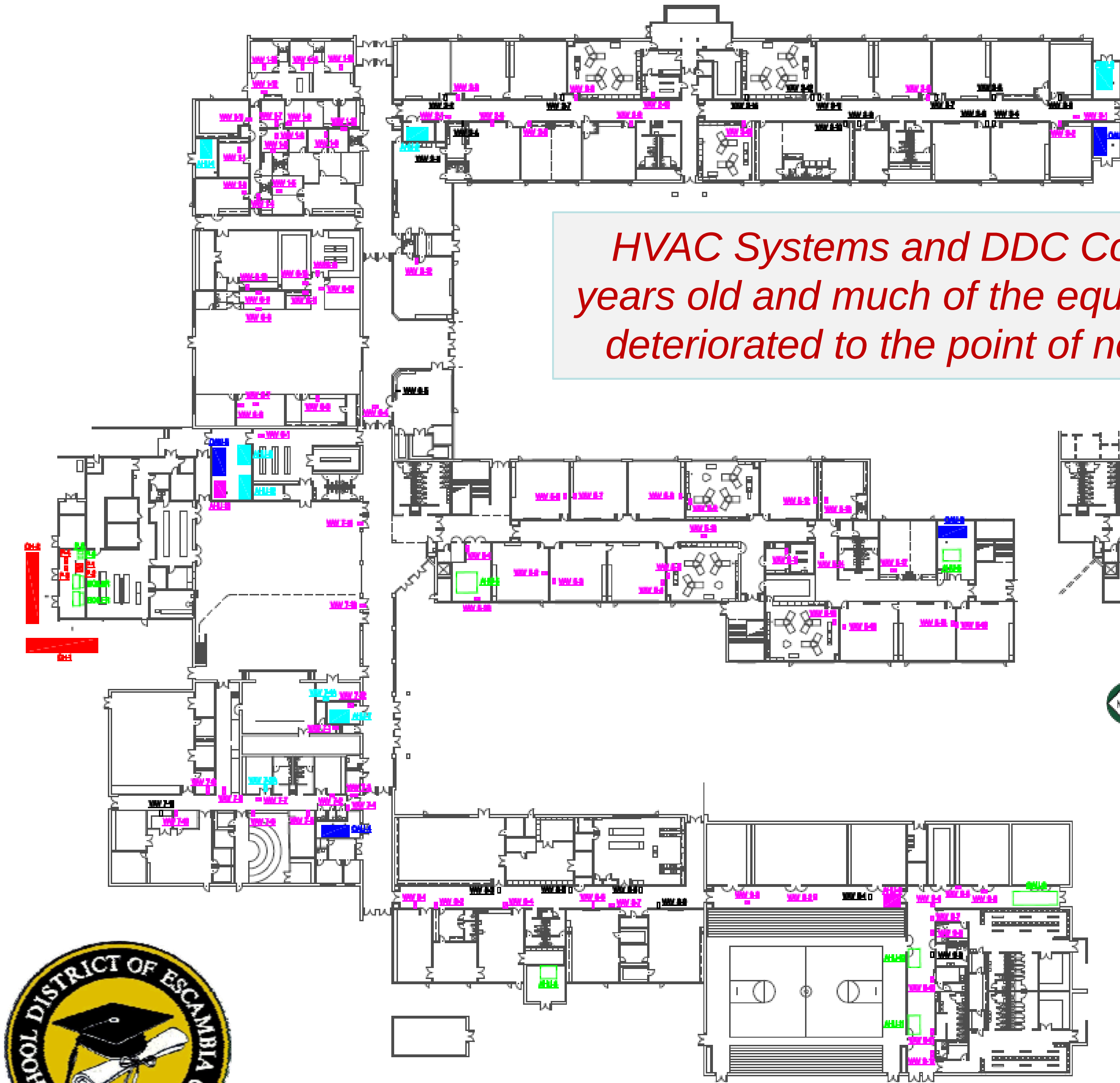


BAILEY MIDDLE SCHOOL

Facility Overview – Overall Plan View

HVAC Systems and DDC Controls were over 20 years old and much of the equipment had physically deteriorated to the point of needing replacement.

CAMPUS HVAC EQUIPMENT PLAN - SECOND FLOOR
NOT TO SCALE



CAMPUS HVAC EQUIPMENT PLAN - FIRST FLOOR
NOT TO SCALE

Projects Completed as of January 2013

Phased HVAC Systems Replacement:

Summer 2007 – Phase I Equipment Replacement *(not commissioned)*
replaced most of the VAV Terminal Units, two air handling units
Cost = $440,323

Summer 2010 – Phase II Equipment Replacement *(Limited Cx)*
replaced all dedicated outside air units
Cost = $416,459

Summer 2011 – Phase III Equipment Replacement *(Limited Cx)*
replaced six air handling units
Cost = $524,672

Summer 2012 – Phase IV Equipment Replacement *(Limited Cx)*
replaced air cooled chillers, chilled water pumps, new switchgear
Cost = $633,689

Equipment-Level 'limited commissioning' was conducted on these first four phases of equipment replacement…. The energy benefits were also limited.

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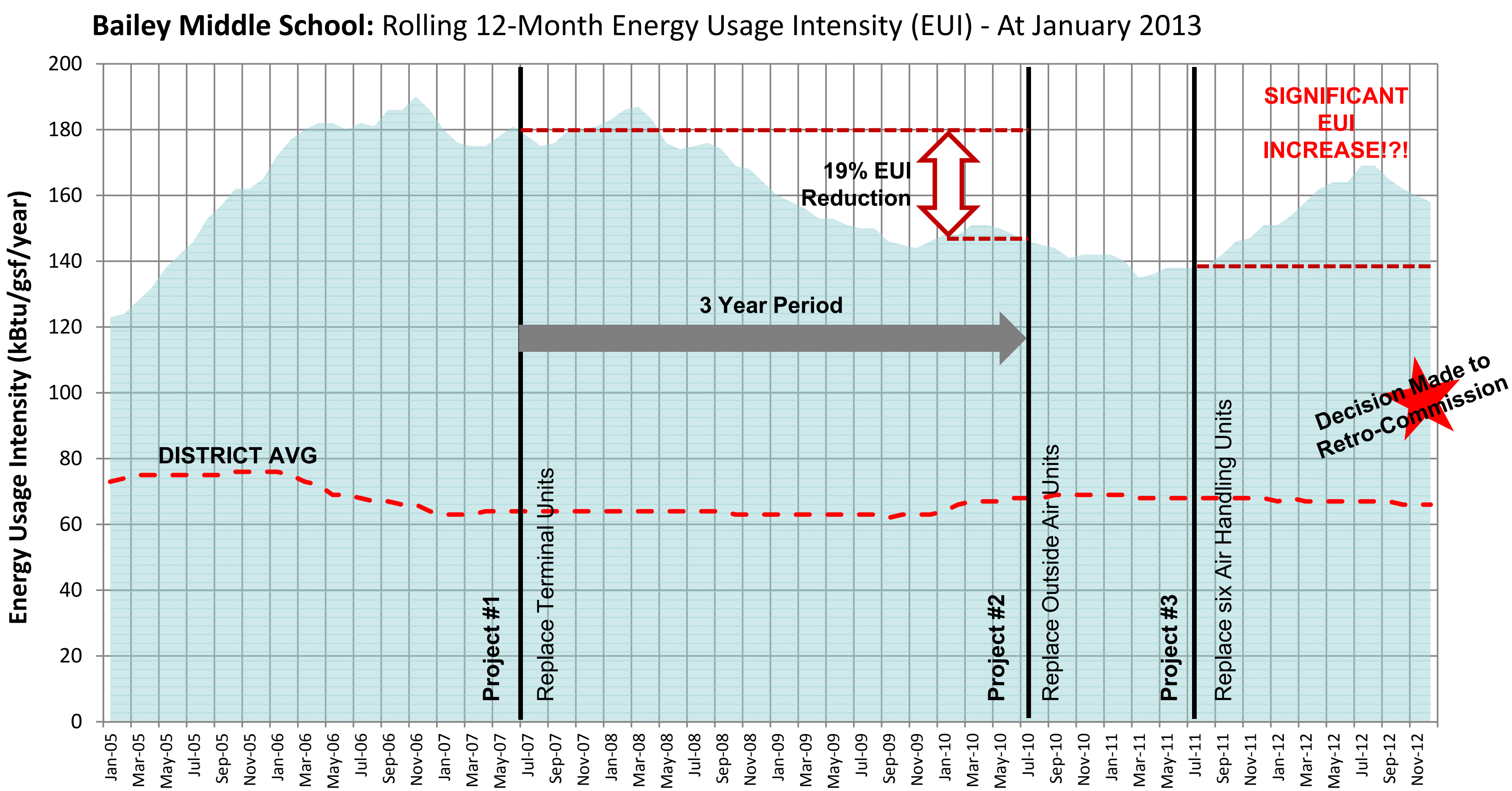
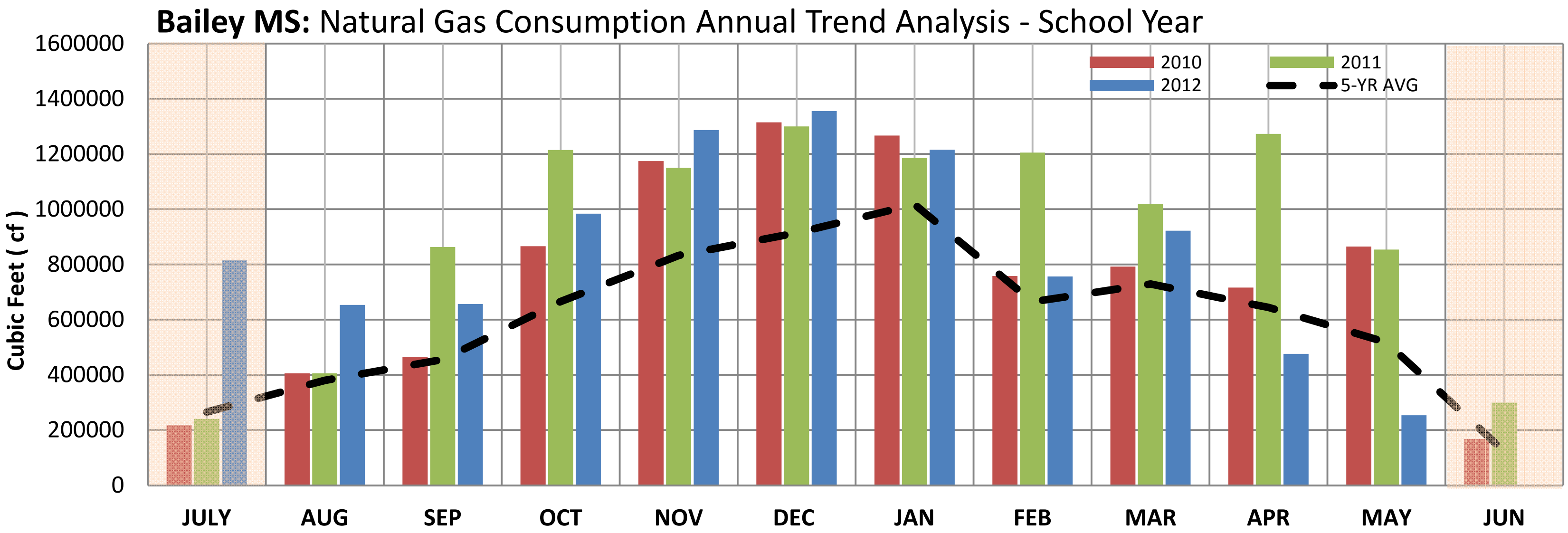
Historical EUI – Bailey Middle School

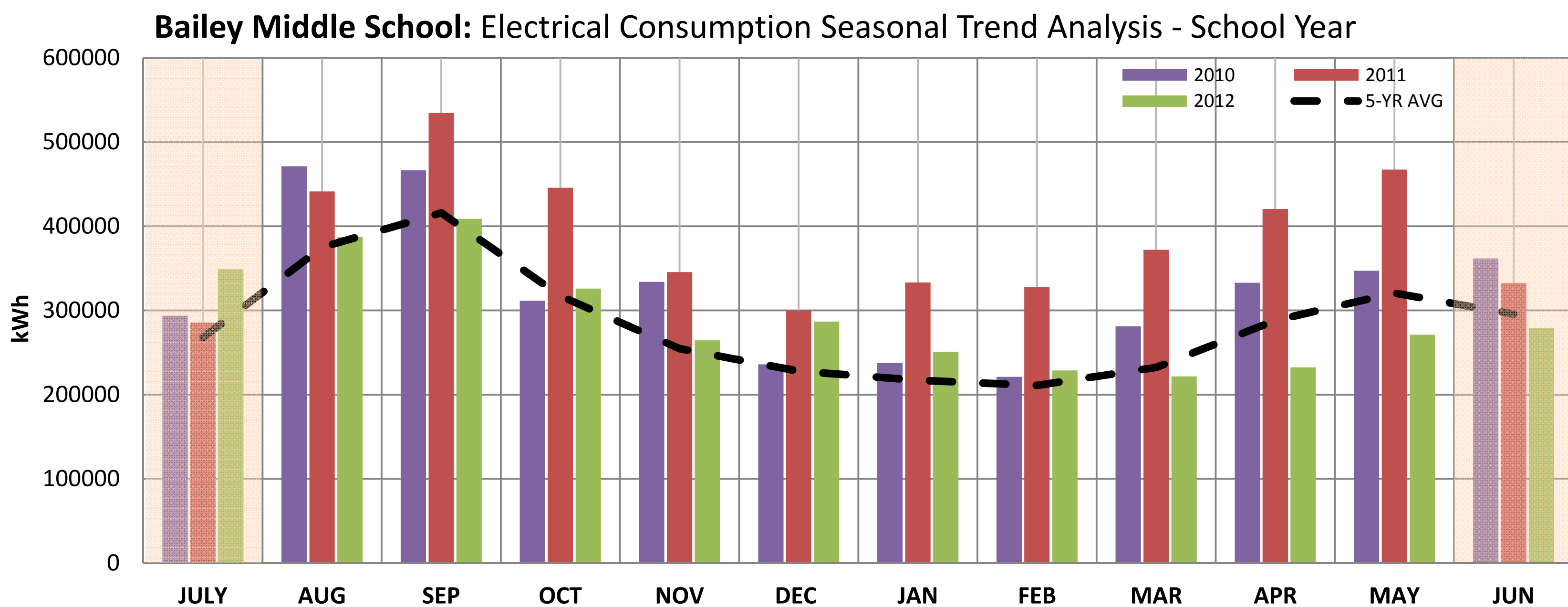
As HVAC Replacement projects were completed there was not significant decrease seen in the energy consumption of the campus, below chart illustrates projects completed through January 2013



System Replacement was not resulting in significant or persistent reduction of energy consumption!

Historical Annual Consumption Profiles

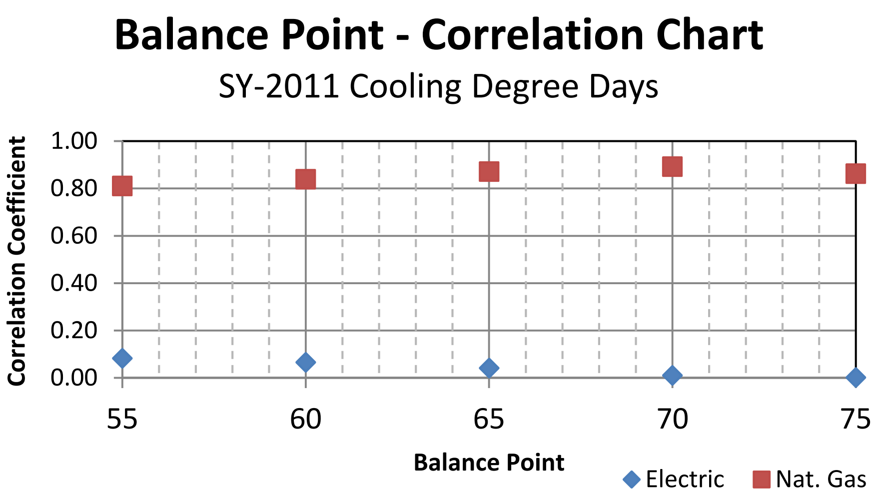




Exploring the Historical Data for Insight

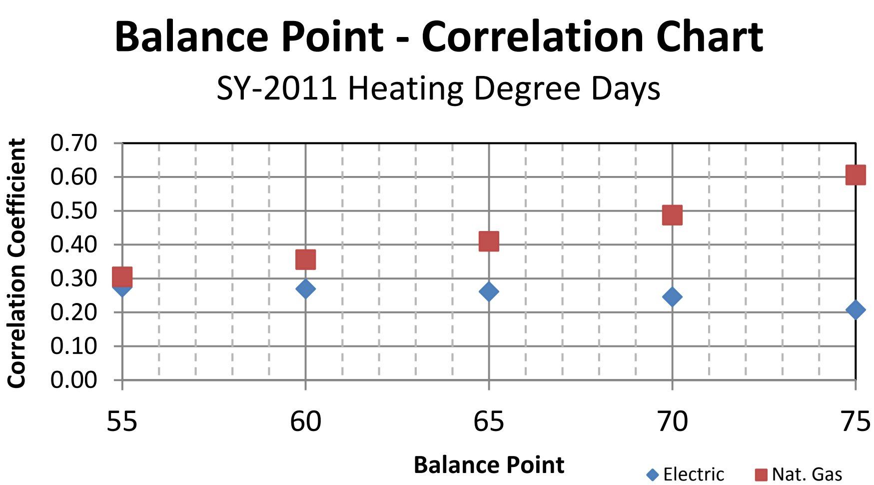
Regression Analysis of the historical utility consumption data against historical weather can provide a great deal of insight into the operation of a building… also compared against its benchmark peers.

Regression Balance Point Analysis of Electric and Natural Gas for SY-2011:



So… in SY-2011 the Natural Gas consumption had a very high correlation (above 0.80) with the Cooling DD ?!?!?

AND… Electric consumption had nearly ZERO correlation with Cooling DD ?!?!

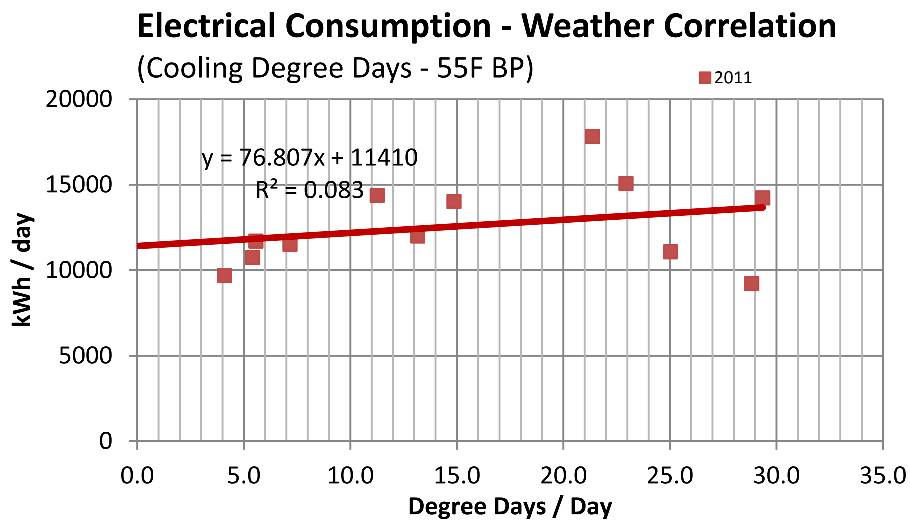


AND… the optimum balance point for Natural Gas consumption (highest R^2) was above 75F balance point?!

Exploring the Historical Data for Insight

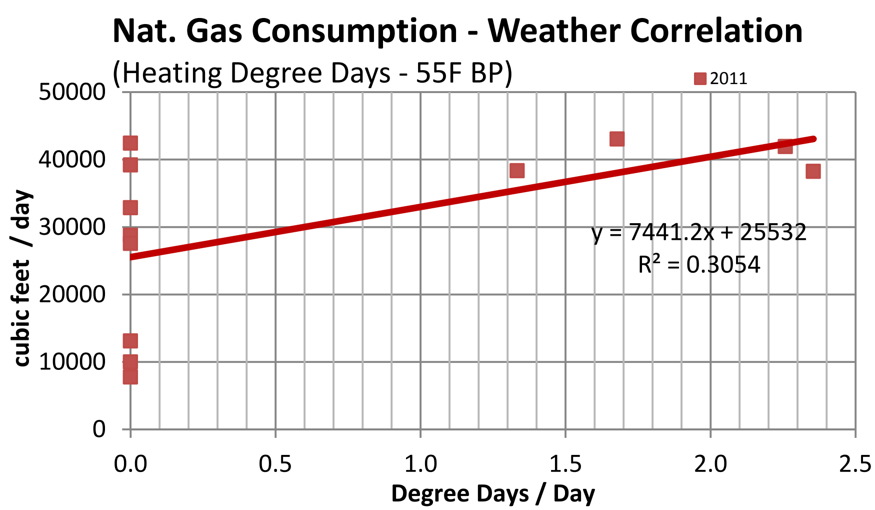
Regression Analysis of the historical utility consumption data against historical weather can provide a great deal of insight into the operation of a building… also compared against its benchmark peers.

Regression Chart Analysis of Electric and Natural Gas for SY-2011 :



Correlation Analysis for Electrical consumption to CDD reveals very low response to weather and high baseline consumption – not as expected.

Daily Consumption: 11,410 kWh / day
Correlation: 0.083



Correlation Analysis for Natural Gas consumption to HDD also indicates low response to weather and high baseline consumption – not as expected.

Daily Consumption: 7,441 cf / day
Correlation: 0.31

Projects Planned After January 2013

Upcoming capital equipment replacement project would complete the multi-phased replacement of the entire HVAC System. For this phase the Cx scope of work was increased to include ‘full services’ including design review and post installation performance monitoring.

Summer 2013 – Phase V Equipment Replacement
replaced six air handling units, new hot water boilers and pumps
Cost = $625,600

It was decided that along with commissioning of the new equipment to be installed in the Summer of 2013 we would also Retro-Cx the entire HVAC system.

Summer / Fall 2013 – Retro-Commissioning of entire building HVAC System
included all equipment replaced to date to be re-commissioned alongside of the equipment installed in the final phase of work
Cost = $82,000 *(just Commissioning Services)*

2014 to Present – On-Going Monitoring-Based Commissioning

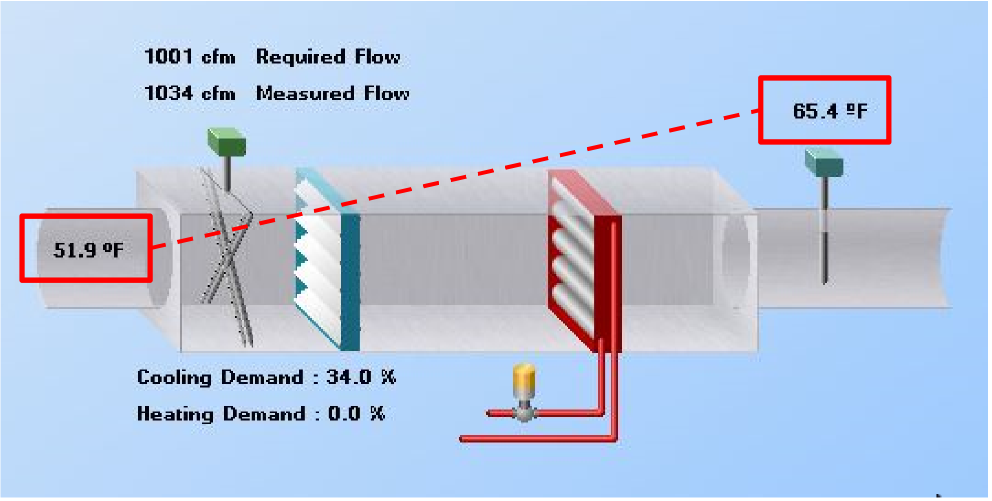
Retro-Commissioning Efforts - Investigation

Summer 2013 Investigation Found: (partial list)

VAV Terminal Units:

- 46% of VAV had airflow calibration error more than 10%
- 70% of VAV were re-calibrated during Retro-Commissioning

  Cumulative airflow measurement error of over +20,000 cfm
- 42% of thermostats had error greater than +/-1F, most reading warm
- Many VAV controllers were simply failed and needing to be replaced
- *Biggest find was that a very large quantity of VAV hot water reheat valves were either leaking by or were simply failed open!*
- Hot water system balance had been 'un-done' by maintenance over years



Example: VAV Reheat Valve Failure / Leaking By

Retro-Commissioning Efforts - Investigation

Summer 2013 Investigation Found: (partial list)

Air Handling Units:

- Ineffective or overridden supply air temperature reset and static pressure reset logic resulted in nearly no system optimization
- One AHU VFD was in hand at 100% because drive circuit would not function

Outside Air Units:

- LON comm failure to units resulted in supply air temperature set points and dew point set points defaulting to 32F…. Cooling coil valves stayed open 100% always.
- OAU for one wing would not operate and hadn't operated for at least a year.
- Non-optimized LAT set point control

Temperature Setpoint	32.000 ºF
Supply VFD Signal	99.000 %
Supply Low Alarm	0.0 %
Supply Fan Alarm	0.0 %
Supply Fan	100.0 %
Supply CFM Setpoint	7139
Status	8
Start/Stop	100.0 %
Supply Air Damper Alarm	0.0 %
Reset Alarms	0.0 %
Reheating	0.000 %
Preheat Temperature	80.780 ºF
Preheat	0.000 %
Phase Alarm	0.0 %
Outside Air Temperature	80.780 ºF
Outside Air Humidity	82.600 %
OnOff	100.0 %
Global Alarm	0.0 %
Freeze Alarm	0.0 %
Fire Smoke Alarm	0.0 %
Discharge Temperature	67.460 ºF
Dewpoint Setpoint	32.000 ºF
Cooling	100.000 %
Cold Coil Temperature	47.660 ºF

Out of Control OAU

Retro-Commissioning Efforts - Investigation

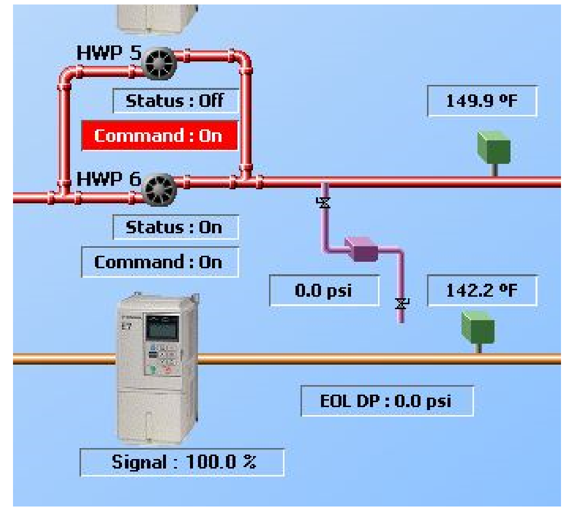
Summer 2013 Investigation Found: (partial list)

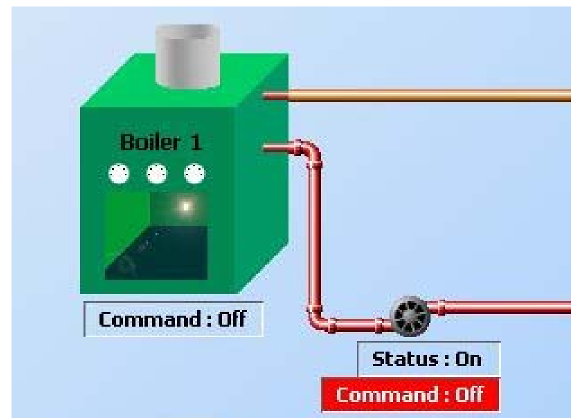
Heating Plant:

- Heating water pumps running at 100% always due to failed DP sensor
- Boiler enable / disable from BAS not functioning therefore plant running continuously

Cooling Plant:

- Low building chilled water temperature differential (<5F) causing excessive flow
- Excessive building flow causing to run two chillers to prevent reverse flow at the primary-secondary bypass
- Failed end-of line DP sensor causing plant to control building pumps by plant DP sensor only with no reset logic





Hot Water System Issues

Retro-Commissioning Efforts - Implementation

Corrective Measures Implemented Summer 2013 – end of 2013:

1. Replace ALL terminal unit hot water control valves and balancing valves
2. Replace existing AHU DDC controllers with new BACNET controllers
3. Replace AHU variable frequency drive that would not function
4. Troubleshoot and repair LON integration to OAU factory controllers
5. Replace all AHU-9 VAV DDC controllers with new BACNET controllers
6. Calibrate, repair, replace miscellaneous BAS sensors and devices
7. Calibrate all VAV terminal unit airflow measurement

COST of Only Corrective Measures = $67,101

Retro-Commissioning Efforts - Implementation

Conservation Measures Implemented Summer 2013 – Winter 2013:

8. Add additional building controller to allow for expanded building optimization logic and trending *(allowed On-Going Cx monitoring)*

9. Modify Chiller Plant to be variable flow primary and variable flow secondary

10. Add Space Humidity sensors to all air handling units for proper SAT reset while ensuring not sacrificing proper space moisture conditions

11. Provide new sequences and reprogram ALL AHU, OAU, and cooling / heating plants – ‘end-to-end optimization’ logic

12. Functional Performance Test of ALL HVAC systems to new sequences

13. Implement and utilize extensive BAS trend data analysis and automated monitoring to ensure proper operation and persistence of savings

TOTAL COST of EBCx Services, Repairs, and Conservation Measures = $218,494

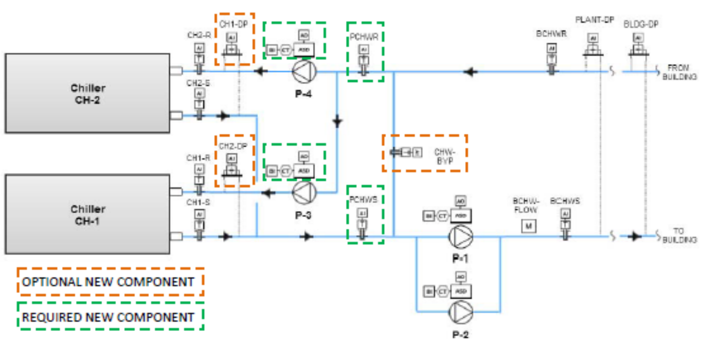
Retro-Commissioning Efforts - Implementation

A very important aspect of this retro-commissioning effort was the creation of new control sequences for all of the systems in the building. BES authored and documented these sequences for the Owner.

Chilled Water System

Two Air Cooled Chillers / VV Primary & VV Secondary Pumping

System Control Schematic



I/O Devices List

DEVICE DESCRIPTOR	BAS POINT NAME	SIGNAL TYPE	COMMENT
P-1 Pump Speed	P1-SPD	AO	Secondary pump
P-2 Pump Speed	P2-SPD	AO	Secondary pump
P-3 Pump Speed	P3-SPD	AO	Primary pump
P-4 Pump Speed	P4-SPD	AO	Primary pump
Pump 1 Start / Stop	P1-SS	BO	Secondary pump
Pump 2 Start / Stop	P2-SS	BO	Secondary pump
Pump 3 Start / Stop	P3-SS	BO	Primary pump
Pump 4 Start / Stop	P4-SS	BO	Primary pump

Interlocked Equipment List

EQUIPMENT TAG	DESCRIPTION	COMMENT
P-3	Primary Chiller Pump	Interlocked with CH-1
P-4	Primary Chiller Pump	Interlocked with CH-2

I/O Sensors List

SENSOR DESCRIPTOR	BAS POINT NAME	SIGNAL TYPE	COMMENT
Bldg CHW Return Temp	BCHWR	AI	Matched Pair
Bldg CHW Supply Temp	BCHWS	AI	Matched Pair
Bldg CHW Flow	BCHW-FLOW	AI	-
Building Diff Pressure	BLDG-DP	AI	Remotely Mounted
Plant CHW Return Temp	PCHWR	AI	Matched Pair
Plant CHW Supply Temp	PCHWS	AI	Matched Pair
Bypass CHW Temp	CHW-BYP	AI	Not Control, indicator only

Leaving Water Temperature Control: Each chiller shall control its leaving water temperature to the current chilled water supply setpoint (CHWS-SP) by means of its internal controls and safeties.

Safeties: The chillers shall operate subject to their internal safeties and operating limits as configured by the manufacturer.

SECONDARY CHILLED WATER PUMP CONTROL: **Remote DP Based Local DP Reset**

Pump Start / Stop: The DDC system shall energize / de-energize the secondary chilled water pumps – only one chilled water pump shall run at a time, regardless of quantity of chillers operating. The lead secondary chilled water pump shall be started whenever the chilled water system is enabled. The secondary chilled water pump shall be started five minutes prior to the chillers being enabled. If either pump fails (as indicated by current sensor) then the DDC shall automatically start the standby pump and post an alarm to the system. The lead / lag status of the pumps shall be alternated weekly during a normally unoccupied time of day in such a manner as to distribute run-hours evenly between the two pumps. The DDC system shall also allow manual selection of the lead / lag status of the pumps.

Pump Speed Control: The DDC system shall vary the secondary chilled water pump speed to maintain the local hard-wired plant differential pressure (PLANT-DP) at a floating DP setpoint (PLANT-DP-SP). The local plant floating DP setpoint (PLANT-DP-SP) shall be reset upward and downward based on the remote building differential pressure (BLDG-DP). If the remote building DP is below its setpoint then the floating DP setpoint shall be reset upward; if the remote building DP is above setpoint then the floating DP setpoint shall be reset downward. If at any time the remote DP signal fails or is above / below normal range of value then the local plant DP shall be set to the default DP setpoint value and an alarm shall be posted.

PRIMARY CHILLED WATER PUMP CONTROL: **Delta T Matching Control**

Pump Start / Stop: The primary chilled water pumps shall be energized / de-energized by the factory chiller controller subject to internal timers and safeties after the chiller is enabled by the DDC system. If the primary chilled water pumps are not configured to be started / stopped by the chiller controller then the DDC system shall enable the primary pump(s) then five minutes later shall enable the chiller(s). If either pump fails (as indicated by current sensor) then the DDC shall post an alarm to the system and shall disable the associated chiller.

Pump Speed Control: The DDC system shall vary the primary chilled water pump speed to maintain near zero flow in the plant bypass piping. This shall be accomplished by calculating the chilled water plant temperature differential (PCHW-DT) and the building chilled water temperature differential (BCHW-DT) and comparing these values. *These four temperature sensors shall be certified as 'matching pairs'.* The DDC system shall vary the primary chilled water pump speed to maintain the Temperature Differential Comparator ('DT-COMP' = 'BCHW-DT' – 'PCHW-DT') at a value of ZERO. If the DT-COMP variable is LESS THAN ZERO then the primary pump speed shall be INCREASED, if the DT-COMP variable is greater than ZERO then the primary pump speed shall be DECREASED. Primary pump speed shall not be reduced below the minimum speed which was determined to provide the chiller manufacturer's minimum recommended flowrate plus safety as recommended during start-up / commissioning.

Minimum Chiller Flow: The design chilled water flowrate for each chiller is 720 gpm, the manufacturer's recommended minimum chilled water flowrate is 342 gpm. The primary means of minimum chilled water flowrate protection shall be the minimum pump speed (programmed into the VFD, NOT DDC software) determined to result in a flowrate of 400 gpm. Alternate means of identifying flow through the chillers shall be the chilled water pressure differential across each chiller's evaporator (CH1-DP, CH2-DP) as reported to the DDC system. If the chiller is enabled and the differential pressure remains below the corresponding minimum DP for more than 90 seconds then an alarm shall be posted to the DDC system. The chiller evaporator DP transmitter shall be selected such that the DP corresponding to MINIMUM flow is within the MID-RANGE (40%-60%) of the transmitter DP range.

CONTINUING EDUCATION AIA

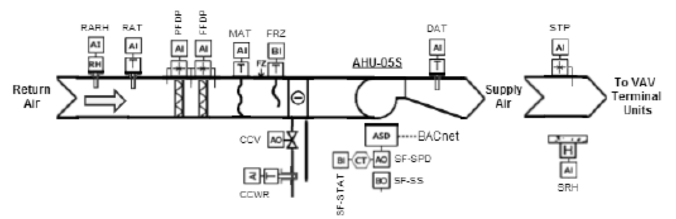
Retro-Commissioning Efforts - Implementation

A very important aspect of this retro-commissioning effort was the creation of new control sequences for all of the systems in the building. BES authored and documented these sequences for the Owner.

AHU-05S

Multi-Zone Variable Volume AHU (No Outside Air)

Air Handling System Control Schematic



I/O Devices List

DEVICE DESCRIPTOR	BAS POINT NAME	SIGNAL TYPE	COMMENT
Cooling Coil Valve	CCV	AO	N.O.
Supply Fan Speed	SF-SPD	AO	*(Min 30% - Verify)*
Supply Fan Status	SF-STATUS	BI	AHU-05S VFD
Supply Fan Alarm	SF-ALM	BI	AHU-05S VFD
Supply Fan Start / Stop	SF-SS	BO	AHU-05S VFD

I/O Sensors List

SENSOR DESCRIPTOR	BAS POINT NAME	SIGNAL TYPE	COMMENT
AHU Discharge Air Temp	DAT	AI	Control of Cooling Coil
Mixed Air Temperature	MAT	AI	Control of Preheat Coil
Return Air Temperature	RAT	AI	Monitor Only
Return Air Relative Humidity	RARH	AI	Monitor Only
Space Relative Humidity	SRH	AI	DAT Setpoint Control
Supply Duct Static Pressure	SP	AI	Fan Speed Control

Software Points List

POINT DESCRIPTOR	BAS POINT NAME	RANGE OR CONDITION	COMMENT
AHU DAT Design Setpoint	DAT-SPT-LO	52.0 deg F	Fixed per Design
AHU DAT Max Setpoint	DAT-SPT-HI	70.0 deg F	Adjustable
DAT Reset Cycle Time	DAT-TIME	180 min	Adjustable
High RH / DAT Setpoint	HUM-HI	60 %RH	Adjustable
Low RH / DAT Setpoint	HUM-LO	50 %RH	Adjustable
Static Pressure Setpoint	SP-SPT	0.5"-2.0 "w.c.	(confirm during Cx)
SP Reset Increment	SP-INC	0.2"	Adjustable
Allowable Error Fraction	SPR-AEF	0.90	Adjustable
VAV Space Cooling Setpoint	VAV-xx-CSPT	74 deg F	

VAV Space Heating Setpoint	VAV-xx-HSPT	70 deg F	
Night Low Limit Setpoint	NLL-SPT	55 deg F	Heat up 5 deg F
Night High Limit Setpoint	NHL-SPT	85 deg F	Cool down 5 deg F
Night High Humidity Limit	NHHL-SPT	65 %RH	Dehumidify until <55%RH

Safety Limits List

POINT DESCRIPTOR	BAS POINT NAME	RANGE OR CONDITION	COMMENT
Freezestat	FRZ	35 deg F	

Sequence of Operation – Air Handling Unit

START / STOP / SAFETIES:

Start/Stop: The AHU supply fan shall be started / stopped by the DDC system according to an Owner provided Occupied / Unoccupied schedule through the variable frequency drive (VFD) enable circuit. The VFD shall be programmed to have a 180 second ramp time from off to full speed. A current switch is installed on the load side of the supply fan VFD (or status contact via the VFD). The DDC system uses this switch (or contact) to confirm the fan is in the desired state (i.e. on or off) and generates an alarm if status deviates from DDC start/stop control and the system goes to Normal Off mode. The DDC system generates a VFD trouble alarm independent from the fan status (if available).

Safeties: If the mixed air temperature is below 35°F, a manual reset freezestat shall interrupt the safety circuit and shut down the VFD. The cooling coil valve opens. All other dampers and valves position to their normal position after the fan is de-energized. If the building fire alarm enters alarm mode, a fire alarm relay shall interrupt the safety circuit and shut down the VFD. All dampers and valves position to their normal position after the fan is de-energized.

FAN SPEED CONTROL with Static Pressure Reset: **Airflow Error Method**

The DDC system shall control the fan speed through the variable frequency drive (VFD) to maintain supply duct static pressure at setpoint. The fan speed shall be reduced down to a minimum speed setpoint determined to provide sufficient pressure to deliver the minimum airflow of all VAV terminal units or the scheduled minimum outside airflow setpoint (whichever speed is greater). Upon start-up the static pressure setpoint shall be set to the middle of the static pressure reset range. The static pressure setpoint shall be reset every 15 minutes between the min and the max setpoint based on the following reset logic:

Airflow Error Method: The DDC shall calculate the total required airflow for the system (sum of all terminal unit current airflow setpoints) and the current total system airflow (sum of all terminal unit actual airflows). The DDC shall calculate the current airflow error fraction by dividing the current system airflow by the total required airflow. If the error fraction is greater than the Allowable Error Fraction setpoint (adjustable) of 0.90 then the static pressure setpoint shall be lowered by the SP Reset Increment (0.2"w.c., adjustable). If the error fraction is less than the Allowable Error Fraction setpoint then the setpoint shall be increased by the SP Reset Increment. *(Min / Max static pressure setpoints determined during Cx).*

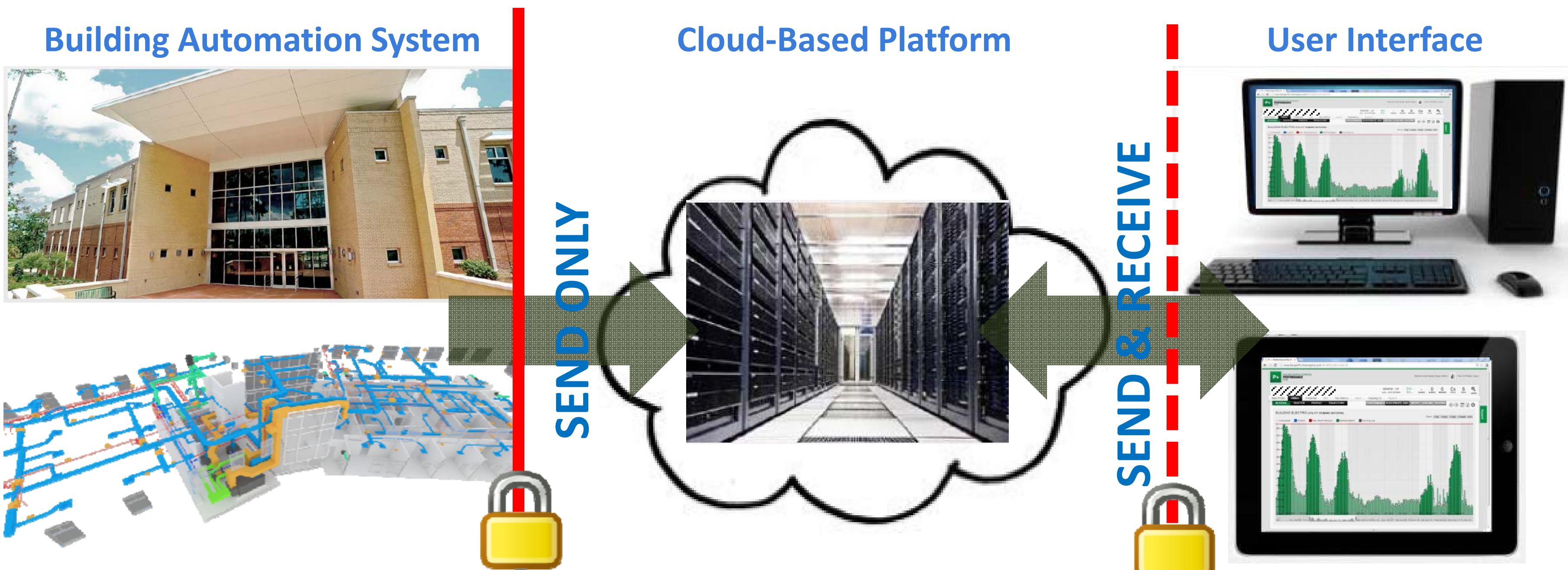
DISCHARGE AIR TEMPERATURE CONTROL: **Cooling Demand & RH Optimization**

The DDC system shall modulate the chilled water control valve as required to maintain discharge air temperature (DAT) at current setpoint which shall vary between the design setpoint and the max reset setpoint of 70F (adjustable). The DAT Reset Increment shall be variable, calculated by: (DAT Max Reset – Design DAT) / (DAT Reset Cycle Time / 15). At start-up the DAT setpoint shall start at the design setpoint.

On-Going Commissioning Methodology

Beginning with the commissioning of the Phase 5 equipment replacement a 3rd party performance monitoring platform was utilized to verify the functional performance of the systems.

System allowed further optimization of system performance as well as automated fault detection and diagnostics (AFDD) capability to prevent system degradation and extend savings persistence.

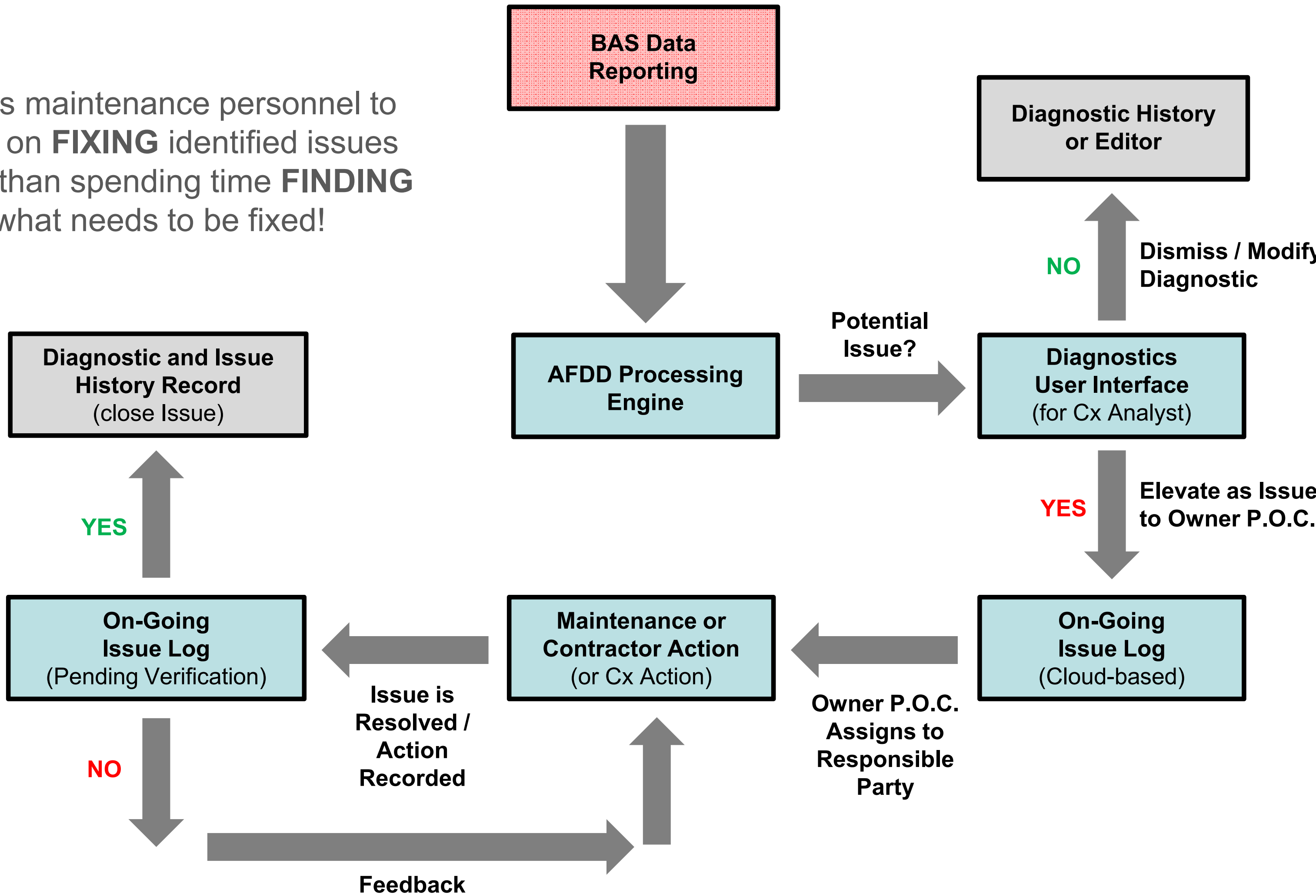


Reports from facility BAS server are transferred (via email, FTP transfer, communicated) to the platform where it is processed and stored in a secure cloud-based enterprise database for access from any internet connected device (PC, tablet, phone) capable of HTML5 browser support

Automated Fault Detection Methodology

On-Going Commissioning fee structure provides a recurring monitoring and analysis fee as well as an ‘investigation allowance’ which the Owner can utilize for the provider to further investigate potential issues.

Allows maintenance personnel to focus on **FIXING** identified issues rather than spending time **FINDING** what needs to be fixed!



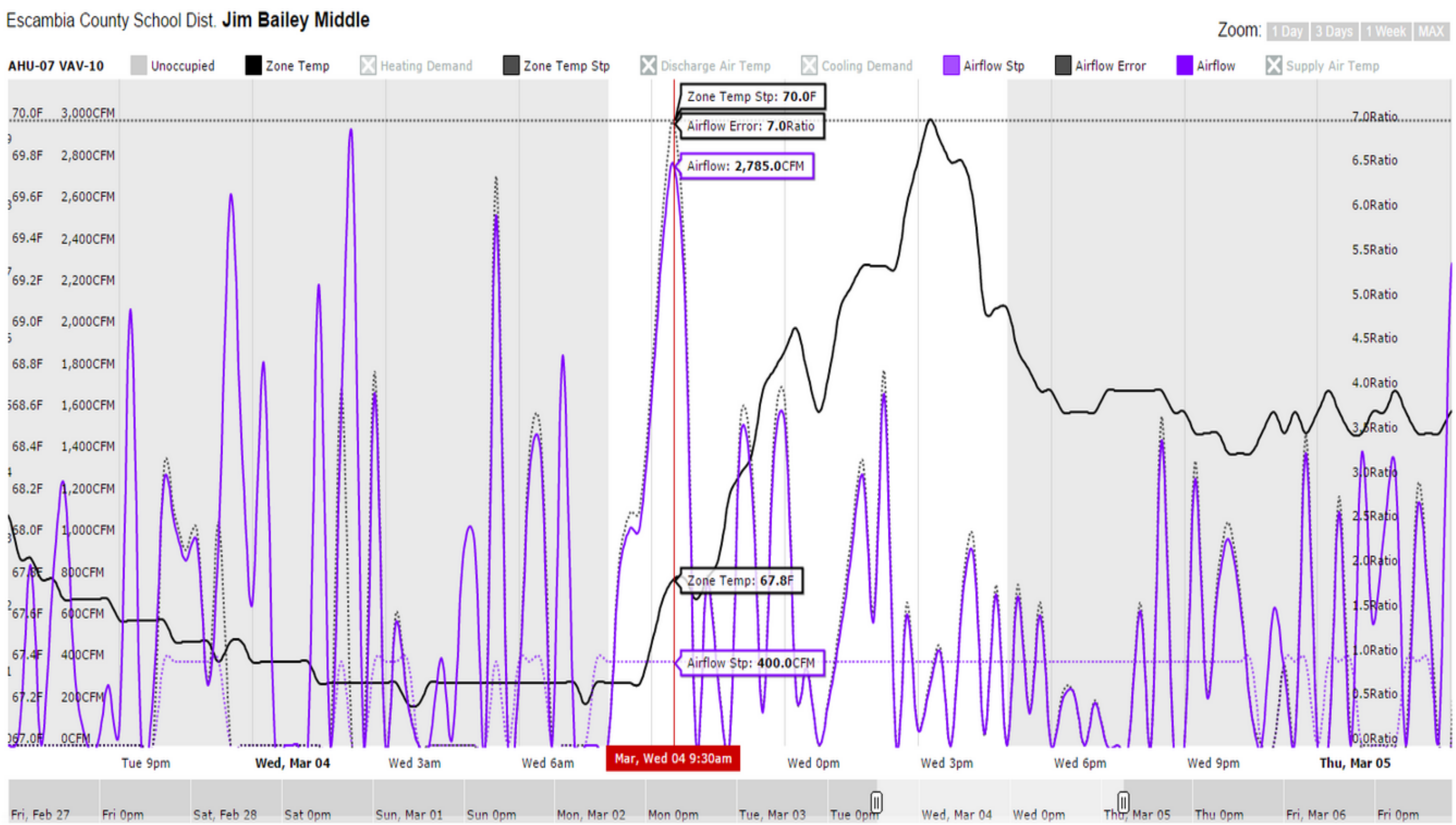
Automated Fault Detection Results

Example Diagnostics: Chilled Water Valve Failed Open / Leaking By

Chilled water valve fails open or in last position… system continues to function fine at the space level as reheat coils ‘do their job’ and provide heat to offset the failed valve – this would go unseen in most cases – AFDD detects and alerts so this can be addressed!

Automated Fault Detection Results

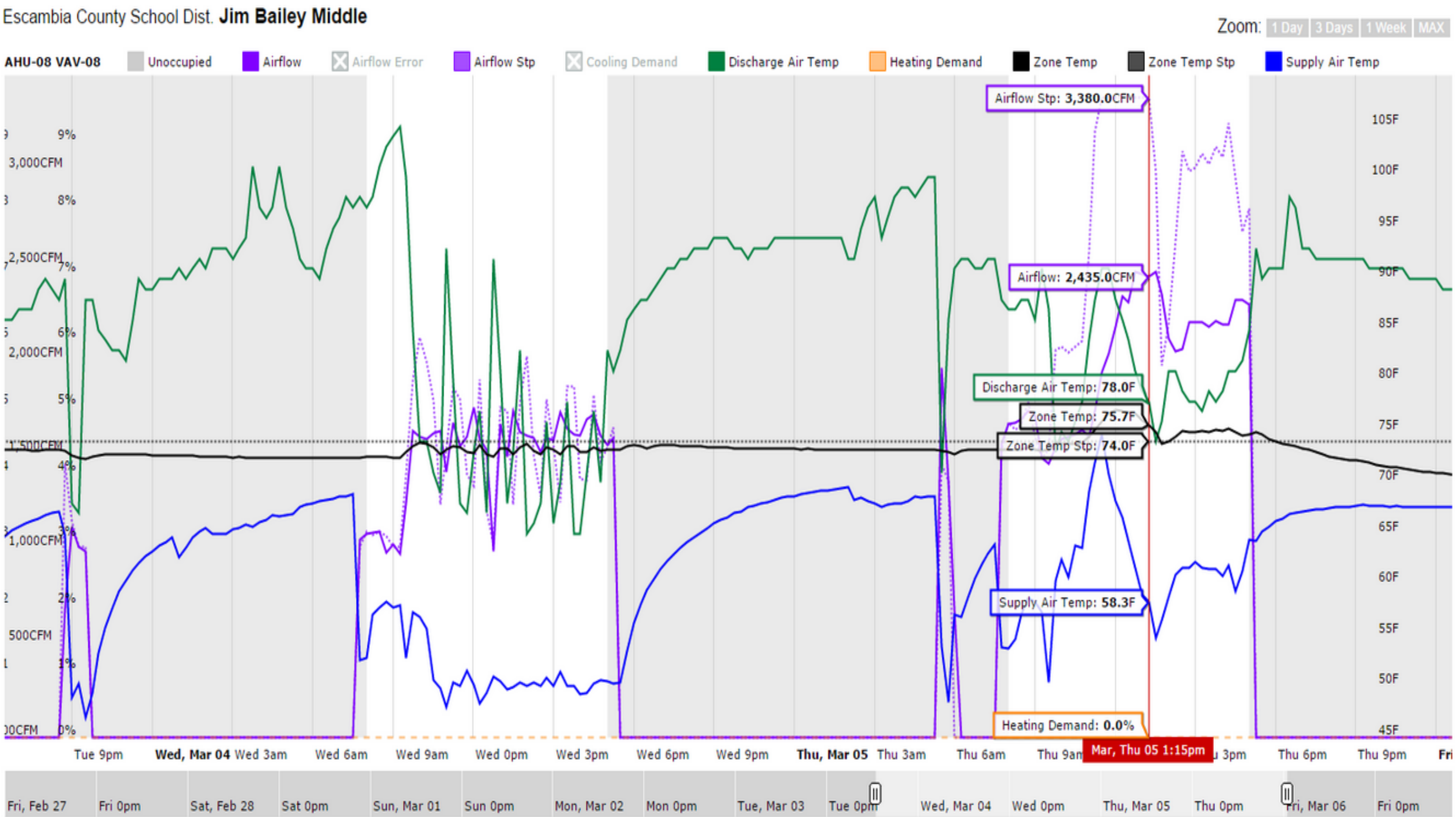
Example Diagnostics: Terminal Unit Airflow Control



Out of control VAV airflow… wasn't causing "too bad" of space temperature control and could go without notice as the controls know 'the show must go on'! AFDD solution catches this as a performance issue even though it may not generate a comfort complaint.

Automated Fault Detection Results

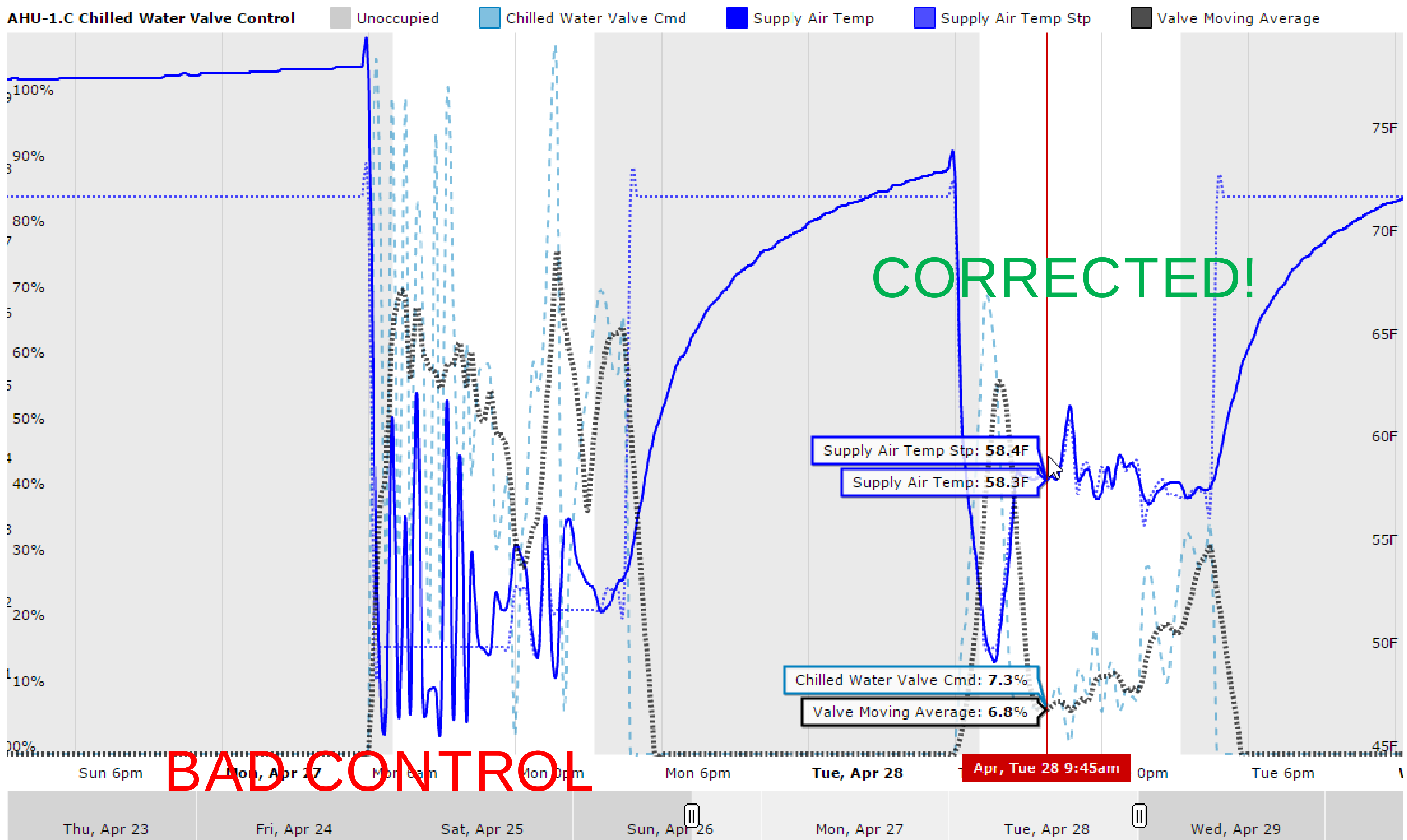
Example Diagnostics: Terminal Unit Hot Water Valve Failed Open / Leaking By



VAV reheat coils leaking by or failing open was one of the primary contributors to this facilities original poor performance… accumulated failures occur hidden from view. This occurred AFTER all of the valves had been replaced, detected automatically, corrected in timely manner.

Automated Fault Detection Results

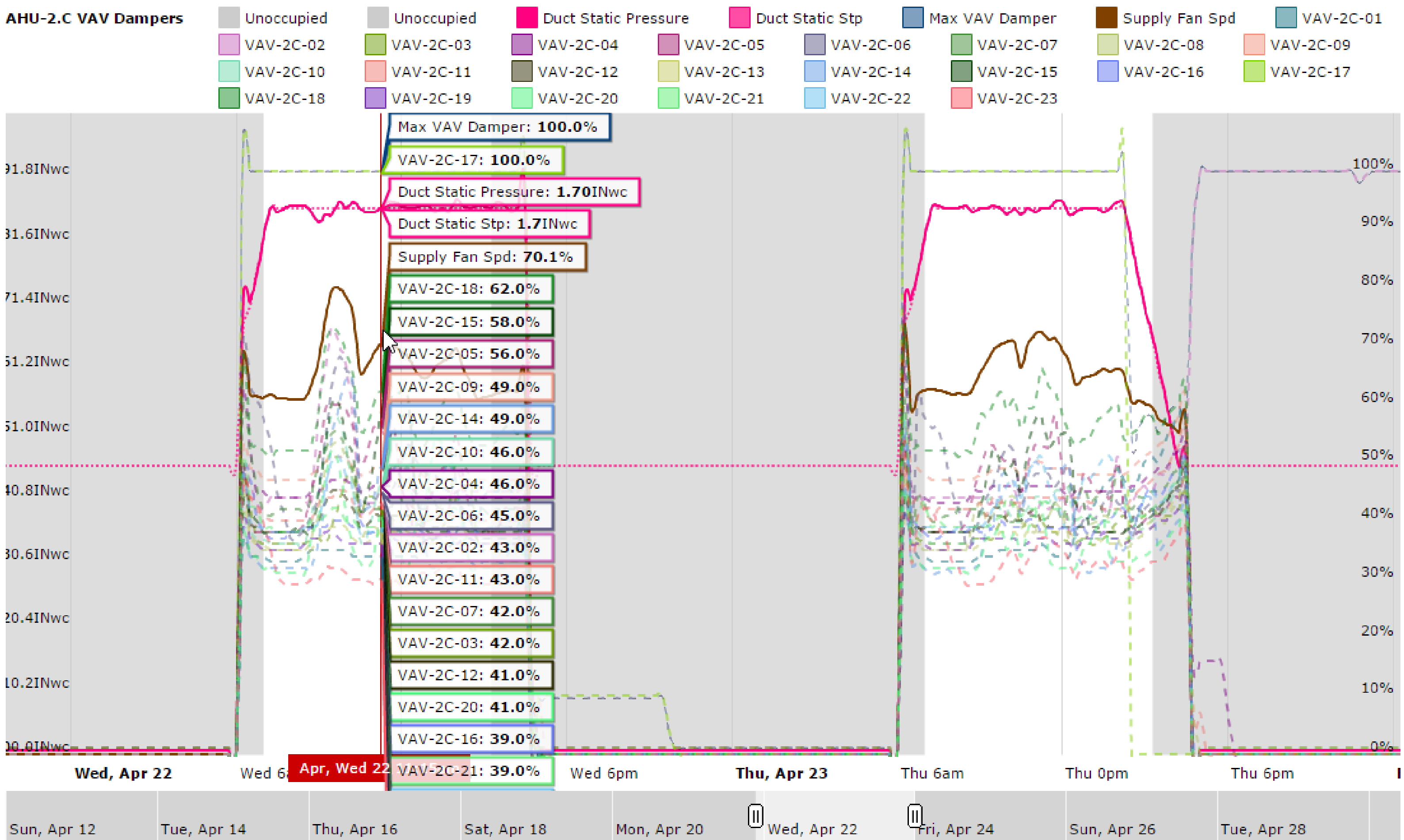
Example Diagnostics: Chilled Water Valve Control Loop Tuning



Control loop tuning is VERY important but often over-looked… difficult at best to determine during 'snapshot' testing. Trend analysis, in this case automated, alerts Cx Analyst to conditions of poor control caused by improperly tuned control loops

Automated Fault Detection Results

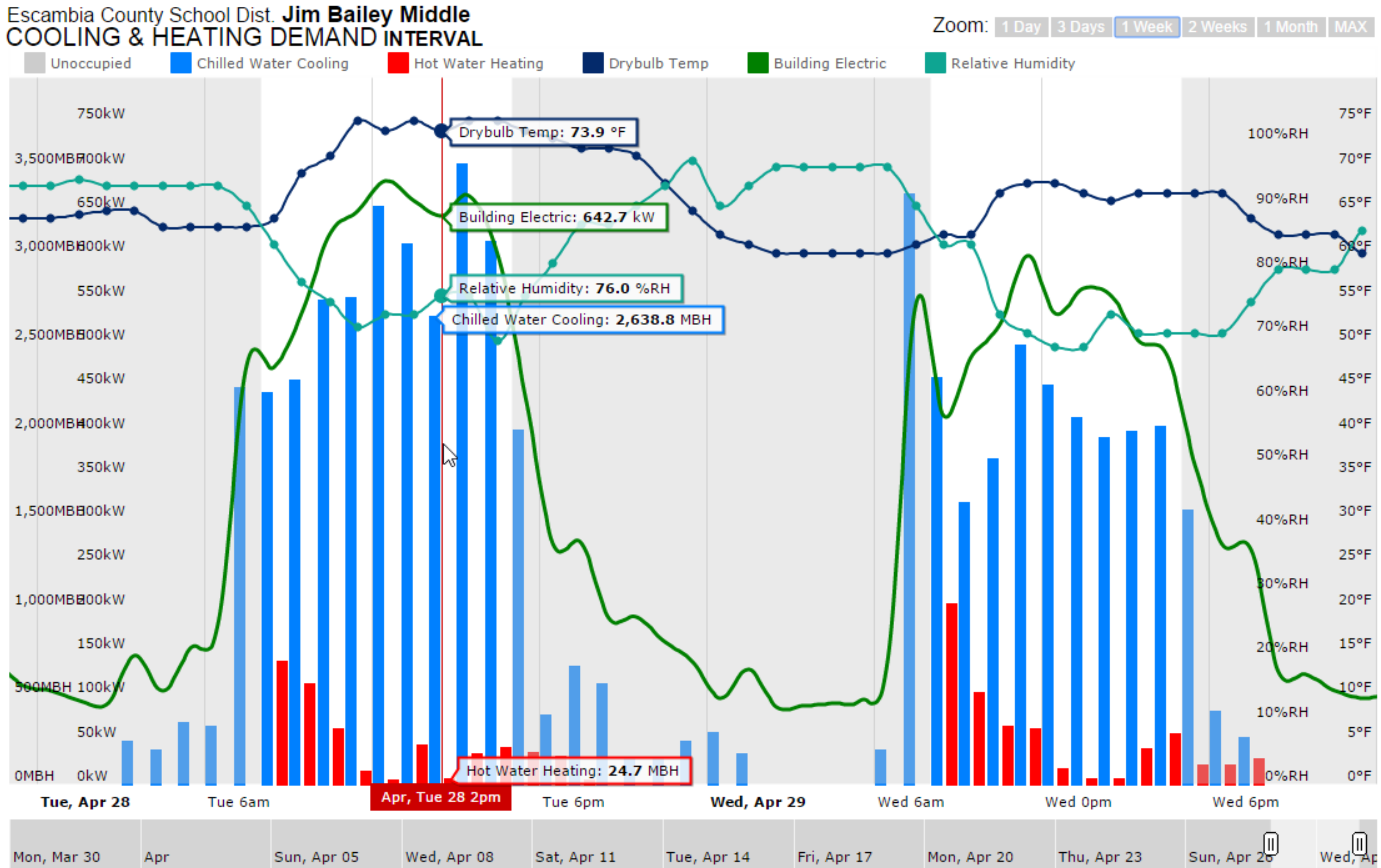
Example Diagnostics: Optimization Routine Outlier Monitoring



A single outlier VAV terminal unit with damper at 100% open causing SP setpoint to not reset… was issue with VAV Controller. After correction the system fan decreased from 70% speed to 50% speed at same conditions… **a fan power decrease of 64%**

On-Going Utility Consumption Monitoring

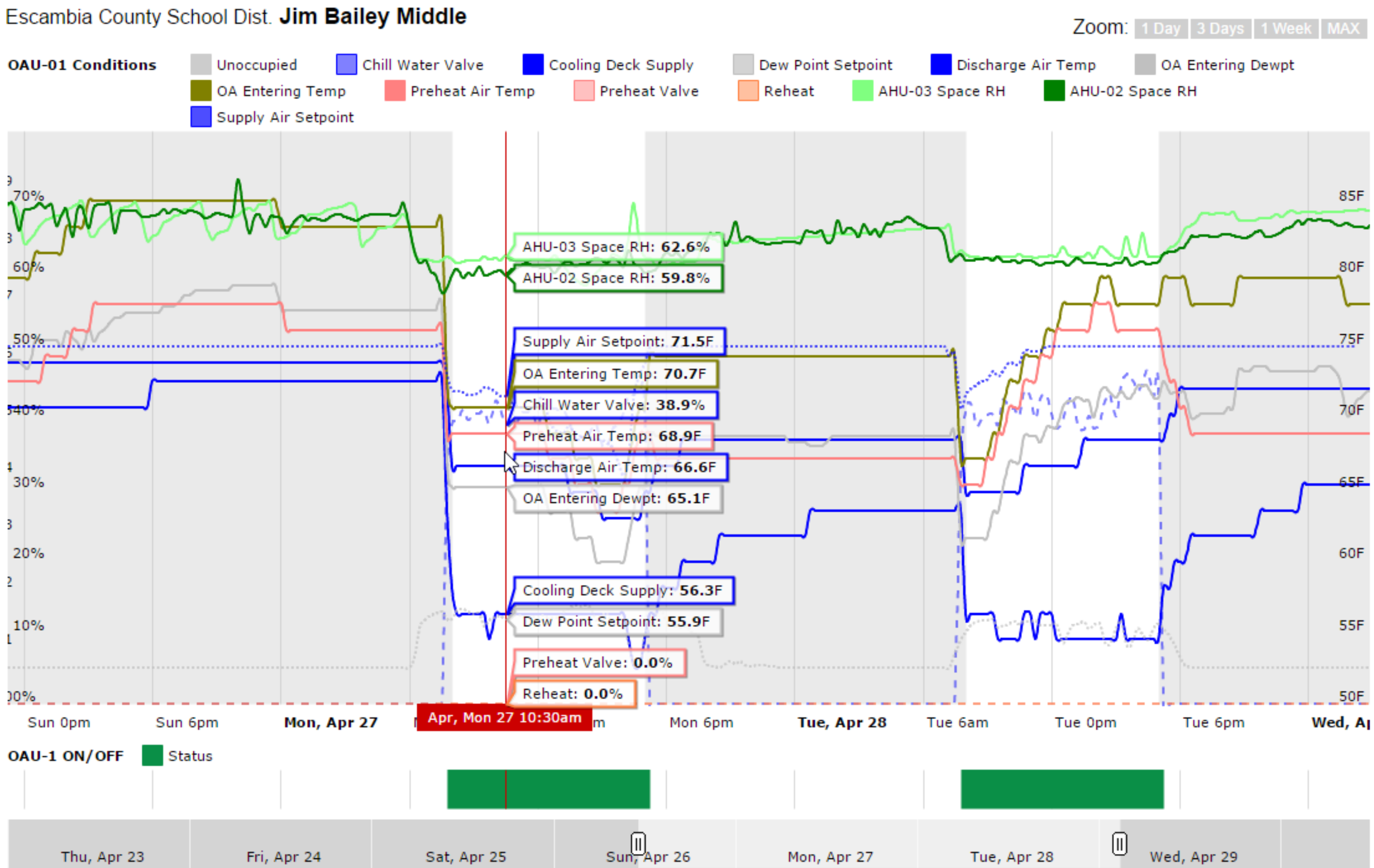
Example Utility Monitoring: Combined Cooling, Heating, Electric Demand Interval Chart



INVALUABLE information both from a performance analysis perspective as well as for operational logic – make metering data at the BAS level a priority on ALL projects!!! However, always keep in mind that the Utility Consumption is a dependent variable – **control the SYSTEM!**

Optimized Outside Air Unit Operation

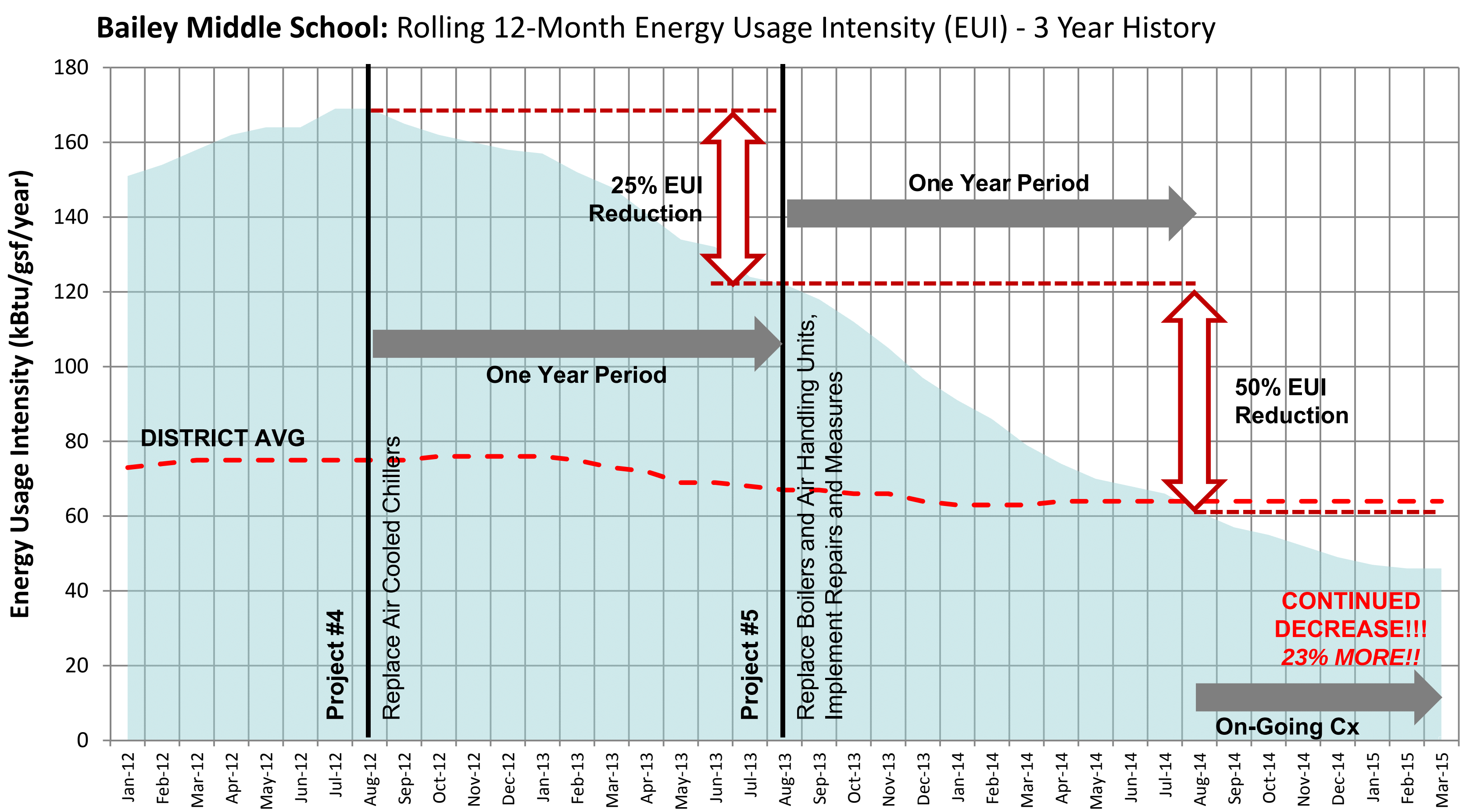
Example Optimization: Outside Air Unit Dew-Point / Discharge Air Temp Set-point Optimization



One of the bigger energy consumption issues was the outside air units… but what was a huge energy penalty had the potential to become a very efficient system feature if it was controlled properly… optimizing dewpoint setpoint by space RH and Discharge Air temp by zone demand

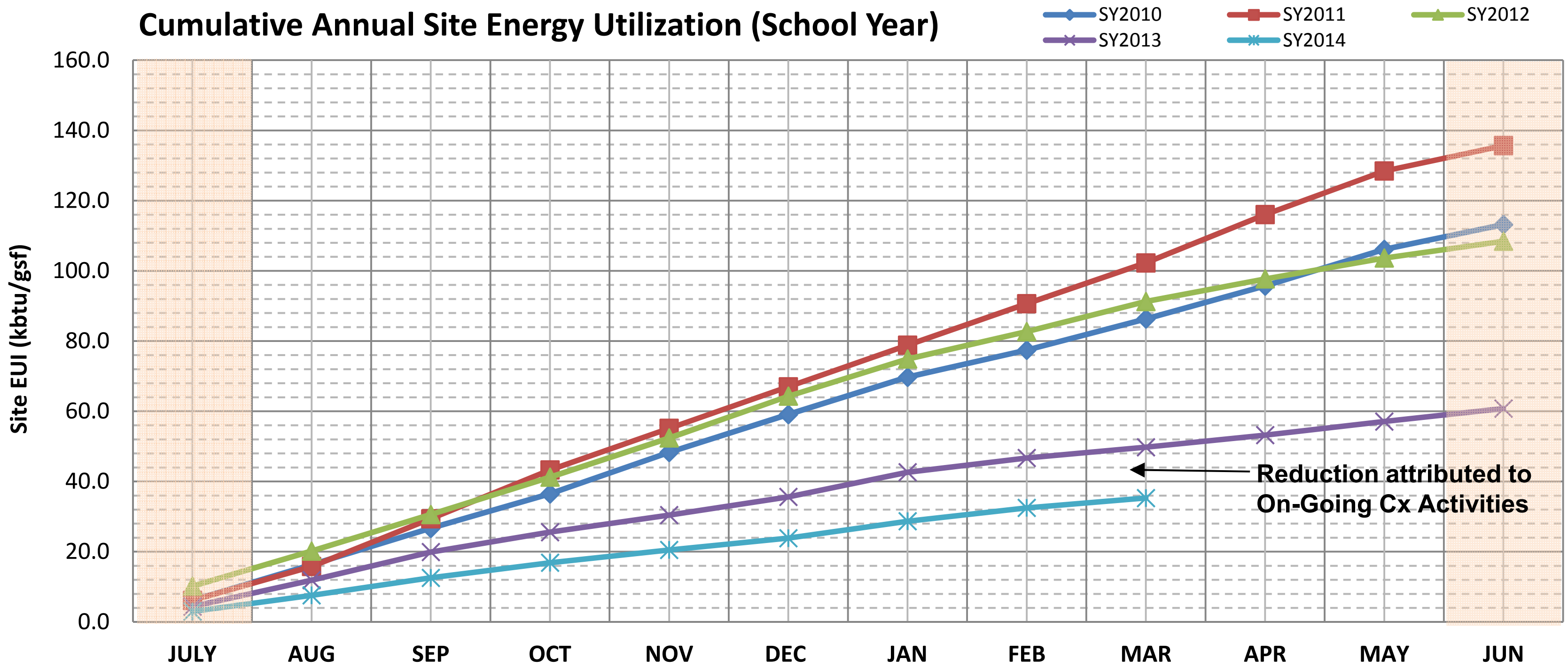
Project Results - Following the Reductions

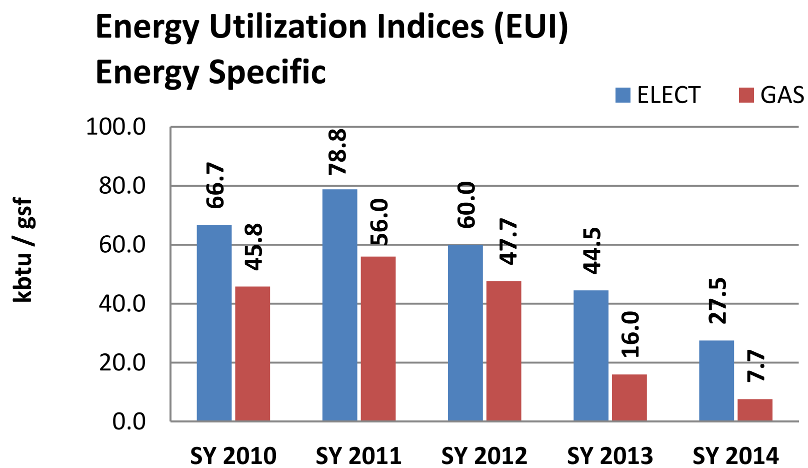
One year following completion of the chiller plant replacement the campus EUI was now 25% below 2012 peak EUI which resulted from savings primarily due to the chiller plant efficiency improvement

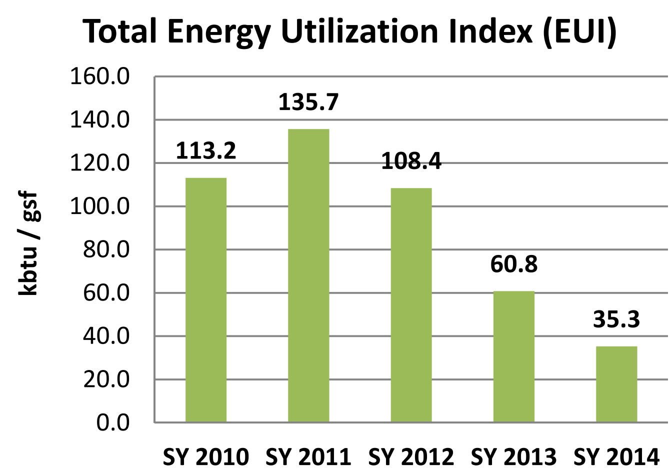


One year following the boiler plant replacement, retro-Cx, and implementation of all of the recommended corrections and conservation measures there was a 50% decrease in EUI!!
Over the next 9 months using On-Going Cx resulted in additional 23% decrease!!!

Project Results – School Year Comparison

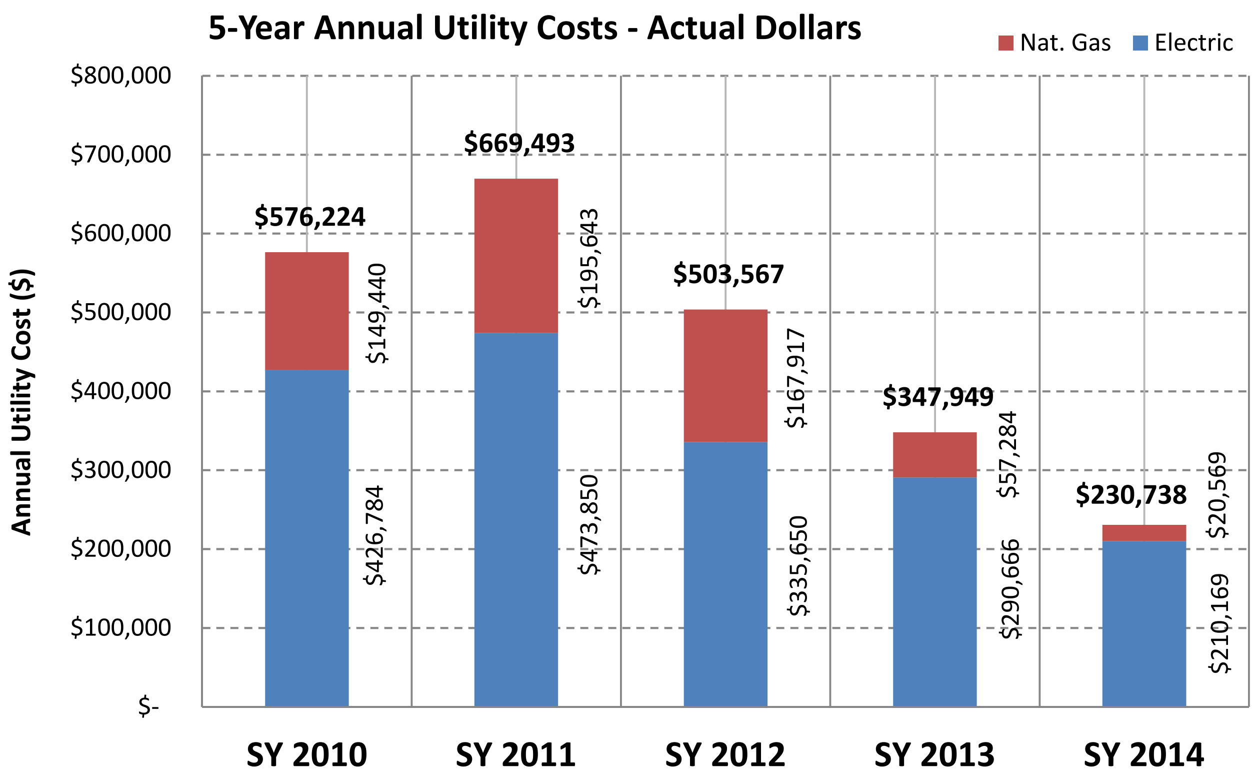






Project Results – School Year Comparison

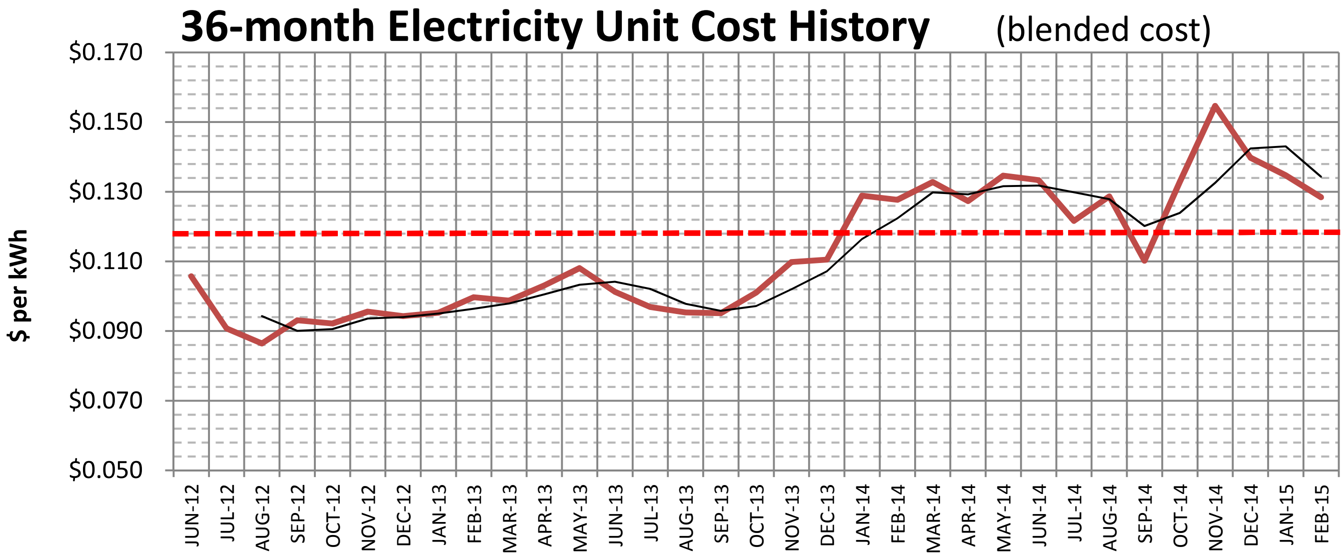
Projected gross (non-corrected) “School Year” savings for SY-2014 compared to SY-2011 are anticipated to be approximately $410,000. This is despite a 20% increase in electrical rate over period!

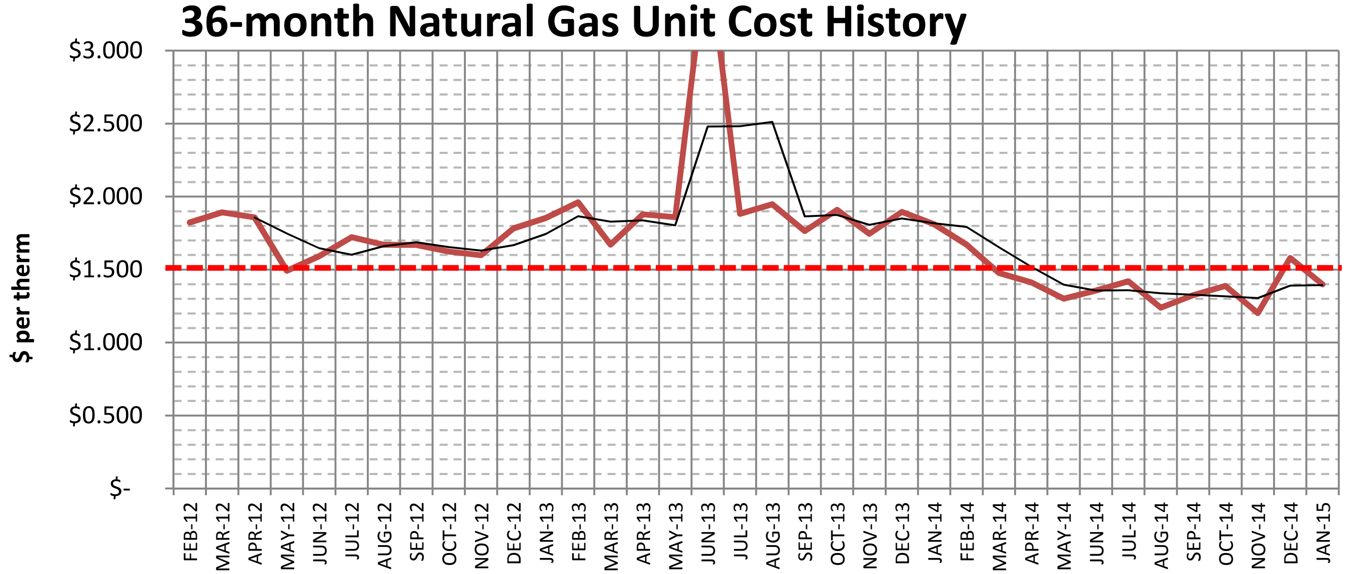


The natural gas service cost for all of SY-2014 will be approximately equal to just the peak month in SY-2012 when December was around $25,000 for that single month. Additional utility cost savings in SY-2014 attributed to On-Going Monitoring Based Cx activities are around $75,000.

Cumulative Total Savings for last three SY since the consumption peaked is near $900,000

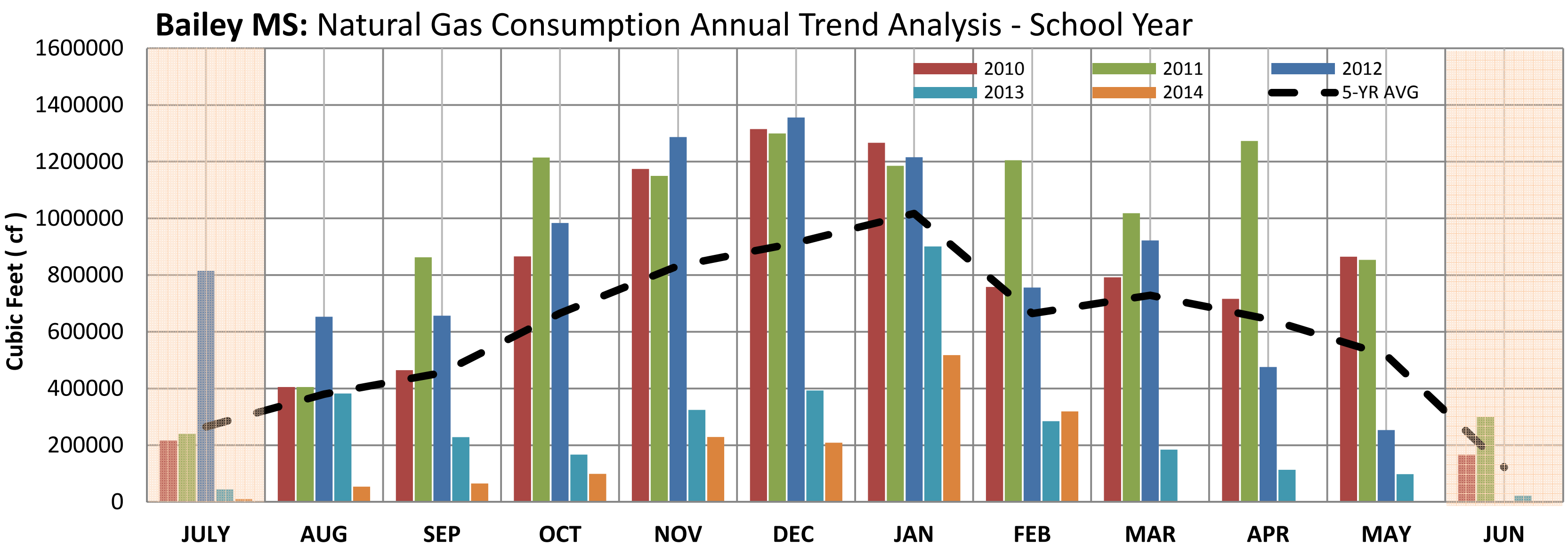
Utility Rate History over the Performance Period

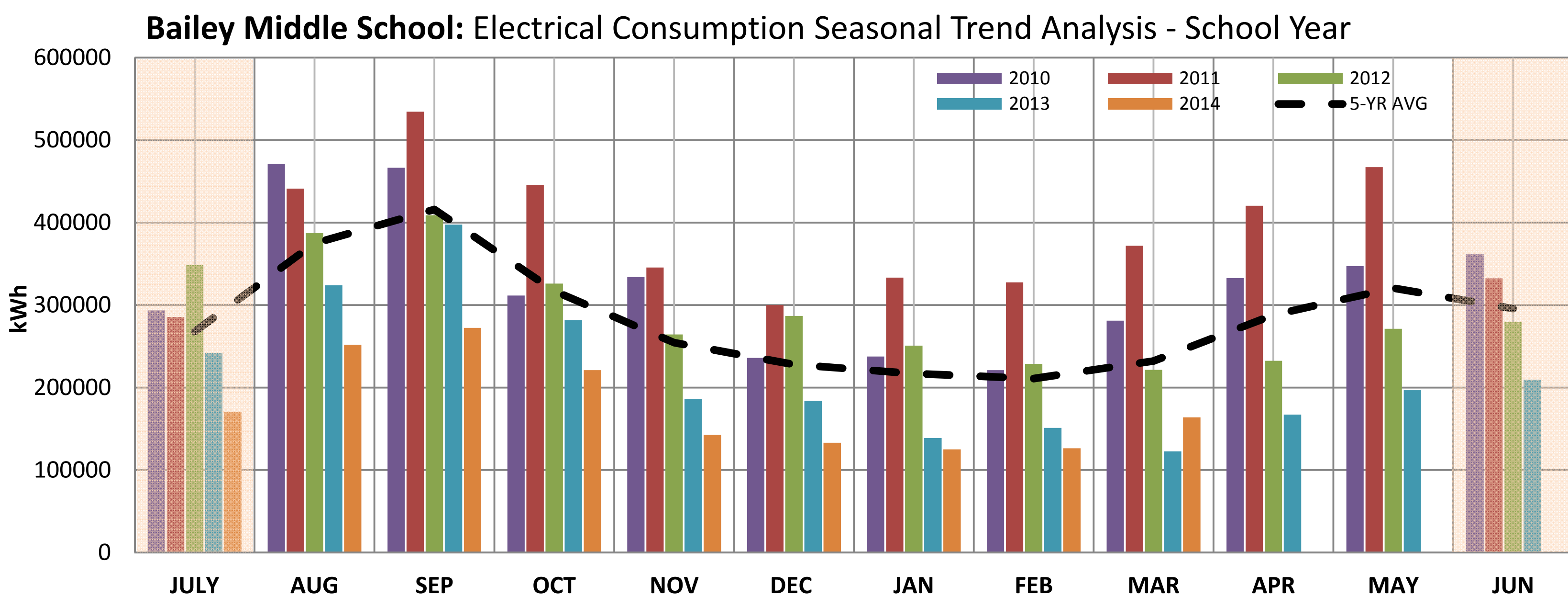




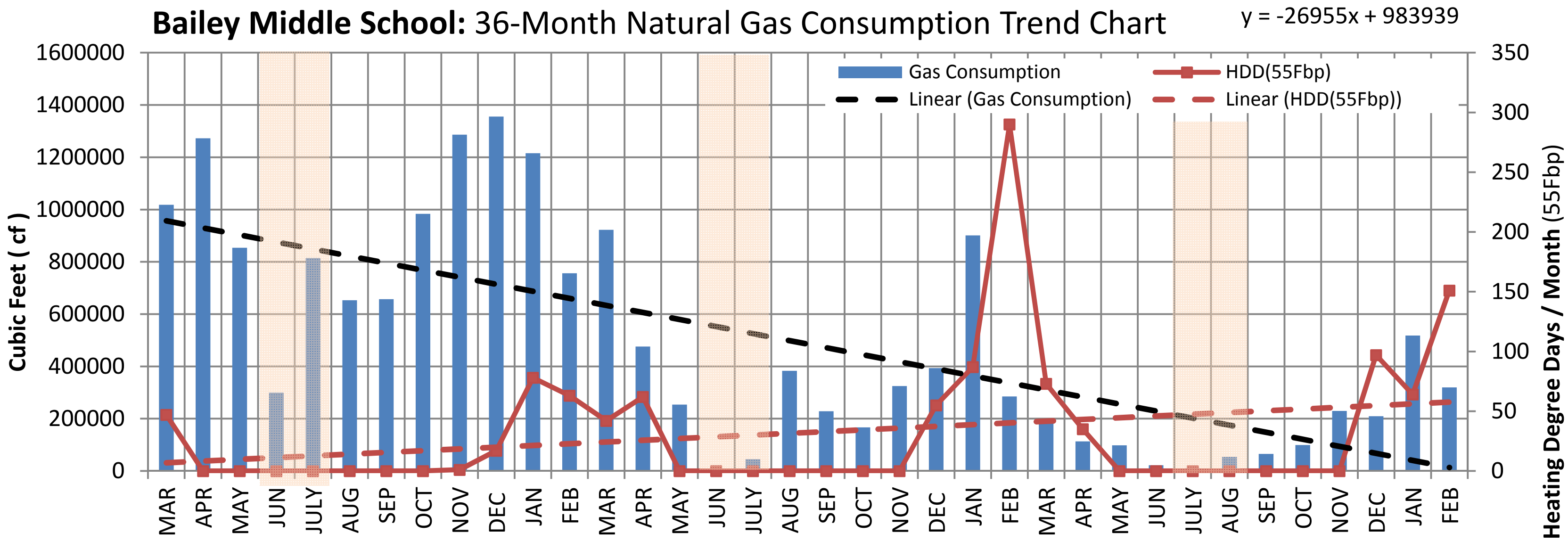
CONTINUING EDUCATION AIA

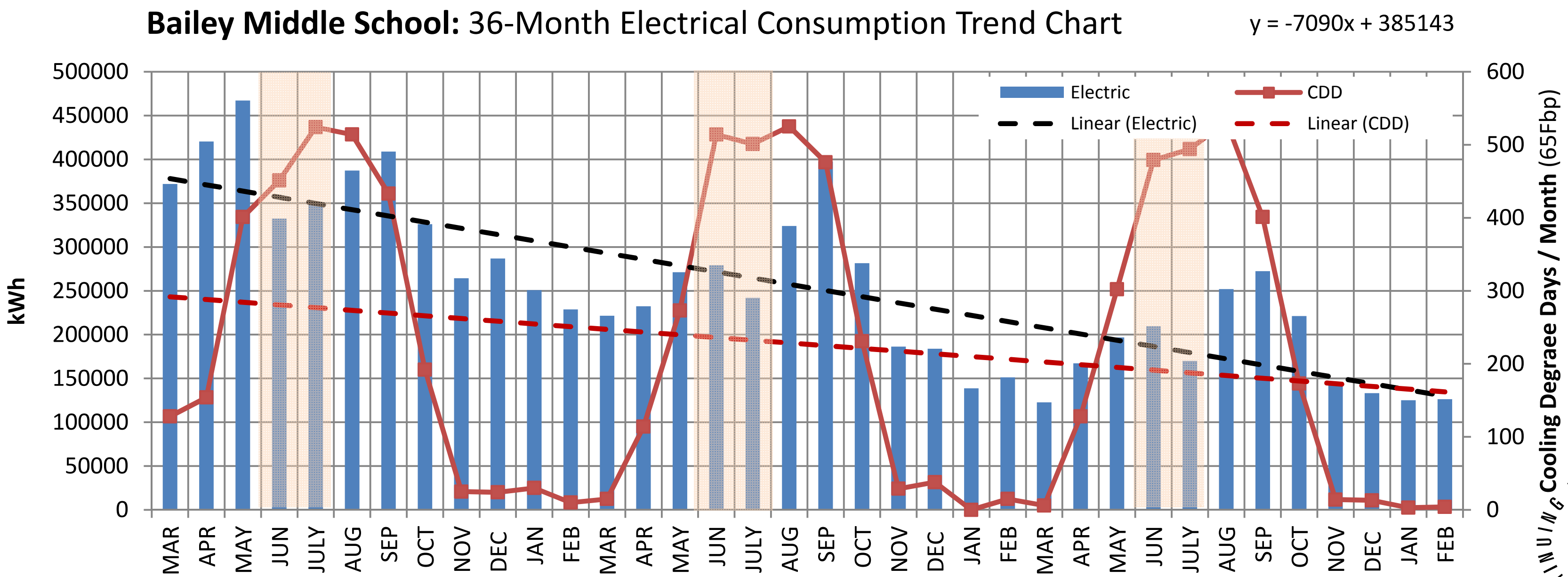
Project Results –Annual Consumption Profiles





Project Results – Consumption Trend Charts





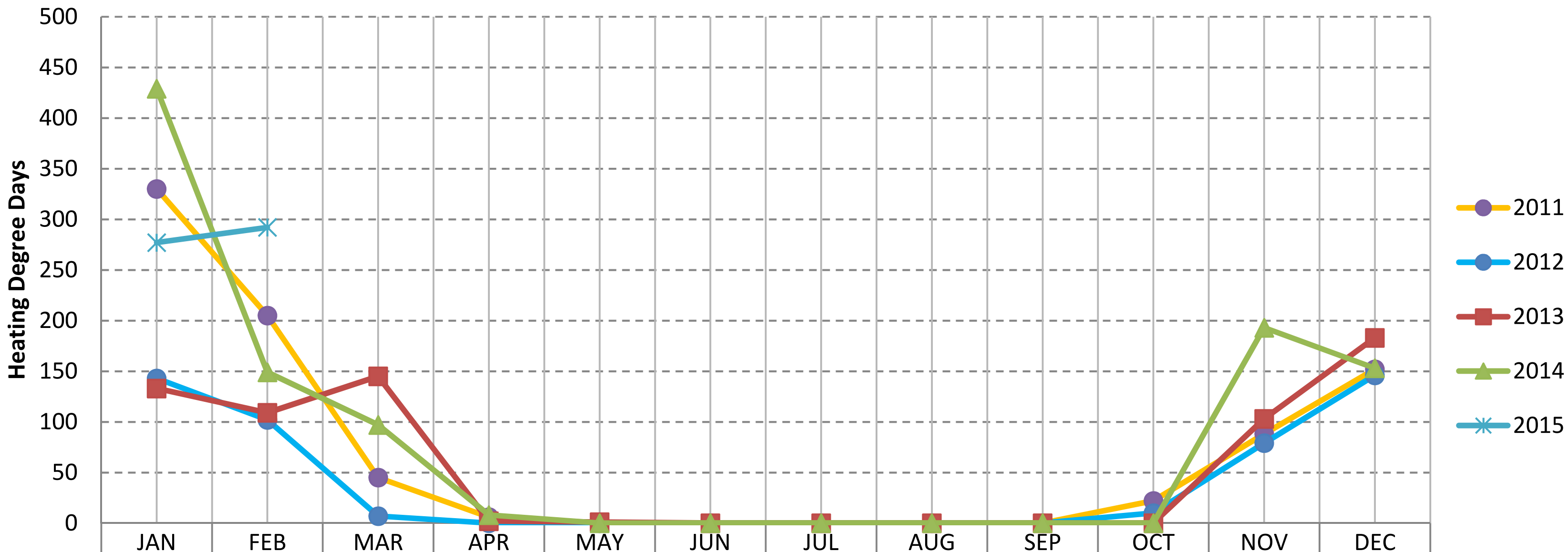
CONTINUING EDUCATION AIA

Did the Weather Help or Hurt the Savings?

This project did not have contract stipulated utility measurement and verification… the M&V that was done was for the purposes of assisting the Owner's facilities personnel obtain funding for similar projects.

BUT… since you asked, here is a Calendar Year HDD Comparison Chart:

Previous Year Degree Day Comparison - Heating Degree Days (60F BP)



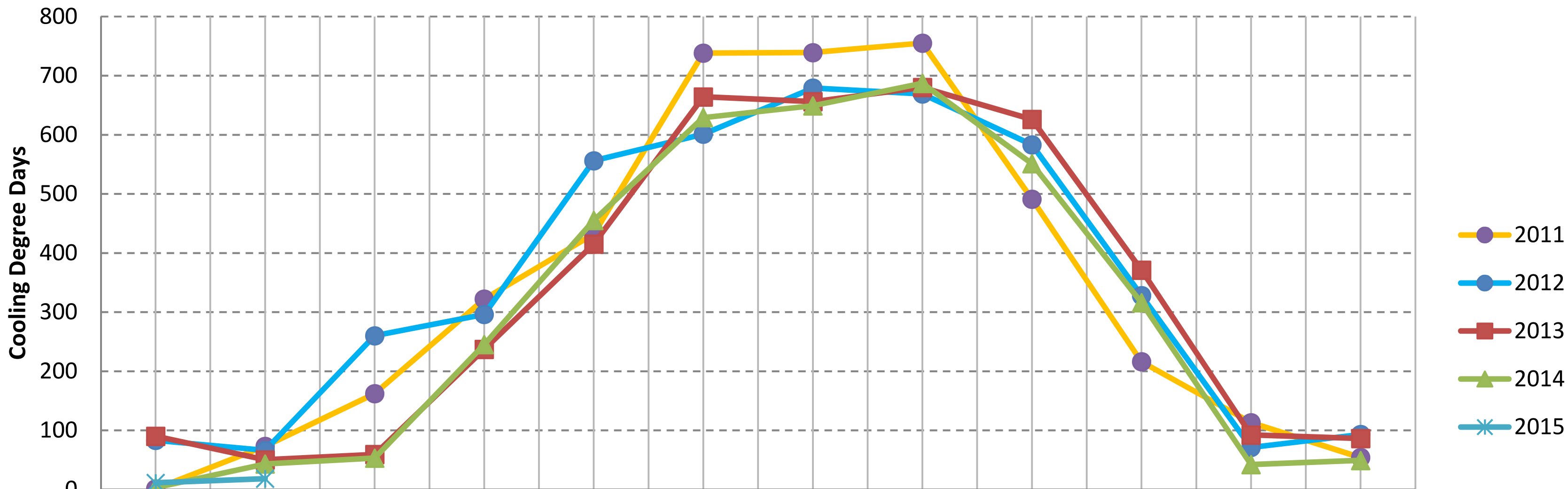
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2011	330	205	45	6	0	0	0	0	0	22	88	152
2012	143	102	7	0	0	0	0	0	0	10	79	146
2013	133	109	145	2	1	0	0	0	0	0	103	183
2014	429	149	97	8	0	0	0	0	0	0	193	153
2015	277	292										

Did the Weather Help or Hurt the Savings?

This project did not have contract stipulated utility measurement and verification… the M&V that was done was for the purposes of assisting the Owner's facilities personnel obtain funding for similar projects.

BUT… since you asked, here is a Calendar Year CDD Comparison Chart:

Previous Year Degree Day Comparison - Cooling Degree Days (60F BP)

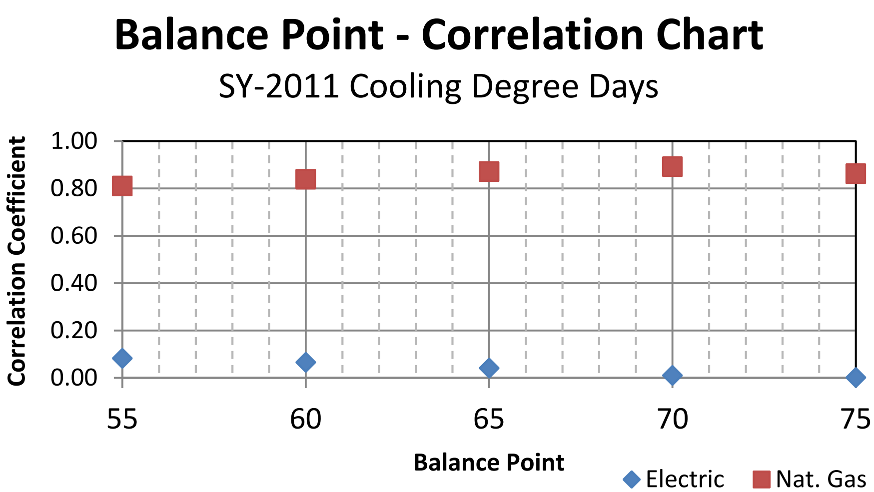


	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2011	1	73	162	322	432	738	739	755	491	216	113	54
2012	83	66	260	296	556	601	679	669	583	328	71	93
2013	90	50	59	237	415	664	656	680	626	371	92	86
2014	3	43	53	245	455	629	649	687	551	316	42	49
2015	11	18										

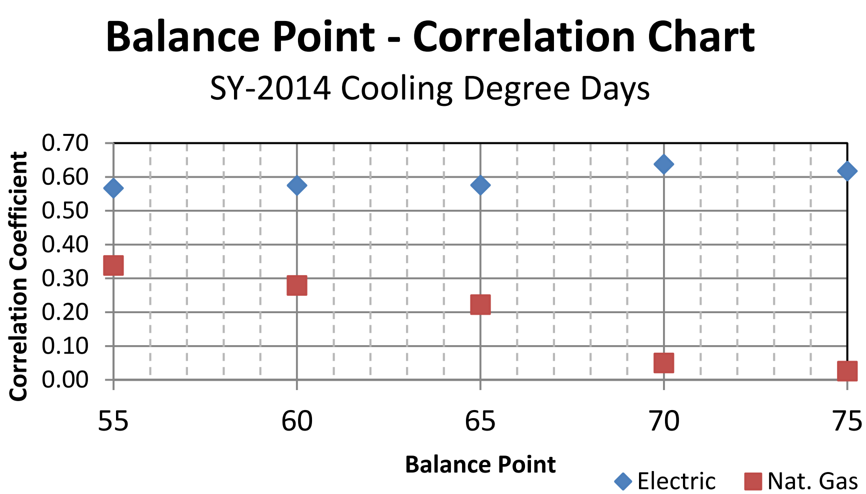
Revisit the Weather Correlation Analysis

After completing the project we revisit our original weather to consumption correlation to see the impact of the project on the building consumption characteristics.

Regression Balance Point Analysis of Electric, SY-2011 compare to SY-2014:



BEFORE….



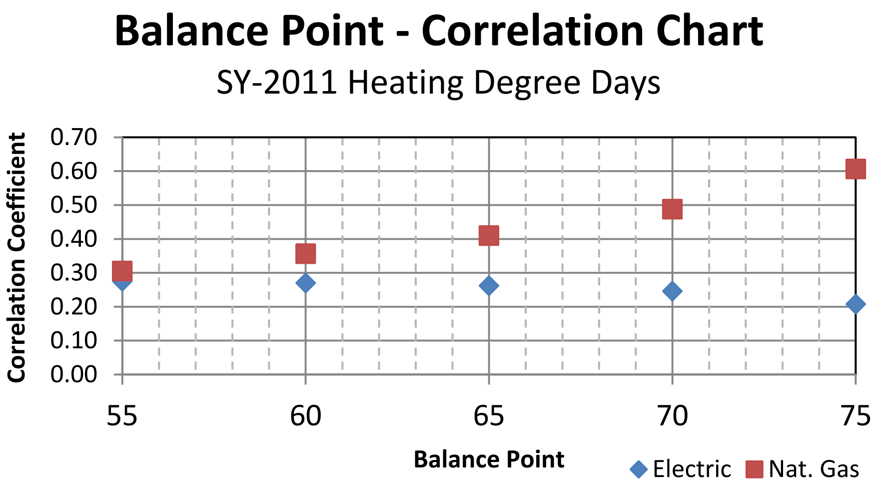
AFTER….

We see a completely different statistical relationship… Electric consumption now has a significant correlation with CDD and Natural Gas consumption does not!

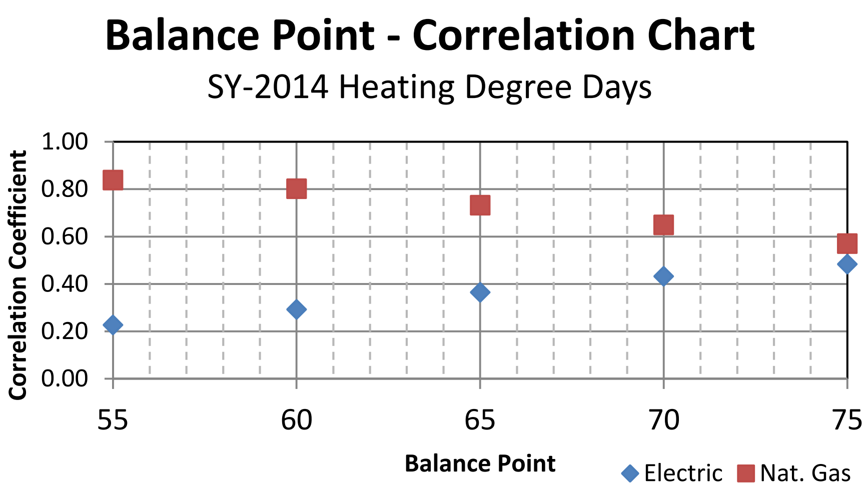
Revisit the Weather Correlation Analysis

After completing the project we revisit our original weather to consumption correlation to see the impact of the project on the building consumption characteristics.

Regression Balance Point Analysis of Electric and Natural Gas for SY-2011:



BEFORE....



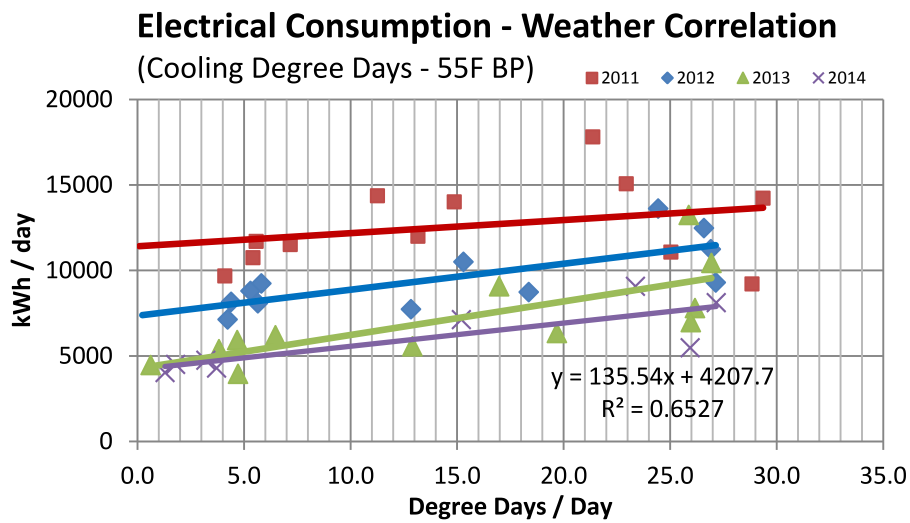
AFTER....

Gas consumption now is very well correlated to HDD and the optimum balance point is at or below 55F as it should be!

Revisit the Weather Correlation Analysis

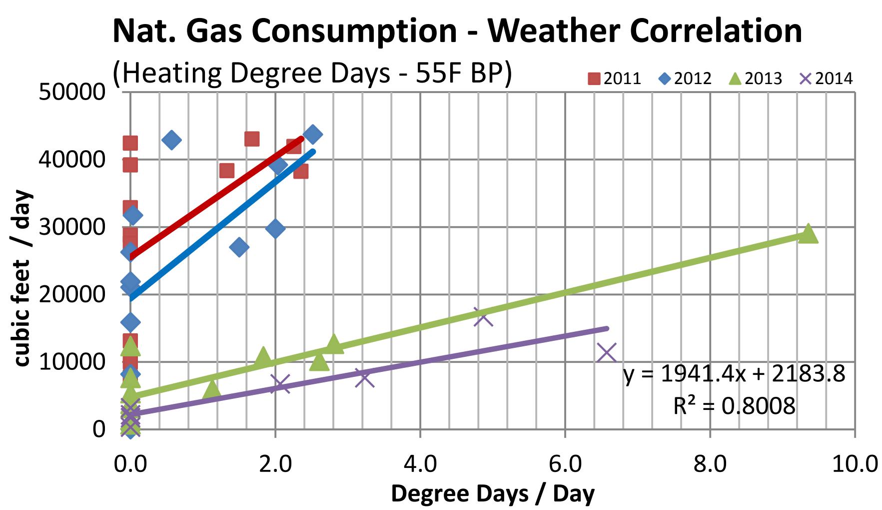
After completing the project we revisit our original weather to consumption correlation to see the impact of the project on the building consumption characteristics.

Regression Chart Analysis of Electric and Natural Gas for SY-2011 through SY-2014:



SY-2011:
Daily Consumption: 11,410 kWh / day
Correlation: 0.083

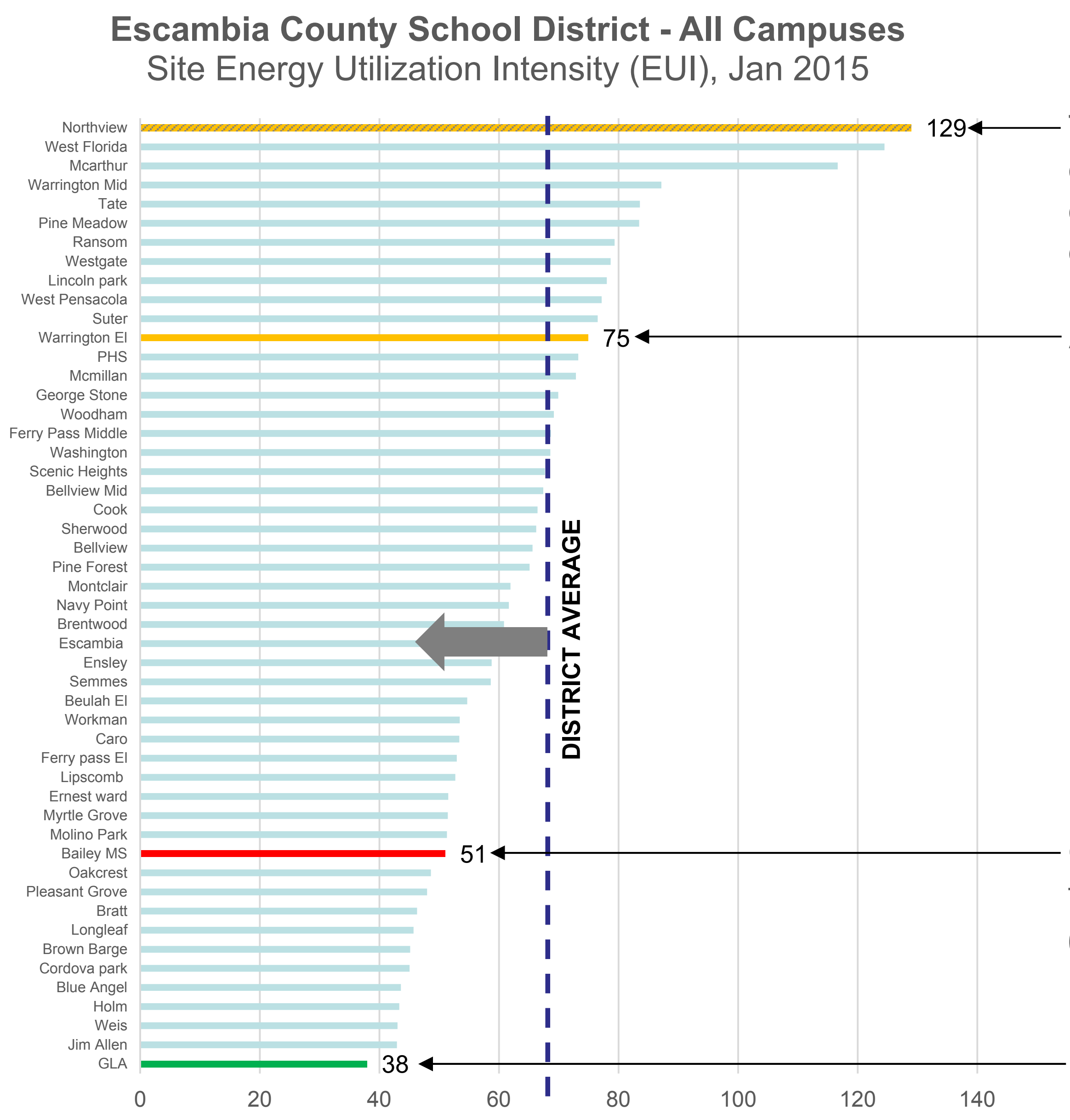
SY-2014:
Daily Consumption: 4,208 kWh / day
Correlation: 0.65



SY-2011:
Daily Consumption: 7,441 cf / day
Correlation: 0.31

SY-2014:
Daily Consumption: 2,184 cf / day
Correlation: 0.80

Project Results – Revisit Campus Portfolio



This summer's NEXT big focus campus… HVAC Replacement, campus Cx, monitoring coming…

Another project campus that is in the middle of EBCx and is using AFDD / monitoring… ***(35% EUI Reduction)***

Get in line – you're next!!!

Campus EUI as of two years following decision to do EBCx project ***(68% EUI Reduction)***

Newer school that started using On-Going Cx / Monitoring, **19% EUI Reduction in two years**

CONTINUING EDUCATION AIA®

Questions / Comments / Discussion

Lessons Learned / Results of Case Study:

- ✓ Always Commission every project no matter how simple it may seem
- ✓ Limiting the scope of Commissioning will limit the benefits of Commissioning
- ✓ Treat equipment replacement projects as “Energy Projects” – just replacing equipment will not necessarily reduce energy consumption
- ✓ ‘Optimization’ routines must be thought through well and monitored so that they don’t become ‘stuck’ at one extreme of the logic loop
- ✓ Even buildings perceived as having ‘poor envelopes’ can be decent performing buildings – don’t make excuses for your buildings!
- ✓ Incorporate building-level (at minimum) metering of components contributable to the building EUI… even better, sub-metering of end-uses!
- ✓ If performance is not monitored as part of the functional testing then we are ‘leaving money on the table’
- ✓ Performance will degrade over time, you must find a solution that will allow for continuous and consistent monitoring
- ✓ Ensure that your On-Going Commissioning solution has a defined path for resolving found issues – finding them is only half the battle

Thanks for your time!!!

This concludes The American Institute of Architects Continuing Education Systems Course

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