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Pathian Incorporated

PEDCO FIFTH ANNUAL High Performance BUILDINGS SEMINAR

USING ENERGY ANALYTICS TO IDENTIFY AND QUANTIFY ENERGY SAVING OPPORTUNITIES

Presented by: Daniel Buchanan, President and Founder of Pathian Incorporated

Discussion topics:

- Brief introduction to Pathian and what we do
- Introduce the US Patents we use to identify energy saving opportunities with real-time analytics
- We will explain how our Virtual Energy Audit (VEA) solution is applied to:
  - Generate HVAC equipment performance profiles and variance reports
  - How we can use these performance curves to describe HVAC Control Sequences of Operation in perfect detail
  - How Global Energy Efficiency Standards (GEES) are used to identify energy saving opportunities
- Case Study: VV Central Chilled Water Plant VEA
  - Show how we can use pictures (i.e. curves) to identify energy saving opportunities

Who is Pathian?

- Engineering and SaaS Energy Analytics Company
  - Typically we partner with your local engineering companies and HVAC control system manufactures to provide advanced energy analytic solutions to their customer base
  - PEDCO is one of our Authorized Representatives

What we do

- We use real-time analytics, in the form of Virtual Energy Audit to identify and quantify energy saving opportunities

- Primary focus of our analytics is optimizing large complex HVAC mechanical systems with emphasis in healthcare space and commercial buildings over 100,000 sq ft in size

- Typically we setup analytics and our Authorized Representatives use our real-time tools and reports to make energy savings recommendations:
  - These can be as simple as setpoint changes to large fully engineered energy savings projects

What we use

- We utilize two complementary US patents to help us identify energy saving opportunities:

  1) Pathian® Analysis: Energy analytic process that solves weather normalization errors in energy benchmarking systems

  2) POBPC: Collection of Best Practice operational methods that forces large complex mechanical system to work as one large machine. Typical energy reduction of 20% or more are achieved by this process

- One is an Energy Conservation Measure (ECM) and the other an analytic tool used to identify energy saving opportunities

Our results (locally in healthcare)

Building	Area, SF	Baseline year	Electricity		Natural Gas		Annual Cost Savings, $/yr	Annual Cost Savings, $/sf
			Annual reduction* kWh/yr	%	Annual reduction* MCF/yr	%		
Hospital 1	1,259,501	2005	13,020,000	37%	67,900	42%	$1,380,000	$1.10
Hospital 2	907,635	2007	6,650,000	23%	38,400	25%	$657,500	$0.72
Hospital 3	389,900	2010	2,635,000	22%	6,957	14%	$246,000	$0.63
Hospital 4	937,600	2010	4,915,000	17%	15,447	12%	$470,464	$0.50
Hospital 5	368,800	2010	1,934,772	14%	4,868	10%	$180,000	$0.49
Hospital 6	659,809	2010	1,910,536	13%	19,749	29%	$252,000	$0.38
	4,523,245		**31,065,308**		**153,321**		**$3,185,964**	**$0.70**

- Variances shown represent annual savings of electric and natural gas consumption in 2015 as compared to baseline year shown

Same healthcare network

Total Annual Saving **$2,507,964**

Pathian® Curve Overview

A Pathian® Curve represents *the instantaneous average energy demand, flow, temperature, pressure, position, status or other calculated operating characteristic (i.e. KW/Ton, etc.) of an energy systems overall outside air conditions.*

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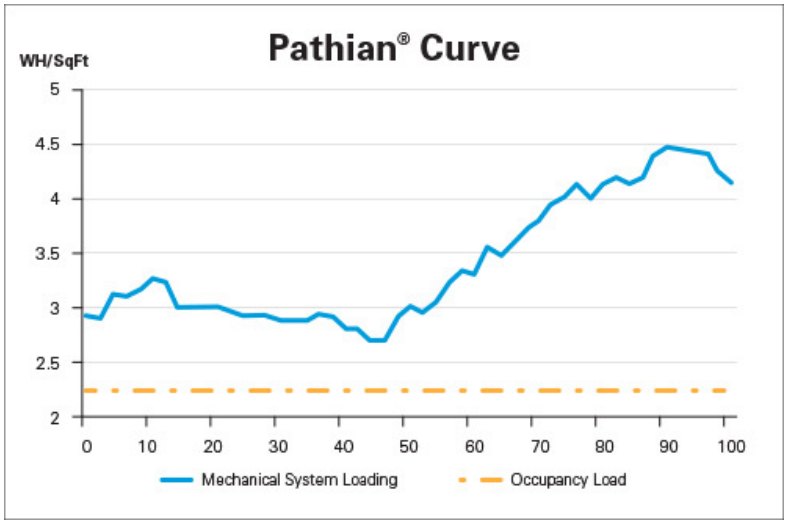

Key differentiators:

- The benchmarking technique creates perfect pictures of how energy systems perform over all weather conditions.
- They are indifferent to geographical locations and calendar time periods
- We can create performance indices that apply globally for buildings and HVAC mechanical systems

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Virtual Energy Audit (VEA) Summary Page

- Real-time VEA usually begins with a review equipment variance summary page
- They list the greatest YTD $ variance in descending order

Equipment variance

Equipment	Benchmark	Current	Variance (%)	Variance ($) ▲	
CHILLER PLANT - PLANT SUMMARY	15,736.76 MMBtu	17,449.93 MMBtu	-10.9 %	($35,146)	Dashboard
CHILLER PLANT - CHILLER SUMMARY	12,611.83 MMBtu	13,699.07 MMBtu	-8.6 %	($22,305)	Dashboard
CHILLER PLANT - CHILLER - 4 (10C/D)	4,719.06 MMBtu	5,356.41 MMBtu	-13.5 %	($13,075)	Dashboard
CHILLER PLANT - CHILLER - 5 (10C/D)	3,772.43 MMBtu	4,146.85 MMBtu	-9.9 %	($7,681)	Dashboard
AC-02 AIR HANDLER UNIT-2	974.99 MMBtu	1,322.60 MMBtu	-35.7 %	($6,664)	Dashboard
CHILLER PLANT - PRIMARY CHW PUMP SUMMARY	722.14 MMBtu	1,041.65 MMBtu	-44.2 %	($6,555)	Dashboard
CHILLER PLANT - PRIMARY CHW PUMP - 8 (10C/D)	379.54 MMBtu	584.40 MMBtu	-54.0 %	($4,203)	Dashboard
CHILLER PLANT - COOLING TOWER SUMMARY	926.34 MMBtu	1,038.89 MMBtu	-12.1 %	($2,309)	Dashboard
CHILLER PLANT - CW PUMPS SUMMARY	1,435.61 MMBtu	1,533.80 MMBtu	-6.8 %	($2,014)	Dashboard
AC-33 AHU-2	342.72 MMBtu	419.52 MMBtu	-22.4 %	($1,575)	Dashboard
CHILLER PLANT - COOLING TOWER - 5	193.51 MMBtu	258.83 MMBtu	-33.8 %	($1,340)	Dashboard

1 2 3 4 5 1 - 10 of 48 items

Link to equip. management page

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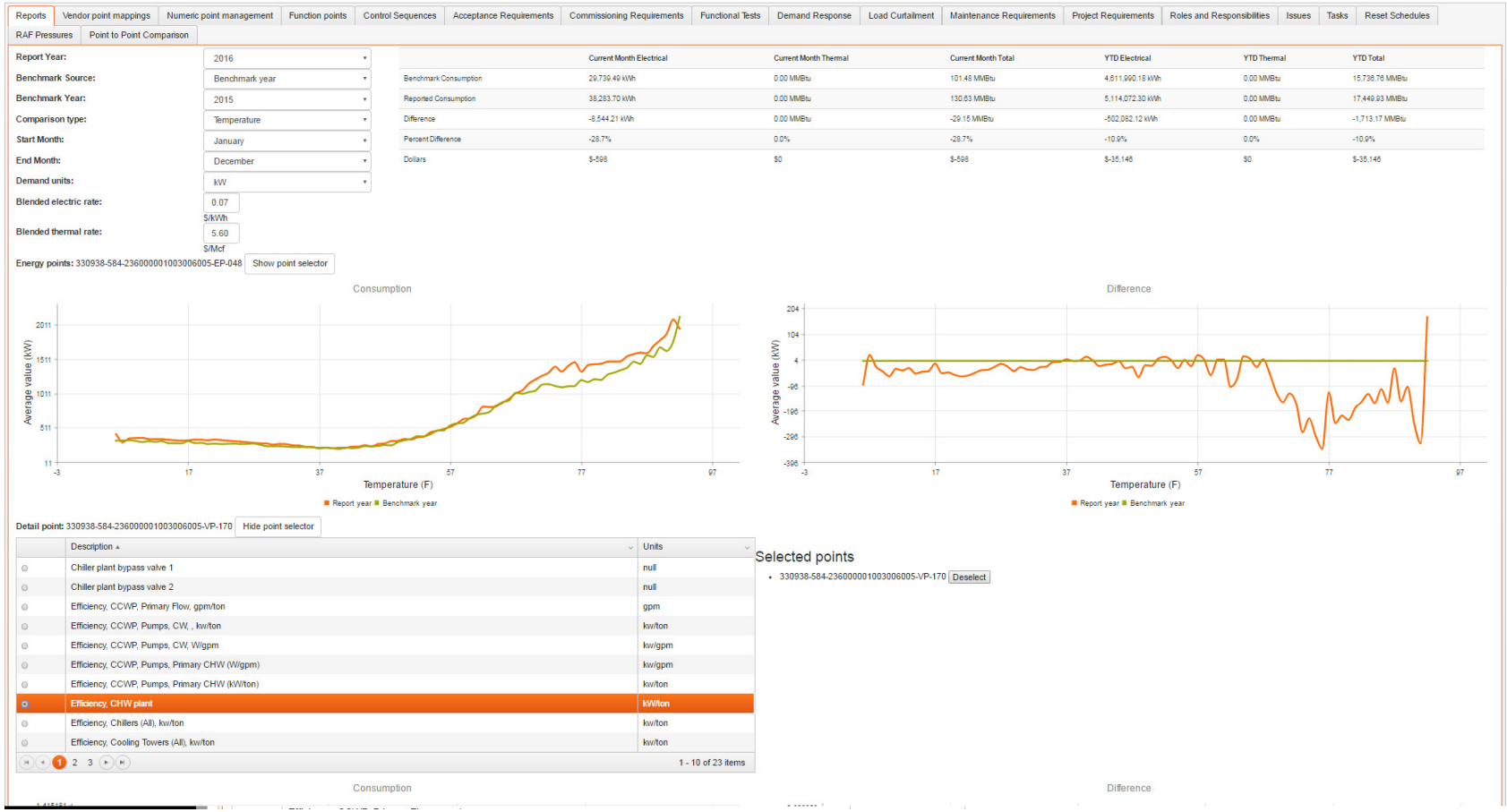
Central Plant Equipment Management Page

- On this page we can select either Energy or Detailed point performance curves
- The application then generates a performance profiles based on your selection



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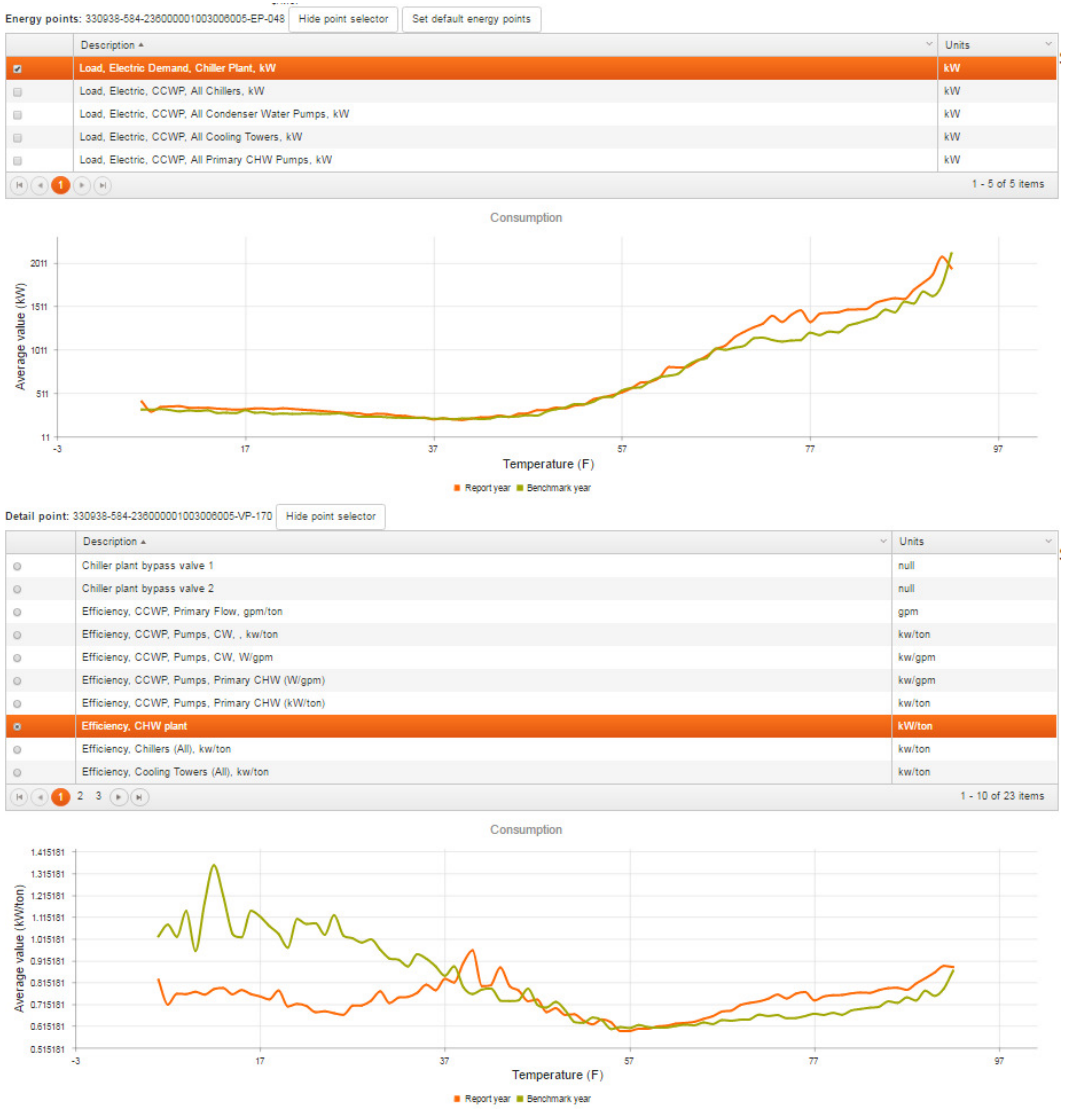
Energy Points vs Detailed Point

- Energy and Detailed points are pictures (i.e. curves) of performance over all OSA weather conditions
- Energy points are expressed in kWh or btu units and can assign a dollar value to variances
- Detailed point curves describe temperature, flow , pressure, status, position or calculated characteristic (i.e. KW/ton, etc.)



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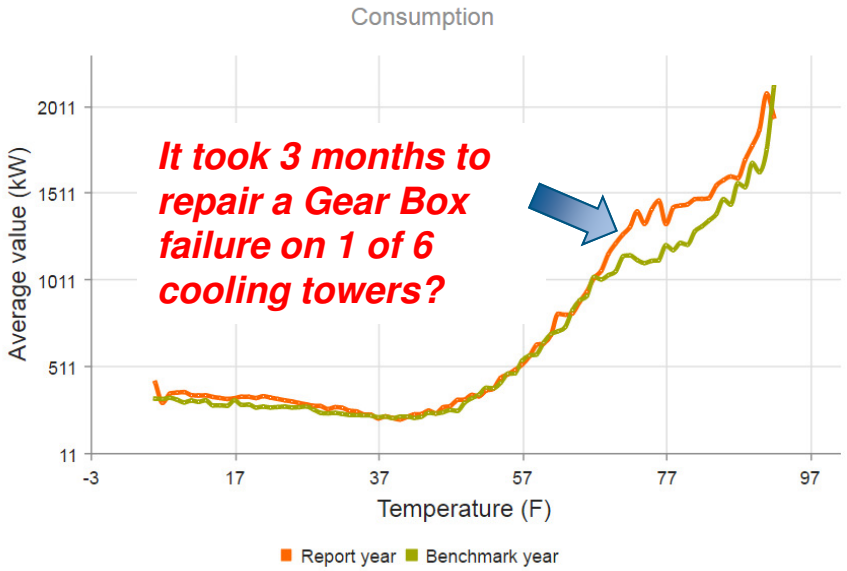
Energy Curve Pick List

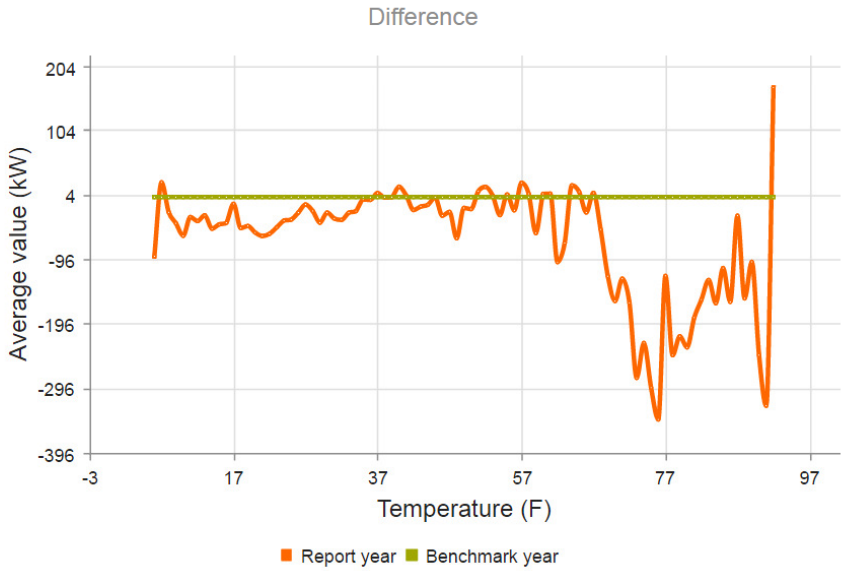
Load, Electric Demand, Chiller Plant, kW

Because it is an energy point we also calculate $$ values for the variance

	Current Month Electrical	Current Month Thermal	Current Month Total	YTD Electrical	YTD Thermal	YTD Total
Benchmark Consumption	29,739.49 kWh	0.00 MMBtu	101.48 MMBtu	4,611,990.18 kWh	0.00 MMBtu	15,736.76 MMBtu
Reported Consumption	38,283.70 kWh	0.00 MMBtu	130.63 MMBtu	5,114,072.30 kWh	0.00 MMBtu	17,449.93 MMBtu
Difference	-8,544.21 kWh	0.00 MMBtu	-29.15 MMBtu	-502,082.12 kWh	0.00 MMBtu	-1,713.17 MMBtu
Percent Difference	-28.7%	0.0%	-28.7%	-10.9%	0.0%	-10.9%
Dollars	$-598	$0	$-598	$-35,146	$0	$-35,146

1 - 5 of 5 items





Detailed Points

- Detailed point curves describe temperature, flow , pressure, status, position or calculated characteristic (i.e. KW/ton, etc.)

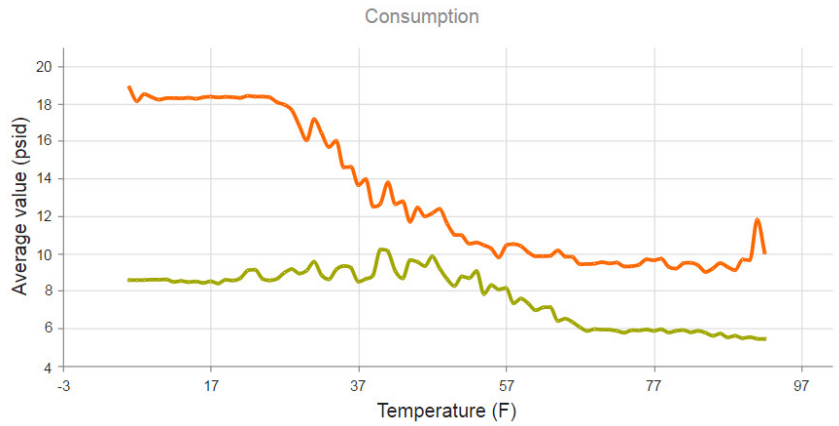
Detail point: 330938-584-236000001003006005-VP-076 Hide point selector

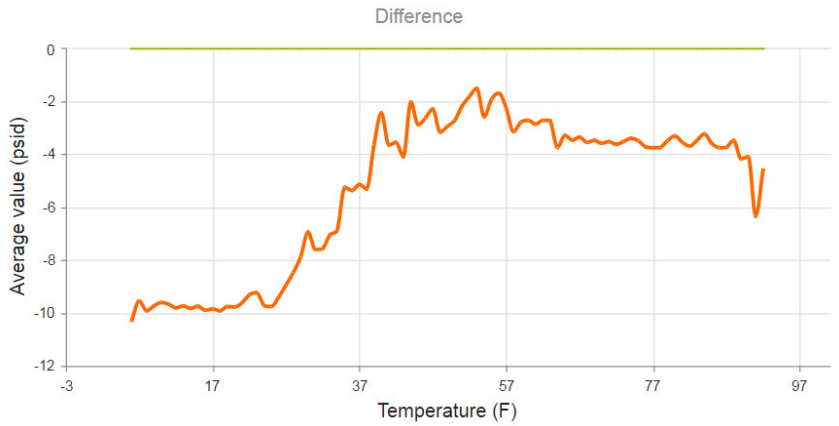
	Description ▲	Units
○	Flow, Chilled Water, Primary Total	gpm
○	Flow, Condenser Water, Total	gpm
○	Load, Electric Demand, Chiller Plant, kW	kW
○	Load, Electric, CCWP, All Chillers, kW	kW
○	Load, Electric, CCWP, All Condenser Water Pumps, kW	kW
○	Load, Electric, CCWP, All Cooling Towers, kW	kW
○	Load, Electric, CCWP, All Primary CHW Pumps, kW	kW
○	Load, Total Chiller Plant, tons	tons
◉	Pressure Differential, Water, System	psid
○	Pressure Differential, Water, System, fthd	fthd

1 2 3 11 - 20 of 23 items

Selected points

- 330938-584-236000001003006005-VP-076 Deselect





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Point to Point Comparisons

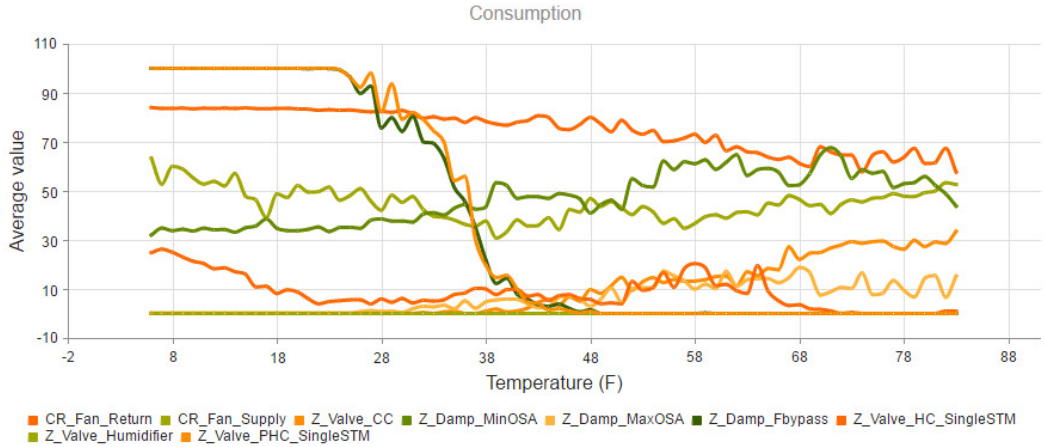
- We can display multiple Detail Points simultaneously to create a perfect picture of the HVAC Sequence of Operation of the equipment

Report Year: 2016
Benchmark Year: 2015
Comparison type: Temperature
Start Month: January
End Month: December
Show benchmark curves:
Export to pdf

Selected points: (Multiple points selected) Hide point selector

	Description	Units
☐	Humidity, Supply Air	%
☐	Load, Electric Demand, Fan - Return, kW	kW
☐	Load, Electric Demand, Fan - Supply, kW	kW
☐	Load, Sensible, PHC (Btu/hr)	Btu/hr
☐	Motor Power, Design, Fan - Return, kW	kw
☐	Motor Power, Design, Fan - Supply, kW	kw
☑	Position, Damper, F/B	
☑	Position, Damper, Max OSA	
☑	Position, Damper, Min OSA	
☑	Position, Valve, CC	

1 2 3 4 11 - 20 of 34 items



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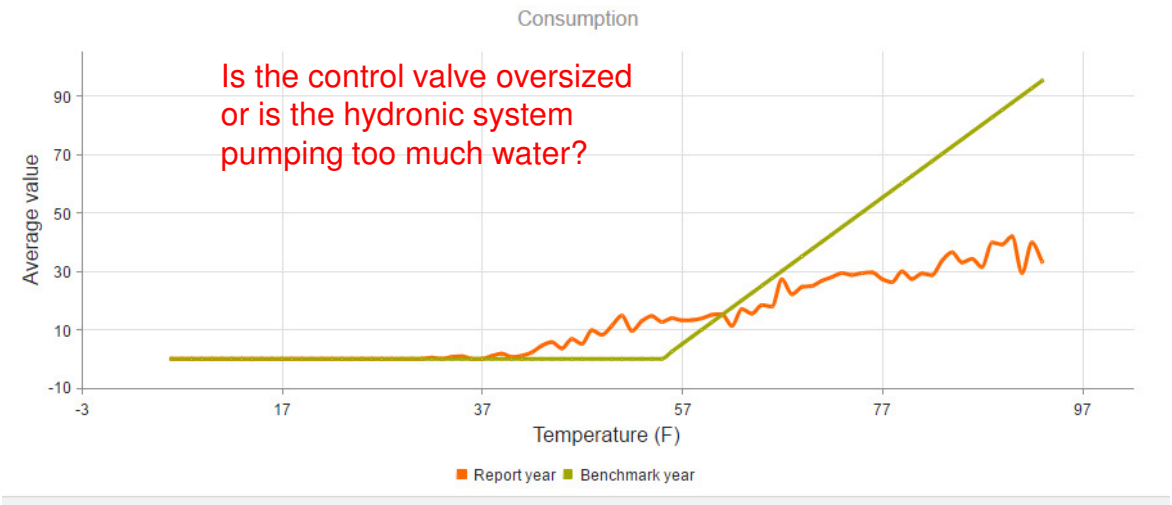
Best in Class Performance Standards Comparisons

- Best in Class Chilled Water Valve Comparison

Detail point: 330938-274-238216001001001-PP-012 Hide point selector

	Description ▲	Units
○	Humidity, Supply Air	%
○	Load, Electric Demand, Fan - Return, kW	kW
○	Load, Electric Demand, Fan - Supply, kW	kW
○	Load, Sensible, PHC (Btu/hr)	Btu/hr
○	Motor Power, Design, Fan - Return, kW	kw
○	Motor Power, Design, Fan - Supply, kW	kw
○	Position, Damper, F/B	
○	Position, Damper, Max OSA	
○	Position, Damper, Min OSA	
●	Position, Valve, CC	

1 2 3 4 11 - 20 of 34 items



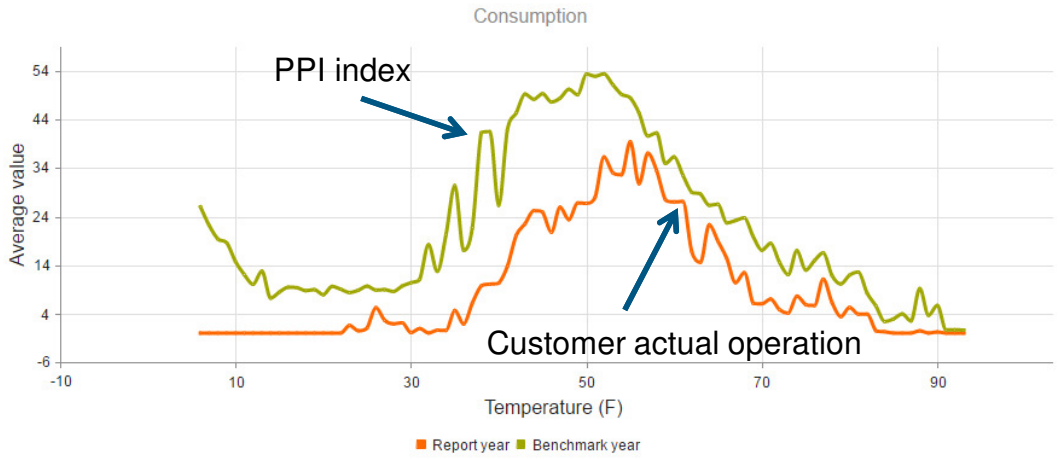
Pathian Performance Index (PPI)

- A PPI is the average measured performance of a peer group, in this case a average position of a air handler relief damper running POBPC

Detail point: 330938-190-233313.13003005005-PP-007 Hide point selector

	Description ▲	Units
○	Position, Damper, F/B	
○	Position, Damper, Max OSA	
○	Position, Damper, Min OSA	
●	Position, Damper, Relief Air	
○	Position, Damper, Return	
○	Position, Valve, CC	
○	Position, Valve, Humidifier Steam	
○	Position, Valve, PHC-HW	
○	Position, Valve, PHC-Single Steam	
○	Pressure, 2/3 SA Duct Static	in wc

1 2 3 4 5 21 - 30 of 43 items



Case Study – Healthcare Chilled Water Plant

2005

- 4 primary VV chillers w/ combined 4,600 tons of cooling capacity
- 2005 minimum winter chilled water load was 800 tons
- The hospital's Energy Star was 8
- In 2005 they installed two new variable volume 1,500 ton chillers whose minimum turn down was designed for 750 tons (1,400 gpm)

2016

- The hospital's Energy Star was 76
- Present minimum winter chilled water load is now 300 tons

Continuous Monitoring & Energy Analytics
Central Utility Plant Virtual Energy Audit (VEA)

Central Chilled Water Plant

Services Overview: Provide continuous performance monitoring and energy analytics for Central Chilled Water Plant (CCWP) data points available from the BMCS. Included are the following:

- Monitor Key Year-to-Year Comparison Metrics to proactively identify variance in system performance
- Compare CCWP performance to peer CCWP's to identify potential operational efficiency improvements
- Quantify YTD variances in energy consumption and costs due to changes in CCWP performance
- Automatically estimate potential energy savings based on peer CCWP PPI comparisons

We will give you pictures of this information

Key Year-to-Year Comparison Metrics			Pathian Performance Index (PPI) Comparisons		
#	Measured Point Description	Units	#	Measured Point Description	Units
1	CCWP Thermal Load	tons	1	CCWP Efficiency	kW/ton
2	CCWP Electric Load	kW	2	Total Chillers, Efficiency	kW/ton
3	CCWP Efficiency	kW/ton	3	Total Cooling Towers, Efficiency	kW/ton
4	Total Chillers, Efficiency	kW/ton	4	Total CHW Pumps, Efficiency	kW/ton
5	Total Cooling Towers, Efficiency	kW/ton	5	Total CW Pumps, Efficiency	kW/ton
6	Total CHW Pumps, Efficiency	kW/ton	6	Temperature, Secondary CHWS	F
7	Total CW Pumps, Efficiency	kW/ton	7	Temperature, Main CWS	F
8	Temperature, Secondary CHWS	F	8	Differential Pressure, CHW System	psid
9	Temperature, Main CWS	F			
10	Differential Pressure, CHW System	psid			

If you give us this information

Preferred Data Requirements - CCWP					
#	Measured Point Description	Units	#	Measured Point Description	Units
1	CCWP Thermal Load	tons	12	Primary CHW Flow	gpm
2	CCWP Electric Load	kW	13	Secondary CHW Flow	gpm
3	Chillers, Total Electric Load	kW	14	Condenser Water Flow	gpm
4	Cooling Towers, Total Electric Load	kW	15	Temperature, Primary CHWS	F
5	CHW Pumps, Total Electric Load	kW	16	Temperature, Primary CHWR	F
6	CW Pumps, Total Electric Load	kW	17	Temperature, Secondary CHWS	F
7	CHW Plant, Efficiency	kW/ton	18	Temperature, Secondary CHWR	F
8	Total Chillers, Efficiency	kW/ton	19	Temperature, Main CWS	F
9	Total Cooling Towers, Efficiency	kW/ton	20	Temperature, Main CWR	F
10	Total CHW Pumps, Efficiency	kW/ton	21	Differential Pressure, CHW System	psid
11	Total CW Pumps, Efficiency	kW/ton	22	CCWP Status	0; 1 (on)

Metrics Displayed in Central Plant VEA Report

- We make three different types of comparisons

Pictures

Performance Variances Comparisons

Performance Index Comparisons

Report Metrics

Point Comparison Metrics		
#	Measured Point Description	Units
1	Plant Efficiency Metrics, kw/ton	kw/ton
2	Plant Efficiency Metrics, W/gpm	kw/gpm
3	Plant Efficiency Metrics, gpm/ton	gpm
4	Temperature Metrics	F
5	CHW System Differential Pressure Metrics	psid

Key Year-to-Year Comparison Metrics		
#	Measured Point Description	Units
1	Thermal Loads, CHW Plant	tons
2	Efficiency, Total Plant	kw/ton
2	Electric Loads, CHW Plant	kW
3	Efficiency, Total Chillers	kw/ton
4	Efficiency, Total Cooling Towers	kw/ton
5	Efficiency, Total Primary CHW Pumps	kw/ton
6	Efficiency, Total Secondary CHW Pumps	kw/ton
7	Efficiency, Total CW Pumps	kw/ton
8	Efficiency, Flow	gpm
9	Temperature Report, CHW/CW	F
10	CHW System Differential Pressure	psid

PPI/BIC Comparison Metrics		
#	Measured Point Description	Units
1	Efficiency, Total Plant	kw/ton
2	Efficiency, Total Chillers	kw/ton
3	Efficiency, Total Cooling Towers	kw/ton
4	Efficiency, Total CHW Pumps	kw/ton
5	Efficiency, Total CW Pumps	kw/ton
6	Temperature Report, CHW/CW	F
7	CHW System Differential Pressure	psid

Pictures

These pictures perfectly describe the oversized Chilled Water Plants performance:

- We can see the plant efficiencies for all central plant equipment over all operating loads

- Where does the over sized plant start to become inefficient?

Around 60 DegF when the CHW bypass valve begins to open

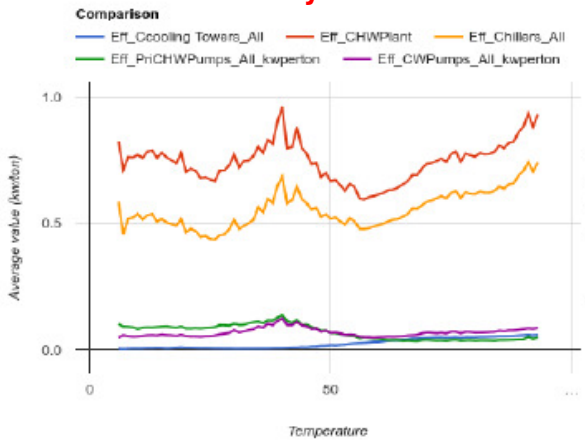
- At what OSA temperature do they stop the lag chiller in the winter?

Around 45 DegF: this reduces minimum chilled water flow from 2,800 gpm to 1,400 gpm

Point Comparison Metrics

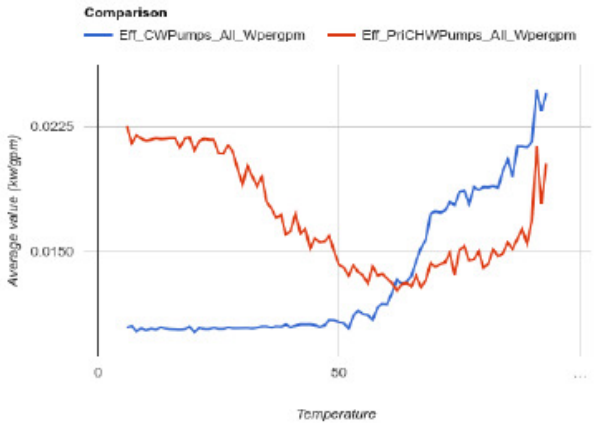
#1 Plant Efficiency Metrics, kw/ton (kw/ton)

Plant Efficiency



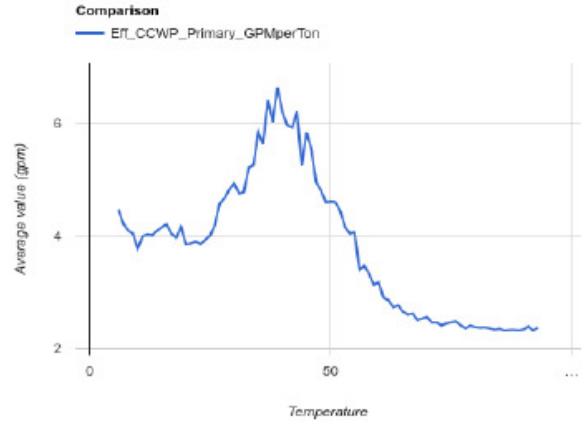
#2 Plant Efficiency Metrics, W/gpm (kw/gpm)

Watts per gpm pumping performances



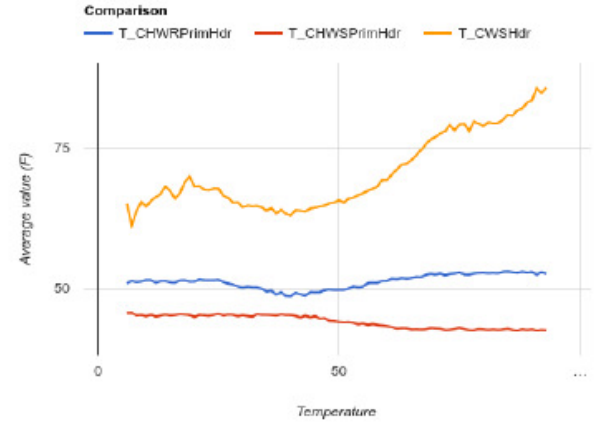
#3 Plant Efficiency Metrics, gpm/ton (gpm)

Efficiency in gpm/ton



#4 Temperature Metrics (F)

Pictures of our temperature profiles

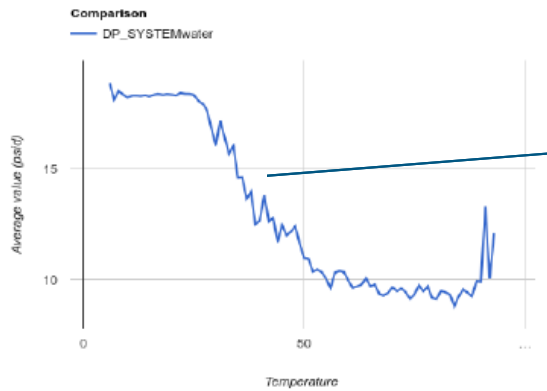


Indexing Performance

- **How pictures and indices work together to pinpoint performance issues**

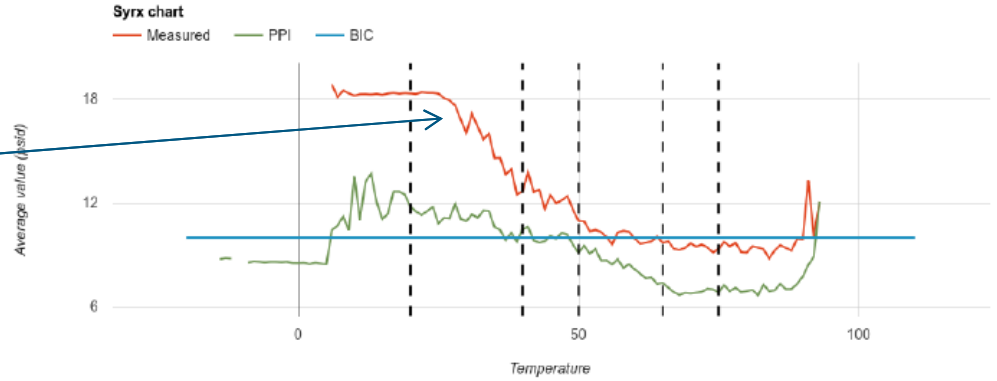
Picture of CHW Hydronic Loop Setpoint

#5 CHW System Differential Pressure Metrics (psid)



Peer Group PPI and BIC indices for VV CHW system pressures

#7 CHW System Differential Pressure (psid)



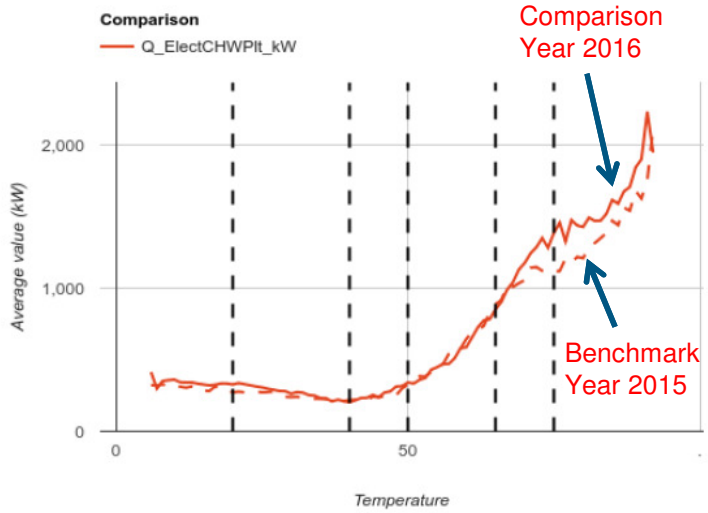
- Issue: In January, the chilled water differential setpoint was mistakenly changed from 10 to 22 psid
- This cost the hospital $56 K per month as a result of additional pumping energy and needless reheating caused by over pressurization
- We identified this problem 30 days before their utility bill were issued

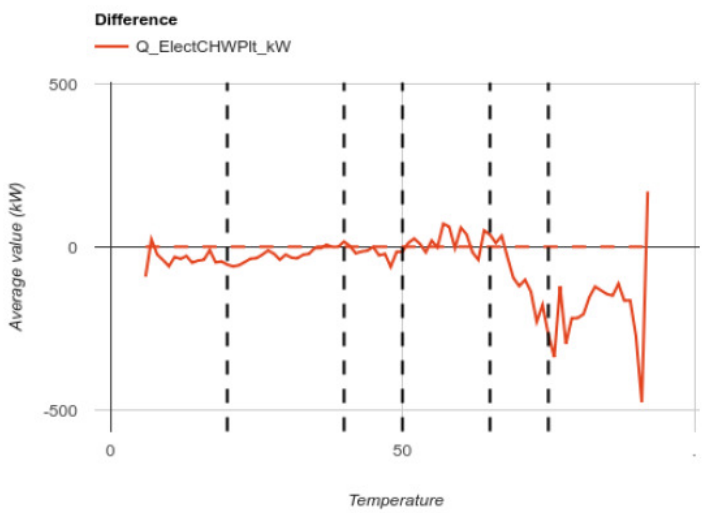
Stage divisions expressed in degrees F All values are hourly averages	Low-Temp Heating < 20	Stage-2 Heating 20 - 40	Stage-1 Heating 40 - 50	Free Cooling 50 - 65	Mech-Cool Stage-1 65 - 75	Mech-Cool Stage-2 > 75	All
Measured	18.34	16.56	12.41	10.19	9.488	9.811	13.02
PPI	10.04	11.08	10.05	8.475	6.937	7.500	9.267
PPI Deviation	-8.300	-5.480	-2.360	-1.718	-2.551	-2.311	-3.758
PPI Deviation (%)	-82.67%	-49.47%	-23.47%	-20.27%	-36.77%	-30.82%	-40.55%
BIC	10.00	10.00	10.00	10.00	10.00	10.00	10.00
BIC Deviation	-8.340	-6.556	-2.412	-0.193	0.512	0.189	-3.025
BIC Deviation (%)	-83.40%	-65.56%	-24.12%	-1.93%	5.12%	1.89%	-30.25%

Variance Metrics

Key Year-to-Year Comparison Metrics
Energy point comparison metrics

#2 Electric Loads, CHW Plant (kW)





Stage divisions expressed in degrees F All values are hourly averages		Low-Temp Heating < 20	Stage-2 Heating 20 - 40	Stage-1 Heating 40 - 50	Free Cooling 50 - 65	Mech-Cool Stage-1 65 - 75	Mech-Cool Stage-2 > 75	All
Q_ElectCHWPlt_kW	Reported	341.7	274.8	255.8	523.4	1,126	1,611	700.5
	Benchmark	304.3	248.5	240.5	540.0	1,045	1,422	641.1
	Difference	-37.33	-26.33	-15.29	16.62	-81.23	-188.9	-59.36
	Difference (%)	-12.27%	-10.60%	-6.36%	3.08%	-7.78%	-13.28%	-9.26%
	Difference ($)	-$2.61	-$1.84	-$1.07	$1.16	-$5.69	-$13	-$4.16

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Deployment Steps of Analytics

- Our SaaS analytics can be deployed by you're your preferred engineering or HVAC control system manufactures
- Our Authorized Representatives (AR) work with you to determine your exact needs and generate SaaS agreements between you and them
- AR gathers all field data and equipment information for product implementation via MS Excel predefined worksheets
- Pathian's contract is with your AR, we will completely setup the analytics, work with control contractors and your IT staff to install
- Your AR or other energy team members can use this tool to identify ECMs
- Typically we map 1,500 control points per one million sq ft of commercial building space
- Currently all major control system manufactures can post data to the Pathian Azure Cloud via standard CSV data drivers developed specifically for the purpose (i.e. Johnson, Siemens, Tridium and other third party devices)

Questions?

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