Big Data Analysis and M&V for Campus Utility System Optimization

By

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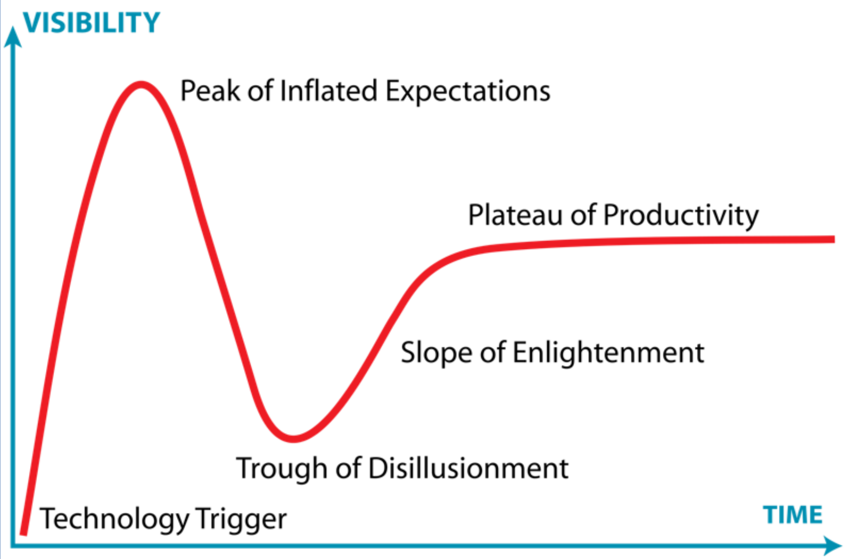
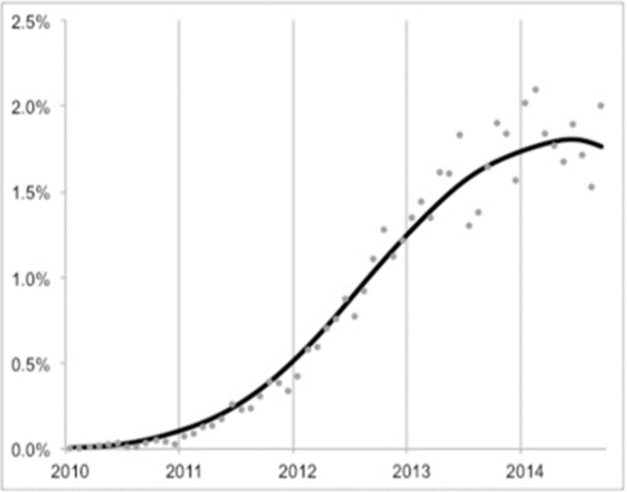
The Trend of "Big Data"

- The Signal and the Noise by Nate Silver
- New technologies follow a predicable curve



Gartner's "Hype Cycle"



Big Data Mentions in Corporate Press Releases

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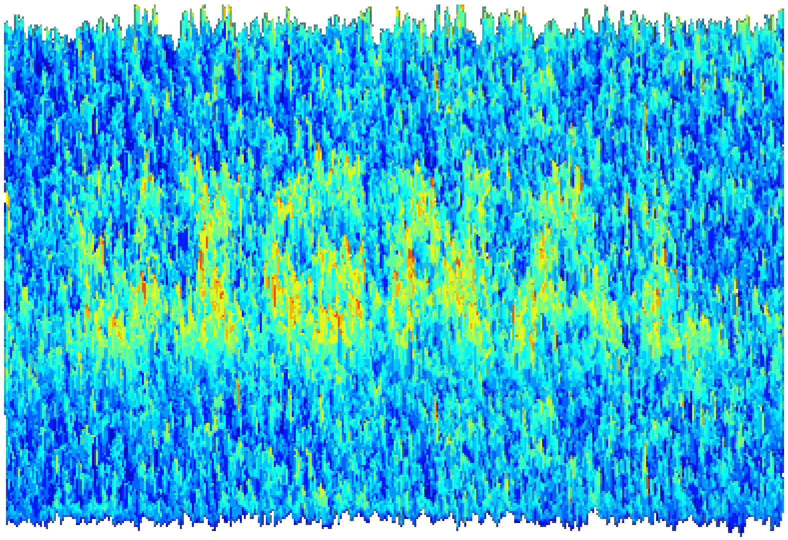
The Signal and the Noise

- Our buildings and plants have been producing big data for decades
- New trend is to draw meaningful conclusions (analytics)



- "Big Data" is about (in a practical sense for our industry):
  1. Internal use of data in our building and plant control systems- a.k.a.- optimal automatic systems control
  2. Data that can be extracted out of the system for analysis. This requires understanding what is "signal" and what is "noise"
- This presentation is about #2

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Extracting Data for Use

- Good news is that building and plant systems are capable of producing and storing vast amounts of data

- Challenge is that this process is not always painless
- There are tools that aim to do this that work on a license basis (Building analytical tools and Data Historians)

- This presentation is about what we see as the practical use of big data for all systems, independent of fee based tools

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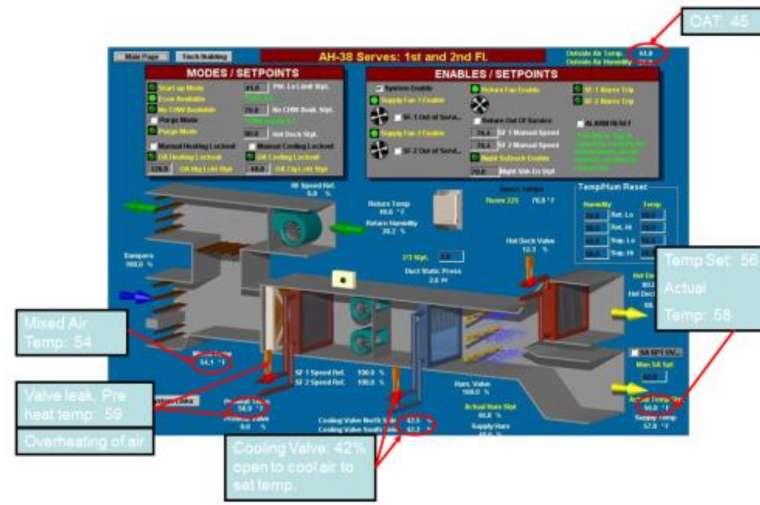
Practical Use of Big Data

- A lot of what Big Data shows can be seen from snapshot views of controls
  - Leaky valves and dampers
  - Mixing water streams
  - Poor economizer control



- Big Data can help quantify these
- An energy checklist might be able to yield similar savings
- All results must still be interpreted by humans (AI not yet there)
- Key to finding faults through controls is to do it on seasonal changes
- Our industry has fallen short in failing to make “Energy Alarms”

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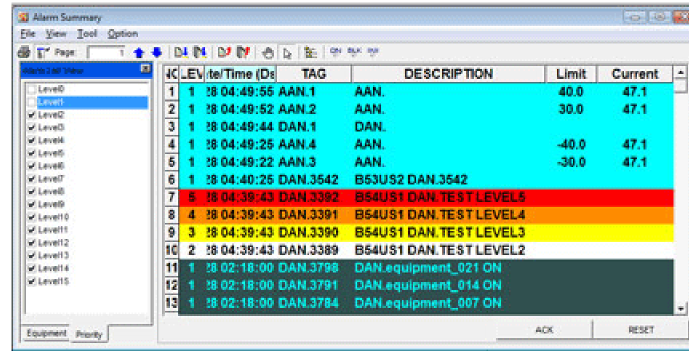
Energy Alarms



- Utilize existing programming structure to identify failures so that you do not have to extract data
  - Example "Energy Alarms"
    - If how water valve is closed and there is a temperature difference greater than 5 degF
    - If mixed air temperature does not match damper position request
    - If outside air dewpoint is less than 55, and supply air temperature is less than 56F
    - If occ sensor has not shown vacant for more than 36 hours
- Use automatic "operator override" reporting tools to eliminate operator overrides
- Implement operator override reporting tool

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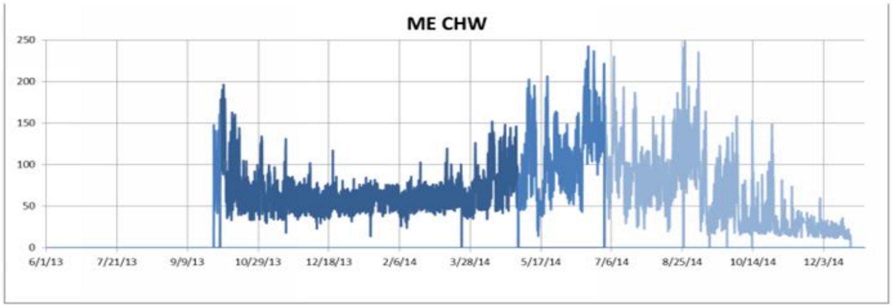
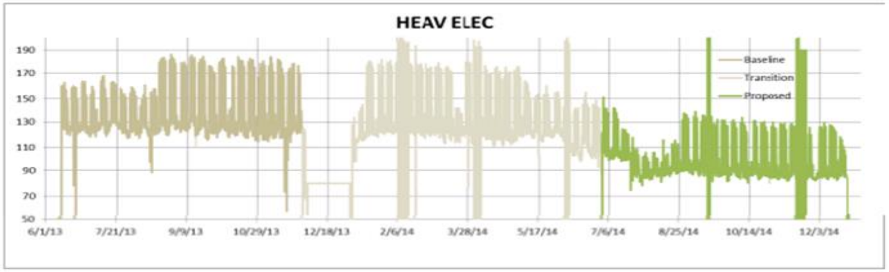
Practical Use of Big Data

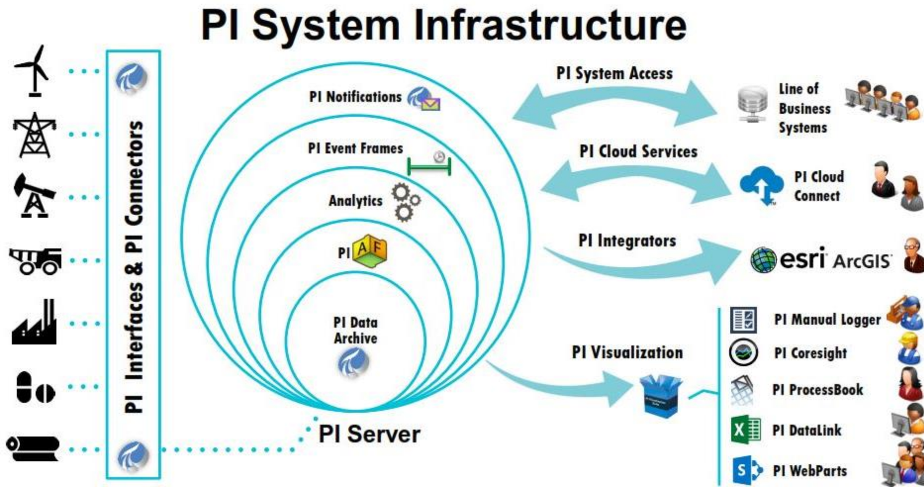
- Big Data is most useful to buildings and plants as a benchmarking and M&V tool
  - External Benchmarking- How does my building/plant compare to outside benchmarks?
  - Internal Benchmarking- How I prioritize energy efficient investments?
  - Project Accountability- How do I know my energy project was successful?

Practical Challenge: Aggregating Data

- Hourly Trends
  - One point per hour
- Bandwidth Limitations
  - Use change of value (COV) for optimization routines
  - Not as much a problem with Industrial Controls
- Commercial vs Industrial Controls
  - One of the major benefits of industrial/process PLC or DCS system is robust Data Historians (Pi Server)
  - Process trends with commercial is possible but cumbersome

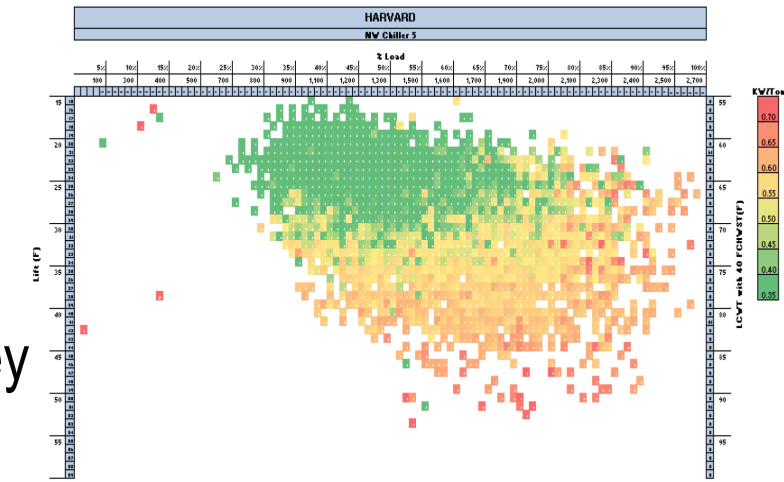


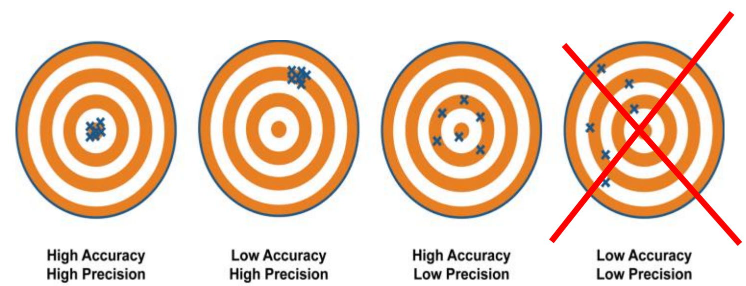




Is Data Accuracy Important?

- It depends, but mostly not as important as precision
- large data sets and multiple data points improve accuracy
- For M&V: consistency in data is key as is establishing correlation
- For performance mapping: sweet spots are determined based on the sensors available which are also controlled sensors
- For fault detection: accuracy can be important





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Is Data Accuracy Important?

- Sensor accuracy varies by device
- Overall accuracy includes:
  - Sensor accuracy
  - Transmitter accuracy
  - A/D conversion
  - Display resolution
  - Wire temperature effects (up to +/-0.8F)

Sensor Type	Standard	Special	Typical Range
Thermocouple Type K	+/- 4.0F	+/- 2.0F	-328F to 2282F
Thermocouple Type J	+/- 4.0F	+/- 2.0F	32F to 1382F
Thermocouple Type E	+/- 3.0F	+/- 1.8F	-328F to 1652F
Thermocouple Type T	+/- 1.8F	+/- 0.9F	-328F to 662F
Thermistor	Typical [1]: +/- 0.17 to 0.36	N/A	-20F to 300F
RTD	Typical [1]: +/- 0.17 to 0.36	N/A	-300F to 1000F

$$\text{Overall accuracy} = \sqrt{(A1^2 + A2^2 + A3^2....)}$$

- Example: CHW Flow meter
  - Temp sensor accuracy= +/- 0.35F
  - 8degF CHW DT (not uncommon for many campuses)
  - Total temperature error (supply and return) = sqrt(.35^2+.35^2+.8^2+.8^2)= +/-1.2F = +/-15%
    - At 5 degF DT= +/- 24%!
  - That is for out of the box overall accuracy of a high quality temp sensor
  - Temp sensors have higher impact on accuracy than flow meters
- Understand that there are inaccuracies, but that in general, the important part is most often the trend of these points

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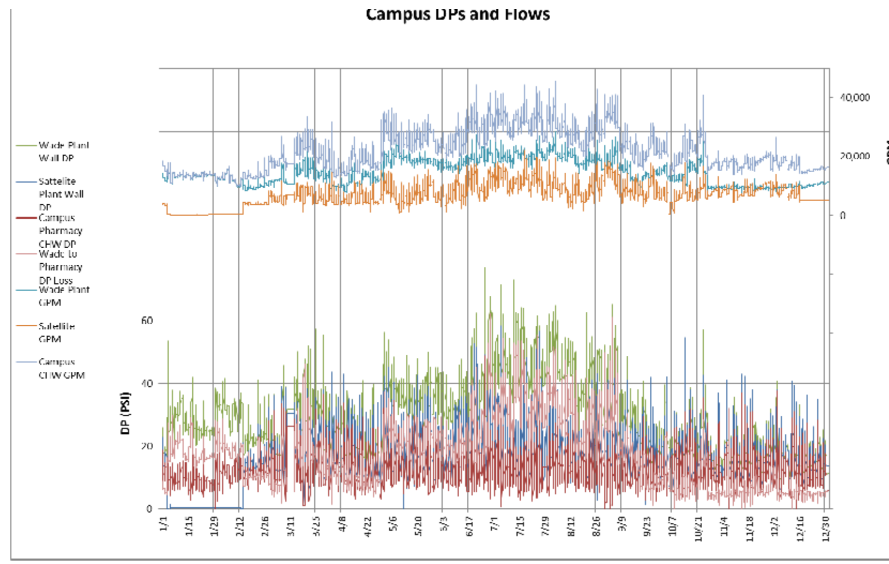
Deciphering, Filtering and Correlating

- Data is only useful if it can be correlated to another variable
  - Time, connected equipment, load, valve position, etc.
  - THE IMPORTANT PART OF DATA IS THE RELATIONSHIPS
  - “Structured Data”

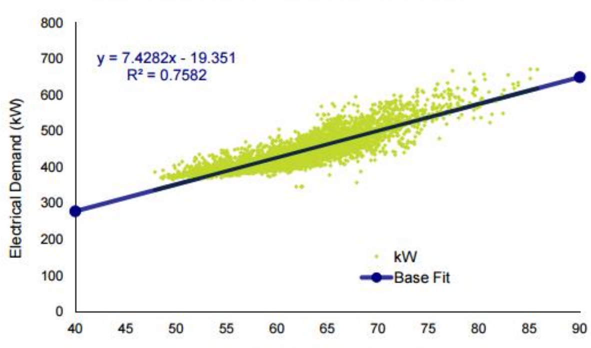


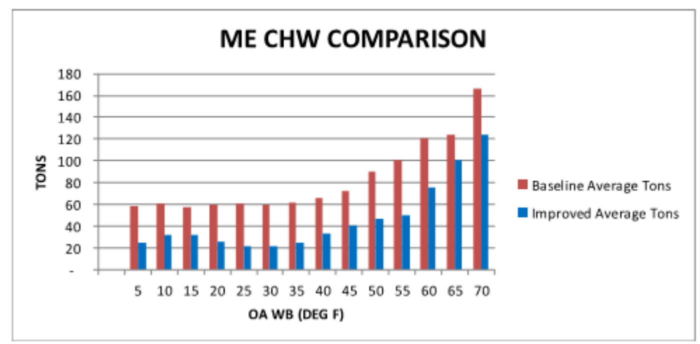
- Data Historians make correlations easy
- For commercial BAS systems, correlations are more difficult
- We use a “Data Smoother” excel spreadsheet to eliminate aberrations, align data to common time stamp
- Email me at jrundell@wmgroupeng.com for copy of spreadsheet

M&V Process

- Industry uses "regression analysis" for M&V (complicated)
- We normalize hourly for CHW on Wet Bulb, Heating on Dry Bulb, Electricity on based on Month
- Download our M&V Data Normalizer at www.wmgroupeng.com or email me at jrundell@wmgroupeng.com

Figure 4-1: Electrical Demand vs. Ambient Temperature

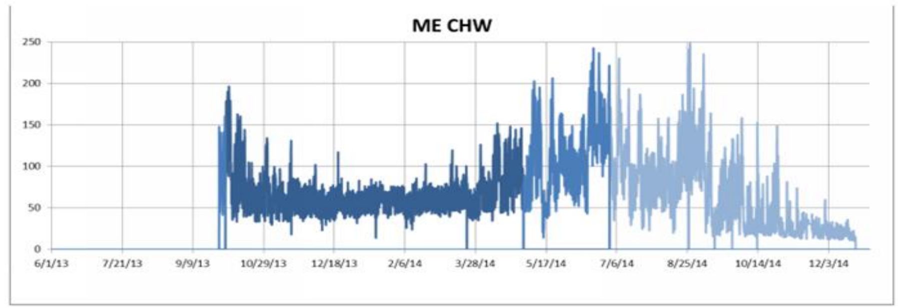


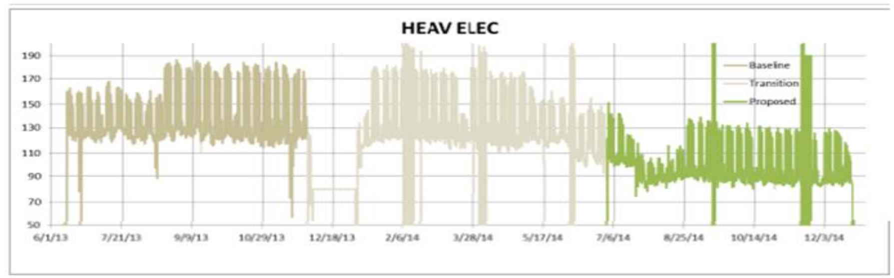


RESULTS	ME CHILLED WATER															
	OA WB Temp (DegF)															
		5	10	15	20	25	30	35	40	45	50	55	60	65	70	Total
Baseline Average Tons		58	61	58	60	60	60	62	66	72	90	101	121	124	166	**1,159**
Improved Average Tons		24	32	32	25	21	21.80	25	33	41	47	50	75	100	124	**651**
Average Savings Tons		34	29	26	35	39	38	37	33	32	43	51	46	23	42	**508**
Average Savings %		58%	47%	45%	58%	65%	64%	60%	50%	44%	48%	51%	38%	19%	25%	**44%**
Annual Hrs		991	992	993	994	995	996	997	998	999	1,000	1,001	1,002	1,003	1,004	**13,965**
Baseline Ton-Hrs		57,747	60,470	57,185	59,443	60,112	59,474	61,931	65,742	72,338	89,996	101,345	120,750	124,126	166,977	**1,157,638**
Improved Ton-Hrs		24,207	31,779	31,348	25,077	21,181	21,708	24,844	33,085	40,544	46,853	49,917	75,074	100,686	124,548	**650,851**
Savings Ton-Hrs		33,540	28,691	25,837	34,366	38,931	37,766	37,087	32,657	31,794	43,143	51,428	45,676	23,440	42,429	**506,787**
																44%

Benefits of M&V

- Every energy project should have some level of M&V
- M&V keeps the implementer “on the hook” for achieving savings
- Identify successes so they can be duplicated





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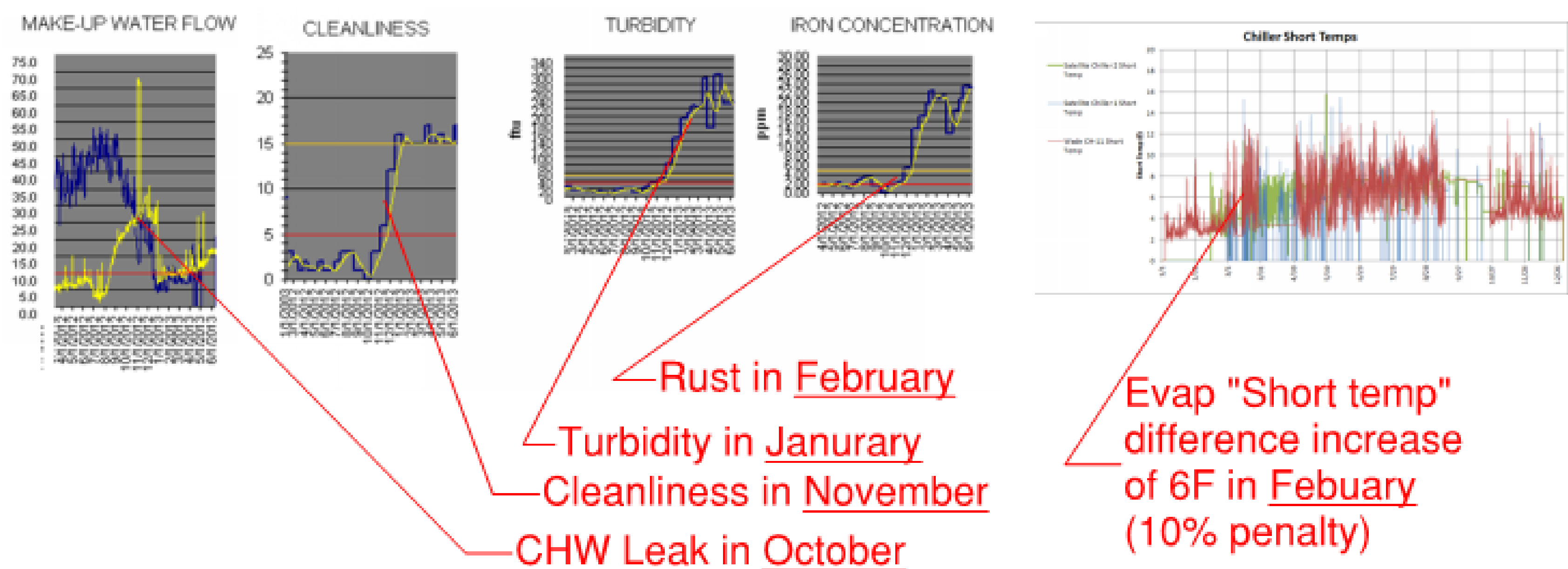
Examples of How to Save Millions with Big Data

- Purdue University
  - Water treatment and chiller short temp
  - Simultaneous heating and cooling
  - Reduction of 1MW by big data analysis on pumping pressue
- Harvard University
  - Training to plant operators
  - Changing operation of cooling towers
- Bristol Meyers Squibb
  - Optimization of air handling units
  - Correction of controls deficiencies

Purdue University- Water Treatment Savings

- High Short Temperature Difference
- Iron Concentration lagged make-up increase by 3 months (rust)
- Short temp increased 2 months later



- **>10% overall plant savings from diagnosis**

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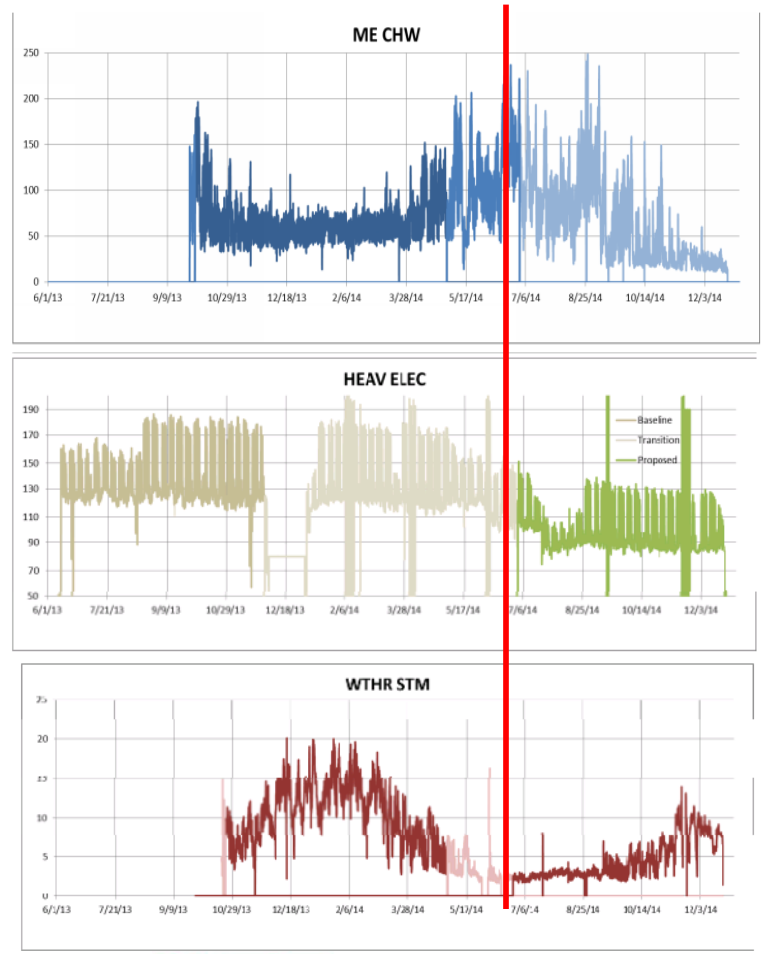
Purdue University- Air Side Savings

- Project Example:
  - Used trended data for 6 months
  - **35% reduction in CHW**
  - **21% reduction in Steam**
  - **14% reduction in electricity**
  - **2 year payback** (at $0.04/kwh)
  - Projected across campus (at $0.04/kwh)
  - $4m annual savings for full campus



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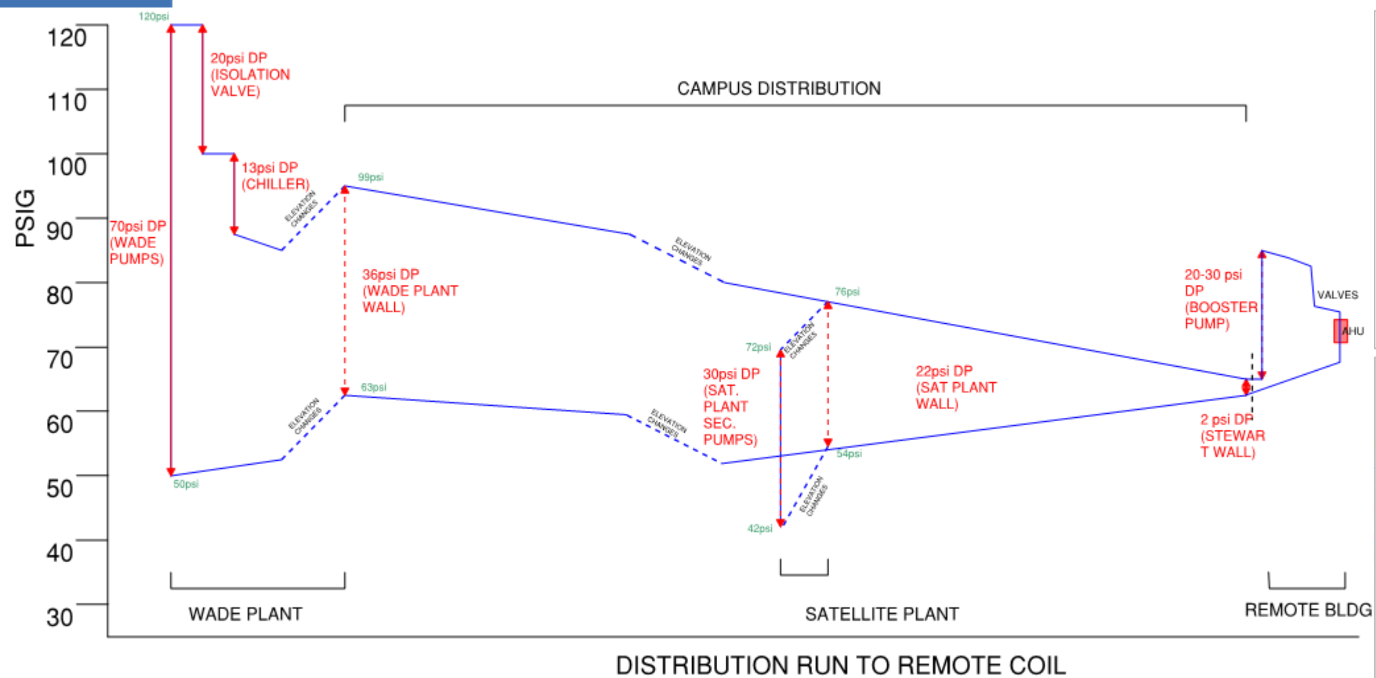
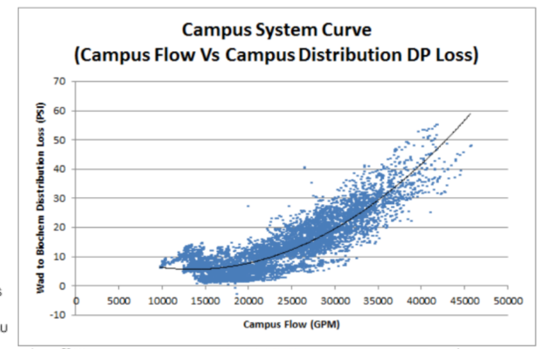
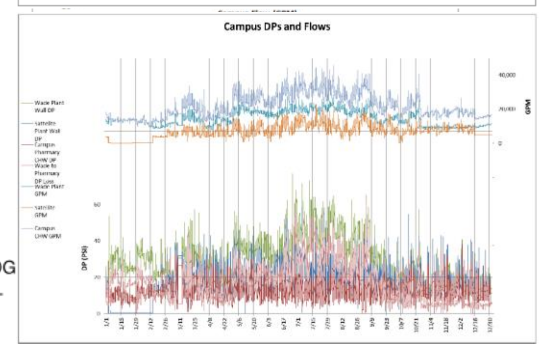
Purdue University- Pump Savings

- ~110 building pumps turned off
- ~1MW peak power savings







DISTRIBUTION RUN TO REMOTE COIL

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August 2013: Day One

Example Existing Plant

Example Chiller Plant:	10,000 Ton system
Average Energy Rate:	0.778 kW/ton
Average Generation Rate:	$0.12/kWh
Cost Per Hour:	$934/hr.

Equivalent Annual Rate:

$2,054,800/yr.

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August 2013: Day Two

First Operating Training

Example Chiller Plant: 10,000 Ton system

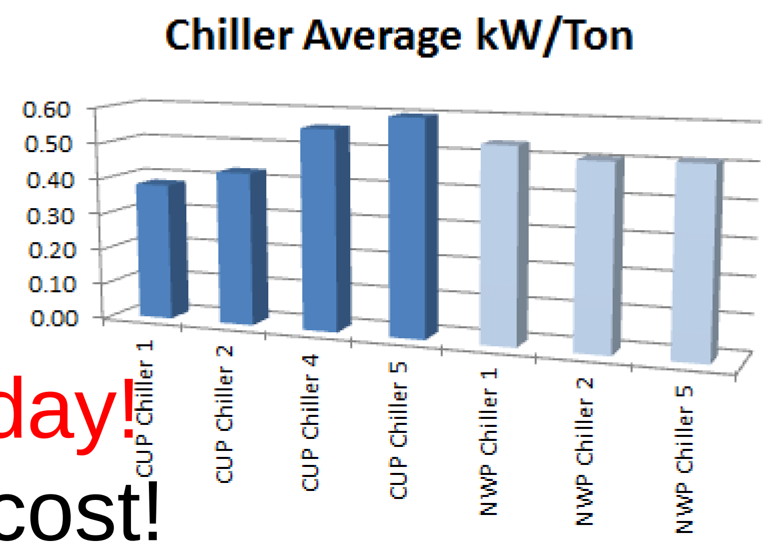
Average Energy Rate: 0.668 kW/ton

Average Generation Rate: $0.12/kWh

Cost Per Hour: $801/hr.

Equivalent Annual Rate:

$1,763,520/yr.



Savings: $291,280/yr.

14% Reduction in one day!

No Capital Investment cost!

Payback in Months

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Conclusions

- Big Data is going through a new technology hype curve but also has real current applications
- The current best uses of Big Data are for M&V and Benchmarking
- Exporting data for fault detection to third party analytics software is beneficial, but savings can also be accomplished through utilizing existing controls interface
- Industrial Controls and Data Historians make processing Big Data for M&V much easier
- Regardless of tools used, human interaction is still needed to separate the "signal" from the "noise"

Thank You

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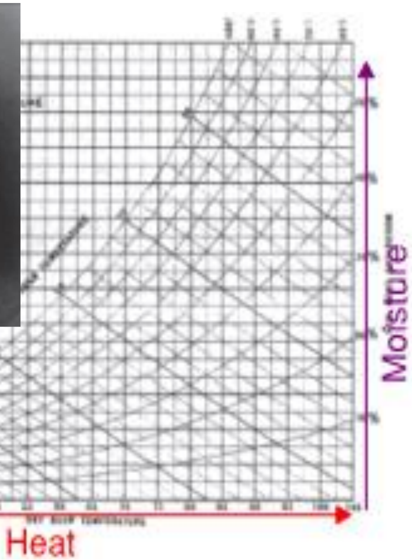
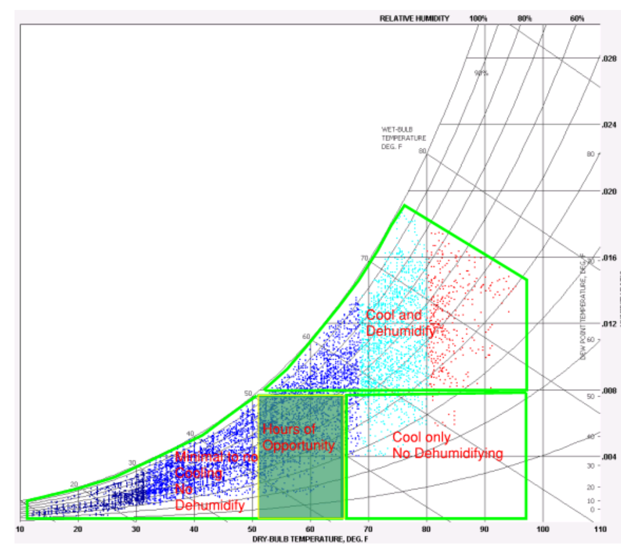
Data and Psychrometric Optimization

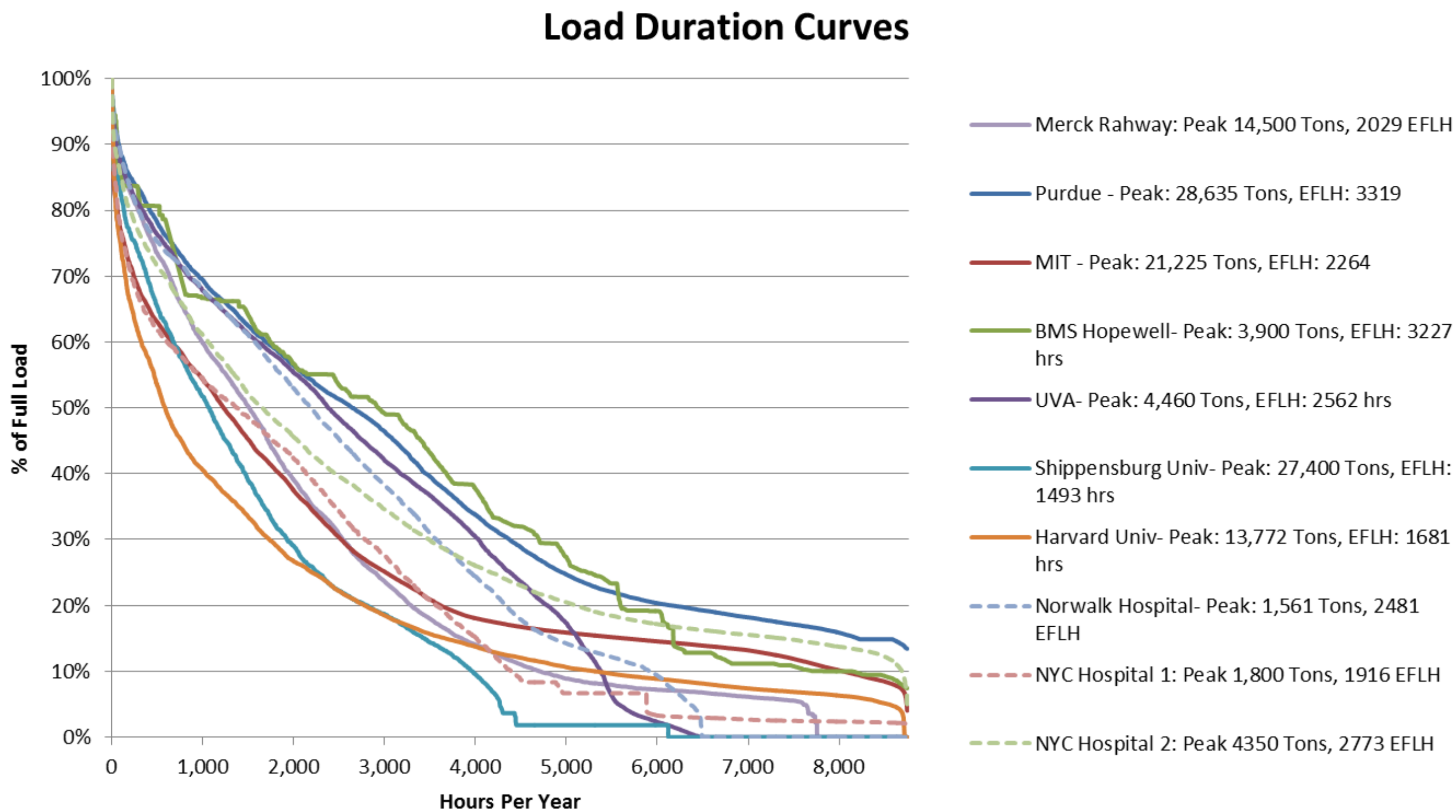
- Why Cool?
  - Dehumidify (most important)
  - Then, maintain space temperature
- Willis Carrier- “The Father of air conditioning”
- Created the first psychrometric chart (1904)
- “The principal function of air conditioning is the control of moisture”
- Use coincident weather data to analyze if dehumidification is needed
- “Psychrometric Optimization”





Examples of Applications of Big Data

- Benchmarking against other sites



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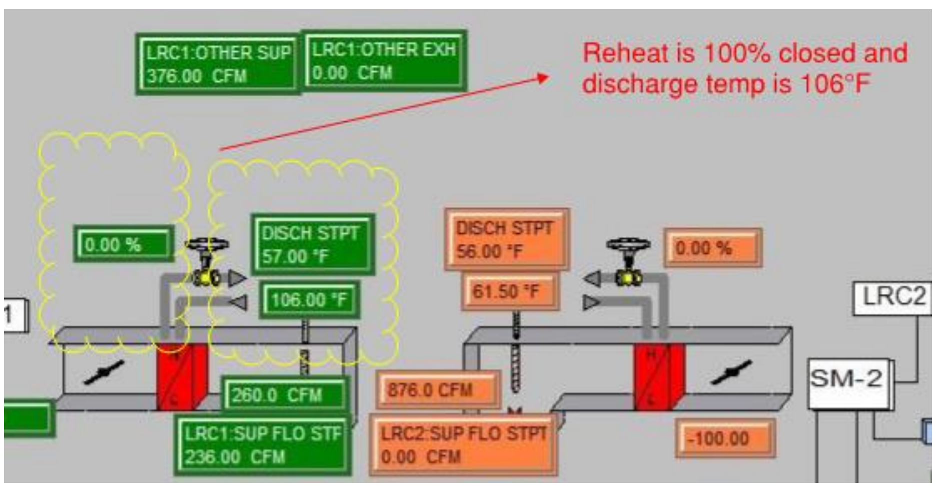
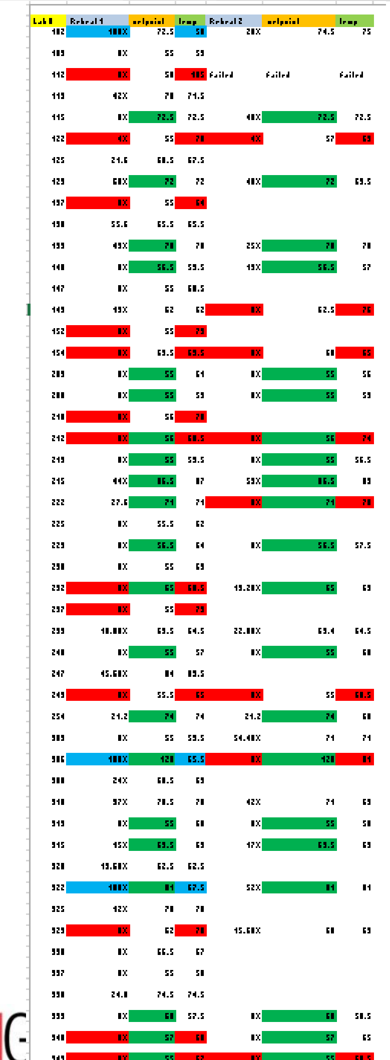
Examples of Applications of Big Data

- Simple review of reheat valve position vs DT found 40% leakage
- Project resulted in **38% chilled water reduction**
- < 1 year payback





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Examples of Applications of Big Data

- Develop a Campus "Hit List" of prioritized buildings

	Steam lb	
	7,540,868.91	Building 25 Steam
		Building 42 Steam
	8,338,922.90	Building 50 Steam
	8,704,981.46	Building 53 Steam
	173,554,437.91	Building 55 Steam
	3,396,060.79	Building 65 Steam
	15,761,117.92	Building 83 Steam
	1,372,750.23	Building 85 Steam
	82,654,423.40	Building 85A Steam
	18,698,836.58	Building 91 Steam
	4,226,006.62	Building 92 Steam
	261,277.89	Building 97 Steam
	23,150,020.72	Building 102 Steam
105,107,109	110,683,052.19	**Building 105 Steam**
	10,359,604.50	Building 111 Steam
	69,953,043.23	Building 115 Steam
	5,006,186.94	Building 125 Steam
	2,219,479.45	Building 133 Steam
	3,729,100.33	Building 134 Steam
	0.00	Building 137 Steam

	Ton-hrs	
	377,065.79	Building 25 Chilled Water
	226,047.59	Building 46 Chilled Water
	747,618.74	Building 48 Chilled Water
	1,831,628.76	Building 50 Chilled Water
	563,596.90	Building 53 Chilled Water
	1,786,968.76	Building 55 Chilled Water
	111,374.63	Building 65 Chilled Water
	0.00	Building 80-84 Chilled Water
	1,434,638.19	Building 83-85 Chilled Water
	192,157.39	Building 92 Chilled Water
105,107,109	3,028,903.55	Building 109 PD Lab Ch Water
	1,387,545.24	Building 111 Chilled Water
	1,692,296.81	Building 115 Chilled Water

- Know and target the energy hogs

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