RCx 101

A Technical Introduction to Existing Building Commissioning

A Closer Look at the 10 Skills

Instructor:

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Senior Engineer

Facility Dynamics Engineering

Ten Key Retrocommissioning Skills

1. Be Able to Benchmarking and Perform Utility Analysis
2. Be able to Scope a Facility
3. Be Familiar with Fundamental Principles and HVAC
4. Understand and Apply the System Concept
5. Be Able to Perform Data Logging and Trend Analysis
6. Be Familiar with Functional Testing Techniques
7. Be Familiar with Data Analysis Techniques
8. Be Familiar with Basic HVAC and Energy Calculations
9. Be Familiar with Cost/Benefit and Return on Investment Calculations
10. Develop a Competency with Control Systems

Ryan's Ten Learning Objectives

Skill 01

Be Able to Benchmarking and Perform Utility Analysis

Learning Objective

Benchmark a facility and analyze its utility consumption patterns using billing and interval data

Ryan's Ten Learning Objectives

Skill 02

Be able to Scope a Facility

Learning Objective

Scope a facility and identify obvious indicators of opportunities to improve performance and/or reduce resource consumption

Ryan's Ten Learning Objectives

Skill 03

Be Familiar with Fundamental Principles and HVAC

Learning Objective

Apply a fundamental knowledge of HVAC systems in the EBCx process, including an understanding of mechanical components, systems and controls

Ryan’s Ten Learning Objectives

Skill 04	**Learning Objective**
Understand and Apply the System Concept	Apply the system concept and develop diagrams that illustrate key systems in a facility

Ryan's Ten Learning Objectives

Skill 05

Be Able to Perform Data Logging and Trend Analysis

Learning Objective

Utilize trending capabilities of control systems to collect building performance data and know how to supplement EMS trend data with data loggers

Ryan's Ten Learning Objectives

Skill 06

Be Familiar with Functional Testing Techniques

Learning Objective

Apply functional testing techniques and know how to develop and run a test targeted at providing the information needed to resolve operational issues

Ryan's Ten Learning Objectives

Skill 07

Be Familiar with Data Analysis Techniques

Learning Objective

Analyze data collected from trends, data loggers and tests to support projects and resolve operational challenges

Ryan's Ten Learning Objectives

Skill 08	Learning Objective
Be Familiar with Basic HVAC and Energy Calculations	Utilize basic HVAC and energy calculations to assess the impact of proposed building improvements

Ryan's Ten Learning Objectives

Skill 09	**Learning Objective**
Be Familiar with Cost/Benefit and Return on Investment Calculations	Apply Return-On-Investment (ROI) calculations to determine the financial cost and benefit of EBCx projects and present this information to facility ownership

Ryan’s Ten Learning Objectives

Skill 10

Develop a Competency with Control Systems

Learning Objective

Apply an understanding of building control systems by developing monitoring points lists, narrative control sequences and logic diagrams, and then use these tools to identify control issues and pursue tuning opportunities

The Evolving Skill Set

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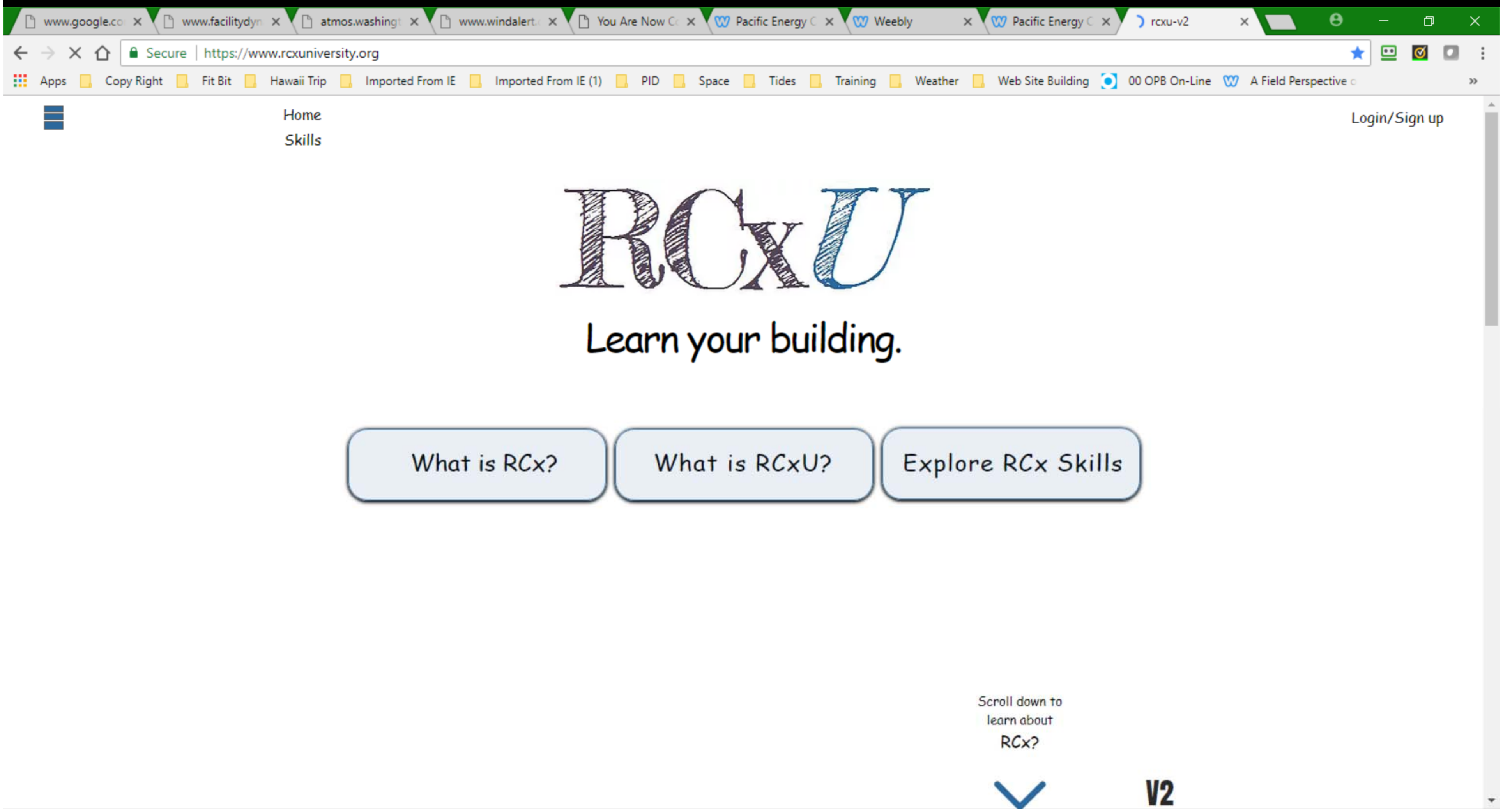
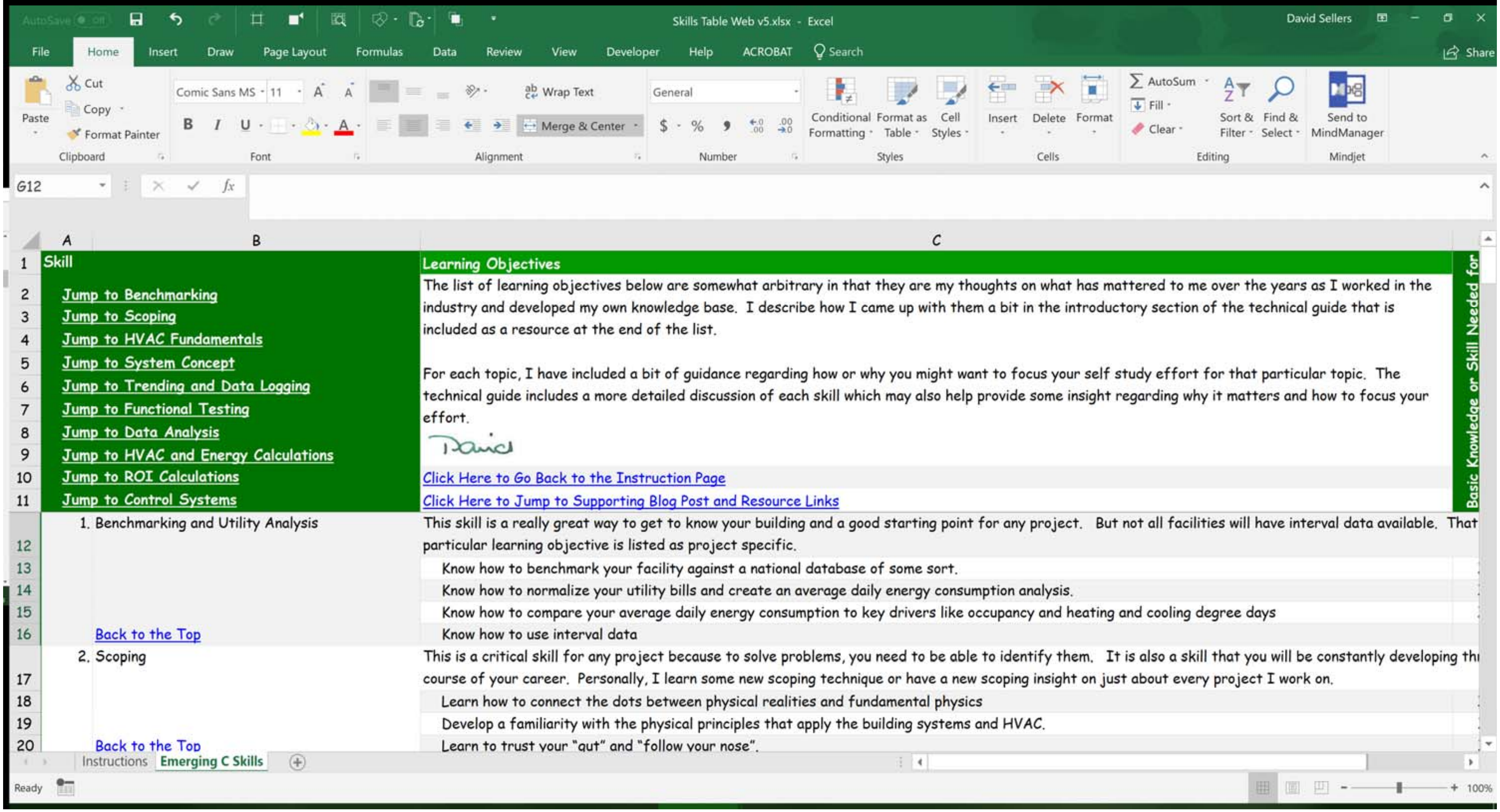
10. Develop Implementation Skills

RCx University

https://www.rcxuniversity.org/



The Emerging C Checklist



Skills Table Web v5.xlsx - Excel

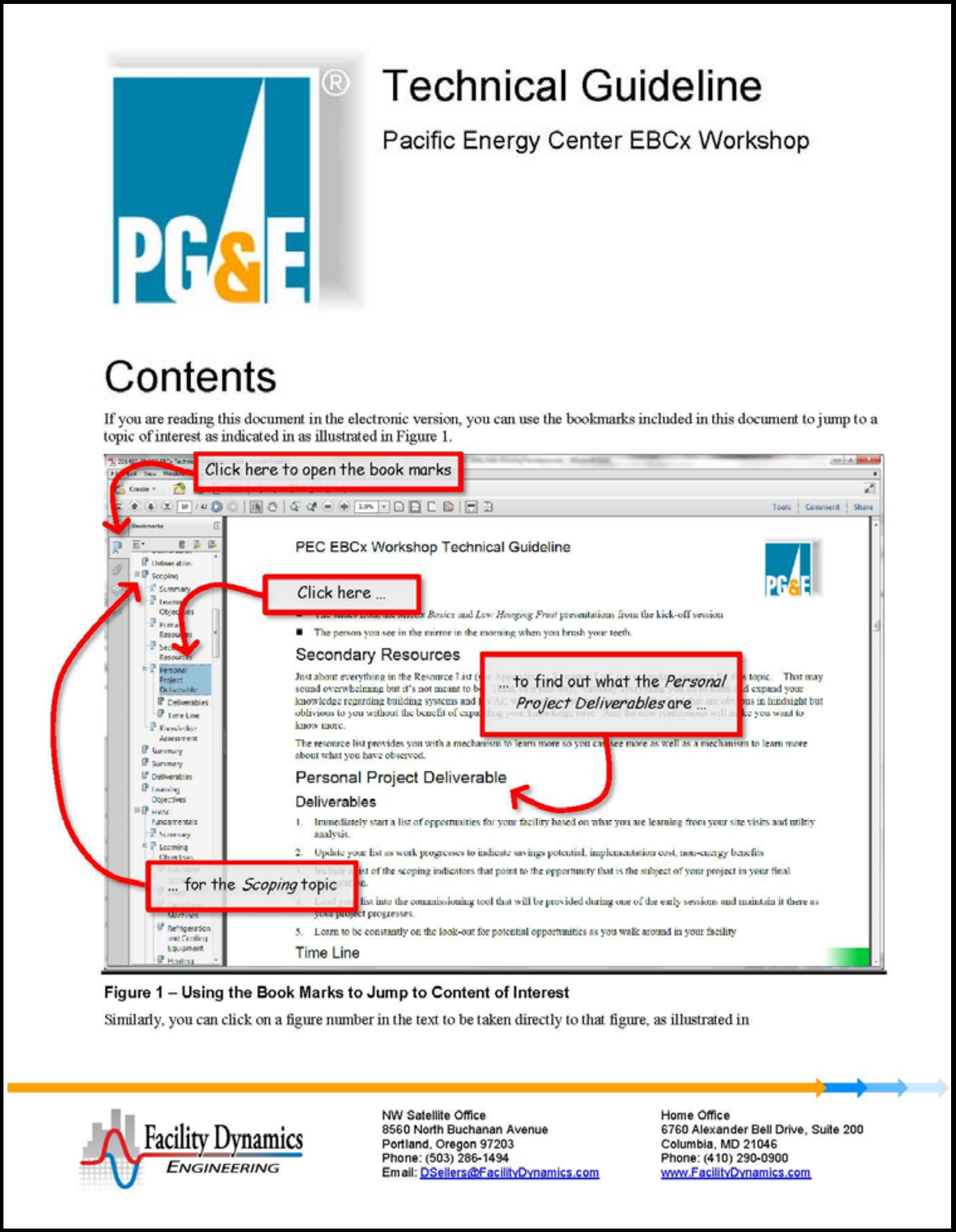
	A / B	C
1	Skill	Learning Objectives
2	Jump to Benchmarking	The list of learning objectives below are somewhat arbitrary in that they are my thoughts on what has mattered to me over the years as I worked in the industry and developed my own knowledge base. I describe how I came up with them a bit in the introductory section of the technical guide that is included as a resource at the end of the list.
3	Jump to Scoping	
4	Jump to HVAC Fundamentals	
5	Jump to System Concept	For each topic, I have included a bit of guidance regarding how or why you might want to focus your self study effort for that particular topic. The technical guide includes a more detailed discussion of each skill which may also help provide some insight regarding why it matters and how to focus your effort.
6	Jump to Trending and Data Logging	
7	Jump to Functional Testing	
8	Jump to Data Analysis	David
9	Jump to HVAC and Energy Calculations	
10	Jump to ROI Calculations	Click Here to Go Back to the Instruction Page
11	Jump to Control Systems	Click Here to Jump to Supporting Blog Post and Resource Links
12	1. Benchmarking and Utility Analysis	This skill is a really great way to get to know your building and a good starting point for any project. But not all facilities will have interval data available. That particular learning objective is listed as project specific.
13		Know how to benchmark your facility against a national database of some sort.
14		Know how to normalize your utility bills and create an average daily energy consumption analysis.
15		Know how to compare your average daily energy consumption to key drivers like occupancy and heating and cooling degree days
16	Back to the Top	Know how to use interval data
17	2. Scoping	This is a critical skill for any project because to solve problems, you need to be able to identify them. It is also a skill that you will be constantly developing thi course of your career. Personally, I learn some new scoping technique or have a new scoping insight on just about every project I work on.
18		Learn how to connect the dots between physical realities and fundamental physics
19		Develop a familiarity with the physical principles that apply the building systems and HVAC.
20	Back to the Top	Learn to trust your "gut" and "follow your nose".

Basic Knowledge or Skill Needed for

Instructions | Emerging C Skills

The Technical Guide

A Tool to Help You Learn



Technical Guideline

Pacific Energy Center EBCx Workshop

Contents

If you are reading this document in the electronic version, you can use the bookmarks included in this document to jump to a topic of interest as indicated in as illustrated in Figure 1.

Figure 1 – Using the Book Marks to Jump to Content of Interest

Similarly, you can click on a figure number in the text to be taken directly to that figure, as illustrated in

Facility Dynamics ENGINEERING

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6760 Alexander Bell Drive, Suite 200
Columbia, MD 21046
Phone: (410) 290-0900
www.FacilityDynamics.com

Ten Key Retrocommissioning Skills

Our Focus for This Class

5. Be Able to Perform Data Logging and Trend Analysis
6. Be Familiar with Functional Testing Techniques
7. Be Familiar with Data Analysis Techniques
8. Be Familiar with Basic HVAC and Energy Calculations
9. Be Familiar with Cost/Benefit and Return on Investment Calculations
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Energy Used vs. Energy Consumed

A Simple System

$$Q_{Btu/Hr} = 500 \times Flow_{gpm} \times \left(t_{Entering,°F} - t_{Leaving,°F} \right)$$

Where:

$Q_{Btu/Hr}$ = Load in Btu/hr

500 = Units conversion constant, good for water between 30 and 200°F

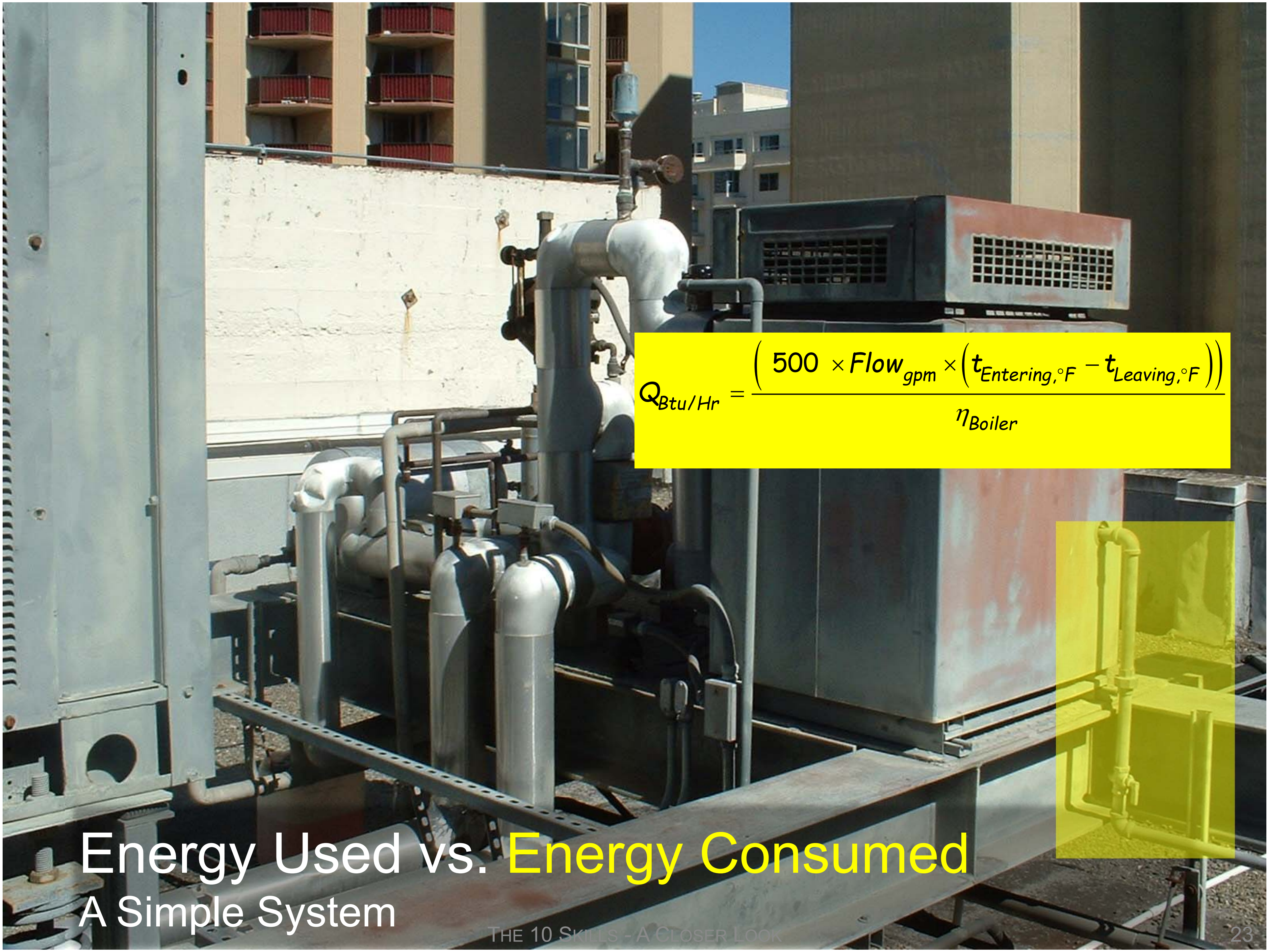
$Flow_{gpm}$ = Flow through the heat exchanger in gallons per minute

$t_{Entering,°F}$ = Temperature entering the heat exchanger in °F

$t_{Leaving,°F}$ = Temperature leaaving the heat exchanger in °F

Energy Used vs. Energy Consumed

A Simple System



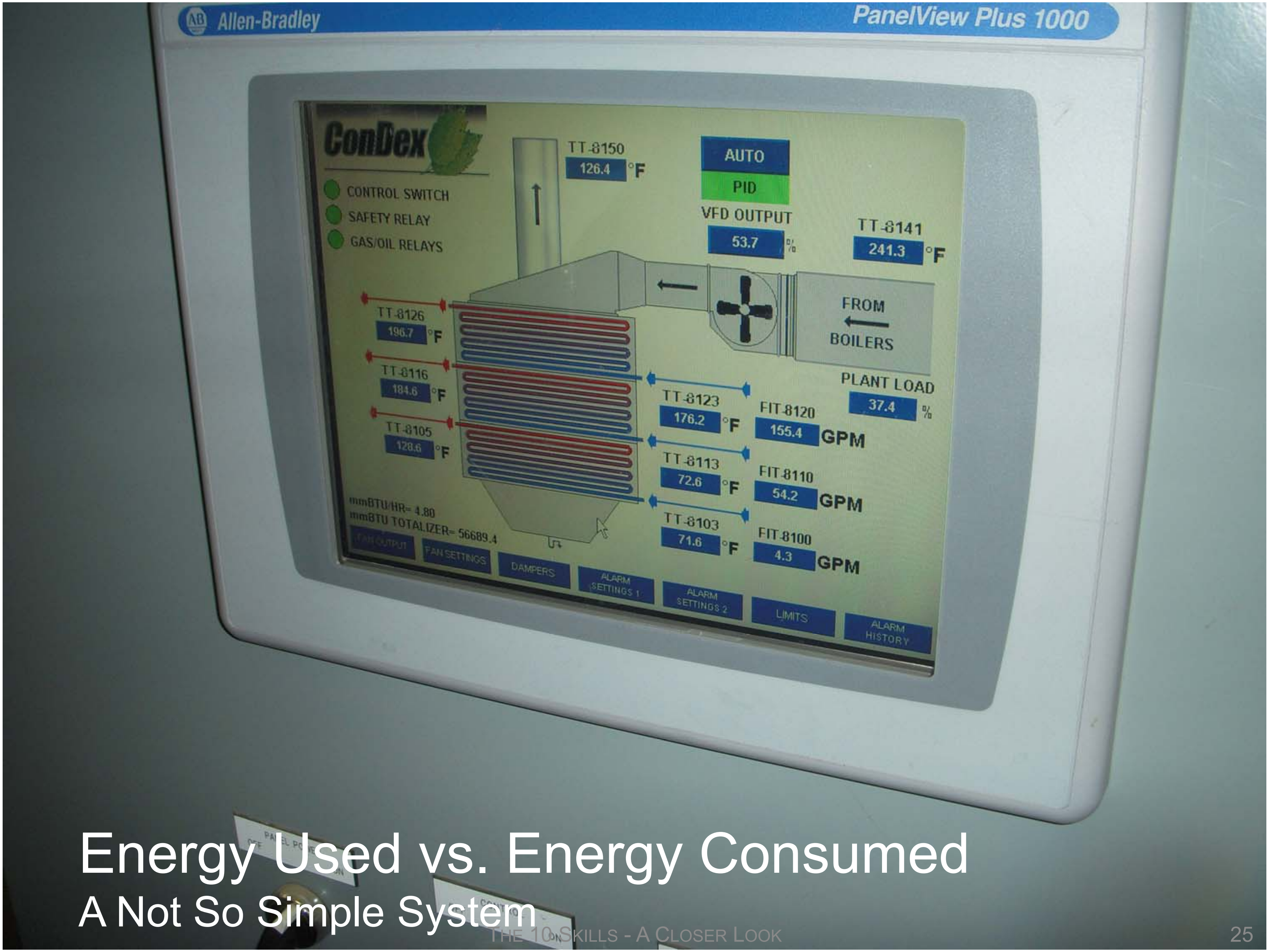
$$Q_{Btu/Hr} = \frac{\left(500 \times Flow_{gpm} \times \left(t_{Entering,°F} - t_{Leaving,°F}\right)\right)}{\eta_{Boiler}}$$

Energy Used vs. Energy Consumed

A Simple System

Energy Used vs. Energy Consumed

A Not So Simple System



Energy Used vs. Energy Consumed

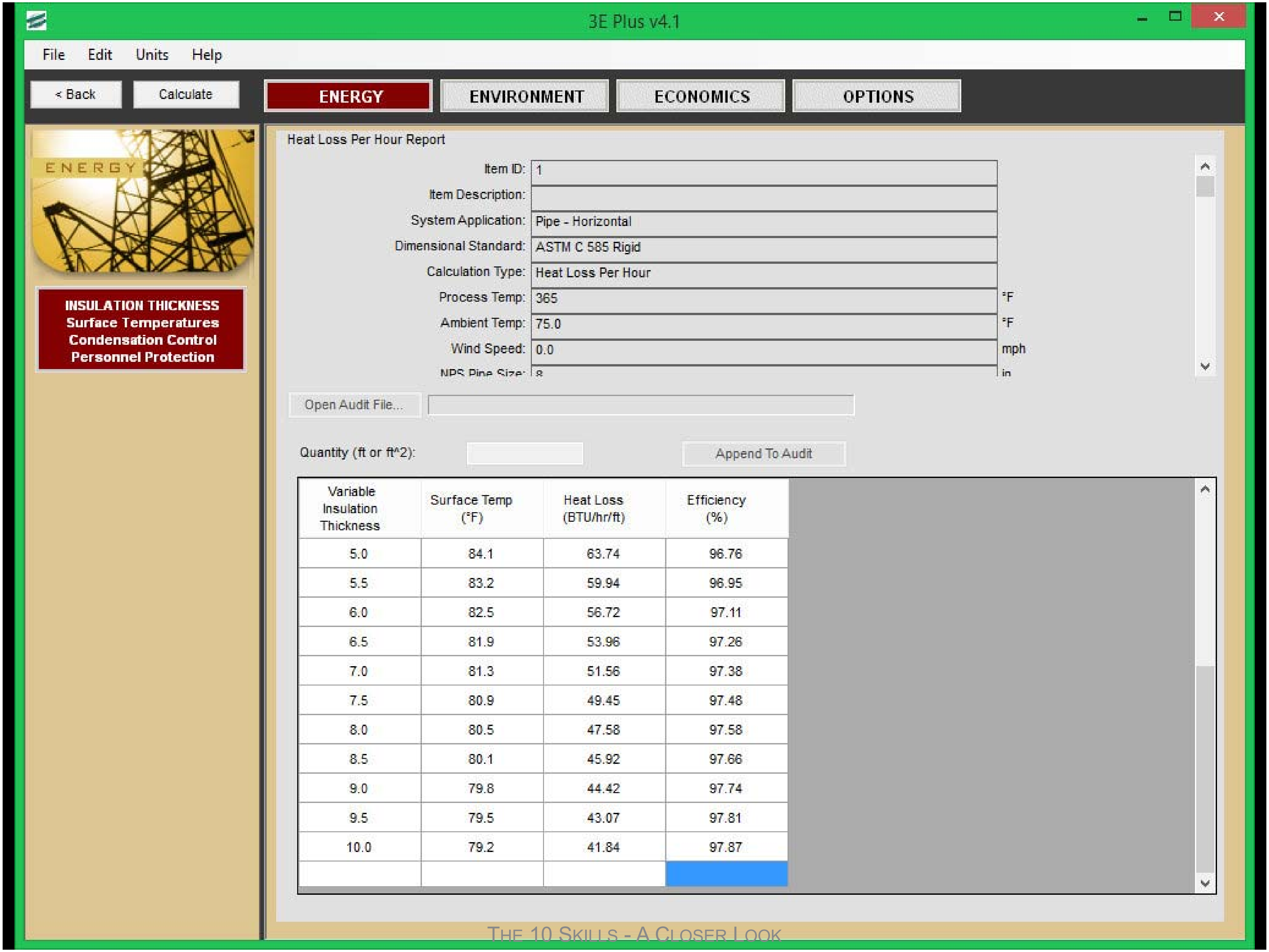
A Not So Simple System

It Takes Energy to Distribute Energy

Conversion

Distribution

Distribution Systems have Parasitic Losses



Variable Insulation Thickness	Surface Temp (°F)	Heat Loss (BTU/hr/ft)	Efficiency (%)
5.0	84.1	63.74	96.76
5.5	83.2	59.94	96.95
6.0	82.5	56.72	97.11
6.5	81.9	53.96	97.26
7.0	81.3	51.56	97.38
7.5	80.9	49.45	97.48
8.0	80.5	47.58	97.58
8.5	80.1	45.92	97.66
9.0	79.8	44.42	97.74
9.5	79.5	43.07	97.81
10.0	79.2	41.84	97.87

Conversion Efficiency vs. Distribution Efficiency Improvements

Conversion Efficiency Improvements

- A very direct function of consumption
- Potentially easy to achieve (change a piece of equipment)
- Potentially very costly to achieve (the equipment you have to change is a prime mover)
- May not address the root cause of the problem (dysfunction at the loads)

Distribution Efficiency Improvements

- Related to consumption, but just about always necessary
- More complex to achieve (requires you address multiple potentially interactive issues)
- Potentially an order of magnitude less costly than changing a prime mover
- Addresses the root cause of the problem

Site vs. Source Energy Perspective

Site Energy

Energy that passes through your meter

Source Energy

Energy that passed through the power plant

Site vs. Source Energy Perspective

Site Energy

Electric Heat is 100% Efficient

Source Energy

Electric Heat is 30% Efficient

Site vs. Source Energy Perspective

Site Energy

Source Energy

Electric Heat is 100% Efficient

Electric Heat is Free

Site vs. Source Energy Perspective

Site Energy

Source Energy

Electric Heat is 100% Efficient

Electric Heat is Sustainable

Site vs. Source Energy Perspective

Site Energy

Electric Heat is 100% Efficient

Source Energy

Sustainable Energy Impacts Salmon Migration

Site vs. Source Energy Perspective

Site Energy

Electric Heat is 100% Efficient

Source Energy

Sustainable Energy Eradicated a Culture

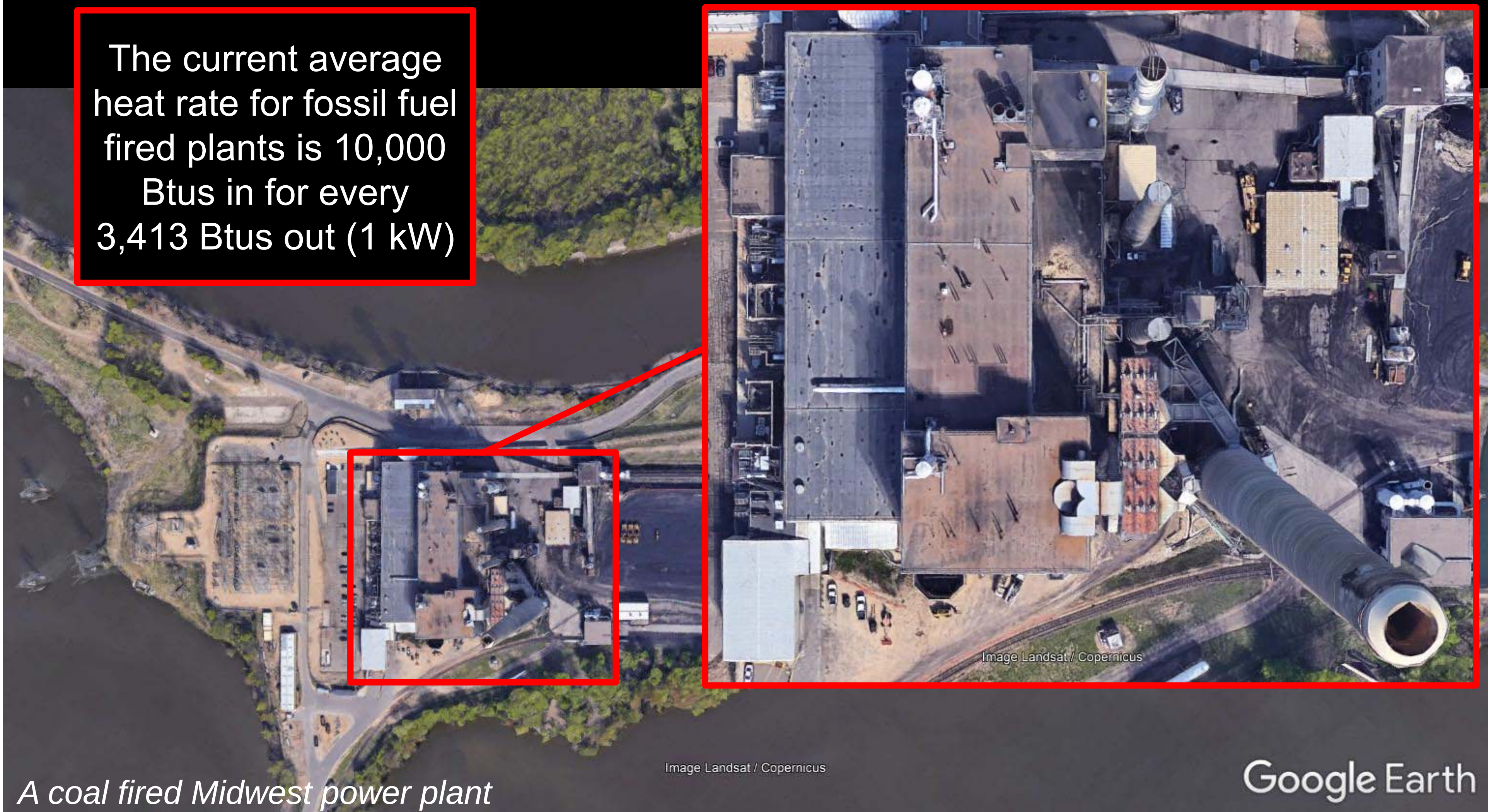
Transmission Losses are Significant

There are currently 6-8% losses in these lines between the power plant and your meter

A coal fired Midwest power plant

Conversion losses are significant

The current average heat rate for fossil fuel fired plants is 10,000 Btus in for every 3,413 Btus out (1 kW)



A coal fired Midwest power plant

Physical Principles will Prevail

Conservation of mass and energy says that all of the mass in this pile of coal other than the fly ash will end up in the atmosphere

A coal fired Midwest power plant

Bottom Line

Generating power consumes finite resources and impacts the environment

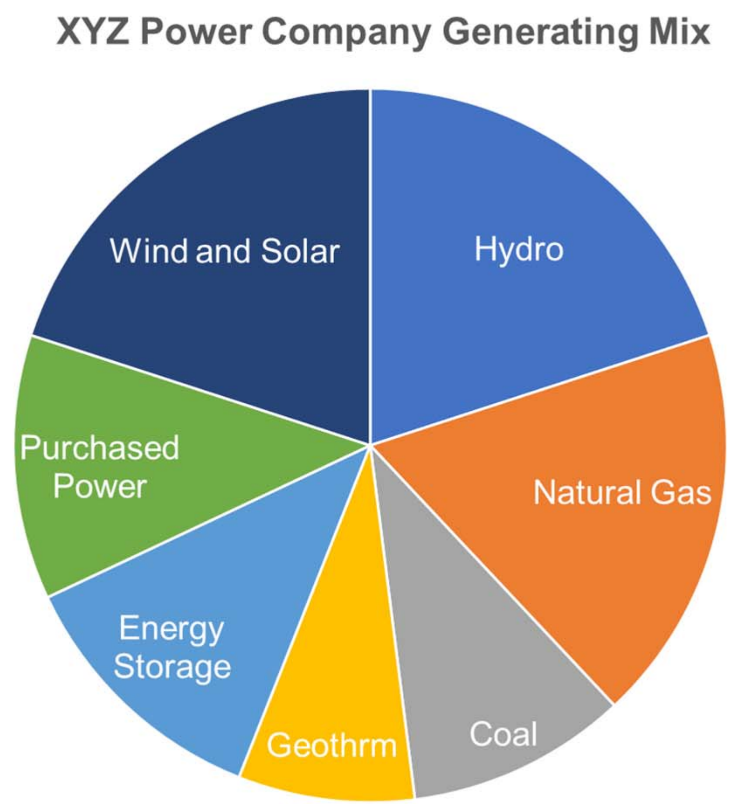
Reducing Atmospheric Impacts

We expect our energy mix to be 70% carbon free by 2040 based on current commitments and mandates, and we're working to deliver the right resources and technologies to make that happen.

Energy Strategy; www.portlandgeneral.com

Reducing Atmospheric Impacts

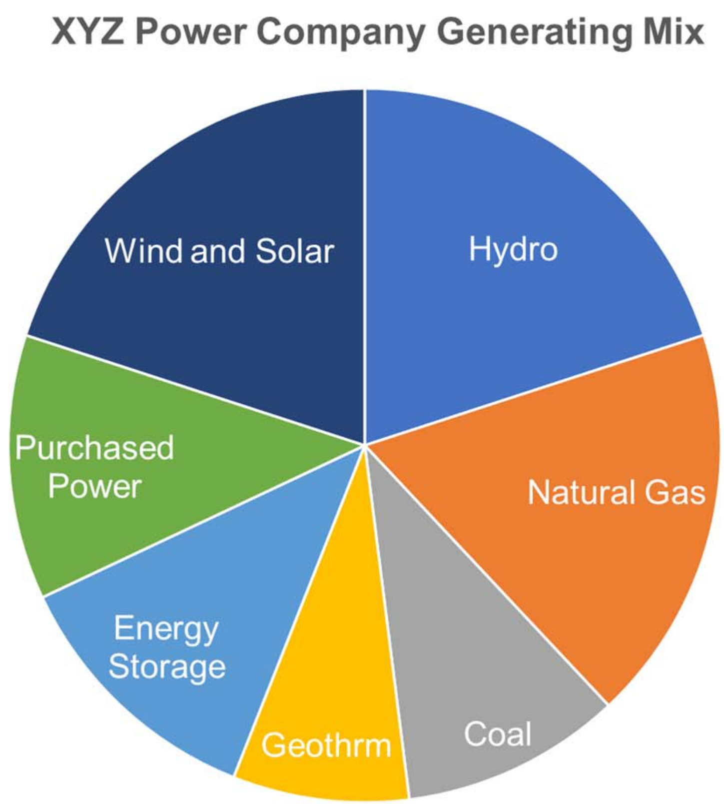
Moving away from carbon fuels is a common, long term goal for many utilities



Reducing atmospheric impacts

The commissioning tool set can have an immediate impact by reducing the need for energy in the first place

It's a win-win situation



Options for Assessment

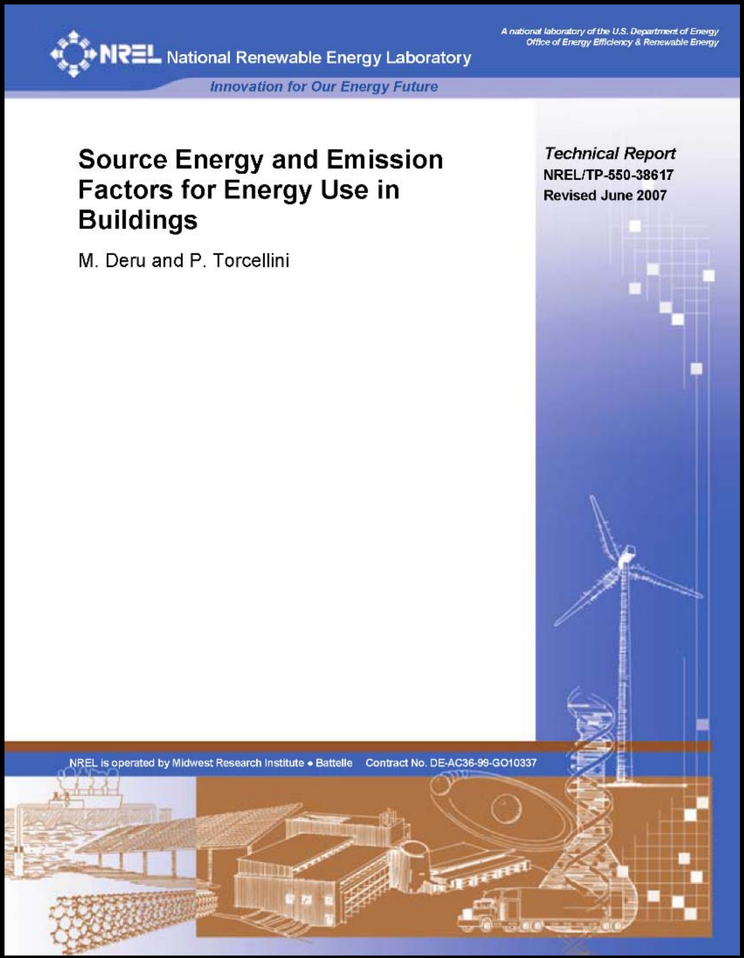
- Measure It

Options for Assessment

- Measure It
- Ask the Plant Operating Team

Options for Assessment

- Measure It
- Ask the Plant Operating Team
- Use Industry Metrics



Skill 01 – Benchmarking and Utility Analysis

Learning Objectives

- Know how to benchmark your facility against a national database of some sort.
- Know how to normalize your utility bills and create an average daily energy consumption analysis.
- Know how to compare your average daily energy consumption to key drivers like occupancy and heating and cooling degree days
- Know how to use interval data

What is Benchmarking?

Benchmarking compares the performance of your facility to that of similar facilities of a similar size, age, occupancy, and function that are located in a similar climate.

Energy Utilization Index (EUI)

The Metric Typically Used to Benchmark

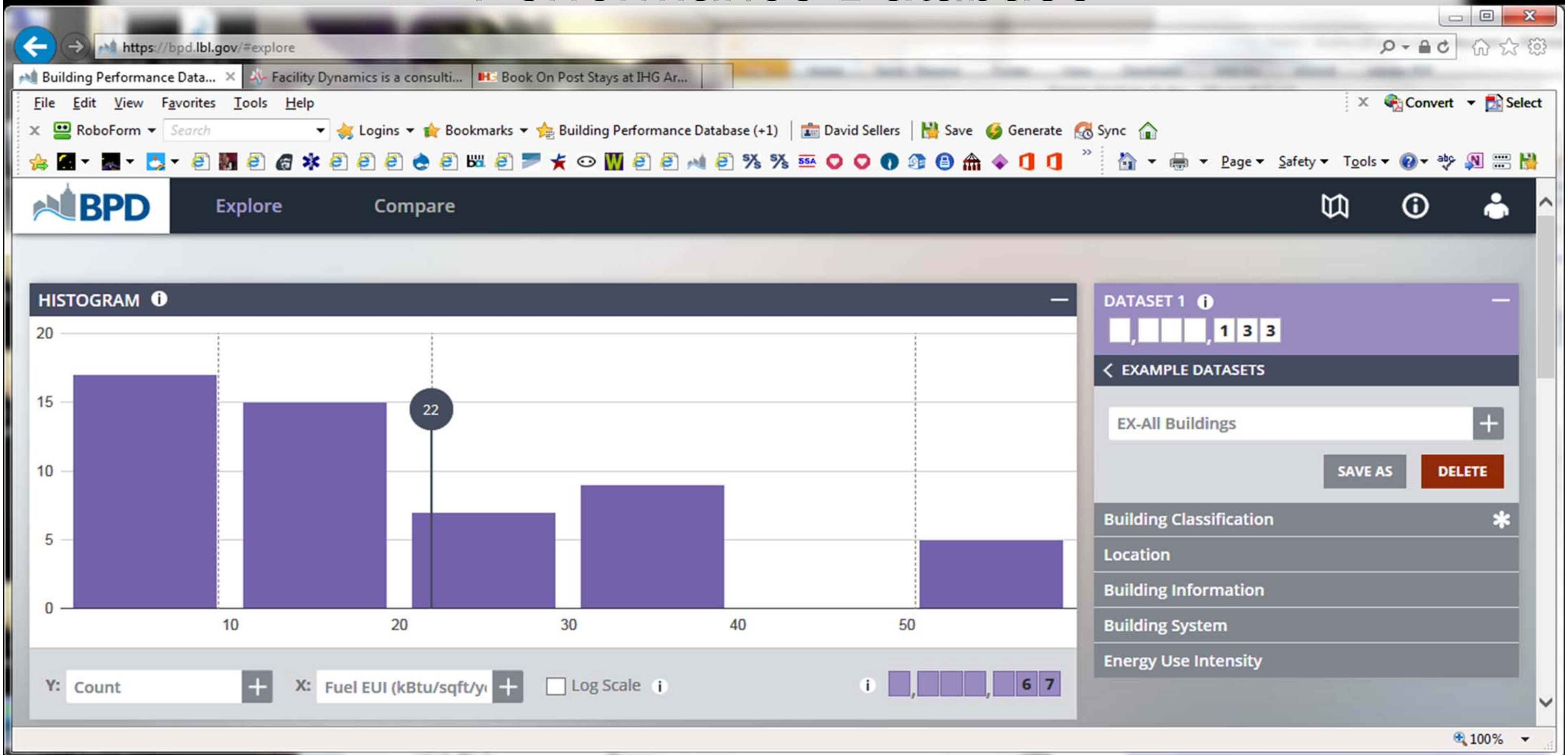
- Requires consumption be converted to a common unit
- KiloBtu's per Square Foot per Year

EUI from 2014 Data					
Source Energy Conversion - Electricity	3.365	Source Energy and Emission Factors for Energy Use in Buildings			
Source Energy Conversion - Gas	1.092	Source Energy and Emission Factors for Energy Use in Buildings			
Btu per kWh	3,413				
Btu per therm	100,000				
Building square footage (no mech space)	10,715	Formulas in the square foot tab of Multiople Location Cost anr Kwh.xls			
Energy Source	Whole Building Energy Benchmark				
	Site Energy		Source Energy		
	Billed Units	Btus	Billed Units	Btus	
Electricity	190,716	650,914,664	641,760	2,190,327,844	
Gas therms	4,021	402,149,182	4,391	439,146,906	
Total Btus		1,053,063,845		2,629,474,750	
Total kBtus		1,053,064		2,629,475	
kBtu/sq.ft.		98		245	

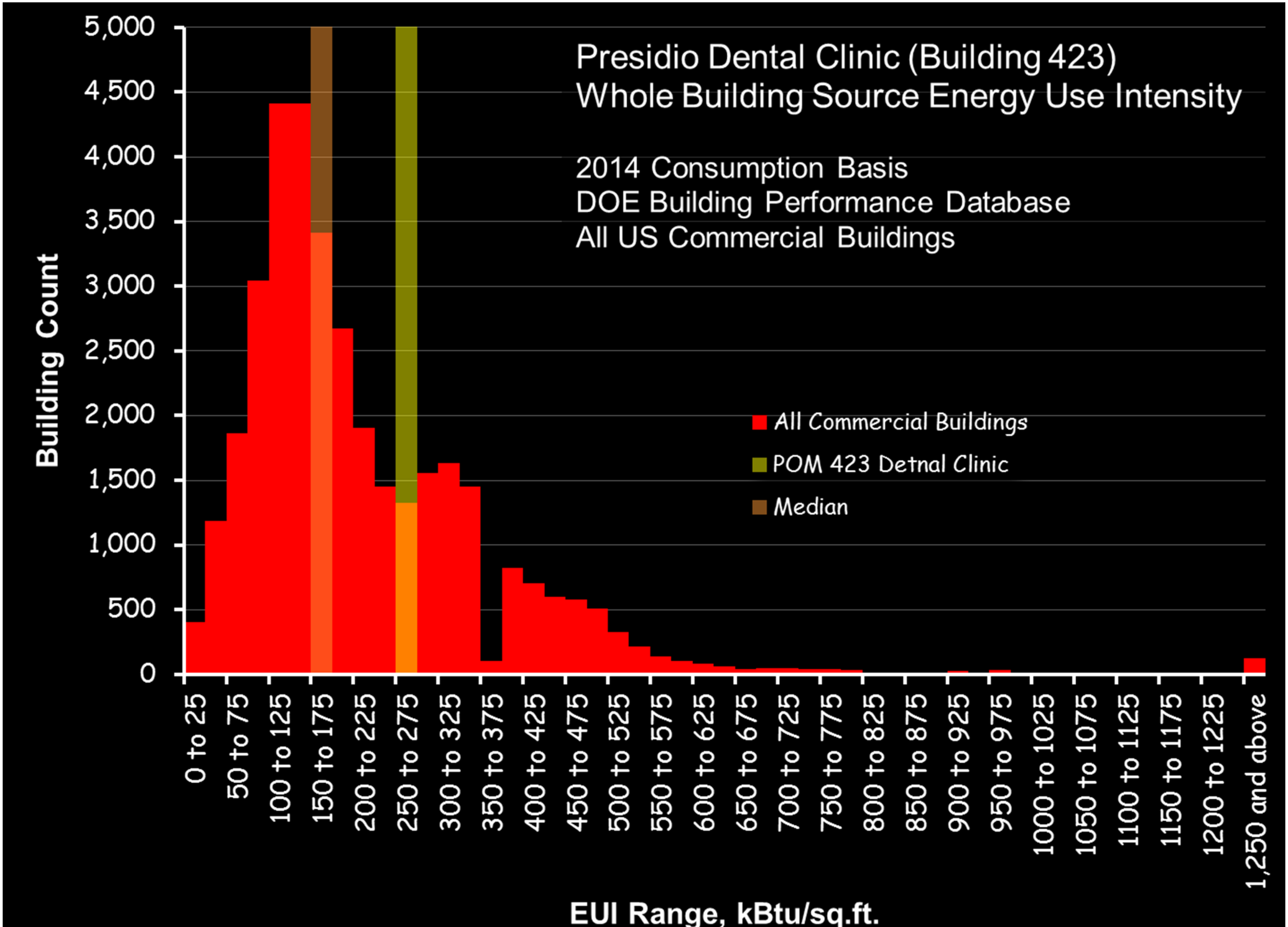
Benchmarking Resources

- Building Performance Database
  - https://bpd.lbl.gov/
- EnergyStar Portfolio Manager
  - http://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager
- Labs 21
  - http://labs21benchmarking.lbl.gov/
- Oakridge National Labs
  - http://eber.ed.ornl.gov/benchmark/bench.htm

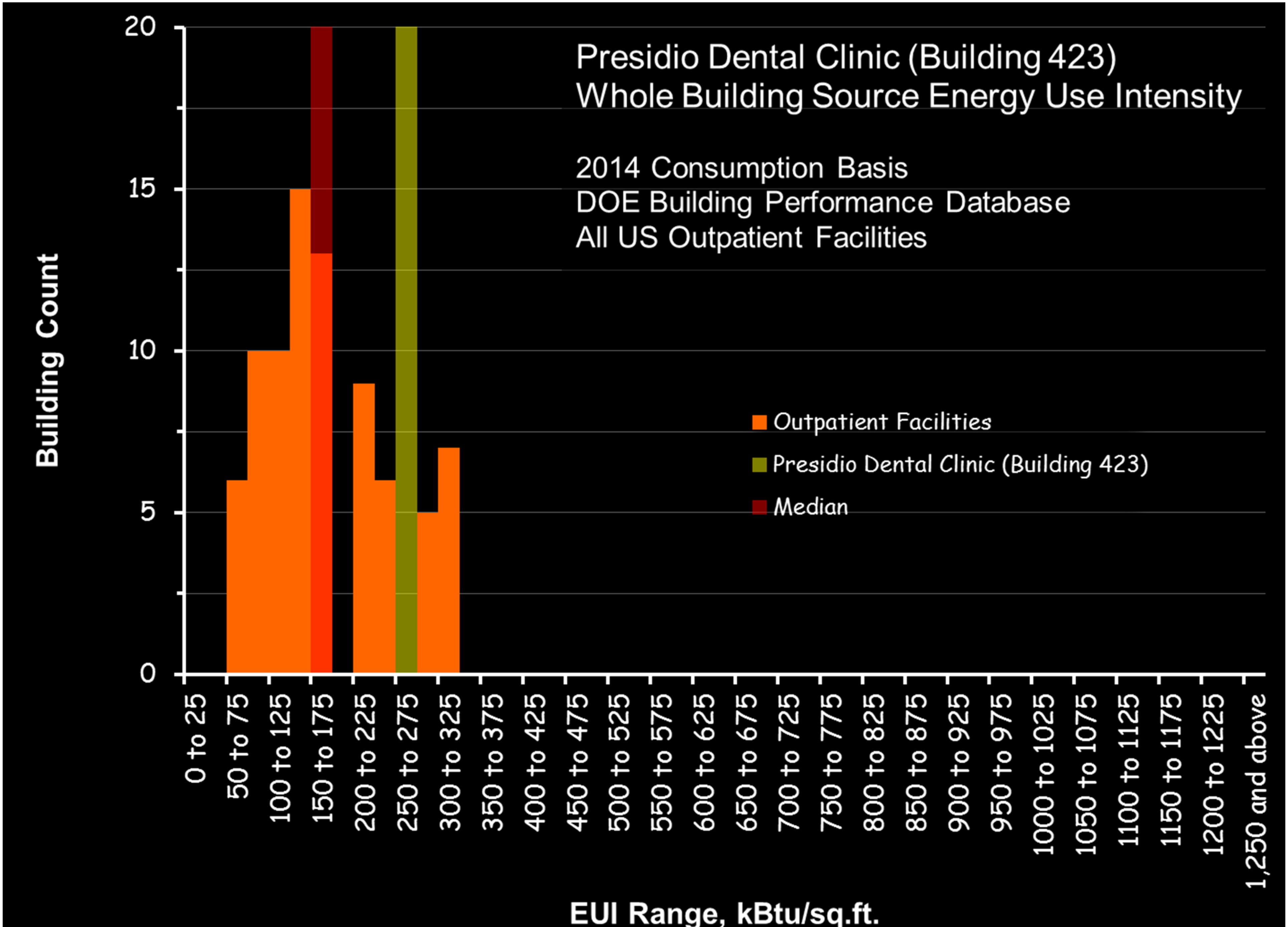
Benchmarking Against CBECS via DOE Buildings Performance Database



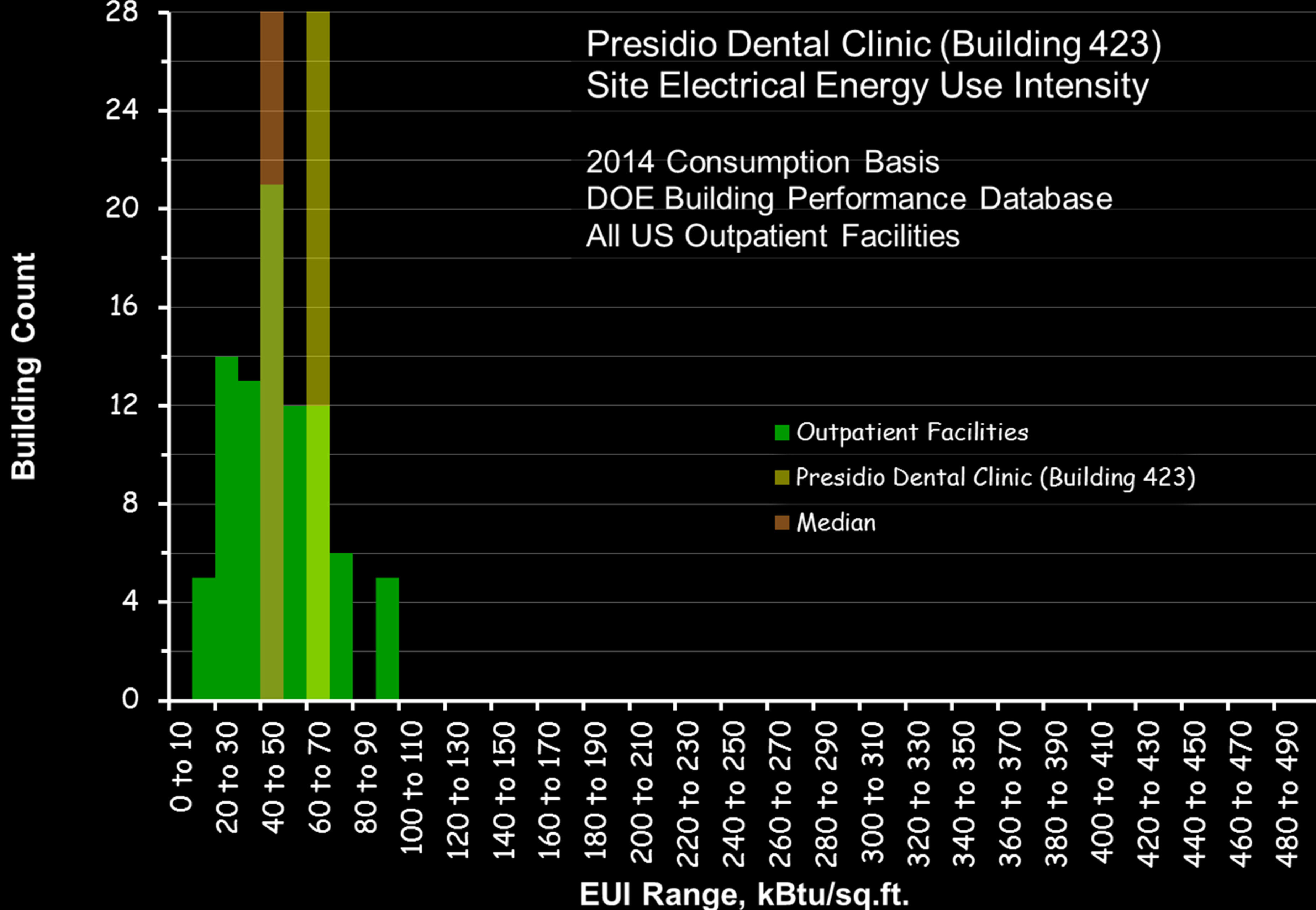
https://bpd.lbl.gov/

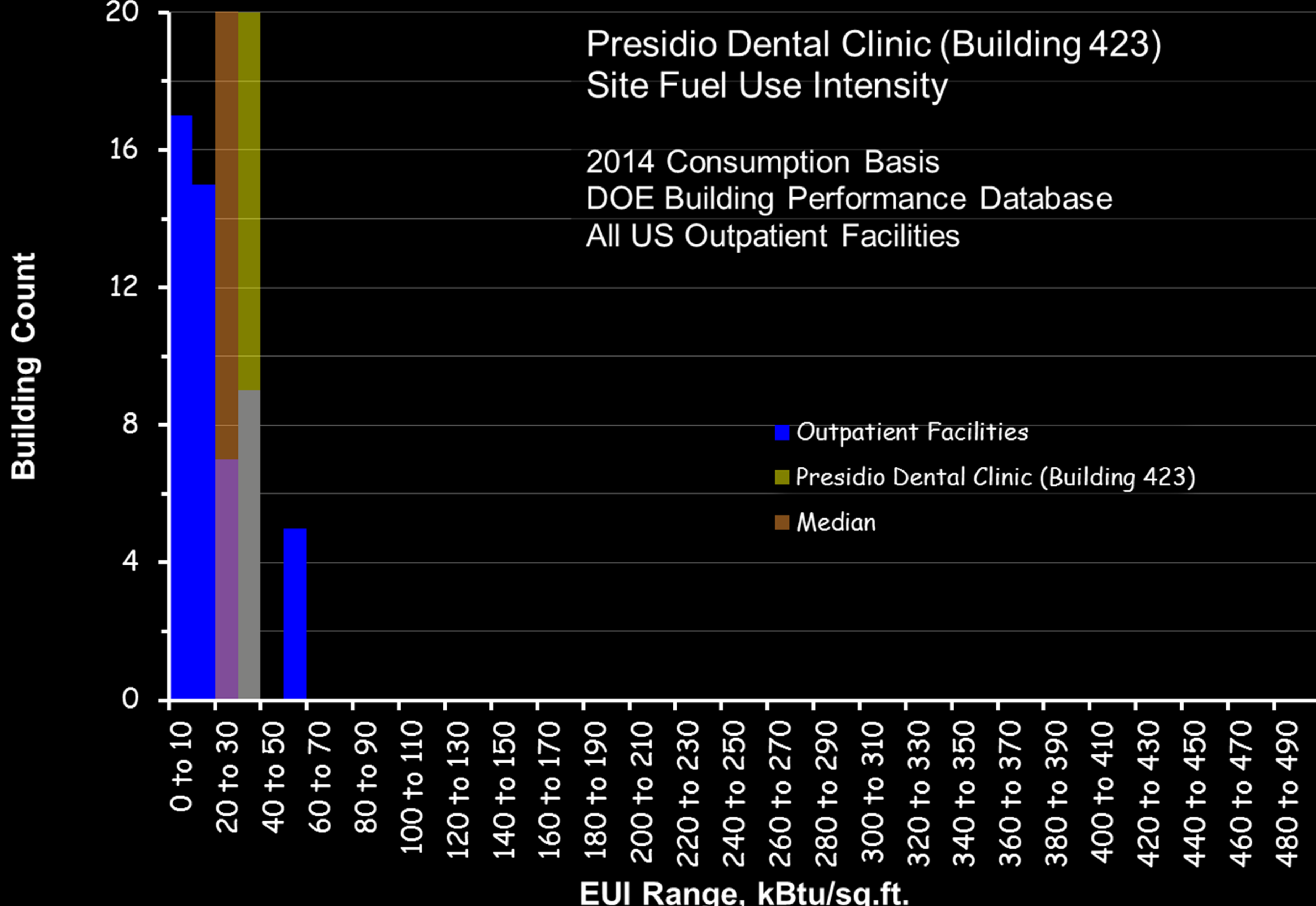


Presidio Dental Clinic (Building 423)
Whole Building Source Energy Use Intensity
2014 Consumption Basis
DOE Building Performance Database
All US Commercial Buildings
All Commercial Buildings
POM 423 Detnal Clinic
Median
Building Count
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0 to 25
50 to 75
100 to 125
150 to 175
200 to 225
250 to 275
300 to 325
350 to 375
400 to 425
450 to 475
500 to 525
550 to 575
600 to 625
650 to 675
700 to 725
750 to 775
800 to 825
850 to 875
900 to 925
950 to 975
1000 to 1025
1050 to 1075
1100 to 1125
1150 to 1175
1200 to 1225
1,250 and above
EUI Range, kBtu/sq.ft.



Presidio Dental Clinic (Building 423)
Whole Building Source Energy Use Intensity
2014 Consumption Basis
DOE Building Performance Database
All US Outpatient Facilities
Outpatient Facilities
Presidio Dental Clinic (Building 423)
Median
Building Count
20
15
10
5
0
0 to 25
50 to 75
100 to 125
150 to 175
200 to 225
250 to 275
300 to 325
350 to 375
400 to 425
450 to 475
500 to 525
550 to 575
600 to 625
650 to 675
700 to 725
750 to 775
800 to 825
850 to 875
900 to 925
950 to 975
1000 to 1025
1050 to 1075
1100 to 1125
1150 to 1175
1200 to 1225
1,250 and above
EUI Range, kBtu/sq.ft.


Presidio Dental Clinic (Building 423)
Site Electrical Energy Use Intensity
2014 Consumption Basis
DOE Building Performance Database
All US Outpatient Facilities
Outpatient Facilities
Presidio Dental Clinic (Building 423)
Median
Building Count
0
4
8
12
16
20
24
28
0 to 10
20 to 30
40 to 50
60 to 70
80 to 90
100 to 110
120 to 130
140 to 150
160 to 170
180 to 190
200 to 210
220 to 230
240 to 250
260 to 270
280 to 290
300 to 310
320 to 330
340 to 350
360 to 370
380 to 390
400 to 410
420 to 430
440 to 450
460 to 470
480 to 490
EUI Range, kBtu/sq.ft.


Presidio Dental Clinic (Building 423)
Site Fuel Use Intensity
2014 Consumption Basis
DOE Building Performance Database
All US Outpatient Facilities
Building Count
20
16
12
8
4
0
Outpatient Facilities
Presidio Dental Clinic (Building 423)
Median
0 to 10
20 to 30
40 to 50
60 to 70
80 to 90
100 to 110
120 to 130
140 to 150
160 to 170
180 to 190
200 to 210
220 to 230
240 to 250
260 to 270
280 to 290
300 to 310
320 to 330
340 to 350
360 to 370
380 to 390
400 to 410
420 to 430
440 to 450
460 to 470
480 to 490
EUI Range, kBtu/sq.ft.

What is Utility Consumption Analysis?

- Utility consumption analysis looks for trends in utility consumption patterns that are indicators of opportunities to save resources. These patterns are also indicators of the persistence of benefits provided by past projects
  - Average daily basis
  - Normalized to the calendar month

Average Daily Energy Consumption Analysis

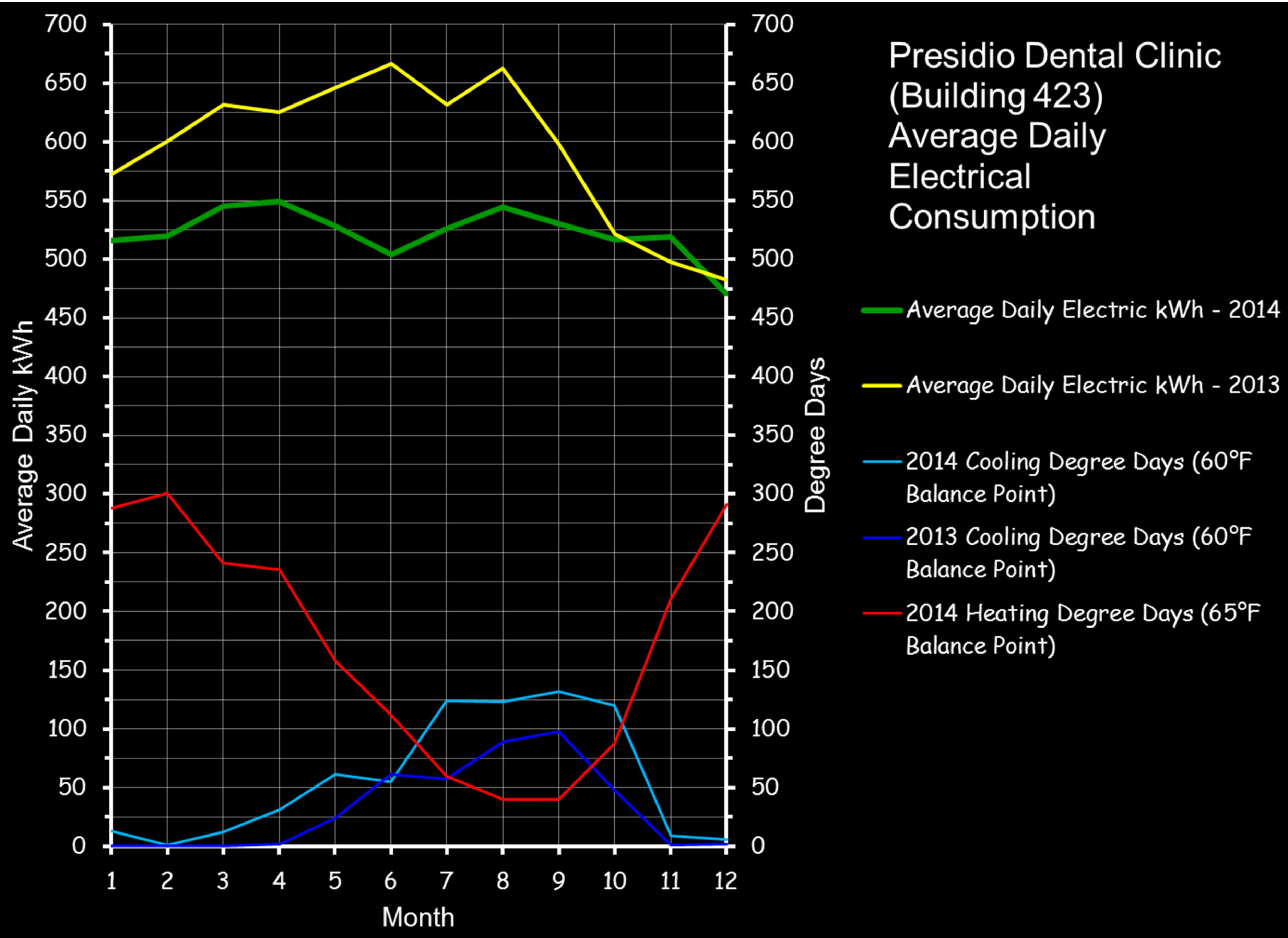
Compare average monthly patterns to potential drivers

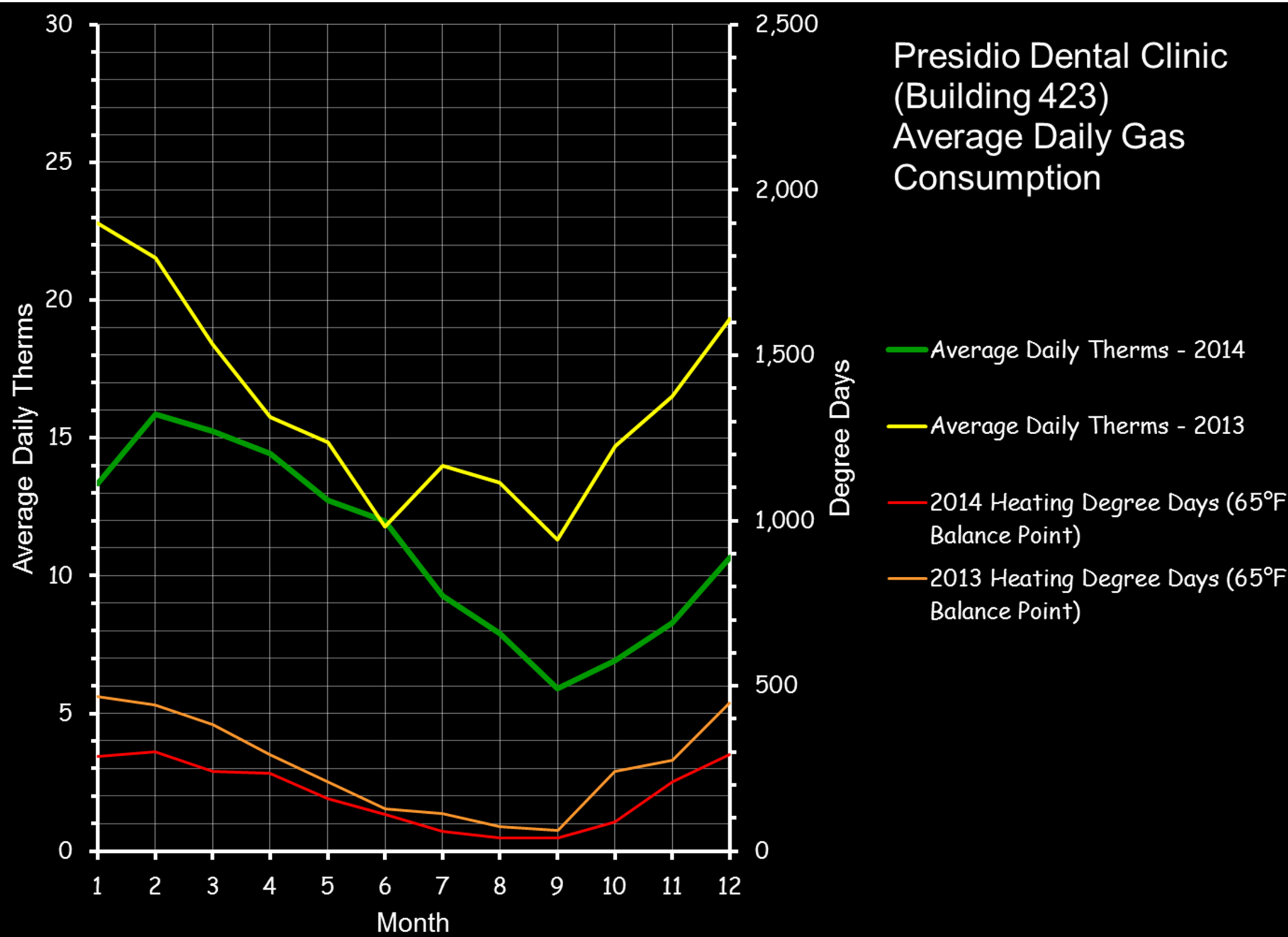
- Heating and cooling degree days (http://www.weatherdatadepot.com/)
- Occupancy patterns
- Production

Critical considerations

- Data needs to be averaged over the days in the billing period
- Data needs to be normalized to the month not the billing period

Utility Consumption Analysis Tool (UCAT) will do the work for you (www.CACx.org)


Presidio Dental Clinic
(Building 423)
Average Daily
Electrical
Consumption
Average Daily Electric kWh - 2014
Average Daily Electric kWh - 2013
2014 Cooling Degree Days (60°F Balance Point)
2013 Cooling Degree Days (60°F Balance Point)
2014 Heating Degree Days (65°F Balance Point)
Average Daily kWh
Degree Days
Month
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
1
2
3
4
5
6
7
8
9
10
11
12

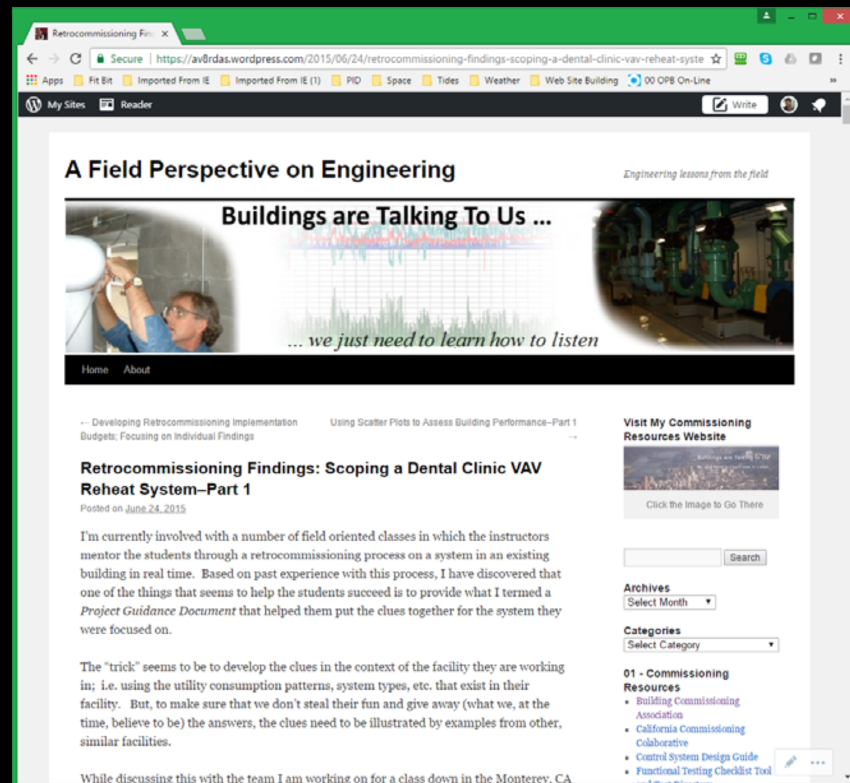

Presidio Dental Clinic
(Building 423)
Average Daily Gas
Consumption
Average Daily Therms - 2014
Average Daily Therms - 2013
2014 Heating Degree Days (65°F Balance Point)
2013 Heating Degree Days (65°F Balance Point)
Average Daily Therms
Degree Days
Month
30
25
20
15
10
5
0
2,500
2,000
1,500
1,000
500
0
1
2
3
4
5
6
7
8
9
10
11
12

An Example

Retrocommissioning Findings: Scoping a Dental Clinic VAV Reheat System–Part 1

Available at www.Av8rDAS.com

- Follow the blog link
- Search for “Dental”



Leveraging the Utility Data

Use the utility data to “frame” your project

- Reverse engineer the savings potential from utility consumption, industry metrics and past experience
- Reverse engineer the over-all project budget from what is justified by the savings potential and the Owner’s financial metrics
- Reverse engineer budget line item amounts from past experience if needed
- Quantify risk by assessing the obvious

Leveraging the Utility Data

Utility Consumption Analysis Tool (UCAT)

- Allows very quick assessments of utility consumption patterns based on billing data and use

LBNL Commissioning Cost and Benefit Reports

- Provides savings metrics for EBCx and other Cx processes
  - General case median for EBCx is 16% reduction
    - Upper limit – 31%
    - Lower limit – 9%
  - Includes metrics by building type too

Free download from www.CACx.org

- Select “Resources” then “Tools and Templates” then “Existing Building Cx”

Free download from http://cx.lbl.gov/

- Select Cost-Benefit Assessments
- 2004 Assessment is the foundation
- 2009 Assessment updates the 2004 report
- MBCx report focuses on the UC/CSU/IOU program

Dental Clinic Annual Consumption

Annual Consumption - From a baseline report, utility bills, utility meters, etc.			
	Energy	$	
Electricity - kWh/$ per year	190,716	$36,236	Source = Dental Clinic Energy Analysis v1.xlsx
Thermal at the Central Plant - Therms/$ per year	4,021	$4,021	Source = Dental Clinic Energy Analysis v1.xlsx
TOTAL		$40,258	$ per year
		$3.76	$ per square foot per year
EUI Factors	Site Energy	Source Energy	
Electrical Energy	61	204	kBtu/sq.ft./yr.
Thermal Energy	38	41	kBtu/sq.ft./yr.
Total	98	245	kBtu/sq.ft./yr.
Savings Projection Based on the LBNL Cost Benefit Study			
LBNL Cx Cost Benefit Median Energy Savings (2009 update) -		16%	of Whole Building Energy Consumption.
	Low End	High End	
Potential savings range for the purposes of our discussion -	10%	16%	Set based on LBNL Metric and engineering judgement related to observations on site and the special systems present
Potential annual savings -	$4,026	$6,441	$ per year
Potential electrical savings -	19,072	30,515	kWh per year
Potential thermal savings -	402	643	Therms per year

Dental Clinic Project Budget Range

Annual Consumption - From a baseline report, utility bills, utility meters, etc.					
	Energy	$			
Electricity - kWh/$ per year	190,716	$36,236	Source = Dental Clinic Energy Analysis v1.xlsx		
Thermal at the Central Plant - Therms/$ per year	4,021	$4,021	Source = Dental Clinic Energy Analysis v1.xlsx		
TOTAL		$40,258	$ per year		
		$3.76	$ per square foot per year		
EUI Factors	Site Energy	Source Energy			
Electrical Energy	61	204	kBtu/sq.ft./yr.		
Thermal Energy	38	41	kBtu/sq.ft./yr.		
Total	98	245	kBtu/sq.ft./yr.		
Savings Projection Based on the LBNL Cost Benefit Study					
LBNL Cx Cost Benefit Median Energy Savings (2009 update) -		16%	of Whole Building Energy Consumption.		
	Low End	High End			
Potential savings range for the purposes of our discussion -	10%	16%	Set based on LBNL Metric and engineering judgement related to observations on site and the special systems present		
Potential annual savings -	$4,026	$6,441	$ per year		
Potential electrical savings -	19,072	30,515	kWh per year		
Potential thermal savings -	402	643	Therms per year		
Expenditure Justified by Anticipated Savings					
Simple payback time frame -	5	years	10	years	
Savings range -	Low End	High End	Low End	High End	
Energy savings after the indicated interval, 2013 $ -	$20,129	$32,206	$40,258	$64,412	
Incentive, 2013 $ -	$0	$0	$0	$0	
Total, 2013 $ -	$20,129	$32,206	$40,258	$64,412	

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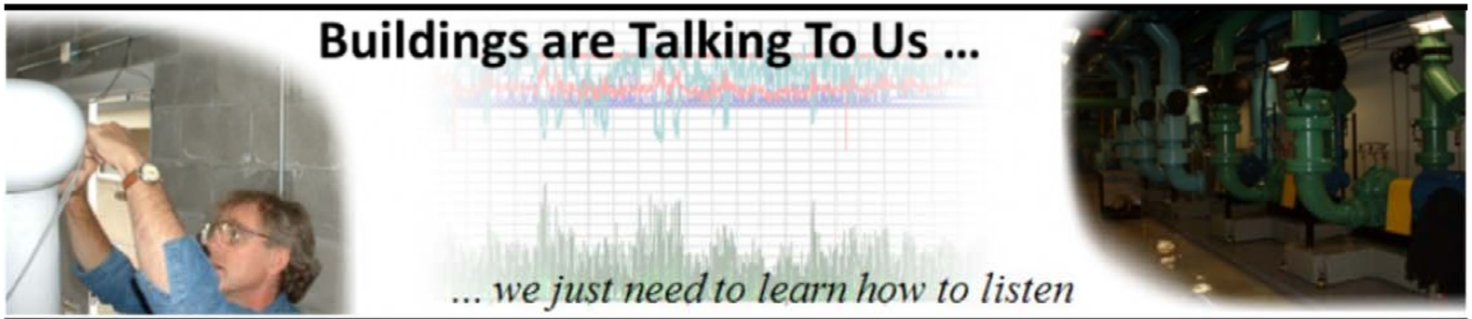
A Field Perspective on Engineering

Engineering lessons from the field



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← Annotating Charts in Excel

Developing Retrocommissioning Implementation Budgets; Focusing on Individual Findings →

Developing Retrocommissioning Implementation Budgets; Establishing the Big Picture

Posted on May 1, 2015

This string of posts started out as an e-mail response to a number of people involved with a Marriott training class where I teach the technical track. As the e-mail got longer and broader in scope, I realized that the information would be useful to a broader audience, including attendees in next year's class. So I decided to develop a string of blog posts on the topic in place of the e-mail.

This first post will discuss using industry metrics and the Owner's financial metrics and tolerance for risk along with utility analysis techniques and scoping skills to bracket the potential savings a project might deliver along with an order of magnitude for the project

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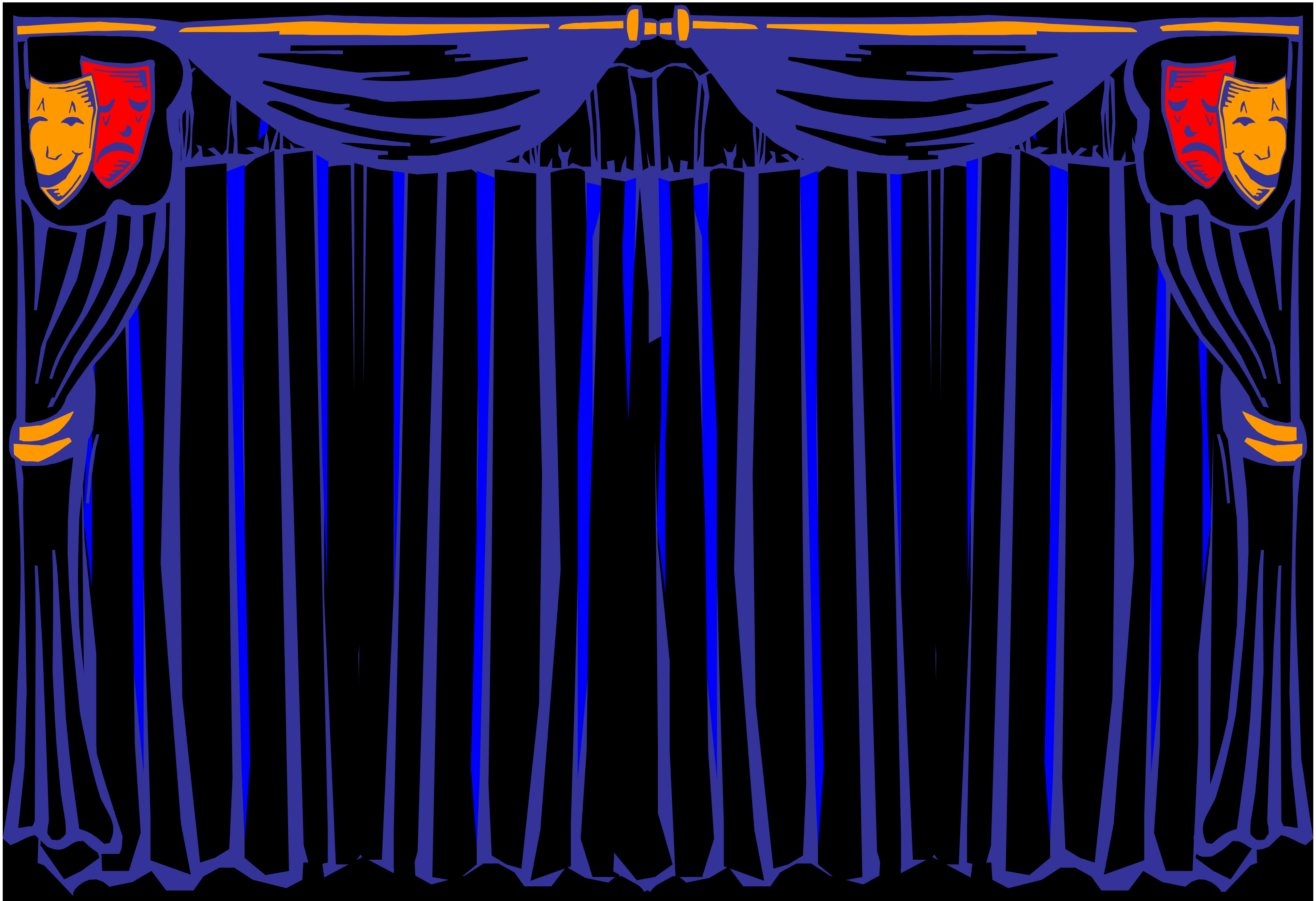
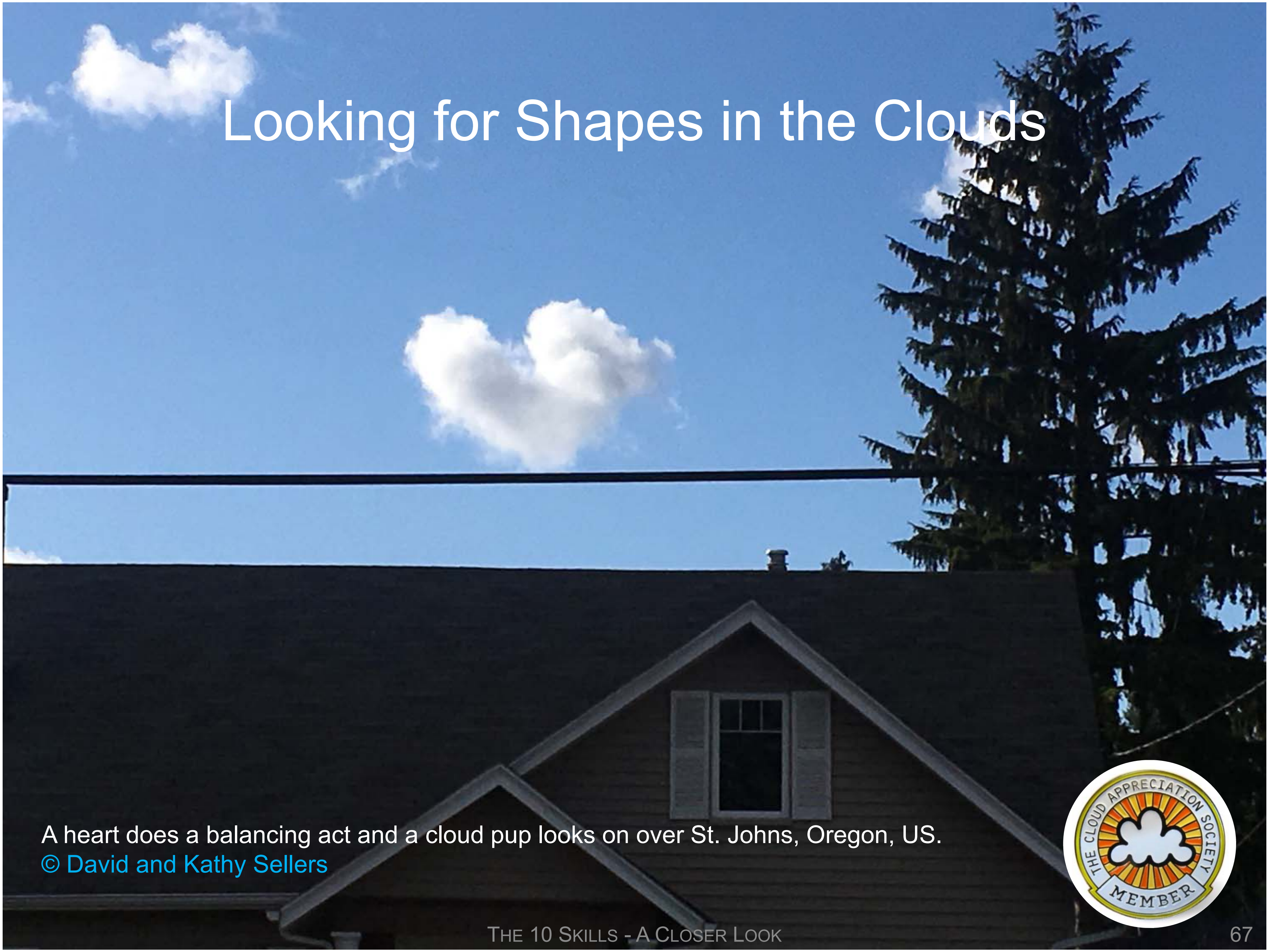


Looking for Shapes in the Clouds

An Eagle over Cambridge, UK.
© Christie Nel

Looking for Shapes in the Clouds



A heart does a balancing act and a cloud pup looks on over St. Johns, Oregon, US.
© David and Kathy Sellers

Looking for Shapes in the Clouds

A Cloud Revealing Something About Buildings.
[© JR Hott]

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A Cloud Revealing Something About Buildings.
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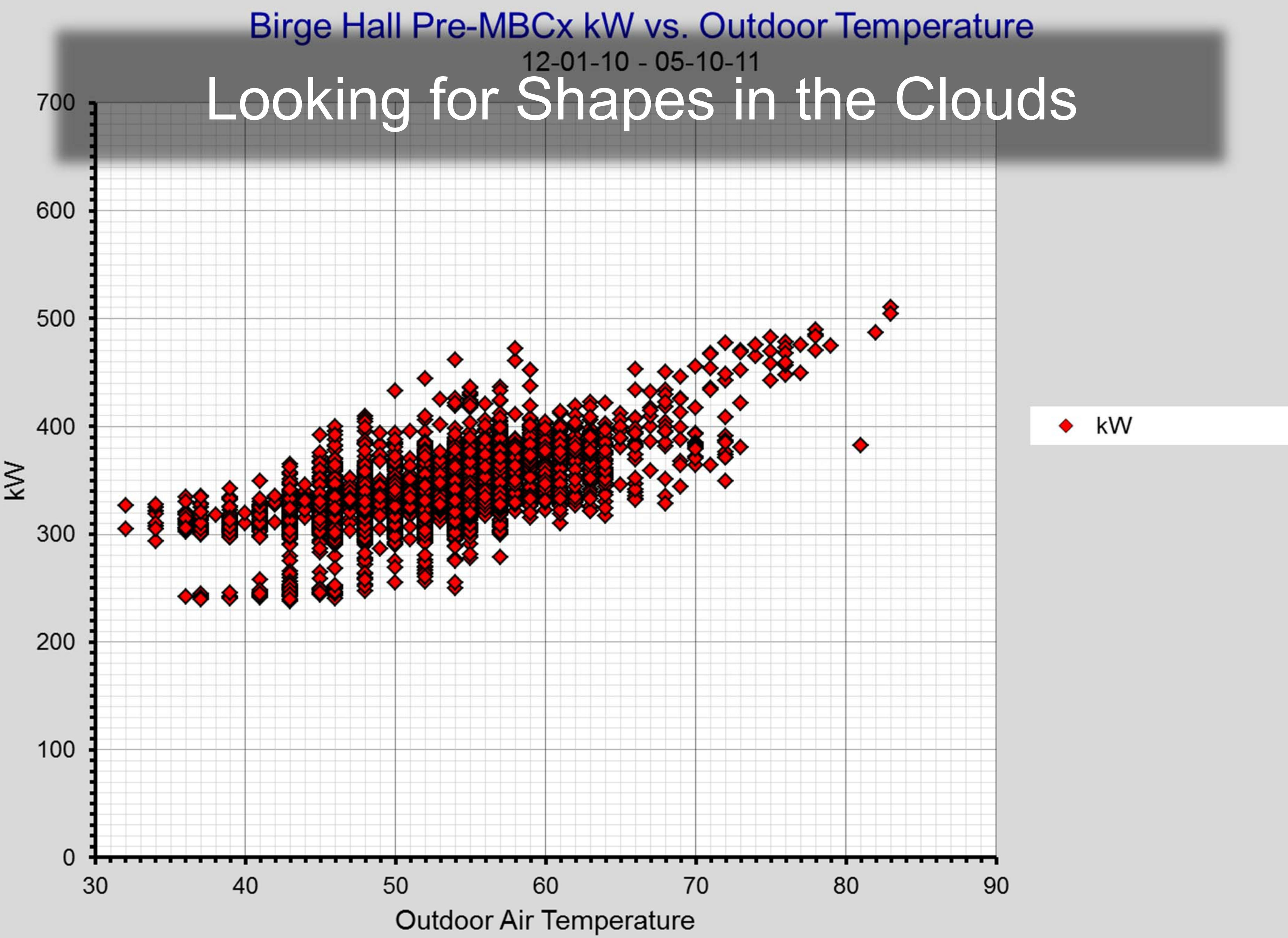
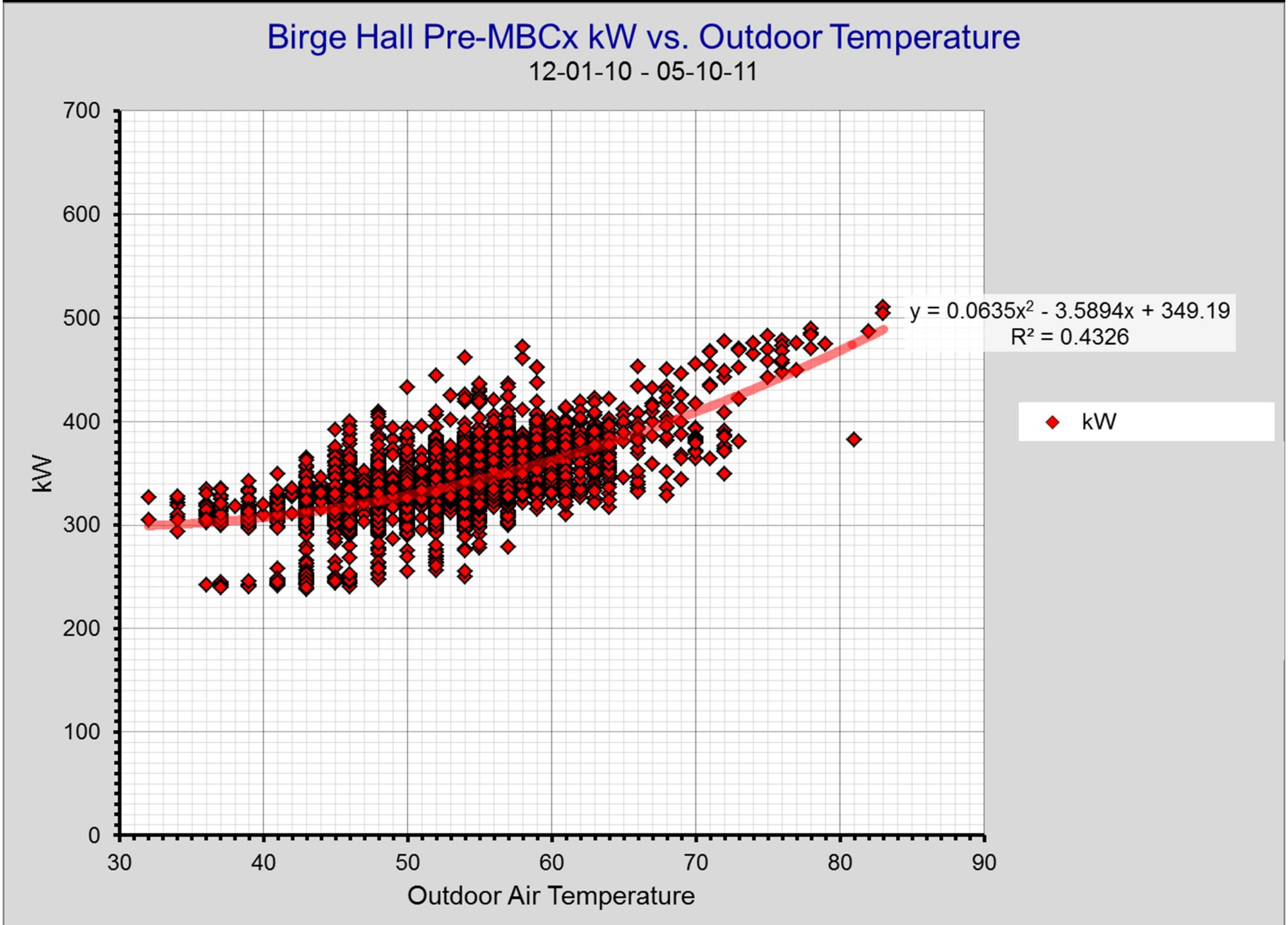
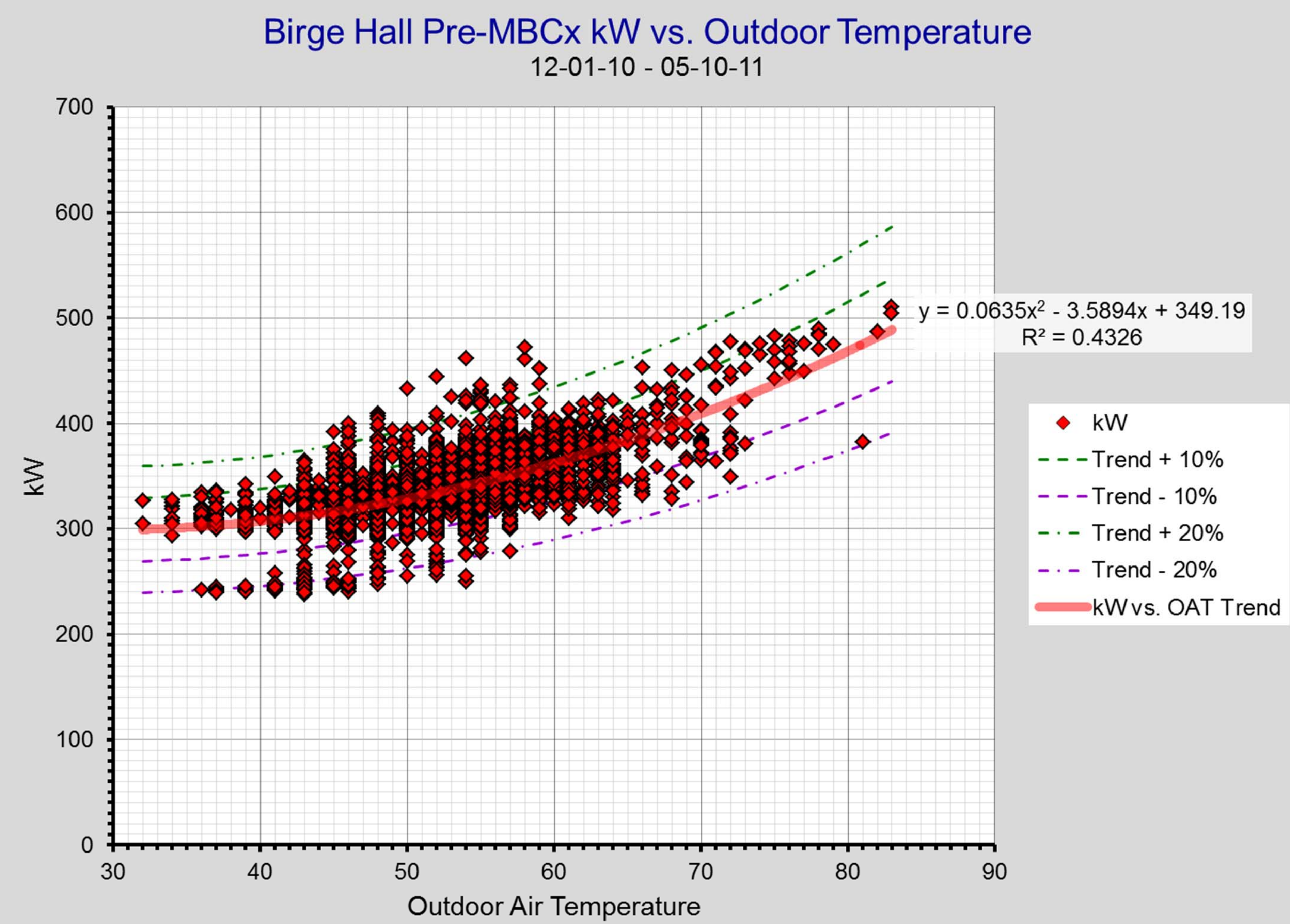
Regressions

- Step 1
  - Develop a relationship defining how one parameter (often called the dependent variable) varies as a function of a second parameter (often called the independent variable) based on measured data
- Step 2
  - Use that relationship to project how the dependent variable might behave under conditions for which you only have independent variable data

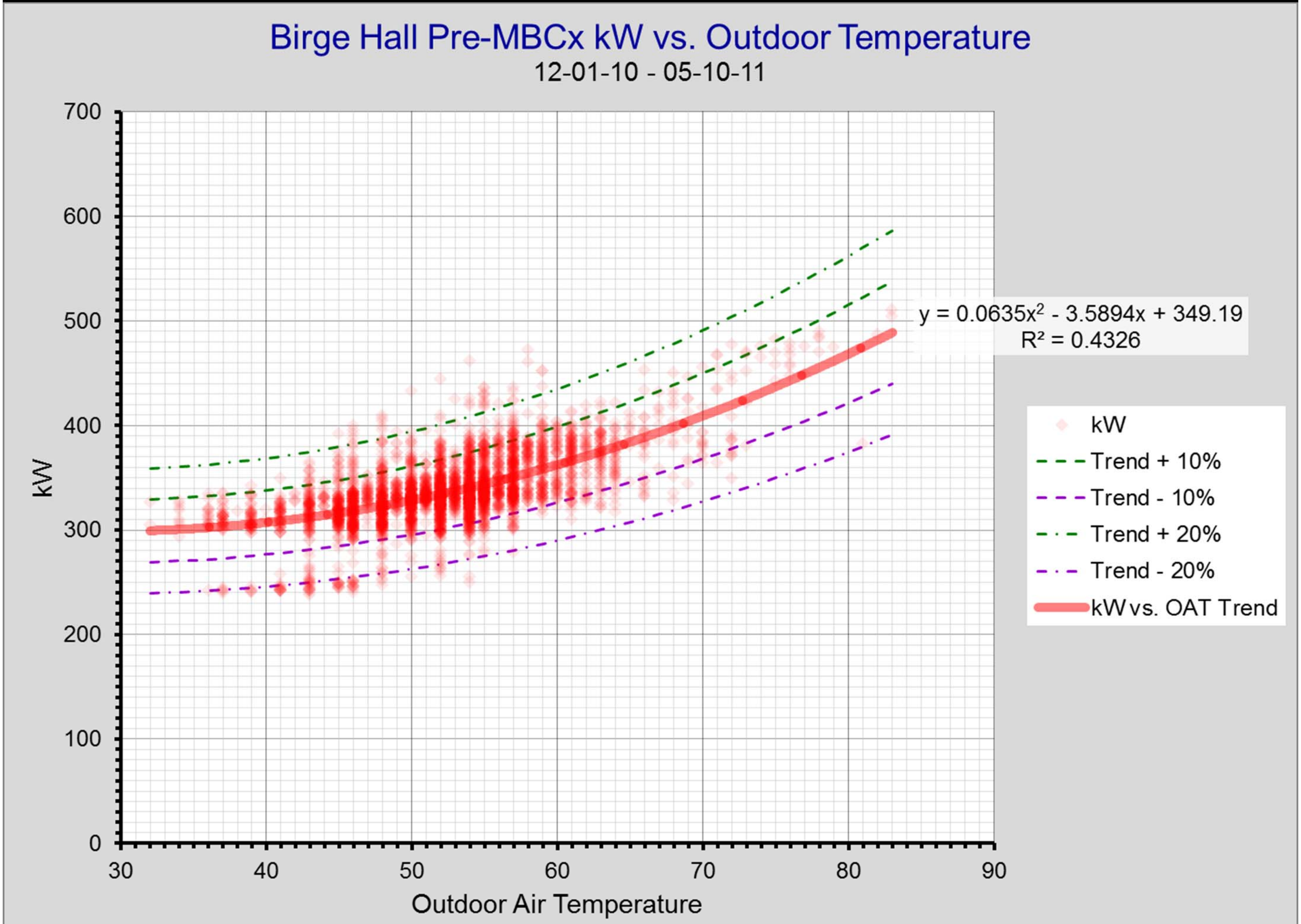
Looking for Shapes in the Clouds



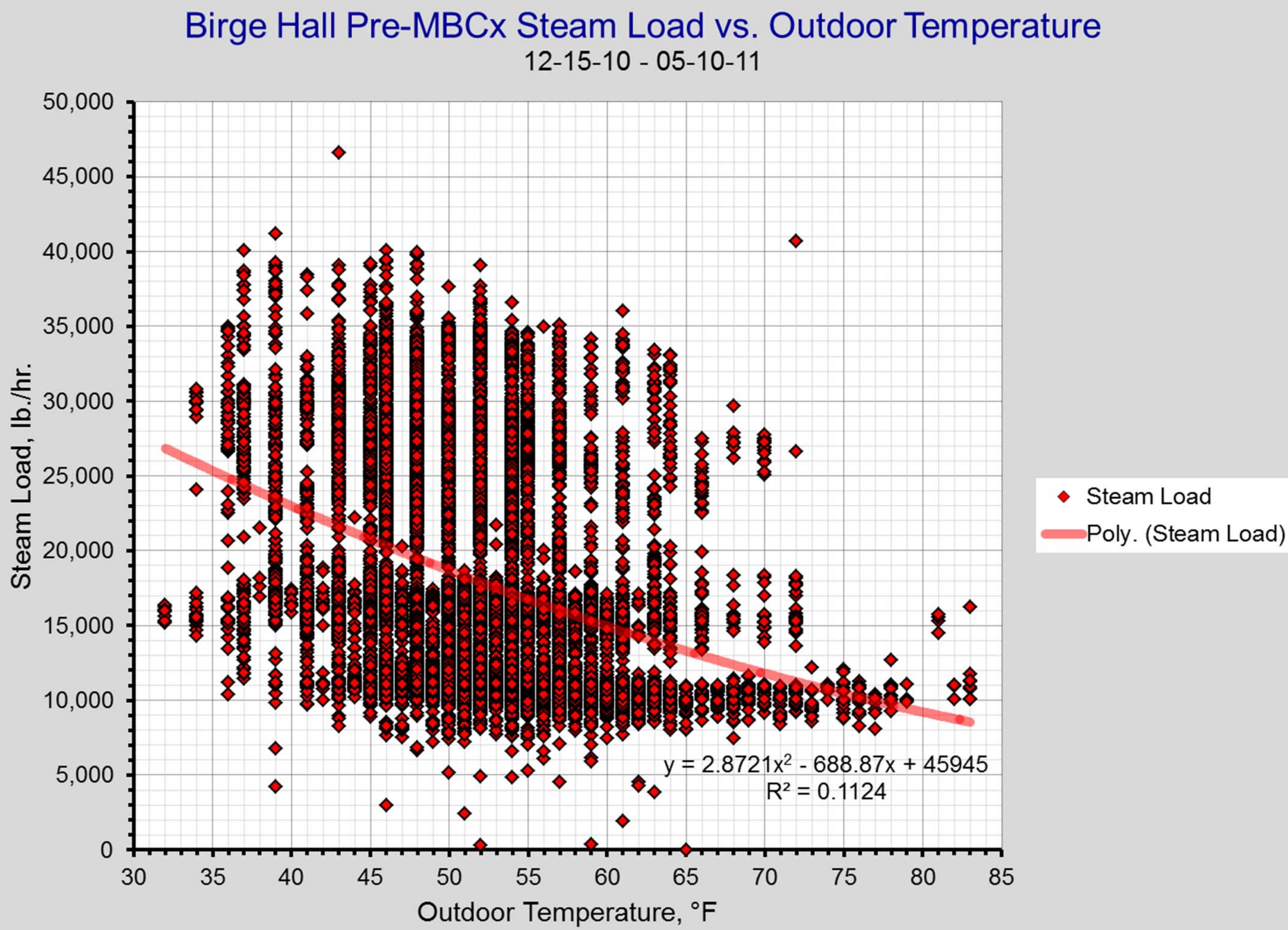

Birge Hall Pre-MBCx kW vs. Outdoor Temperature
12-01-10 - 05-10-11
700
600
500
400
300
200
100
0
kW
30
40
50
60
70
80
90
Outdoor Air Temperature
y = 0.0635x2 - 3.5894x + 349.19
R² = 0.4326
kW



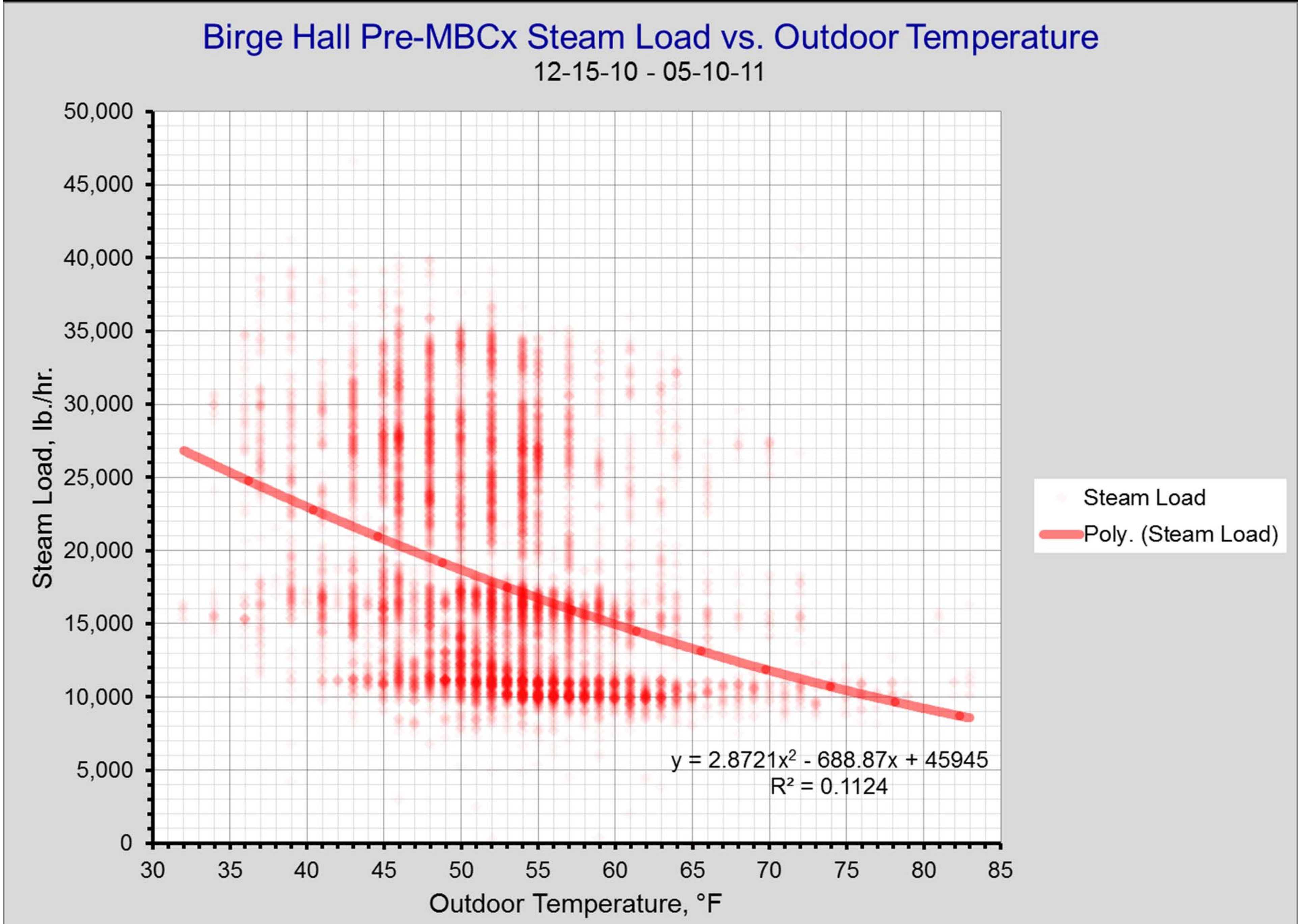
Birge Hall Pre-MBCx kW vs. Outdoor Temperature
12-01-10 - 05-10-11
700
600
500
400
300
200
100
0
kW
30
40
50
60
70
80
90
Outdoor Air Temperature
y = 0.0635x² - 3.5894x + 349.19
R² = 0.4326
kW
Trend + 10%
Trend - 10%
Trend + 20%
Trend - 20%
kW vs. OAT Trend



Birge Hall Pre-MBCx kW vs. Outdoor Temperature
12-01-10 - 05-10-11
kW
700
600
500
400
300
200
100
0
30
40
50
60
70
80
90
Outdoor Air Temperature
y = 0.0635x² - 3.5894x + 349.19
R² = 0.4326
kW
Trend + 10%
Trend - 10%
Trend + 20%
Trend - 20%
kW vs. OAT Trend



Birge Hall Pre-MBCx Steam Load vs. Outdoor Temperature
12-15-10 - 05-10-11
Steam Load, lb./hr.
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
30
35
40
45
50
55
60
65
70
75
80
85
Outdoor Temperature, °F
y = 2.8721x² - 688.87x + 45945
R² = 0.1124
Steam Load
Poly. (Steam Load)



Birge Hall Pre-MBCx Steam Load vs. Outdoor Temperature
12-15-10 - 05-10-11
Steam Load, lb./hr.
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
30
35
40
45
50
55
60
65
70
75
80
85
Outdoor Temperature, °F
Steam Load
Poly. (Steam Load)
y = 2.8721x² - 688.87x + 45945
R² = 0.1124

Mining Utility Interval Data

1. Start with a basic data set from a smart meter
   - Once a day is workable
   - Once an hour is better

     Once every 15 minutes may be possible

Address	607 LAWTON RD, MONTEREY, CA 93940						
Account Numbe	5491342676						
Service	5491342801						
TYPE	DATE	START TI	END TIM	USAGI	UNIT	COST	NOTES
Electric usage	6/9/2014	0:00	0:14	9.6	kWh	$1.52	
Electric usage	6/9/2014	0:15	0:29	9.12	kWh	$1.44	
Electric usage	6/9/2014	0:30	0:44	8.28	kWh	$1.31	
Electric usage	6/9/2014	0:45	0:59	8.88	kWh	$1.40	
Electric usage	6/9/2014	1:00	1:14	9.24	kWh	$1.46	
Electric usage	6/9/2014	1:15	1:29	8.28	kWh	$1.31	
Electric usage	6/9/2014	1:30	1:44	8.52	kWh	$1.34	
Electric usage	6/9/2014	1:45	1:59	9	kWh	$1.42	
Electric usage	6/9/2014	2:00	2:14	9.96	kWh	$1.57	
Electric usage	6/9/2014	2:15	2:29	8.28	kWh	$1.31	
Electric usage	6/9/2014	2:30	2:44	9	kWh	$1.42	
Electric usage	6/9/2014	2:45	2:59	8.28	kWh	$1.31	
Electric usage	6/9/2014	3:00	3:14	8.28	kWh	$1.31	
Electric usage	6/9/2014	3:15	3:29	9	kWh	$1.42	
Electric usage	6/9/2014	3:30	3:44	8.4	kWh	$1.33	
Electric usage	6/9/2014	3:45	3:59	8.28	kWh	$1.31	
Electric usage	6/9/2014	4:00	4:14	8.4	kWh	$1.33	
Electric usage	6/9/2014	4:15	4:29	9.12	kWh	$1.44	
Electric usage	6/9/2014	4:30	4:44	8.28	kWh	$1.31	

Mining Utility Interval Data

2. Combine the data and time stamps into one cell and then correlate the date and time with an outdoor air temperature or other data like occupancy, production, etc.

Address	607 LAWTON RD, MONTEREY, CA 93940								
Account Numbe	5491342676								
Service	5491342801								
TYPE	DATE	START TI	END TIM	USAGI	UNIT	COST	NOTES	Date and Time	Outdoor Temperature, °F
Electric usage	6/9/2014	0:00	0:14	9.6	kWh	$1.52		6/9/2014 0:00	57.90
Electric usage	6/9/2014	0:15	0:29	9.12	kWh	$1.44		6/9/2014 0:15	57.20
Electric usage	6/9/2014	0:30	0:44	8.28	kWh	$1.31		6/9/2014 0:30	57.20
Electric usage	6/9/2014	0:45	0:59	8.88	kWh	$1.40		6/9/2014 0:45	57.20
Electric usage	6/9/2014	1:00	1:14	9.24	kWh	$1.46		6/9/2014 1:00	55.90
Electric usage	6/9/2014	1:15	1:29	8.28	kWh	$1.31		6/9/2014 1:15	55.40
Electric usage	6/9/2014	1:30	1:44	8.52	kWh	$1.34		6/9/2014 1:30	55.40
Electric usage	6/9/2014	1:45	1:59	9	kWh	$1.42		6/9/2014 1:45	55.40
Electric usage	6/9/2014	2:00	2:14	9.96	kWh	$1.57		6/9/2014 2:00	55.90
Electric usage	6/9/2014	2:15	2:29	8.28	kWh	$1.31		6/9/2014 2:15	55.40
Electric usage	6/9/2014	2:30	2:44	9	kWh	$1.42		6/9/2014 2:30	55.40
Electric usage	6/9/2014	2:45	2:59	8.28	kWh	$1.31		6/9/2014 2:45	55.40
Electric usage	6/9/2014	3:00	3:14	8.28	kWh	$1.31		6/9/2014 3:00	55.90
Electric usage	6/9/2014	3:15	3:29	9	kWh	$1.42		6/9/2014 3:15	55.40
Electric usage	6/9/2014	3:30	3:44	8.4	kWh	$1.33		6/9/2014 3:30	55.40
Electric usage	6/9/2014	3:45	3:59	8.28	kWh	$1.31		6/9/2014 3:45	53.60
Electric usage	6/9/2014	4:00	4:14	8.4	kWh	$1.33		6/9/2014 4:00	55.00
Electric usage	6/9/2014	4:15	4:29	9.12	kWh	$1.44		6/9/2014 4:15	55.00
Electric usage	6/9/2014	4:30	4:44	8.28	kWh	$1.31		6/9/2014 4:30	55.00

Mining Utility Interval Data

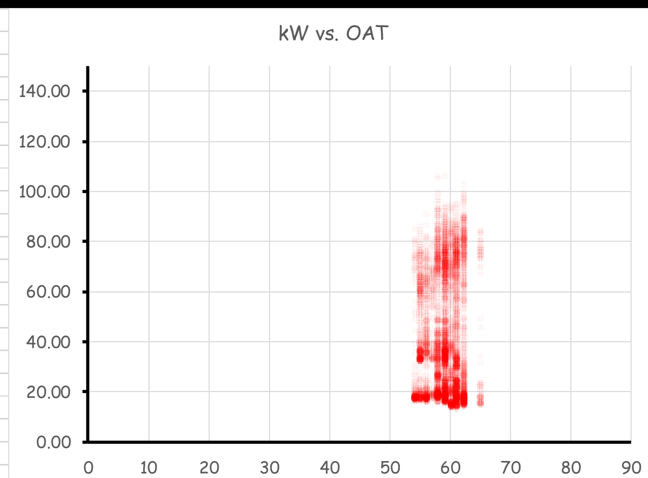
3. Use Excel Functions to break out useful data like kW and data that can be used as a "filter" like hour of day, day of week, month, etc.

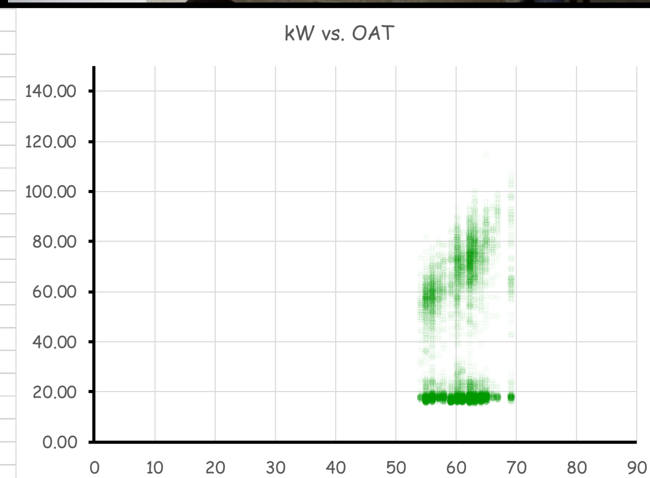
Address	607 LAWTON RD, MONTEREY, CA 93940																			
Account Numbe	5491342676																			
Service	5491342801																			
TYPE	DATE	START TI	END TIM	USAGI	UNIT	COST	NOTES	Date and Time	Outdoor Temperature, °F	Time interval, Hours	Demand, kW	Year	Month	Day of Month	Day of Week (Sunday is 1)	Year and Month	Hour of Day	Interval Counter	1 if demand is above 20 kW	1 if demand is above 50 kW
Electric usage	6/9/2014	0:00	0:14	9.6	kWh	$1.52		6/9/2014 0:00	57.90			2014	6	9	2	2014/6	0	1	0	0
Electric usage	6/9/2014	0:15	0:29	9.12	kWh	$1.44		6/9/2014 0:15	57.20	0.25	36.48	2014	6	9	2	2014/6	0	1	1	0
Electric usage	6/9/2014	0:30	0:44	8.28	kWh	$1.31		6/9/2014 0:30	57.20	0.25	33.12	2014	6	9	2	2014/6	0	1	1	0
Electric usage	6/9/2014	0:45	0:59	8.88	kWh	$1.40		6/9/2014 0:45	57.20	0.25	35.52	2014	6	9	2	2014/6	0	1	1	0
Electric usage	6/9/2014	1:00	1:14	9.24	kWh	$1.46		6/9/2014 1:00	55.90	0.25	36.96	2014	6	9	2	2014/6	1	1	1	0
Electric usage	6/9/2014	1:15	1:29	8.28	kWh	$1.31		6/9/2014 1:15	55.40	0.25	33.12	2014	6	9	2	2014/6	1	1	1	0
Electric usage	6/9/2014	1:30	1:44	8.52	kWh	$1.34		6/9/2014 1:30	55.40	0.25	34.08	2014	6	9	2	2014/6	1	1	1	0
Electric usage	6/9/2014	1:45	1:59	9	kWh	$1.42		6/9/2014 1:45	55.40	0.25	36.00	2014	6	9	2	2014/6	1	1	1	0
Electric usage	6/9/2014	2:00	2:14	9.96	kWh	$1.57		6/9/2014 2:00	55.90	0.25	39.84	2014	6	9	2	2014/6	2	1	1	0
Electric usage	6/9/2014	2:15	2:29	8.28	kWh	$1.31		6/9/2014 2:15	55.40	0.25	33.12	2014	6	9	2	2014/6	2	1	1	0
Electric usage	6/9/2014	2:30	2:44	9	kWh	$1.42		6/9/2014 2:30	55.40	0.25	36.00	2014	6	9	2	2014/6	2	1	1	0
Electric usage	6/9/2014	2:45	2:59	8.28	kWh	$1.31		6/9/2014 2:45	55.40	0.25	33.12	2014	6	9	2	2014/6	2	1	1	0
Electric usage	6/9/2014	3:00	3:14	8.28	kWh	$1.31		6/9/2014 3:00	55.90	0.25	33.12	2014	6	9	2	2014/6	3	1	1	0
Electric usage	6/9/2014	3:15	3:29	9	kWh	$1.42		6/9/2014 3:15	55.40	0.25	36.00	2014	6	9	2	2014/6	3	1	1	0
Electric usage	6/9/2014	3:30	3:44	8.4	kWh	$1.33		6/9/2014 3:30	55.40	0.25	33.60	2014	6	9	2	2014/6	3	1	1	0
Electric usage	6/9/2014	3:45	3:59	8.28	kWh	$1.31		6/9/2014 3:45	53.60	0.25	33.12	2014	6	9	2	2014/6	3	1	1	0
Electric usage	6/9/2014	4:00	4:14	8.4	kWh	$1.33		6/9/2014 4:00	55.00	0.25	33.60	2014	6	9	2	2014/6	4	1	1	0
Electric usage	6/9/2014	4:15	4:29	9.12	kWh	$1.44		6/9/2014 4:15	55.00	0.25	36.48	2014	6	9	2	2014/6	4	1	1	0
Electric usage	6/9/2014	4:30	4:44	8.28	kWh	$1.31		6/9/2014 4:30	55.00	0.25	33.12	2014	6	9	2	2014/6	4	1	1	0

Mining Utility Interval Data

4. Have Fun

	Before	After
Hours in data set -	10,919	10,919
Hours infiltered data set -	2,016	2,208
kWh -	75,908	72,600



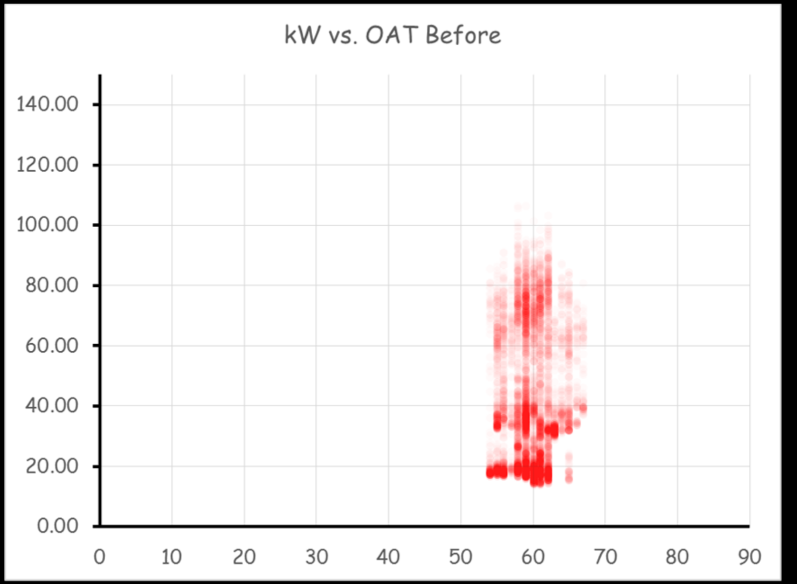


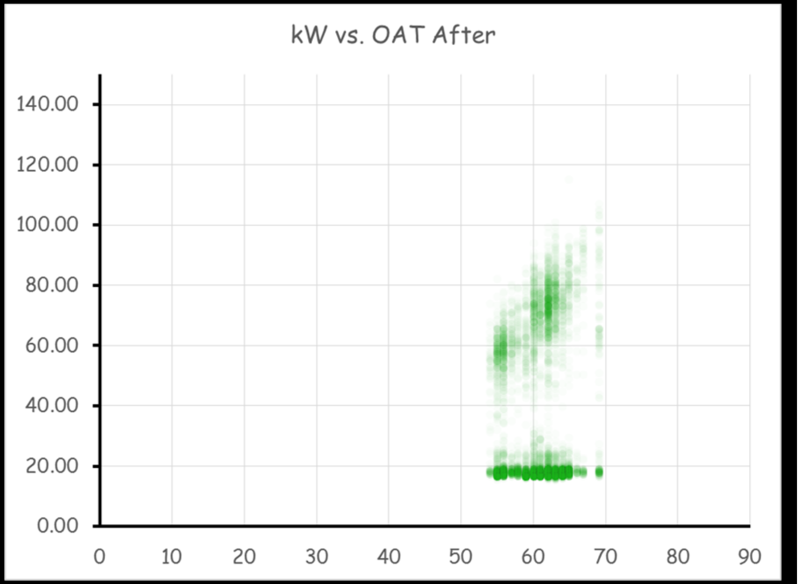
USAGE	UNITS	COST	NOTES	Time interval, Hours	Demand, kW	Outdoor Temperature, °F	Year	Month	Day of Month	Day of Week (Sunday is 1)	Year and Month	Hour of Day	Interval Counter	1 if demand is above 20 kW	1 if demand is above 50 kW
9.6	kWh	$1.52				57.90	2014	6	9	2	2014/6	0	1	0	0
9.12	kWh	$1.44		0.25	36.48	57.90	2014	6	9	2	2014/6	0	1	1	0
8.28	kWh	$1.31		0.25	33.12	57.90	2014	6	9	2	2014/6	0	1	1	0
8.88	kWh	$1.40		0.25	35.52	57.90	2014	6	9	2	2014/6	0	1	1	0
9.24	kWh	$1.46		0.25	36.96	57.90	2014	6	9	2	2014/6	1	1	1	0

Mining Utility Interval Data

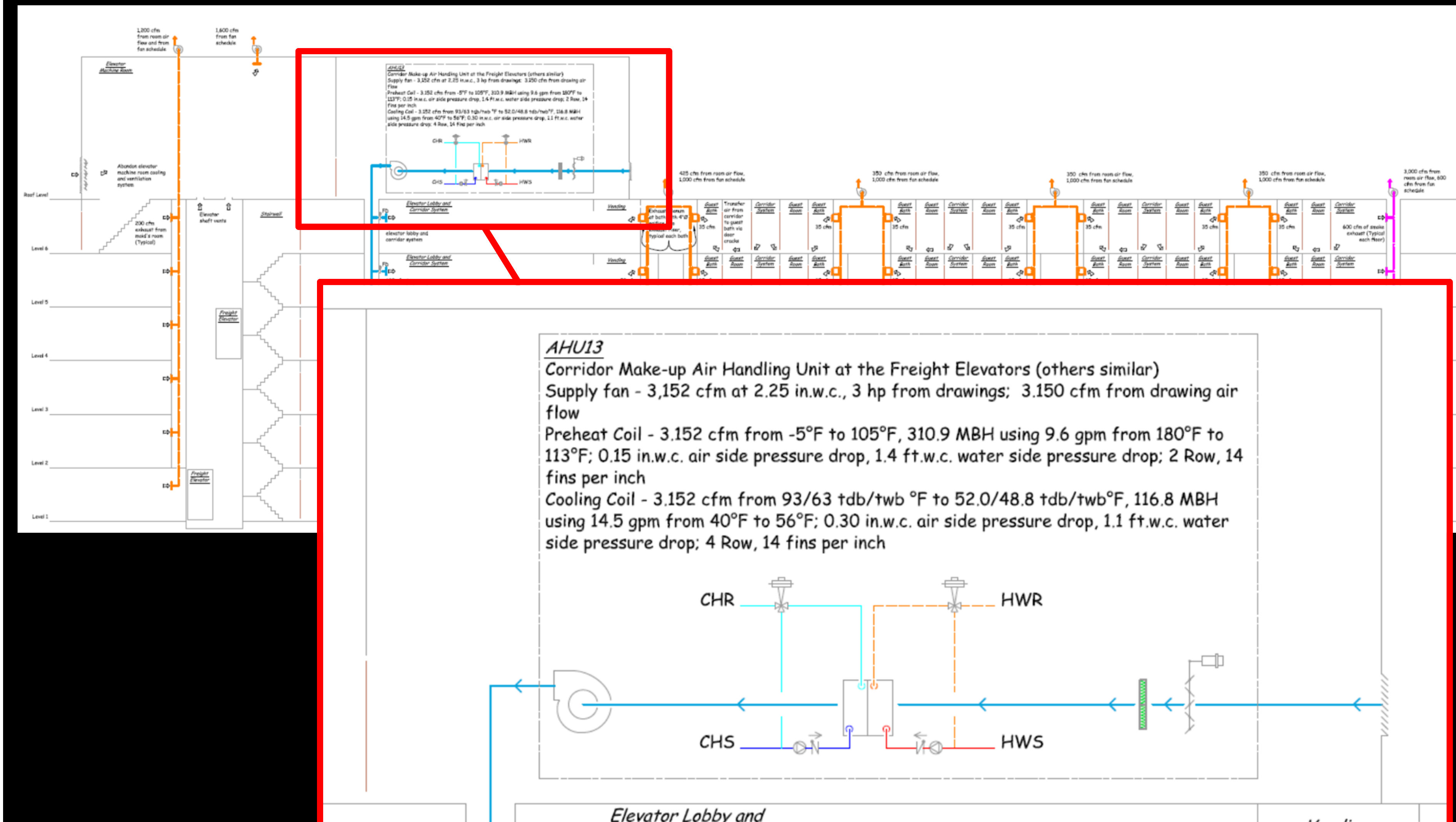
When the consumption pattern changes, the cloud pattern changes

- Good Measurement and Verification (M&V) tool
- Good persistence tool

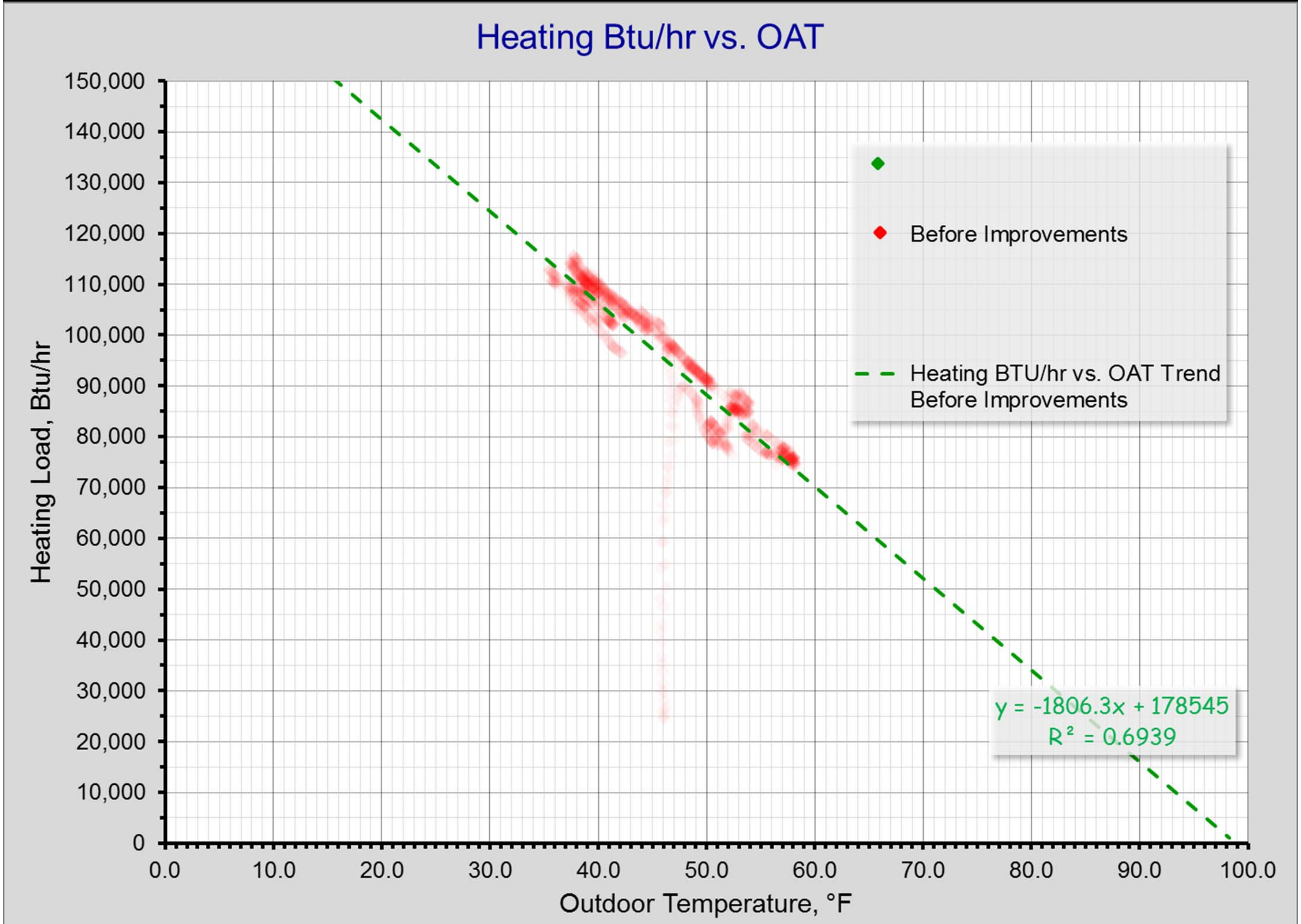


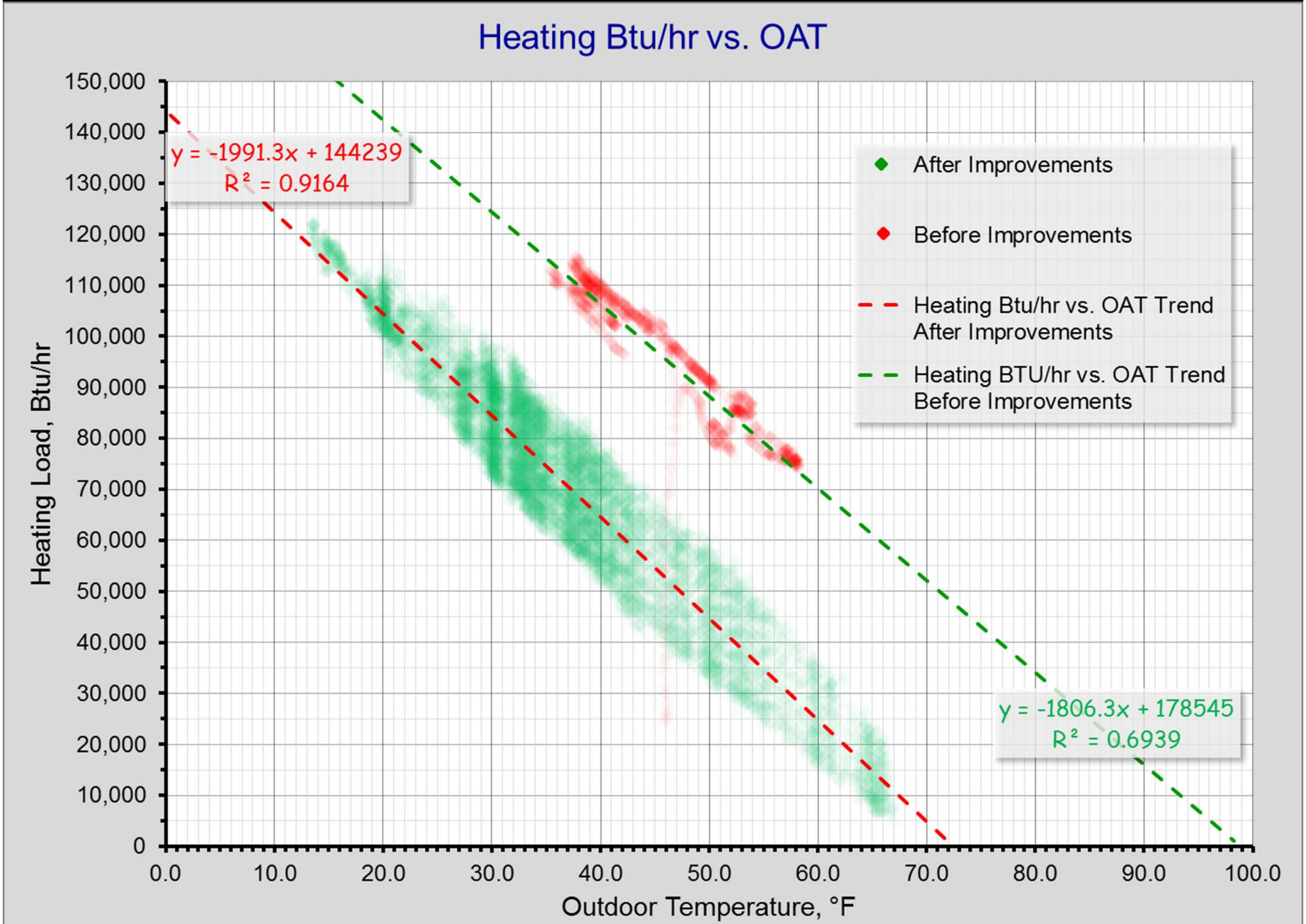


Applied at a System Level

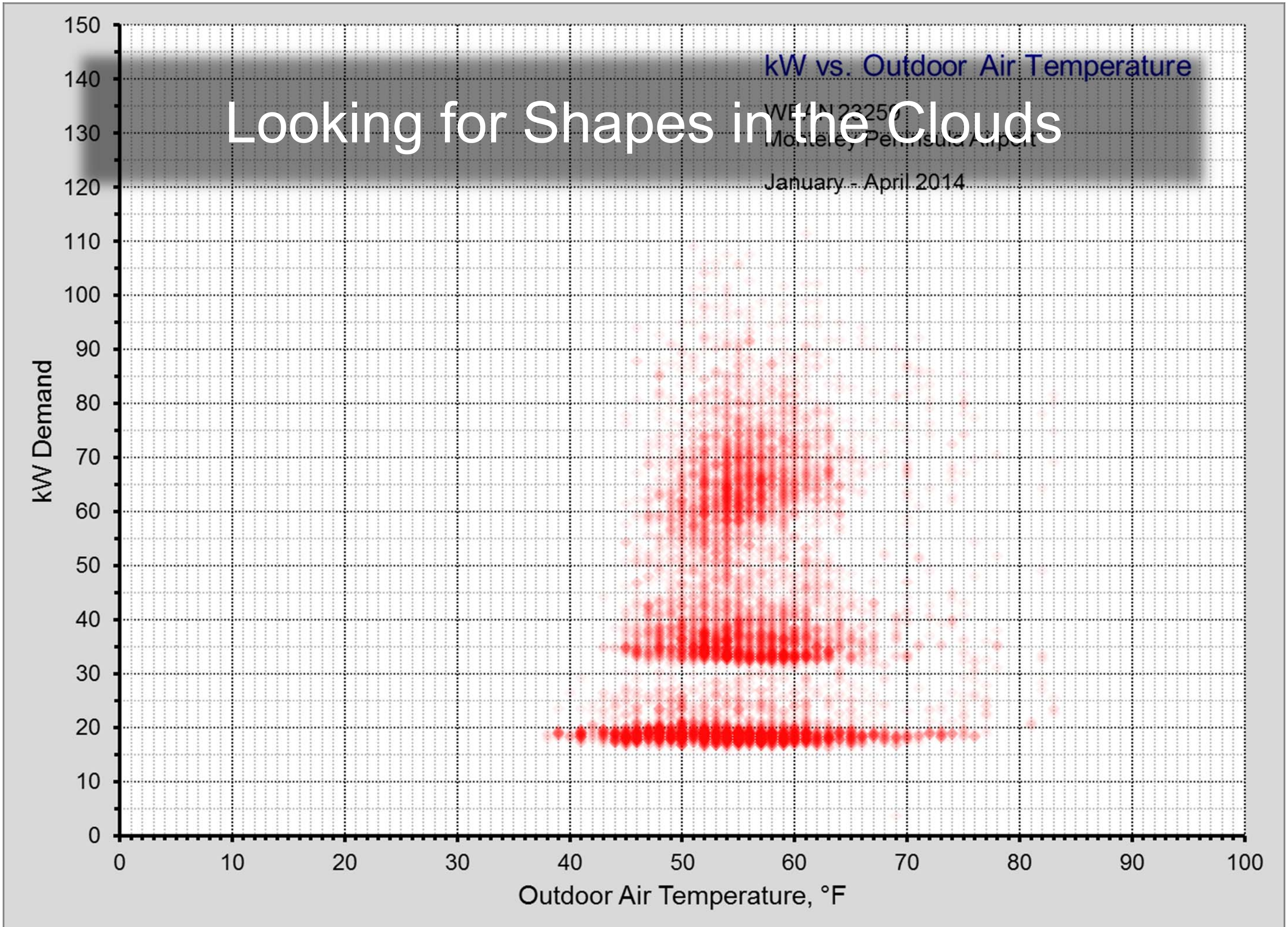


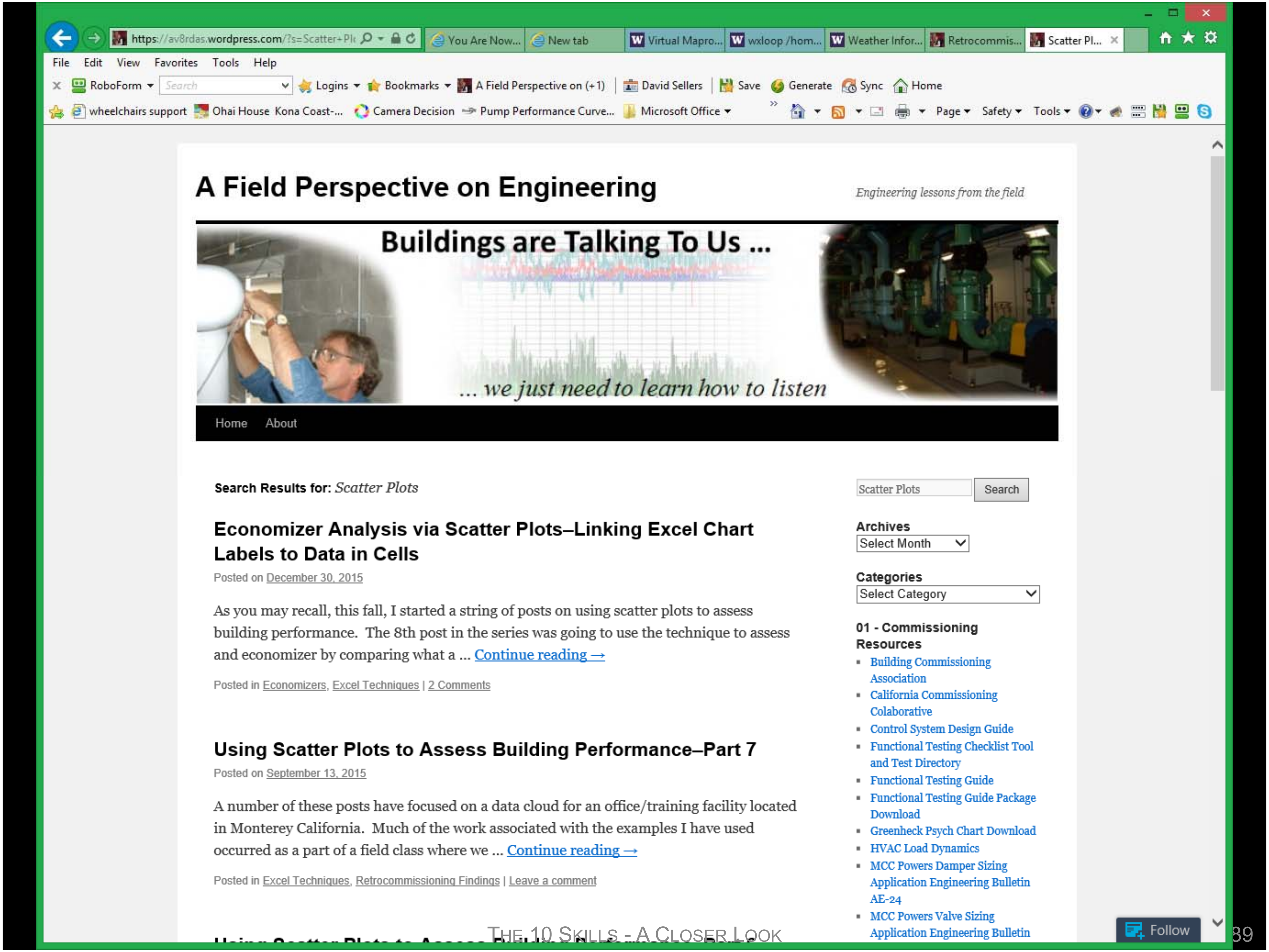
Regressions and Savings Assessments


Heating Btu/hr vs. OAT
Heating Load, Btu/hr
150,000
140,000
130,000
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
Outdoor Temperature, °F
Before Improvements
Heating BTU/hr vs. OAT Trend Before Improvements
y = -1806.3x + 178545
R² = 0.6939


Heating Btu/hr vs. OAT
y = -1991.3x + 144239
R² = 0.9164
After Improvements
Before Improvements
Heating Btu/hr vs. OAT Trend After Improvements
Heating BTU/hr vs. OAT Trend Before Improvements
y = -1806.3x + 178545
R² = 0.6939
Heating Load, Btu/hr
Outdoor Temperature, °F
150,000
140,000
130,000
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0

Looking for Shapes in the Clouds





A Field Perspective on Engineering

Engineering lessons from the field

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Search Results for: *Scatter Plots*

Economizer Analysis via Scatter Plots–Linking Excel Chart Labels to Data in Cells

Posted on December 30, 2015

As you may recall, this fall, I started a string of posts on using scatter plots to assess building performance. The 8th post in the series was going to use the technique to assess and economizer by comparing what a … Continue reading →

Posted in Economizers, Excel Techniques | 2 Comments

Using Scatter Plots to Assess Building Performance–Part 7

Posted on September 13, 2015

A number of these posts have focused on a data cloud for an office/training facility located in Monterey California. Much of the work associated with the examples I have used occurred as a part of a field class where we … Continue reading →

Posted in Excel Techniques, Retrocommissioning Findings | Leave a comment

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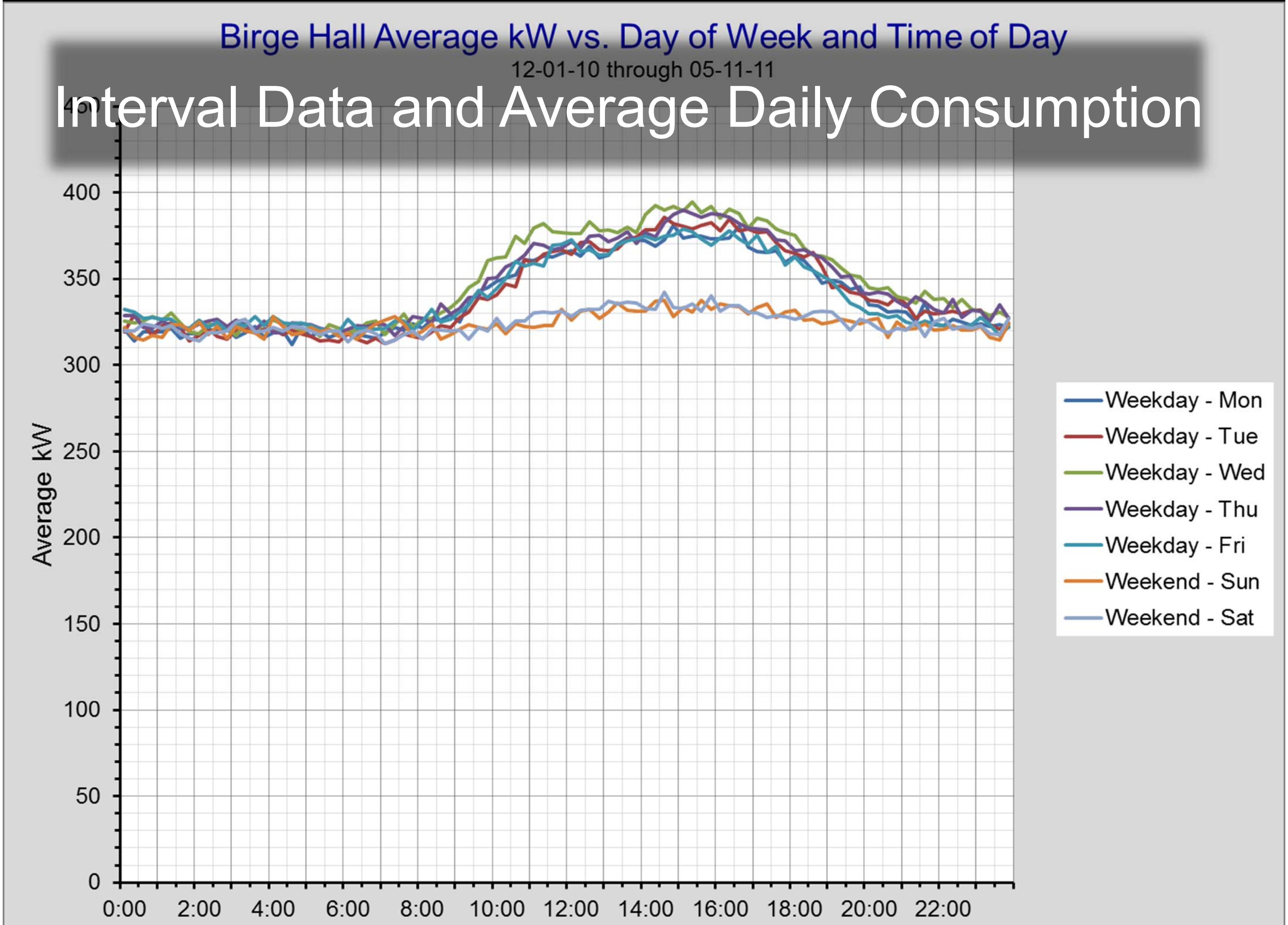
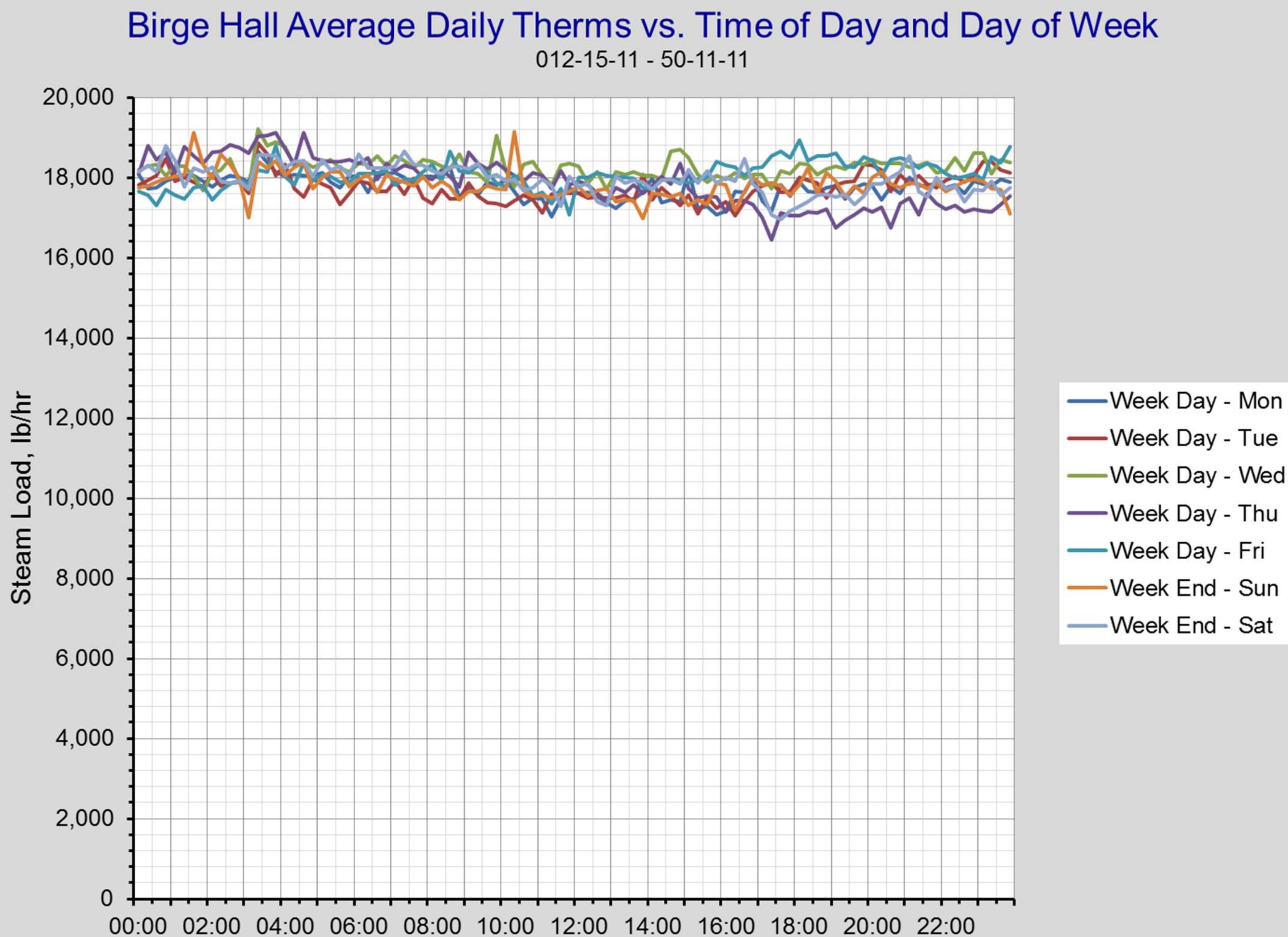
Follow

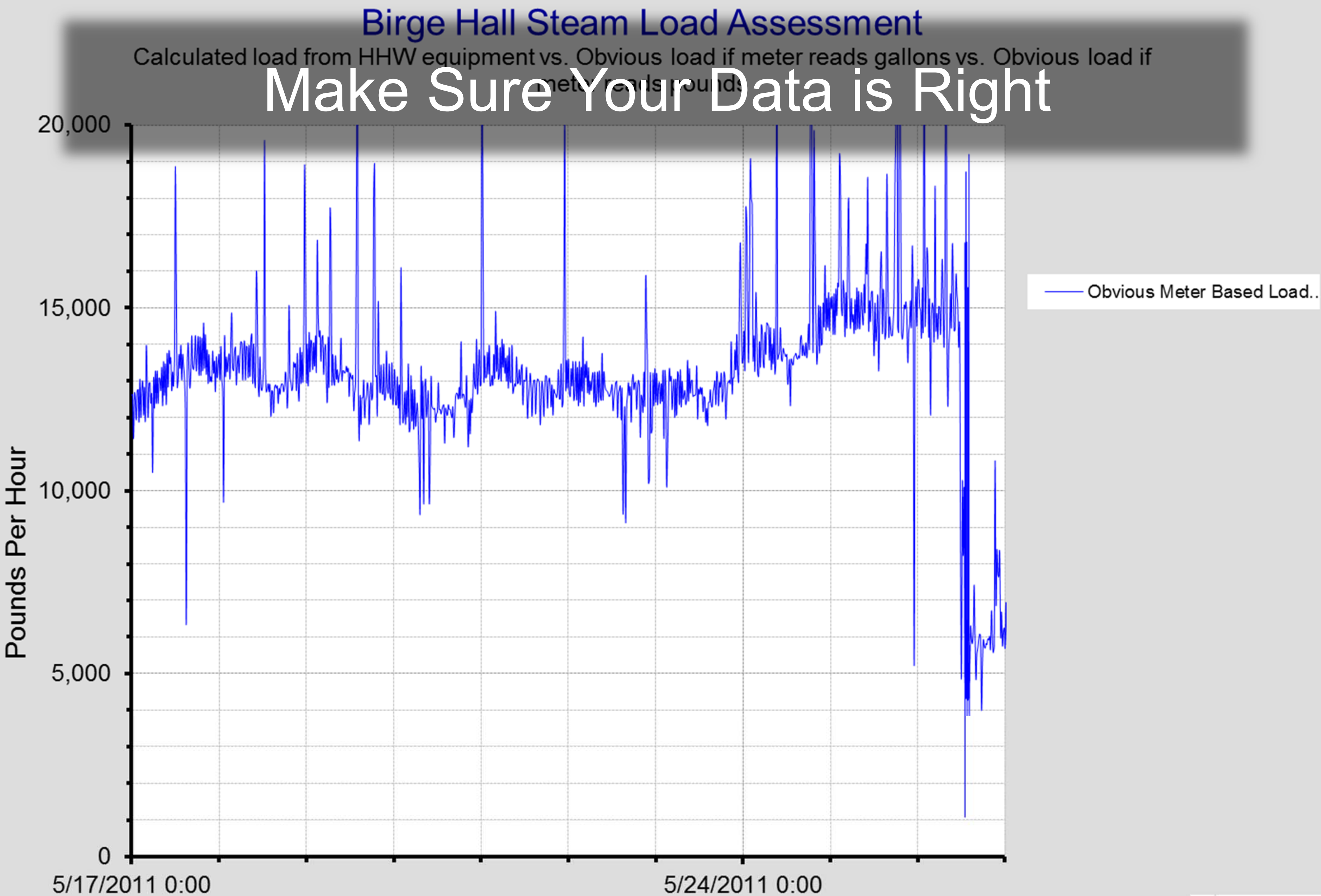
Interval Data and Average Daily Consumption





Birge Hall Average Daily Therms vs. Time of Day and Day of Week
012-15-11 - 50-11-11
Steam Load, lb/hr
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
00:00
02:00
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Week Day - Mon
Week Day - Tue
Week Day - Wed
Week Day - Thu
Week Day - Fri
Week End - Sun
Week End - Sat

Make Sure Your Data is Right



Load Projections Based on Equipment and SEP Metrics

Steam loads from original drawing capacities

Item	Rating, lb/hr	Assumed load	Comment
DHW Heaters	4,000	2,000	Rating based on trap rating from original drawings, Suspect real consumption is minimal and very intermittent
HHW Hx	6,500	3,250	Assumed load based on pump rated flow at design temperature rise
Still	90	45	3/4" line, assumed very intermittent
Future loads	Unknown	0	1" capped connection on each floor is available
TOTAL	10,590	5,295	

Steam loads from original equipment metrics

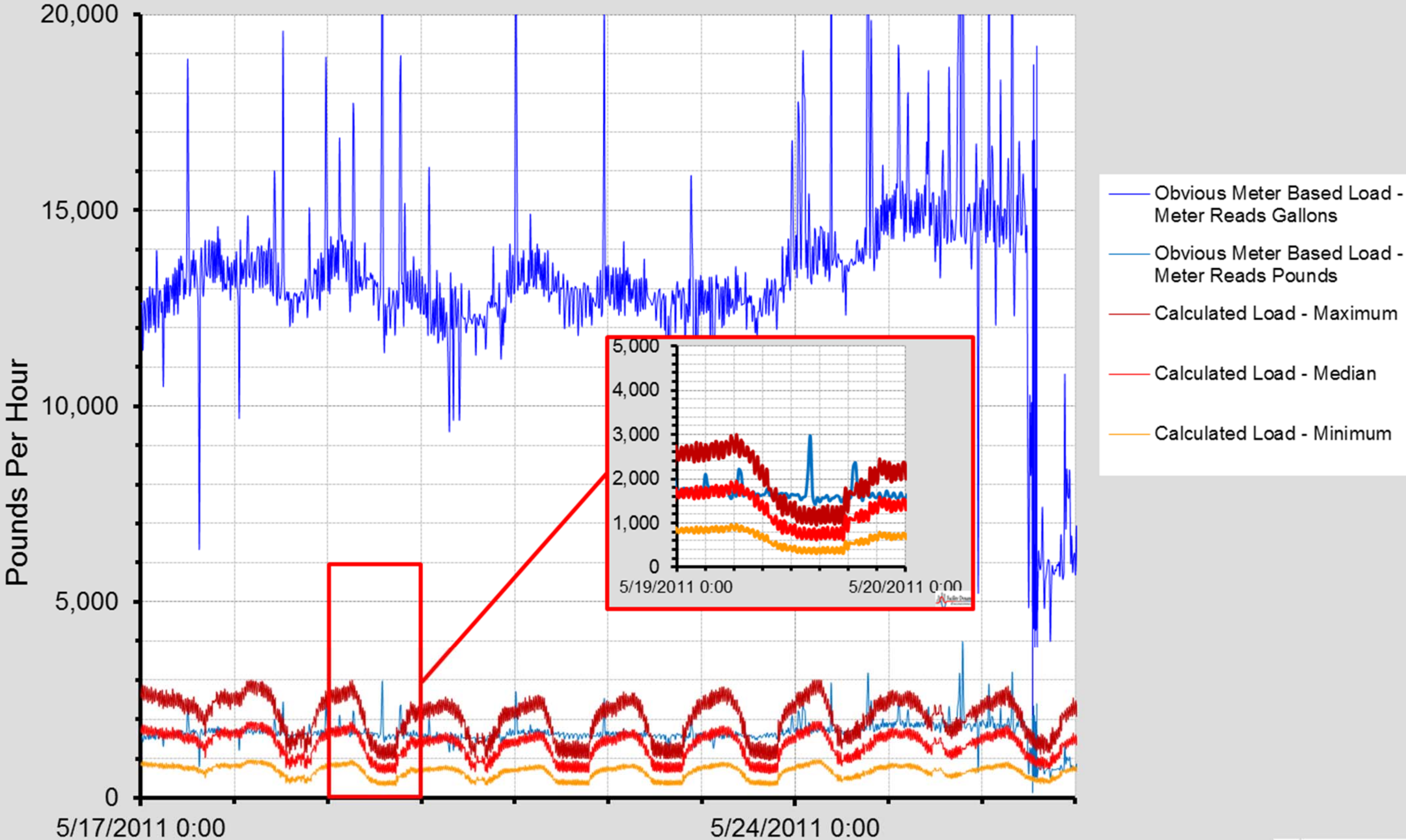
Original steam meter size -	12,000	lb/hr (from original drawings)
Steam PRV station rating for HHW Hx -	7,500	lb/hr (from original drawings)
Original Hx Rating -	6,500	lb/hr (from original drawings)
HW system rating - 500 x pump gpm x Δt -	3,250	lb/hr (from original drawings)

Steam loads from SEP metrics

SEP Annual Consumption Metric -	113,750	therms/year at the central plant
SEP steam system efficiency -	12.5	th/MMBtu
-	80%	
SEP metric at the building -	91,000	therms/year at the building
-	10	therms/hour average
-	1,039	lb/hr
Building squarefootage -	97,768	sq.ft.
Index -	1.16	therms per sq.ft per year

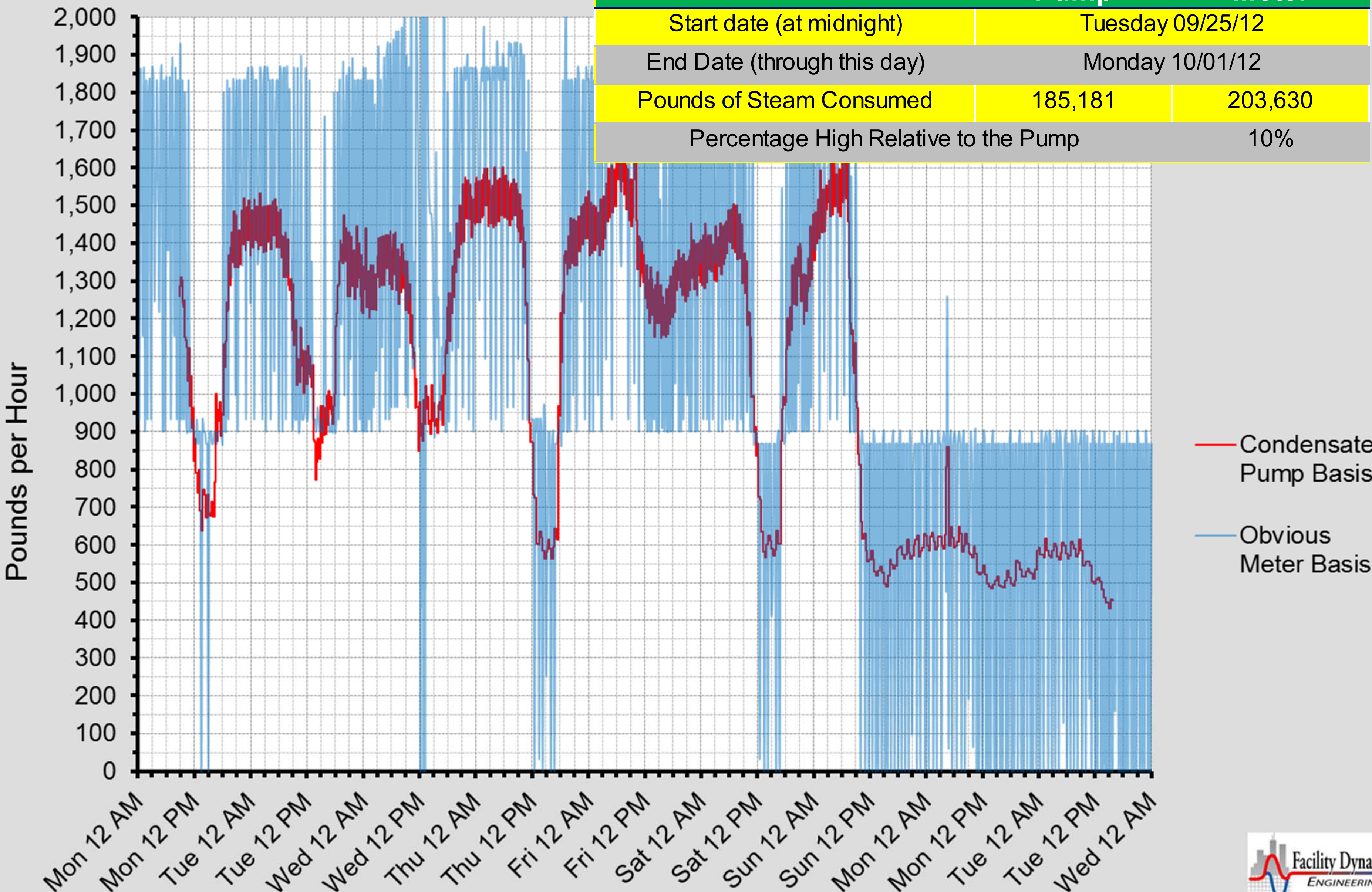
Birge Hall Steam Load Assessment

Calculated load from HHW equipment vs. Obvious load if meter reads gallons vs. Obvious load if meter reads pounds



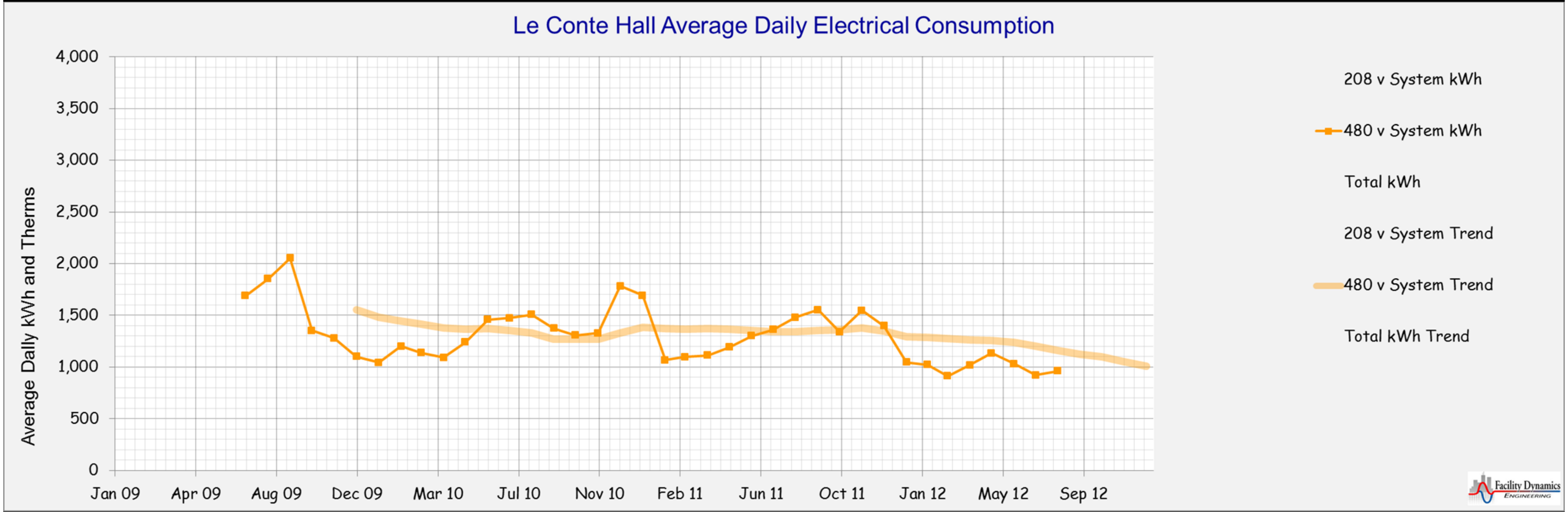
Birge Hall Condensate Pump Based Steam Consumption vs. Obvio

Monday, Septembe

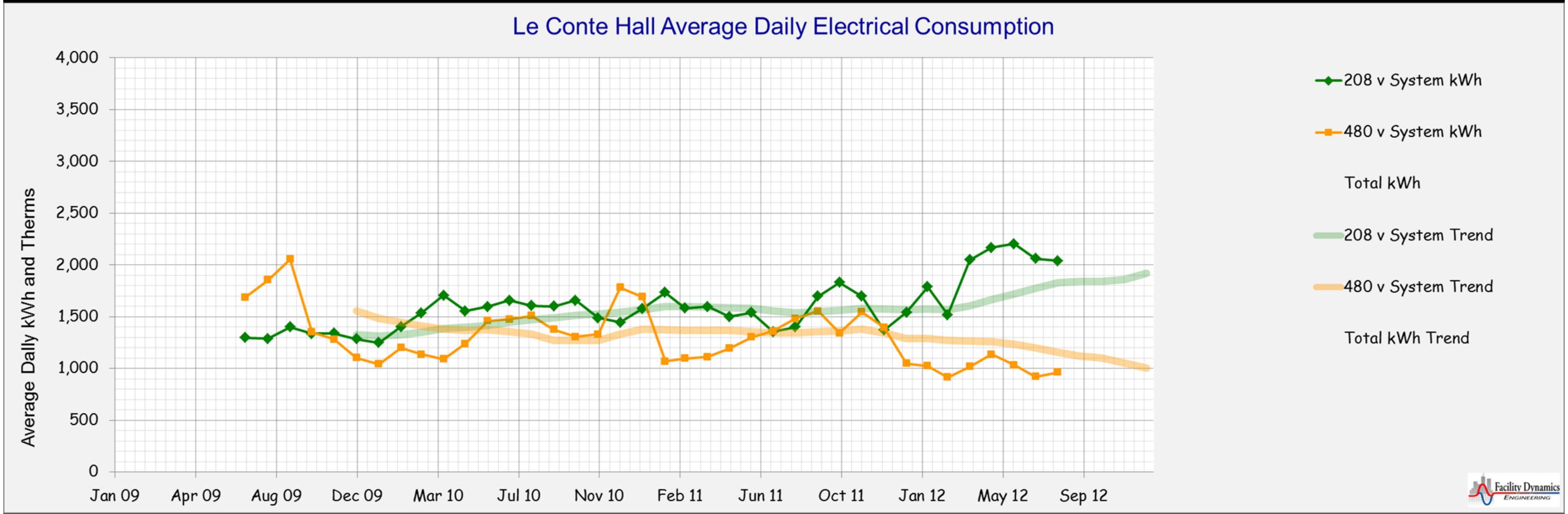


Basis	Condensate Pump	Obvious Meter
Start date (at midnight)	Tuesday 09/25/12	
End Date (through this day)	Monday 10/01/12	
Pounds of Steam Consumed	185,181	203,630
Percentage High Relative to the Pump		10%

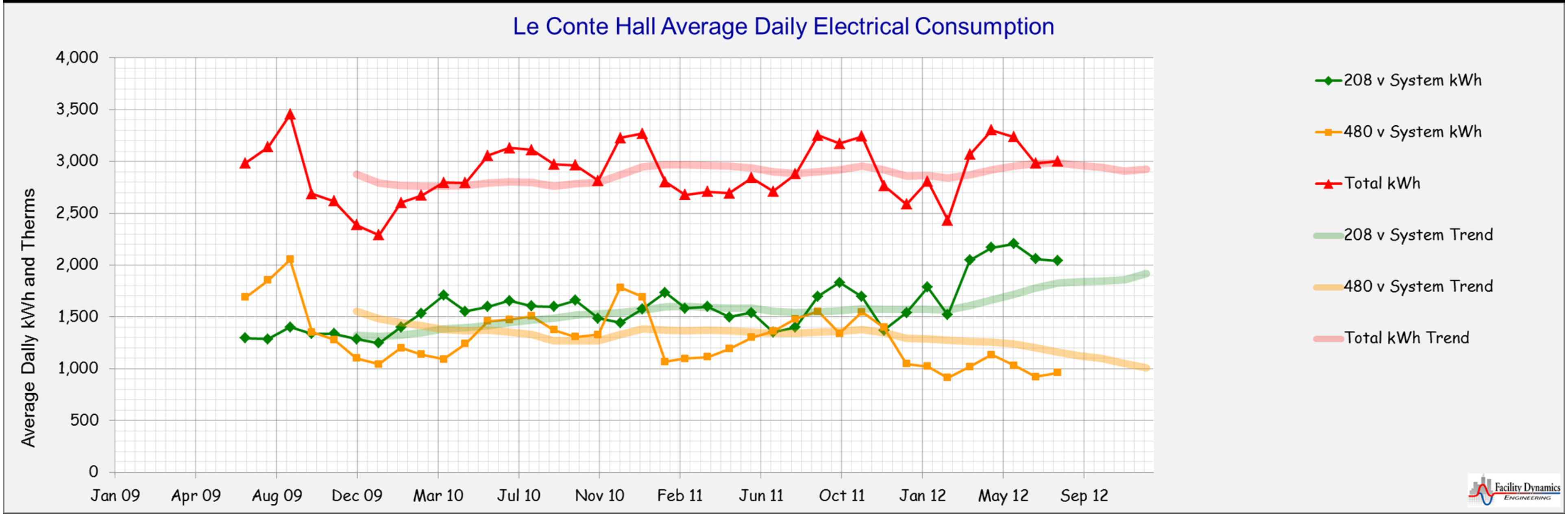
Success in One Area can be Masked by Increasing Loads in Other Areas



Success in One Area can be Masked by Increasing Loads in Other Areas



Success in One Area can be Masked by Increasing Loads in Other Areas



Skill 02 – Scoping

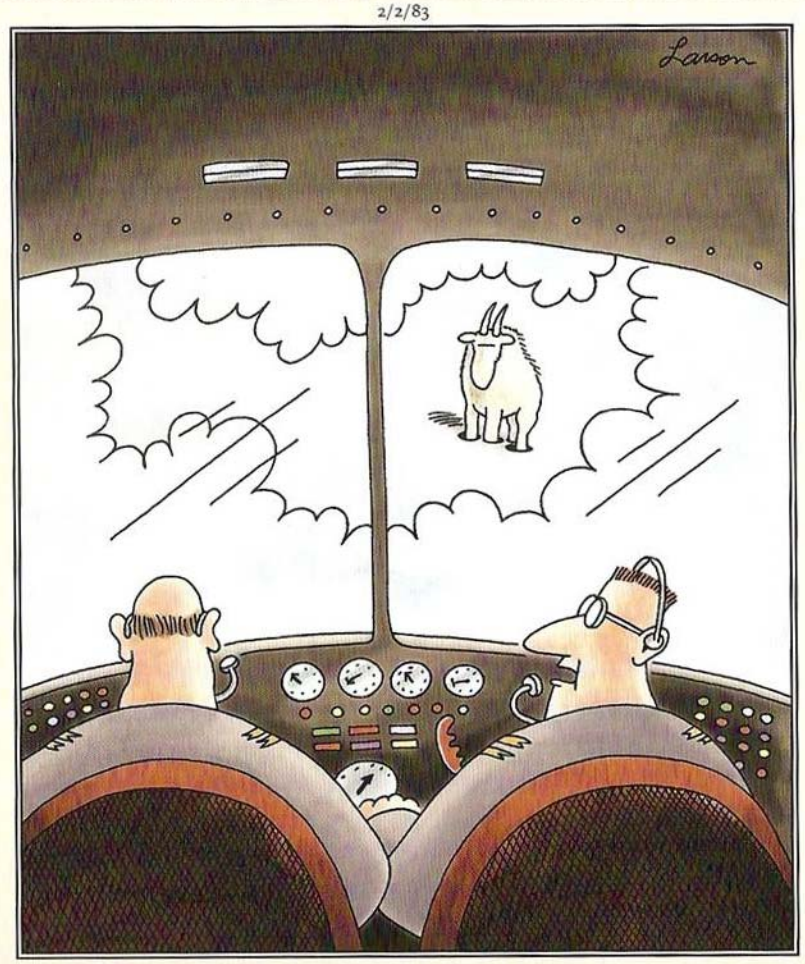
Learning Objectives

- Learn how to connect the dots between physical realities and fundamental physics
- Develop a familiarity with the physical principles that apply the building systems and HVAC.
- Learn to trust your “gut” and “follow your nose”.

Skill 02 – Scoping

Looking for Obvious Clues

- Do things make sense?
  - Should the outdoor air dampers be open or closed given the current conditions?
  - Should the chilled water coil be active given the current conditions?
  - Are things running when they don't need to run?



"Say ... what's a mountain goat doing way up here in a cloud bank?"

What’s Obvious to One May Not Be Obvious to Another

Skill 02 – Scoping

Applying Fundamental Principles can be Helpful

- Fundamental principle

  Power used over time is energy

$$kWh = kW \times Hours_{kWLevel}$$

- Helpful insights
  1. *If I optimize the number of hours that a machine operates, I will save energy*
  2. *If I reduce the power required by a machine to operate for any period of time, I will save energy*

Skill 02 – Scoping

Applying Fundamental Principles can be Helpful

- Fundamental principle

Pump power is a direct function of the flow and head produced

- Helpful insights
  1. *If I reduce the head or the flow, I will reduce the power required*
  2. *If there is unnecessary head or flow that I can eliminate, I will reduce the power required*

$$Bhp_{Pump} = \left(\frac{Flow \times Head}{3{,}960 \times Efficiency_{Pump}} \right)$$

$$kW_{Pump} = 0.746 \times Bhp_{Pump}$$

Skill 02 – Scoping

Applying Fundamental Principles can be Helpful

$$Pressure_{New} = Pressure_{Old} \times \left(\frac{Flow_{New}}{Flow_{Old}} \right)^2$$

- Fundamental principle

  Head required varies as the square of the flow

- Helpful insights
  1. *If I cut the flow in half the pressure required to produce it will be cut to 25% of what it was for a fixed system*
  2. *For a fixed system, pump power will vary in proportion to the cube of the flow*

Skill 02 – Scoping

Applying Fundamental Principles can be Helpful

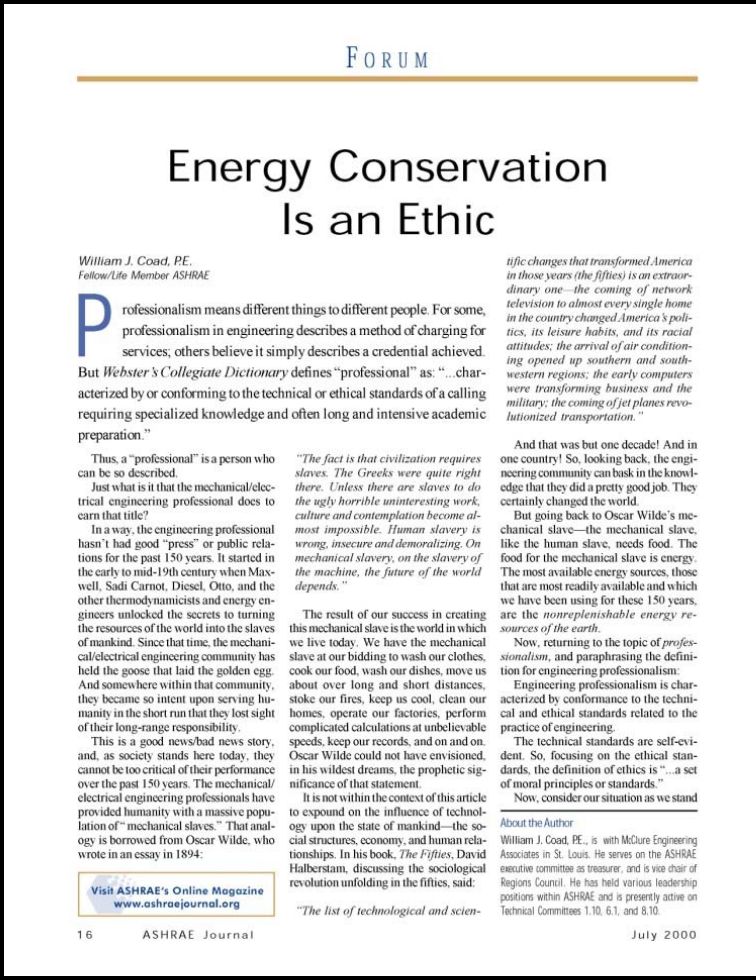
- Fundamental principle

As an engineer, I my actions will result in the expenditure of energy and other resources

- Helpful insight

I have more than a technical and financial responsibility for resource expenditures, I also have an ethical responsibility

http://tinyurl.com/EnergyEthic



FORUM

Energy Conservation Is an Ethic

William J. Coad, P.E.
Fellow/Life Member ASHRAE

Professionalism means different things to different people. For some, professionalism in engineering describes a method of charging for services; others believe it simply describes a credential achieved. But *Webster's Collegiate Dictionary* defines "professional" as: "...characterized by or conforming to the technical or ethical standards of a calling requiring specialized knowledge and often long and intensive academic preparation."

Thus, a "professional" is a person who can be so described.

Just what is it that the mechanical/electrical engineering professional does to earn that title?

In a way, the engineering professional hasn't had good "press" or public relations for the past 150 years. It started in the early to mid-19th century when Maxwell, Sadi Carnot, Diesel, Otto, and the other thermodynamicists and energy engineers unlocked the secrets to turning the resources of the world into the slaves of mankind. Since that time, the mechanical/electrical engineering community has held the goose that laid the golden egg. And somewhere within that community, they became so intent upon serving humanity in the short run that they lost sight of their long-range responsibility.

This is a good news/bad news story, and, as society stands here today, they cannot be too critical of their performance over the past 150 years. The mechanical/electrical engineering professionals have provided humanity with a massive population of "mechanical slaves." That analogy is borrowed from Oscar Wilde, who wrote in an essay in 1894:

"The fact is that civilization requires slaves. The Greeks were quite right there. Unless there are slaves to do the ugly horrible uninteresting work, culture and contemplation become almost impossible. Human slavery is wrong, insecure and demoralizing. On mechanical slavery, on the slavery of the machine, the future of the world depends."

The result of our success in creating this mechanical slave is the world in which we live today. We have the mechanical slave at our bidding to wash our clothes, cook our food, wash our dishes, move us about over long and short distances, stoke our fires, keep us cool, clean our homes, operate our factories, perform complicated calculations at unbelievable speeds, keep our records, and on and on. Oscar Wilde could not have envisioned, in his wildest dreams, the prophetic significance of that statement.

It is not within the context of this article to expound on the influence of technology upon the state of mankind—the social structures, economy, and human relationships. In his book, *The Fifties*, David Halberstam, discussing the sociological revolution unfolding in the fifties, said:

"The list of technological and scientific changes that transformed America in those years (the fifties) is an extraordinary one—the coming of network television to almost every single home in the country changed America's politics, its leisure habits, and its racial attitudes; the arrival of air conditioning opened up southern and southwestern regions; the early computers were transforming business and the military; the coming of jet planes revolutionized transportation."

And that was but one decade! And in one country! So, looking back, the engineering community can bask in the knowledge that they did a pretty good job. They certainly changed the world.

But going back to Oscar Wilde's mechanical slave—the mechanical slave, like the human slave, needs food. The food for the mechanical slave is energy. The most available energy sources, those that are most readily available and which we have been using for these 150 years, are the *nonreplenishable energy resources of the earth.*

Now, returning to the topic of *professionalism*, and paraphrasing the definition for engineering professionalism:

Engineering professionalism is characterized by conformance to the technical and ethical standards related to the practice of engineering.

The technical standards are self-evident. So, focusing on the ethical standards, the definition of ethics is "...a set of moral principles or standards."

Now, consider our situation as we stand

About the Author

William J. Coad, P.E., is with McClure Engineering Associates in St. Louis. He serves on the ASHRAE executive committee as treasurer, and is vice chair of Regions Council. He has held various leadership positions within ASHRAE and is presently active on Technical Committees 1.10, 6.1, and 8.10.

Visit ASHRAE's Online Magazine www.ashraejournal.org

16 ASHRAE Journal July 2000

Skill 02 – Scoping

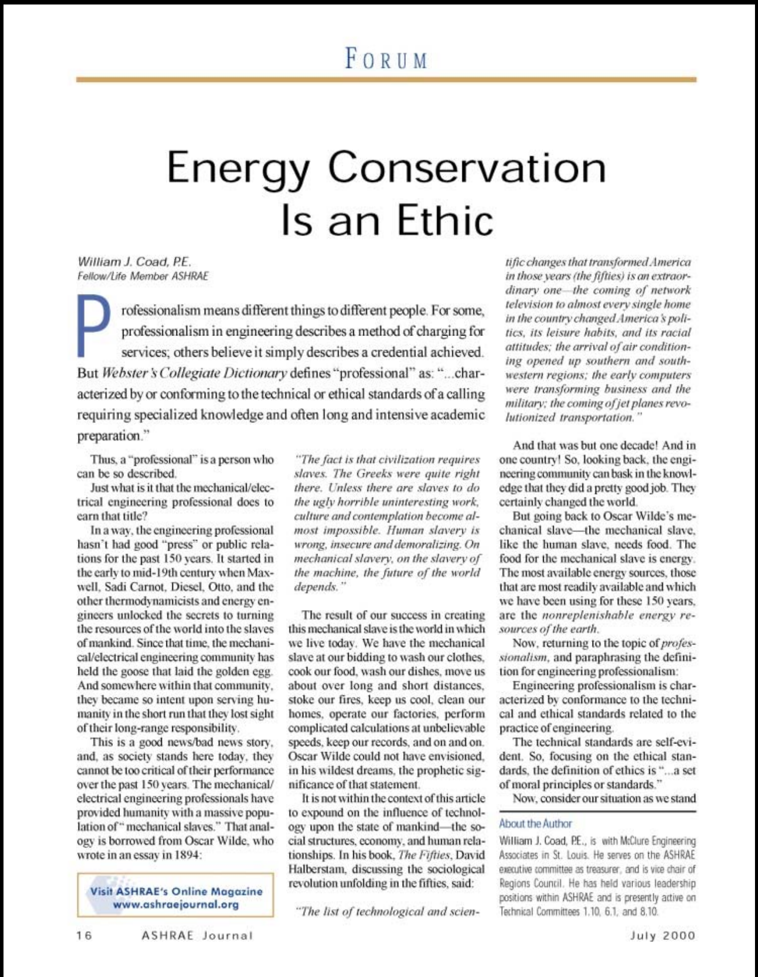
Applying Fundamental Principles can be Helpful

- Fundamental principle

The fundamental goal of most building systems is to provide an environment that is safe, clean, comfortable and productive

- Helpful insight

If, in the name of efficiency and sustainability, I do something that makes the built environment unsafe, unclean, uncomfortable or unproductive, then I have done a disservice



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Looking at a Few Examples

Equipment in “Hand”

- Very common
- Potential big savings for a low cost (maybe)

Looking at a Few Examples

Equipment in "Hand"

- The Applicable Fundamental Principles

$$Bhp_{Pump} = \left(\frac{Flow \times Head}{3{,}960 \times Efficiency_{Pump}} \right)$$

$$kW_{Pump} = 0.746 \times Bhp_{Pump}$$

$$kWh = kW \times Hours_{kWLevel}$$

Looking at a Few Examples

Equipment in “Hand”

- Evaluating the savings with field data …

$$Bhp_{Pump} = \left(\frac{Flow \times Head}{3{,}960 \times Efficiency_{Pump}} \right)$$

The pump is probably throttled to design conditions

The pump nameplate probably reflects design conditions

Looking at a Few Examples

Equipment in "Hand"

- Evaluating the savings with field data …

... operator insights …

$$Bhp_{Pump} = \left(\frac{Flow \times Head}{3{,}960 \times Efficiency_{Pump}} \right)$$

$$kW_{Pump} = 0.746 \times Bhp_{Pump}$$

$$kWh = kW \times Hours_{kWLevel}$$

The operators typically can provide key information like hours of operation and when they need to start chillers vs. using economizer cooling

Looking at a Few Examples

Equipment in “Hand”

- Evaluating the savings with field data …

... operator insights …

... and climate data

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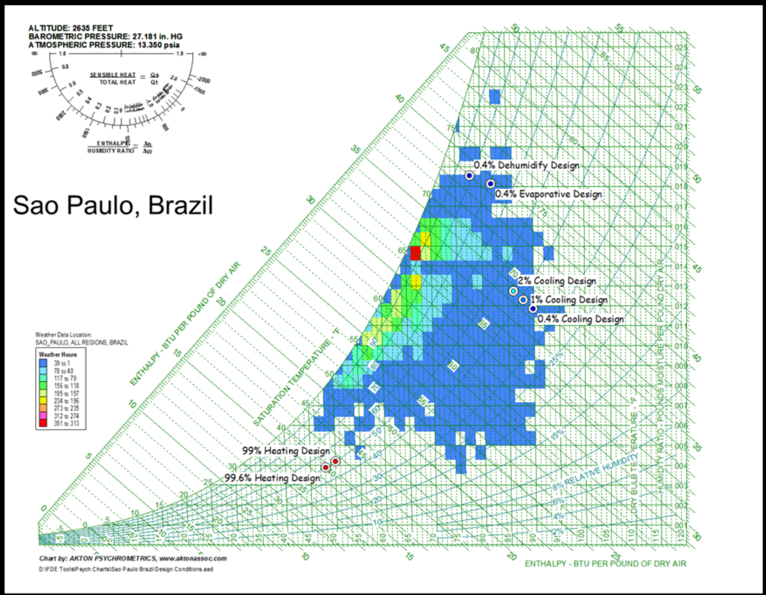
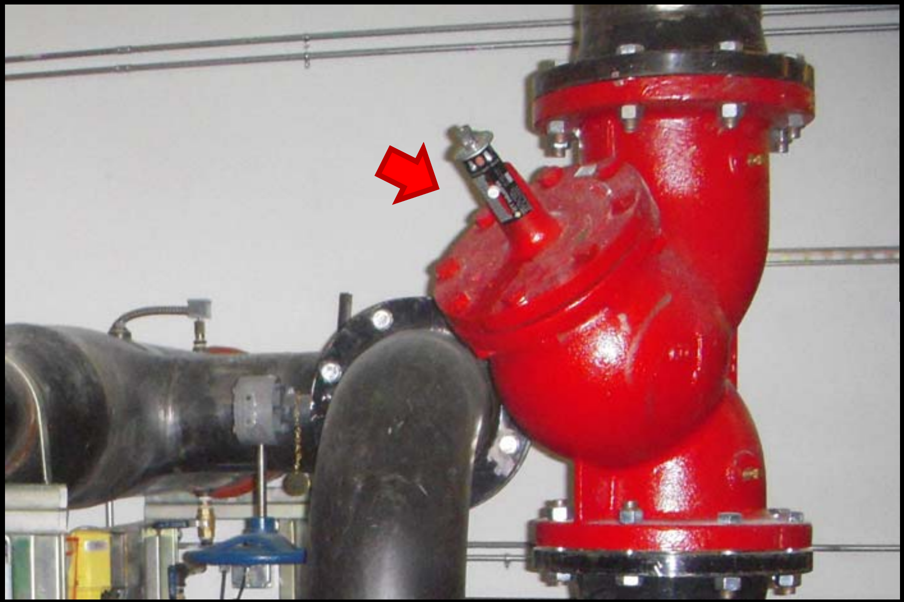


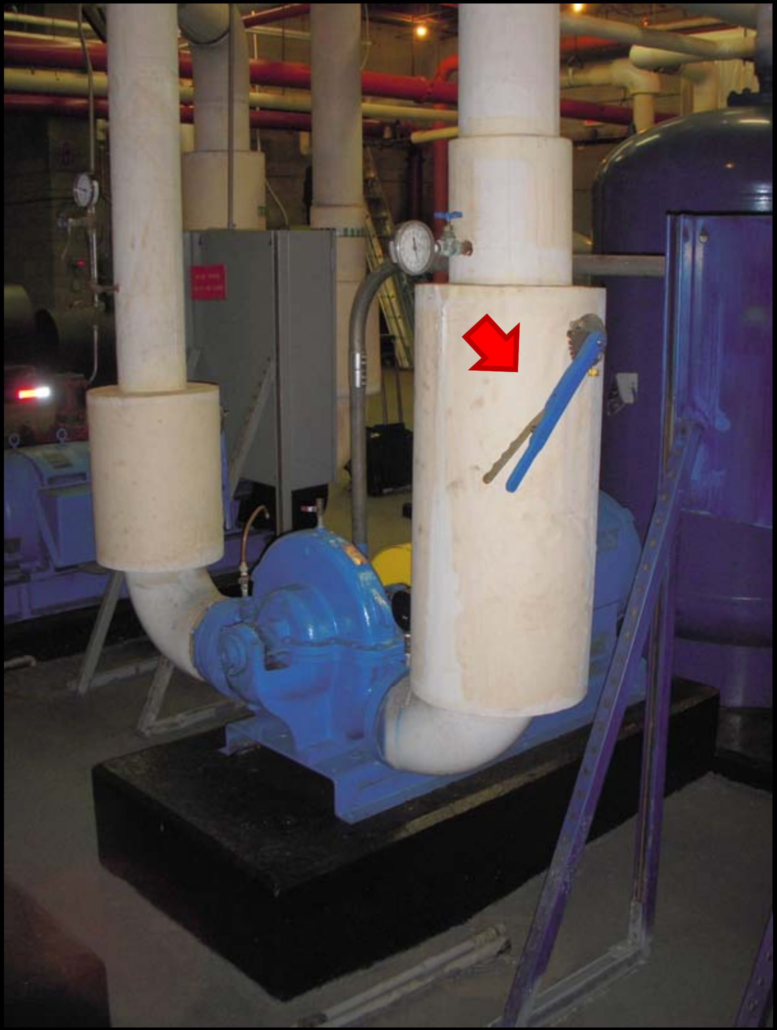
Bin data, TMY data or hourly weather data from a national climate resource can provide a sense of how many hours a year exist at the conditions associated with different operating modes

Looking at a Few Examples

Throttled Pumps

- Very common
- Many ways to achieve the savings with pros and cons to each that will be equipment and site specific





Looking at a Few Examples

Throttled Pumps

- The Applicable Fundamental Principle

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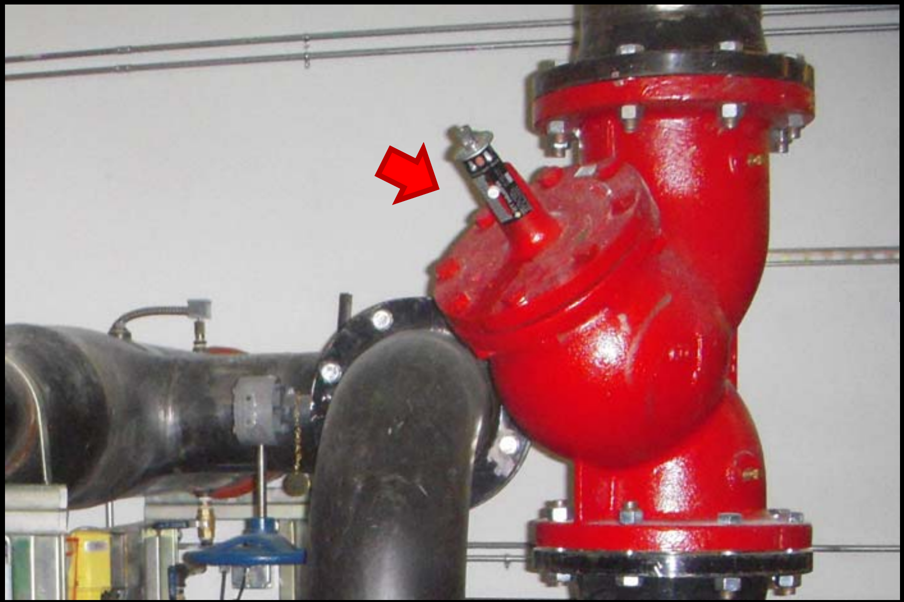


Skill 03 - HVAC Fundamentals

A Really Big Topic

1. Saturated Systems
2. Loads
3. Centrifugal Machines
4. Piping Systems
5. Refrigeration and Cooling Equipment
6. Heating Equipment
7. Variable Flow Water Systems
8. Duct Systems
9. Economizers
10. Makeup and Exhaust Systems
11. Variable Air Volume Systems

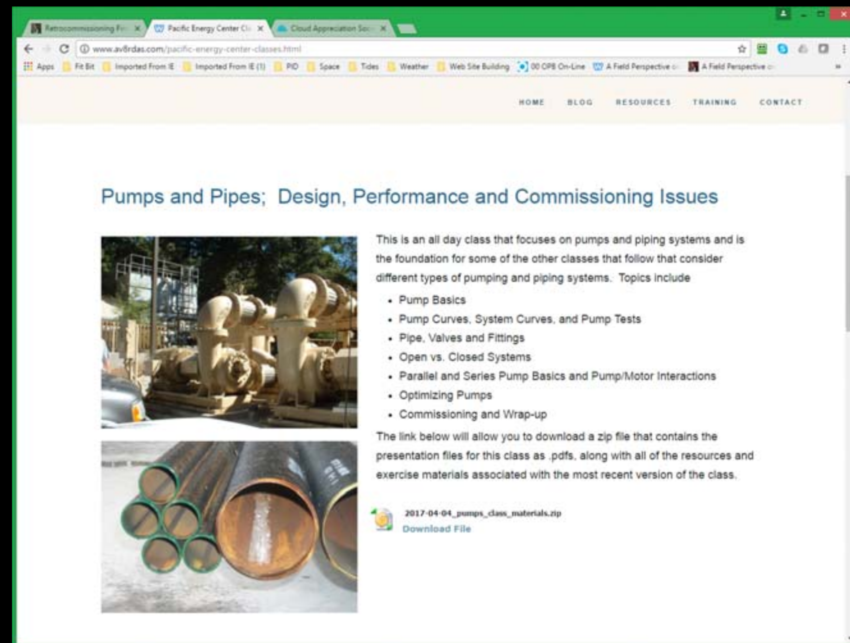
The Fundamental Principle Behind Centrifugal Machines

A Resource

The “Materials from Classes and Presentations” page on my website

Available at www.Av8rDAS.com

- Pick the “Resources” drop down …
- … then “Materials from Classes and Presentations” …
- … then “Pacific Energy Center Classes”



Skill 04 – The System Concept

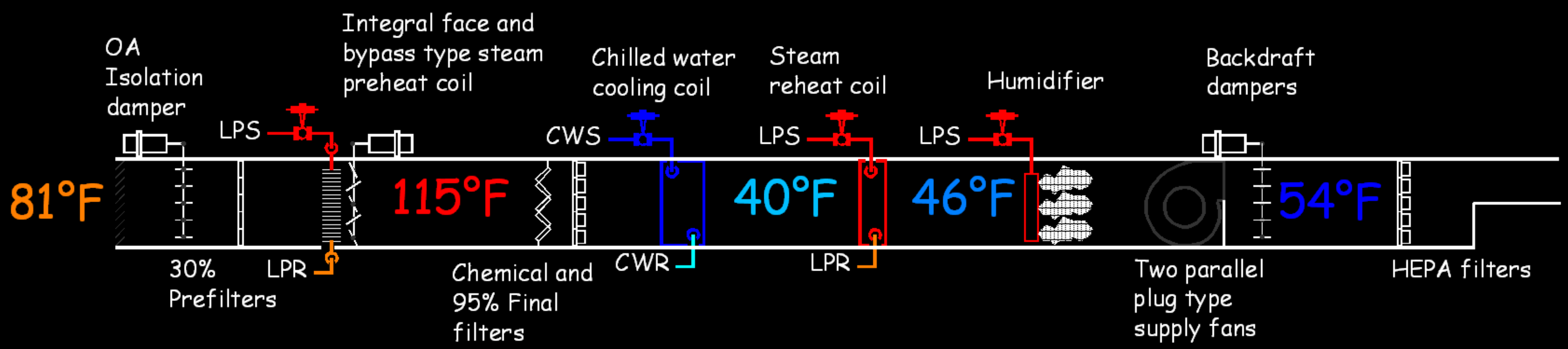
Learning Objectives

- Recognize how important it is to think in terms of systems, not just components and sub-assemblies when dealing with HVAC processes and building systems.
- Recognize that the building envelope itself is a critical part of a facility's HVAC systems.
- Know how to go about developing a system diagram for an air system and water system.
- Know how to use the system diagram to understand the system and facilitate diagonstics and communications with the project team.

The System Concept

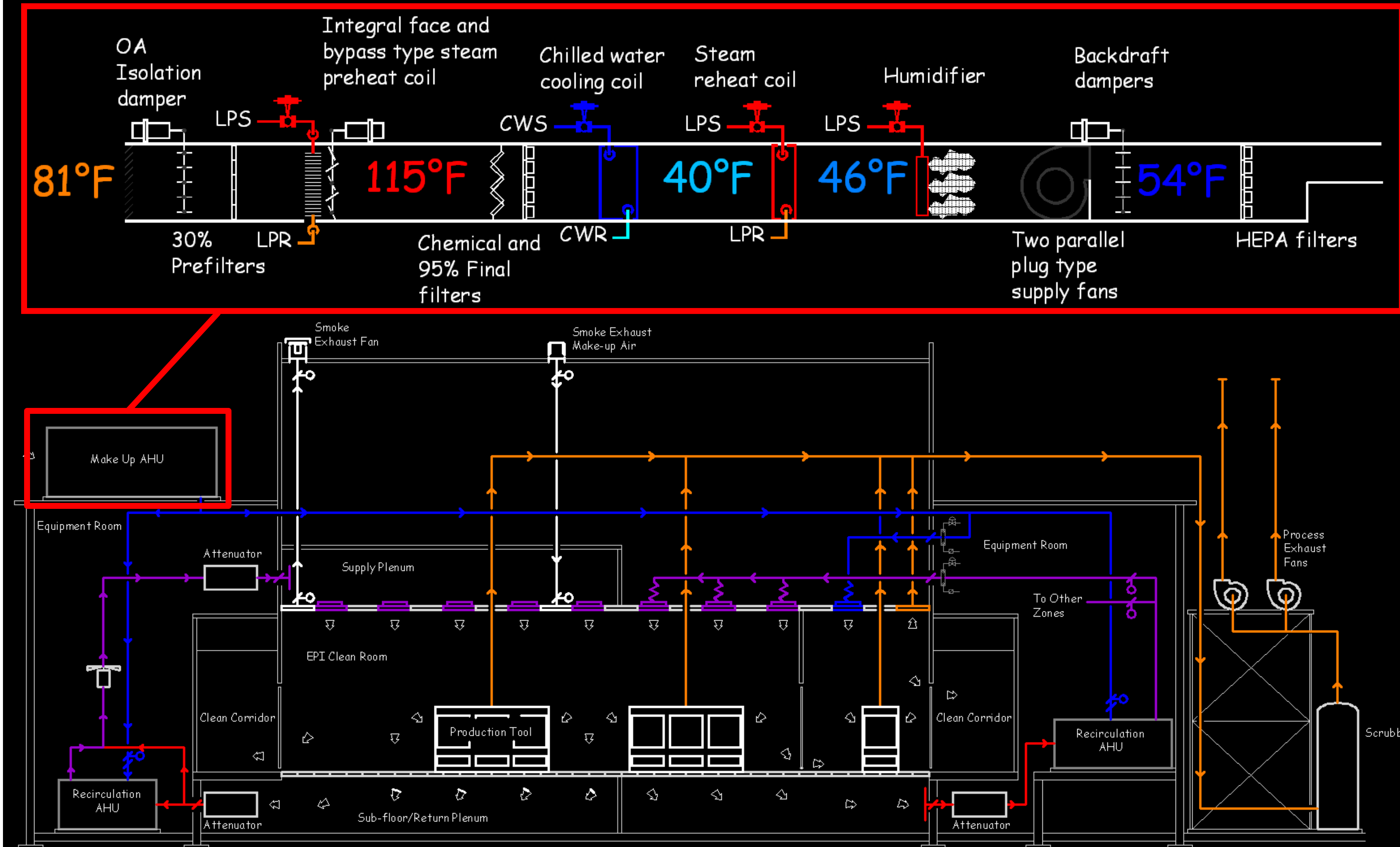
Fundamental to Understanding how Equipment and Machinery will be Integrated and Interact with Other Machines, Systems, Building Occupants, Building Processes, and the Climate

Its Not Just an Air Handling Unit …



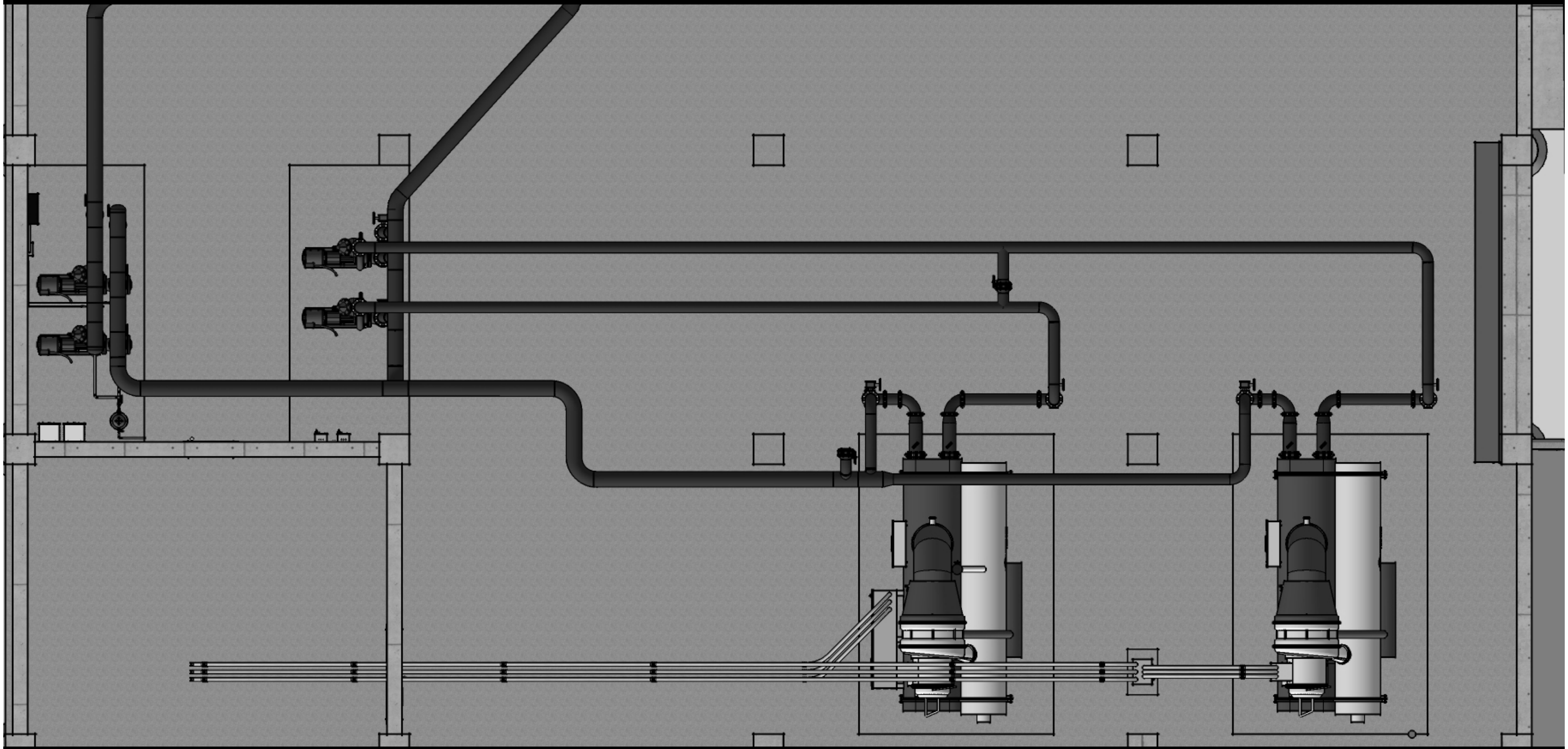
Its Not Just an Air Handling Unit …

…*It's an Air Handling System*



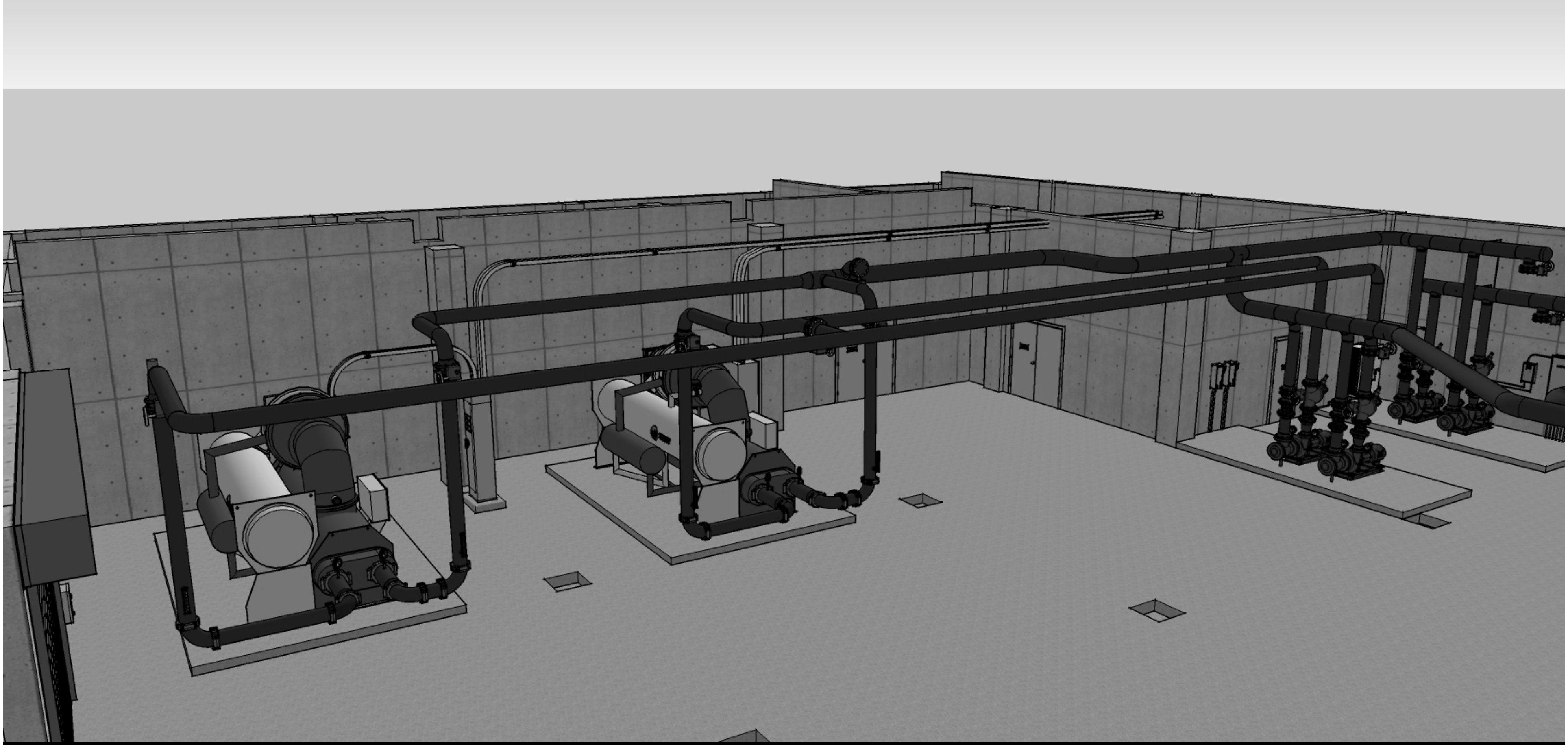
The Physical Configuration Needs to Match Design Intent

The piping plan



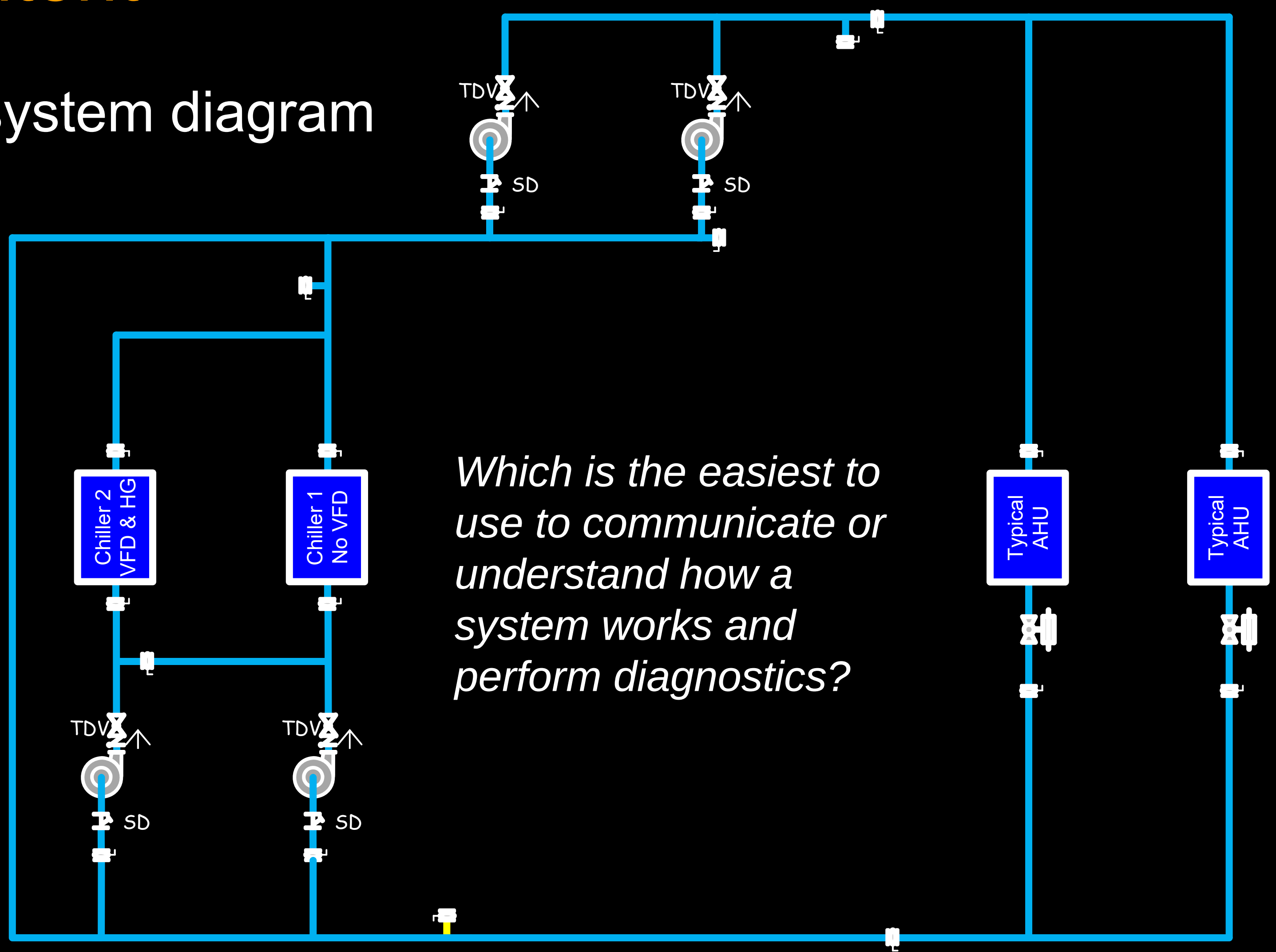
The Physical Configuration Needs to Match Design Intent

The piping isometric



The Physical Configuration Needs to Match Design Intent

The piping system diagram



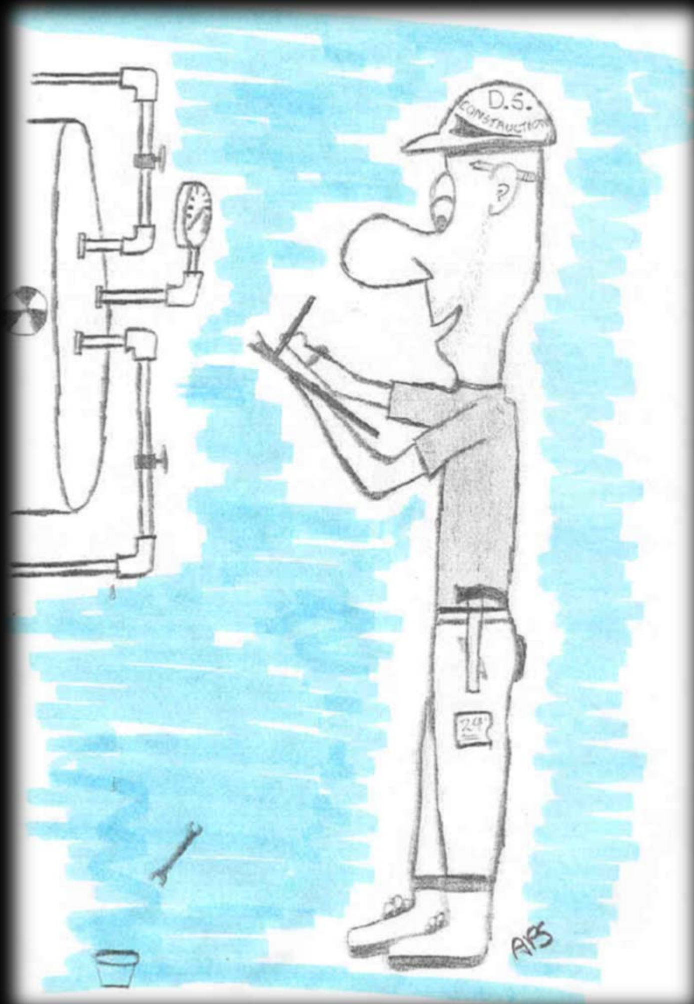
Which is the easiest to use to communicate or understand how a system works and perform diagnostics?

Skill 05 – Data Logging and Trend Analysis
One of the Ways a Building Talks to Us

Learning Objectives

- Know how to launch a typical logger and retrieve data from it.
- Know how to identify the appropriate points to monitor for the purposes of diagnostics and troubleshooting.
- Know how to match sensor selections to the requirements of a project so that you develop meaningful data.
- Know how to interface the sensors you have selected with the logger you are using.
- Know how to install sensors in systems so they provide meaningful data reflecting the conditions you are actually trying to monitor.

A Simple, Common Data Logging System



Le Conte Hall

- UC Berkeley Physics Department Home
- 148,000 square feet
- Four floors plus basement
  - Floors 1 and 2 - Classrooms and research
  - Floors 3 and 4 - Offices, class rooms, informal meeting space
- Interconnected with other physics department buildings
- MBCx program participant since 2009
- MBCx Best Practices Award winner for the 2009 program cycle

It Takes a Team to Succeed

Left to Right

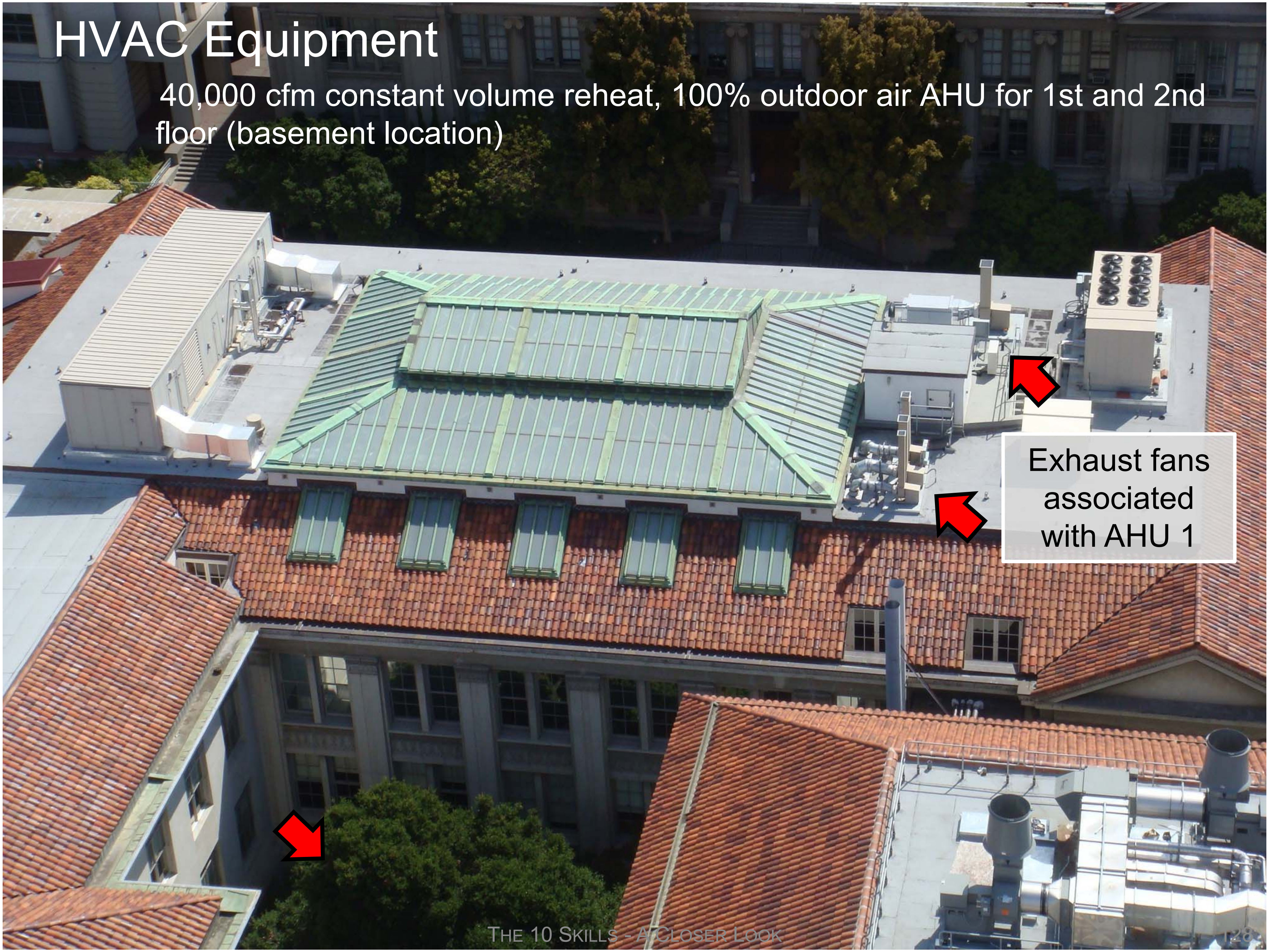
Anthony Vitan, Eleanor Crump, Julia Gee, Chuck Frost

2004 – 2007 Renovation

- Seismic issues
- Deferred maintenance
- Reconfiguration
- Restoration
- MEP Update

HVAC Equipment

40,000 cfm constant volume reheat, 100% outdoor air AHU for 1st and 2nd floor (basement location)




HVAC Equipment
32,000 cfm constant volume reheat, economizer equipped AHU for 3rd and 4th floor

HVAC Equipment

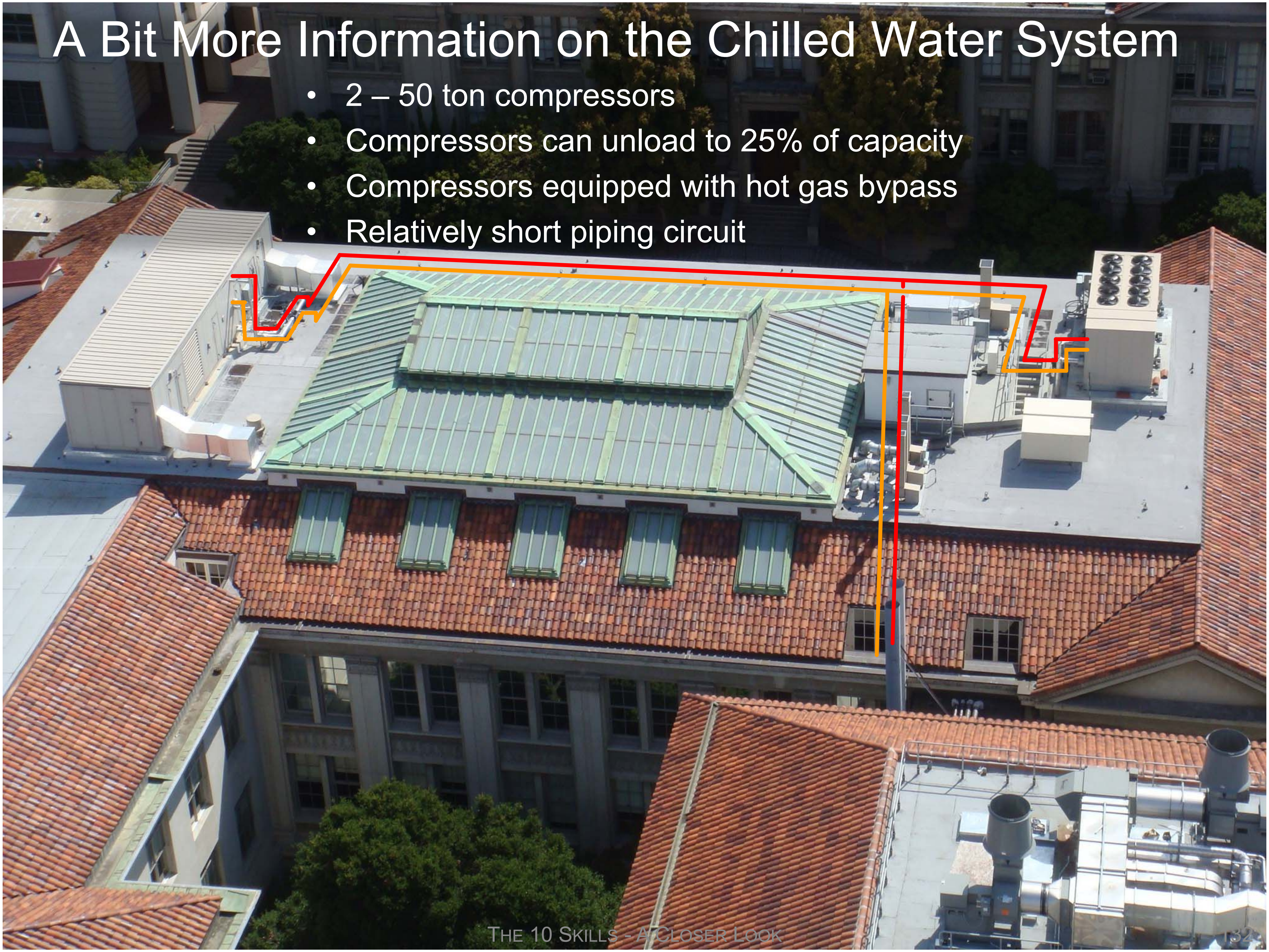
Steam fired variable flow heating hot water system (basement location)

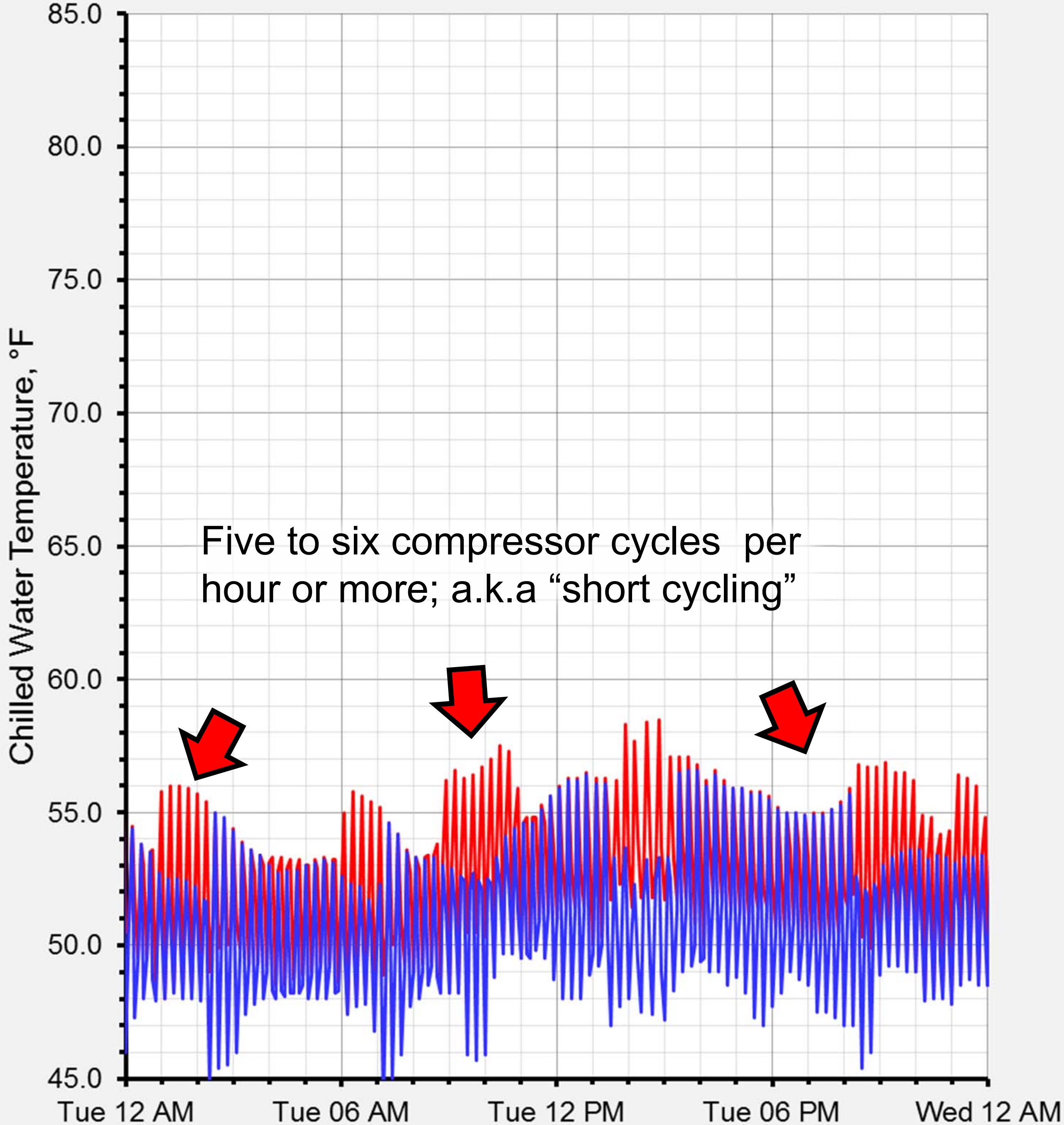
HVAC Equipment

Air cooled constant volume chilled water system

A Bit More Information on the Chilled Water System

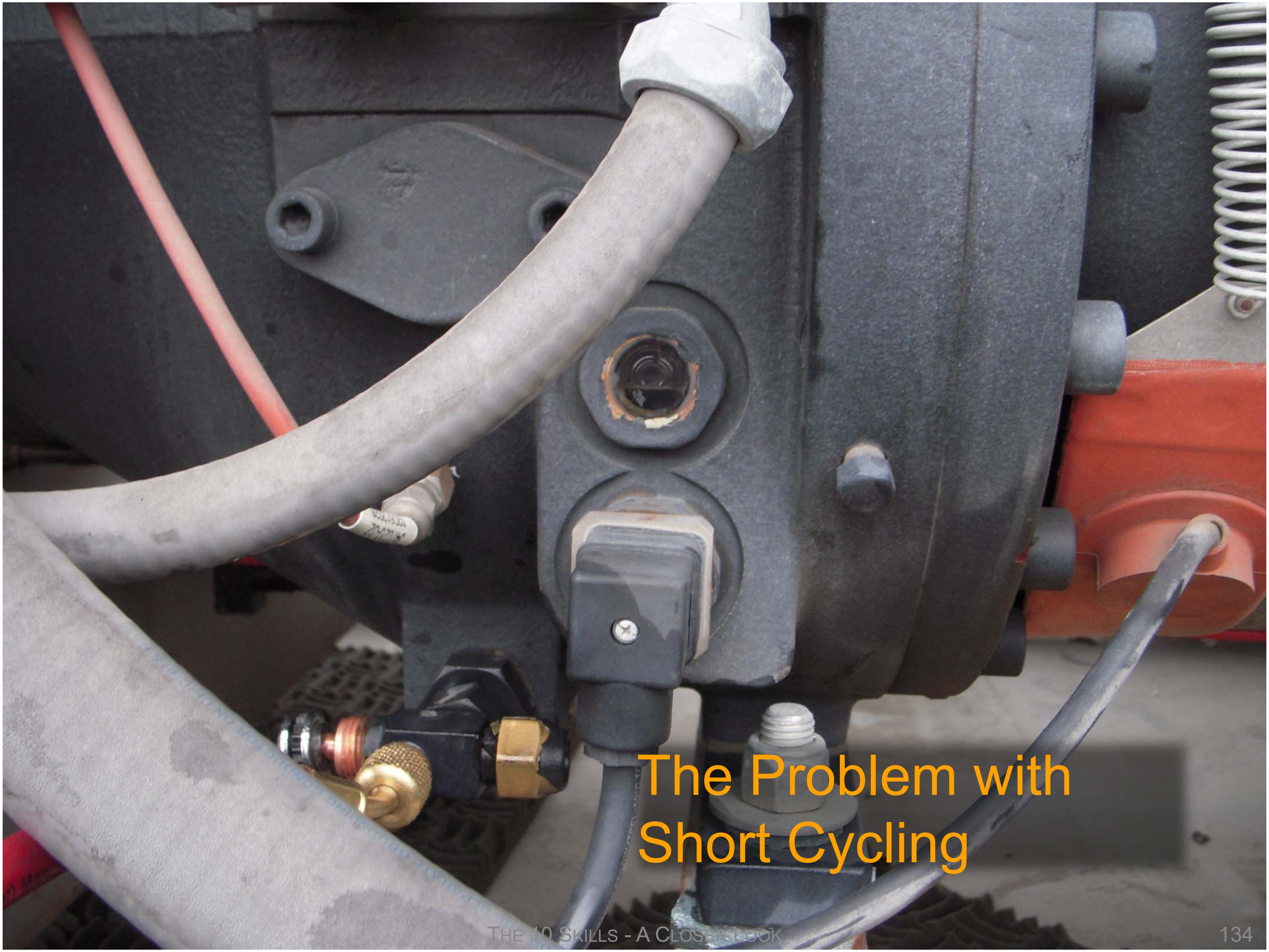
- 2 – 50 ton compressors
- Compressors can unload to 25% of capacity
- Compressors equipped with hot gas bypass
- Relatively short piping circuit





Le Conte Hall Chilled Water System Prior to Flywheel Operation

Tuesday, January 18, 2011

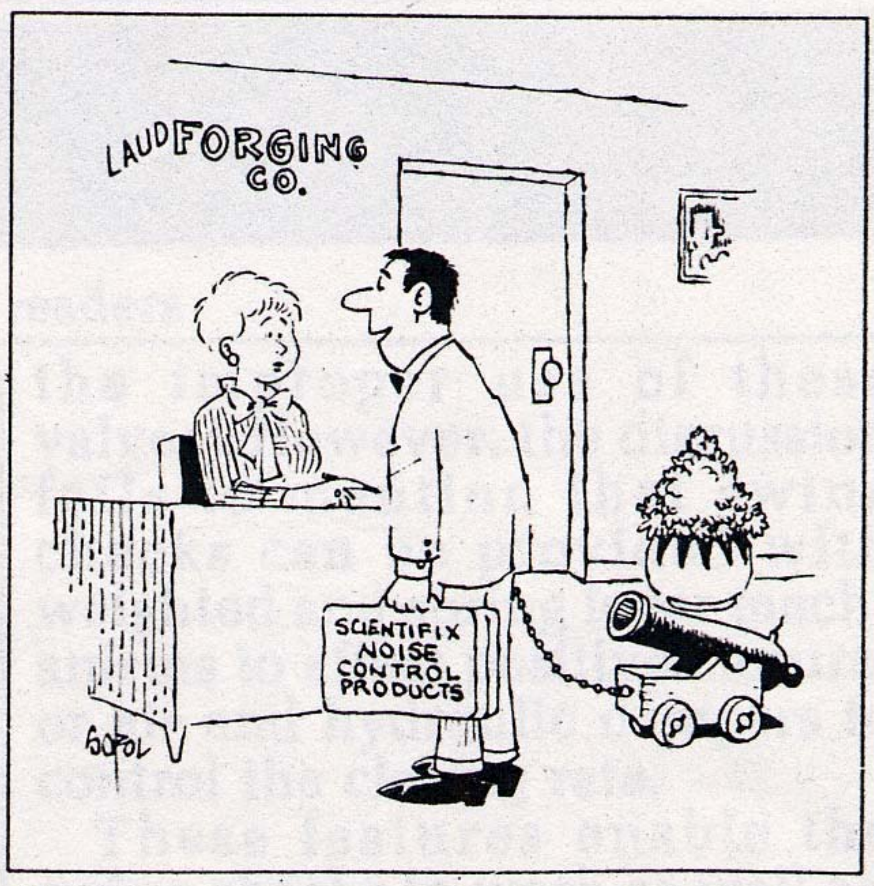

The Problem with
Short Cycling

Skill 06 – Functional Testing
A Way to Ask the Building a Question

Learning Objectives

- Know the basic elements of a functional test.
- Know how to develop a functional test that will deliver the data you need to resolve a problem or improve efficiency or operations.

Special Equipment May Be Required



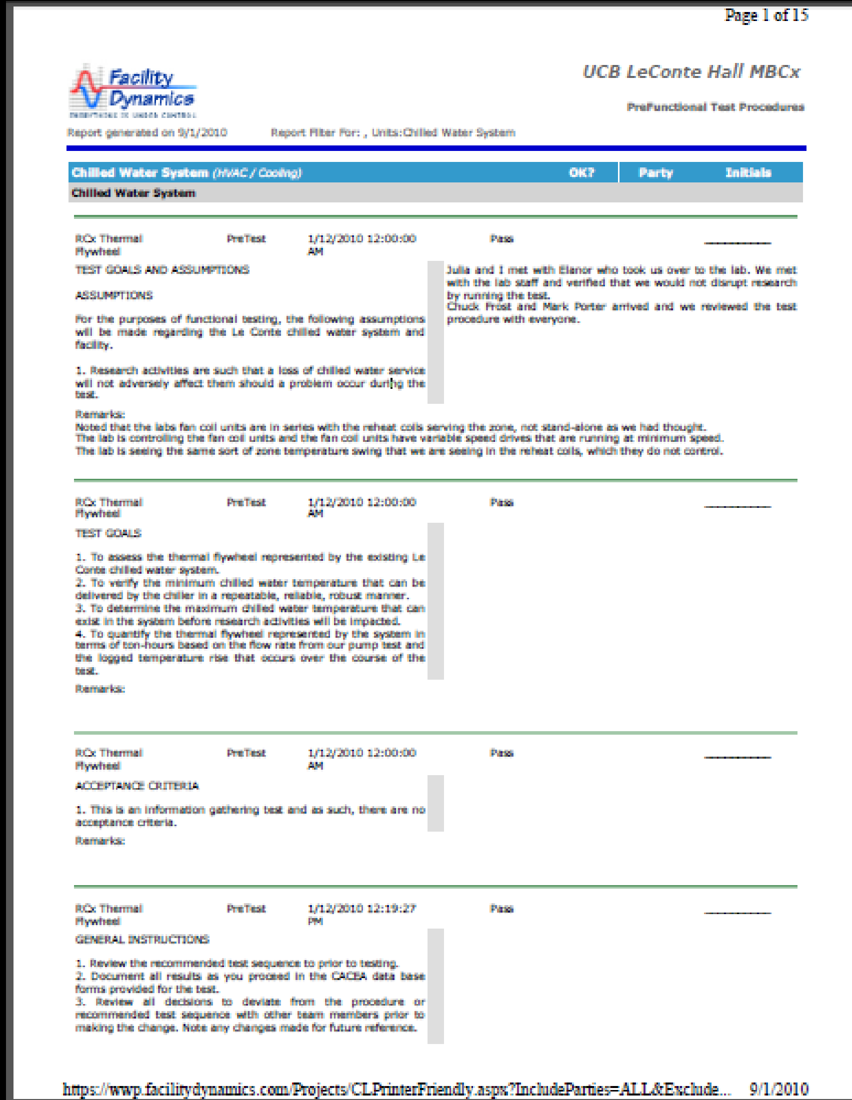
"I have an appointment to demonstrate our new line of ear protectors."

How Do We Ask the Building a Question?

We perform a functional test

Functional test components

- Statement of purpose
- Instructions for using the test form
- Equipment requirements
- Acceptance criteria
- Precautions
- Documentation
- Procedure
- Return to Normal and Follow-up



Page 1 of 15

UCB LeConte Hall MBCx

PreFunctional Test Procedures

Report generated on 9/1/2010   Report Filter For: , Units:Chilled Water System

Chilled Water System *(HVAC / Cooling)*			OK?	Party	Initials
Chilled Water System					
RCx Thermal Flywheel	PreTest	1/12/2010 12:00:00 AM	Pass		________

TEST GOALS AND ASSUMPTIONS

ASSUMPTIONS

For the purposes of functional testing, the following assumptions will be made regarding the Le Conte chilled water system and facility.

1. Research activities are such that a loss of chilled water service will not adversely affect them should a problem occur during the test.

Julia and I met with Elanor who took us over to the lab. We met with the lab staff and verified that we would not disrupt research by running the test.
Chuck Frost and Mark Porter arrived and we reviewed the test procedure with everyone.

Remarks:
Noted that the labs fan coil units are in series with the reheat coils serving the zone, not stand-alone as we had thought.
The lab is controlling the fan coil units and the fan coil units have variable speed drives that are running at minimum speed.
The lab is seeing the same sort of zone temperature swing that we are seeing in the reheat coils, which they do not control.

RCx Thermal Flywheel	PreTest	1/12/2010 12:00:00 AM	Pass	________

TEST GOALS

1. To assess the thermal flywheel represented by the existing Le Conte chilled water system.
2. To verify the minimum chilled water temperature that can be delivered by the chiller in a repeatable, reliable, robust manner.
3. To determine the maximum chilled water temperature that can exist in the system before research activities will be impacted.
4. To quantify the thermal flywheel represented by the system in terms of ton-hours based on the flow rate from our pump test and the logged temperature rise that occurs over the course of the test.

Remarks:

RCx Thermal Flywheel	PreTest	1/12/2010 12:00:00 AM	Pass	________

ACCEPTANCE CRITERIA

1. This is an information gathering test and as such, there are no acceptance criteria.

Remarks:

RCx Thermal Flywheel	PreTest	1/12/2010 12:19:27 PM	Pass	________

GENERAL INSTRUCTIONS

1. Review the recommended test sequence to prior to testing.
2. Document all results as you proceed in the CACEA data base forms provided for the test.
3. Review all decisions to deviate from the procedure or recommended test sequence with other team members prior to making the change. Note any changes made for future reference.

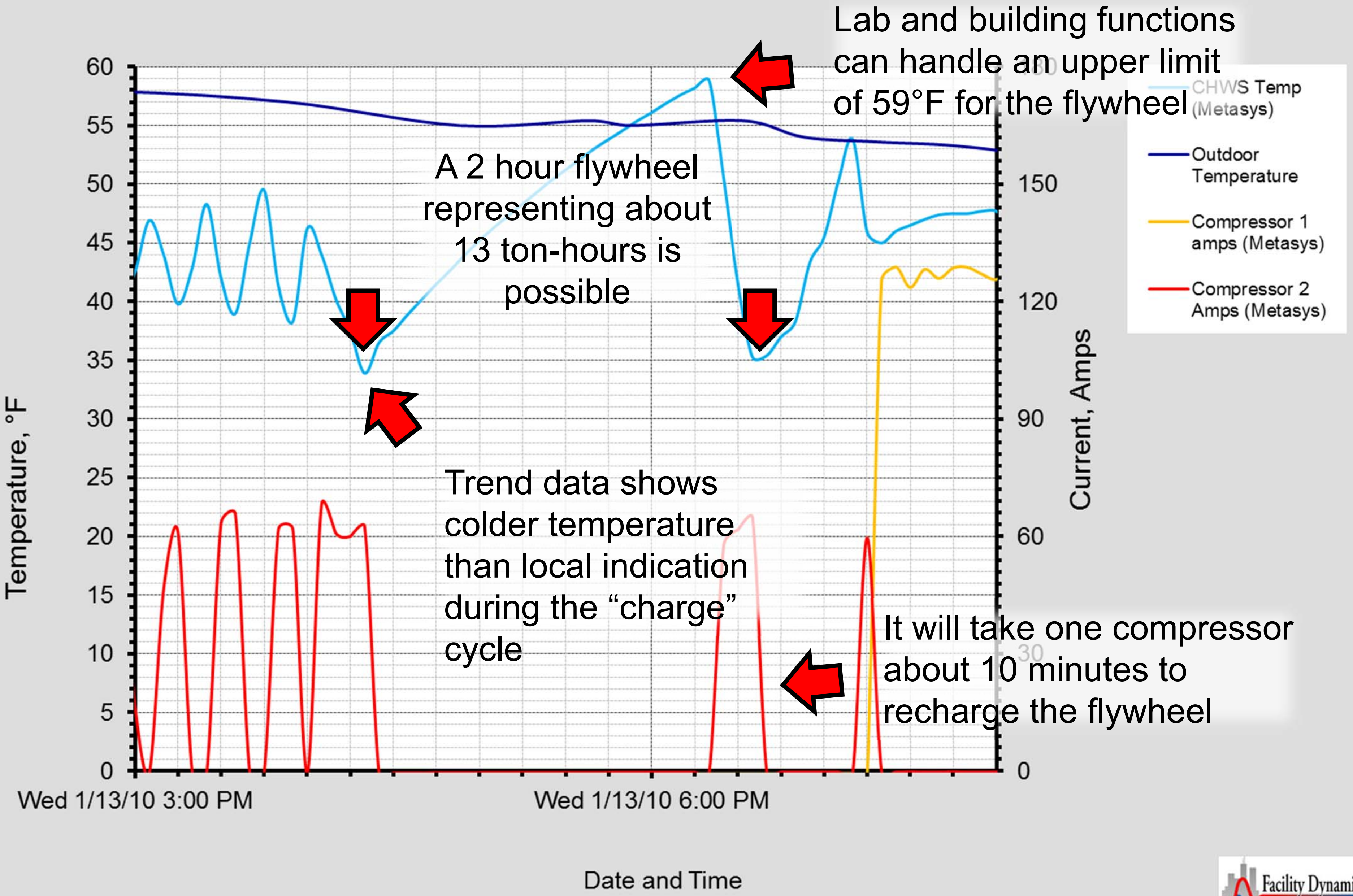
https://wwp.facilitydynamics.com/Projects/CLPrinterFriendly.aspx?IncludeParties=ALL&Exclude...   9/1/2010

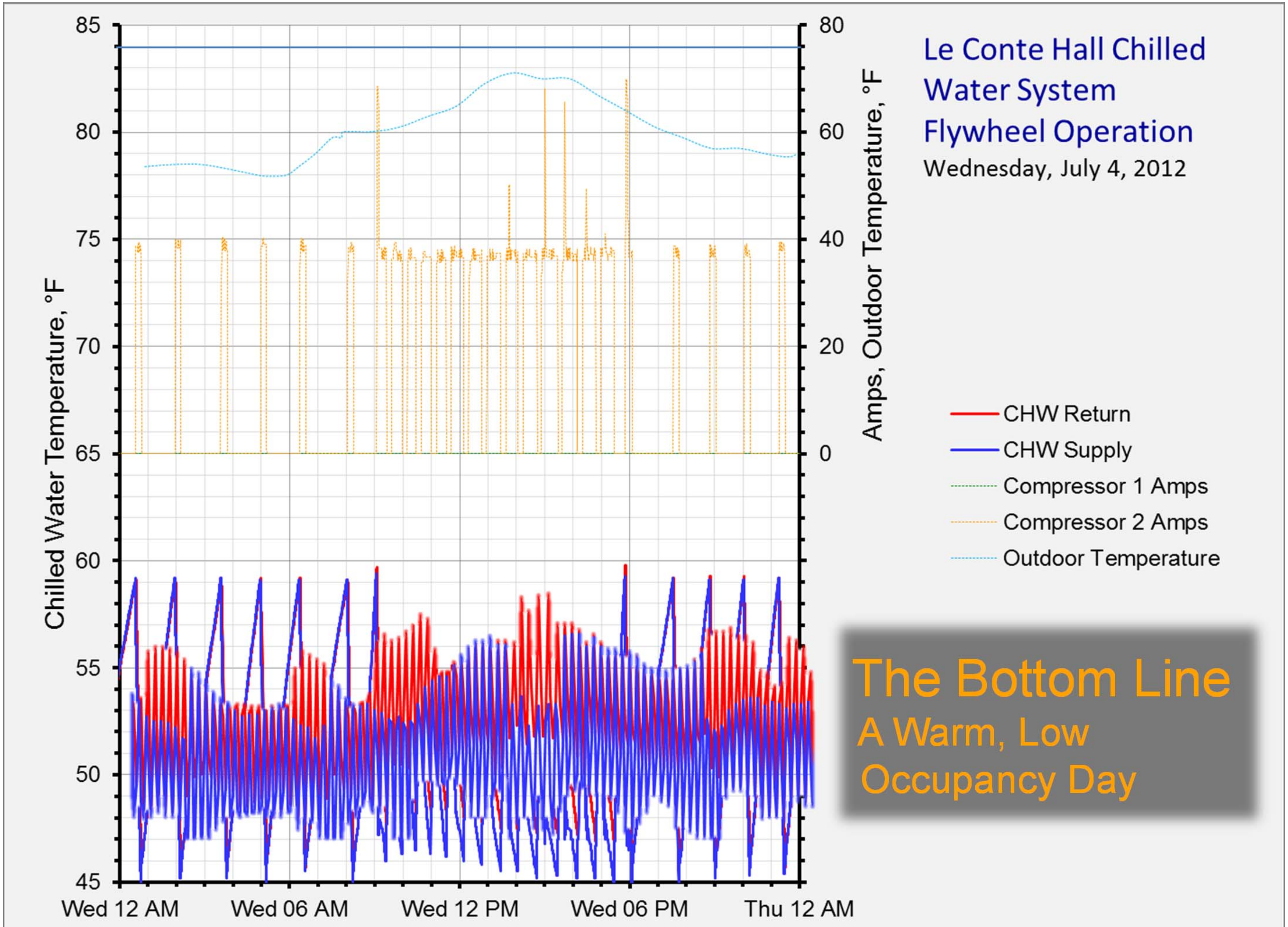
Skill 07 – Data Analysis
Listening to What the Building Said

Learning Objectives

- Know how to import logged data into Excel and other tools and create meaningful, legible, annotated charts and graphs to convey the results of analysis and diagnostic efforts.
- Know how to review data and pick up patterns from the data that reveal issues and solutions.
- Know how to use the internet and other resources to find case studies and examples similar to a problem you are studying and glean appropriate data analysis techniques from the work of others
- Know how to import graphs and tables generated in Excel into PowerPoint

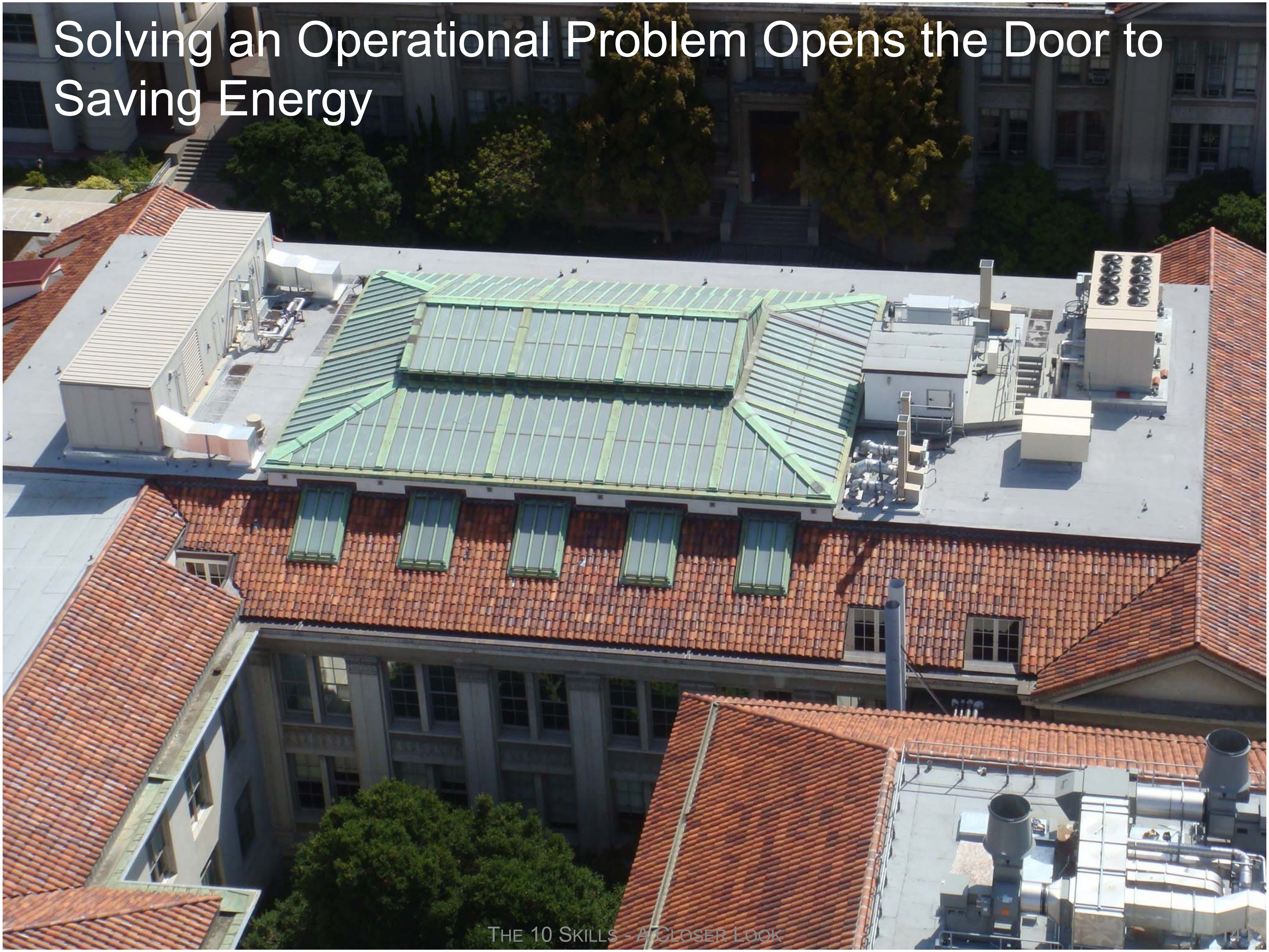
Le Conte Hall CHW System Flywheel Test





Le Conte Hall Chilled Water System Flywheel Operation
Wednesday, July 4, 2012
Chilled Water Temperature, °F
Amps, Outdoor Temperature, °F
85
80
75
70
65
60
55
50
45
80
60
40
20
0
Wed 12 AM
Wed 06 AM
Wed 12 PM
Wed 06 PM
Thu 12 AM
CHW Return
CHW Supply
Compressor 1 Amps
Compressor 2 Amps
Outdoor Temperature
The Bottom Line
A Warm, Low Occupancy Day

Solving an Operational Problem Opens the Door to Saving Energy



Skill 08 – HVAC and Energy Calculations

Learning Objectives

- Become familiar with the fundamental equations associated with HVAC equipment power and energy use.
- Know how to used field measurements, design parameters, and estimates to evaluate the equations and predict power requirements.
- Know how to use spread sheet techniques like hour by hour calculations and bin calculations to extrapolate power calculations over time and predict energy consumption.

Skill 08 – HVAC and Energy Calculations

$$Q_{\text{Btu per hour}} = 1.08 \times Flow_{\text{Cubic Feet per Minute}} \times \left(Temperature_{\text{In, °F}} - Temperature_{\text{Out, °F}}\right)$$

Where:

$Q_{\text{Btu per hour}}$ = Sensible energy change in the air stream

1.08 = Unit conversion constant for dry air at 70°F

$Flow_{\text{Cubic Feet per Minute}}$ = The flow rate for the current operating mode based on TAB data

$\left(Temperature_{\text{In, °F}} - Temperature_{\text{Out, °F}}\right)$ = Heat exchanger temperature difference

Skill 08 – HVAC and Energy Calculations

$$Q_{\text{Btu per hour}} = 4.5 \times Flow_{\text{Cubic Feet per Minute}} \times \left(Enthalpy_{\text{In, Btu per pound}} - Enthalpy_{\text{Out, Btu per pound}}\right)$$

Where:

$Q_{\text{Btu per hour}} =$ Total energy change in the air stream

$4.5 =$ Unit conversion constant for dry air at 70°F

$Flow_{\text{Cubic Feet per Minute}} =$ The flow rate for the current operating mode based on TAB data

$\left(Enthalpy_{\text{In, Btu per pound}} - Enthalpy_{\text{Out, Btu per pound}}\right) =$ Heat exchanger enthalpy difference

Skill 08 – HVAC and Energy Calculations

$$kW = \left(\frac{Flow_{cfm} \times Static_{in.w.c.}}{6{,}356 \times \eta_{Fan} \times \eta_{Belts} \times \eta_{Motor} \times \eta_{VSD}} \right) \times .746$$

Where:

kW = Input to the system to produce the flow and static pressure.

Flow = Flow rate in cubic feet per minute. Generally speaking, we try to use a field measurement for this. If that is not available we will use a value from a tab report. Lacking that we will use a design metric from the original drawings or an equipment submittal.

Static = The fan static pressure in inches water column. Since fan static as defined by AMCA is difficult to measure in the field, we usually try to derive this number from the fan curve using two other feild measurements like flow and fan speed or flow and power. Lacking those measurements we will use a value derived from a TAB report or the design value.

6,356 = A units conversion constant that is good for air at approximately 0 - 2,000 $feet_{msl}$ and between -40°F and 120°F.

η_{Fan} = Fan static efficiency. We usually try to get this number from the fan curve or from the fan's rated brake horse power (bhp), flow and static. Lacking that, we will make a geometrically similar fan selection (same flow rate, static, wheel diameter, wheel type, and speed) using manufacturer's software and use that efficiency.

η_{Motor} = Motor efficiency. We usually try to get the motor performance curve and select the efficiency from the curve for the bhp that the fan wheel is extracting from it. If we can't get the motor curve, we use a similar motor selected from MotorMaster™ International. In all cases we adjust the efficiency for the motor operating point vs. using the motor's rated nameplate efficiency.

η_{VSD} = Variable speed drive efficiency. Where possible, we try to get the manufacturer's data for this. But this data is difficult to obtain and not consistent in its development. Lacking manufacture specific data, we use generic data as published by the Department of Energy on their Industrial Best Practices web site.

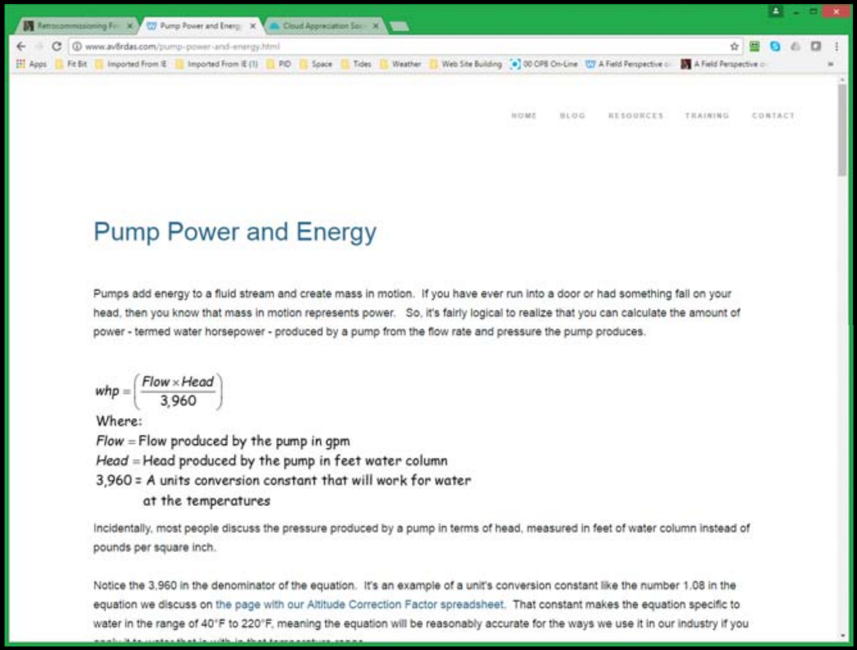
.746 = Horsepower to kW conversion constant.

A Resource

The “Useful Formulas” page on my website

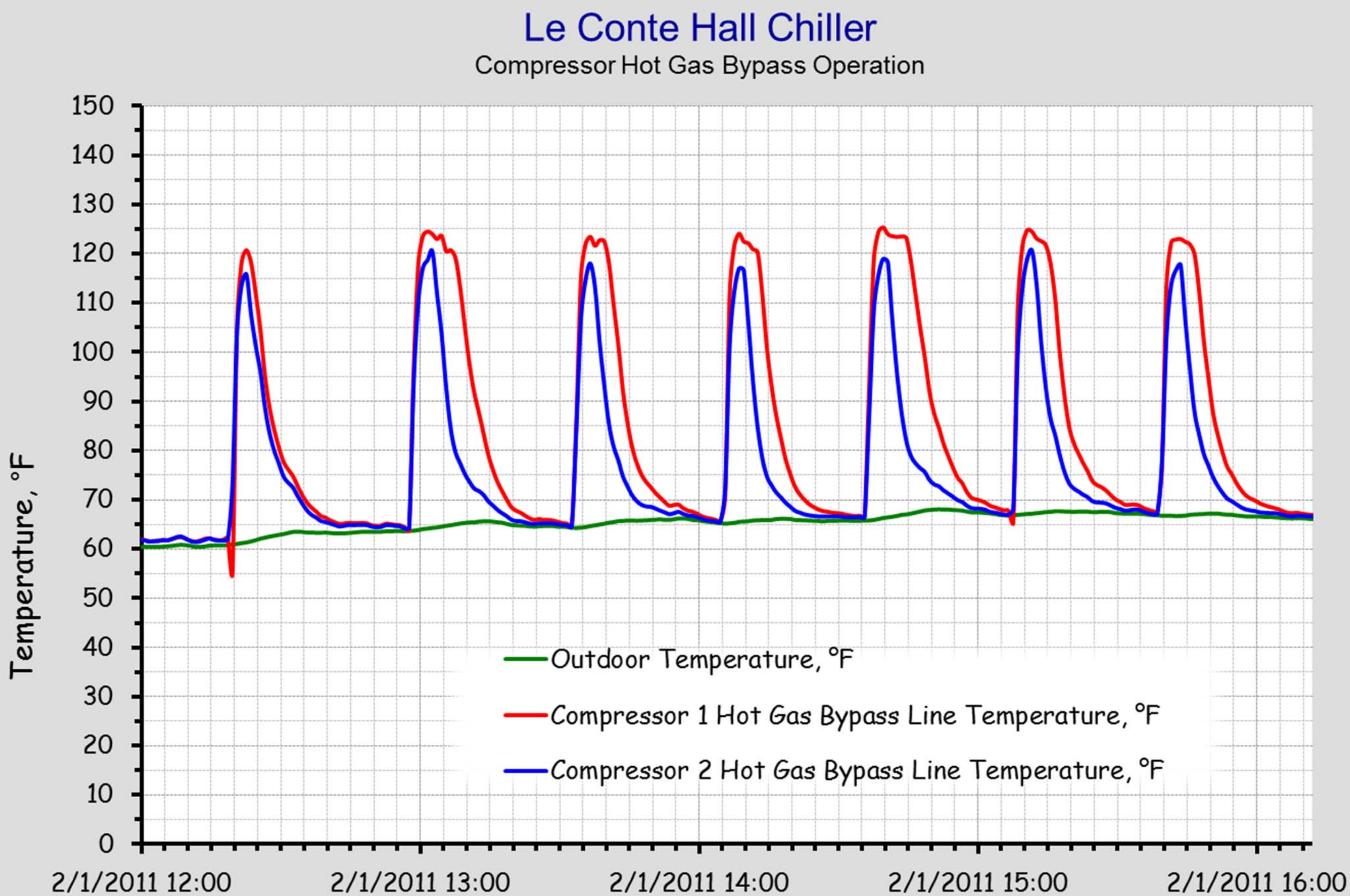
Available at www.Av8rDAS.com

- Pick the “Resources” drop down …
- … then “Useful Formulas” …
- … then the formula of interest



LeConte Hall

Post Implementation Energy Not What We Expected



Le Conte Hall Chiller
Compressor Hot Gas Bypass Operation
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Temperature, °F
Outdoor Temperature, °F
Compressor 1 Hot Gas Bypass Line Temperature, °F
Compressor 2 Hot Gas Bypass Line Temperature, °F
2/1/2011 12:00
2/1/2011 13:00
2/1/2011 14:00
2/1/2011 15:00
2/1/2011 16:00

Unnecessary Hot Gas = Unrealized Savings

Good News

Flywheel cycle captures 26,900 kWh/$2,690 of savings via the MBCx project

- Testing performed as part of the general MBCx effort
- Programming modified “on the fly”

Additional savings potential justifies a factory service call

- Perform routine checks and maintenance
- Optimize set points
- Optimize controls

Bad News

11,404 kWh/$1,140 of savings “left on the table

Skill 09 – Return On Investment Calculations (ROI)

Learning Objectives

- Know how to consider and evaluate all of the benefits associated with an energy or resource conservation project and include those metrics in your sales pitch.
- Become familiar with your client's or organization's financial perspective and related assessment strategies.

What's the Right Answer?

It Depends

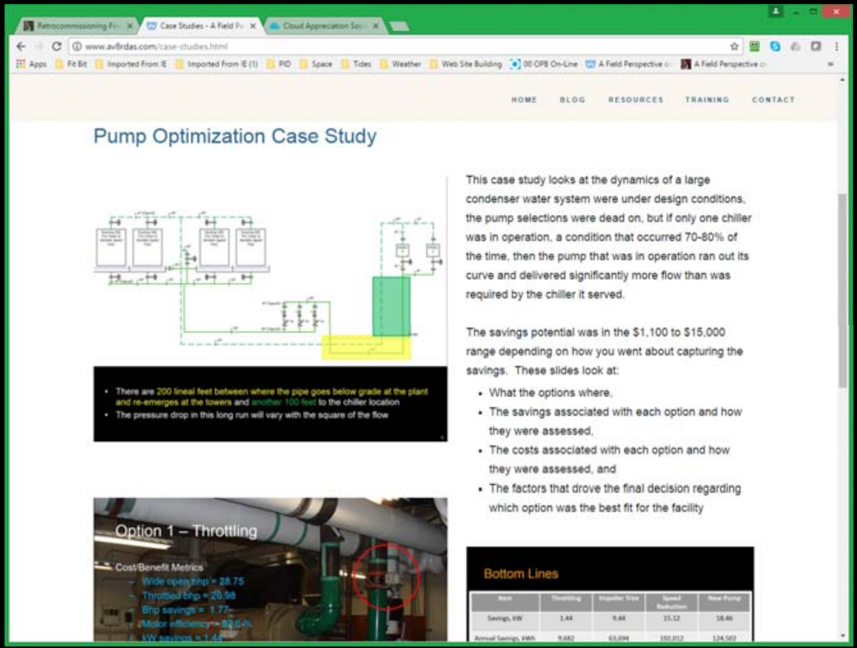
Item	Throttling	Impeller Trim	Speed Reduction	New Pump
Savings, kW	1.44	9.44	15.12	18.46
Annual Savings, kWh	9,682	63,694	102,012	124,502
Annual Savings	$1,162	$7,643	$12,241	$14,940
Implementation Cost	$1,000 or less	$5,000 or less	$12,850	$39,557 minimum
Simple Payback, Years	.86 or less	.65 or less	1.05	2.65 or more

An Example

The Case Studies page on my website

Available at www.Av8rDAS.com

- Pick the “Resources” drop down …
- … then “Materials from Classes and Presentations” …
- … then “Case Studies”



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- Optimize set points
- Optimize controls

Bad News

11,404 kWh/$1,140 of savings “left on the table

Summary		
Savings via Proper Hot Gas Adjustment -	$1,140	per year
Service Call Clst -	$4,250	
Simple Payback -	3.73	years

Skill 10– Control System Competency
Another Big One

Learning Objectives

- Understand and be able to explain, in general terms, how a proportional control system works as well as PID.
- Understand and be able to explain basic control system concepts like open vs. closed loops, and digital vs. analog signals.

Skill 10– Control System Competency
Another Big One

Learning Objectives

- Understand and be able to explain common optimization strategies like the “two thirds rule” and reset strategies,
- Appreciate the impact that lags can have on your control processes and the implications in terms the quality of the equipment you procure.

Skill 10– Control System Competency
Another Big One

Learning Objectives

- Understand why pneumatic controls require a different skill set and level of effort if they are to be maintained so they deliver repeatable, robust, reliable performance relative to a DDC system
- Understand why DDC systems from different vendors are seldom equivalent “out of the box”.
- Understand why the engineering associated with your control system design may be the most critical element of the over-all project design

Skill 10– Control System Competency
Another Big One

Learning Objectives

- Be familiar with and be able to defend the value of a control design that includes a system diagram complemented with a point list, a logic diagram, a detailed narrative control sequence and very specific product requirements.
- Become familiar with your client's or organization's control system standards.

Skill 10– Control System Competency
Another Big One

Learning Objectives

- Understand the critical role that the installing contractor plays in the over-all success of a control system.
- Recognize and have some familiarity with all of the factors that can come into play in determining the over-all performance of your control system; things like sensor accuracy, A to D conversion accuracy, network architecture, memory, graphics, and trending capabilities.

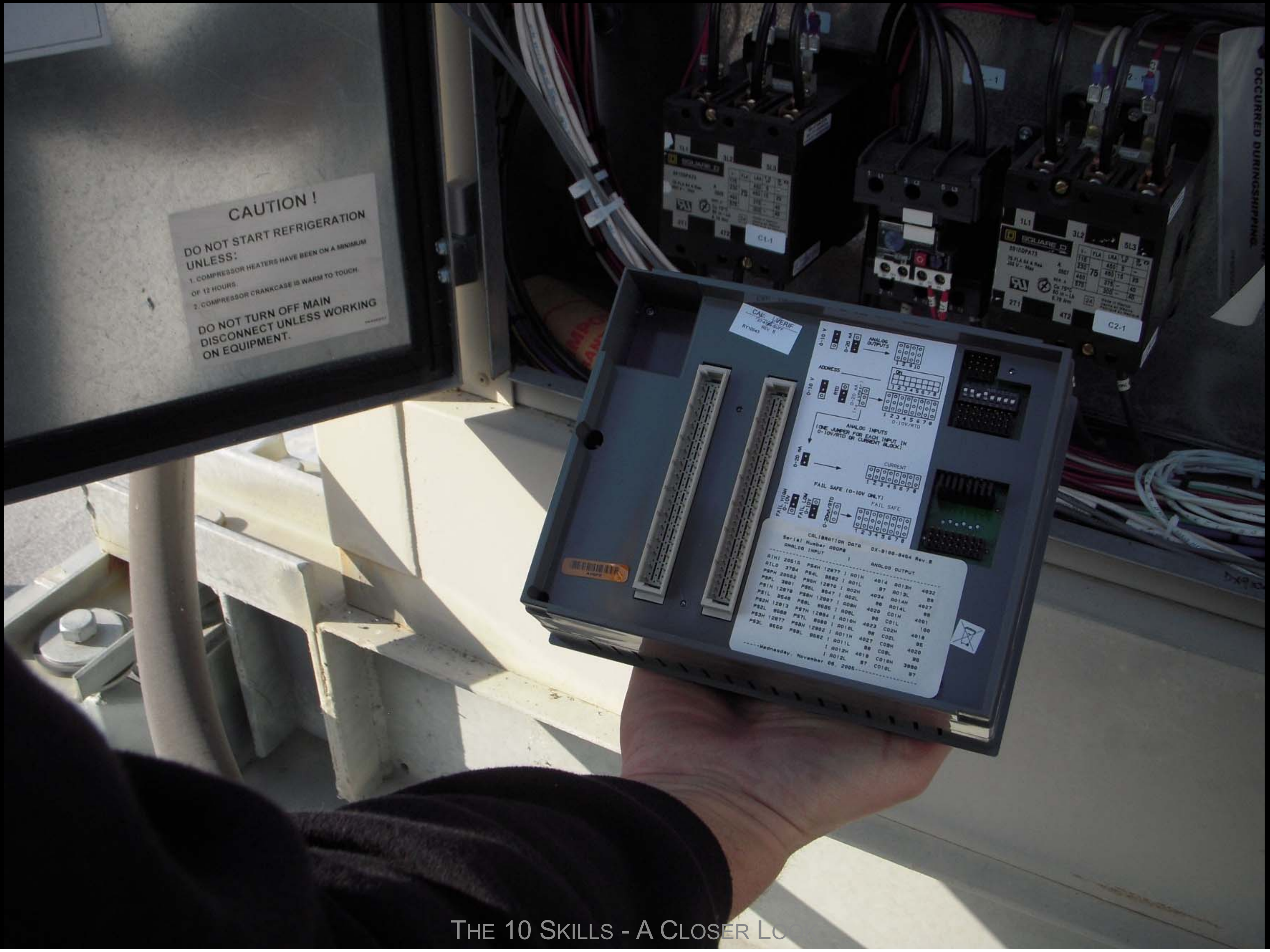
Skill 10– Control System Competency

Another Big One

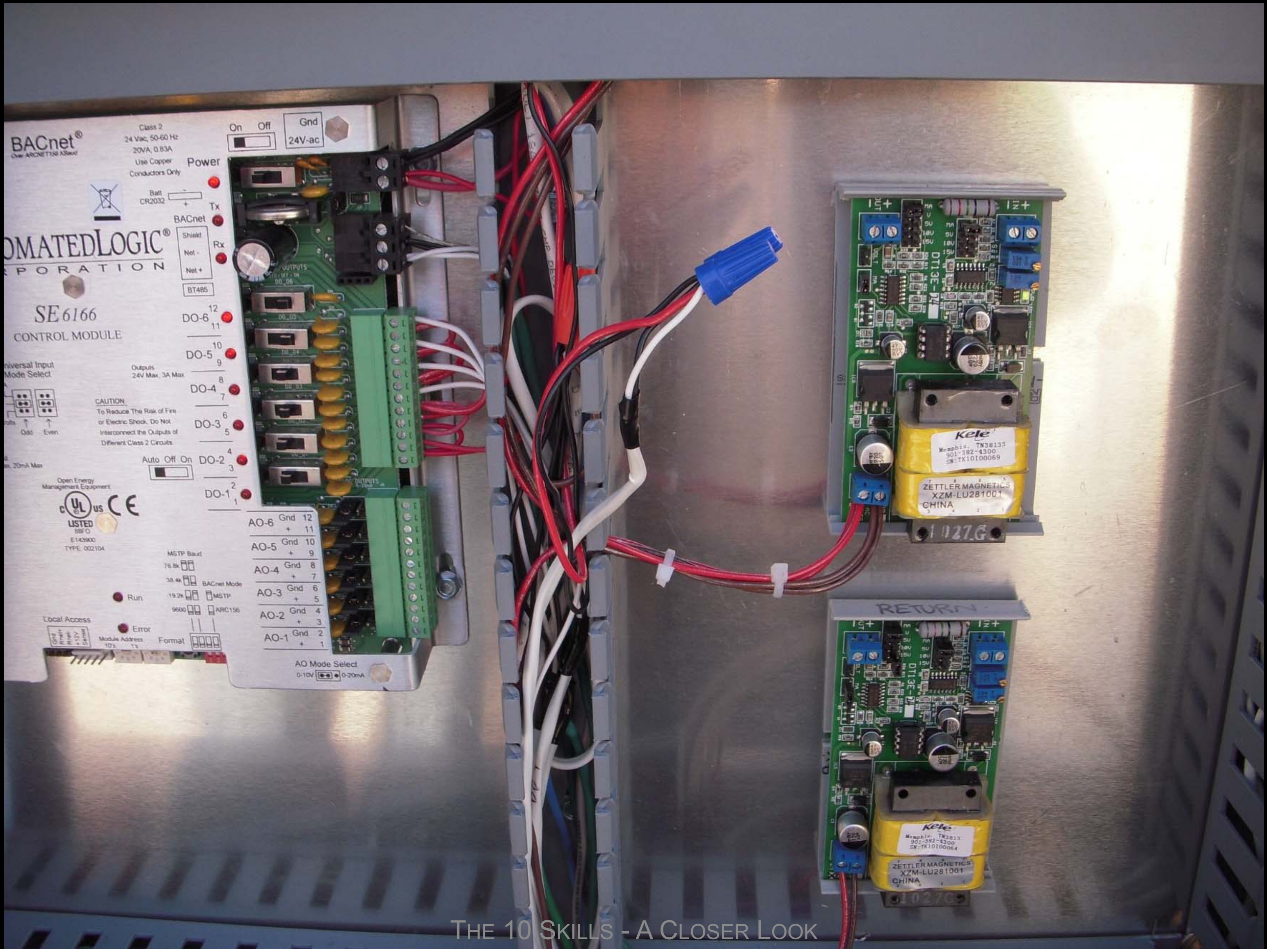
Learning Objectives

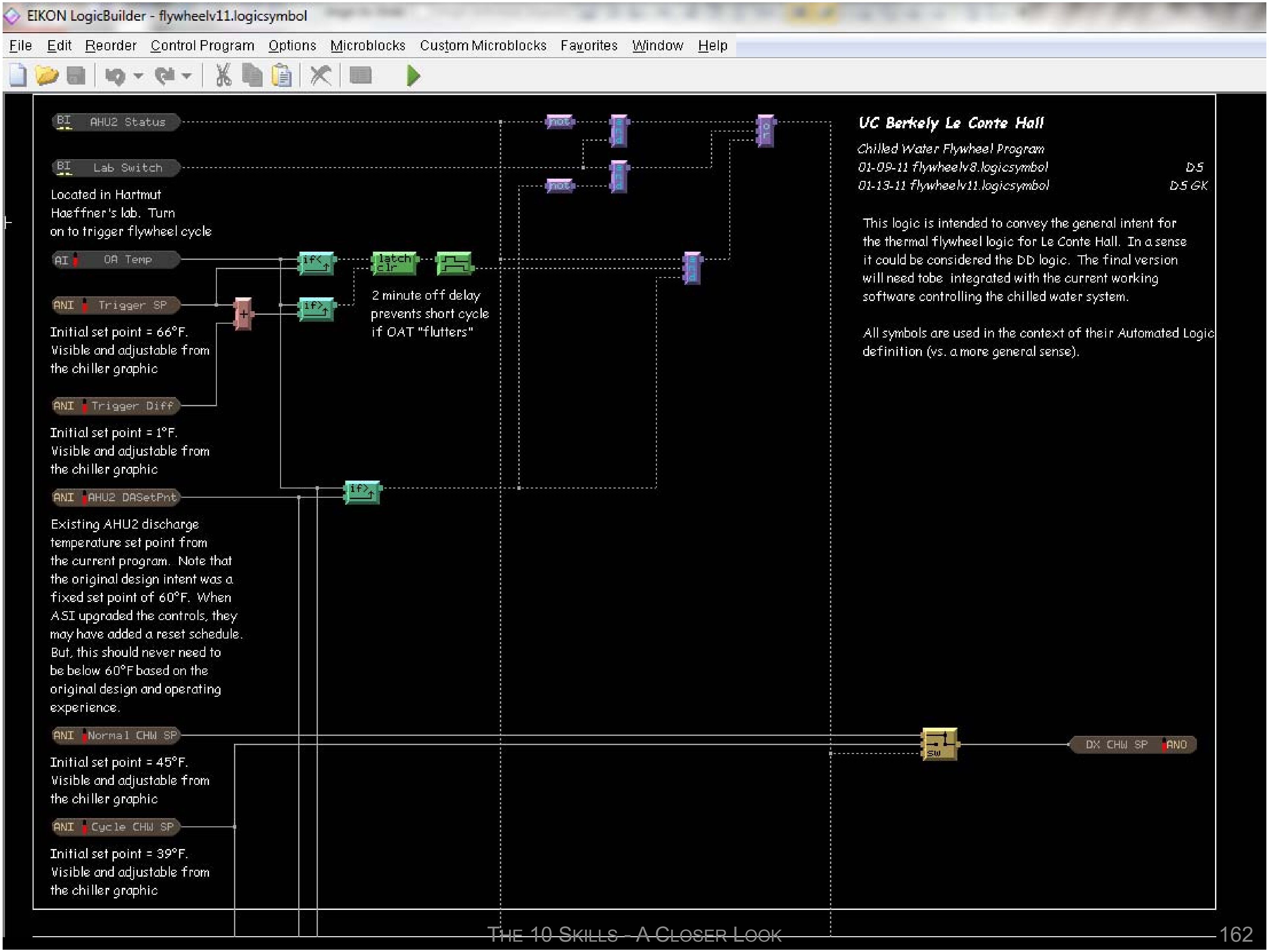
- Recognize and be able to explain why “open protocols” like BACNet, Lon, and Modbus to name a few are useful tools in terms of allowing different systems to share information but that they are not a panacea that will provide for a seamless, high-performance integration of multiple vendors.
- Recognize that the physical points necessary to control a system and the physical points necessary to properly operate and maintain a system,

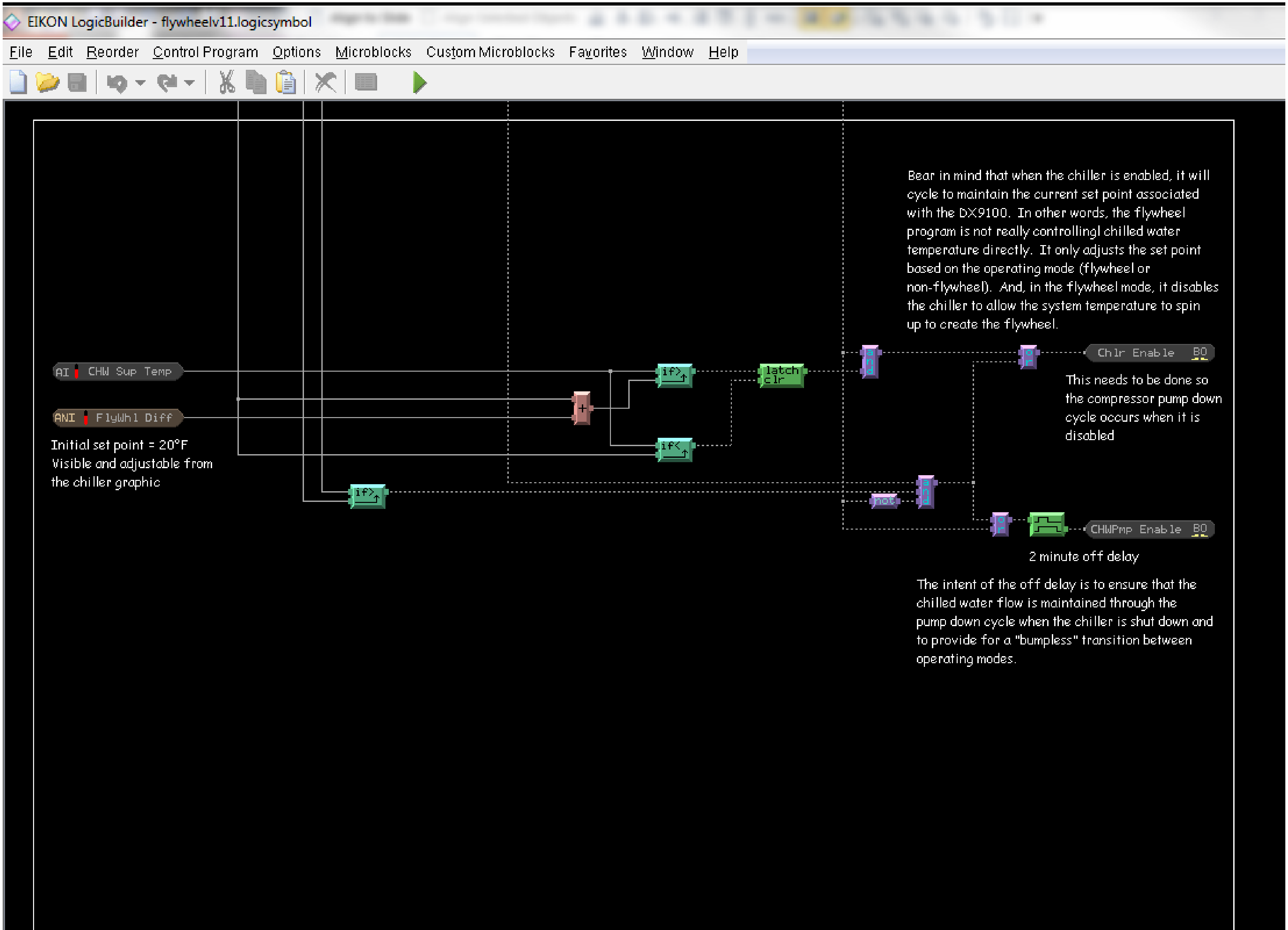
Competency can have Big Benefits



Competency can have Big Benefits




EIKON LogicBuilder - flywheelv11.logicsymbol
File Edit Reorder Control Program Options Microblocks Custom Microblocks Favorites Window Help
BI AHU2 Status
BI Lab Switch
Located in Hartmut Haeffner's lab. Turn on to trigger flywheel cycle
AI OA Temp
ANI Trigger SP
Initial set point = 66°F. Visible and adjustable from the chiller graphic
ANI Trigger Diff
Initial set point = 1°F. Visible and adjustable from the chiller graphic
ANI AHU2 DASetPnt
Existing AHU2 discharge temperature set point from the current program. Note that the original design intent was a fixed set point of 60°F. When ASI upgraded the controls, they may have added a reset schedule. But, this should never need to be below 60°F based on the original design and operating experience.
ANI Normal CHW SP
Initial set point = 45°F. Visible and adjustable from the chiller graphic
ANI Cycle CHW SP
Initial set point = 39°F. Visible and adjustable from the chiller graphic
not
not
and
and
or
and
if<
if>
if>
latch clr
2 minute off delay prevents short cycle if OAT "flutters"
sw
DX CHW SP ANO
UC Berkely Le Conte Hall
Chilled Water Flywheel Program
01-09-11 flywheelv8.logicsymbol DS
01-13-11 flywheelv11.logicsymbol DS GK
This logic is intended to convey the general intent for the thermal flywheel logic for Le Conte Hall. In a sense it could be considered the DD logic. The final version will need tobe integrated with the current working software controlling the chilled water system.
All symbols are used in the context of their Automated Logic definition (vs. a more general sense).


EIKON LogicBuilder - flywheelv11.logicsymbol
File Edit Reorder Control Program Options Microblocks Custom Microblocks Favorites Window Help
Bear in mind that when the chiller is enabled, it will cycle to maintain the current set point associated with the DX9100. In other words, the flywheel program is not really controllingl chilled water temperature directly. It only adjusts the set point based on the operating mode (flywheel or non-flywheel). And, in the flywheel mode, it disables the chiller to allow the system temperature to spin up to create the flywheel.
AI CHW Sup Temp
ANI FlyWhl Diff
Initial set point = 20°F
Visible and adjustable from the chiller graphic
if>
if<
latch clr
not
Chlr Enable BO
This needs to be done so the compressor pump down cycle occurs when it is disabled
CHWPmp Enable BO
2 minute off delay
The intent of the off delay is to ensure that the chilled water flow is maintained through the pump down cycle when the chiller is shut down and to provide for a "bumpless" transition between operating modes.

Bottom Lines

1. Benchmarking and Utility Analysis techniques provide quick clues for:
   - Identifying opportunities
   - Focusing efforts
   - Projecting outcomes
   - Demonstrating results
   - Ensuring persistence
2. Scoping skills help to firm up the picture based on the realities of the building
3. The skills that follow allow you to build from what you learn from the utility data and scoping to capture savings and improve performance

Let’s Go Scope a Facility