Building Tune-ups & Commissioning

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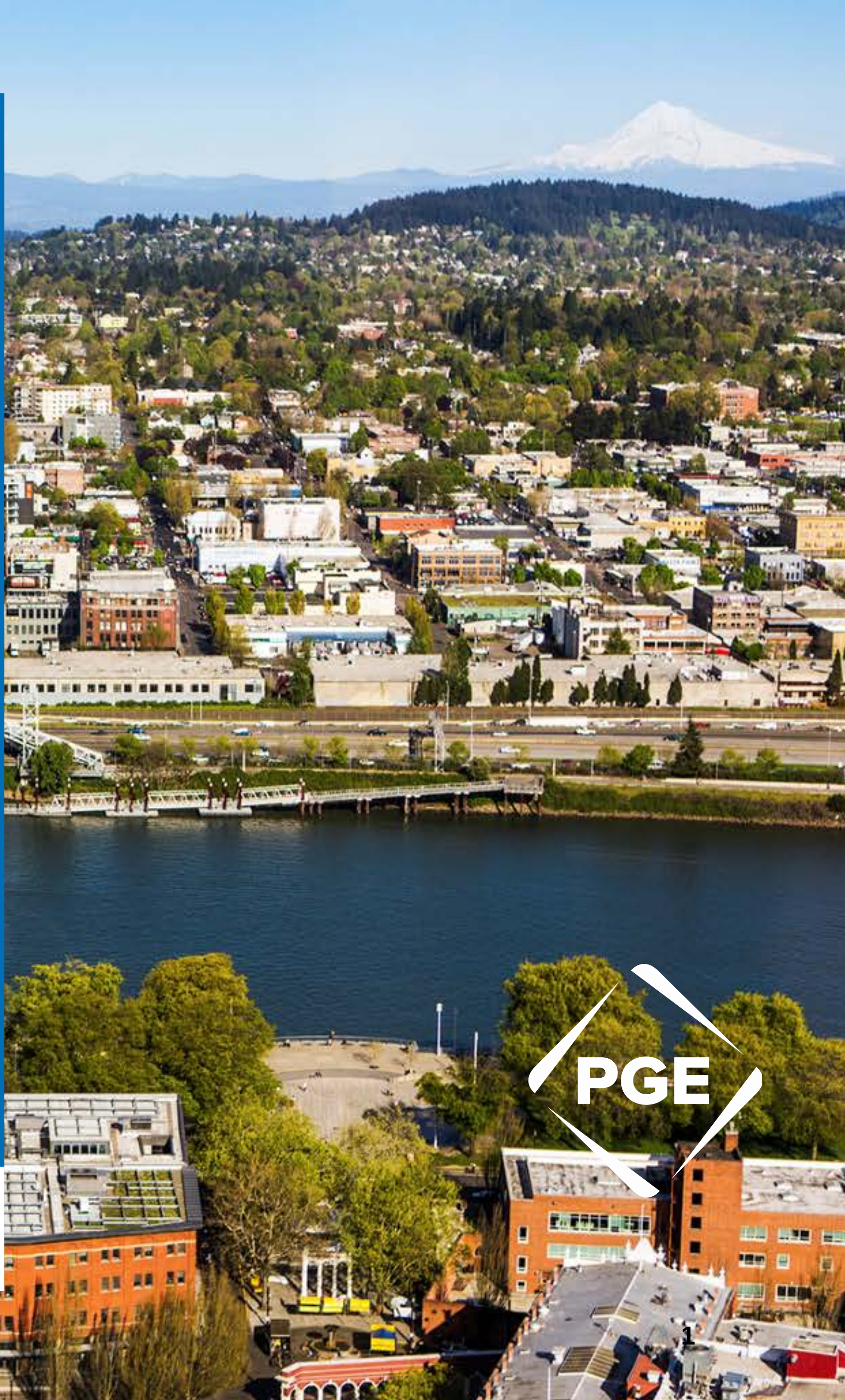
Facility Dynamics Engineering

April 18, 2018



Learning objectives

- Understand what building commissioning is and why it's important
- Identify the differences between a new construction and an existing building commissioning process
- Become familiar with the commissioning tool set
- Describe some of the holistic benefits of the commissioning process

Agenda

- What is building commissioning?
- Why do we need to commission?
- Commissioning's benefits
- Functional testing and the commissioning time line
- The system concept
- The load profile
- The control system
- Commissioning and the broader perspective

What is building commissioning?

The definition of commissioning and the flavors it comes in

Dictionary definition

Com·mis·sion

kəˈmiSHən

Verb; Gerund or present participle: Commissioning

1. Give an order for or authorize the production of (something such as a building, equipment, or work of art).

The portrait was commissioned by his widow in 1792

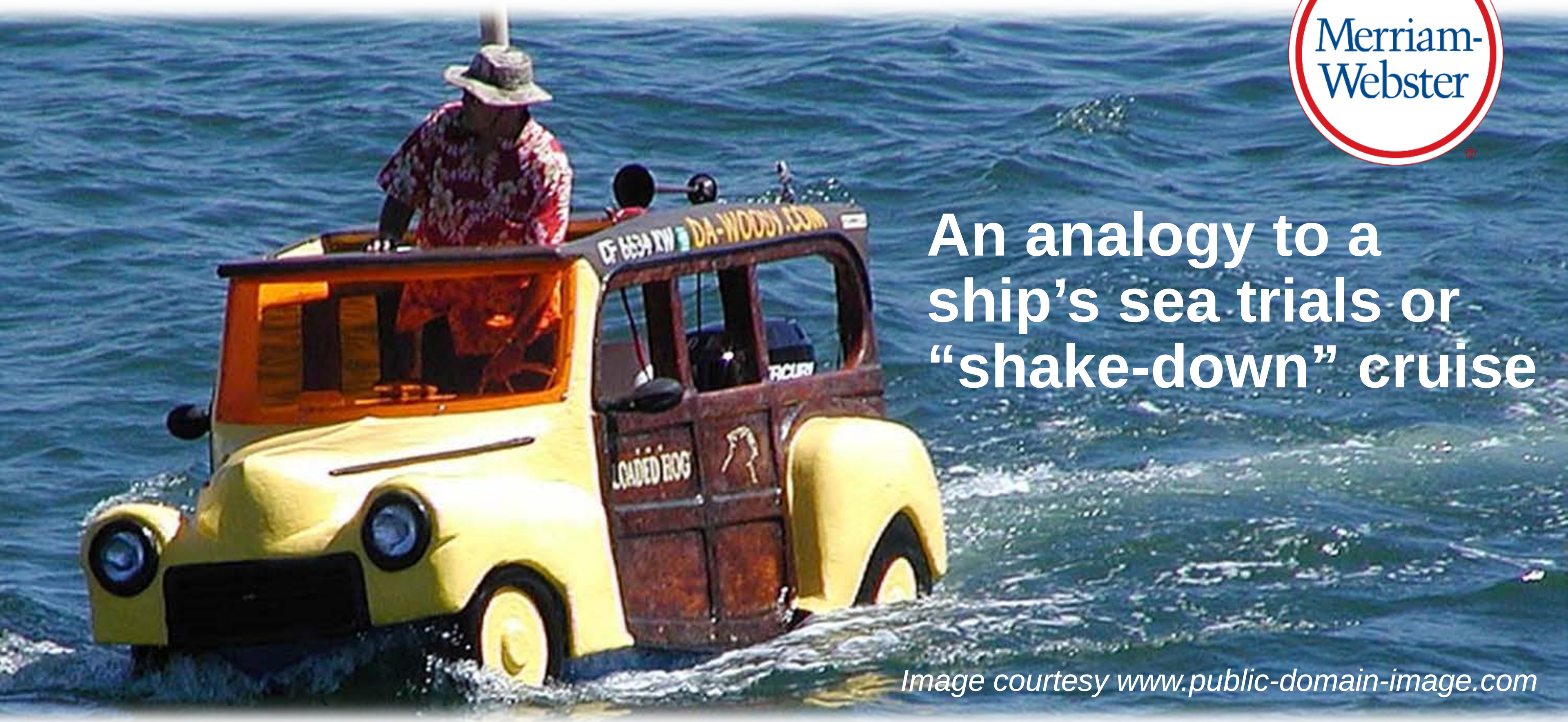
synonyms: order, authorize, bespeak

2. Bring (something newly produced, such as a factory or machine) into working condition.

We had a few hiccups getting the heating equipment commissioned

Dictionary definition

Merriam-Webster



An analogy to a ship’s sea trials or “shake-down” cruise

Image courtesy www.public-domain-image.com

It’s about performance and integration

Commissioning is a systematic process of ensuring that all building systems perform interactively according to the contract documents, the design intent and the Owner’s operational needs

- Begins in predesign
- Documents the design intent
- Continues through construction, acceptance, the warranty period, and through the building’s life cycle
- Includes functional testing
- Includes training
- Documents performance

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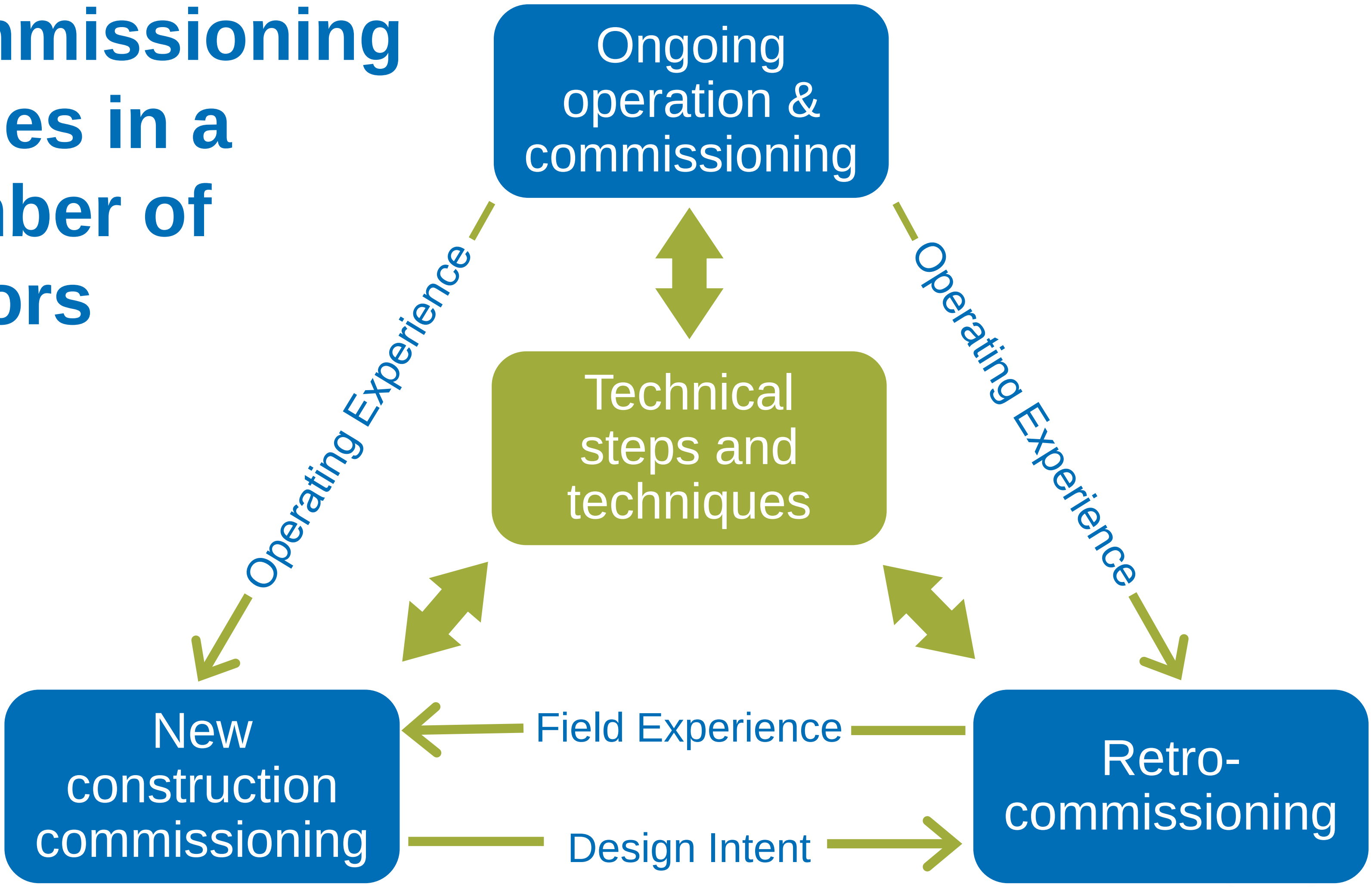
Commissioning comes in a number of flavors



What is retrocommissioning?

In general terms, it's the same thing as:

- RCx
- Existing Building Commissioning
- EBCx
- Recommissioning
- Building tune-up

What is ongoing commissioning?

Continuous Commissioning™

A Trademarked Process Developed by Texas A&M

Operating the building properly

What folks called it when I started doing this stuff (1976)

Commissioning is a team effort

No matter what the flavor

The building systems aren't the only thing that will be interactive and require integration from the Cx provider.

Farside Early Experiments in Transportation Cartoon Here

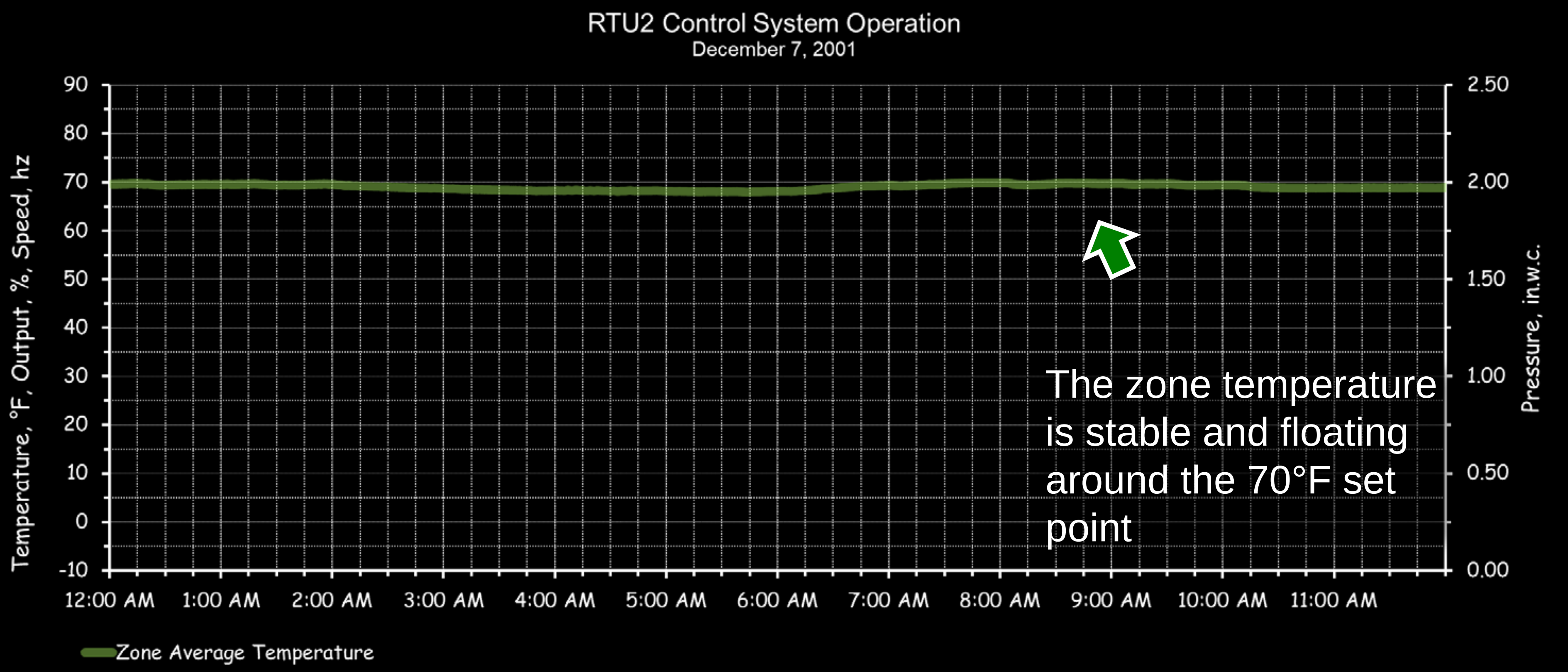
Why do we need to commission?

You may not fully comprehend the situation

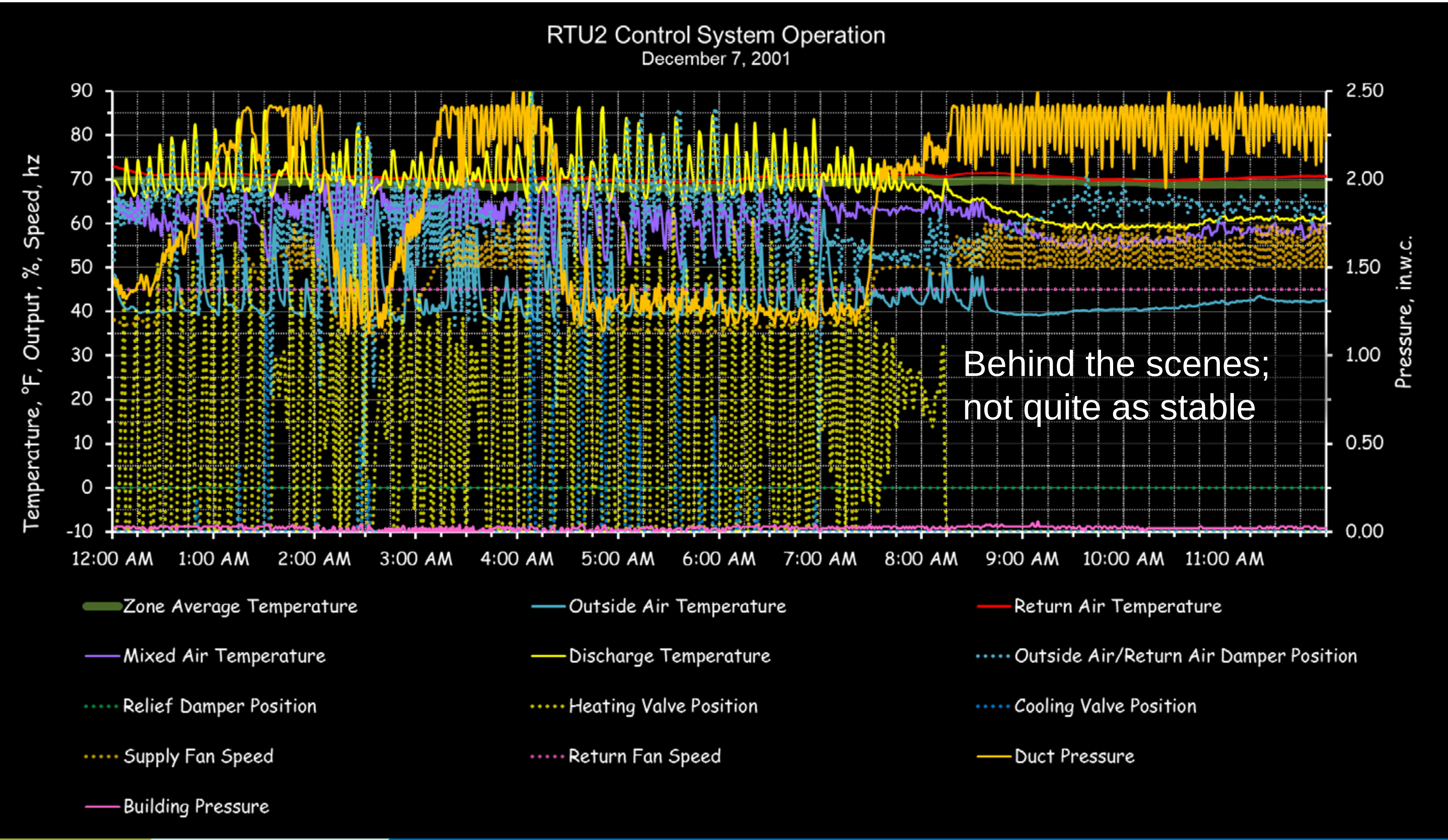
"… If you are piloting an untested vehicle on it's first test flight and that vehicle contains more propellant than was ever placed on a launch pad before and the vehicle was assembled by the low bidder and you aren't a little nervous, then you don't fully comprehend the situation"

Paraphrased; John Young to Barbara Walters when asked if he would be nervous as the test pilot on the first manned shuttle flight

Things may seem fine at the office …



… but HVAC is dynamic and complex



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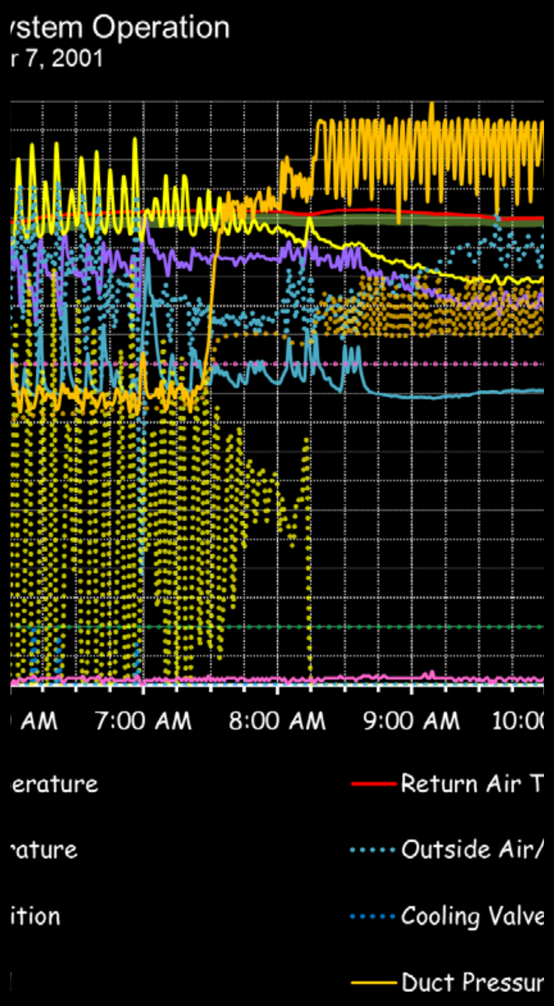
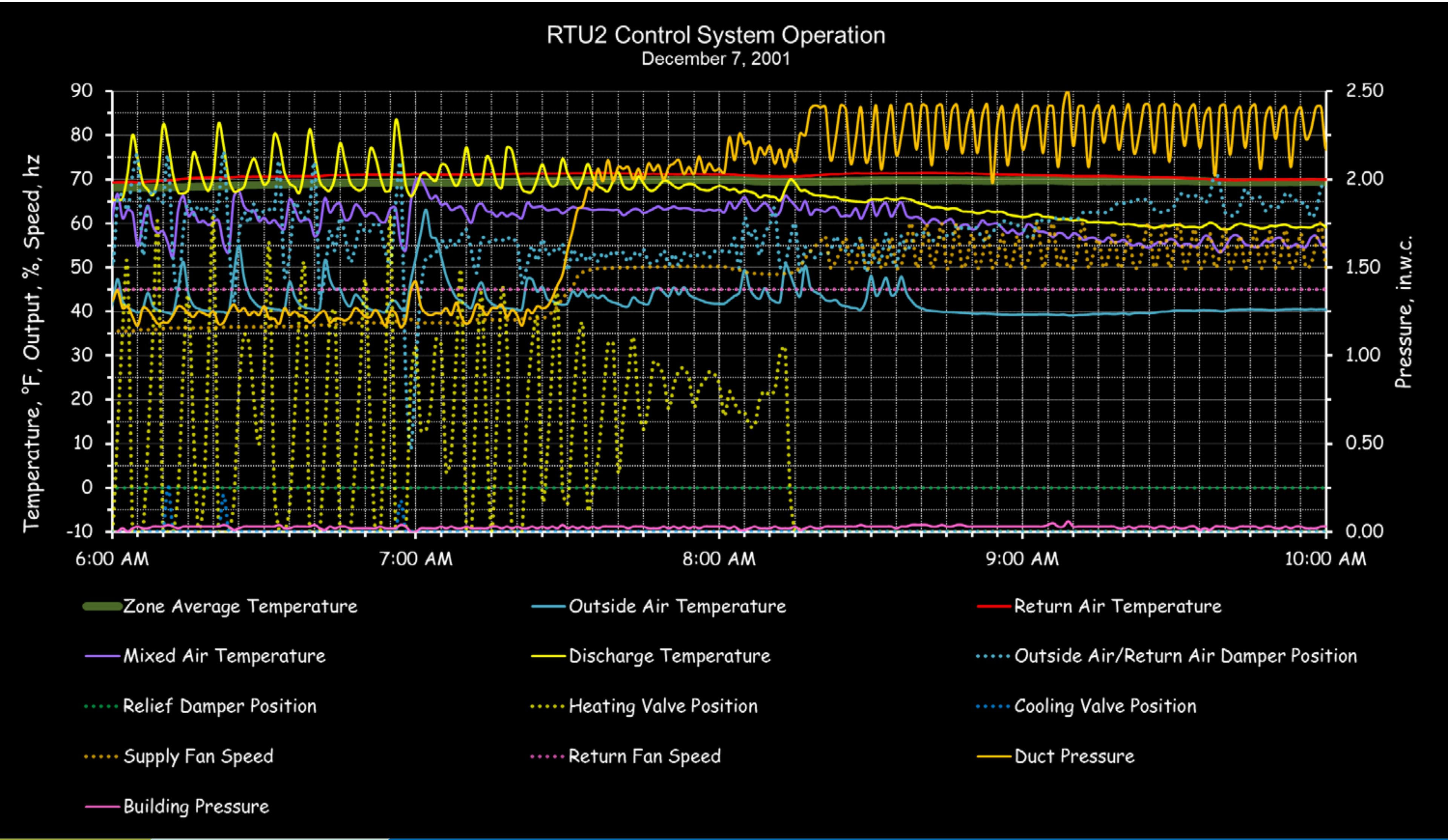
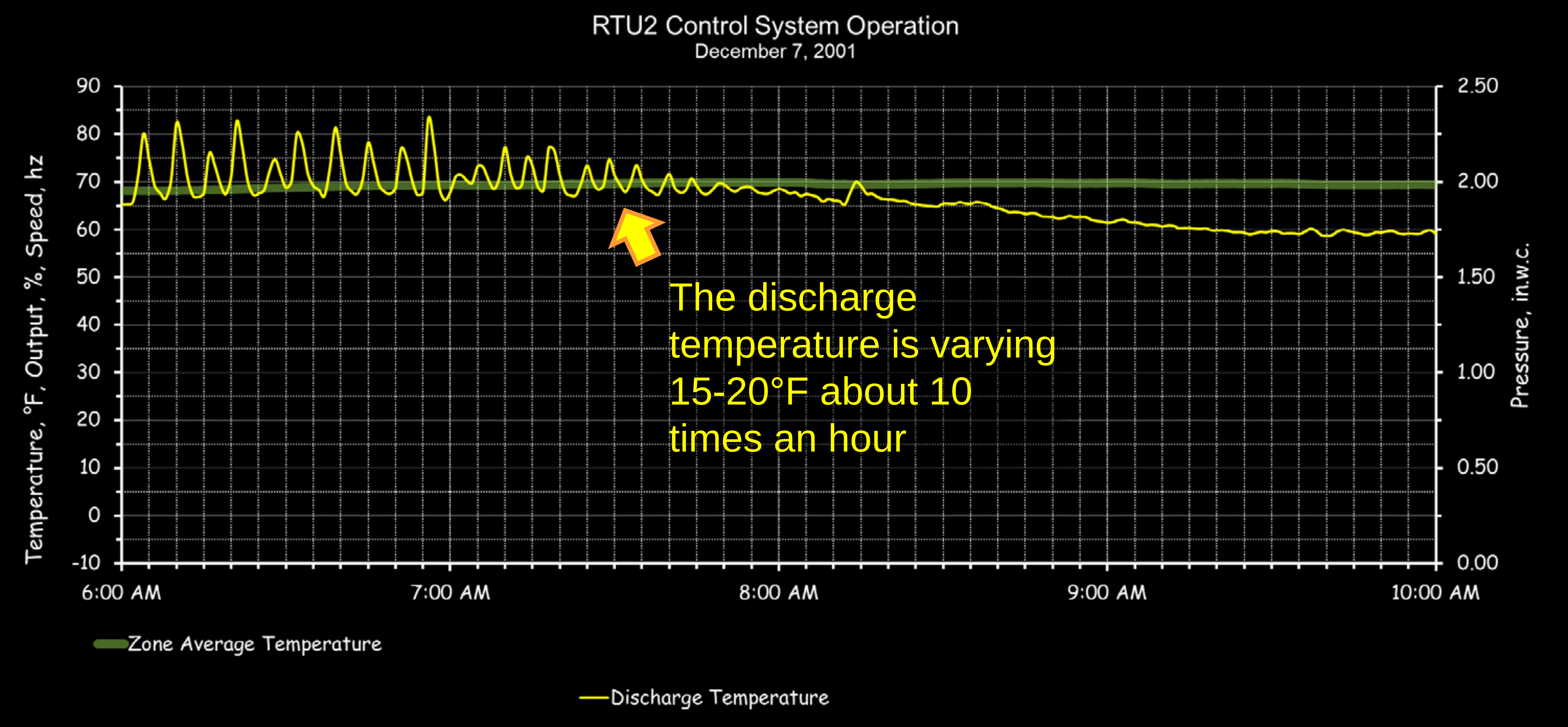


… and HVAC can be insidious



… and HVAC can be insidious



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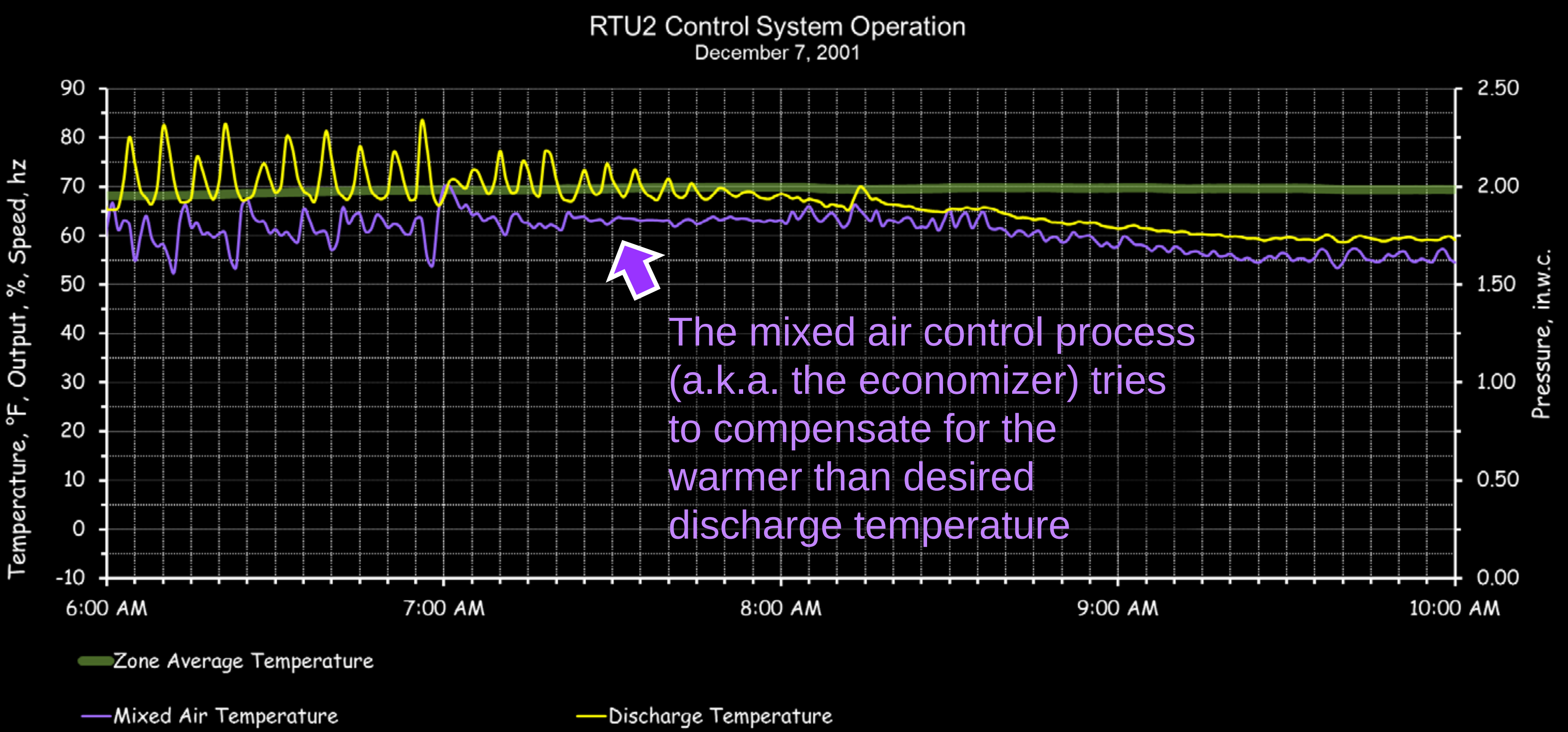
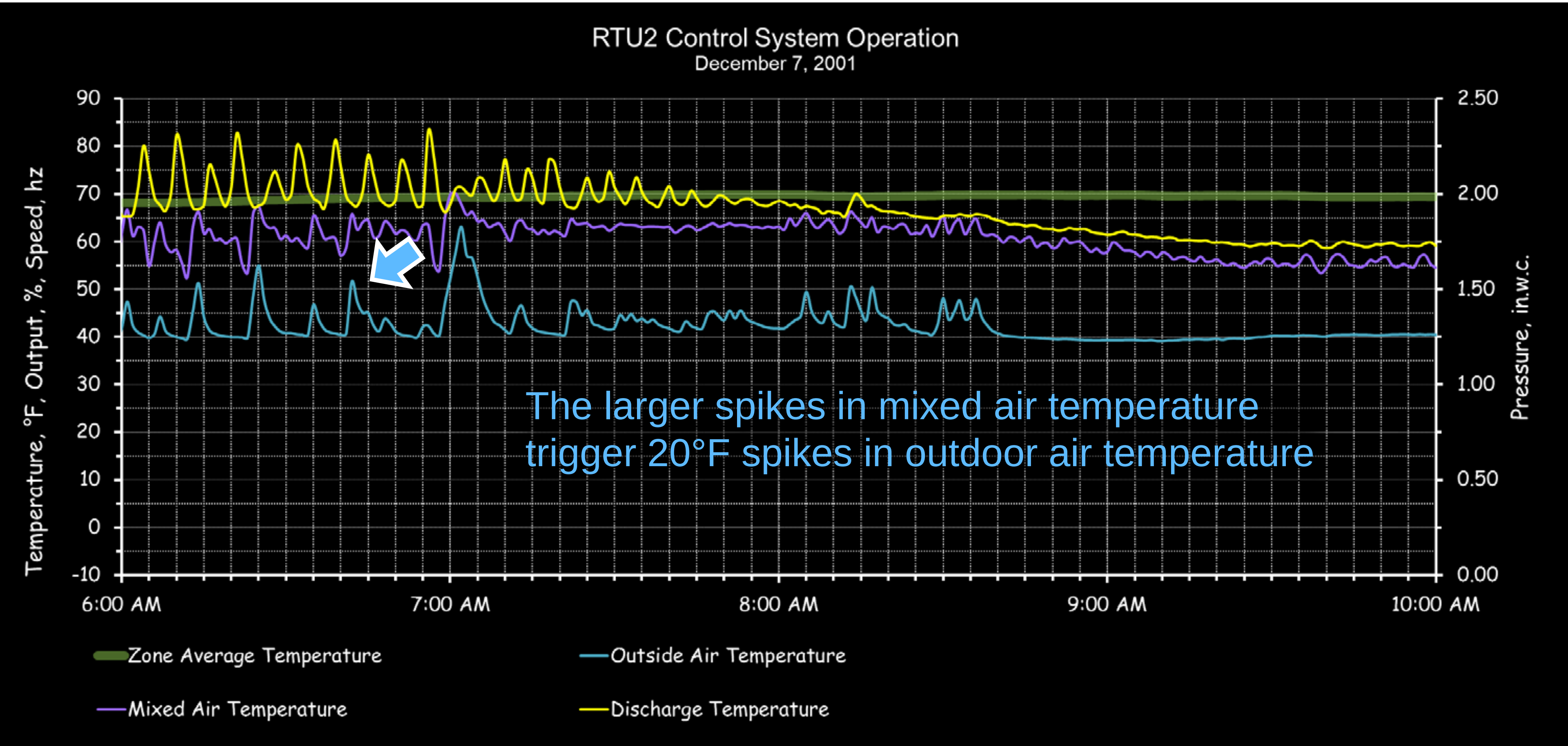
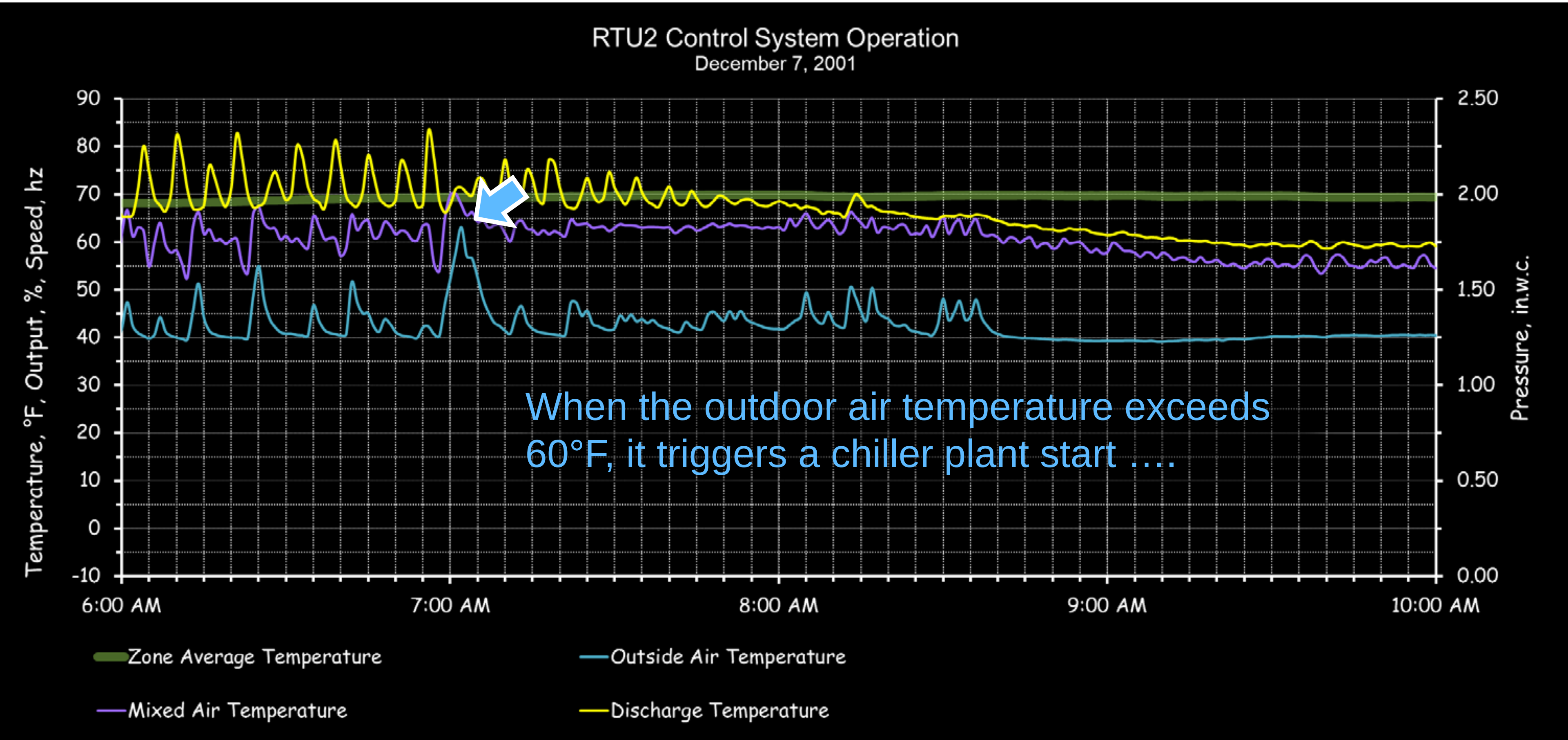


The mixed air control process (a.k.a. the economizer) tries to compensate for the warmer than desired discharge temperature

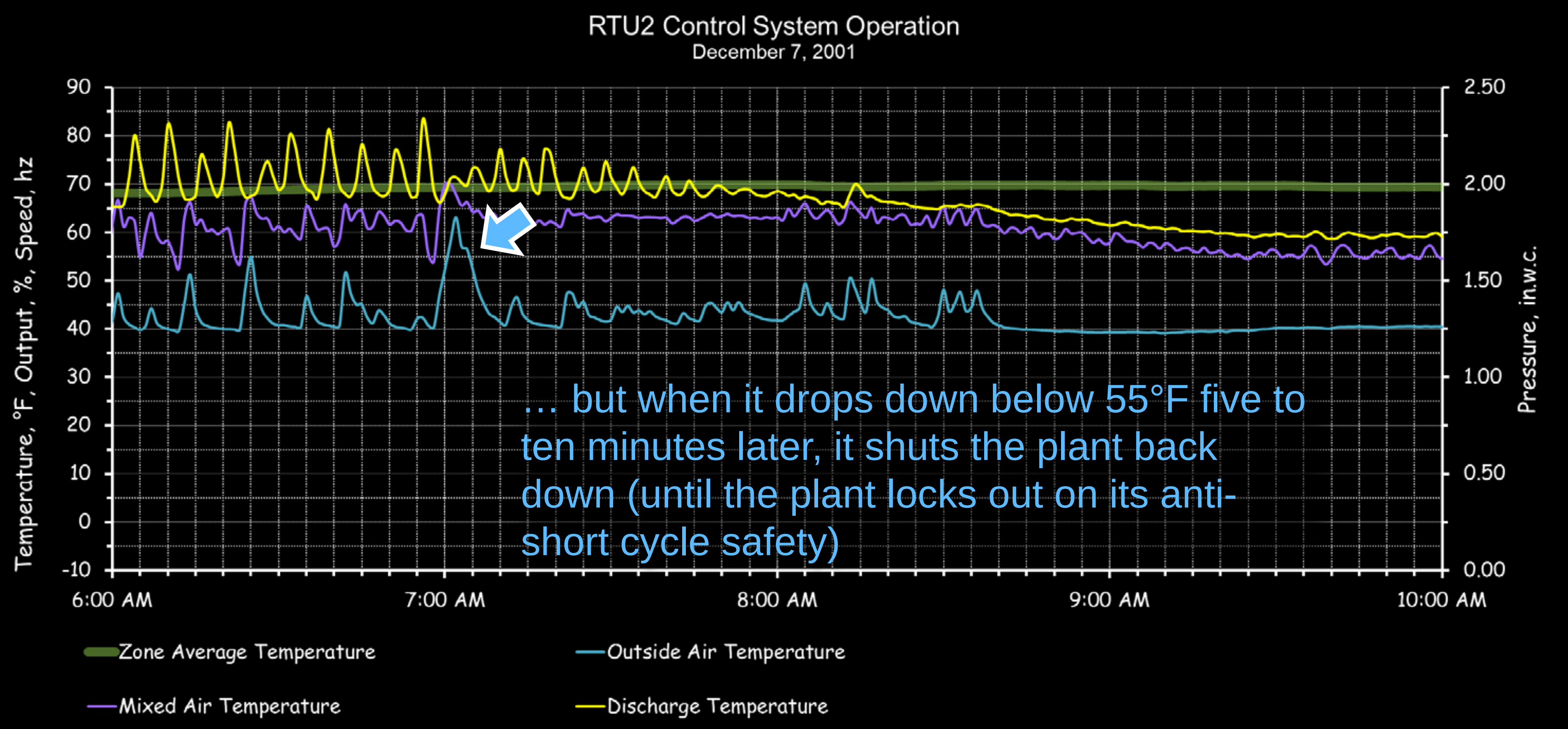
… and HVAC can be insidious



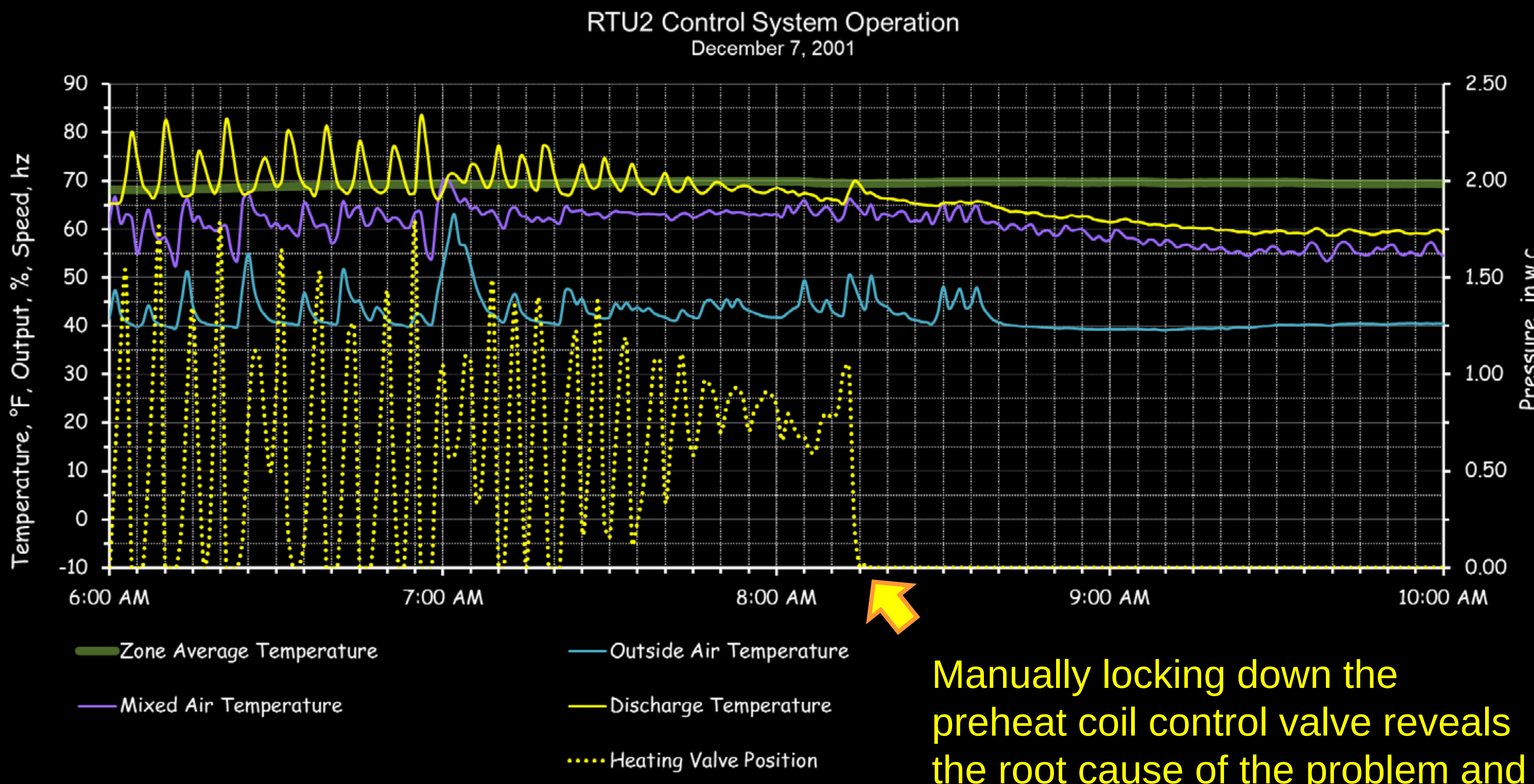
… and HVAC can be insidious



… and HVAC can be insidious

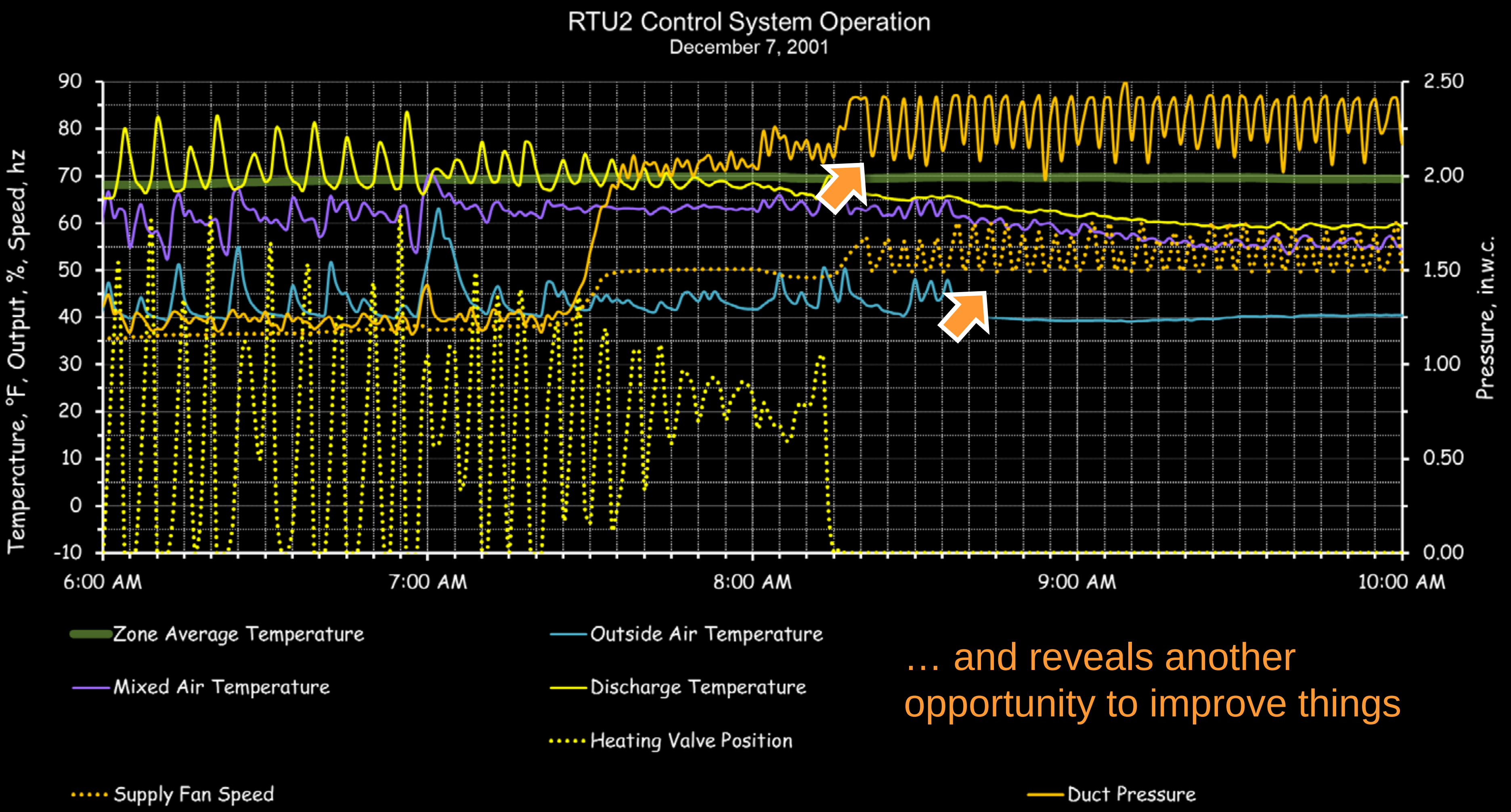


… and HVAC can be insidious



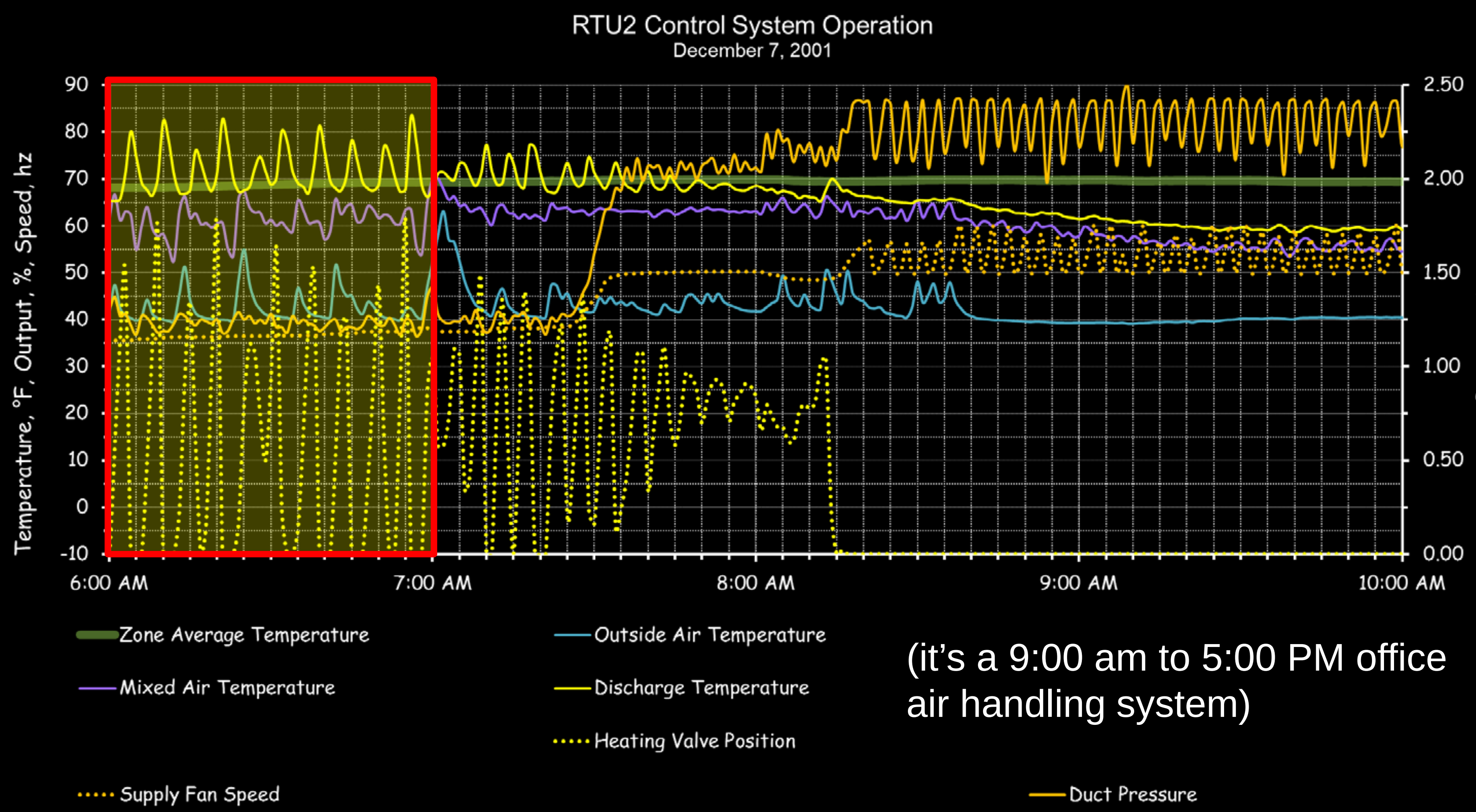
Manually locking down the preheat coil control valve reveals the root cause of the problem and how to solve it …

… and HVAC can be insidious



… and reveals another opportunity to improve things

And let's not miss the obvious



(it's a 9:00 am to 5:00 PM office air handling system)

Buildings don’t perform as intended

The future is not in plastics, my boy, the future is in construction.

Dr. Joseph Lstiburek

Buildings don't perform as intended

The future is not in plastics, my boy, the future is in construction. ***Actually, the future is in fixing construction.***

Dr. Joseph Lstiburek

Commissioning's benefits

Typical new construction Cx issues

- Poor turn-down capabilities
- Unanticipated interactions
- Pump head is excessive
- Fan static is insufficient
- Rouge zones
- Control sensor calibration
- Control sensor location
- Control system logic
- Control system design
- Schedules missing
- Equipment missing

Typical existing building Cx issues

- Poor turn-down capabilities
- Unanticipated interactions
- Pump head is excessive
- Fan static is insufficient
- Rouge zones
- Control sensor calibration
- Control sensor location
- Control system logic
- Control system design
- Schedules missing
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Typical existing building Cx issues

- Poor turn-down capabilities
- Unanticipated interactions
- Pump head is excessive
- Fan static is insufficient
- Rouge zones
- Control sensor calibration
- Control sensor location
- Control system logic
- Control system design
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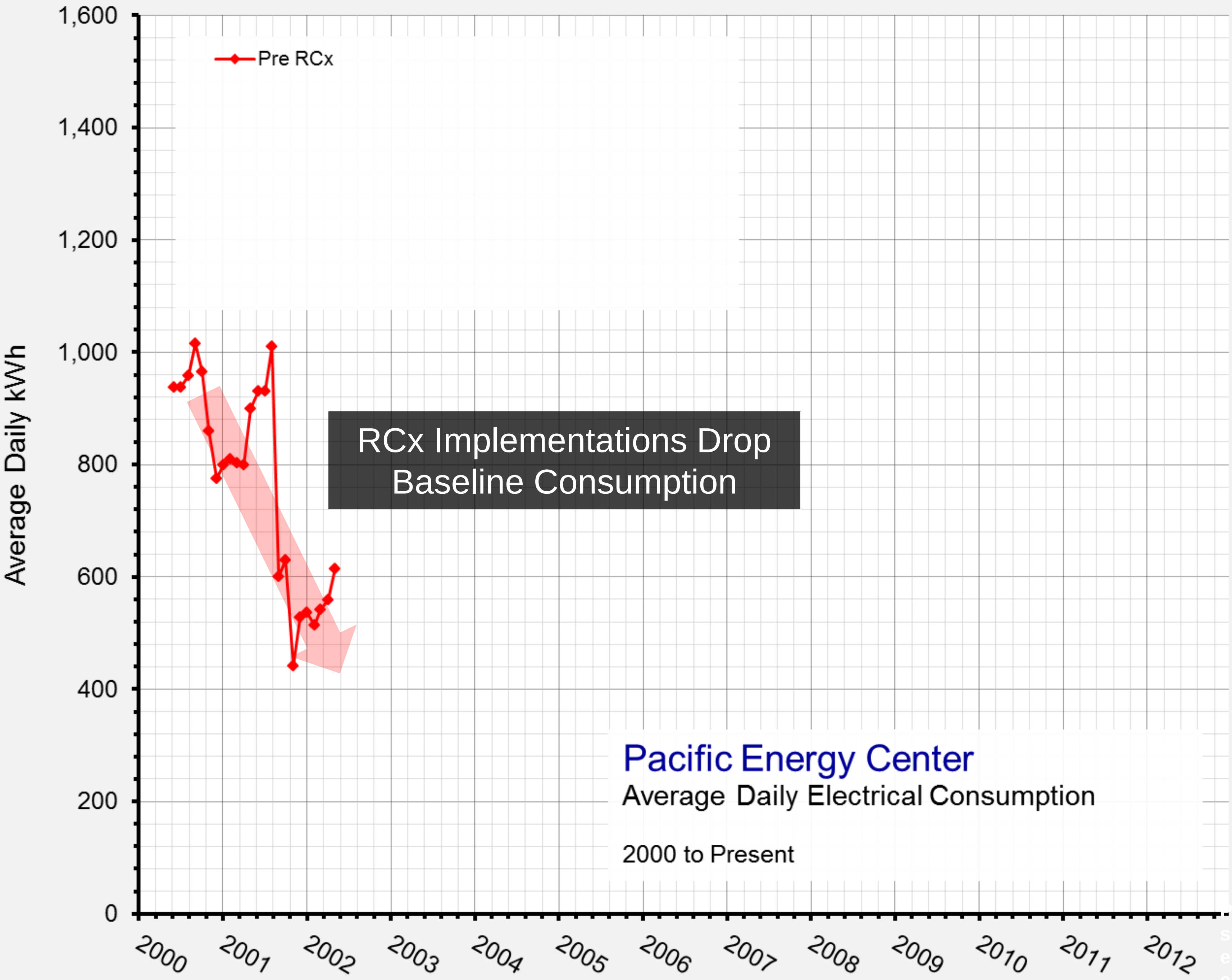
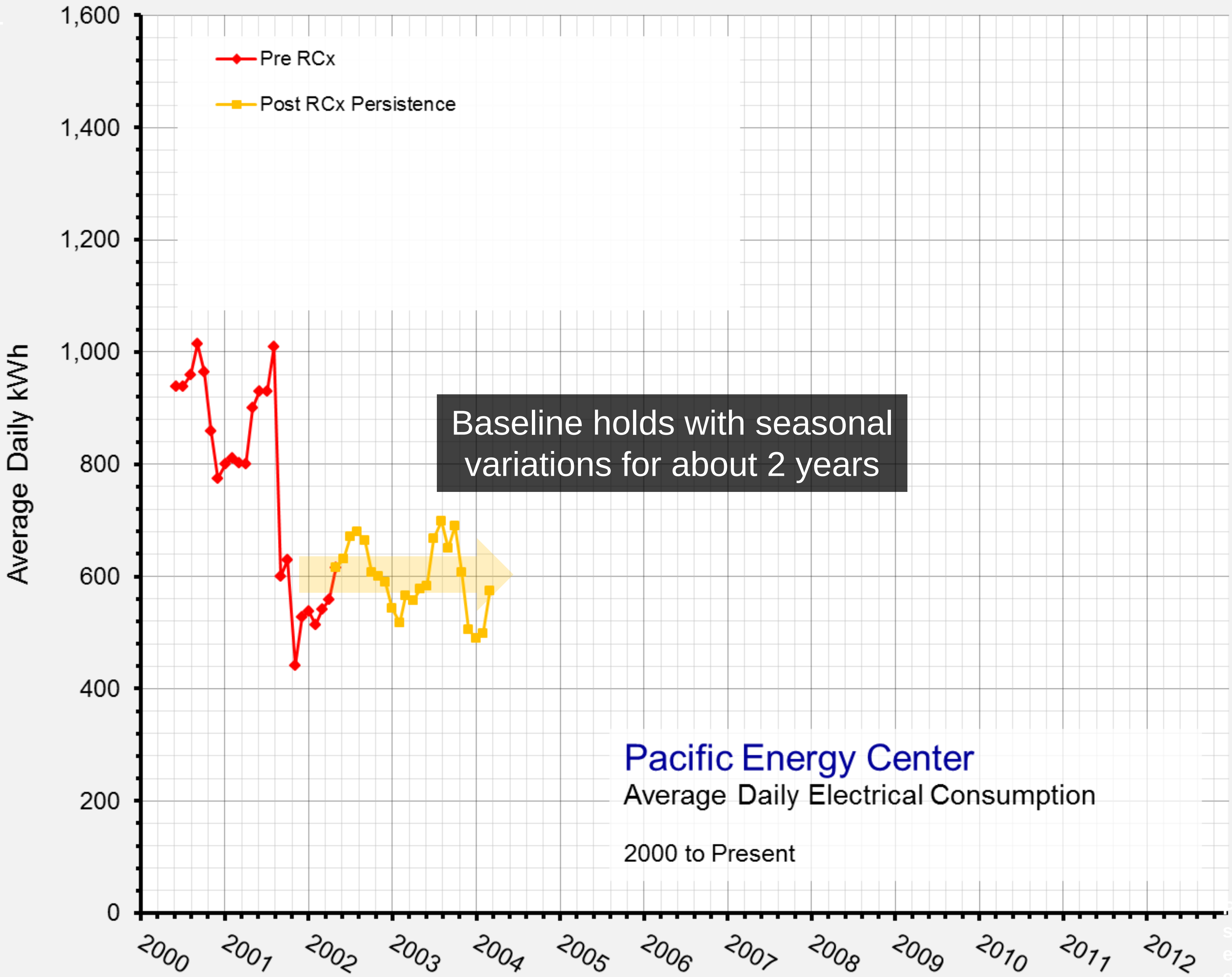
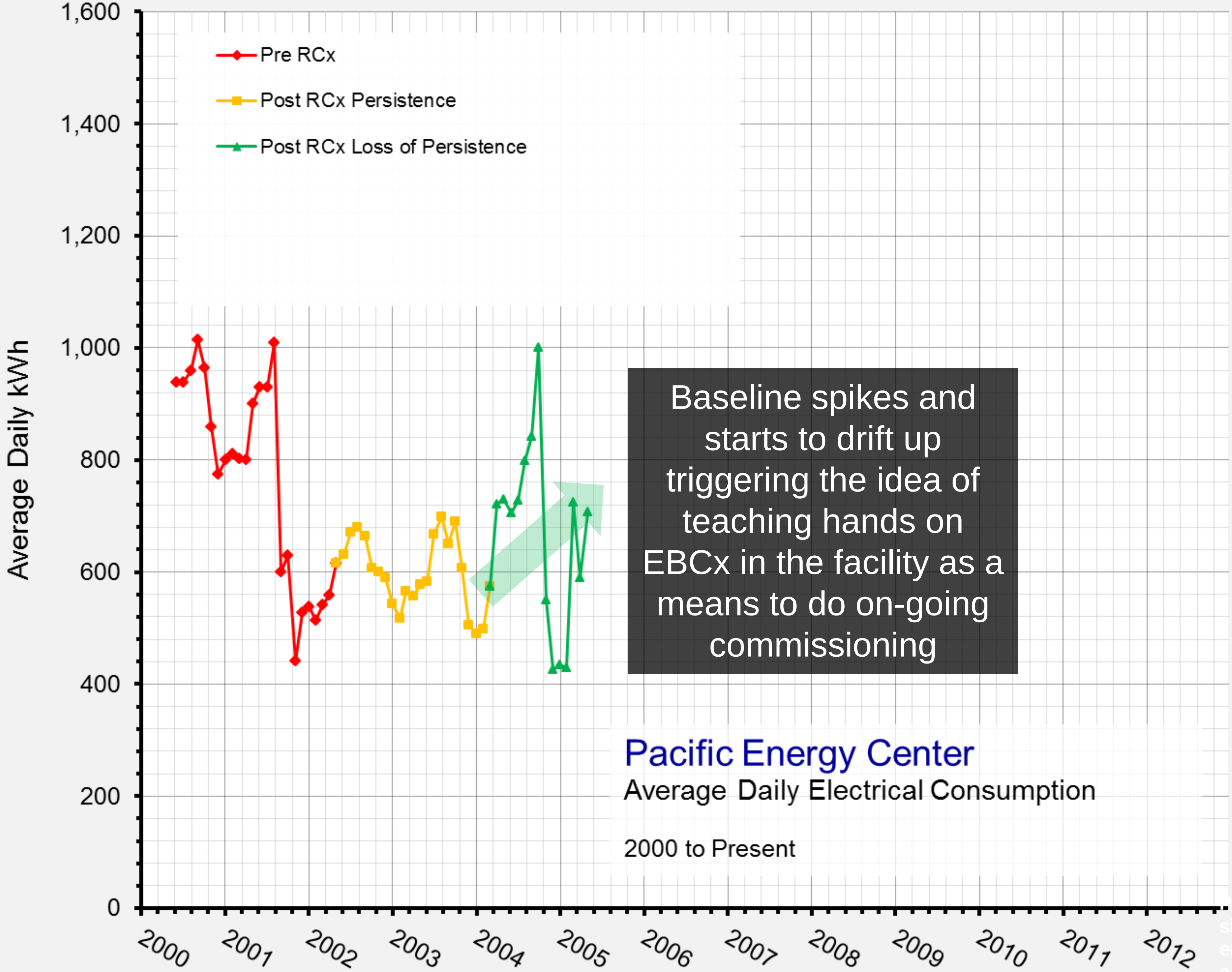
- Equipment missing

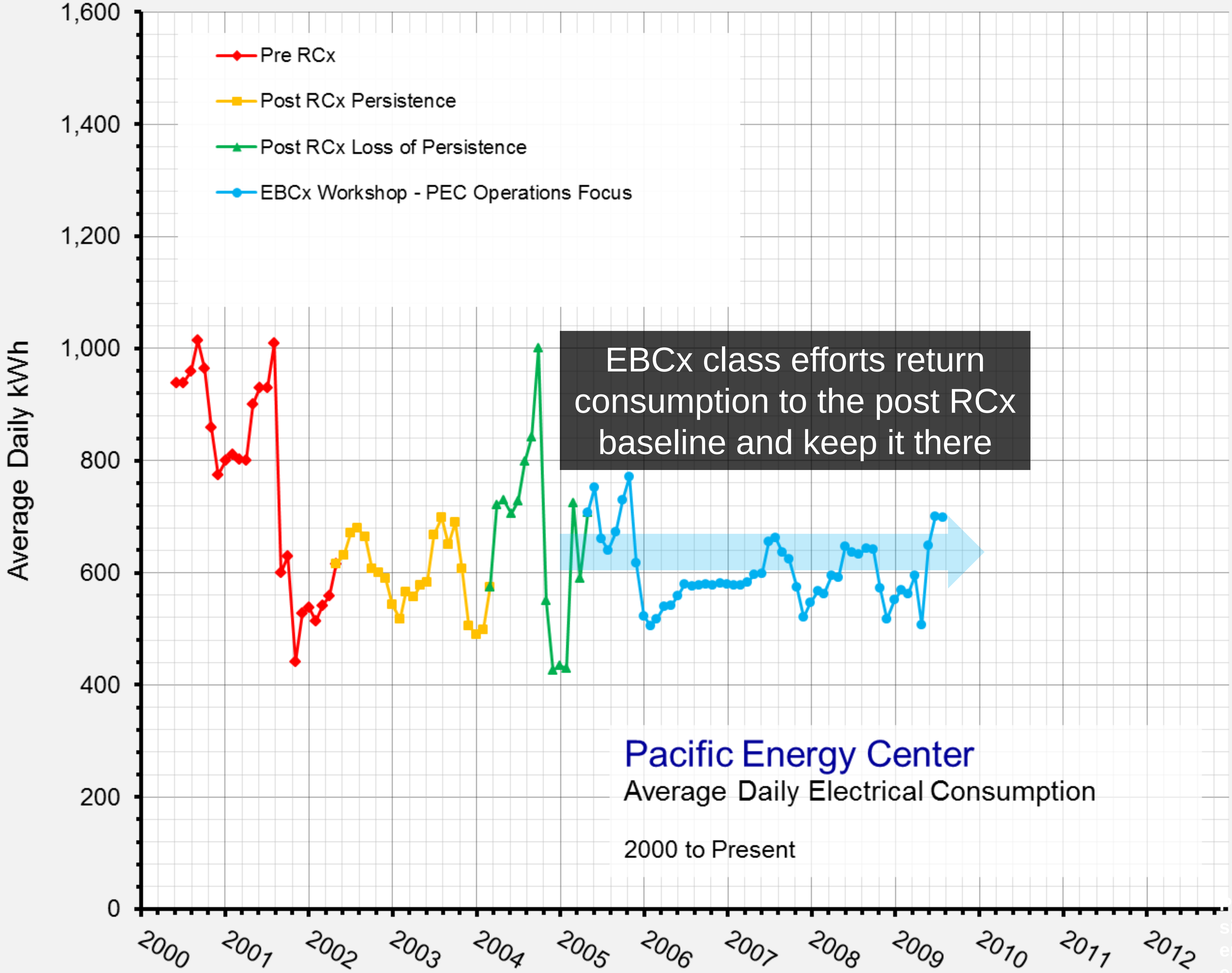
- Most existing building commissioning issues are unresolved new construction commissioning issues or design issues
- Existing building commissioning issues are excellent design review targets

Savings vs. persistent savings

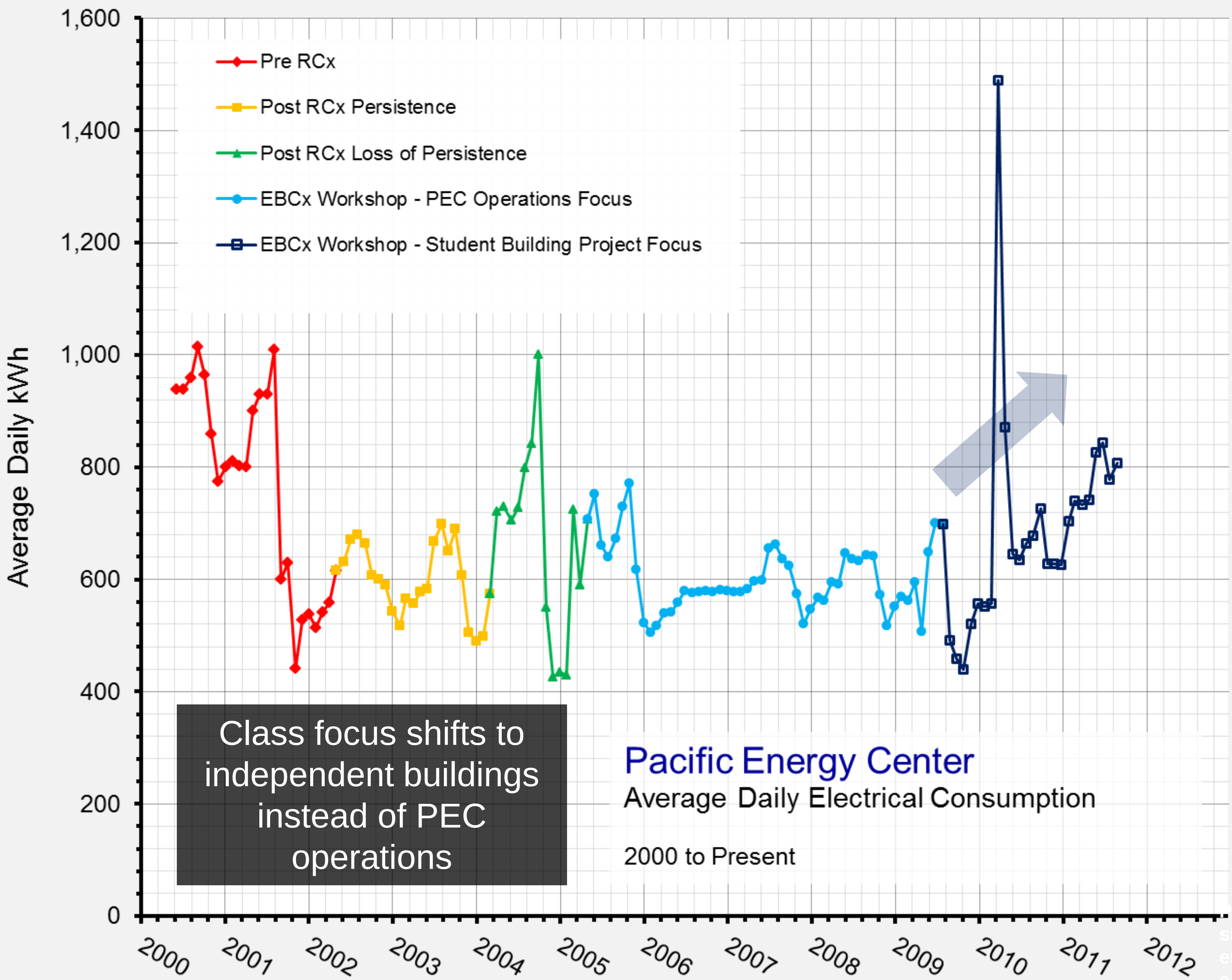

Pre RCx
RCx Implementations Drop
Baseline Consumption
Pacific Energy Center
Average Daily Electrical Consumption
2000 to Present
Average Daily kWh
1,600
1,400
1,200
1,000
800
600
400
200
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012

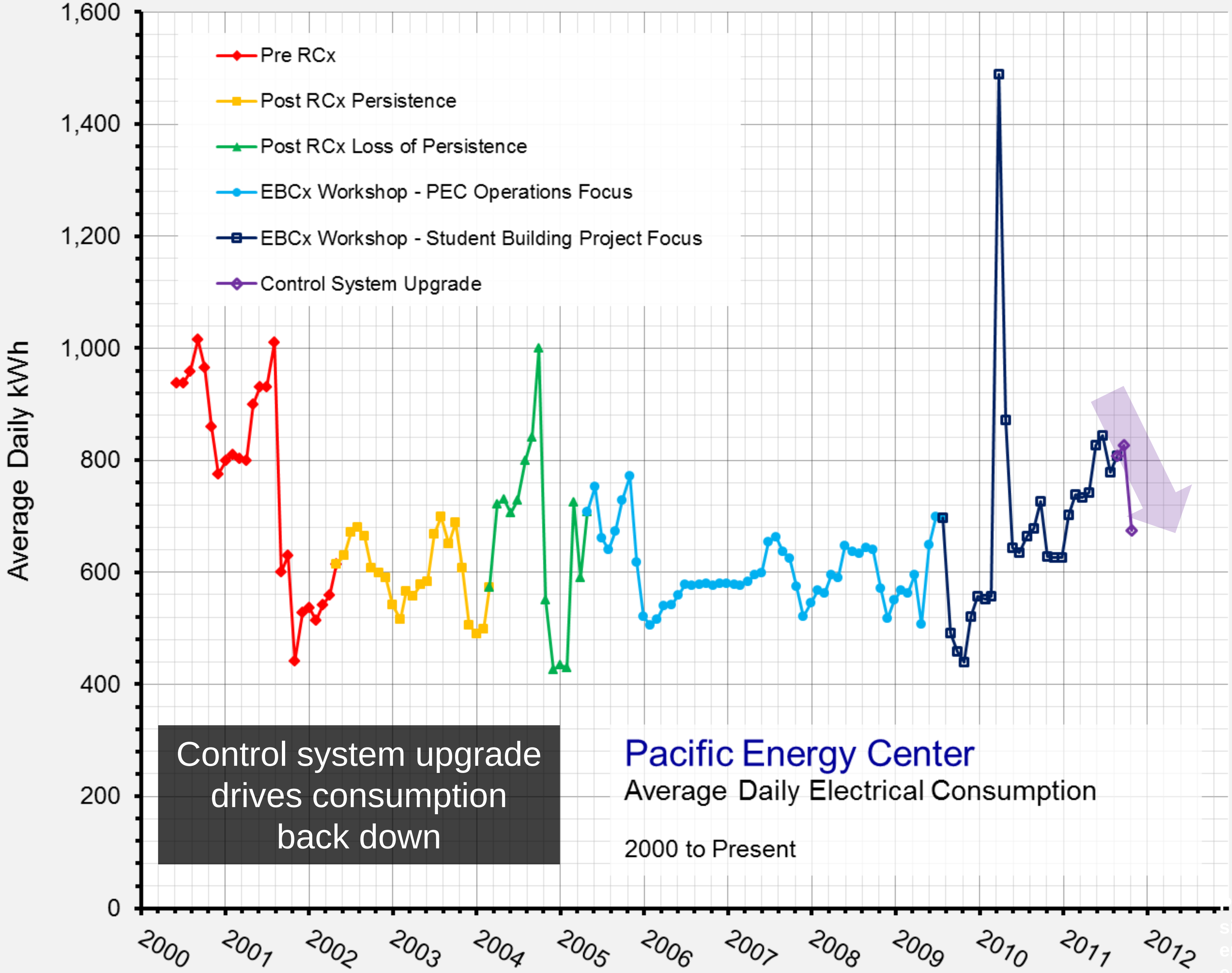

Pre RCx
Post RCx Persistence
Average Daily kWh
1,600
1,400
1,200
1,000
800
600
400
200
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Baseline holds with seasonal variations for about 2 years
Pacific Energy Center
Average Daily Electrical Consumption
2000 to Present


1,600
1,400
1,200
1,000
800
600
400
200
0
Average Daily kWh
Pre RCx
Post RCx Persistence
Post RCx Loss of Persistence
Baseline spikes and starts to drift up triggering the idea of teaching hands on EBCx in the facility as a means to do on-going commissioning
Pacific Energy Center
Average Daily Electrical Consumption
2000 to Present
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012



1,600
1,400
1,200
1,000
800
600
400
200
0
Average Daily kWh
Pre RCx
Post RCx Persistence
Post RCx Loss of Persistence
EBCx Workshop - PEC Operations Focus
EBCx class efforts return consumption to the post RCx baseline and keep it there
Pacific Energy Center
Average Daily Electrical Consumption
2000 to Present
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012


Average Daily kWh
1,600
1,400
1,200
1,000
800
600
400
200
0
Pre RCx
Post RCx Persistence
Post RCx Loss of Persistence
EBCx Workshop - PEC Operations Focus
EBCx Workshop - Student Building Project Focus
Class focus shifts to independent buildings instead of PEC operations
Pacific Energy Center
Average Daily Electrical Consumption
2000 to Present
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012



1,600
1,400
1,200
1,000
800
600
400
200
0
Average Daily kWh
Pre RCx
Post RCx Persistence
Post RCx Loss of Persistence
EBCx Workshop - PEC Operations Focus
EBCx Workshop - Student Building Project Focus
Control System Upgrade
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Control system upgrade drives consumption back down
Pacific Energy Center
Average Daily Electrical Consumption
2000 to Present

Achieving persistence is the challenge

In a system, a process that occurs will tend to increase the total entropy of the universe.

2nd Law of Thermodynamics

- Things wear
- Heat transfer characteristics change
- Things break
- People forget
- People make mistakes

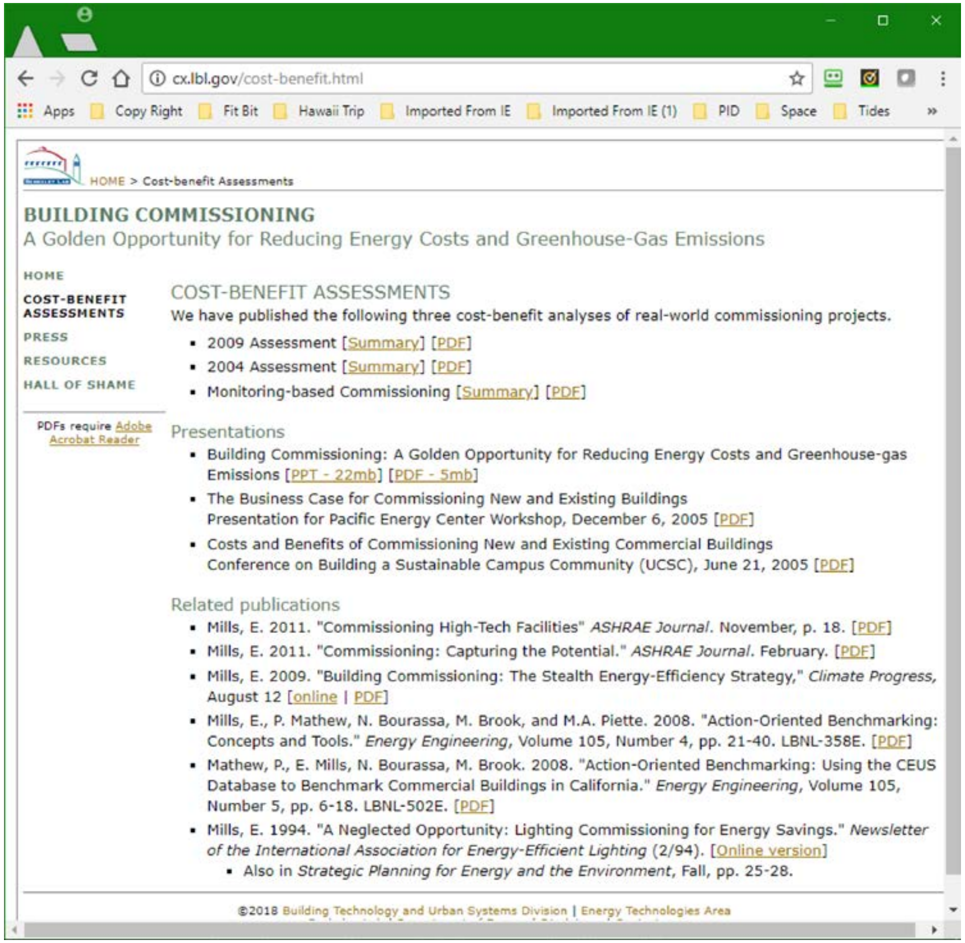

Image courtesy Jay Cmiel, San Jose Marriott

Achieving persistence is rewarding

Lawrence Berkeley National Labs published a meta-study on the benefits of commissioning in 2004

- Updated on 2009
- Currently being updated again

http://cx.lbl.gov/cost-benefit.html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BUILDING COMMISSIONING

A Golden Opportunity for Reducing Energy Costs and Greenhouse-Gas Emissions

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COST-BENEFIT ASSESSMENTS

We have published the following three cost-benefit analyses of real-world commissioning projects.

- 2009 Assessment [Summary] [PDF]
- 2004 Assessment [Summary] [PDF]
- Monitoring-based Commissioning [Summary] [PDF]

Presentations

- Building Commissioning: A Golden Opportunity for Reducing Energy Costs and Greenhouse-gas Emissions [PPT - 22mb] [PDF - 5mb]
- The Business Case for Commissioning New and Existing Buildings Presentation for Pacific Energy Center Workshop, December 6, 2005 [PDF]
- Costs and Benefits of Commissioning New and Existing Commercial Buildings Conference on Building a Sustainable Campus Community (UCSC), June 21, 2005 [PDF]

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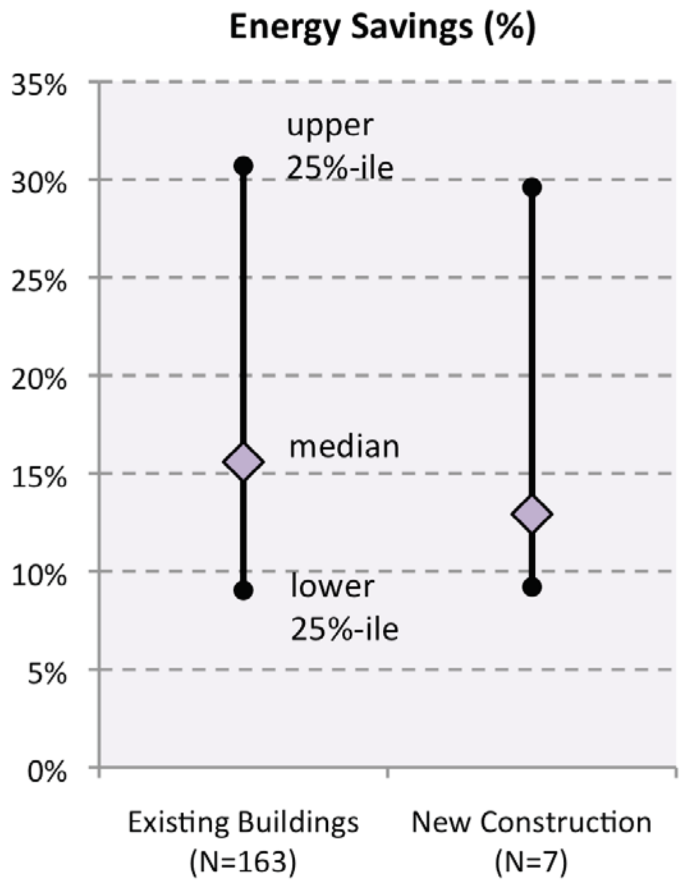

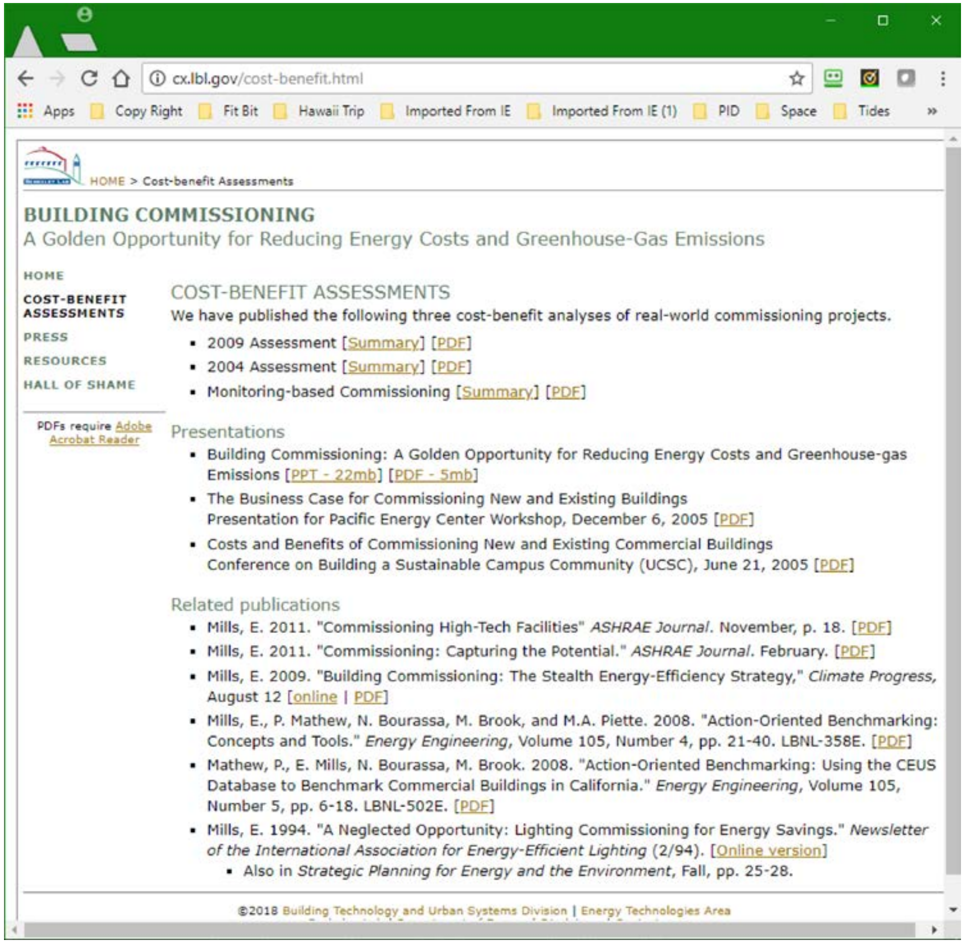

cx.lbl.gov/cost-benefit.html

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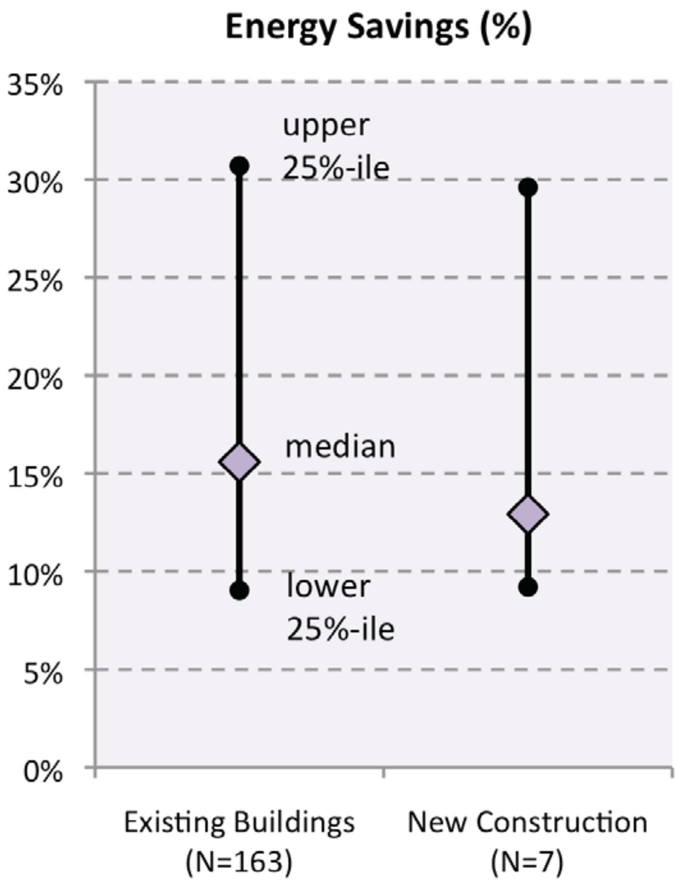
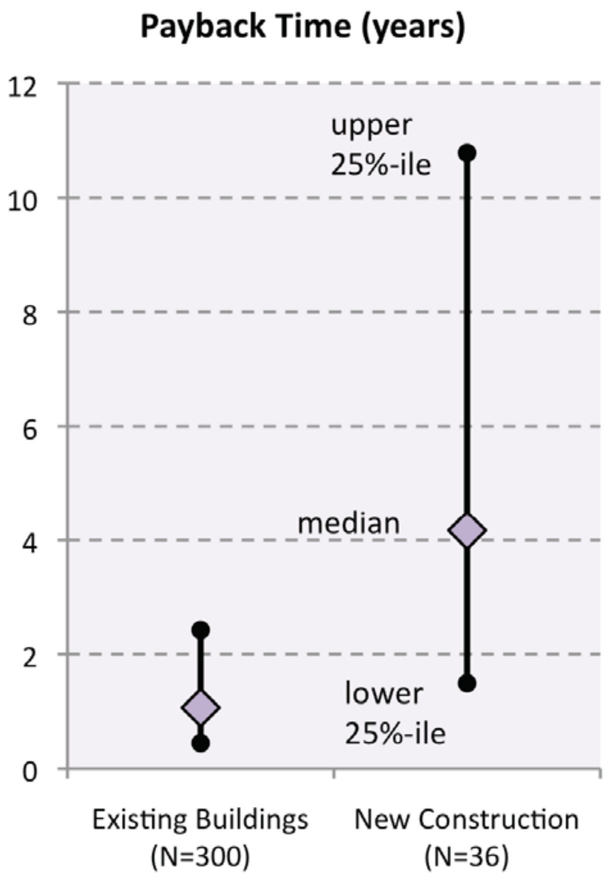
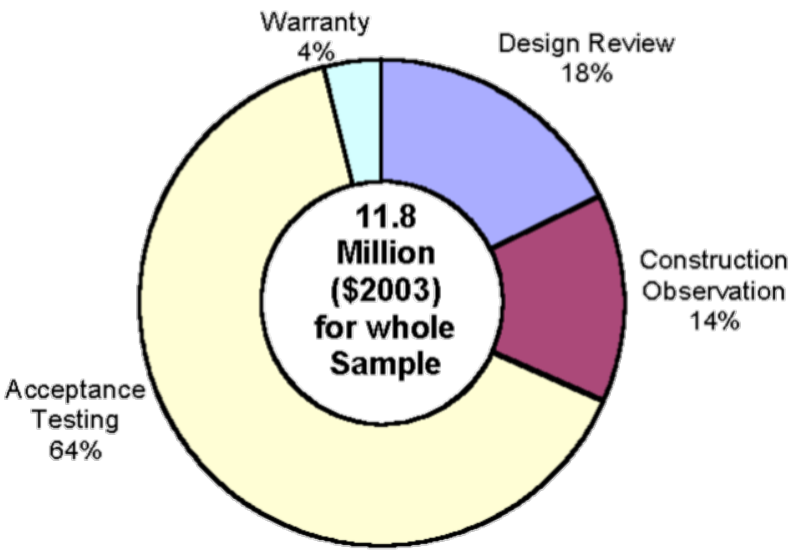




How the budget is spent

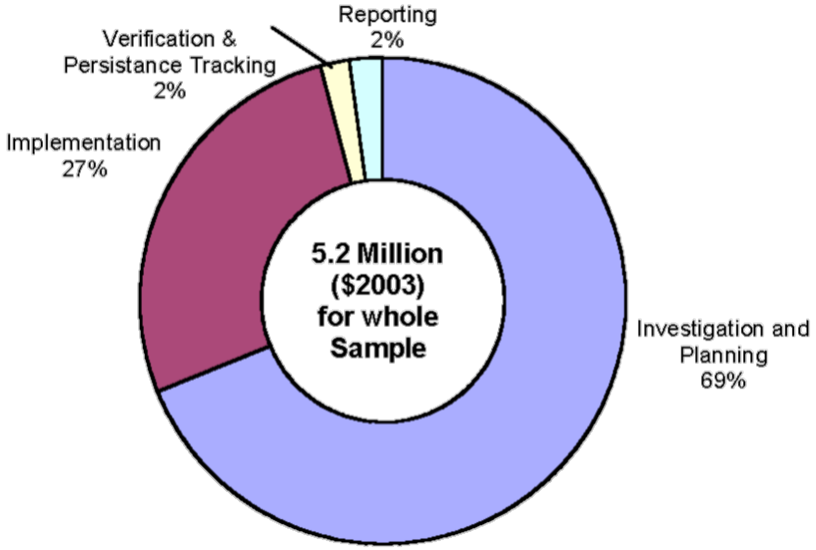
New Construction Cx

Fig 30. Commissioning Cost Allocation
(New Construction, N=5)



Existing Building Cx

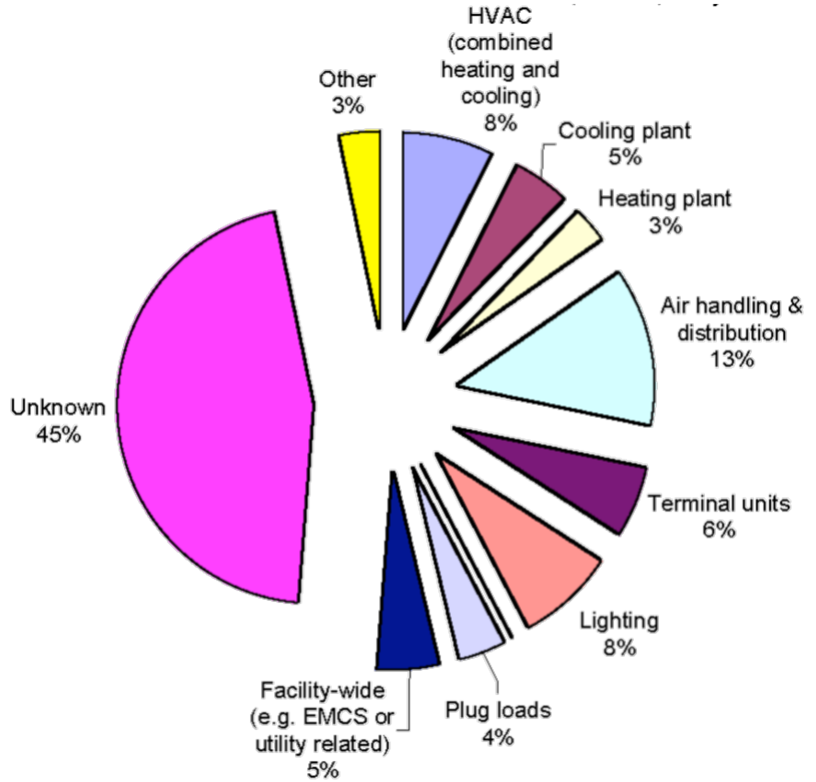
Fig 13. Commissioning Cost Allocation
(Existing Buildings, N=55)



Where the savings are achieved

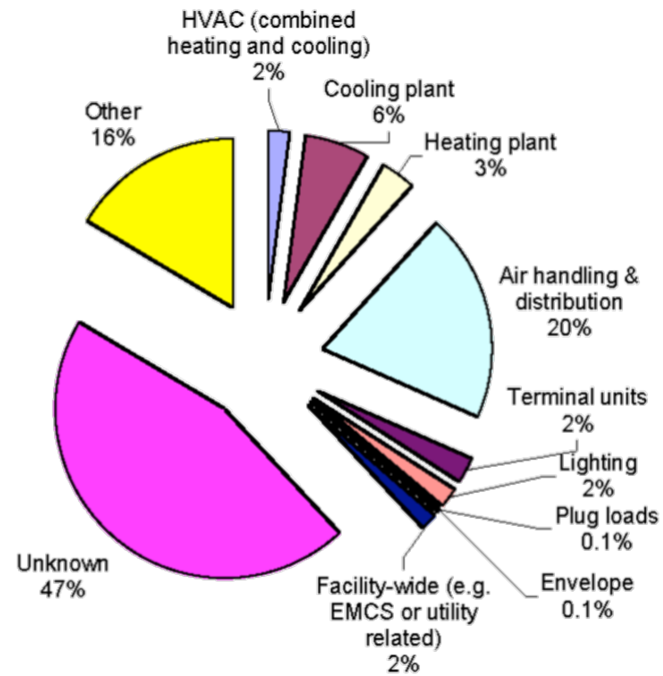
New Construction Cx

Fig 31. Number of Deficiencies Identified by Building System (New Construction, N = 3,305)



Existing Building Cx

Fig 14. Number of Deficiencies Identified by Building System (Existing Buildings, N = 3,500)



There's more to save than energy

From the 2004 LBNL Report:

- Median NCx energy savings
  $0.05 per square foot
- Median NCx NEB savings
  $1.24 per square foot
- Median EBCx energy savings
  $0.26 per square foot
- Median EBCx NEB savings
  $0.18 per square foot

NEB = NEI = Non Energy Benefit or Impact

NCx – New Construction Cx

EBCx = Existing Building Cx

Cx = Commissioning

(from Rx as in a prescription)

Figure 16. *Non-energy benefits observed following commissioning.*

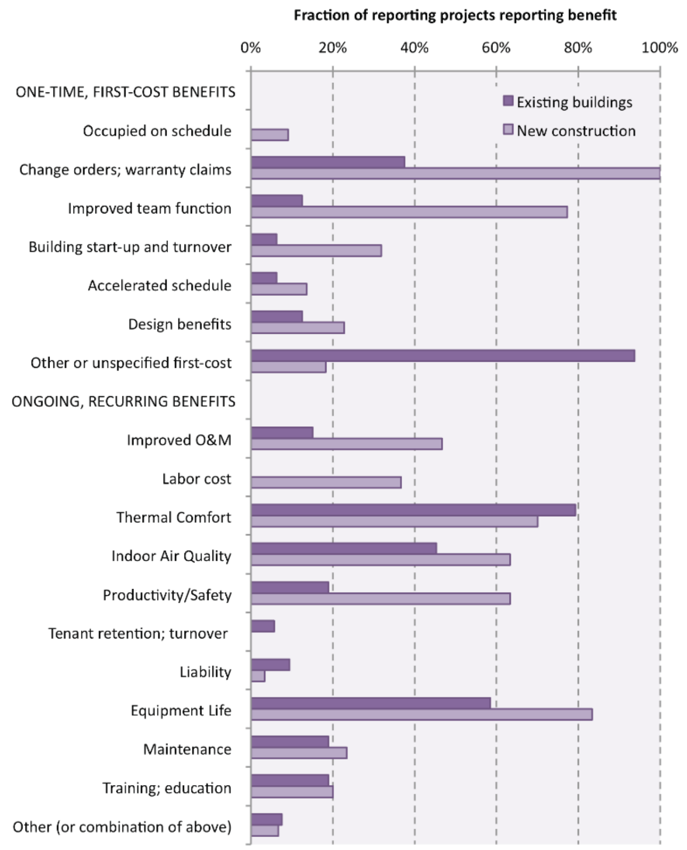


Figure 16. *Non-energy benefits observed following commissioning.*

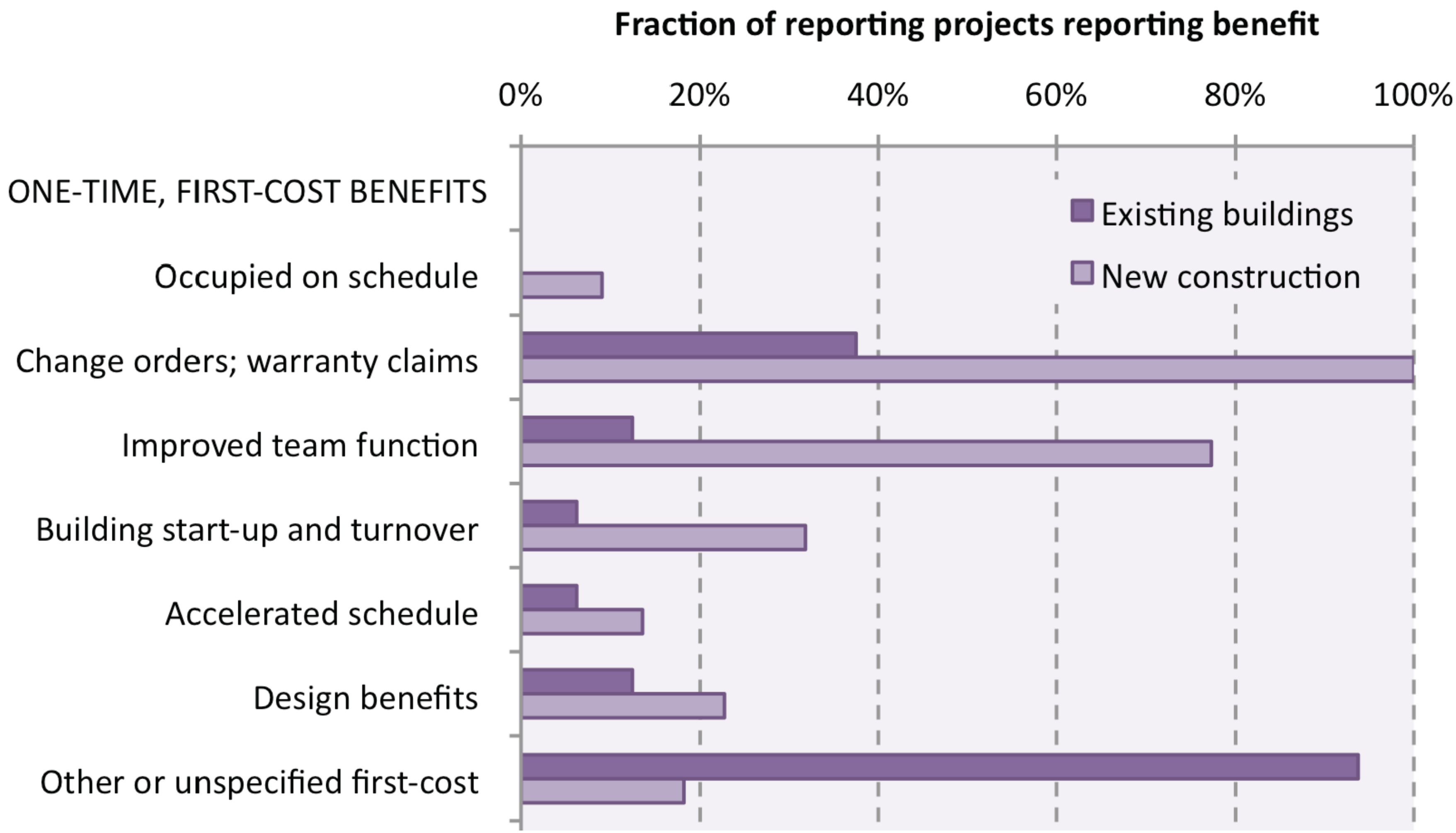
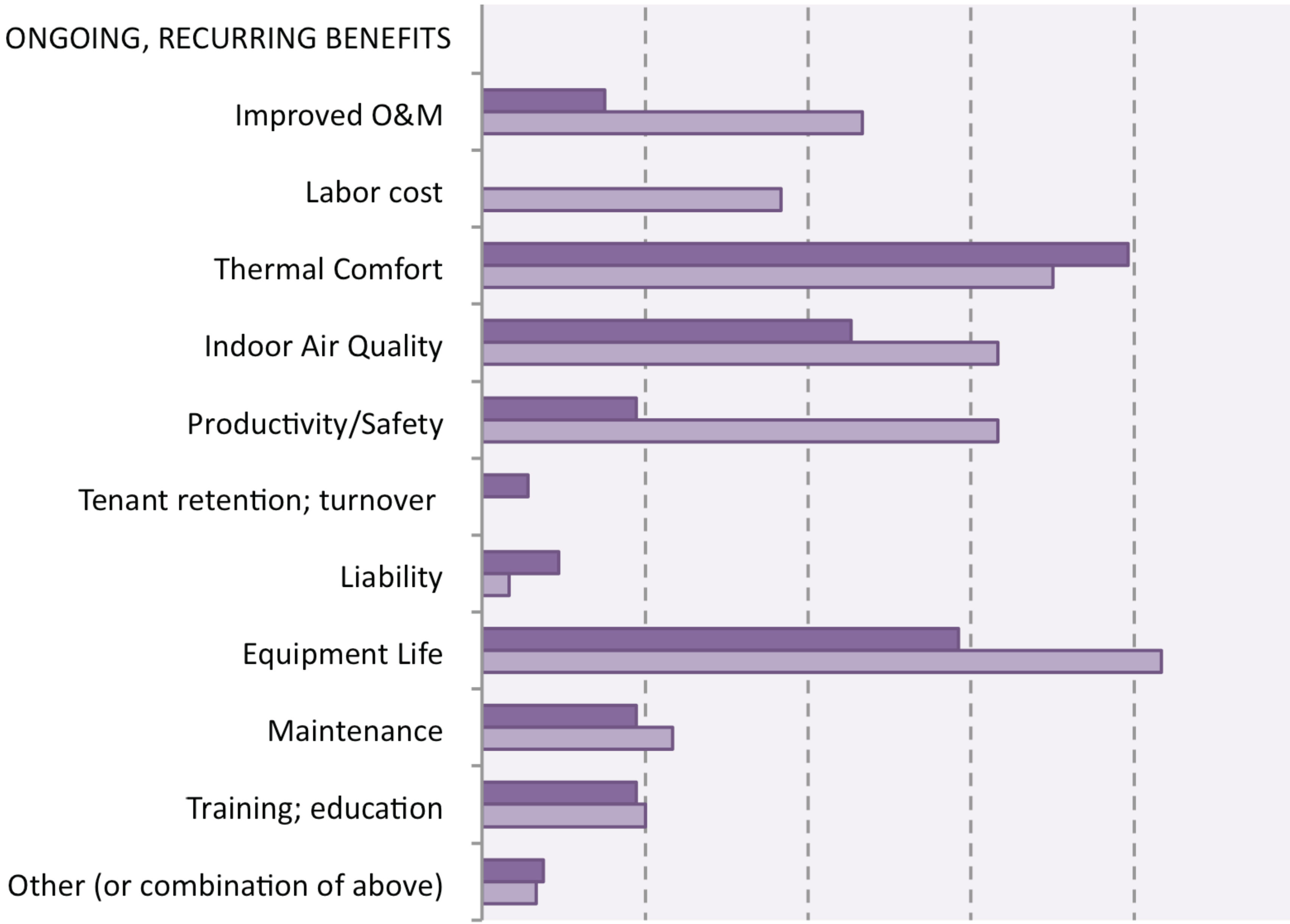


Figure 16. *Non-energy benefits observed following commissioning.*



Functional testing and the commissioning time line

Functional testing

- Core element of any commissioning process
- Validates machinery and systems
  - Do they deliver?
  - Why don't they deliver?
  - Do the work well together?
  - Why aren't they working well together
  - Was it big enough?
  - How big should it be?

Forced vs. Natural Response Testing

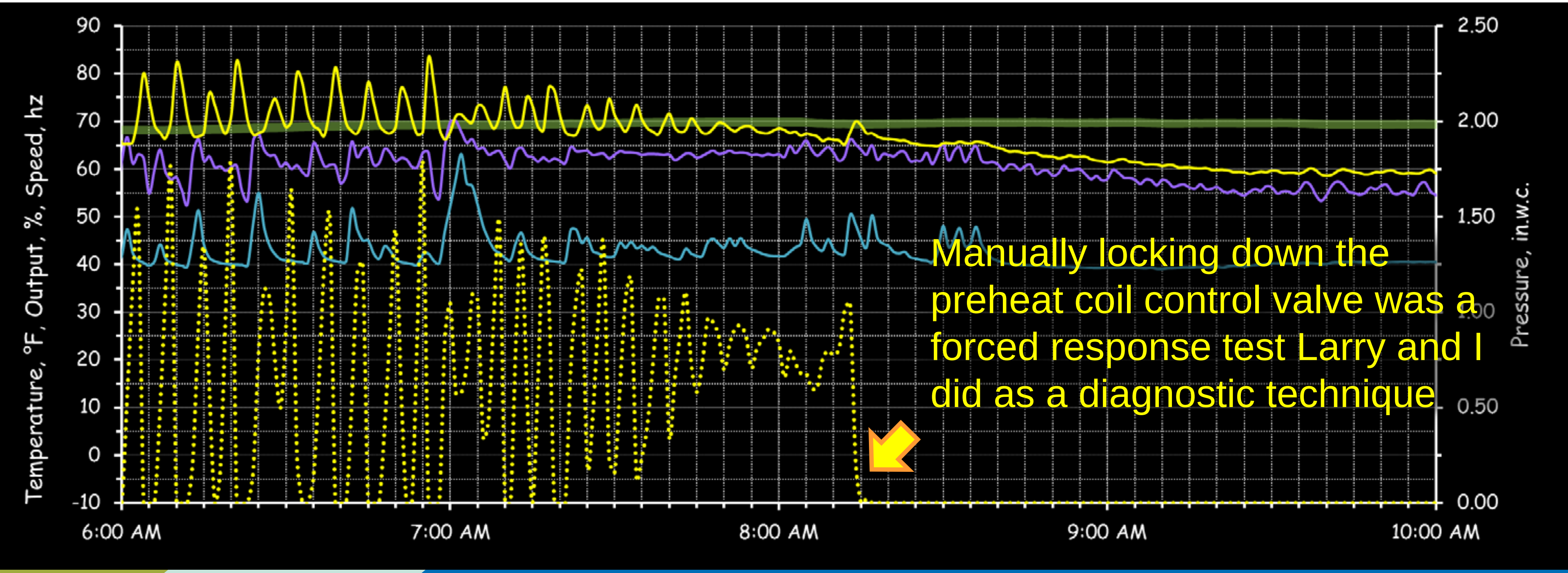
Forced Response Testing

I force a change and watch how the system responds

Forced vs. Natural Response Testing

Forced Response Testing

I force a change and watch how the system responds



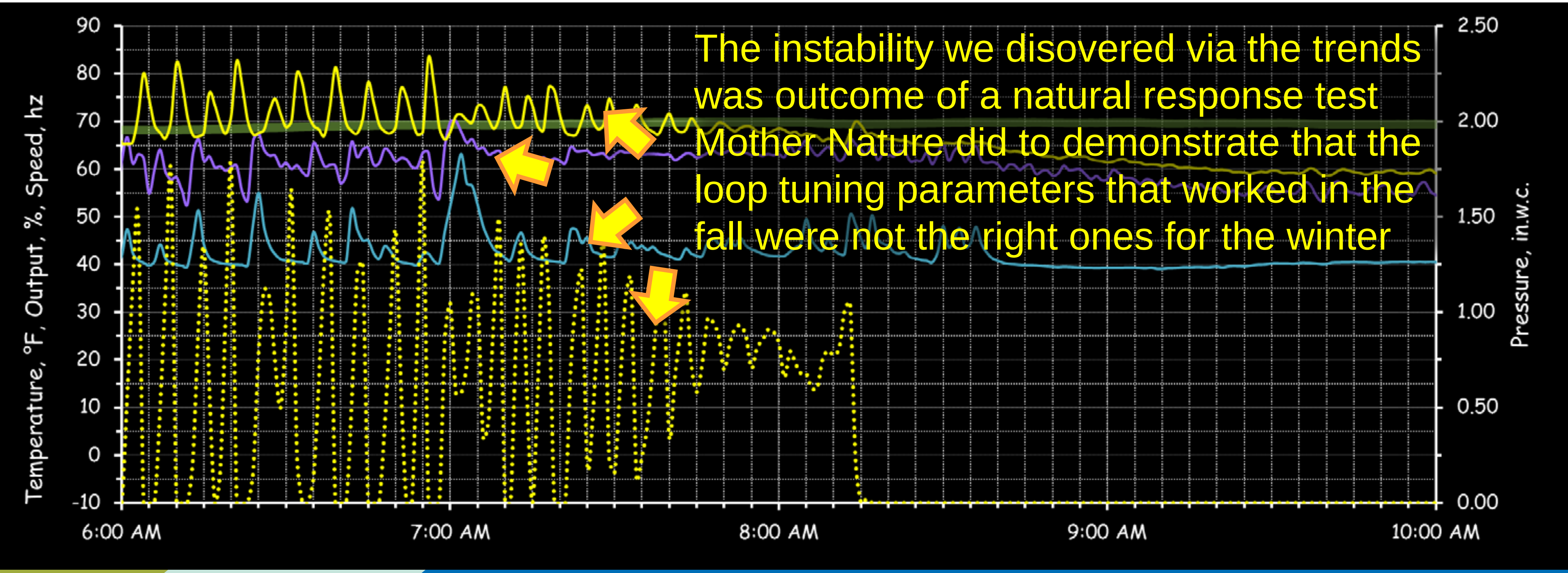
Forced vs. Natural Response Testing

Forced Response Testing

I force a change and watch how the system responds

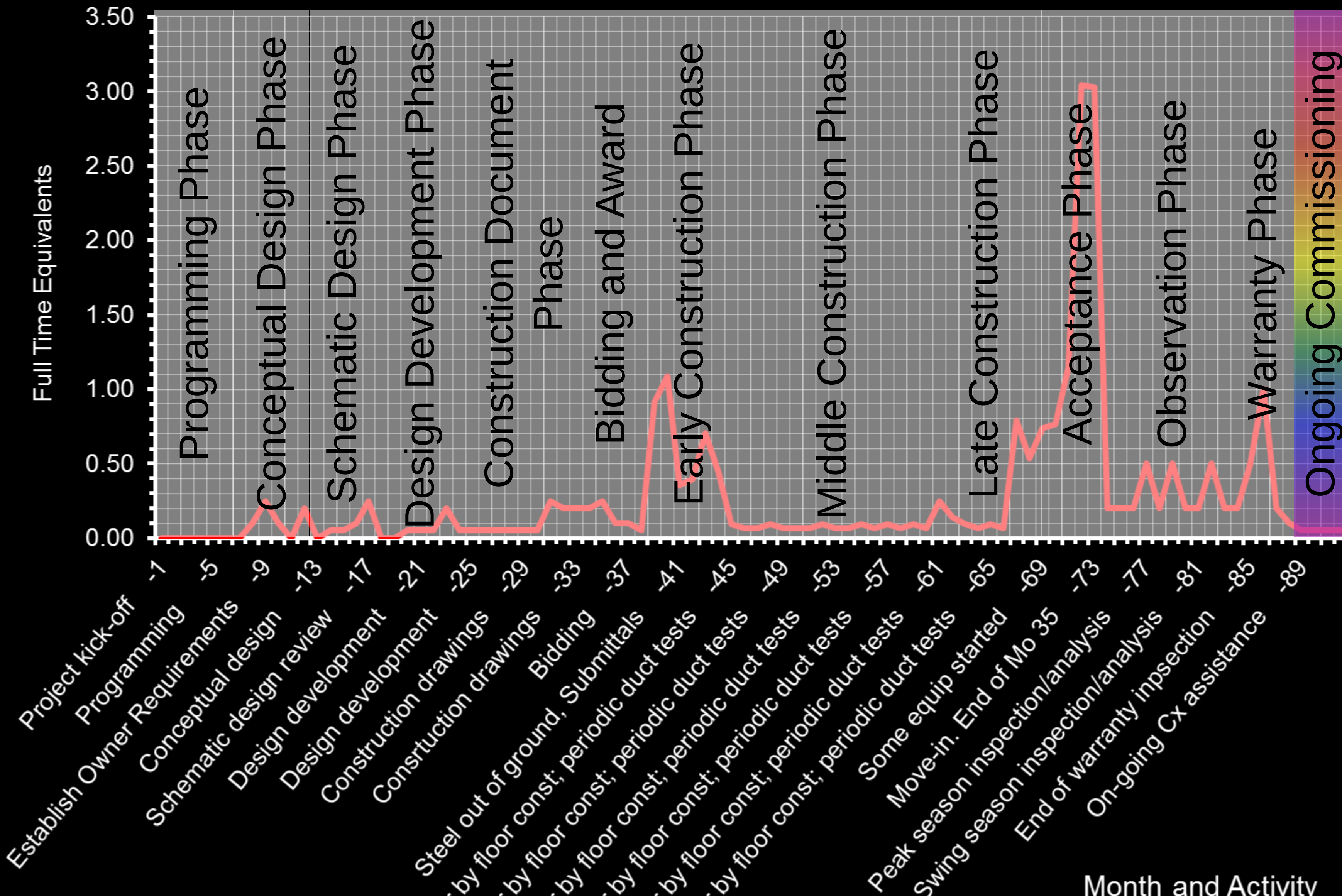
Natural Response Testing

I observe how a system responds to the normal course of events



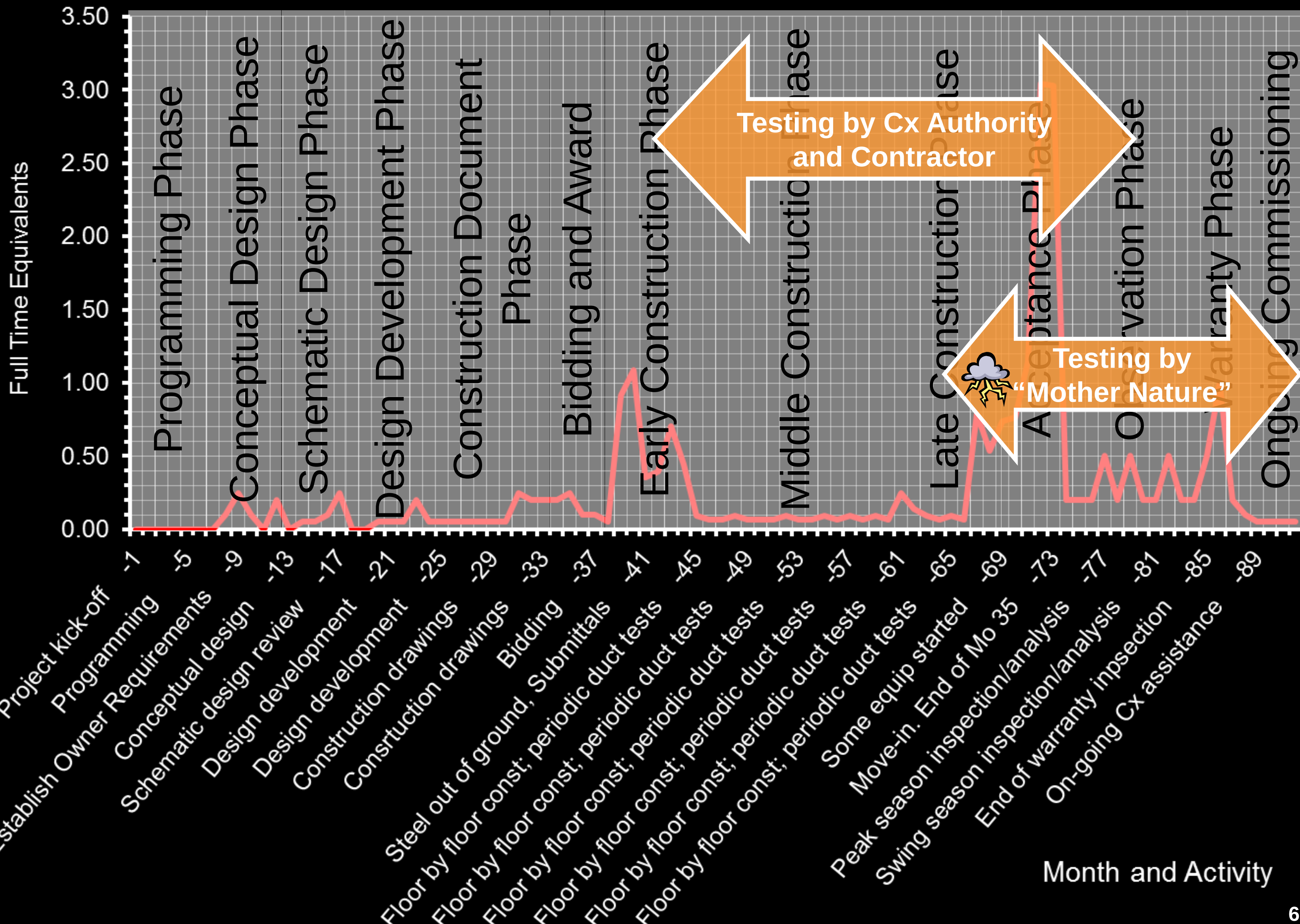
Typical New Construction Commissioning Activity

600,000 sq.ft. High Rise Basis



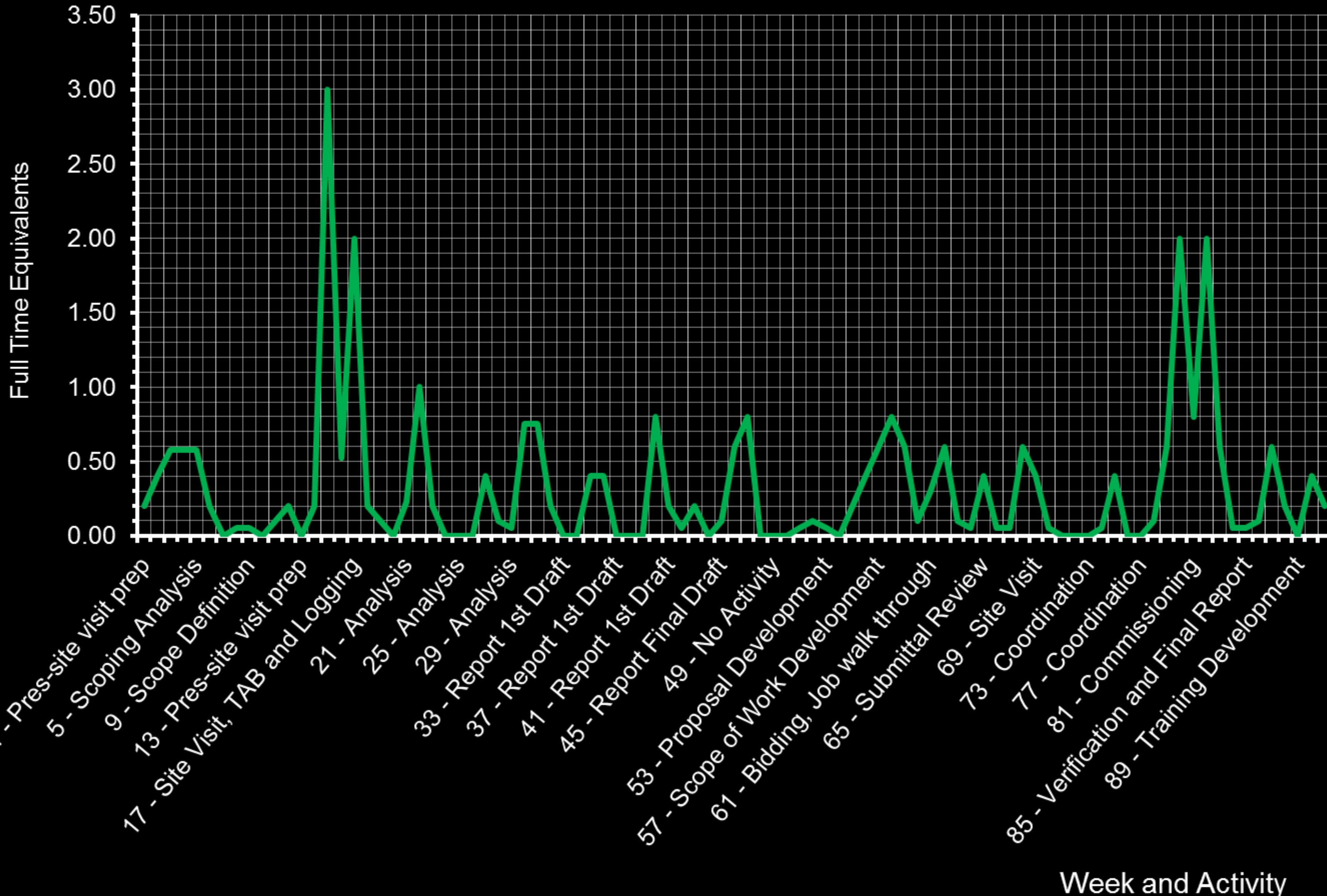
Typical New Construction Commissioning Activity

600,000 sq.ft. High Rise Basis



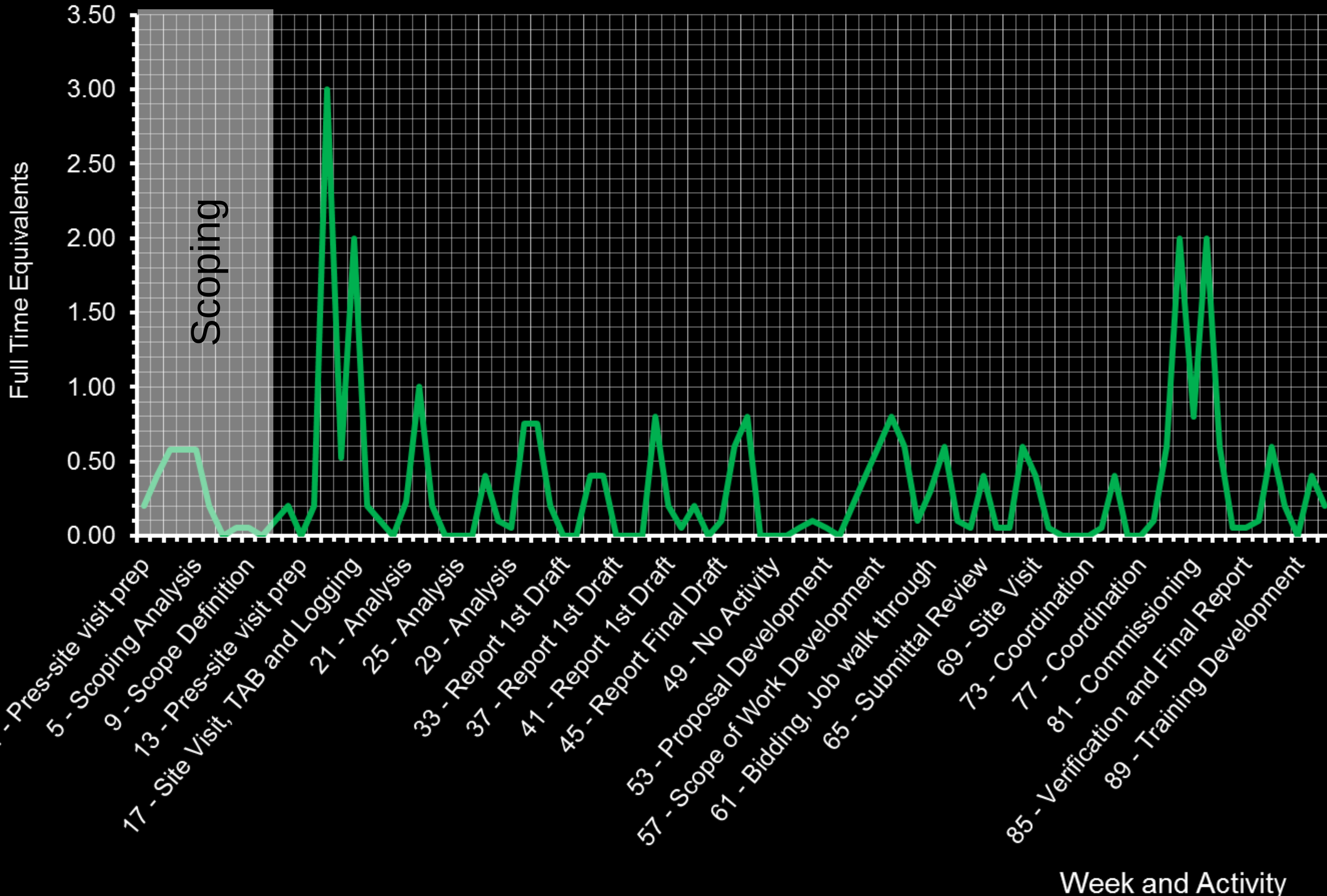
Typical Existing Building Construction Commissioning Activity

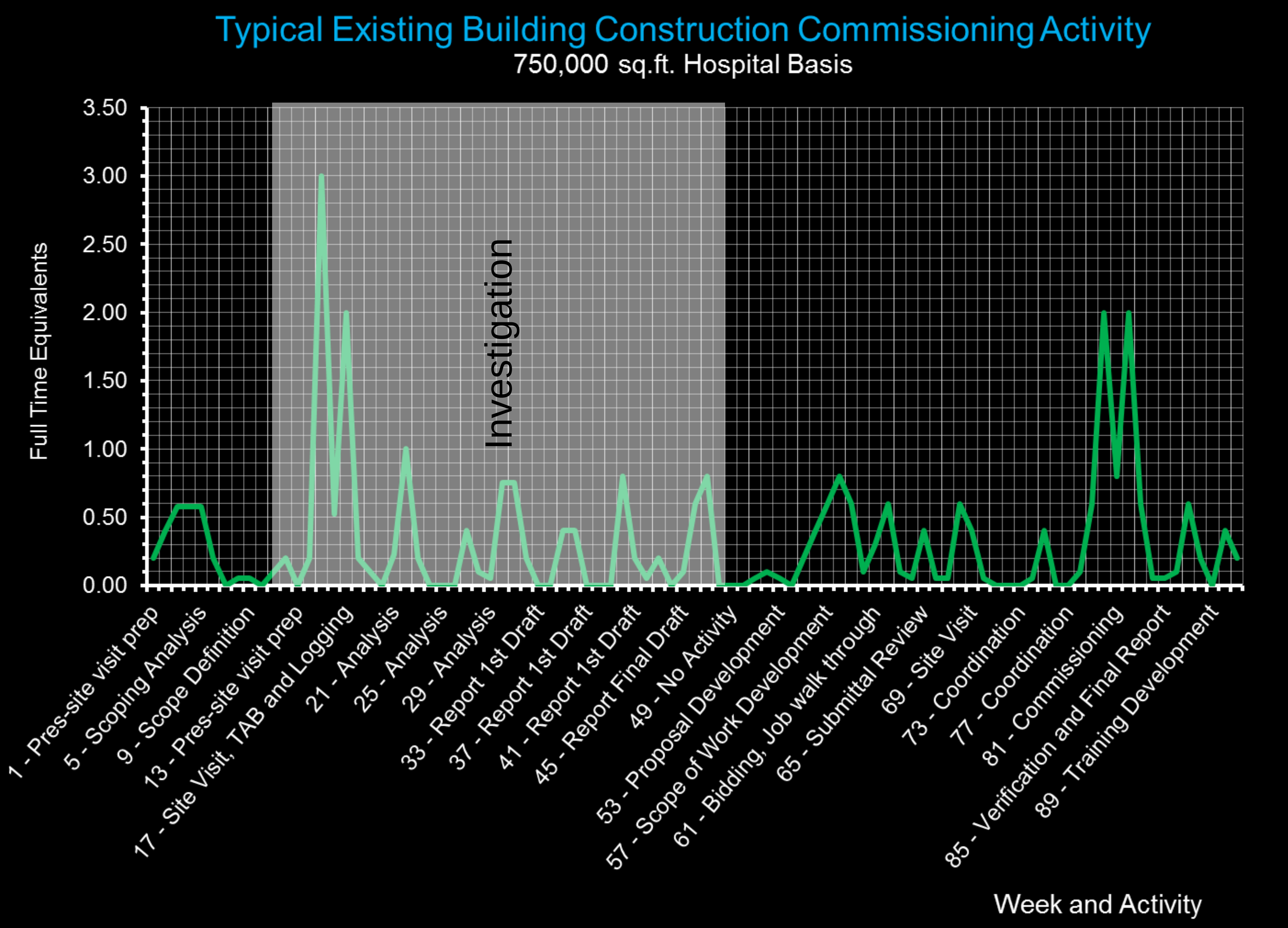
750,000 sq.ft. Hospital Basis

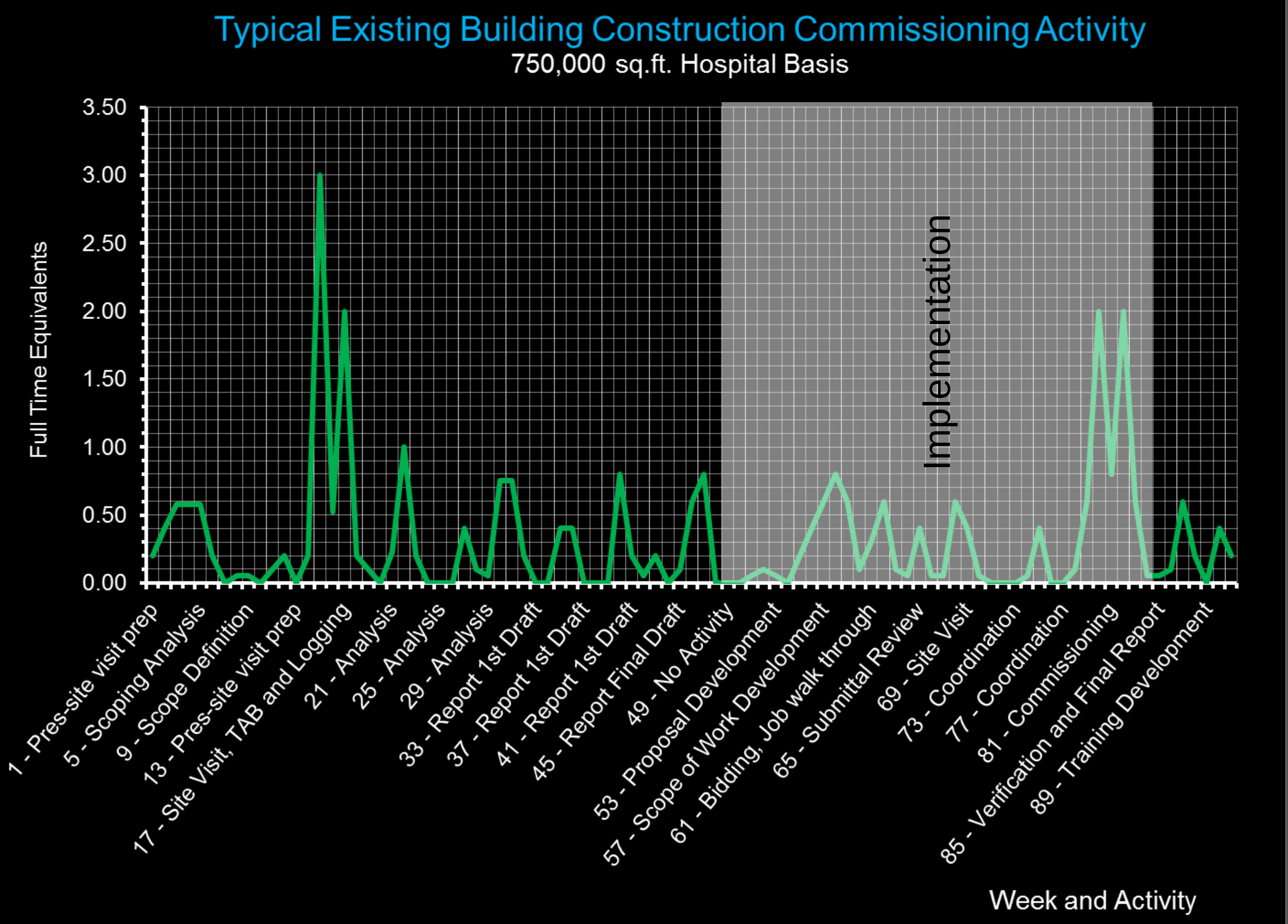


Typical Existing Building Construction Commissioning Activity

750,000 sq.ft. Hospital Basis




Typical Existing Building Construction Commissioning Activity
750,000 sq.ft. Hospital Basis
Full Time Equivalents
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Investigation
1 - Pres-site visit prep
5 - Scoping Analysis
9 - Scope Definition
13 - Pres-site visit prep
17 - Site Visit, TAB and Logging
21 - Analysis
25 - Analysis
29 - Analysis
33 - Report 1st Draft
37 - Report 1st Draft
41 - Report 1st Draft
45 - Report Final Draft
49 - No Activity
53 - Proposal Development
57 - Scope of Work Development
61 - Bidding, Job walk through
65 - Submital Review
69 - Site Visit
73 - Coordination
77 - Coordination
81 - Commissioning
85 - Verification and Final Report
89 - Training Development
Week and Activity



Typical Existing Building Construction Commissioning Activity
750,000 sq.ft. Hospital Basis
Full Time Equivalents
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Implementation
1 - Pres-site visit prep
5 - Scoping Analysis
9 - Scope Definition
13 - Pres-site visit prep
17 - Site Visit, TAB and Logging
21 - Analysis
25 - Analysis
29 - Analysis
33 - Report 1st Draft
37 - Report 1st Draft
41 - Report 1st Draft
45 - Report Final Draft
49 - No Activity
53 - Proposal Development
57 - Scope of Work Development
61 - Bidding, Job walk through
65 - Submittal Review
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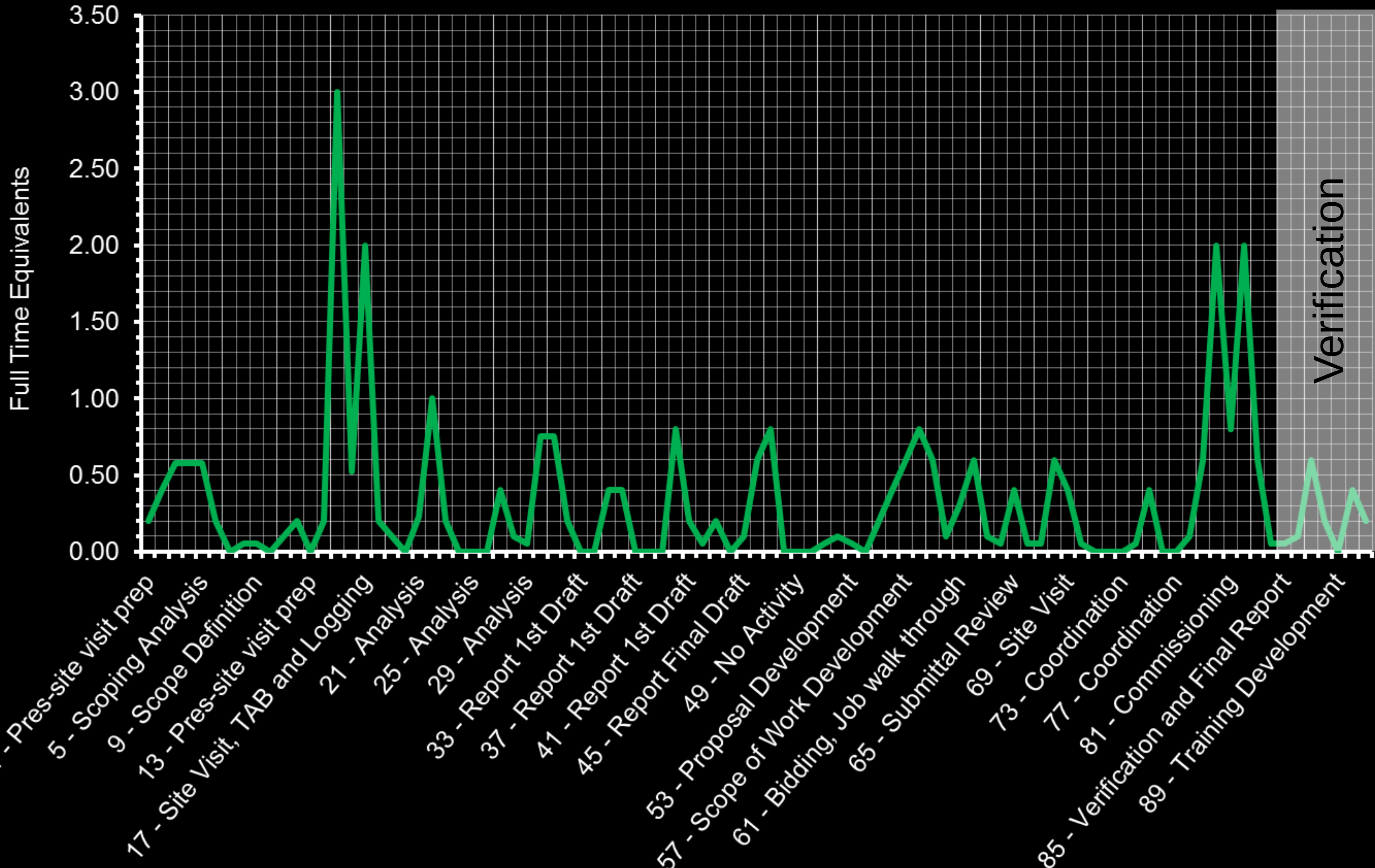
89 - Training Development
Week and Activity

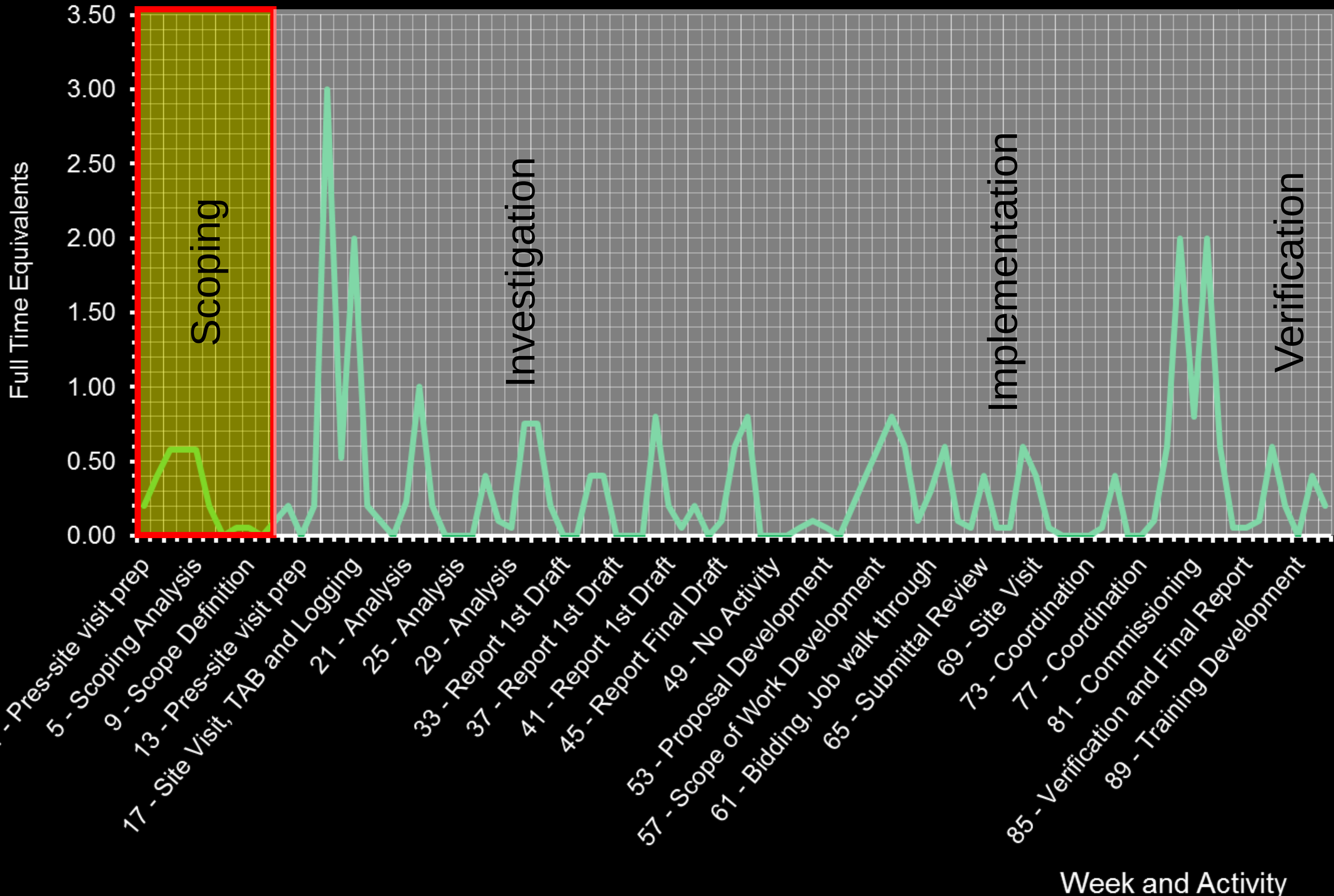
Typical Existing Building Construction Commissioning Activity

750,000 sq.ft. Hospital Basis



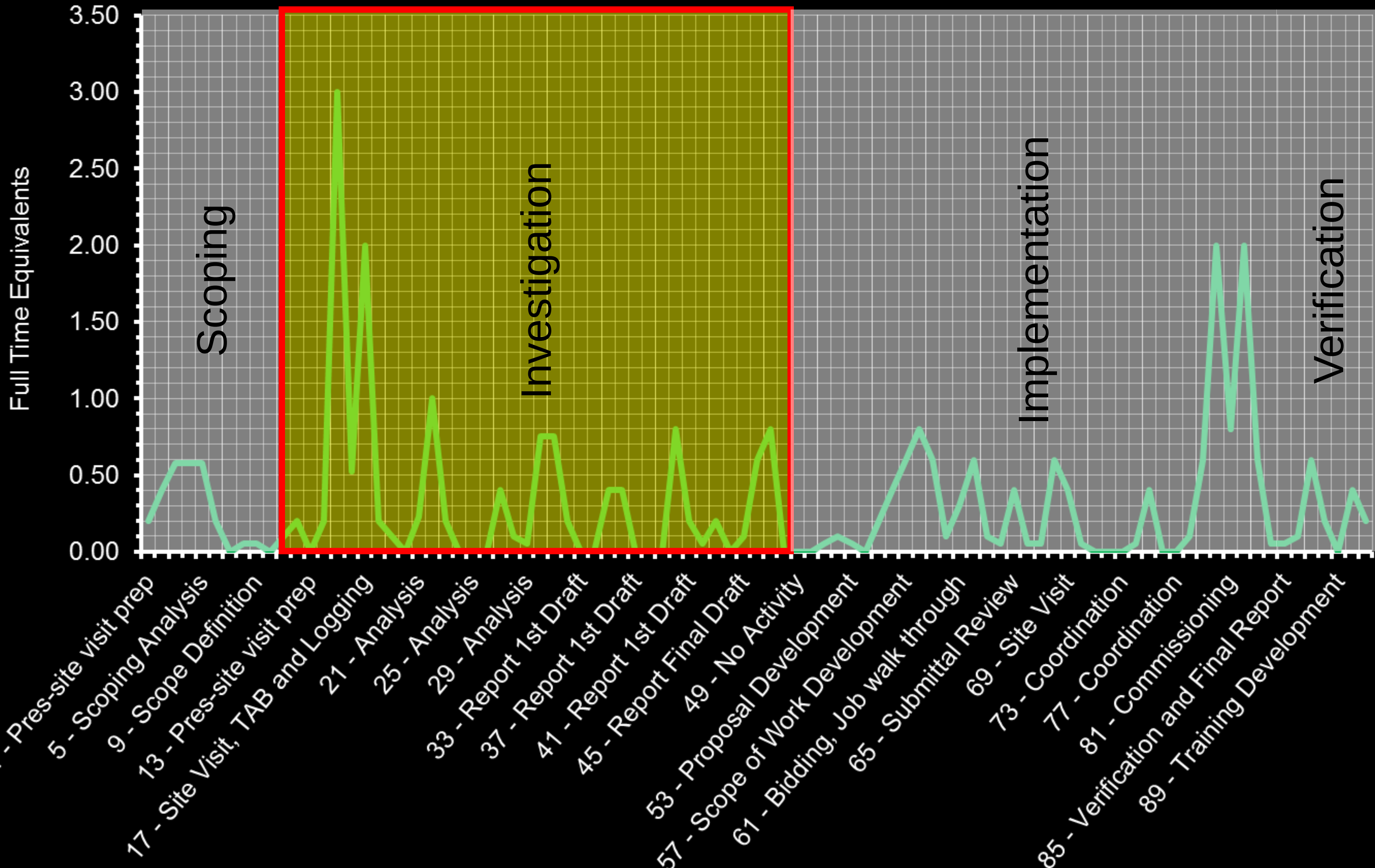
Typical Existing Building Construction Commissioning Activity

750,000 sq.ft. Hospital Basis



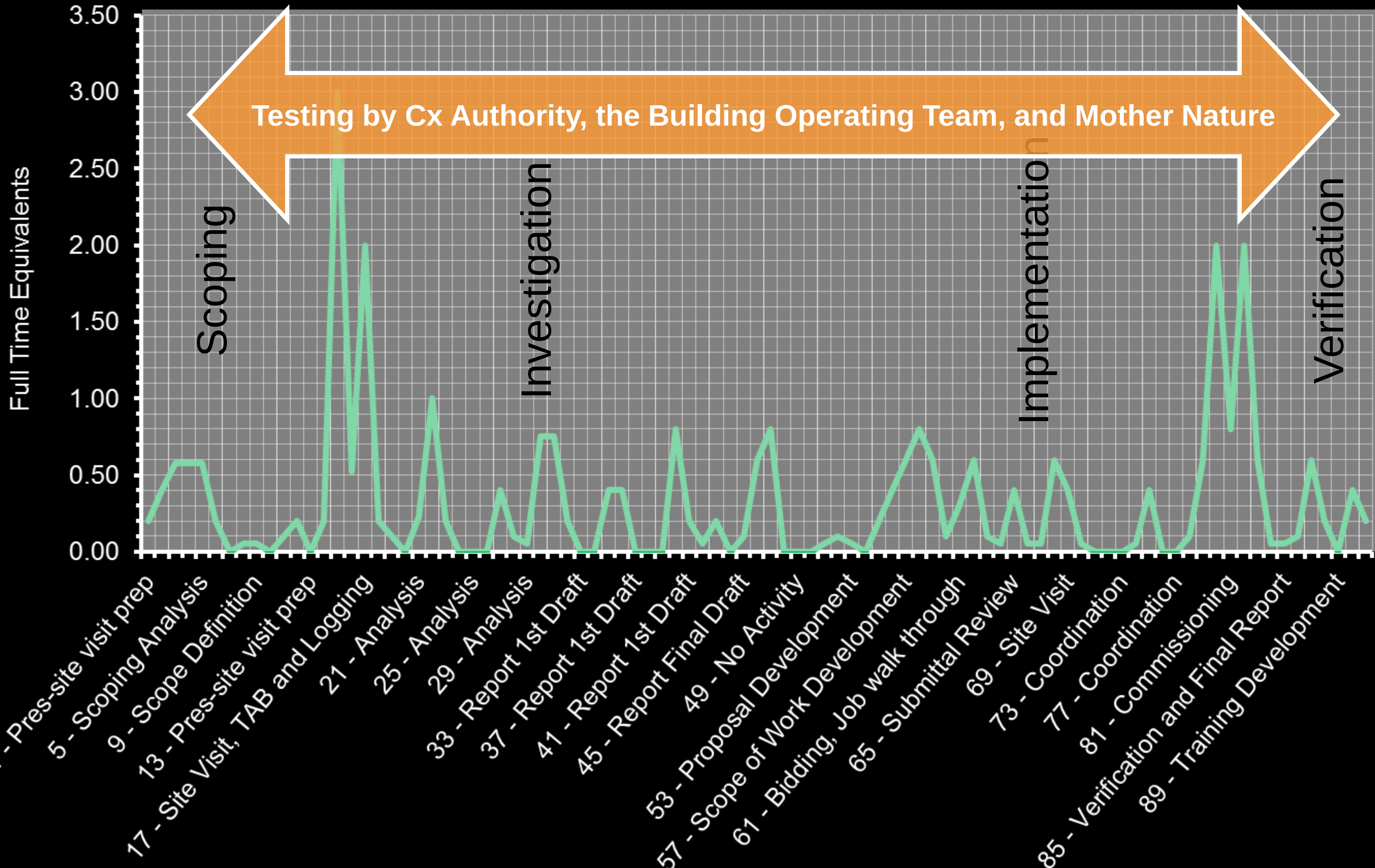
Typical Existing Building Construction Commissioning Activity

750,000 sq.ft. Hospital Basis



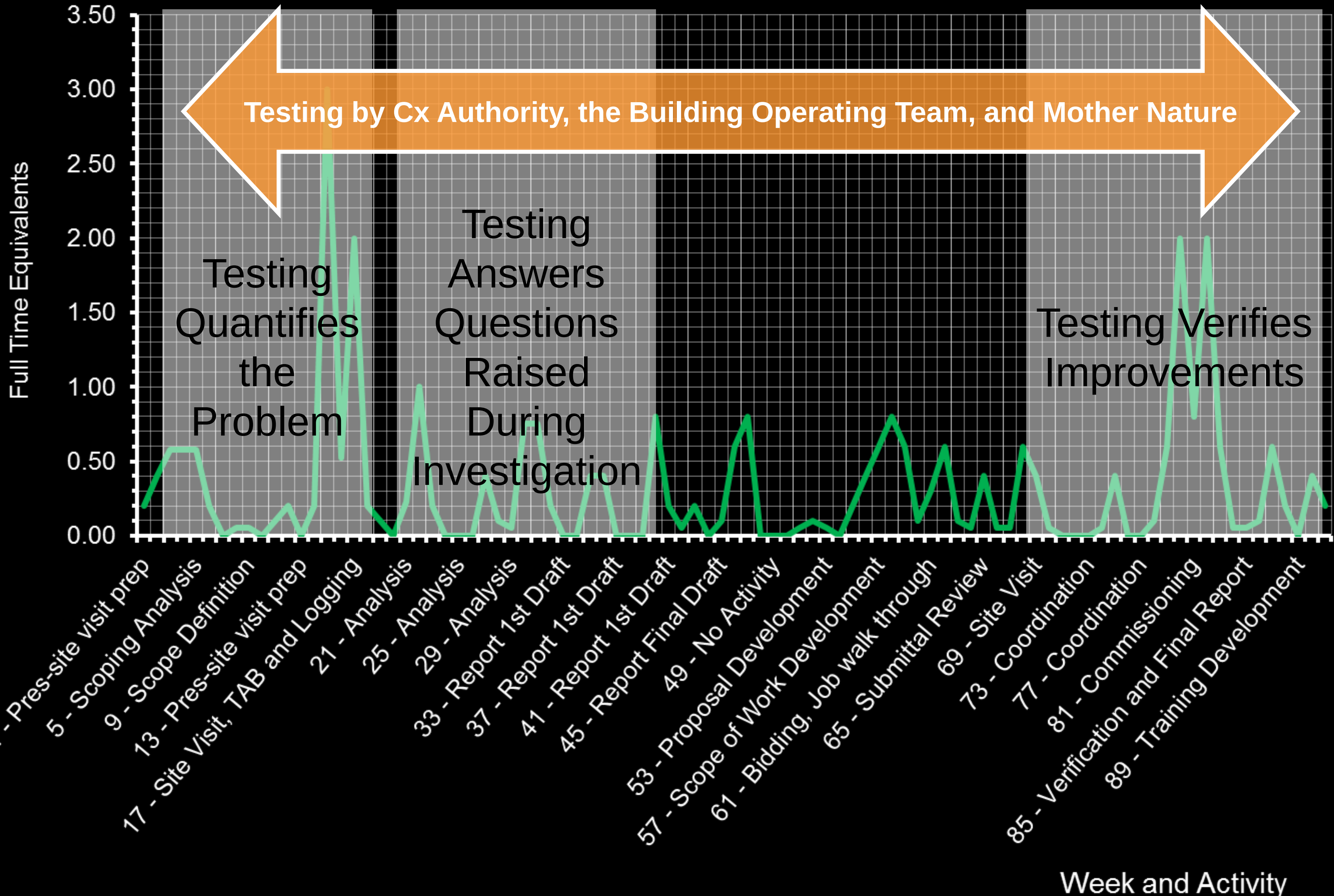
Typical Existing Building Construction Commissioning Activity

750,000 sq.ft. Hospital Basis



Typical Existing Building Construction Commissioning Activity

750,000 sq.ft. Hospital Basis



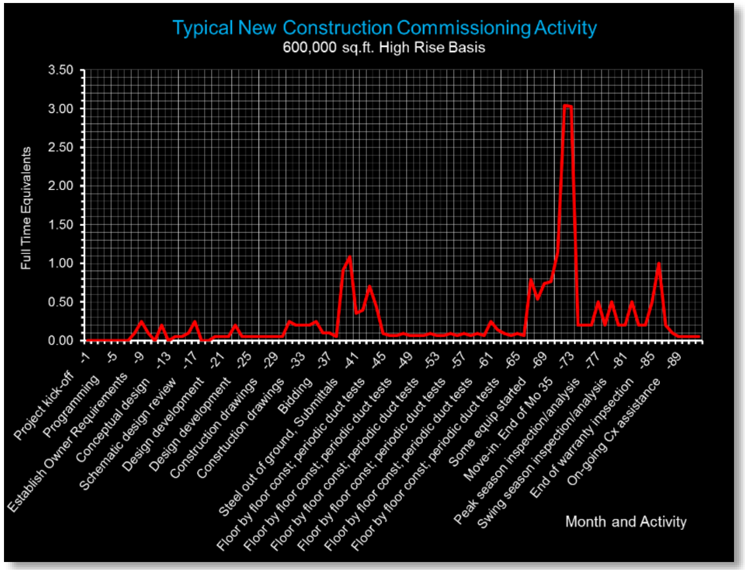
Key differences

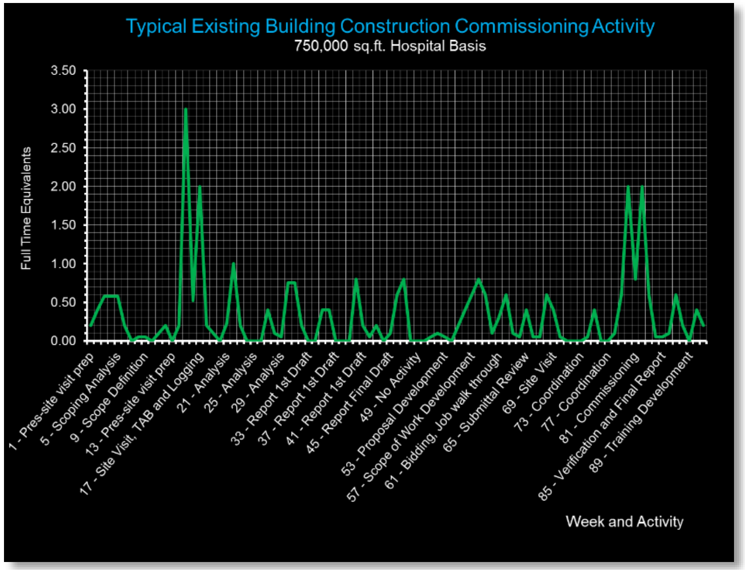
New construction

- Trying to prove design intent
- Demonstrate all elements of the system meet requirements
- Verification and quality assurance process

Existing building

- Trying to understand design intent
- Focused on certain elements of the system
- Diagnostic and troubleshooting process

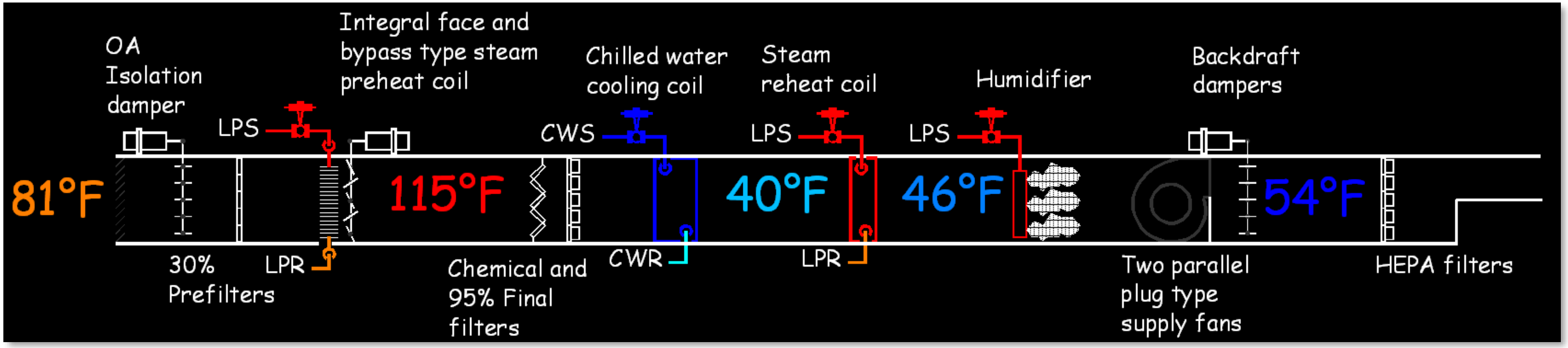




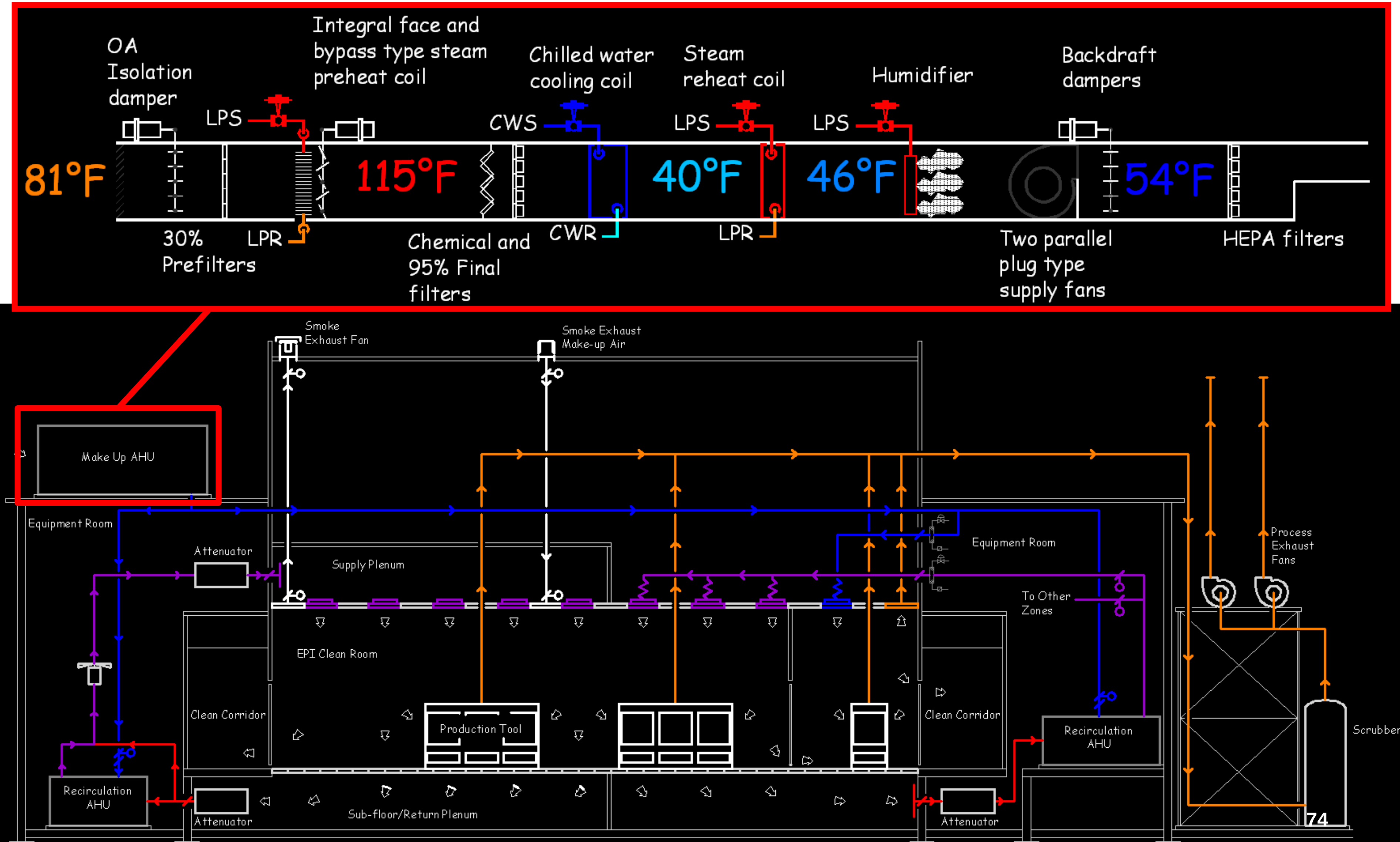
The system concept

Critical to success for design, commissioning and operation

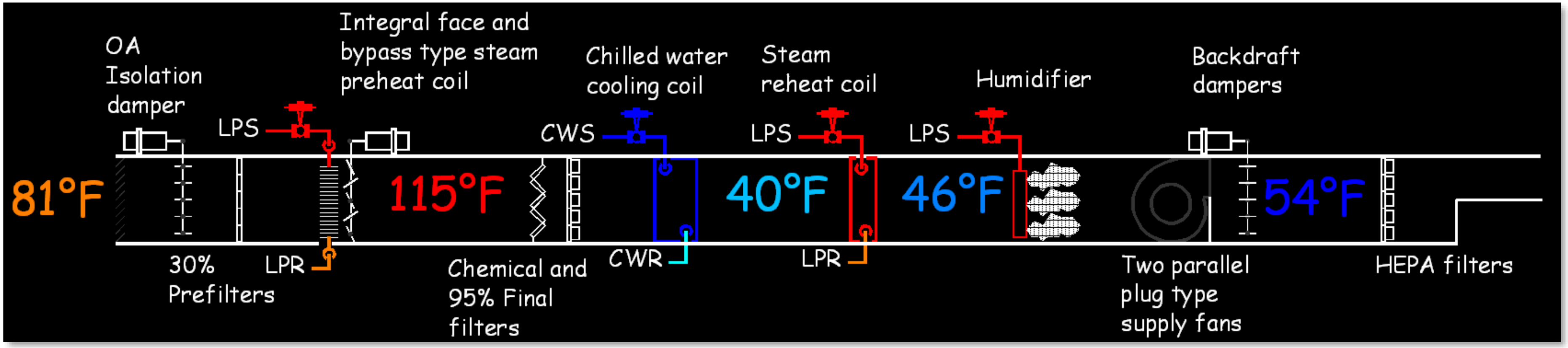
It’s not just an air handling unit …



It’s an air handling system



It’s not just an air handling unit …



Visit http://www.av8rdas.com/case-studies.html#MAUOptimize for details

The load profile

The design day vs. reality

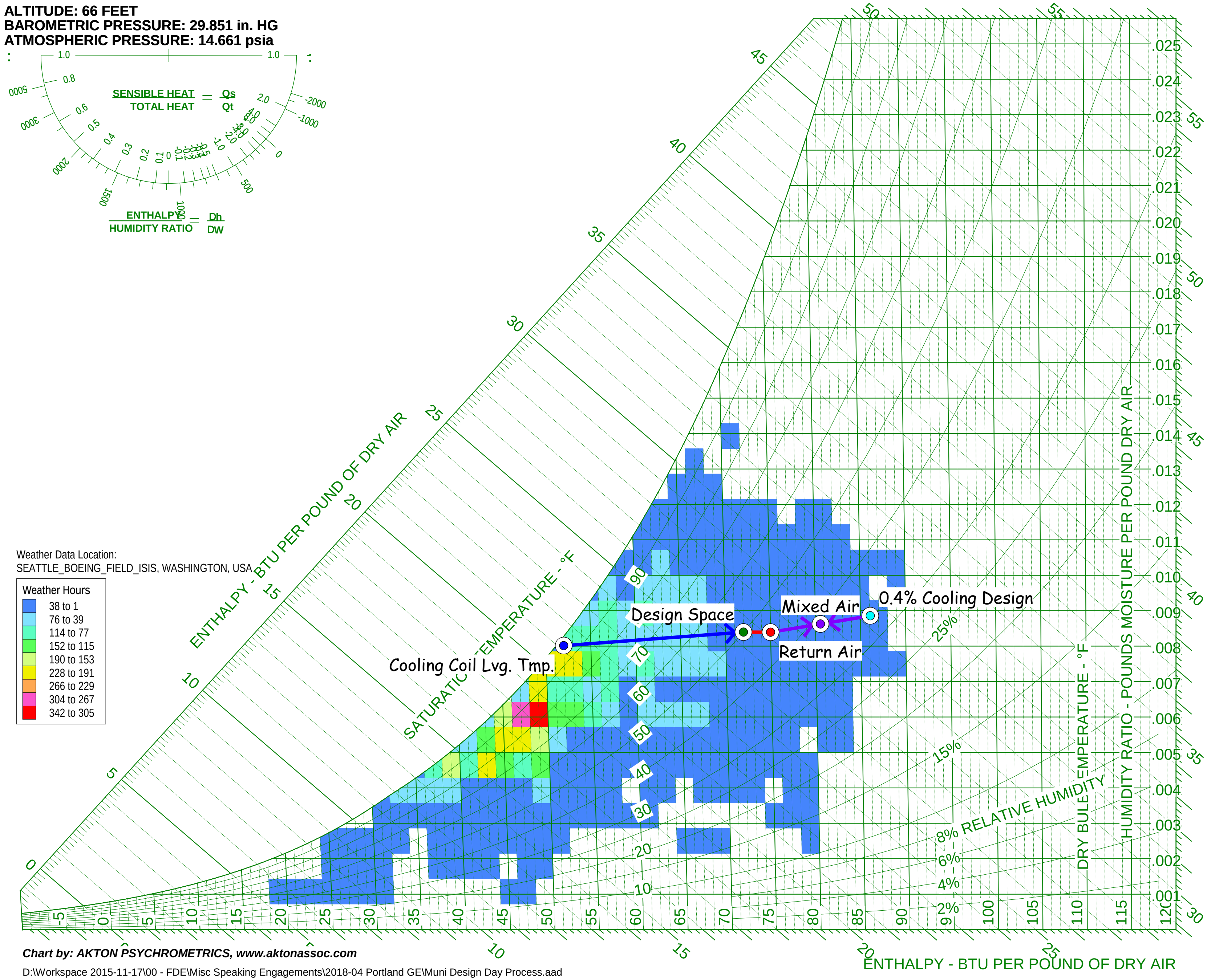


Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com

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Load profile drivers

1. The state of the air

$$v = \frac{1}{x_a}\left[\left|\frac{RT}{p}\right| \bullet \frac{1}{a} \bullet \left(x_a{}^2 A_{aa} + 2x_a x_w A_{aw} - X_a{}^3 A_{www} p\right)\beta\right]$$

$$h = \left[x_a h_a^{\circ} + \left(0.62198 x_w h_w^{\circ}\right)\beta - \left(x_a{}^2 B_{aa} + 2x_a x_w B_{aw} + x_w{}^2 B_{aw} + x_w{}^2 B_{ww}\right) \bullet p\alpha - \frac{1}{2} x_w{}^3 B_{www} p^2 \alpha\right]\frac{1}{x_a} + \bar{h}_a W \bar{h}_w$$

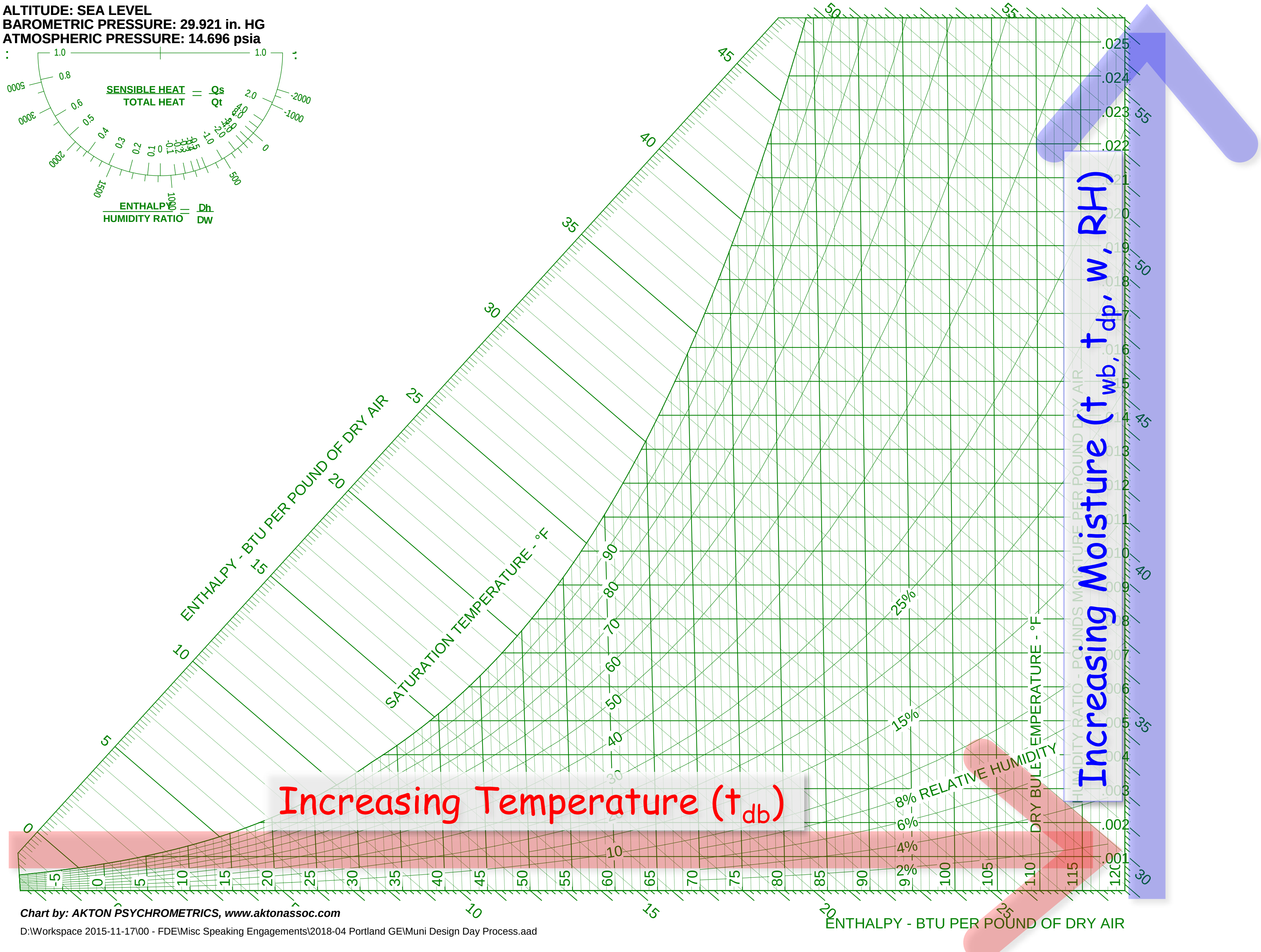
2. The nature of the process occurring at the load

$$\bar{Q} + \sum_1 \left[\dot{m} \times \left(u_1 + \frac{p_1 v_1}{J} + \frac{z_1}{J} + \frac{V_1^2}{2gJ}\right)\right] = \frac{\bar{W}}{J} + \sum_2 \left[\dot{m} \times \left(u_2 + \frac{p_2 v_2}{J} + \frac{z_2}{J} + \frac{V_2^2}{2gJ}\right)\right]$$

3. The process design target

$t_{db} = 72.000°F$, $t_{wb} = 60.064°F$, $t_{dp} = 52.370°F$, $h = 26.435$ Btu/lb$_m$,

$w = 58.73$ grains$_{H_2O}$/lb$_{m_{DA}}$, RH $= 50.000$, $\upsilon = 13.611$ ft^3/lb$_m$, $\rho = .0741$ lb$_m$/ft^3


ALTITUDE: SEA LEVEL
BAROMETRIC PRESSURE: 29.921 in. HG
ATMOSPHERIC PRESSURE: 14.696 psia
SENSIBLE HEAT / TOTAL HEAT = Qs / Qt
ENTHALPY / HUMIDITY RATIO = Dh / DW
ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE - °F
RELATIVE HUMIDITY
DRY BULB TEMPERATURE - °F
HUMIDITY RATIO - POUNDS MOISTURE PER POUND DRY AIR
Increasing Temperature (tdb)
Increasing Moisture (twb, tdp, w, RH)
Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com
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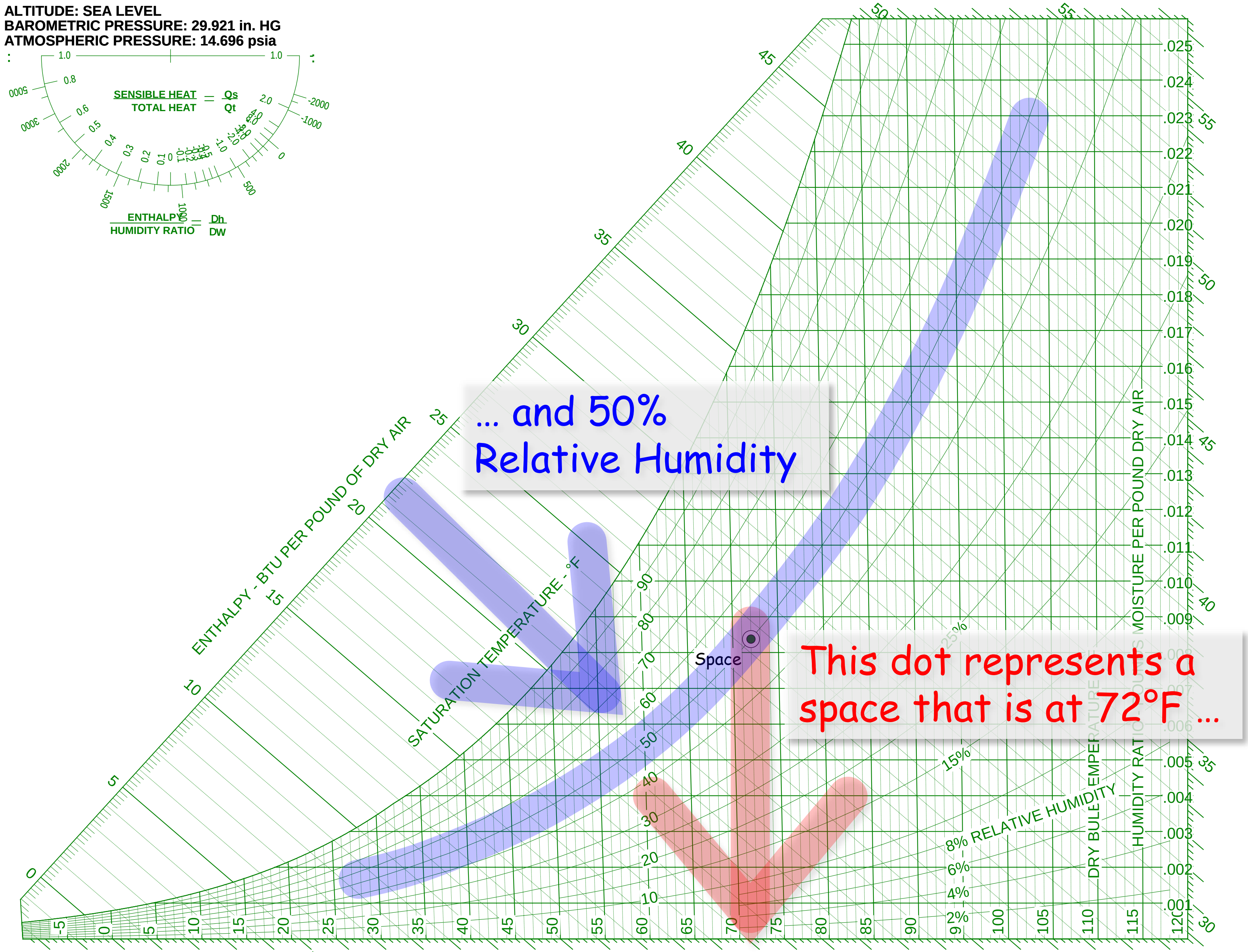

Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com

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The cooling design conditions

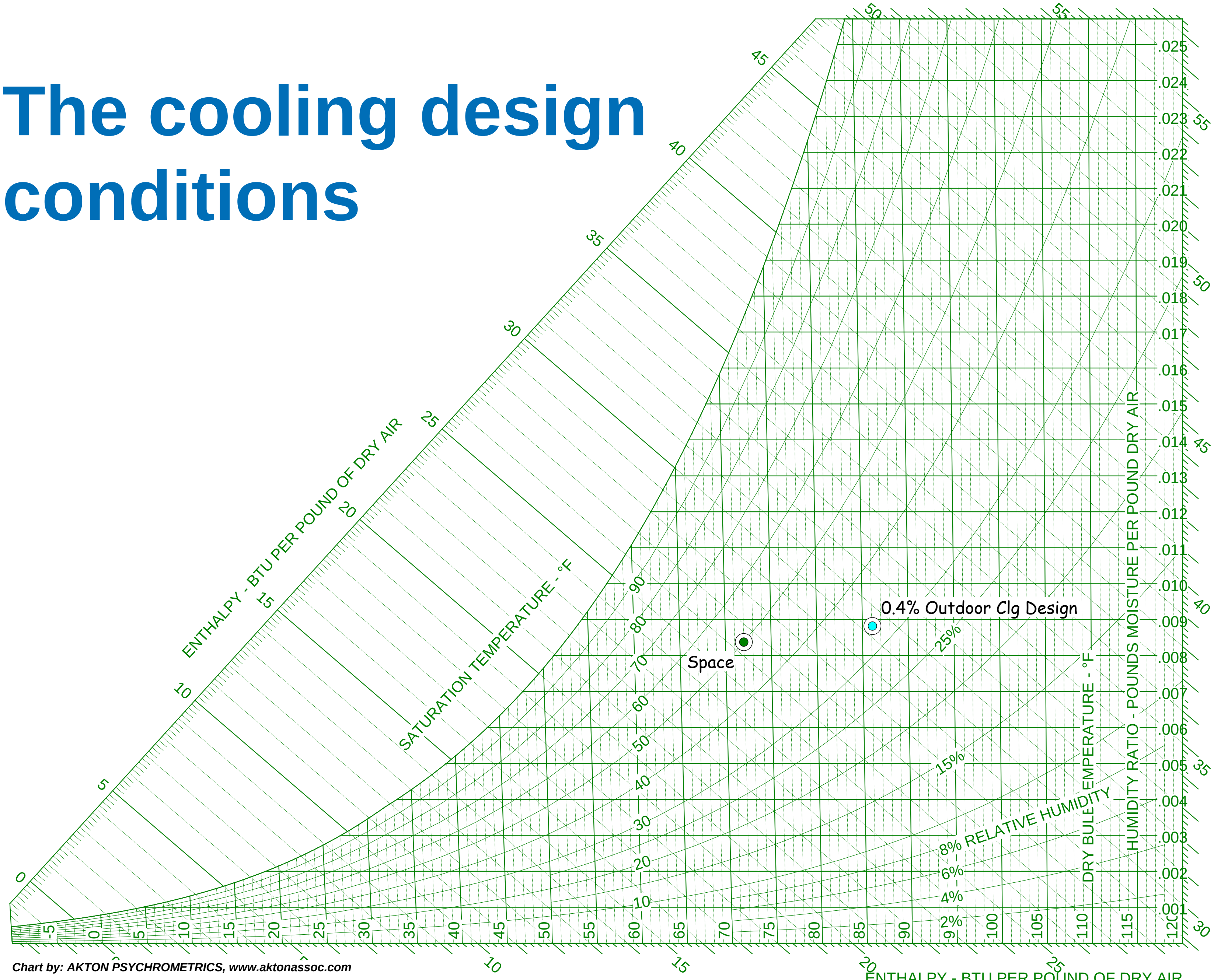

Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com

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The design HVAC process

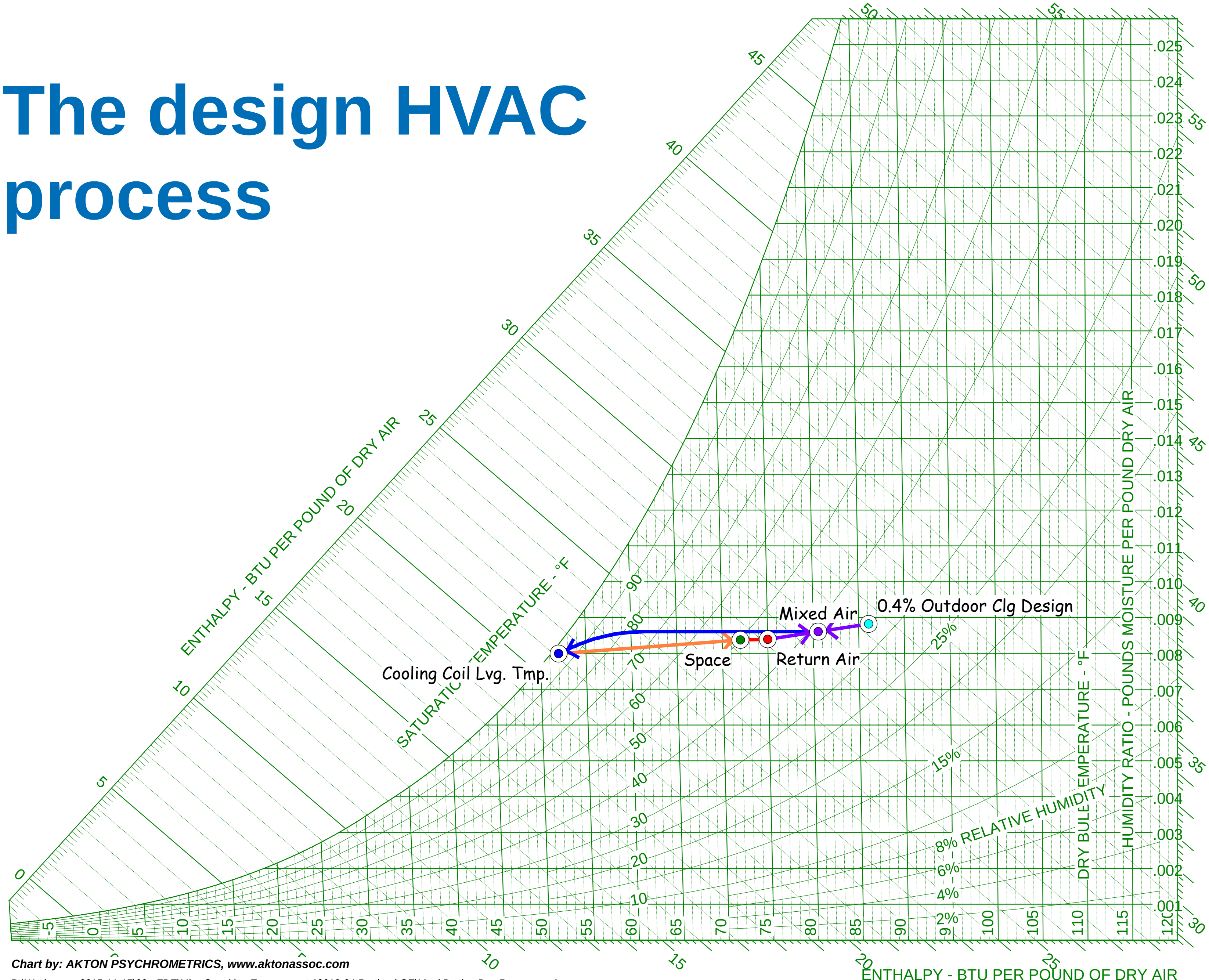

Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com

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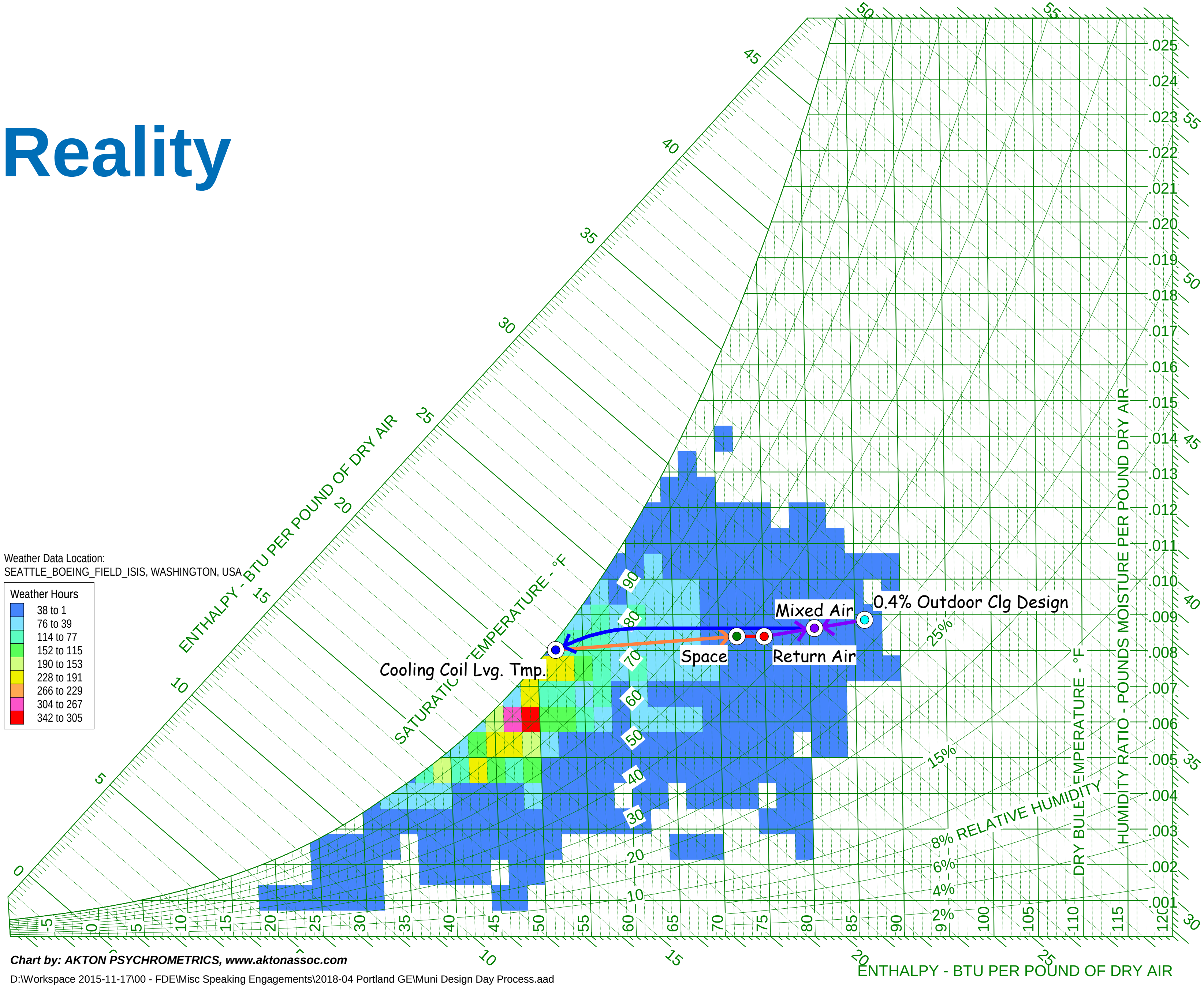
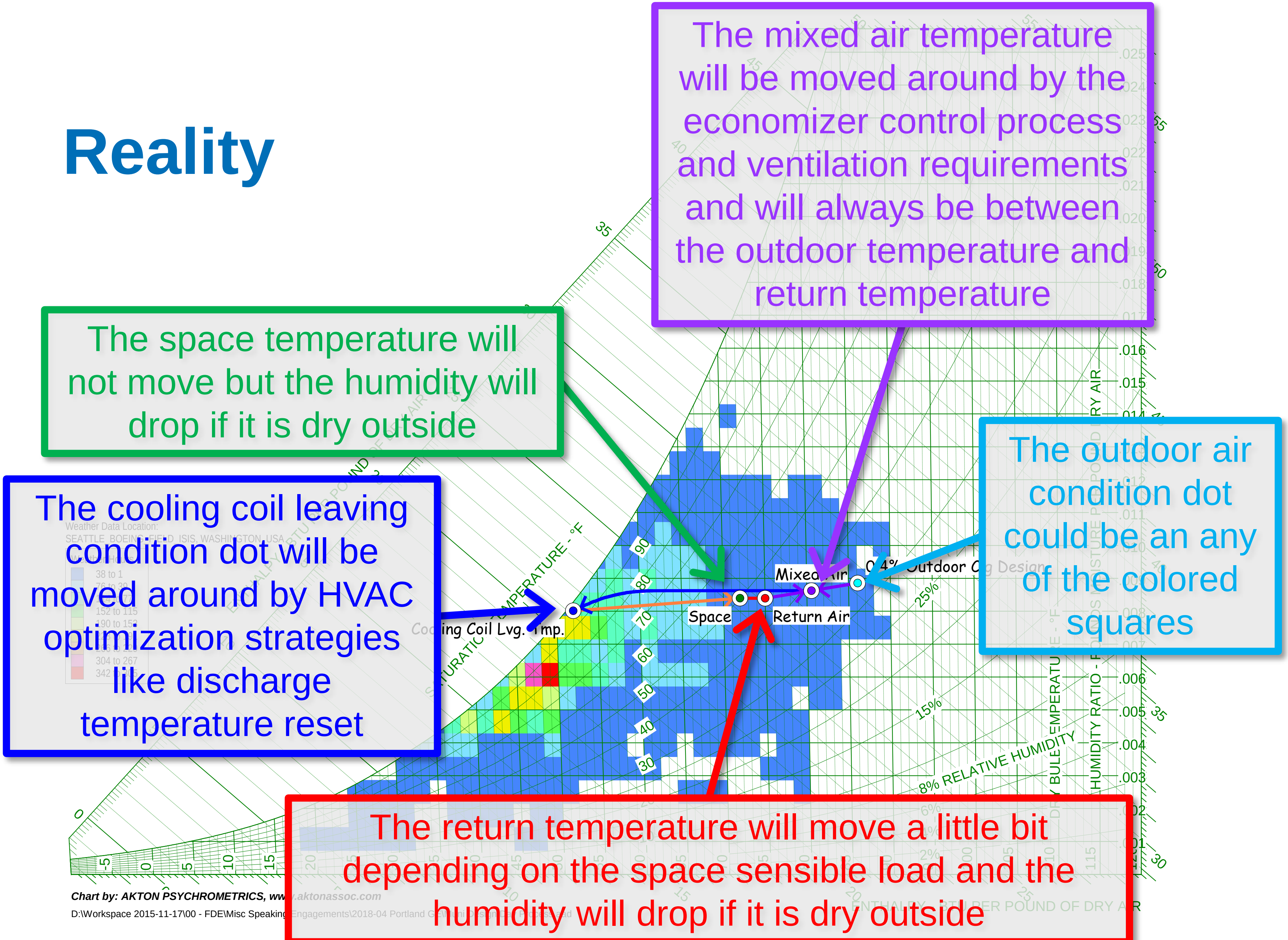
Reality


Weather Data Location:
SEATTLE_BOEING_FIELD_ISIS, WASHINGTON, USA
Weather Hours
38 to 1
76 to 39
114 to 77
152 to 115
190 to 153
228 to 191
266 to 229
304 to 267
342 to 305
0.4% Outdoor Clg Design
Mixed Air
Space
Return Air
Cooling Coil Lvg. Tmp.
ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE - °F
DRY BULB TEMPERATURE - °F
HUMIDITY RATIO - POUNDS MOISTURE PER POUND DRY AIR
8% RELATIVE HUMIDITY
25%
15%
6%
4%
2%
Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com
D:\Workspace 2015-11-17\00 - FDE\Misc Speaking Engagements\2018-04 Portland GE\Muni Design Day Process.aad

Reality


The mixed air temperature will be moved around by the economizer control process and ventilation requirements and will always be between the outdoor temperature and return temperature
The space temperature will not move but the humidity will drop if it is dry outside
The cooling coil leaving condition dot will be moved around by HVAC optimization strategies like discharge temperature reset
The outdoor air condition dot could be an any of the colored squares
The return temperature will move a little bit depending on the space sensible load and the humidity will drop if it is dry outside
Mixed Air
Space
Return Air
Cooling Coil Lvg. Tmp.
RELATIVE HUMIDITY
Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com

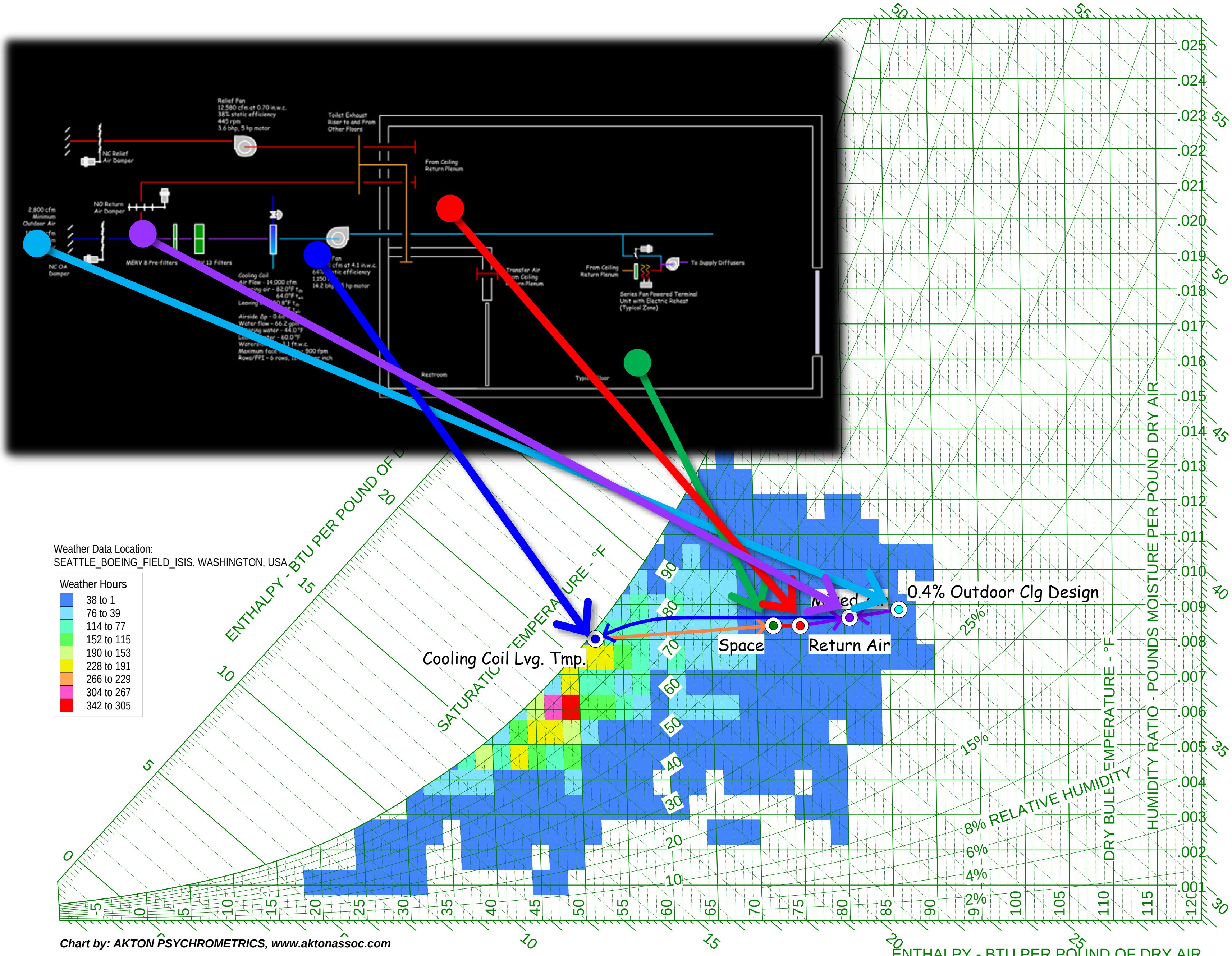


Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com

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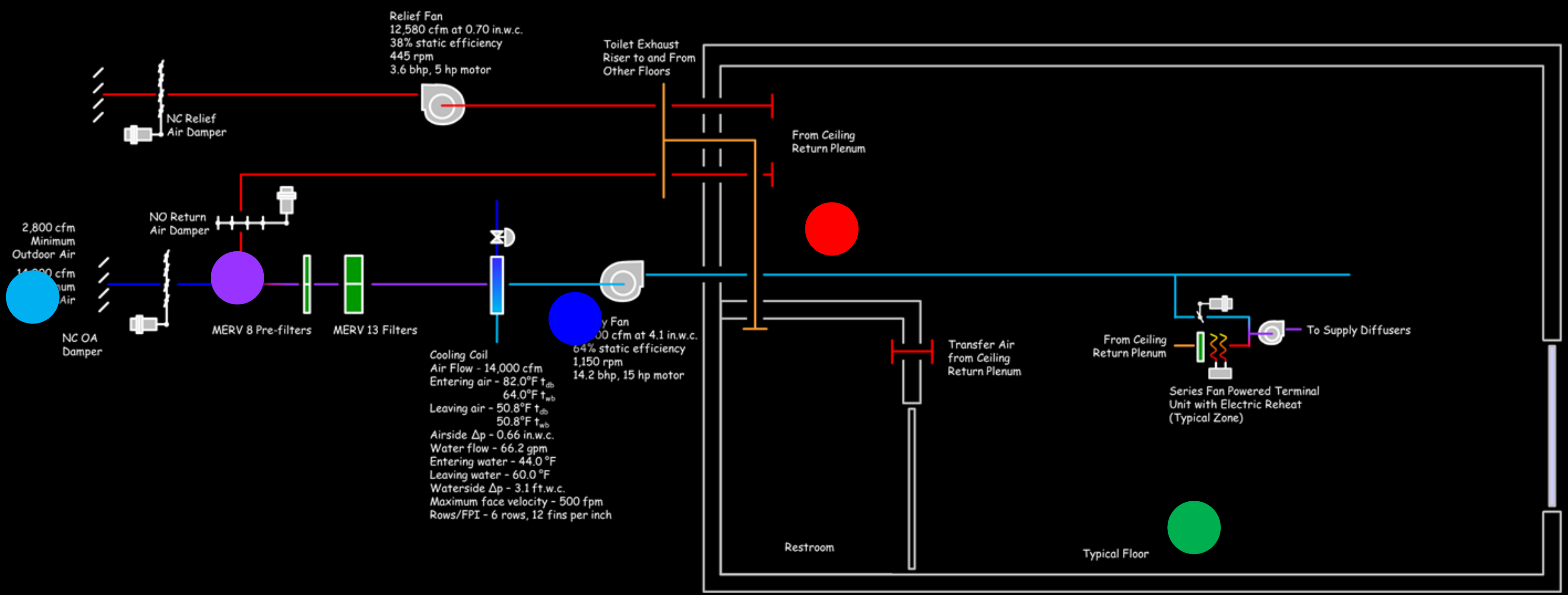
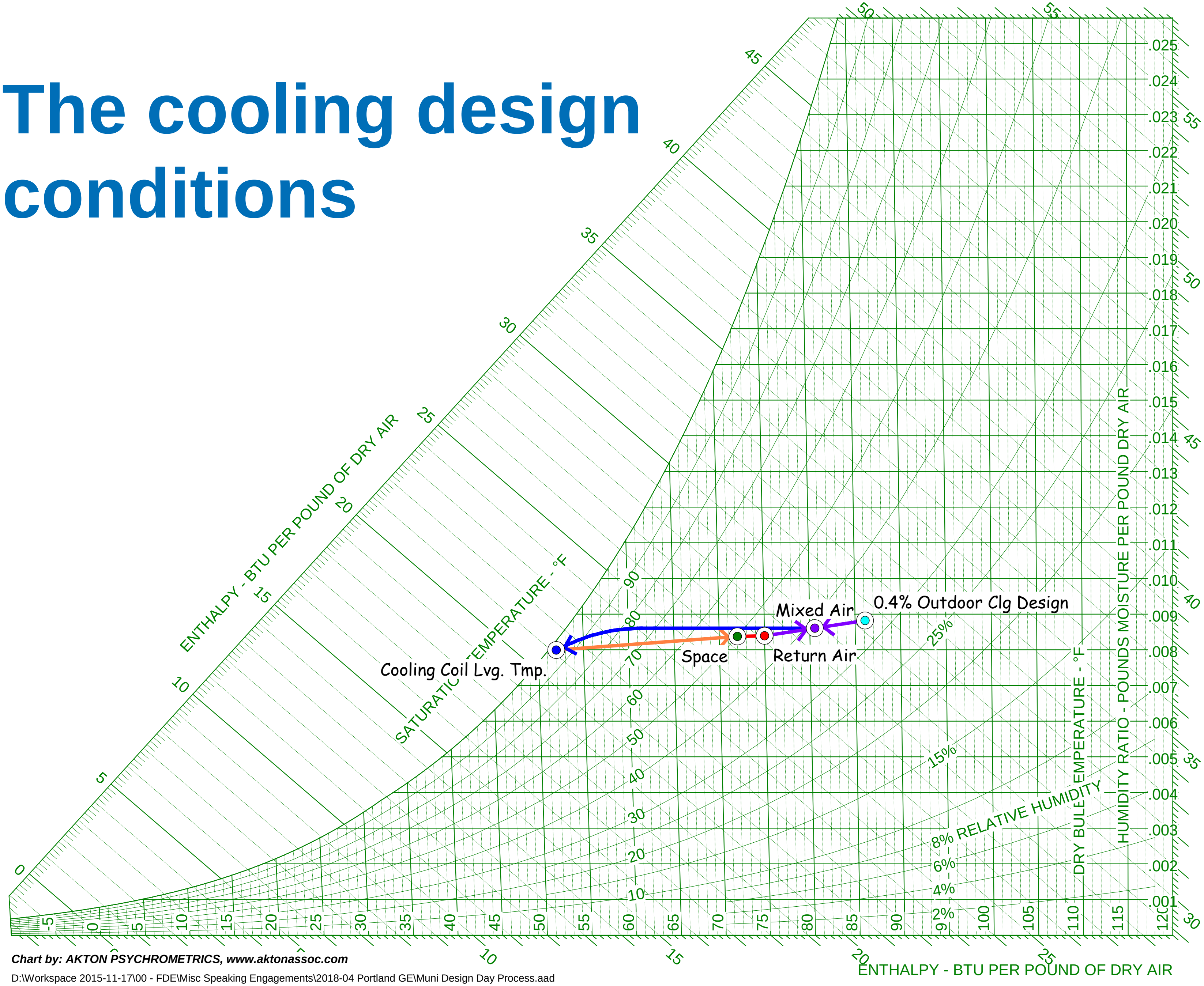
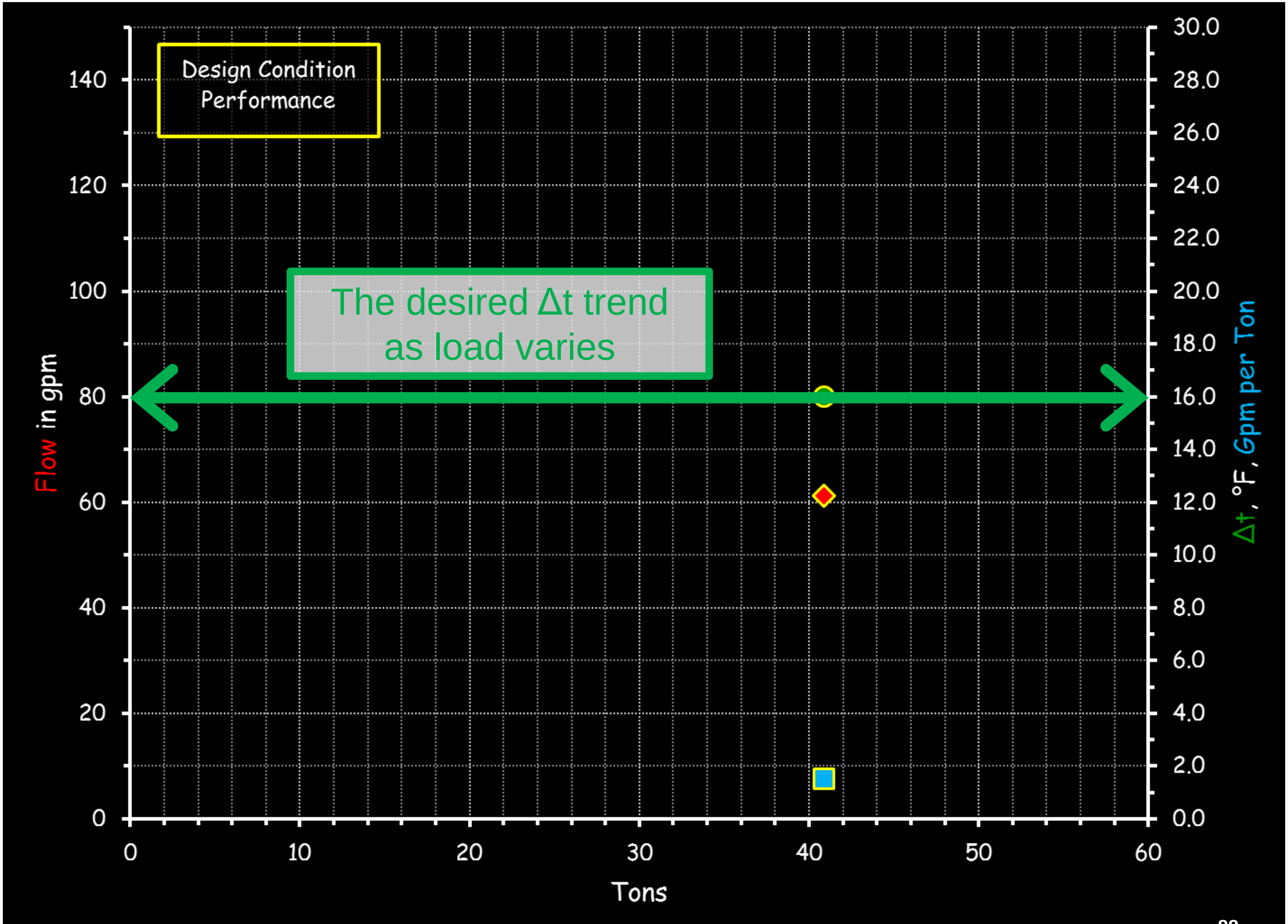
The mixed air condition is the cooling coil entering condition



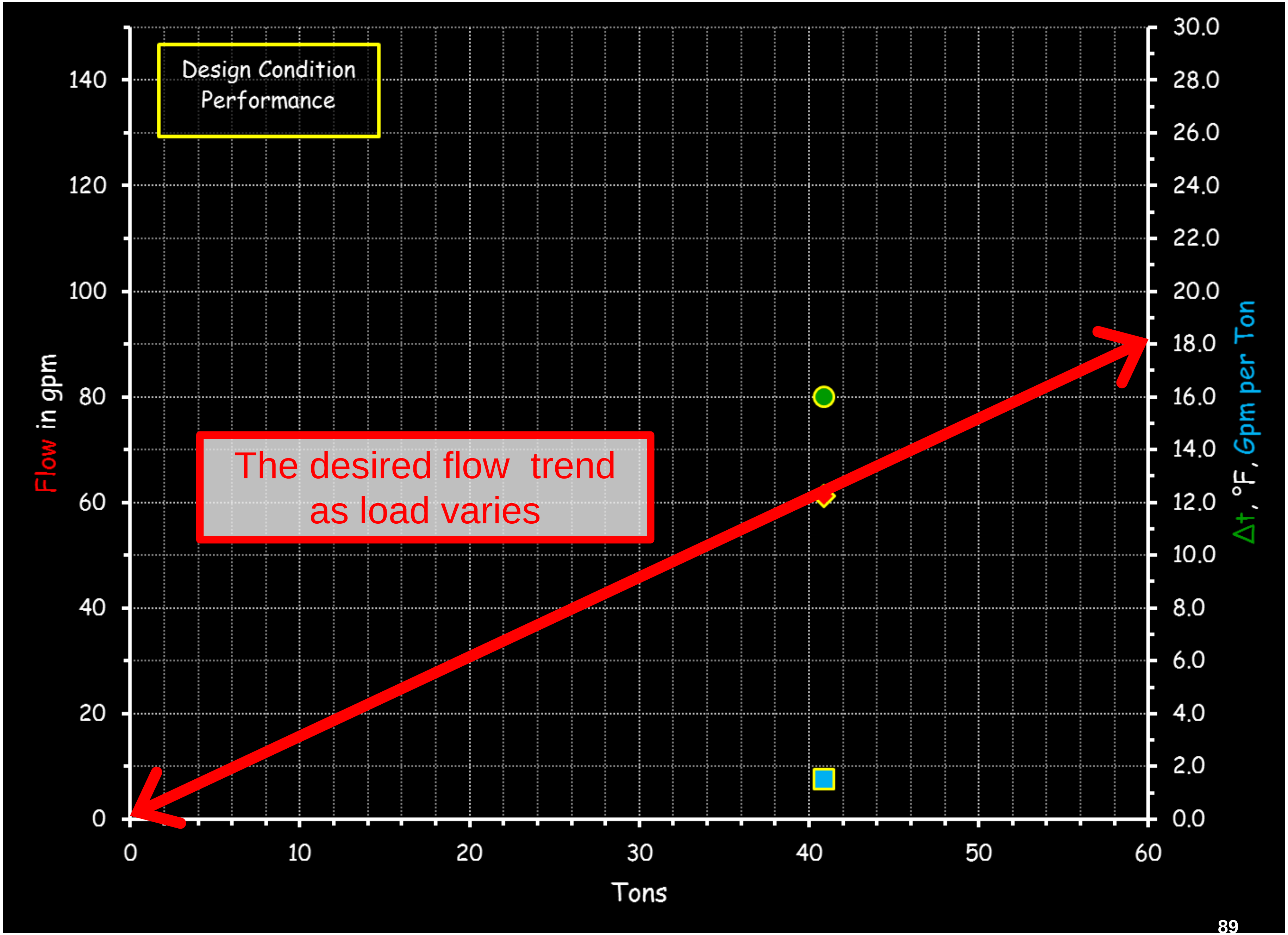
Which means the cooling coil entering condition is highly variable

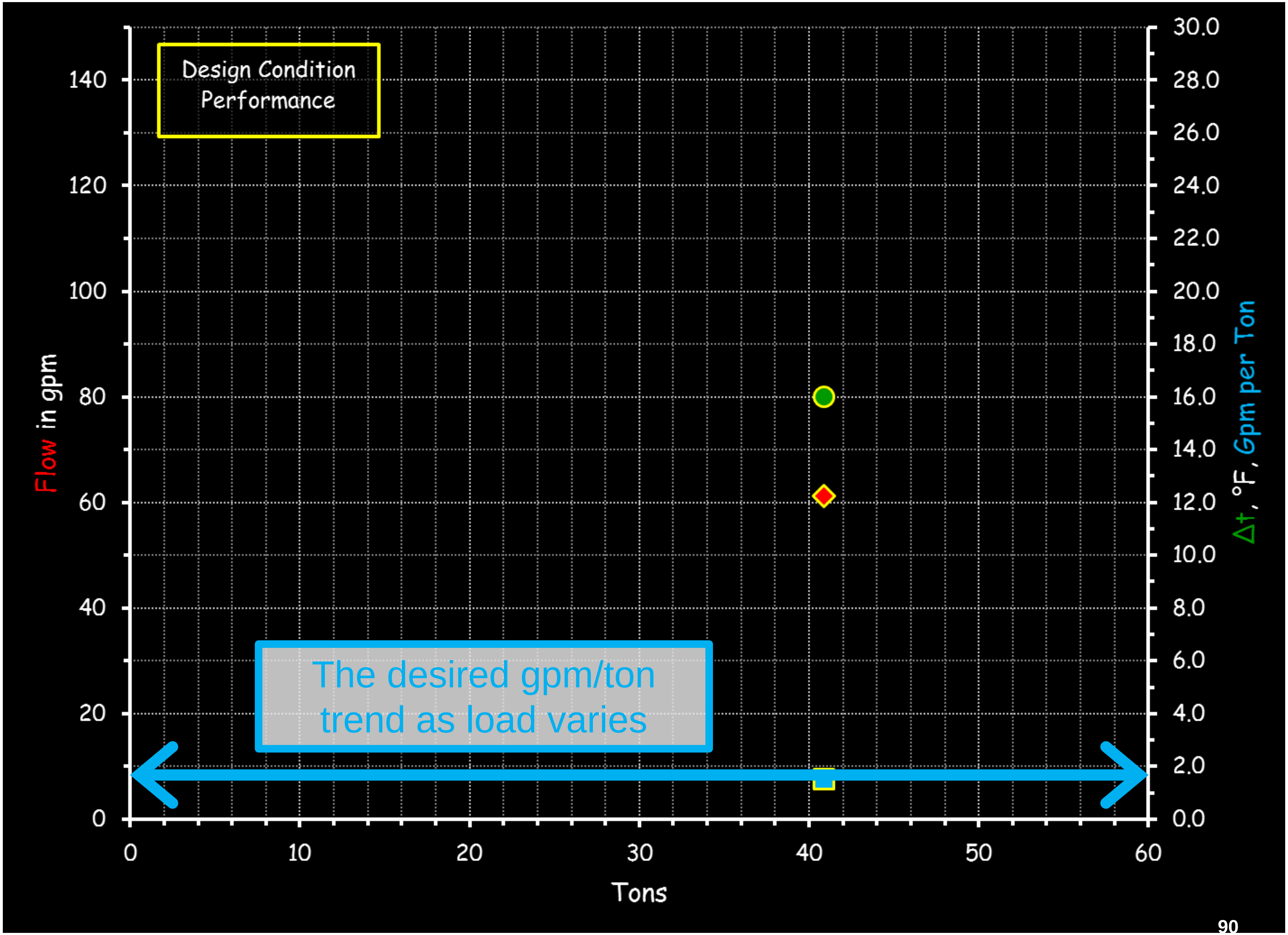
The cooling design conditions





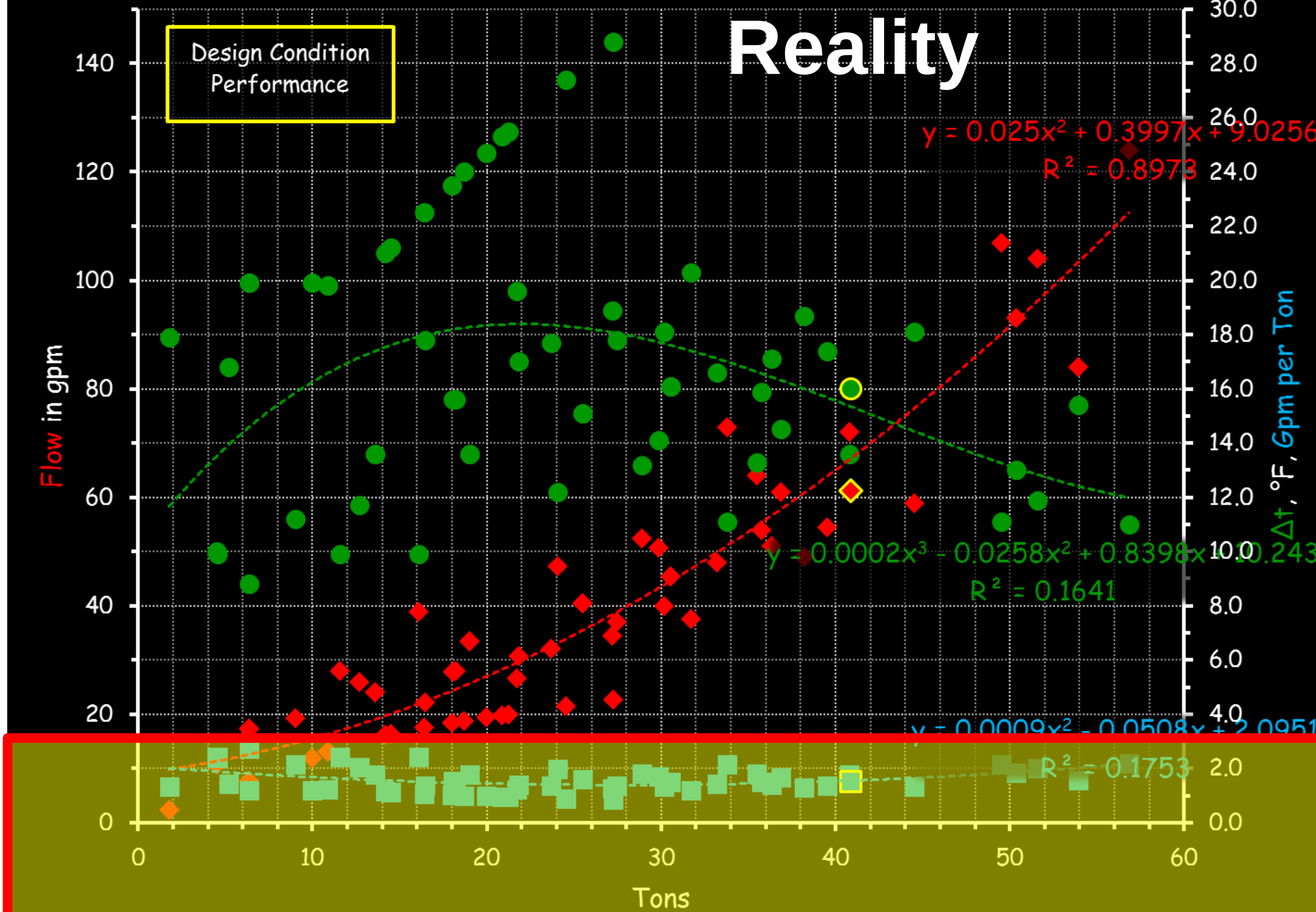
Design Condition
Performance
The desired Δt trend
as load varies
Flow in gpm
Δt, °F, Gpm per Ton
Tons
0
20
40
60
80
100
120
140
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
0
10
20
30
40
50
60


Design Condition Performance
The desired flow trend as load varies
Flow in gpm
Δt, °F, Gpm per Ton
Tons
0
10
20
30
40
50
60
0
20
40
60
80
100
120
140
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0

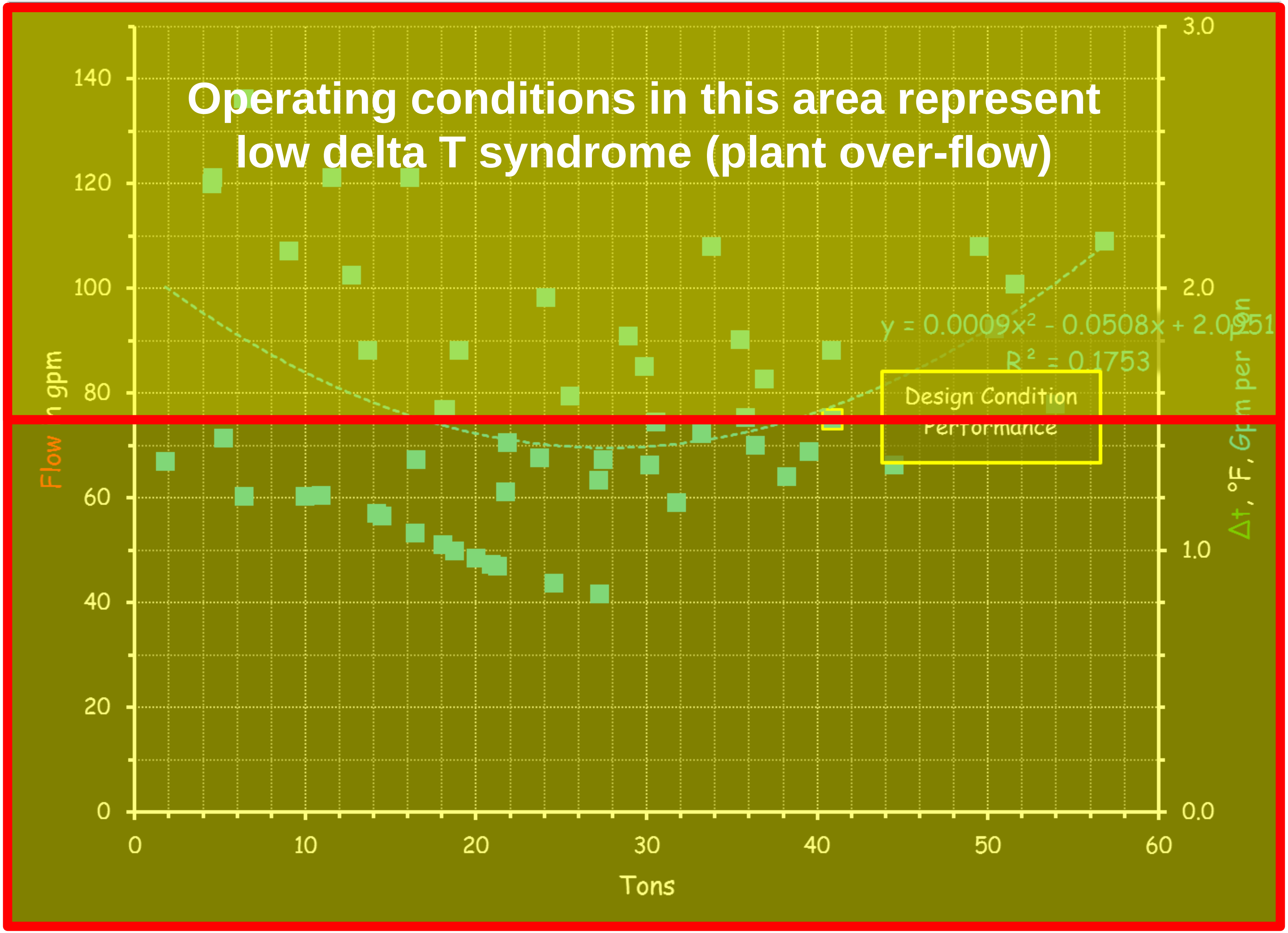


Design Condition
Performance
The desired gpm/ton
trend as load varies
Flow in gpm
Δt, °F, Gpm per Ton
Tons
0
10
20
30
40
50
60
20
40
60
80
100
120
140
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0

Reality

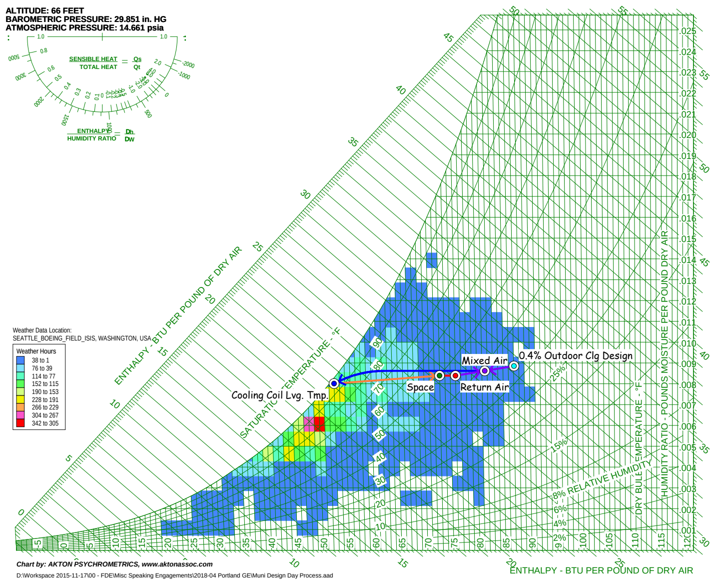


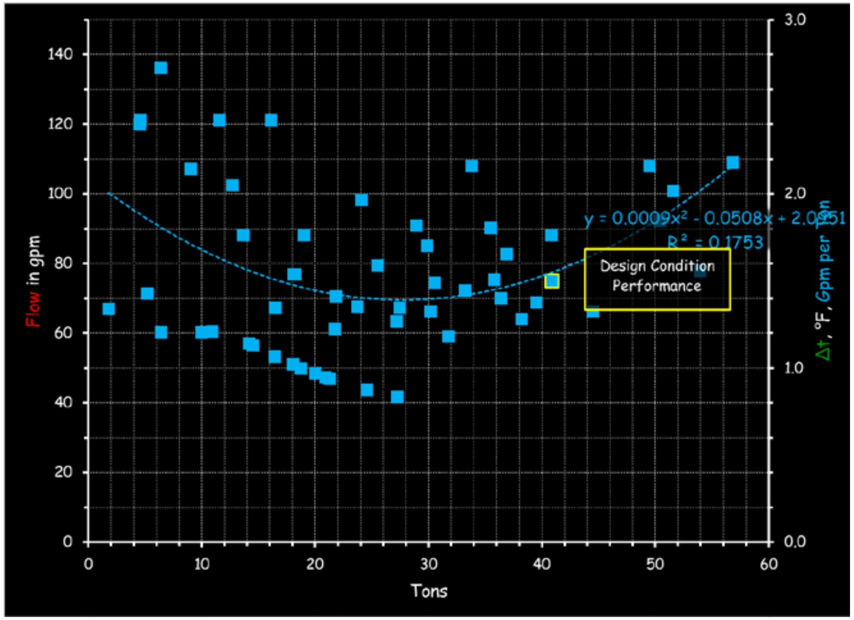
Design Condition
Performance
y = 0.025x² + 0.3997x + 9.0256
R² = 0.8973
y = 0.0002x³ - 0.0258x² + 0.8398x + 10.243
R² = 0.1641
y = 0.0009x² - 0.0508x + 2.0951
R² = 0.1753
Flow in gpm
Δt, °F, Gpm per Ton
Tons
0
10
20
30
40
50
60
20
40
60
80
100
120
140
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0


Operating conditions in this area represent low delta T syndrome (plant over-flow)
y = 0.0009x² - 0.0508x + 2.0951
R² = 0.1753
Design Condition Performance
Flow in gpm
Δt, °F, Gpm per Ton
Tons
0
20
40
60
80
100
120
140
0.0
1.0
2.0
3.0
0
10
20
30
40
50
60

Load profiles and performance vary with climate

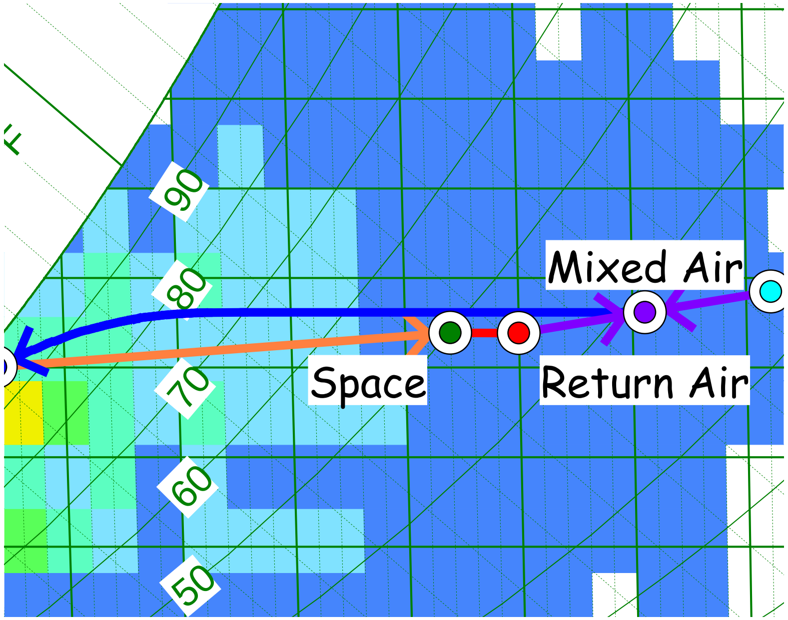
The seasonal and daily load profile seen by our building systems will vary a lot due to the nature of the climate and the performance characteristics of the equipment dealing with the climate.





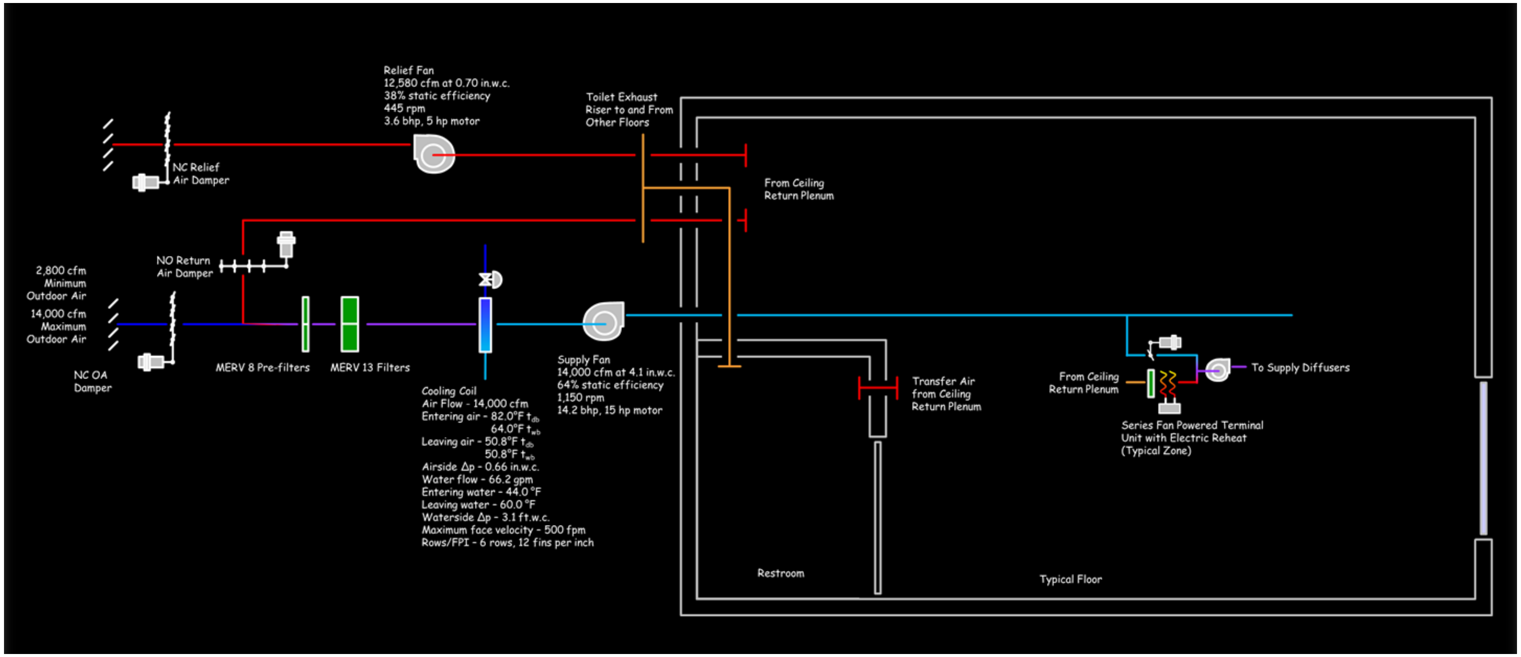
Load profiles and performance vary with climate

But the built environment served by our building systems needs to remain clean, safe, comfortable and productive, no matter what.



Equipment performance must follow load profile

Selecting, controlling and tuning the systems to follow the seasonal and daily load profile is a very important part of the over-all design, commissioning and operation process



The control system

Crucial to optimal performance and energy saving

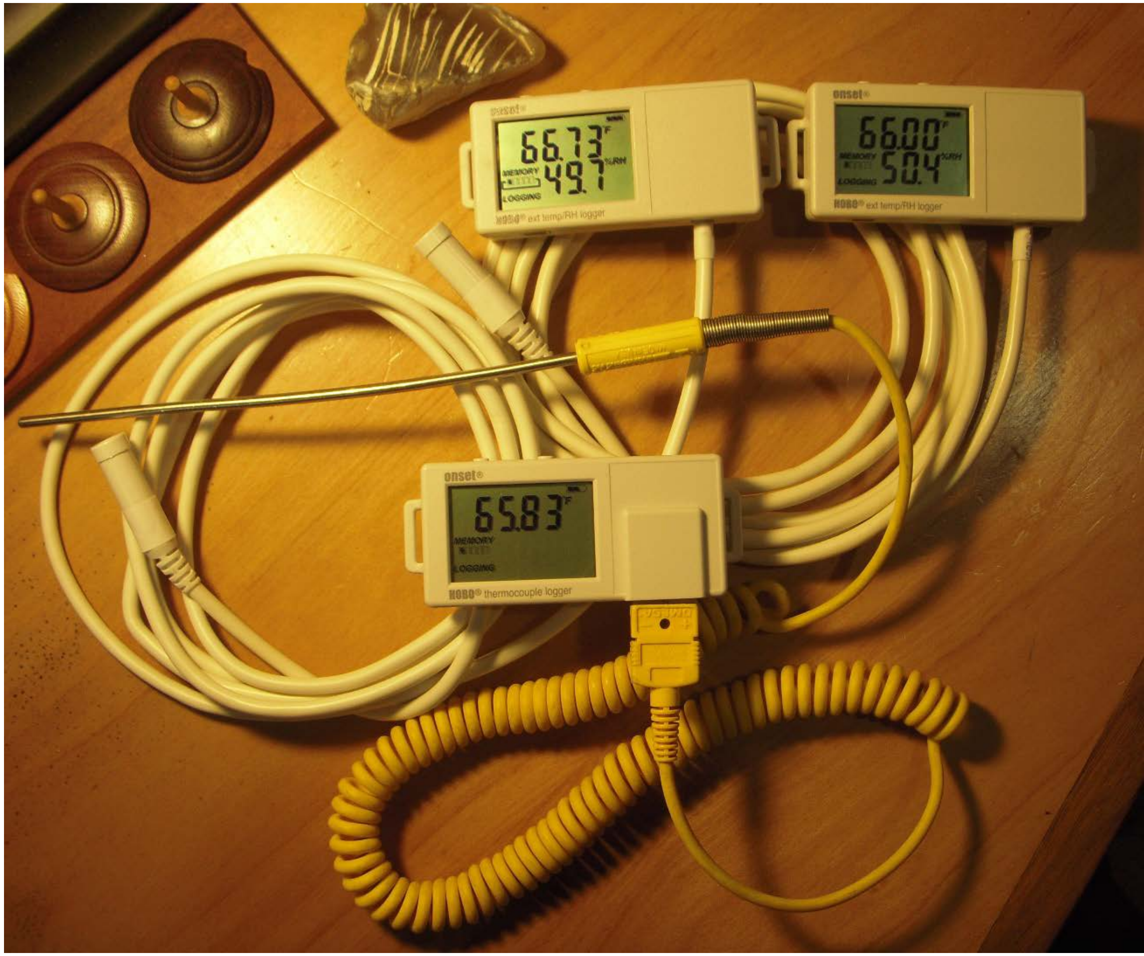
The control system's crucial role

- Ensures systems perform as intended
- Manages system dynamics associated with load profile variations
- Supports functional testing
- Supports data logging and trending
- Supports persistence
- Informs future decisions

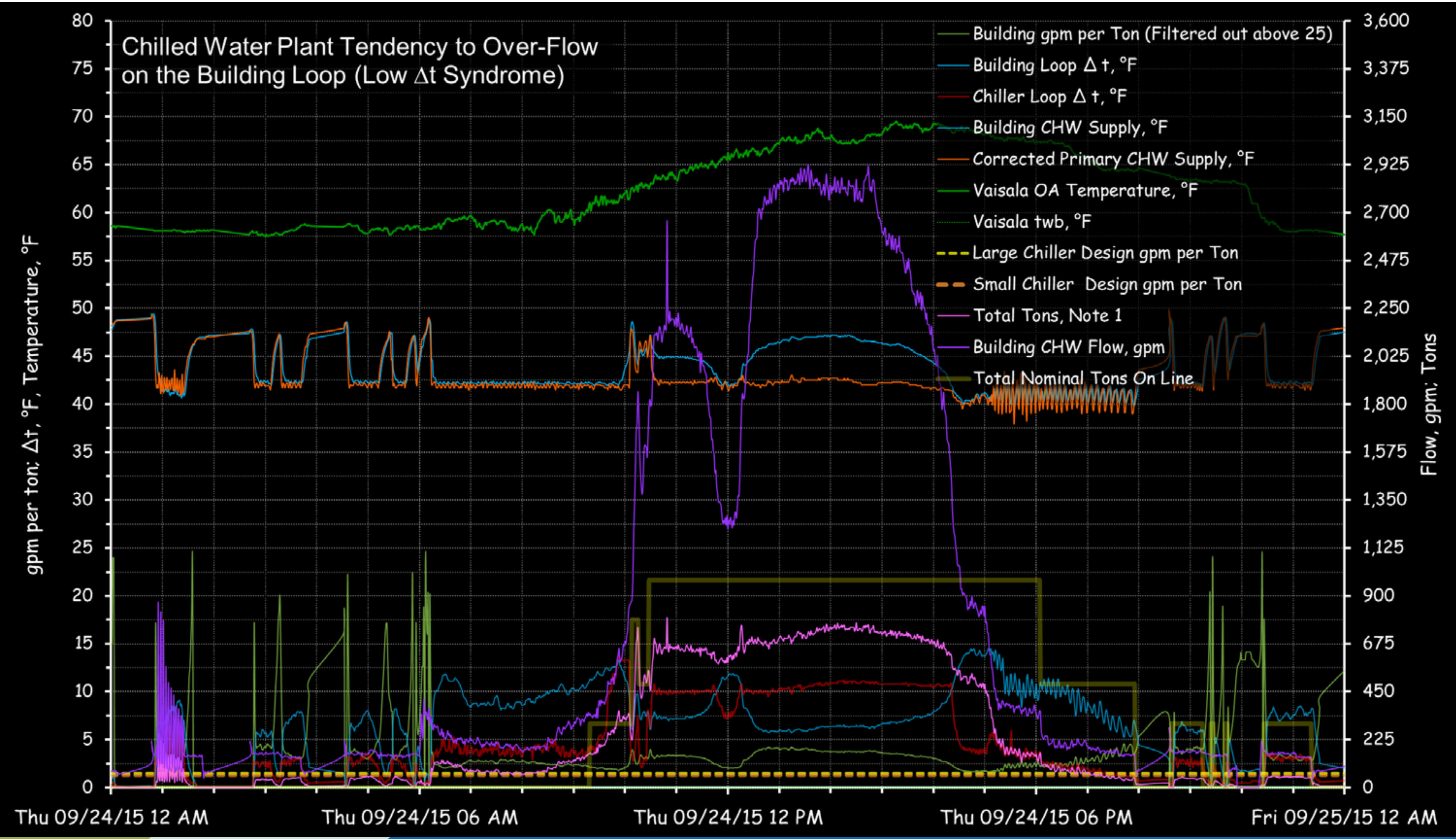
Data loggers

Data loggers supplement the control systems trending capabilities

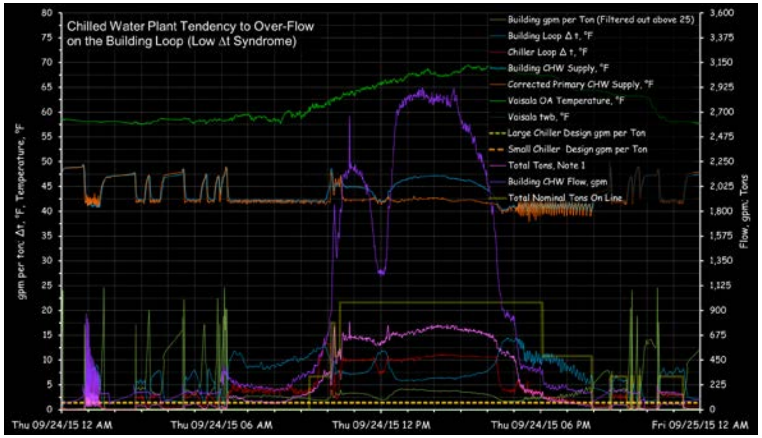
- Potential for faster sampling rates
- Pick up data where points are missing in the control system



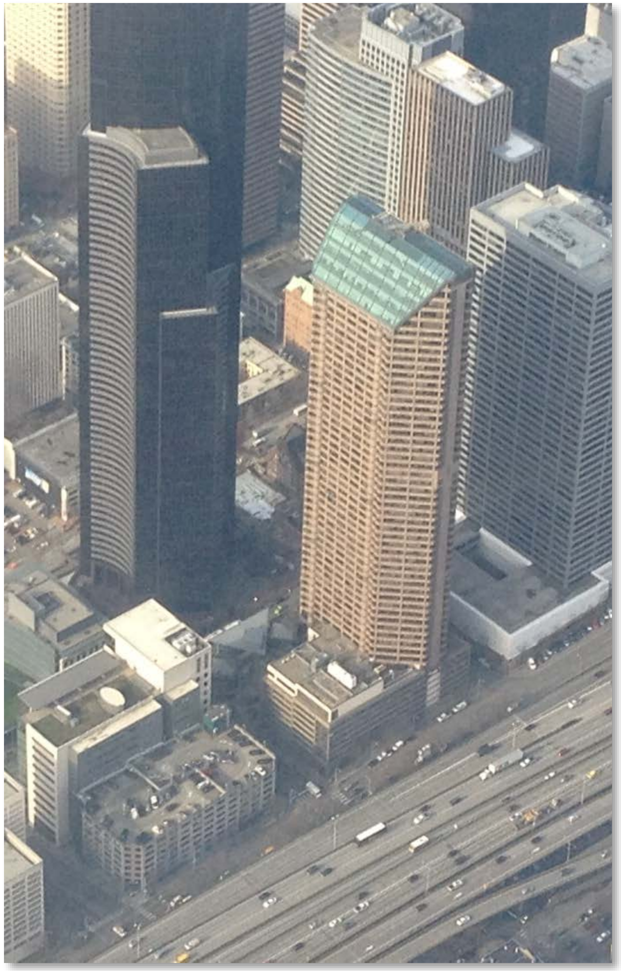
$Data_{Controller} + Data_{Logger}$ = Trend Analysis



Trend analysis + Testing = A building dialog



Example of a load profile dialog



FADE IN:

EXT. EARLY – MORNING

- Cx provider with tool kit enters building and is greeted by the operating staff and a project manager

PROJECT ENGINEER (To Operating Team)

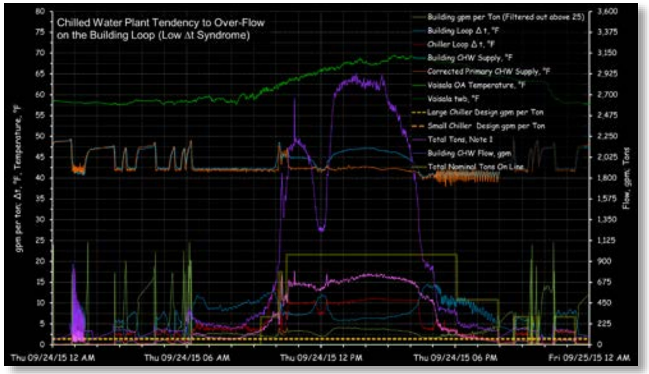
- *Our Cx provider has an idea about how to size the chillers for our new plant and would like to see what we have currently*

CHIEF ENGINEER

- Sure, let's head up and take a look around

FADE TO CHILLER PLANT:

Pump Identification ➔	P14-3 Stand-Alone (Discharge Full Open)			P14-3 Full Open (Pumping through CH-3)		
Service Area	Primary CHW through Chiller 2			Primary CHW through Chiller 2		
Physical Location of Unit	14th Floor Mechanical Room			14th Floor Mechanical Room		
Pump Information:	**Design**	**Submitted/TAB**	**Actual**	**Design**	**Submitted/TAB**	**Actual**
Manufacturer:			Paco			Paco
Model #:			29-60151859001			29-60151859001
Serial #:						
Part / Catalog #:			KP 6015, 6x8x12			KP 6015, 6x8x12
Nameplate GPM:			1,460.0			1,460.0
Actual Flow (GPM)			1,650.0			1,520.0
Nameplate Head (Ft):			50.0			50.0
Differential Pressure (Feet Hd)			50.6			54.5
Nameplate HP:			25.0			25.0
BHP:			24.5			23.8
Nameplate RPM:			1,150			1,150
Actual RPM:			1,181			1,181
Listed Impeller Diameter:			11.9			11.9
Actual Diameter (Tested):			12.1			12.1
Manual Control Information:						
Control Type:	Manual Isolation Valve			Manual Isolation Valve		
Manufacturer:						
Model:						
Device Adjustment Position:			100%			100%
Differential Pressure (Feet Hd)						
Control Information						
Controlled Medium:	Not Applicable			Not Applicable		
Control Type:						
Setpoint (BAS / Local Controller / FDE Measured):						
Final Controlled Device Position (Hz/%Open, etc.):						
Motor Data: Nameplate / Operational						
Manufacturer:	GE			GE		
HP / Efficiency / kW:	25.0	93.6%	Not Listed	25.0	93.6%	Not Listed
BHP Calc'd Meas'd Values / BHP VFD kW / VFD kW	23.6	Not Applicable	Not Applicable	23.5	Not Applicable	Not Applicable
Nameplate RPM / Measured	1,180	1,181		1,180	1,181	
Nameplate Volts:	460			460		
Voltage (VFD Display)	481	483	476	480	482	477
Nameplate Amperage:	30.4			30.4		
Amperage (VFD Display)	29.8	28.2	30.3	29.9	28.0	29.9
SFA:	Not Listed			Not Listed		
SF:	1.15			1.15		
Frame:	324T			324T		
Notes:						



CX PROVIDER

Then I bet the building knows how big the chillers need to be.

We just need to ask it the right questions.

CHIEF ENGINEER

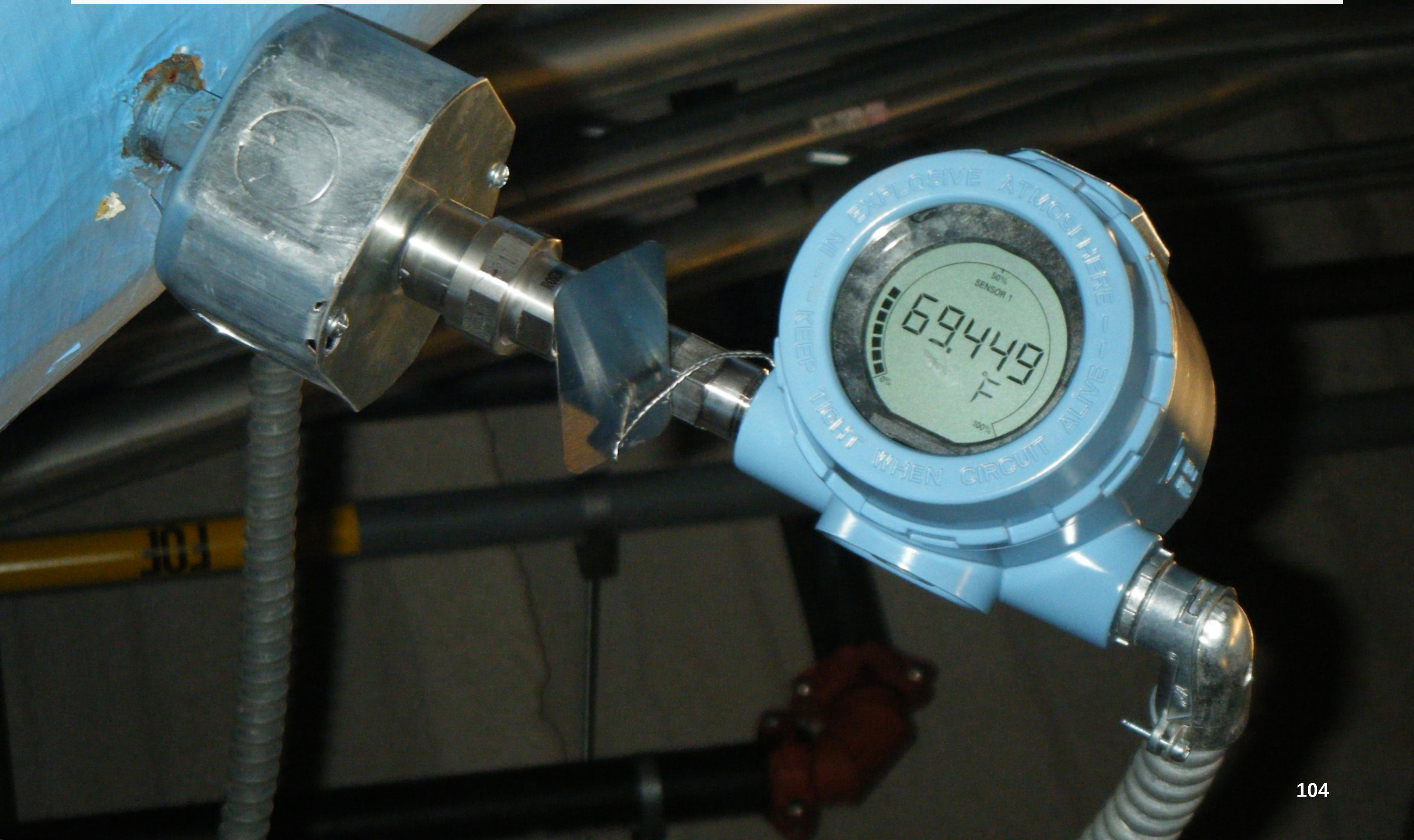
How will we do that?

CX PROVIDER

With functional testing, trending, and data logging.

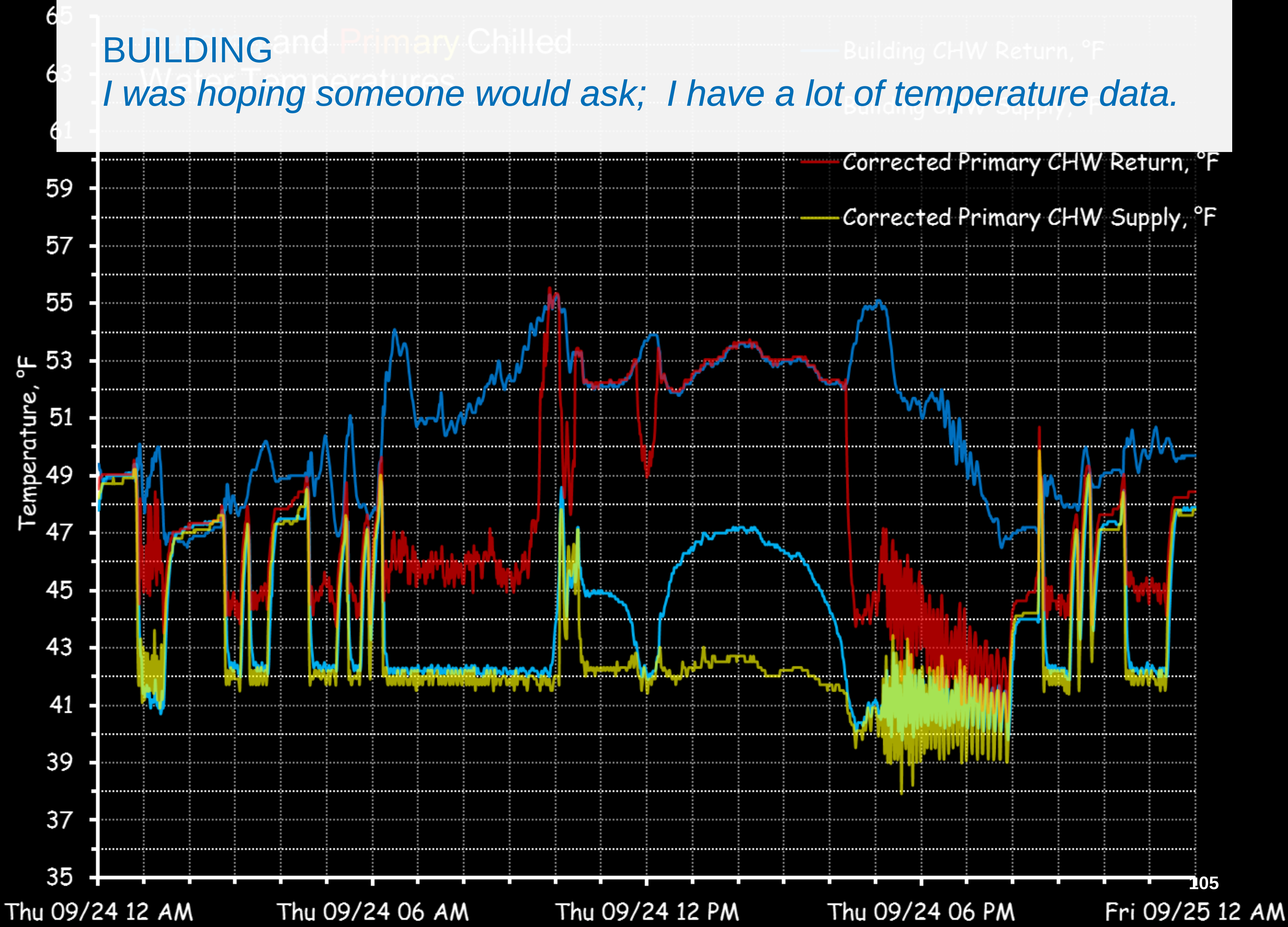
CX PROVIDER (to building)

Tell me about the flow rates and temperatures in your chilled water system.



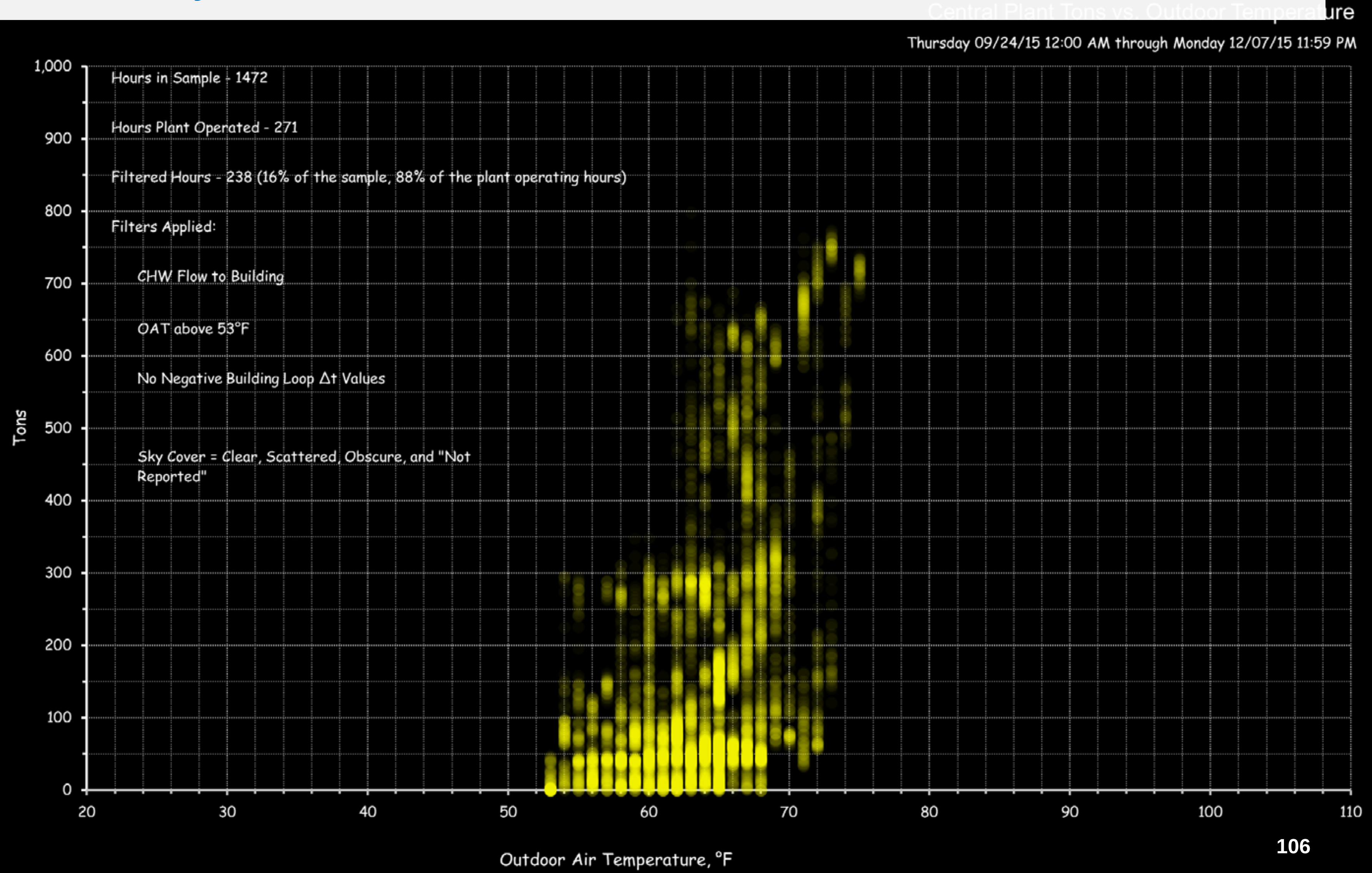
BUILDING

I was hoping someone would ask; I have a lot of temperature data.



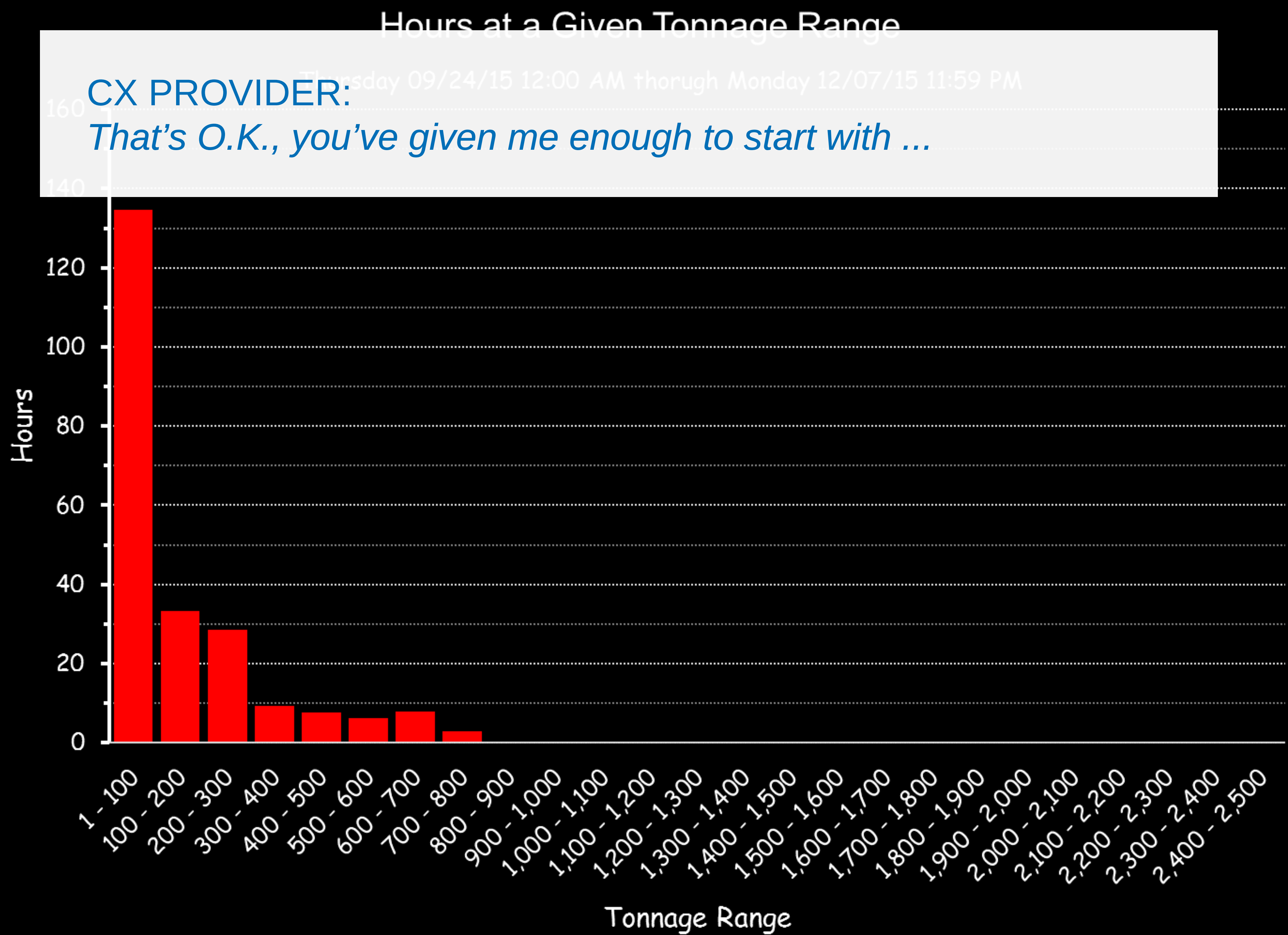
BUILDING:

But I am afraid I only have a couple of months of flow and tonnage data. My flow meter was broken for a while.



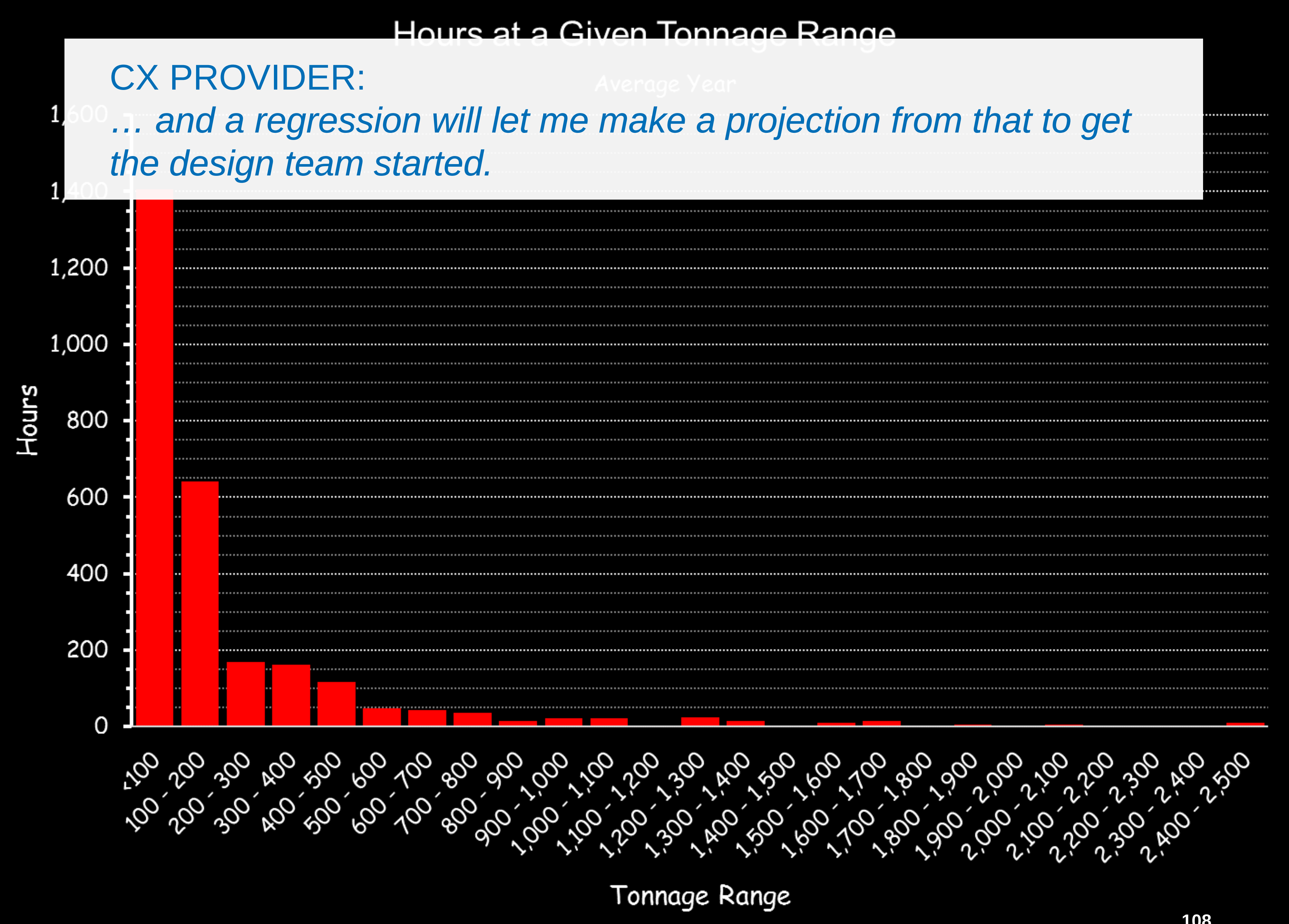
CX PROVIDER:

That's O.K., you've given me enough to start with ...



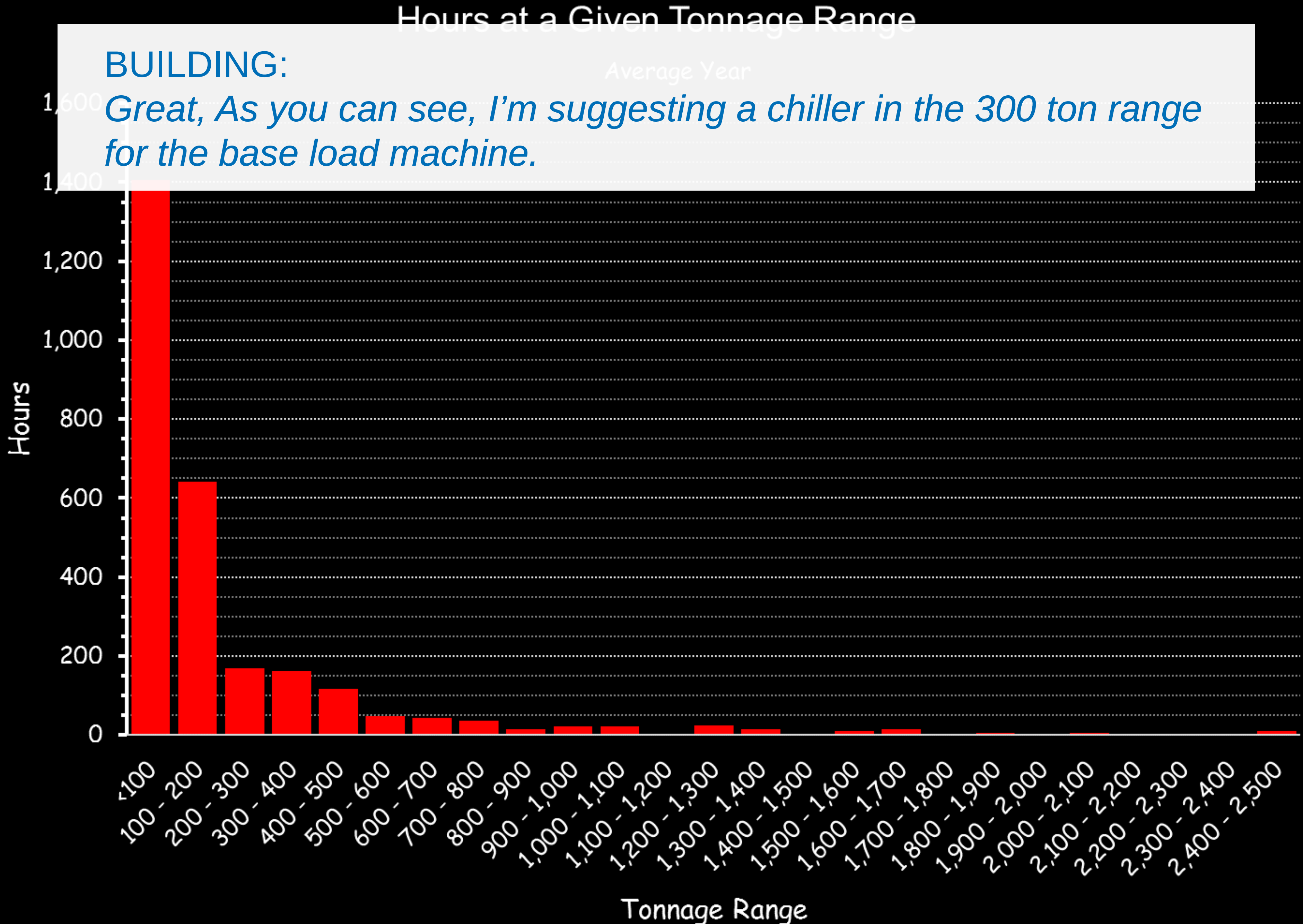
CX PROVIDER:

… and a regression will let me make a projection from that to get the design team started.



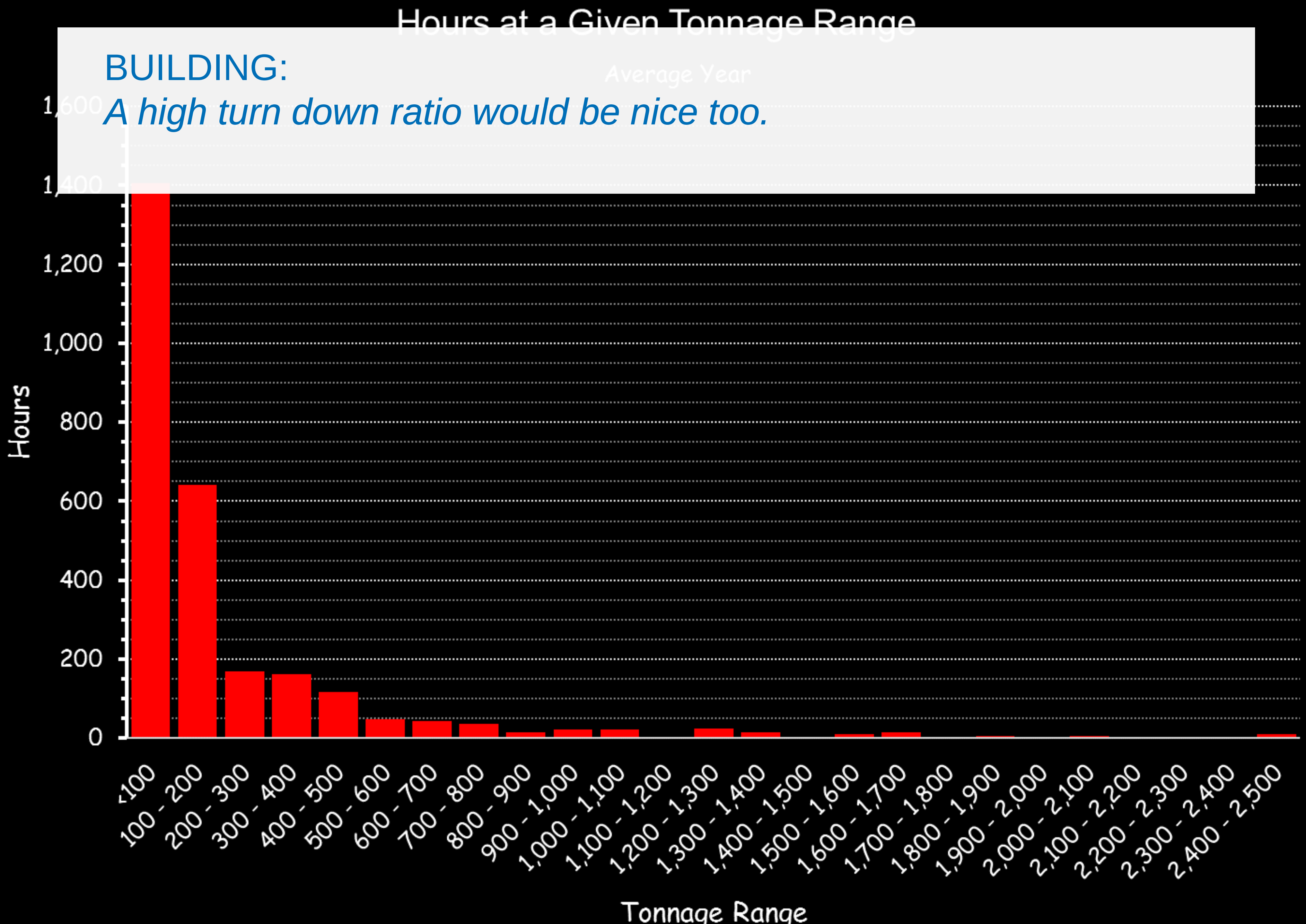
BUILDING:

Great, As you can see, I’m suggesting a chiller in the 300 ton range for the base load machine.



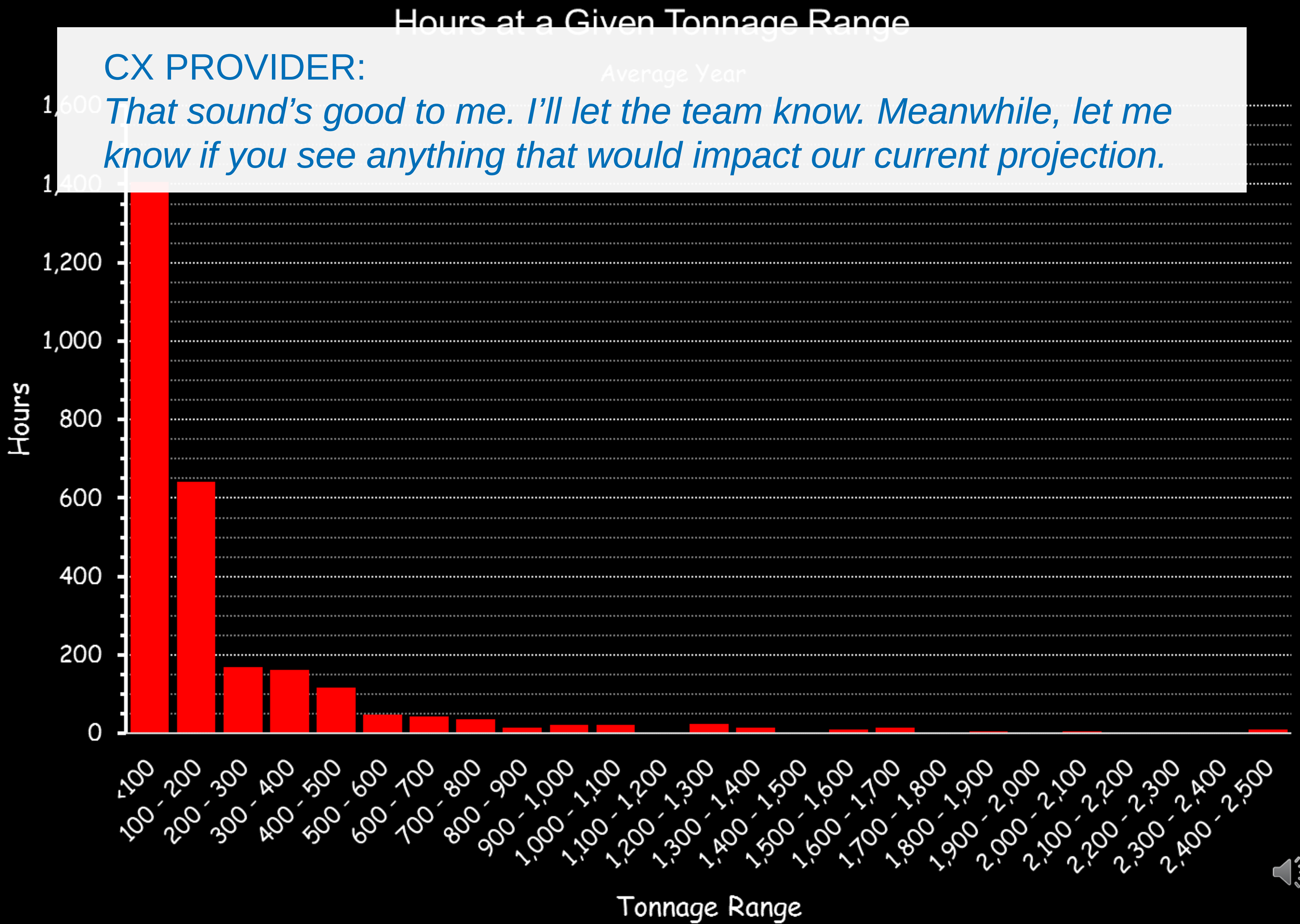
BUILDING:

A high turn down ratio would be nice too.

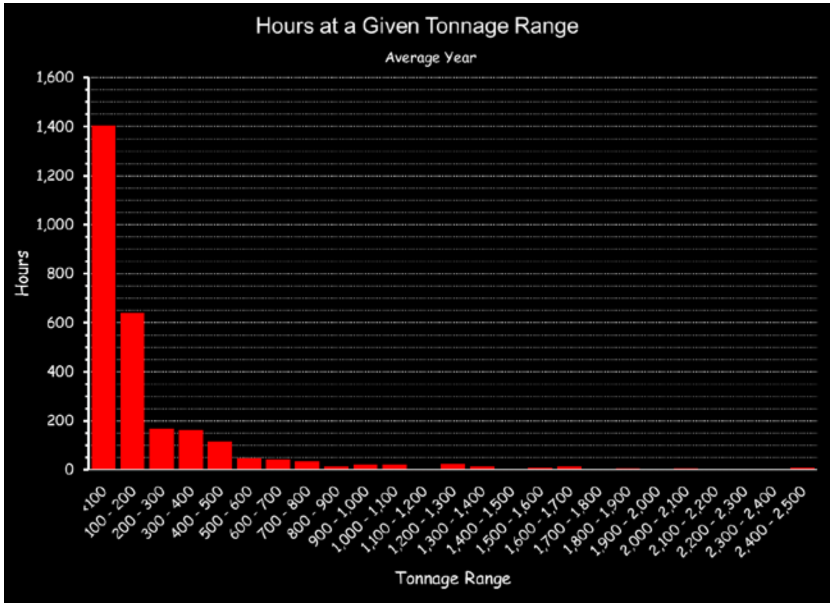


CX PROVIDER:

That sound’s good to me. I’ll let the team know. Meanwhile, let me know if you see anything that would impact our current projection.



The design evolves and is reviewd



FADE OUT:

FADE IN TIME PASSING MUSIC

FADE IN CX PROVIDER DOING DESIGN REVIEW ON THE NEW CENTRAL PLANT DESIGN

BUILDING:

I'm happy to see the design team paid attention to my suggestion about equipment sizes and turn down requirements.

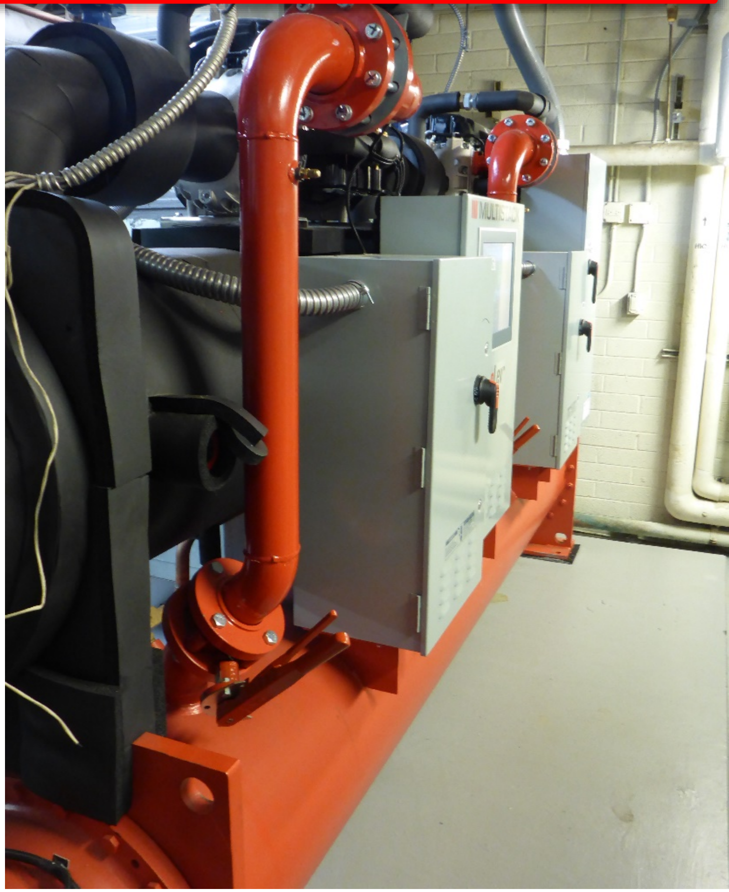
KW/TON	0.554	0.470	0.470

LOCATION		MECH RM	MECH RM	MECH RM
SERVES		CLG WATER	CLG WATER	CLG WATER
CAPACITY	TONS	300.0	1,000.0	1,000.0
	KW/TON	0.554	0.470	0.470
	COP			
COMPRESSOR	TYPE	CNTFGL	CNTFGL	CNTFGL
	QUANTITY: NO	2	3	3
EVAPORATOR	FLOW: GPM	450	1,500	1,500
	EWT: F	59	59	59
	LWT: F	43	43	43
	PD: FT HD	11	18	18
	FOULING FACTOR	0.00010	0.00010	0.00010
CONDENSER	FLOW: GPM	850	2,800	2,800
	EWT: F	86	86	86
	LWT: F	76	76	76
	PD: FT HD	15	16	16
	FOULING FACTOR	0.00025	0.00025	0.00025
REFRIGERANT	TYPE	R-134A	R-134A	R-134A
	CHARGE: LBS	895	2851	2851
ELECTRICAL	VOLT/PHASE	460/3	460/3	460/3
	TOTAL KW	163.3	470.4	470.4
	MCA	261	518 [3]	518 [3]
	MOP	350	724 [3]	724 [3]
	SCCR: AMPS	100,000	100,000	100,000
OPER WEIGHT	WEIGHT: LBS	10,000	35,000	35,000
BASIS OF DESIGN	MANUFACTURER	SMARDT	SMARDT	SMARDT
	MODEL	WA095.2H	WV400.3U	WV400.3U
	NOTES	[1, 2, 4, 6]	[1, 2, 4, 6]	[1, 2, 4, 6]

PROVIDE ALL CHILLERS FROM ONE MANUFACTURER.

NOTES:

1. SINGLE POINT CONNECTION, REFER TO ELECTRICAL DRAWINGS.
2. MAGNETIC BEARING, OIL-LESS COMPRESSORS.
3. RATINGS PER COMPRESSOR.
4. PROVIDE ONE SPARE COMPRESSOR FOR EACH SIZE USED IN THE NOMINAL 300 TON AND 1000 TON CHILLERS. DELIVER AT END OF WARRANTY PERIOD – ALTERNATE BID ITEM.
5. PROVIDE 5 YEAR WARRANTY – ALTERNATE BID ITEM.
6. PROVIDE MARINE BOXES AT ENDS WITH PIPING CONNECTIONS (300 LB PRESSURE CLASS ON EVAPORATOR) AND HINGED ACCESS AT ALL ENDS.



BUILDING:

I think I will need to run some pumps and cooling towers when I run those new chillers. Will that impact how you would sequence them?

PUMPS - HYDRONIC

MARK		P14-1	P14-2	P14-3	P14-4	P14-5	P14-6
LOCATION		MECH RM	MECH RM	MECH RM	MECH RM	MECH RM	MECH RM
SERVES		CHILLED WTR	CHILLED WTR	CHILLED WTR	COND WTR	COND WTR	COND WTR
CAPACITY	FLOW: GPM	500	1,500	1,500	900	3,500	3,500
	TDH: FT	120	160	160	60	60	60
	EFFICIENCY: %	75	79	79	67	74	74
TYPE	DESCRIPTION	VIL	VIL	VIL	VIL	VIL	VIL
	MOTOR RPM	1,800	1,800	1,800	1,800	1,800	1,800
	MAX BHP	27.00	87.00	87.00	21.00	70.00	70.00
	SUCT CONN: IN	6	8	8	8	12	12
	DISCH CONN: IN	6	8	8	8	12	12
	IMP DIA: IN	11.20	13.26	13.26	8.34	10.00	10.00
ELECTRICAL	VOLT/PHASE	460/3	460/3	460/3	460/3	460/3	460/3
	MOTOR HP	40	100	100	25	75	75
	SCCR: AMPS	35,000	65,000	65,000	14,000	35,000	35,000
OPER WEIGHT	WEIGHT: LBS	1,050	2,150	2,150	950	2,600	2,600
BASIS OF DESIGN	MANUFACTURER	PACO	PACO	PACO	PACO	PACO	PACO
	MODEL	VLS 6x6x11.5	VLS 8X8X15	VLS 8X8X15	VLS 6x6x11.5	VLS 12x12x13	VLS 12x12x13
	NOTES	[1, 2, 3, 4]	[1, 2, 3, 4]	[1, 2, 3, 4]	[1, 2, 3, 4]	[1, 2, 3, 4]	[1, 2, 3, 4]

PROVIDE ALL PUMPS FROM ONE MANUFACTURER.

NOTES:

1. REFER TO ELECTRICAL DRAWINGS FOR DISCONNECT SWITCH.
2. PROVIDE WITH VARIABLE FREQUENCY DRIVE AND SUCTION DIFFUSER.
3. MOUNT PUMP ON SPRING ISOLATED CONCRETE INERTIA BASE; OPER WEIGHT DOES NOT INCLUDE INERTIA BASE.
4. PROVIDE ALL PUMPS WITH SUCTION DIFFUSERS; 300 LB PRESSURE CLASS ON CHILLED WATER PUMPS.

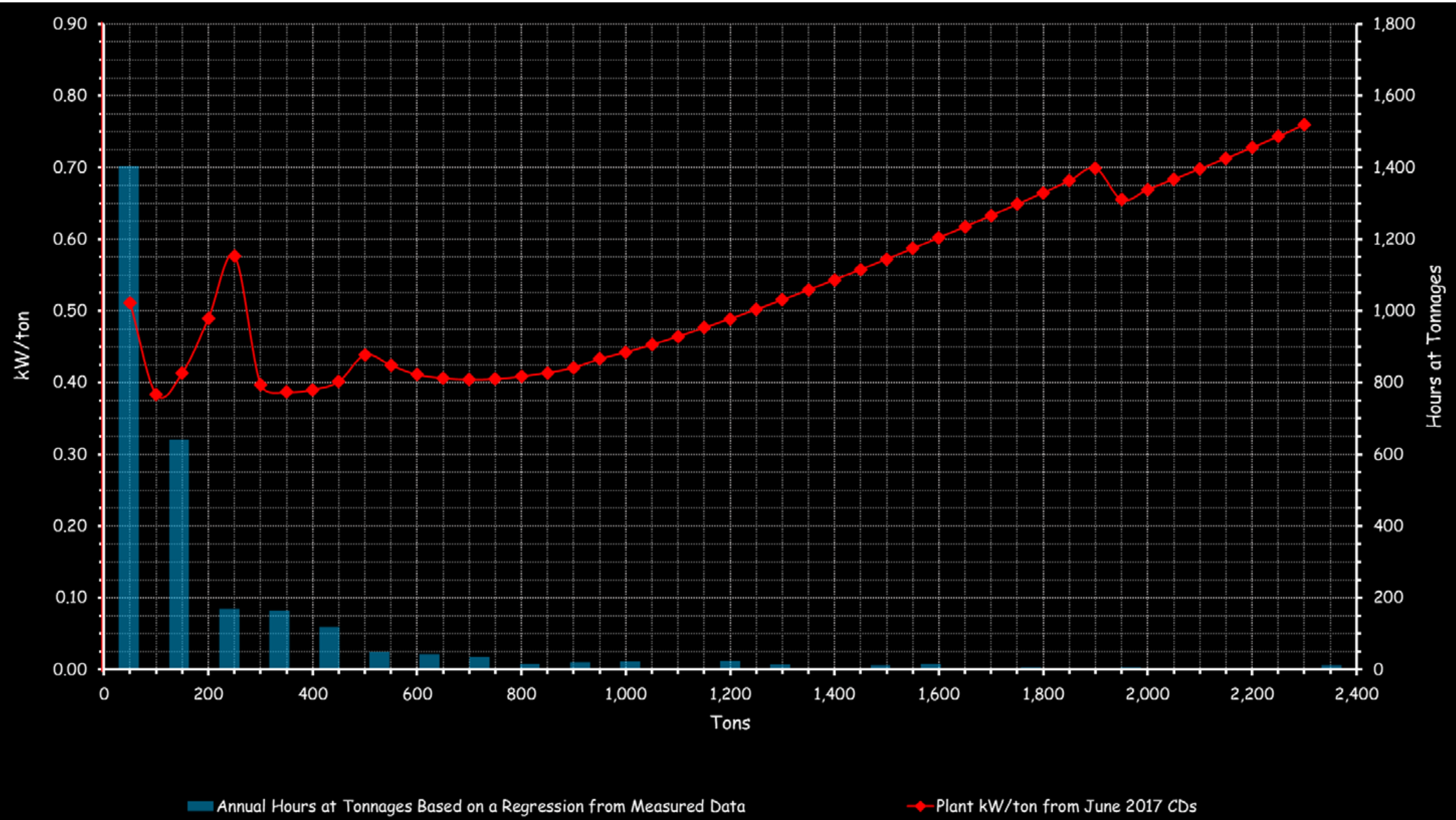
COOLING TOWERS

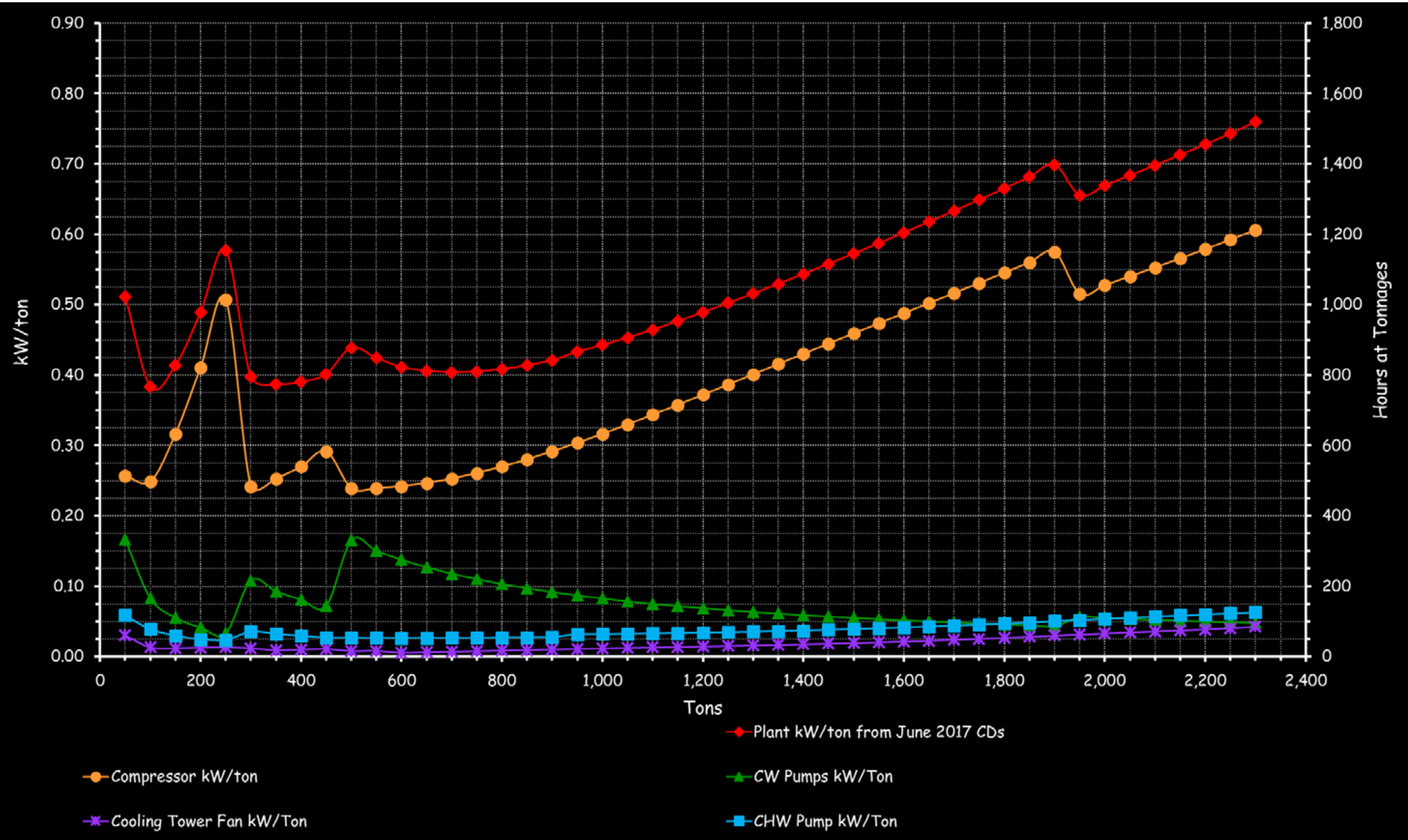
MARK		CT-1A	CT-1B
LOCATION		ROOF	ROOF
SERVES		CHILLERS	CHILLERS
TYPE	AIRFLOW CONFIG	IND DRAFT	IND DRAFT
	DISCHARGE	VERTICAL	VERTICAL
	CELLS	2	2
CAPACITY [1]	HEAT REJ: TONS	1,185	1,185
	FLOW: GPM	3,450	3,450
	AMBIENT WB: F	66	66
	EWT: F	86	86
	LWT: F	76	76
	PD: FT HD	12	12
FAN	TYPE	SILENT PROP	SILENT PROP
	FANS: NO	2	2
	AIRFLOW: CFM	268,800	268,800
	ESP: IN WG	–	–
	TOTAL MOTOR HP	60	60
	PONY MOTOR HP	–	–
	VOLT/PHASE	460/3	460/3
BASIN HEATER	HEATERS	–	–
	CAPACITY: KW	–	–
	VOLT/PHASE	460/3	460/3
ELECTRICAL	SCCR: AMPS	14,000	14,000
OPER WEIGHT	WEIGHT: LBS	43,780	43,780
BASIS OF DESIGN	MANUFACTURER	EVAPCO	EVAPCO
	MODEL	UT–224–418	UT–224–418
	NOTES	[2–7]	[2–7]

PROVIDE ALL COOLING TOWERS FROM ONE MANUFACTURER.

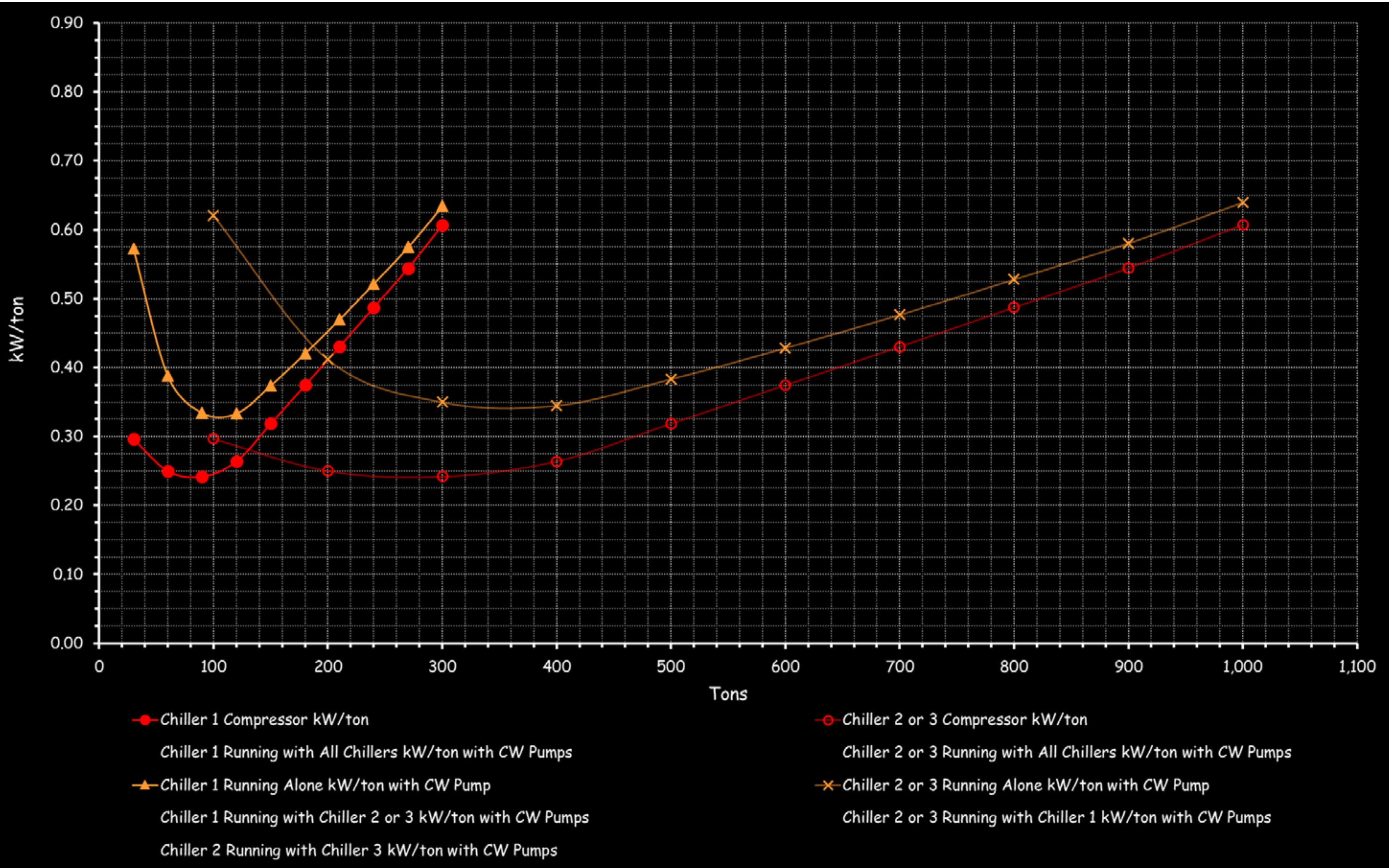
NOTES:

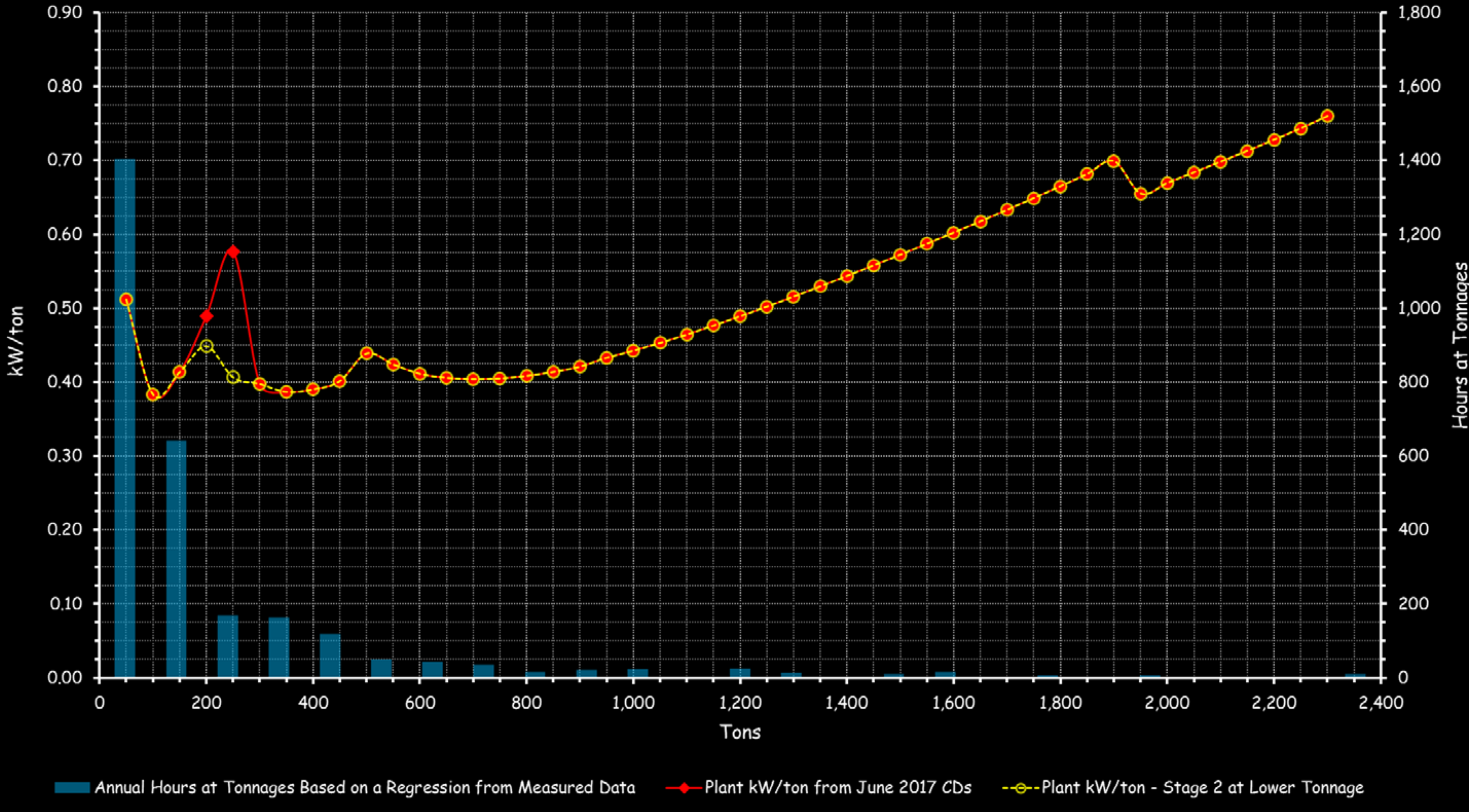
1. CAPACITIES BASED ON WATER.
2. REFER TO ELECTRICAL DRAWINGS FOR MOTOR STARTER AND DISCONNECT SWITCH.
3. PROVIDE WITH VIBRATION CUTOUT SWITCH.
4. PROVIDE WITH VARIABLE SPEED DRIVE AND FAN MOTORS.
5. PROVIDE WITH VORTEX ELIMINATOR AND BOTTOM PIPING CONNECTIONS.
6. PROVIDE STAINLESS STEEL PAN AND SUMP SWEEP PIPING/NOZZLES.
7. PROVIDE WITH REMOVABLE MOTOR LIFTING DAVIT PER 2–CELL TOWER, AND LIFTING DAVIT MOUNTING CHANNEL ON EACH TOWER CELL.


0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
kW/ton
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
Hours at Tonnages
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
2,200
2,400
Tons
Annual Hours at Tonnages Based on a Regression from Measured Data
Plant kW/ton from June 2017 CDs

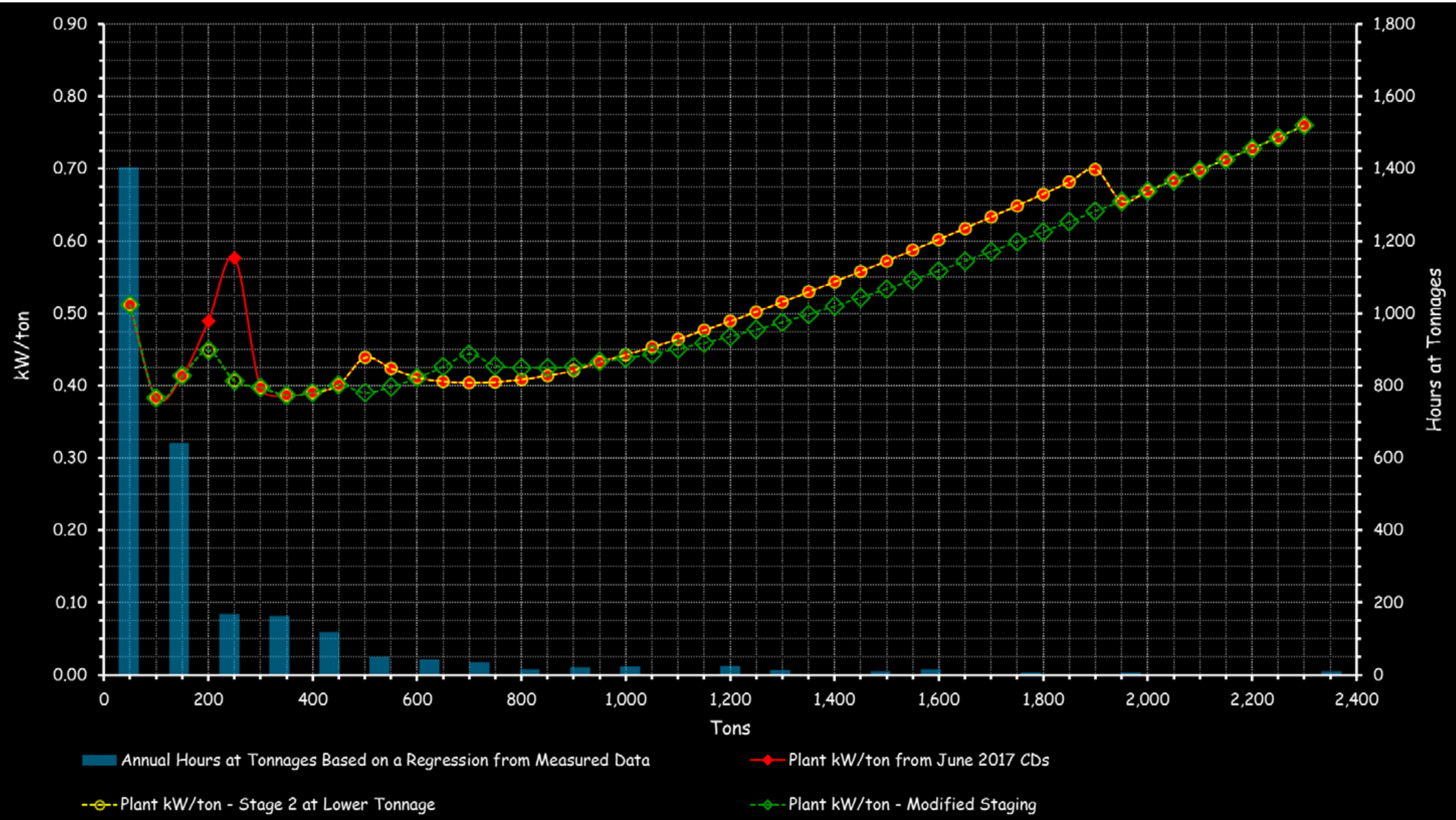


kW/ton
Hours at Tonnages
Tons
Plant kW/ton from June 2017 CDs
Compressor kW/ton
CW Pumps kW/Ton
Cooling Tower Fan kW/Ton
CHW Pump kW/Ton


0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
kW/ton
0
100
200
300
400
500
600
700
800
900
1,000
1,100
Tons
Chiller 1 Compressor kW/ton
Chiller 2 or 3 Compressor kW/ton
Chiller 1 Running with All Chillers kW/ton with CW Pumps
Chiller 2 or 3 Running with All Chillers kW/ton with CW Pumps
Chiller 1 Running Alone kW/ton with CW Pump
Chiller 2 or 3 Running Alone kW/ton with CW Pump
Chiller 1 Running with Chiller 2 or 3 kW/ton with CW Pumps
Chiller 2 or 3 Running with Chiller 1 kW/ton with CW Pumps
Chiller 2 Running with Chiller 3 kW/ton with CW Pumps



0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
kW/ton
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
Hours at Tonnages
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
2,200
2,400
Tons
Annual Hours at Tonnages Based on a Regression from Measured Data
Plant kW/ton from June 2017 CDs
Plant kW/ton - Stage 2 at Lower Tonnage



0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
kW/ton
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
Hours at Tonnages
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
2,200
2,400
Tons
Annual Hours at Tonnages Based on a Regression from Measured Data
Plant kW/ton from June 2017 CDs
Plant kW/ton - Stage 2 at Lower Tonnage
Plant kW/ton - Modified Staging

Bottom line

Com·mis·sion

kəˈmiSHən/Submit

Verb; Gerund or present participle: Commissioning

1. A process during which buildings are mentoring us about design

Operator training

The key to persistence of the benefits of commissioning

Empower your team

The bigger impacts of building commissioning

"We went to explore the Moon, and
in fact discovered the Earth."

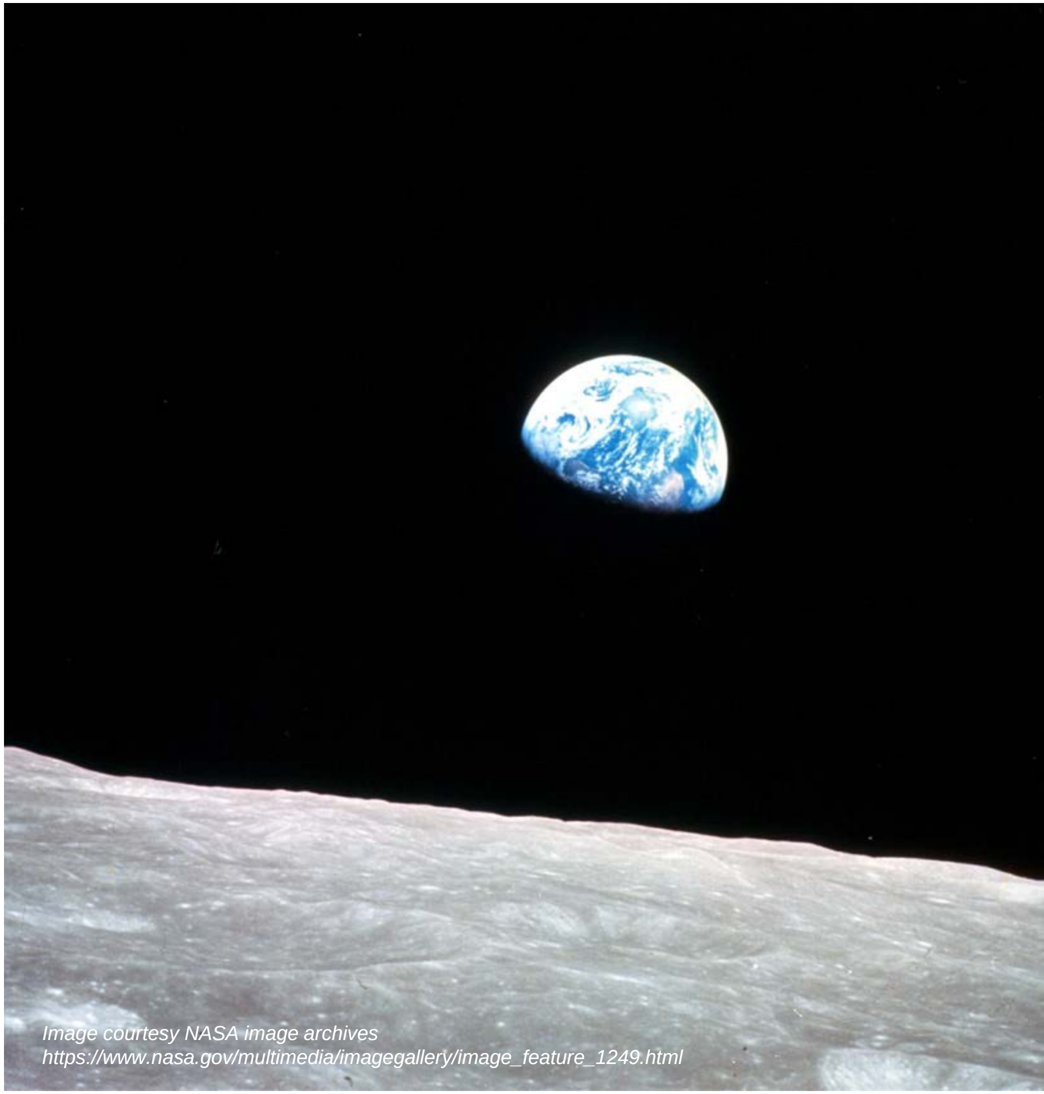
Gene Cernan

Apollo 17 Commander

Why this matters

In a highway service station
Over the month of June
Was a photograph of the earth
Taken coming back from the moon
And you couldn't see a city
On that marbled bowling ball
Or a forest or a highway
Or me here least of all

Joni Mitchell
Refuge of the Roads



“Looking back at Earth from a great distance. I really believe that if the political leaders of the world could see their planet from a distance of 100,000 miles their outlook could be fundamentally changed.”

- Michael Collins; CM Pilot, Apollo 11

“The earth must become as it appears; blue and white, not envious or envied … … Small, shiny, serene, blue and white, FRAGILE. .”

- Michael Collins; CM Pilot, Apollo 11

“We don’t inherit the world from our ancestors, we borrow it from our children.”

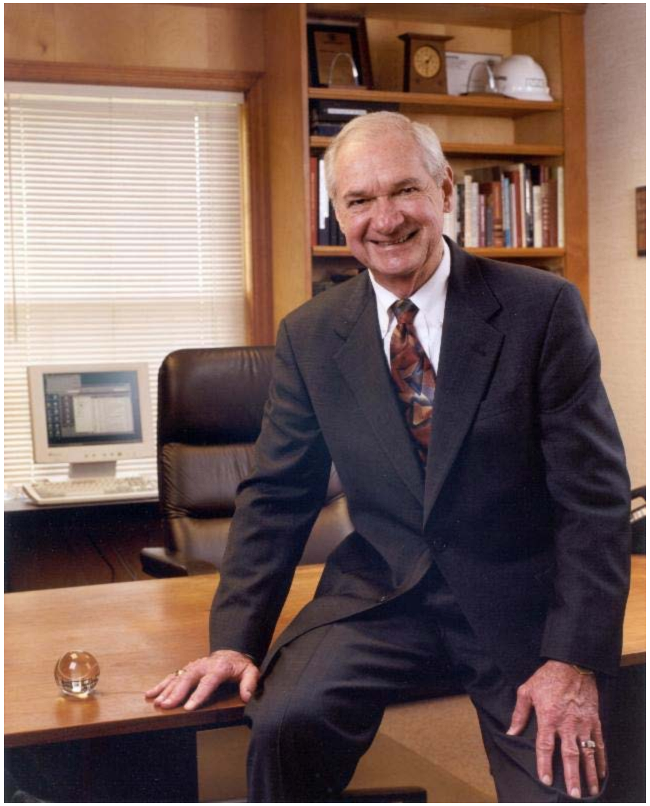
Unknown

Bill Coad's thoughts on the topic

"… that is to practice our profession with an emphasis upon our responsibility to protect the long-range interests of the society we serve and, specifically, to incorporate the ethics of energy conservation and environmental preservation in everything we do."

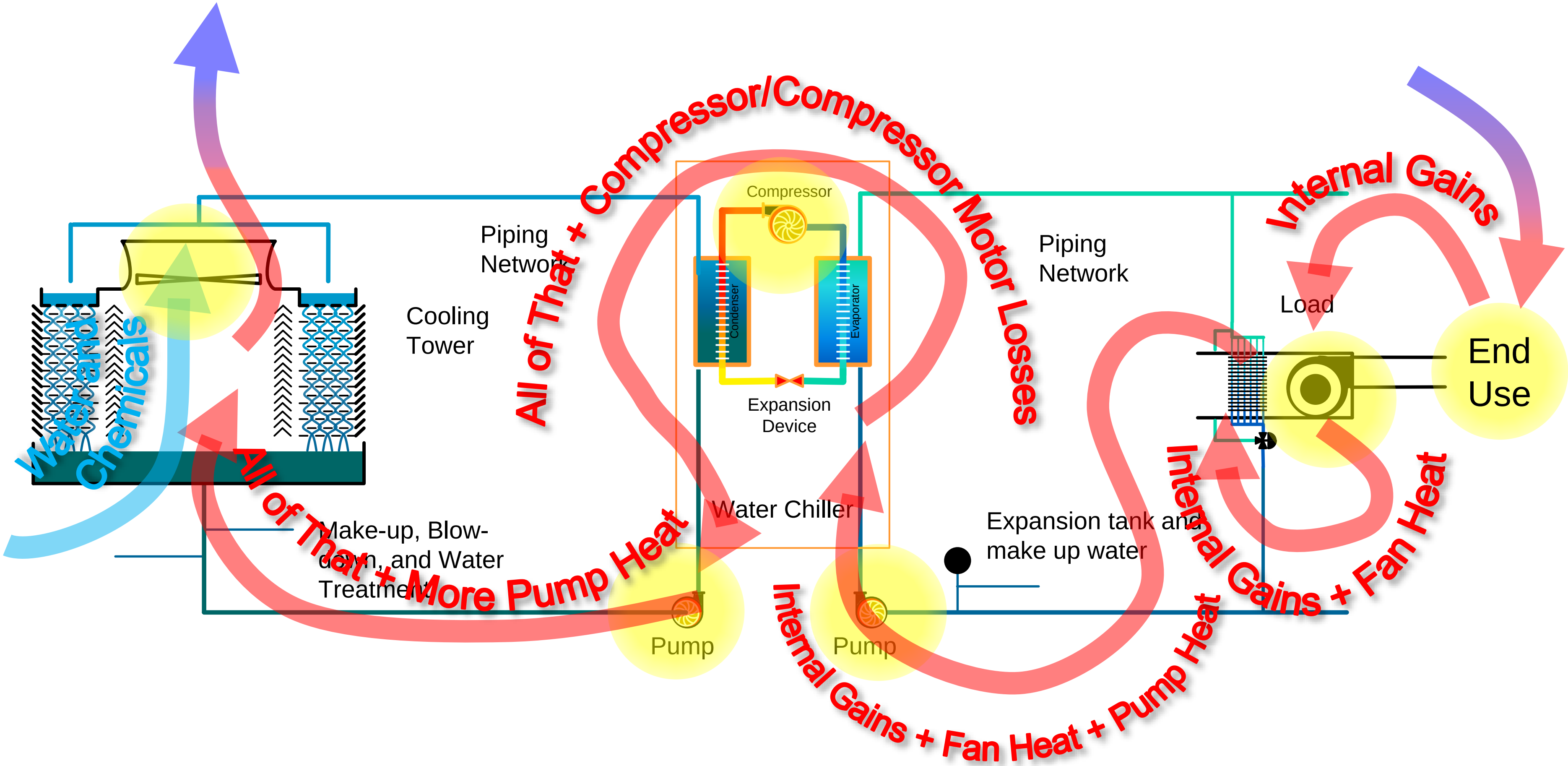
Energy Conservation is an Ethic

ASHRAE Journal, vol. 42, no. 7, p. 16-21

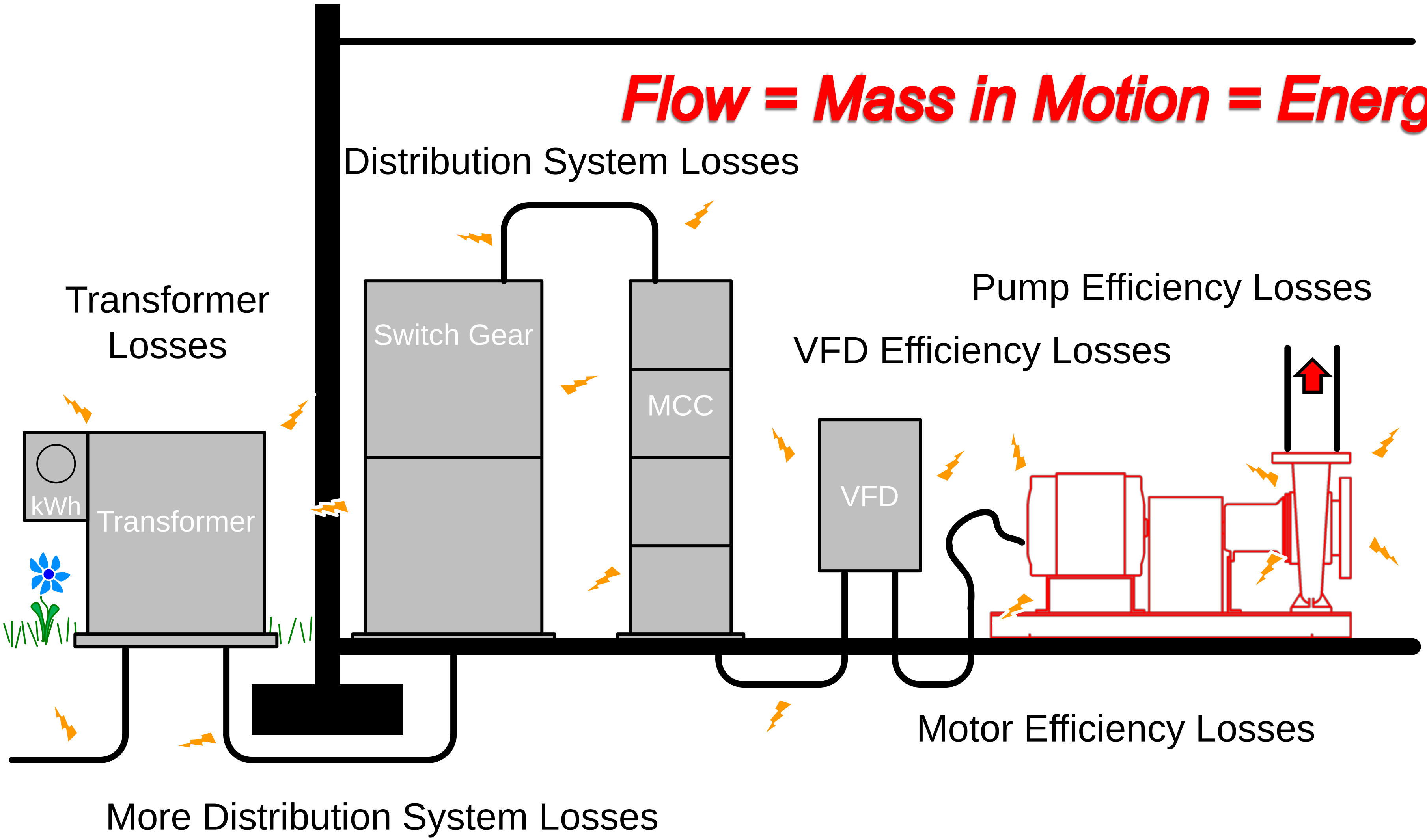


PDF available at http://www.av8rdas.com/bill-coads-writings.html

Applying the commissioning tool set can have ripple effects



Flow = Mass in Motion = Energy



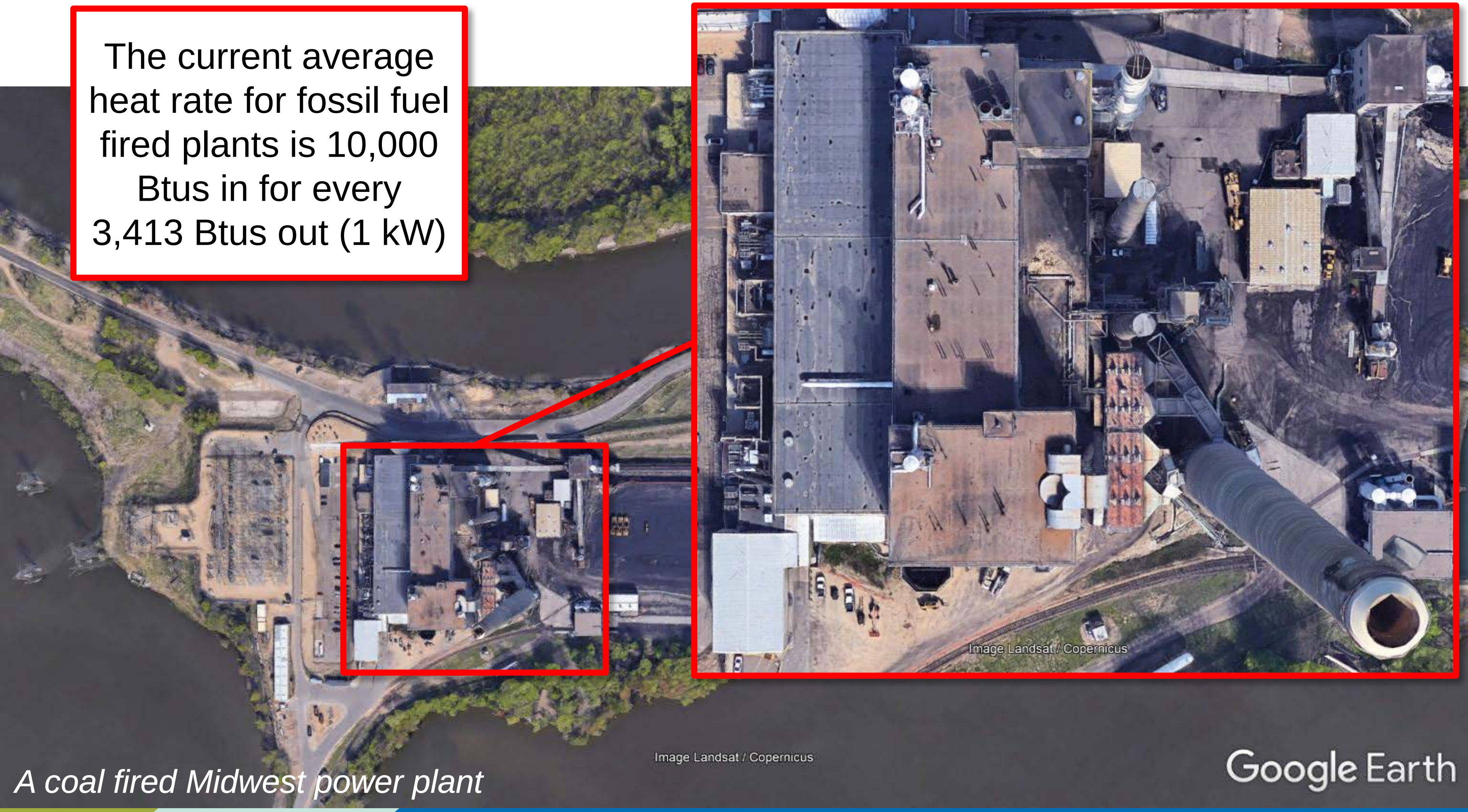
Transmission losses are significant

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

A coal fired Midwest power plant

Bottom line

Generating power consumes finite resources and impacts the environment

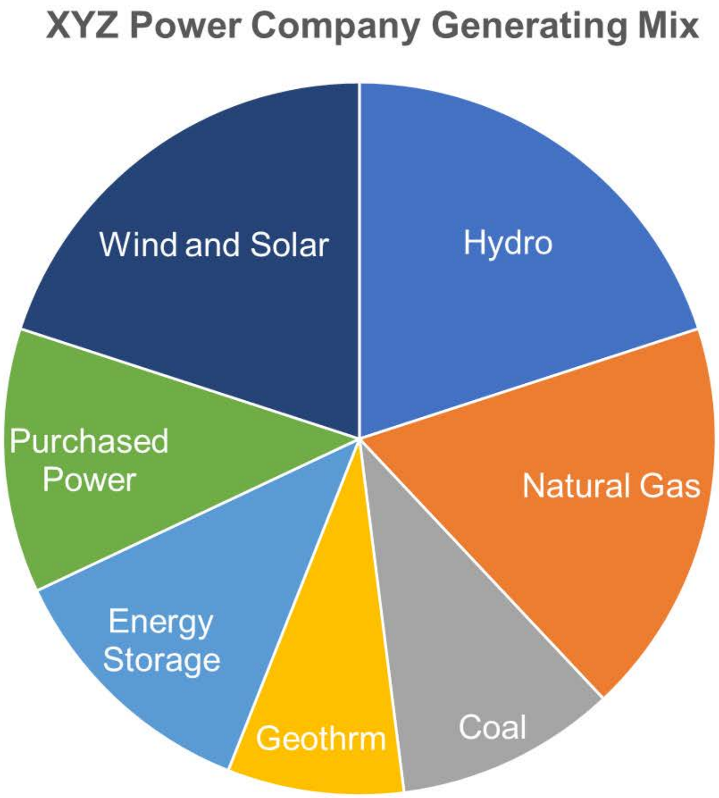
Reducing atmospheric impacts

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

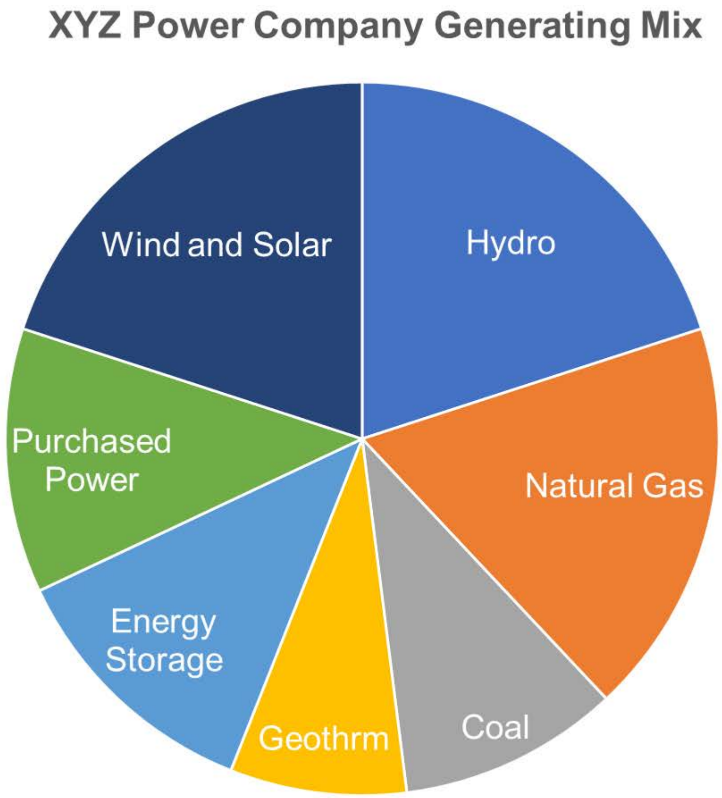
Moving away from carbon fuels is a common, long term goal for many utilities



Reducing atmospheric impacts

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

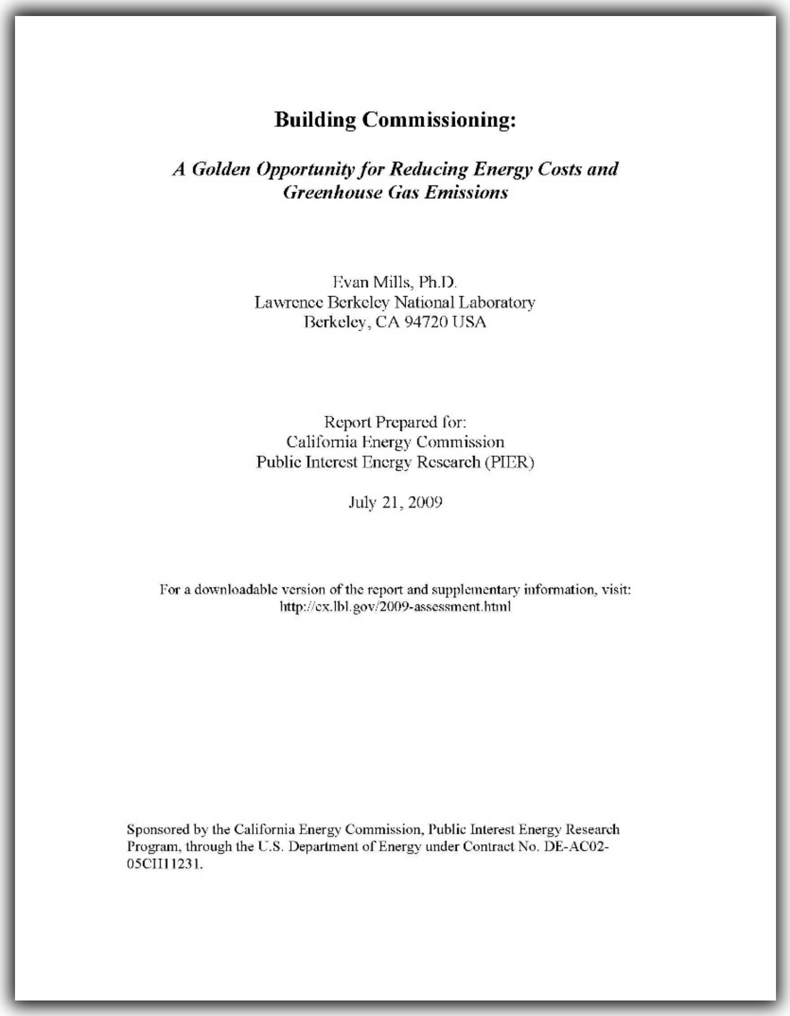
It's a win-win situation



Start to have your own impact

Survey your building inventory for big energy users.

- Read LBNLs report on the costs and benefits of commissioning at http://cx.lbl.gov/cost-benefit.html
- LBNL metrics indicate that the median savings from an EBCx process will be in the range of 16% of the annual energy cost



Building Commissioning:

A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions

Evan Mills, Ph.D.
Lawrence Berkeley National Laboratory
Berkeley, CA 94720 USA

Report Prepared for:
California Energy Commission
Public Interest Energy Research (PIER)

July 21, 2009

For a downloadable version of the report and supplementary information, visit:
http://cx.lbl.gov/2009-assessment.html

Sponsored by the California Energy Commission, Public Interest Energy Research Program, through the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

Try it out on your facility

Apply the commissioning tool set:

- Save resources
- Save dollars
- Treat the planet better

Learn more in the fall

- Attend Portland General Electric's Building Operation & Maintenance class on September 12, 2018 to learn more about how to do this and the benefits

Key takeaways

- Commissioning is a technical process and the people executing it need strong technical skills
- Commissioning is not a one time event; rather, it's a holistic, integrated way of operating a facility through its entire life cycle
- There is a lot going on behind the scenes in a modern building
- The commissioning toolset helps us understand what is going on, eliminate waste, and optimize performance
- Facility operators play a crucial role in the process and should be treated that way
- Commissioning's benefits reach beyond the site boundary

Commissioning is fun!

Facility Dynamics Engineering

Questions?

Thank you for participating!

www.FacilityDynamics.com

Blog - https://av8rdas.wordpress.com/

Commissioning Resource Website - http://www.av8rdas.com/

Give us your feedback

Please complete the session evaluation.

If you would like a copy of the slides, give us your business card as you leave.