Electric LEAGUE of the pacific northwest

Facility Dynamics ENGINEERING

Presented By:

David Sellers; Facility Dynamics Engineering

Senior Engineer

October 23, 2019

Our Agenda for Today

1. Commissioning processes and skills
2. Budgeting and Staffing
   - Existing Building Commissioning
   - New Construction Commissioning
3. A mechanical engineering perspective on electrical systems
4. Introduction to working with SketchUp
5. Lunch
6. Fred Hutchinson mechanical rooms guided tour
7. Using SketchUp to learn about building systems and how to scope them for indicators of opportunity

Our Agenda for Tomorrow

1. Investigating and developing Existing Building Commissioning (EBCx) findings
2. Field exercises
   - Working with pumps
   - Variable speed drive application considerations
3. Implementing improvements
4. Testing and verifying improvements
5. Why this all matters in the bigger picture

Let’s Get to Know Each Other

What’s your name?

Where are you from?

Who do you work for?

A Bit About Me

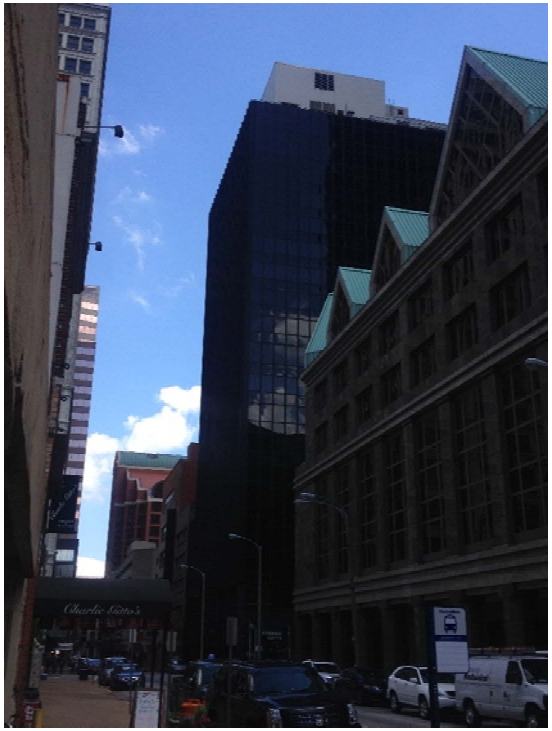
A Bit About Me

I intended to be an aircraft maintenance engineer

How many of you are doing what you went to school to learn to do?

I’m Doing Something Totally Different

I’m Doing Something Totally Different



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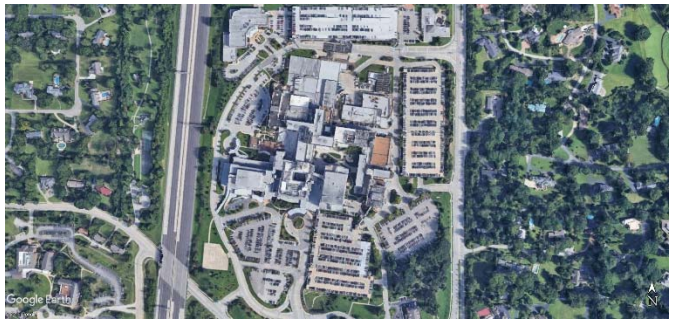

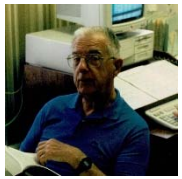

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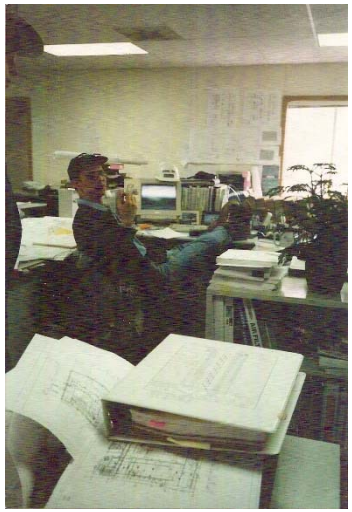


Hillsboro Flying Club
65 years, Since 1954...

I’m Doing Something Totally Different

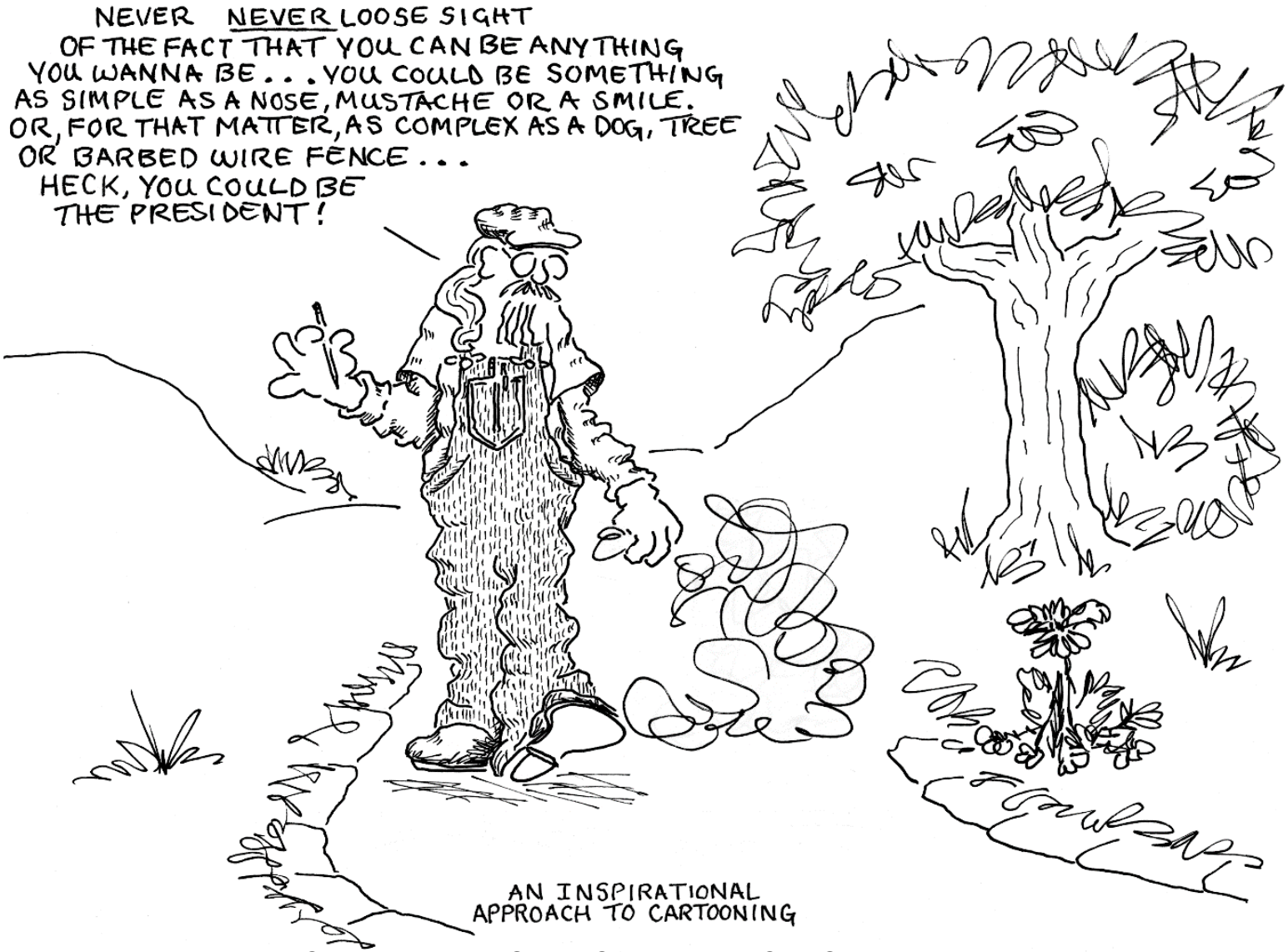
I’m Doing Something Totally Different

Facility Dynamics
ENGINEERING

I’m Doing Something Totally Different

(Go to https://tinyurl.com/PVequalsmRT for more pictures and videos from the balloon flight)

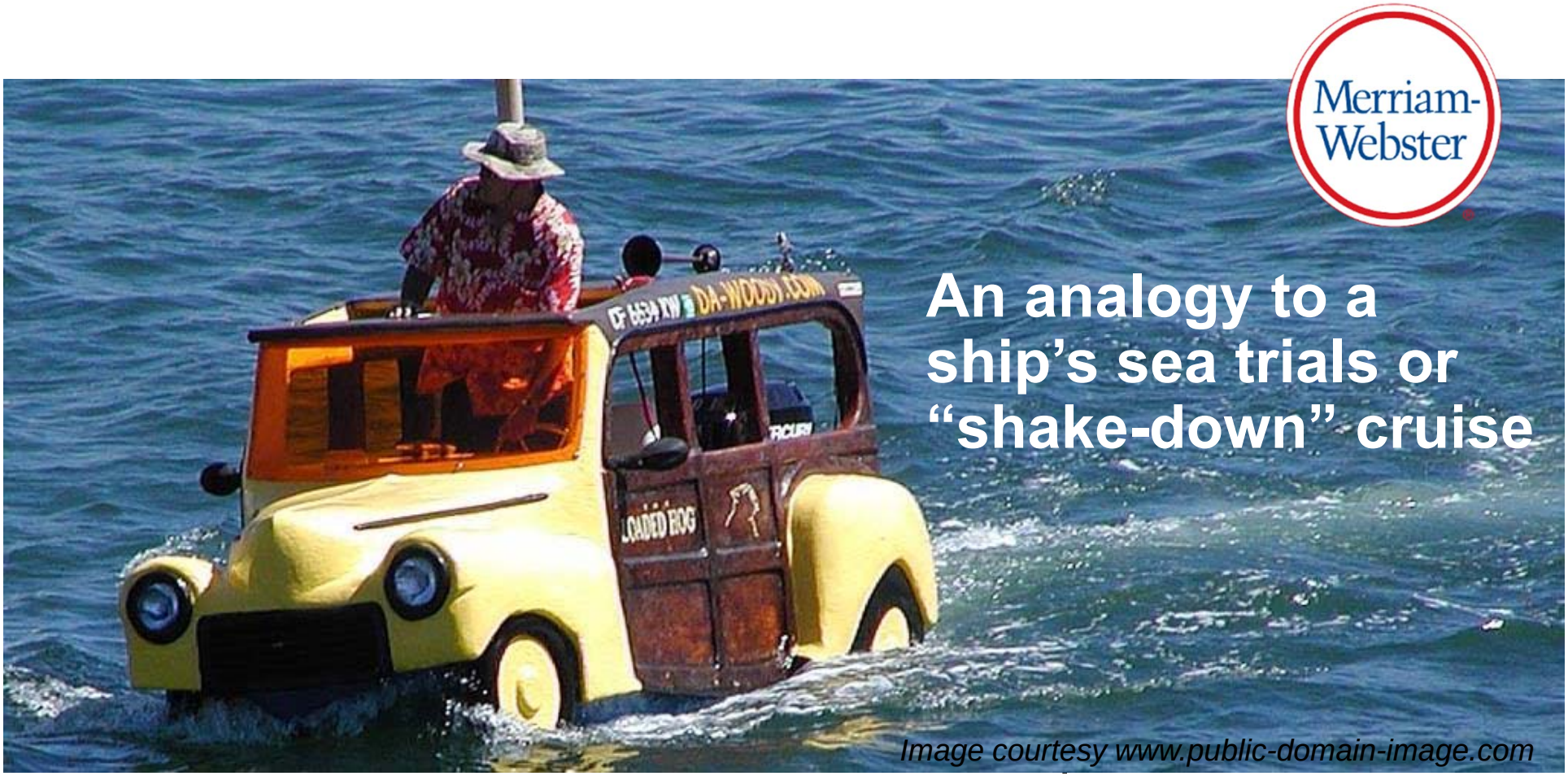
You Can Too


NEVER NEVER LOOSE SIGHT OF THE FACT THAT YOU CAN BE ANYTHING YOU WANNA BE . . . YOU COULD BE SOMETHING AS SIMPLE AS A NOSE, MUSTACHE OR A SMILE. OR, FOR THAT MATTER, AS COMPLEX AS A DOG, TREE OR BARBED WIRE FENCE . . . HECK, YOU COULD BE THE PRESIDENT!
AN INSPIRATIONAL APPROACH TO CARTOONING

I've Had Great Mentors Along the Way

Commissioning

Where the Term Comes Rrom



3 : to put (a ship) in commission

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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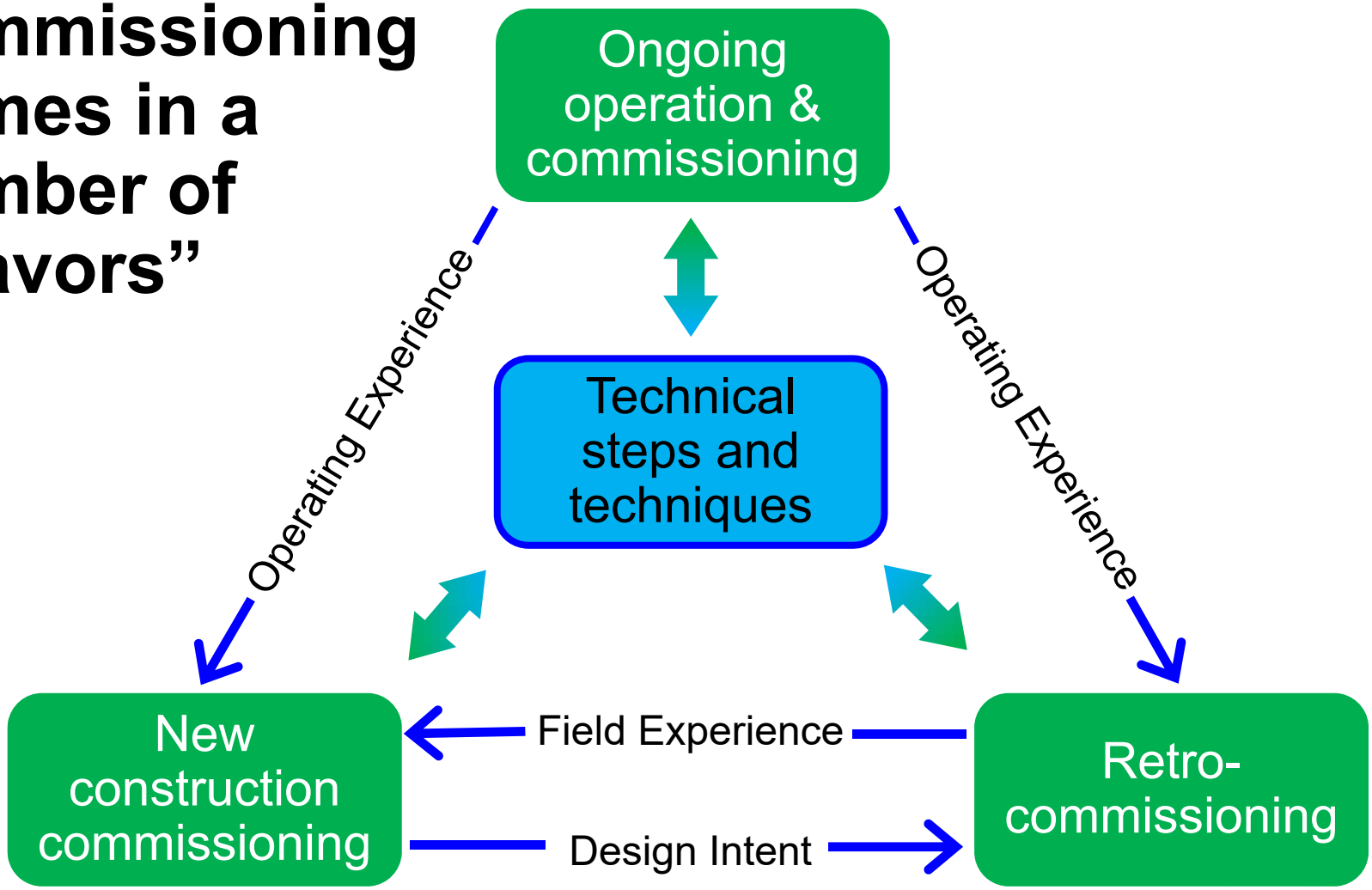
Commissioning Comes in a Number of "Flavors"



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)

Why Do We Install Building Systems

Building Systems Help Us Control the Built Environment

© Brother Placid Sellers; Saint Vincent Archabbey, Latrobe, Pennsylvania; Used with permission

- Keep it clean
- Keep it comfortable
- Keep it safe
- Keep it productive

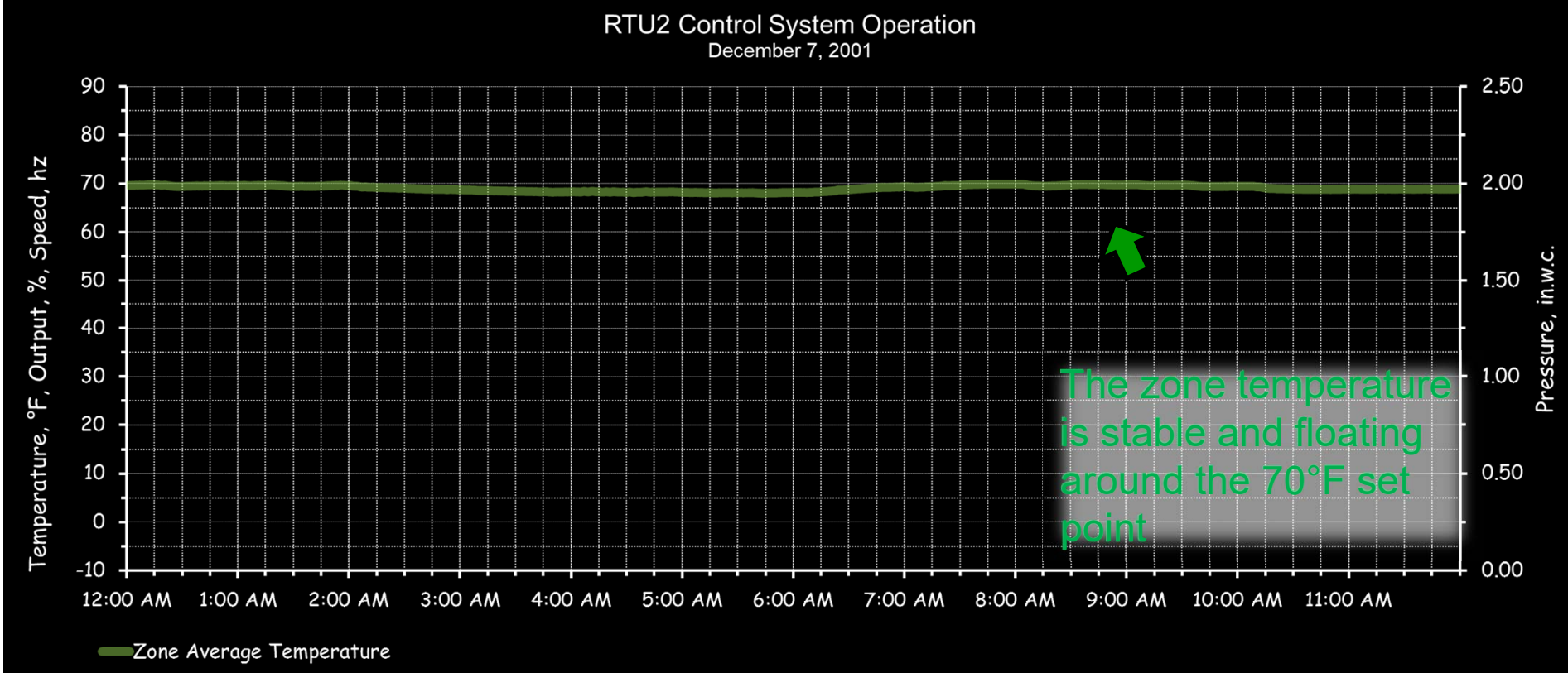
Why Do We Need to Commission Building Systems

We May Not Fully Comprehend the Situation

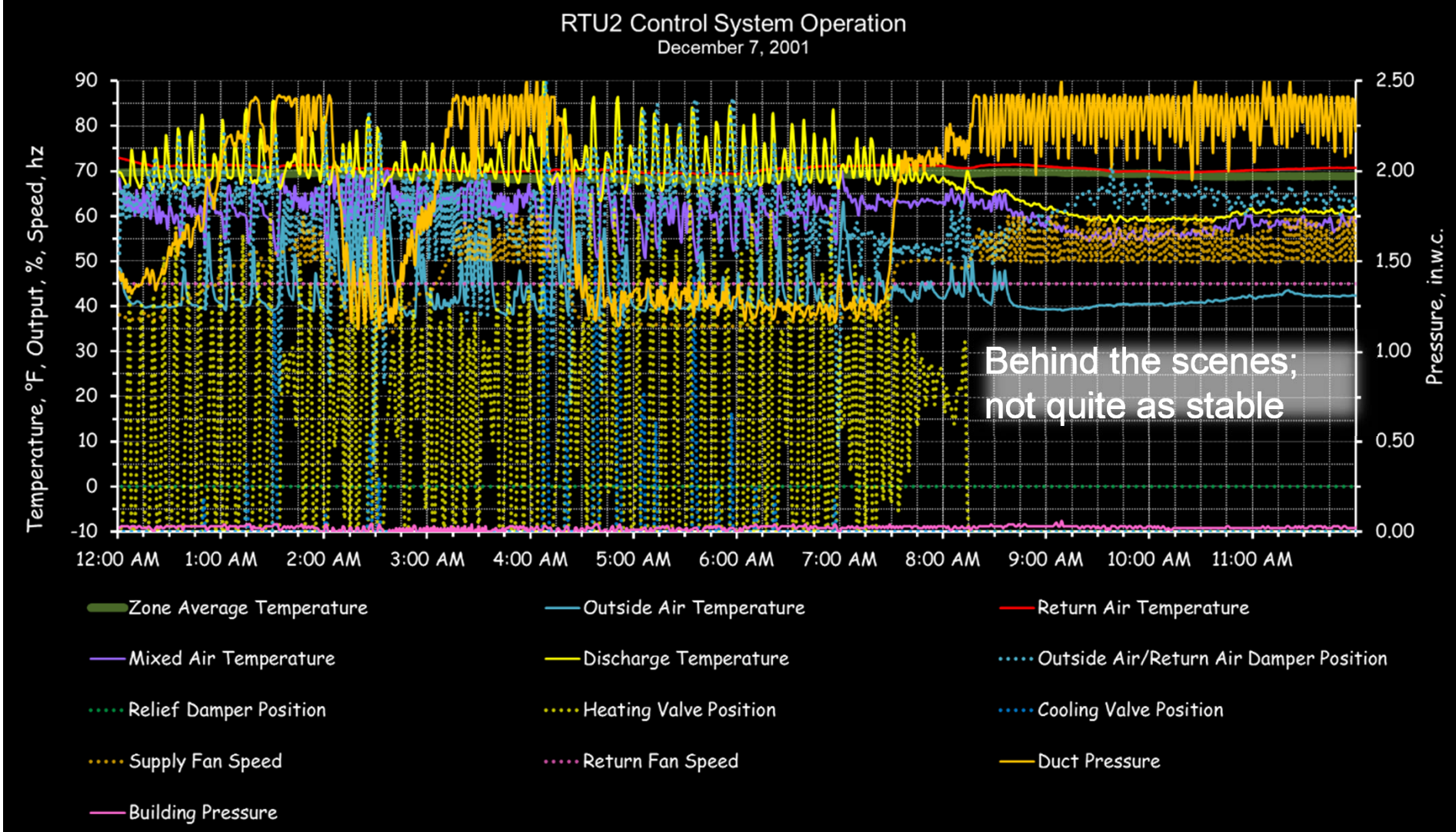
"… If you are piloting an untested vehicle on it's first test flight and that vehicle contains more propellant than was ever placed on a launch pad before and the vehicle was assembled by the low bidder and you aren't a little nervous, then you don't fully comprehend the situation"

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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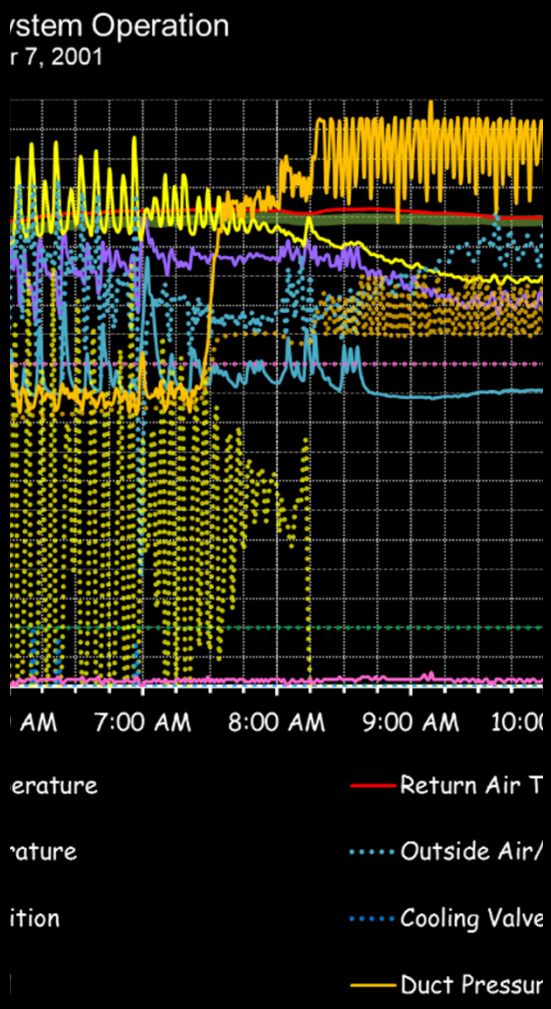

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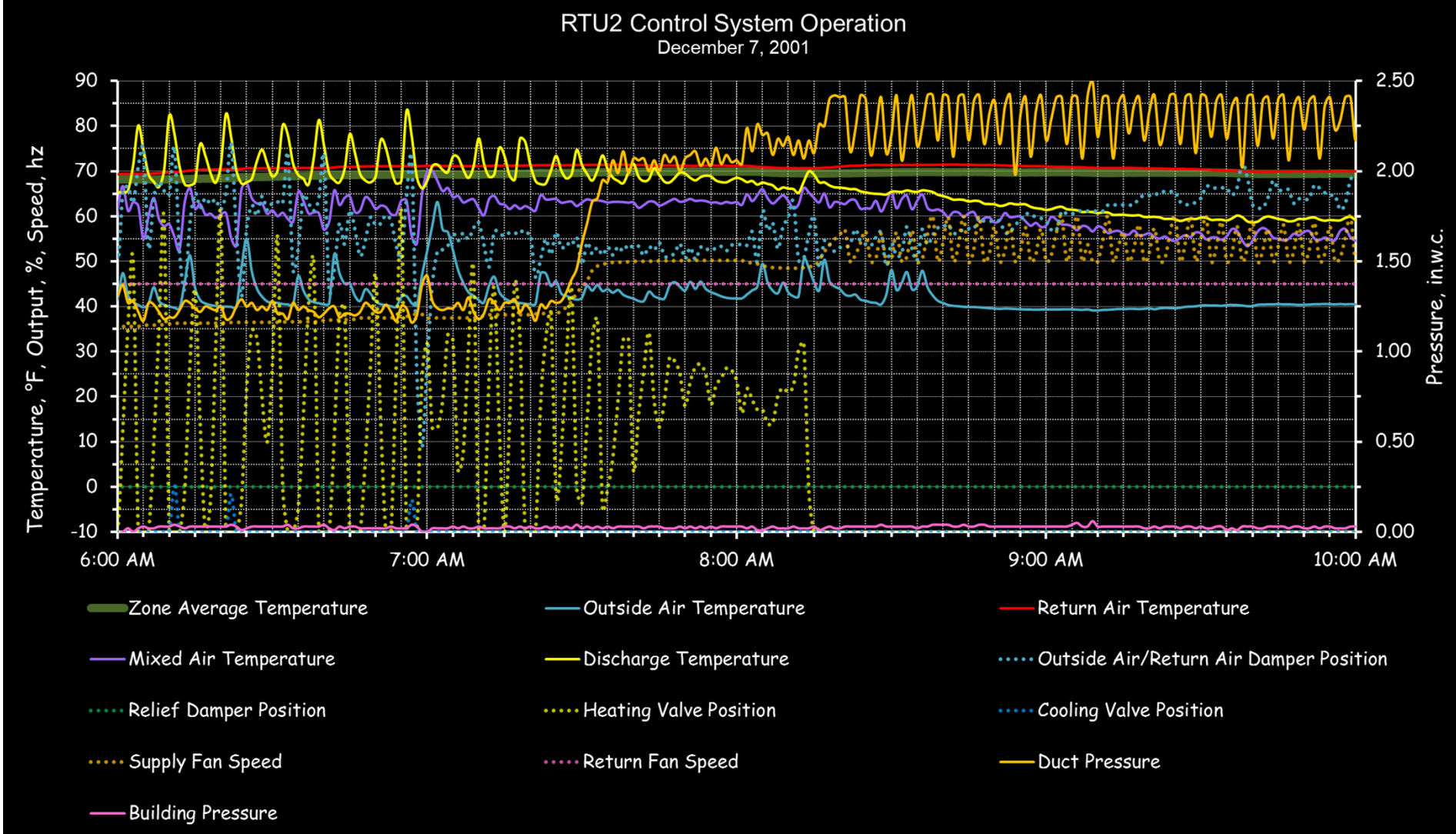

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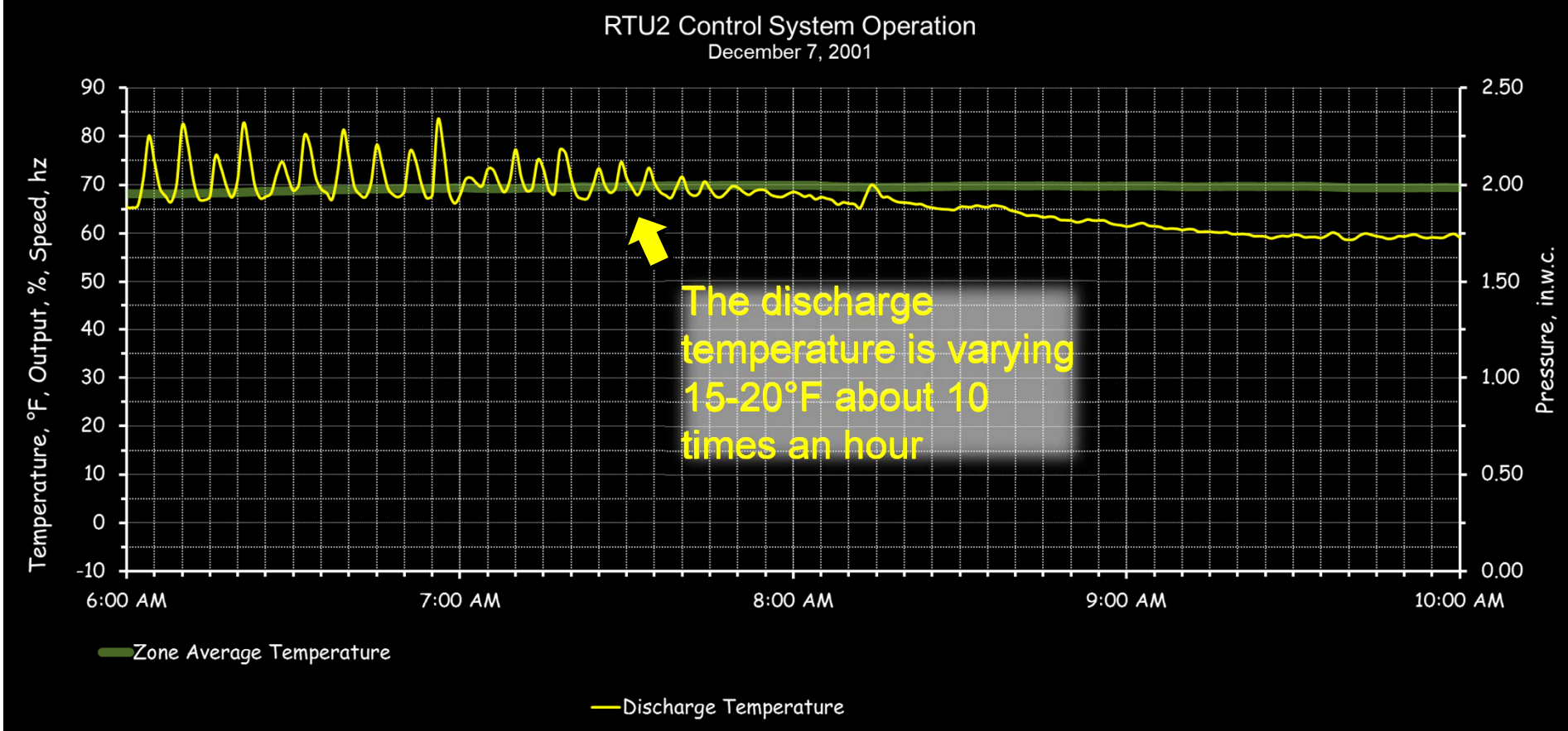

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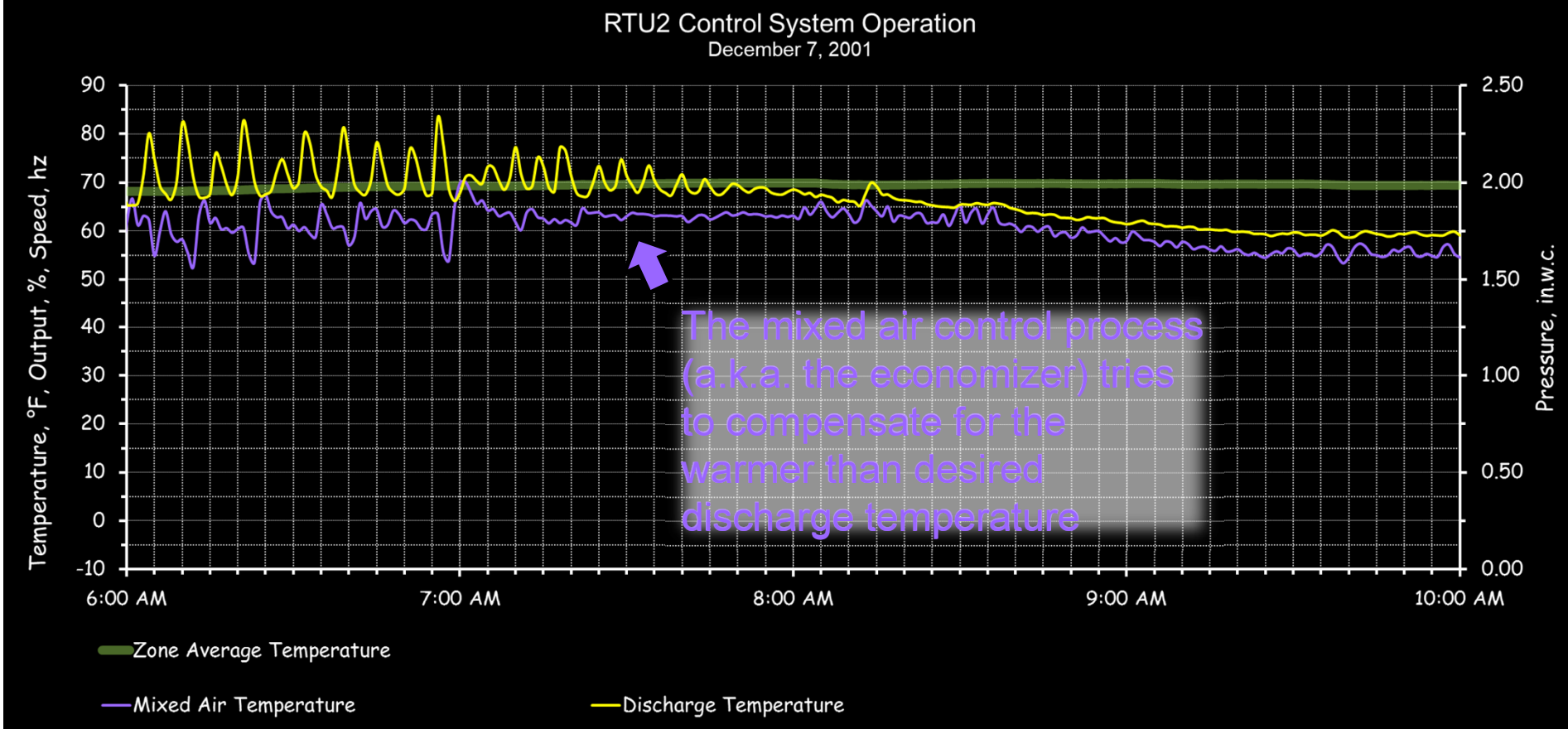

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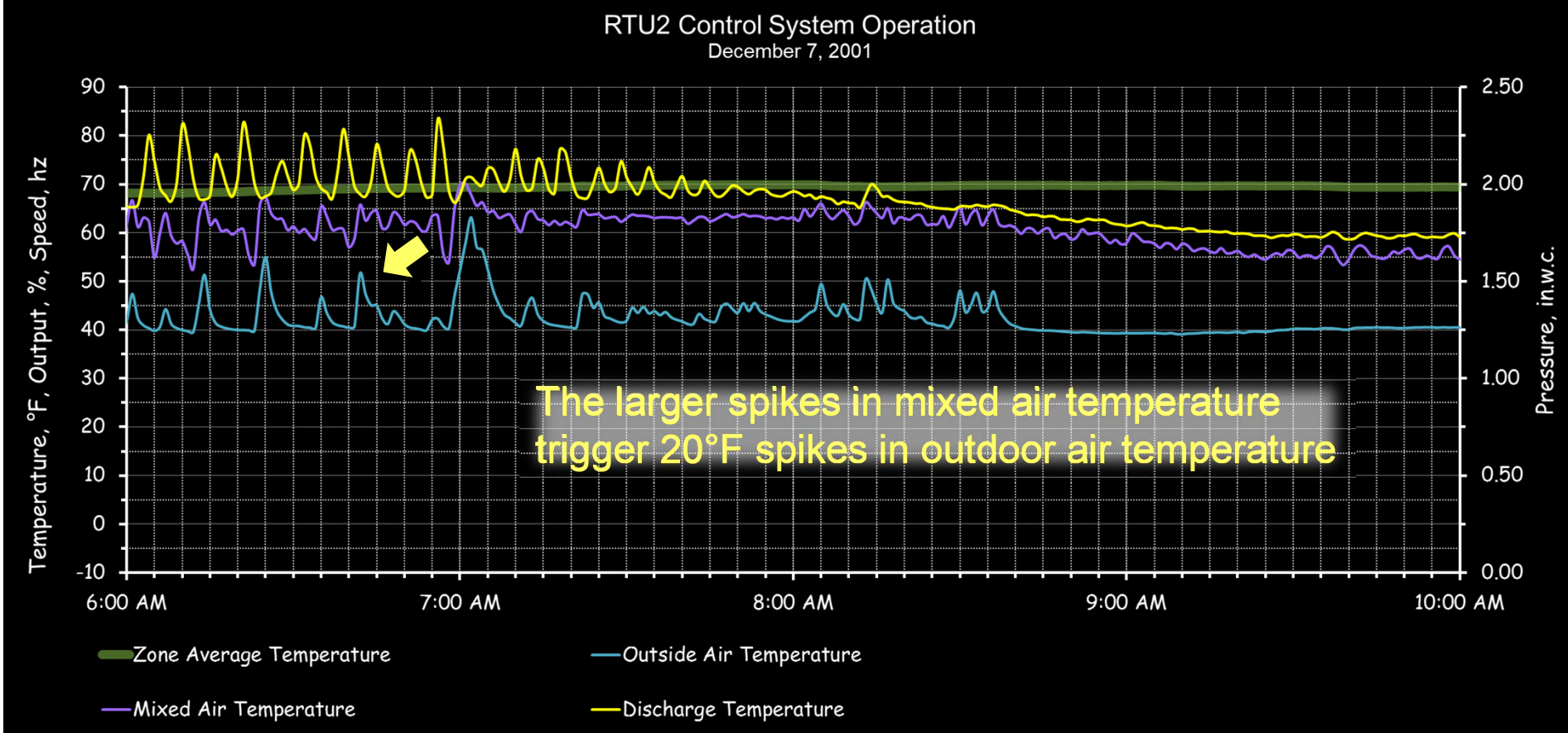

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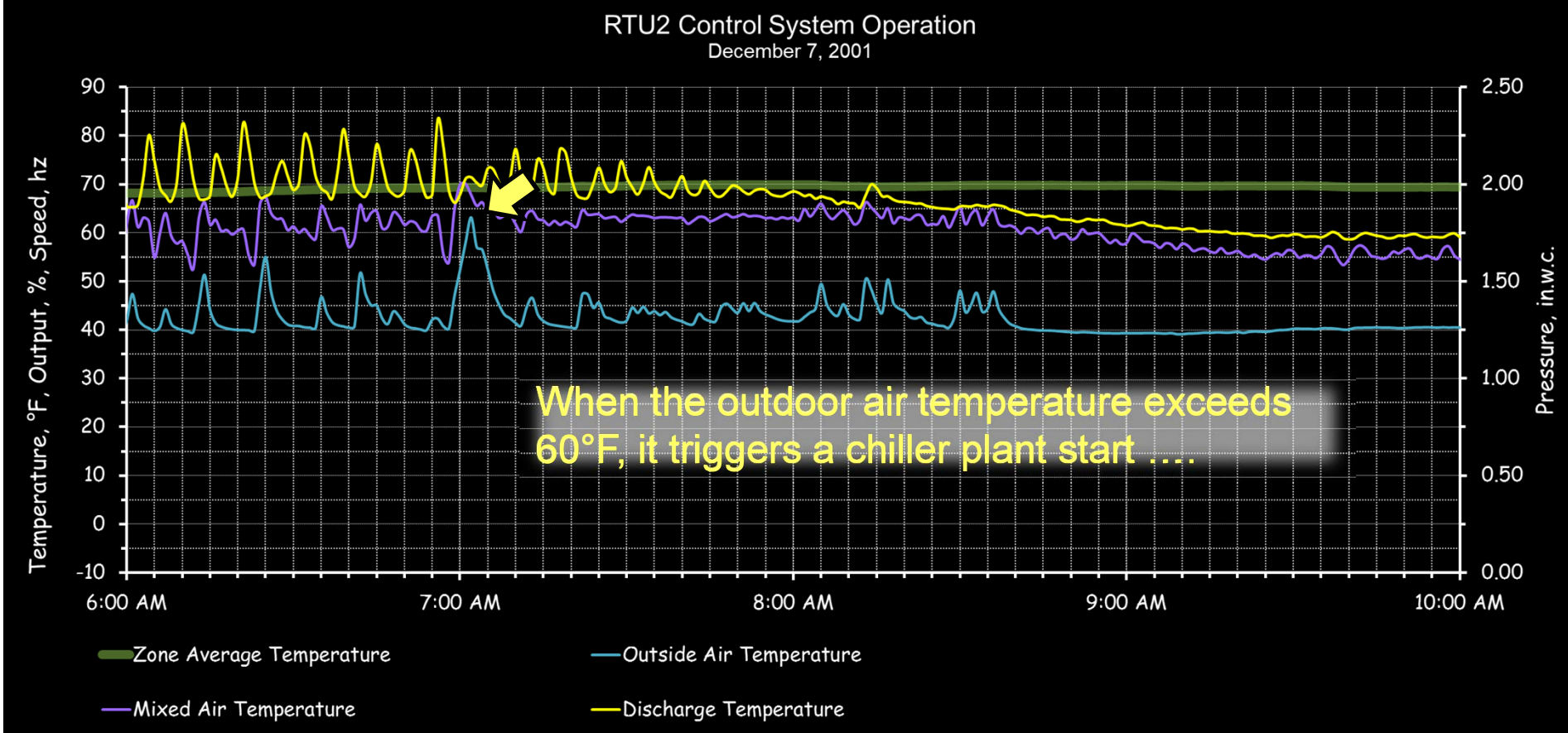

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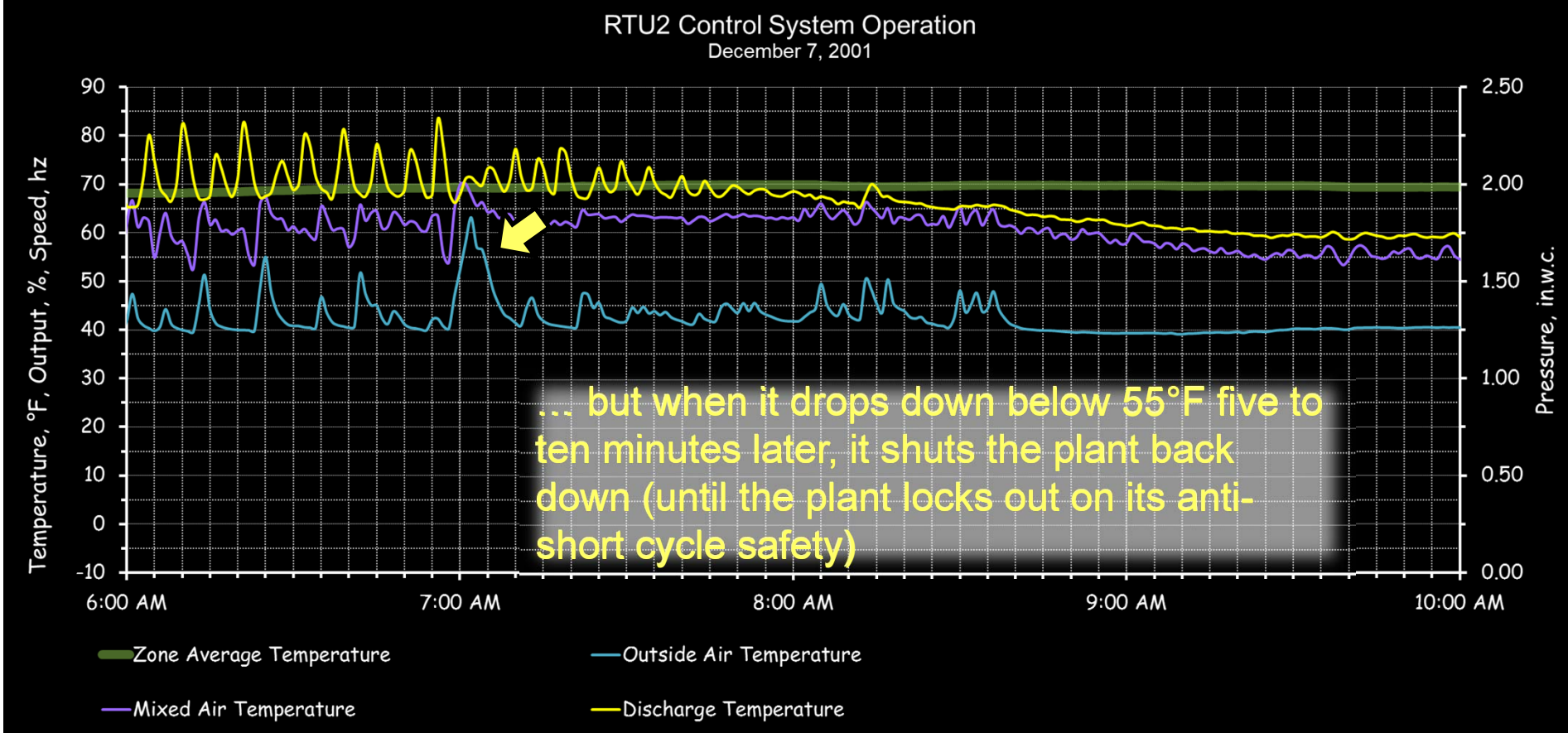
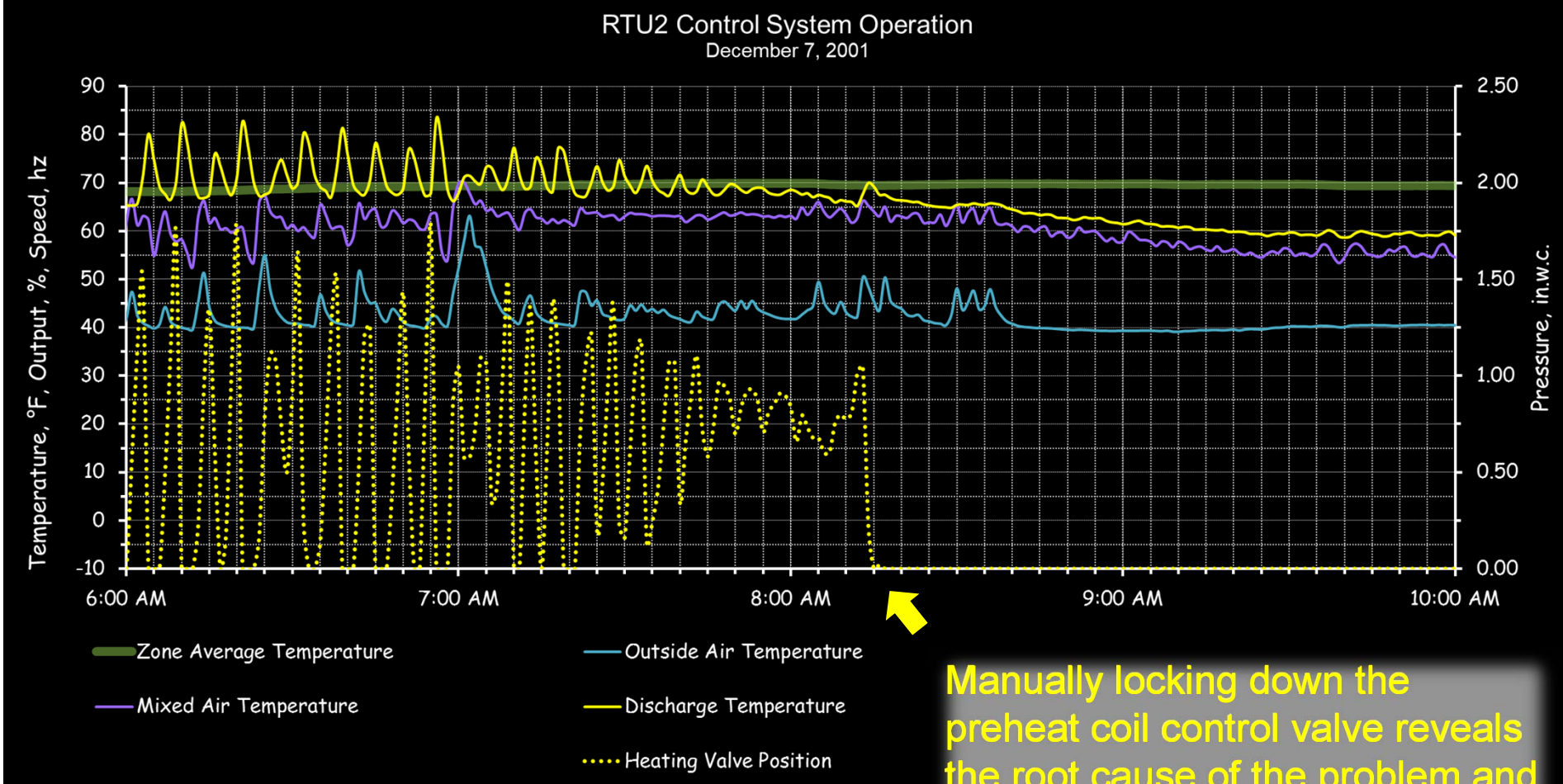


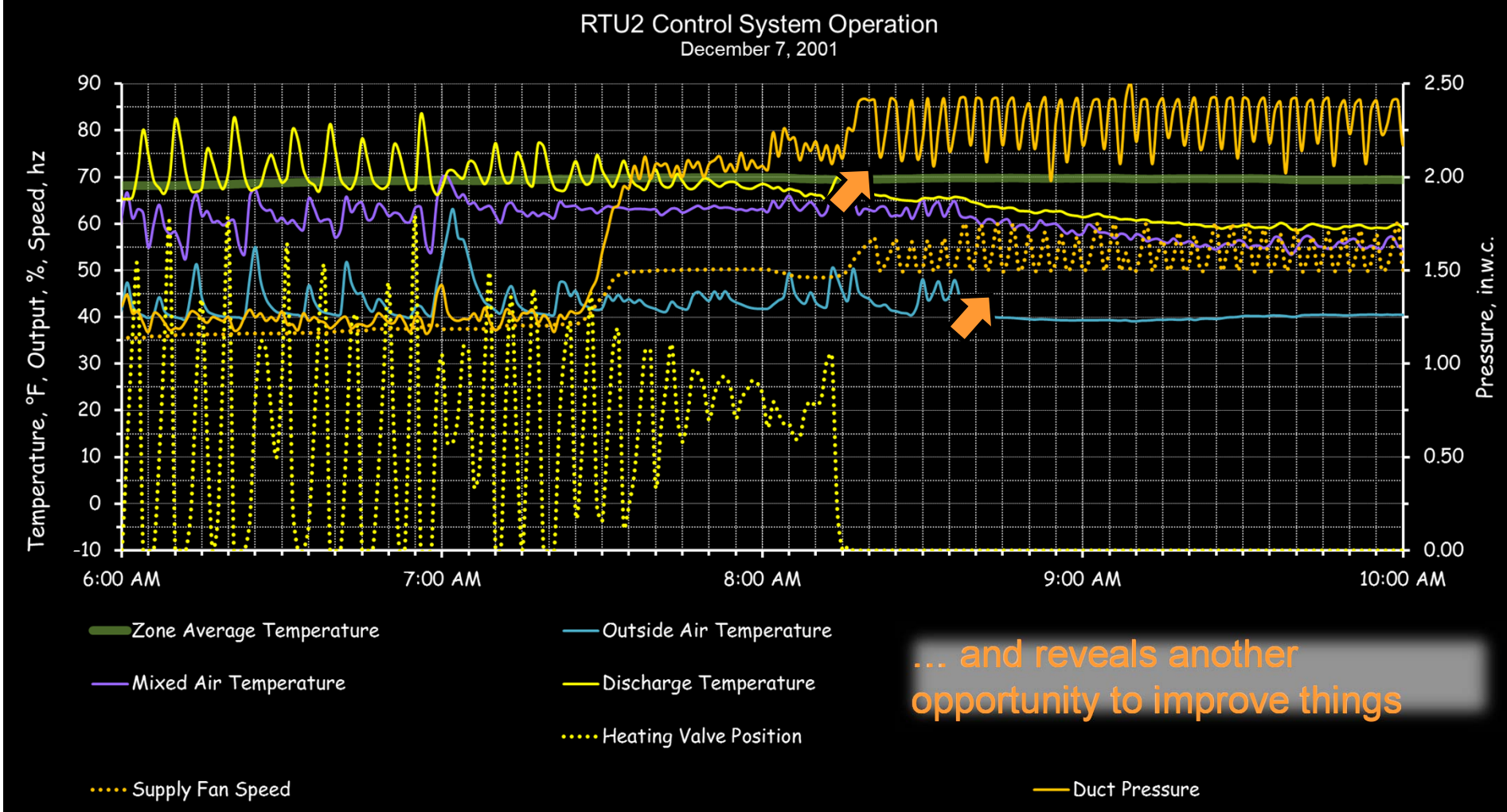
… but when it drops down below 55°F five to ten minutes later, it shuts the plant back down (until the plant locks out on its anti-short cycle safety)

… and HVAC can be Insidious



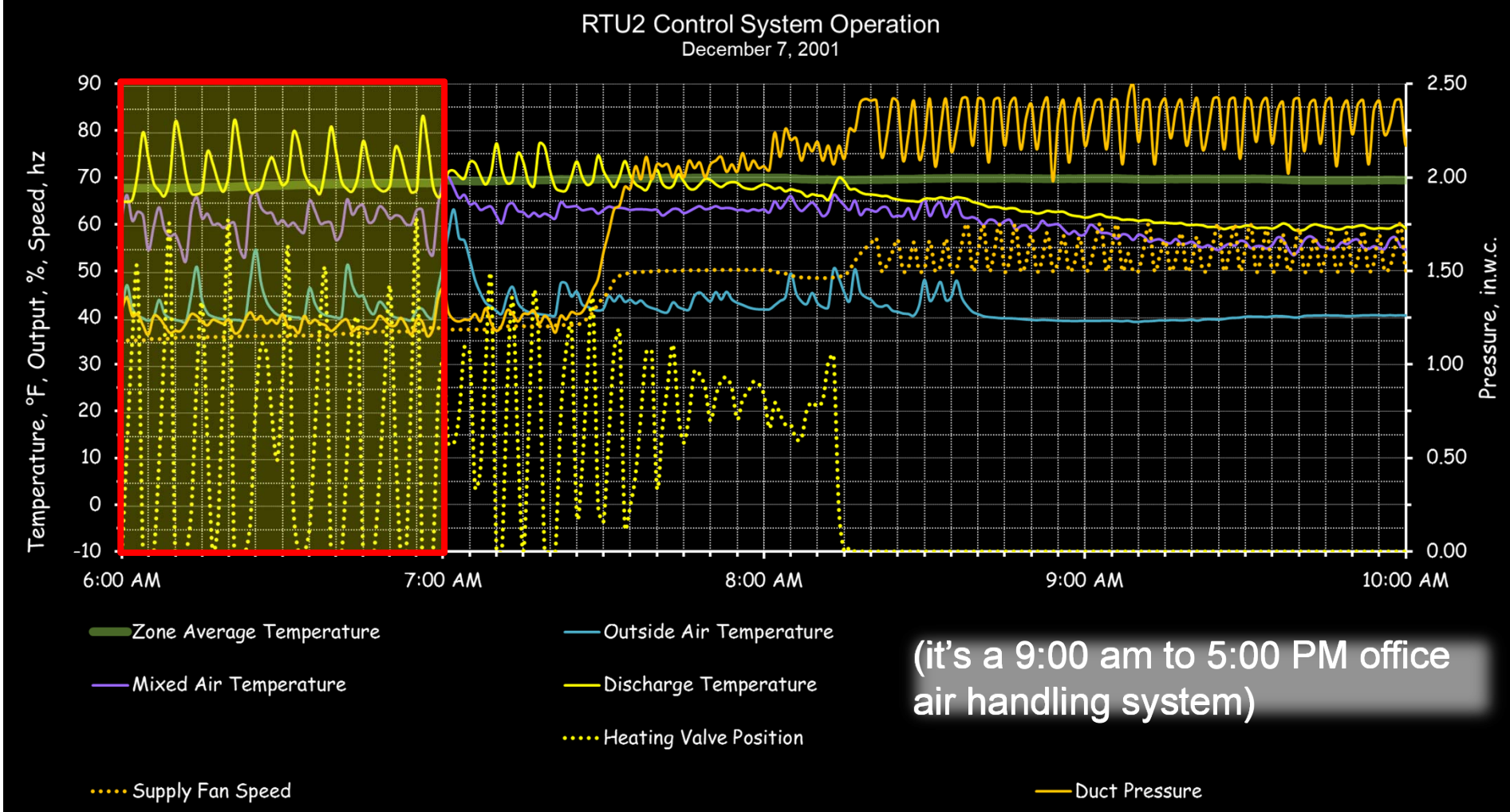
Manually locking down the preheat coil control valve reveals the root cause of the problem and how to solve it …

… and HVAC can be Insidious



… and reveals another opportunity to improve things

And Let's Not Miss the Obvious



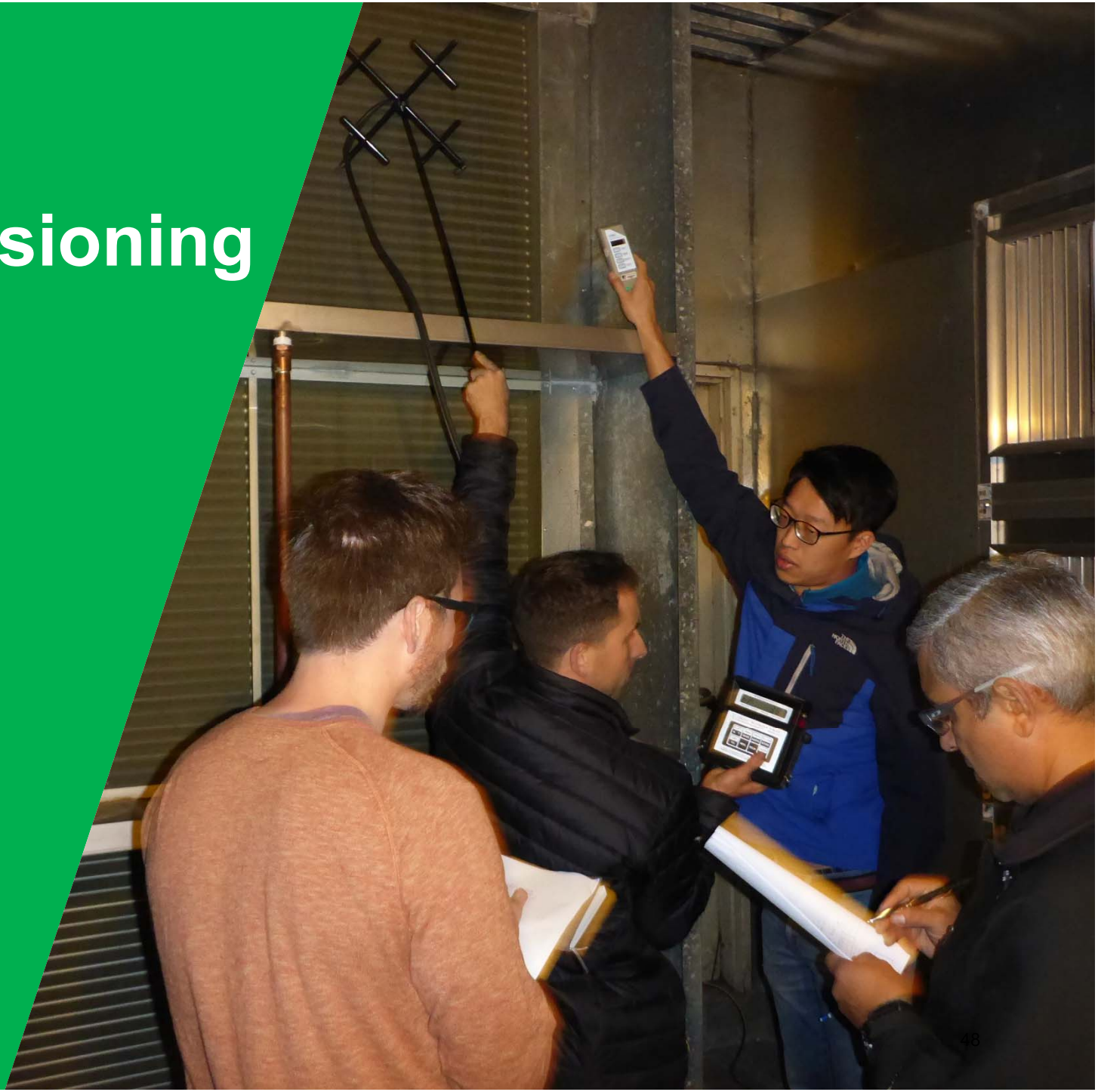
(it's a 9:00 am to 5:00 PM office air handling system)

Bottom Lines

The commissioning process can:

1. Ensure that the facility is clean, safe, comfortable and productive
2. Optimize and improve performance
3. Optimize and reduce resource consumption
4. Minimize wear, tear, and maintenance requirements
5. Be a lot of fun

The Commissioning Skill Set



Key EBCx skills

1. Be able to benchmark and perform utility analysis
2. Be able to scope a facility
3. Be familiar with fundamental principles and building systems
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. Be familiar with implementation strategies and techniques

Key EBCx skills

1. Saturated systems
2. Loads, psychrometrics and envelopes
3. Centrifugal machines
4. Refrigeration and cooling equipment
5. Heating equipment
6. Piping systems
7. Variable flow water systems
8. Duct systems
9. Air and water side economizers
10. Make up air systems and exhaust systems
11. Variable air volume systems
12. Control systems
13. Electrical systems
14. Life safety systems

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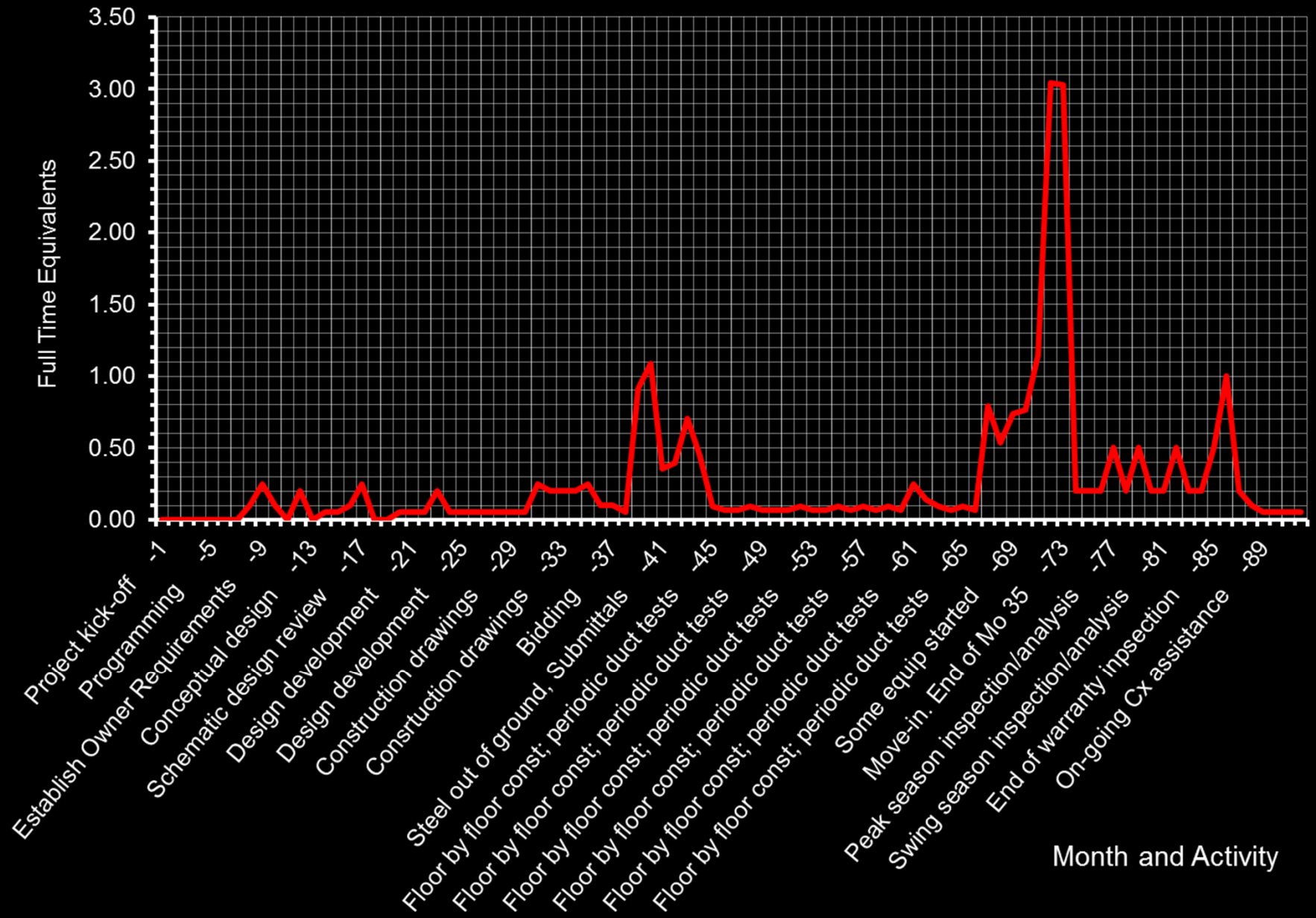
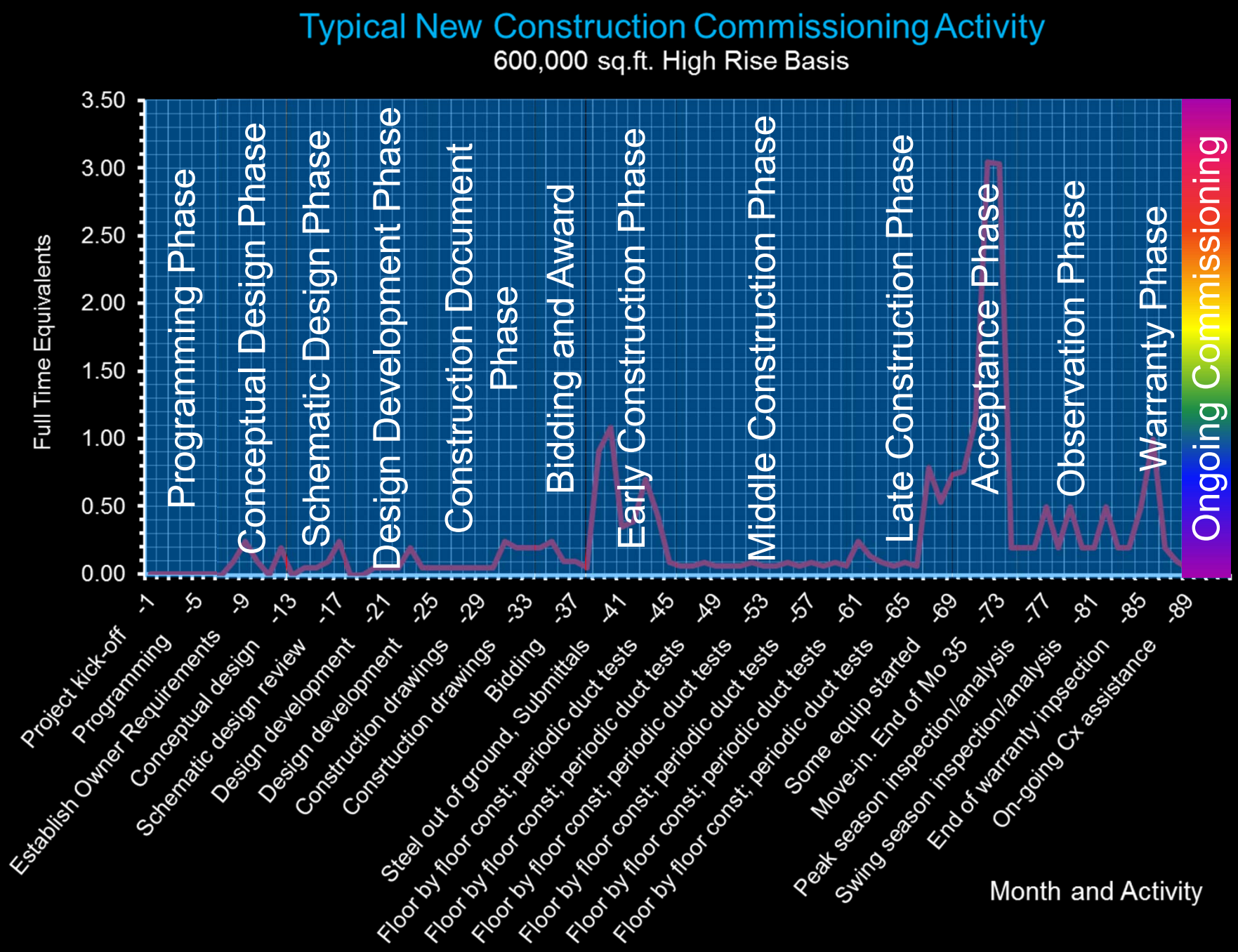
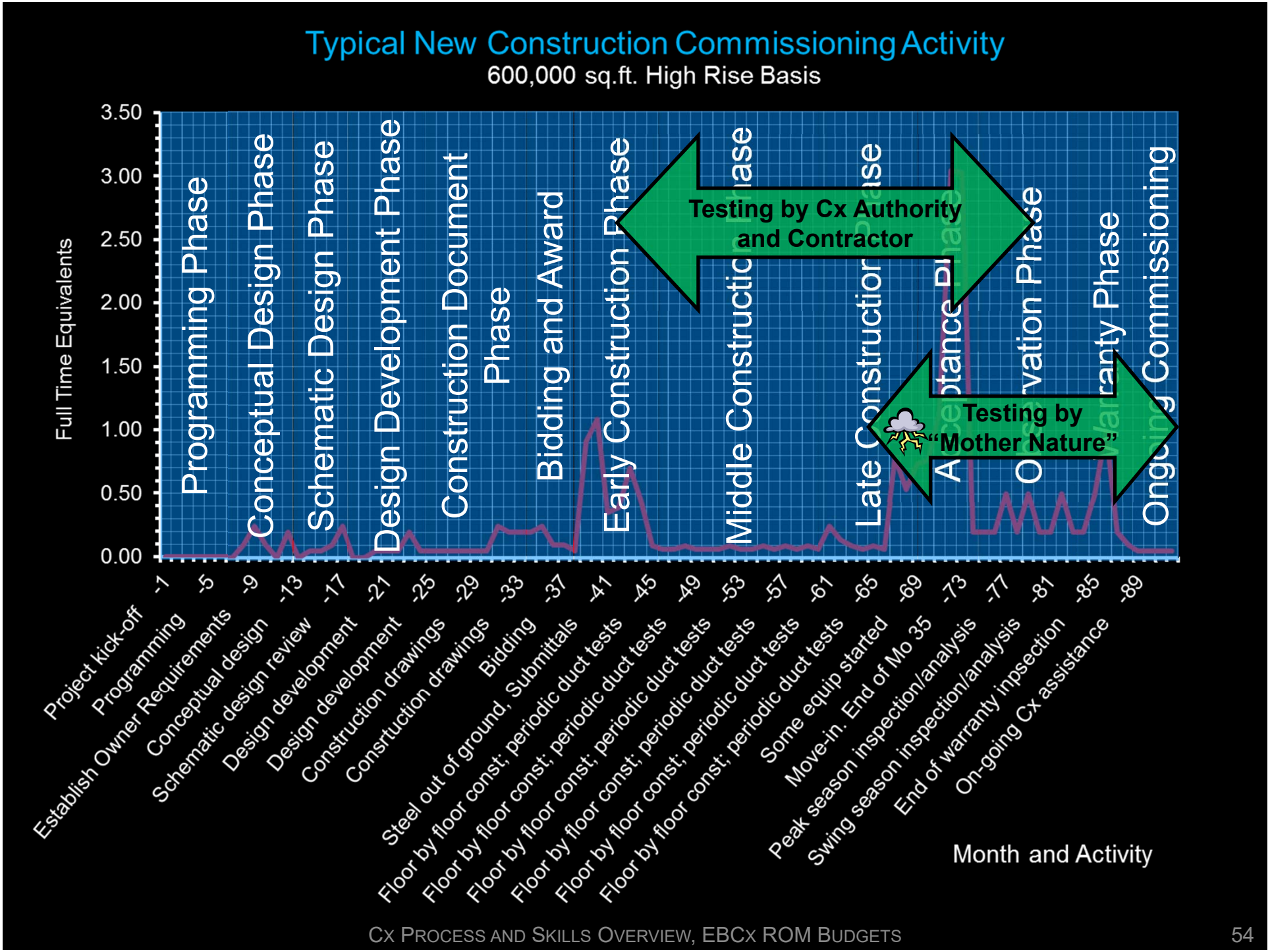
Steps in the New Construction Commissioning Process

Typical New Construction Commissioning Activity

600,000 sq.ft. High Rise Basis




Typical New Construction Commissioning Activity
600,000 sq.ft. High Rise Basis
Full Time Equivalents
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Programming Phase
Conceptual Design Phase
Schematic Design Phase
Design Development Phase
Construction Document Phase
Bidding and Award
Early Construction Phase
Middle Construction Phase
Late Construction Phase
Acceptance Phase
Observation Phase
Warranty Phase
Ongoing Commissioning
-1 Project kick-off
-5 Programming
-9 Establish Owner Requirements
-13 Conceptual design
-17 Schematic design review
-21 Design development
-25 Design development
-29 Construction drawings
-33 Consrtuction drawings
-37 Bidding
-41 Steel out of ground, Submittals
-45 Floor by floor const; periodic duct tests
-49 Floor by floor const; periodic duct tests
-53 Floor by floor const; periodic duct tests
-57 Floor by floor const; periodic duct tests
-61 Floor by floor const; periodic duct tests
-65 Floor by floor const; periodic duct tests
-69 Some equip started
-73 Move-in. End of Mo 35
-77 Peak season inspection/analysis
-81 Swing season inspection/analysis
-85 End of warranty inpsection
-89 On-going Cx assistance
Month and Activity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Conceptual Design Phase
Schematic Design Phase
Design Development Phase
Construction Document Phase
Bidding and Award
Early Construction Phase
Middle Construction Phase
Late Construction Phase
Acceptance Phase
Occupancy Phase
Warranty Phase
Ongoing Commissioning
Testing by Cx Authority and Contractor
Testing by "Mother Nature"
-1 Project kick-off
-5 Programming
-9 Establish Owner Requirements
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-17 Schematic design review
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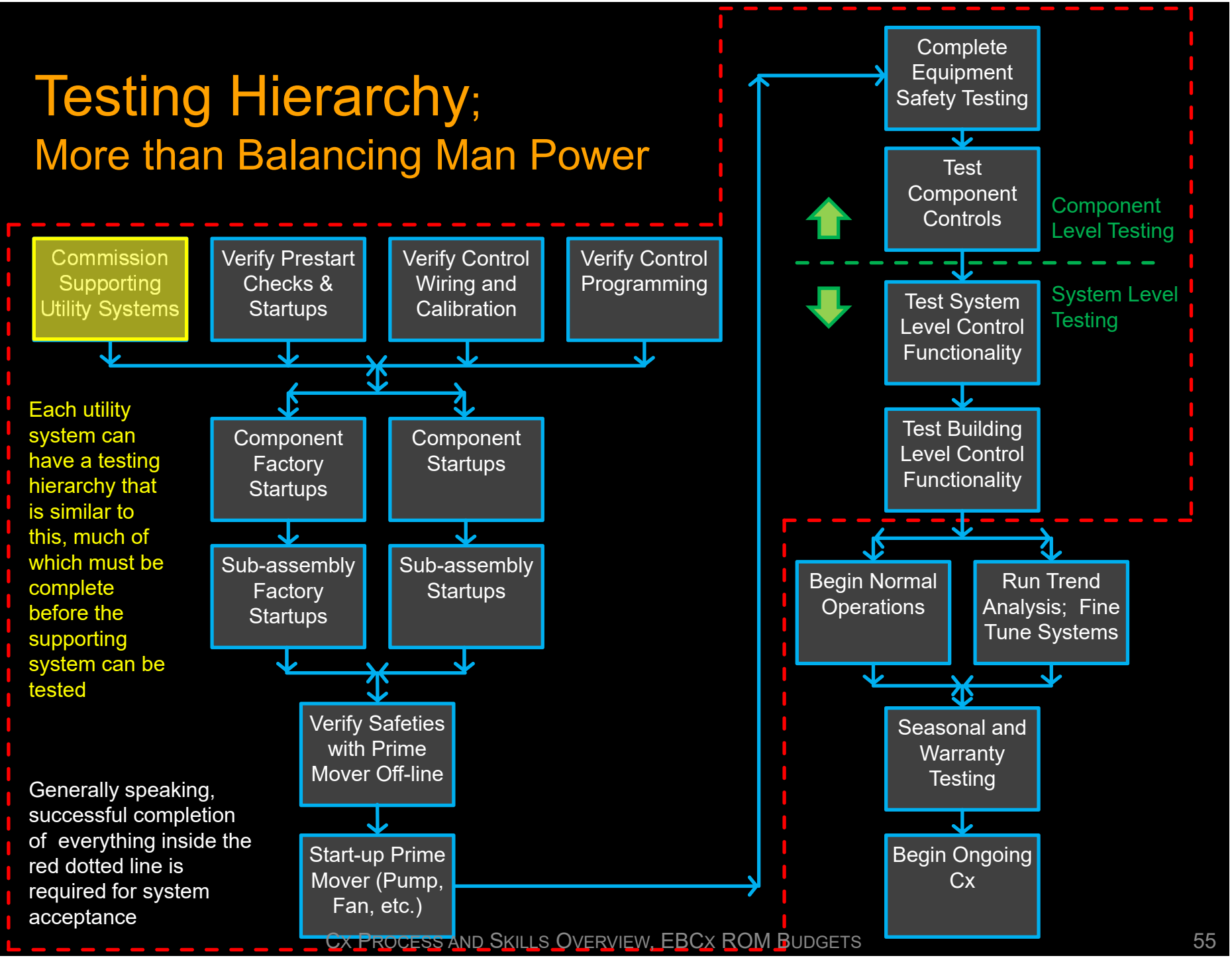
Testing Hierarchy;

More than Balancing Man Power



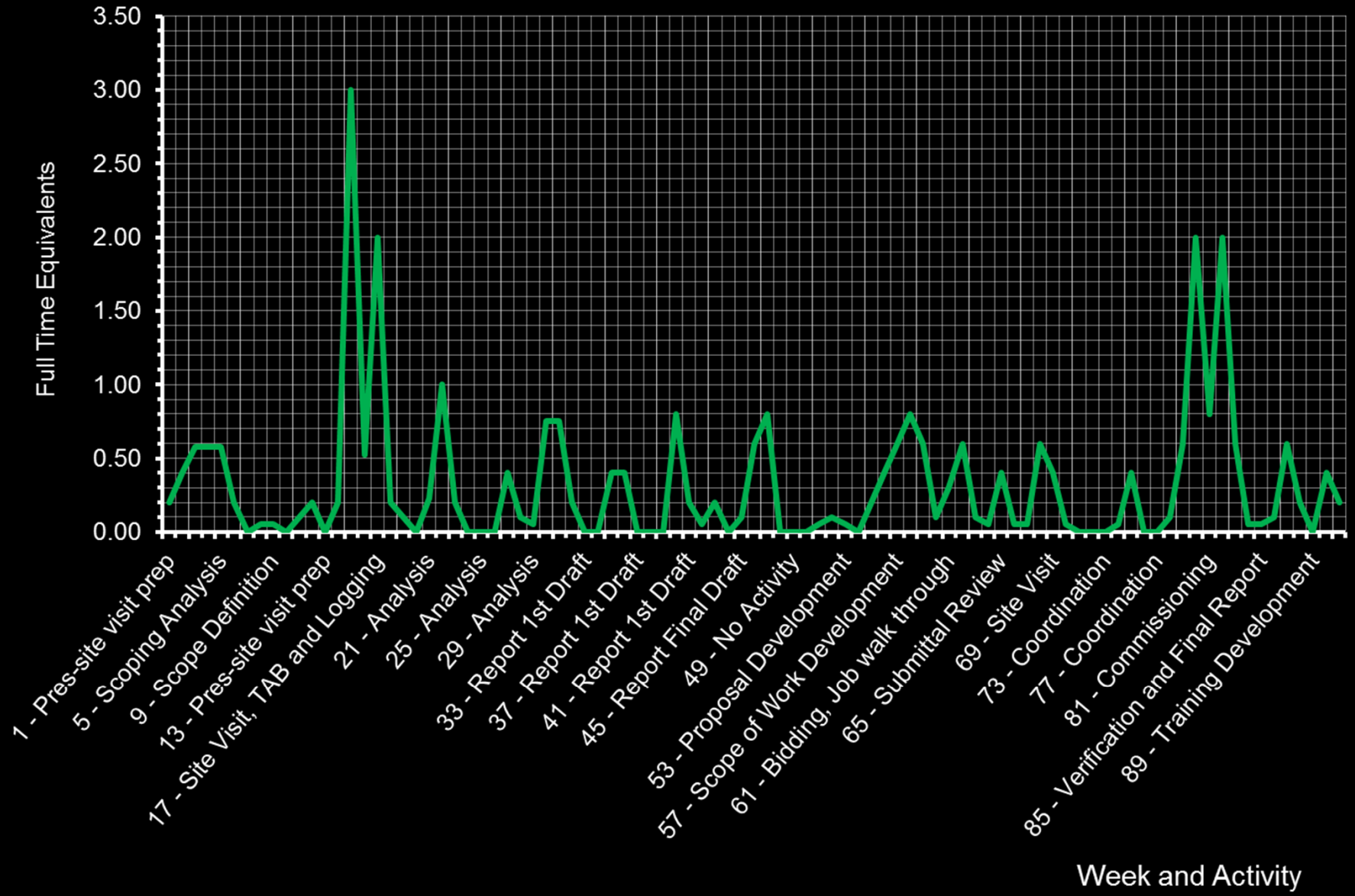
Each utility system can have a testing hierarchy that is similar to this, much of which must be complete before the supporting system can be tested

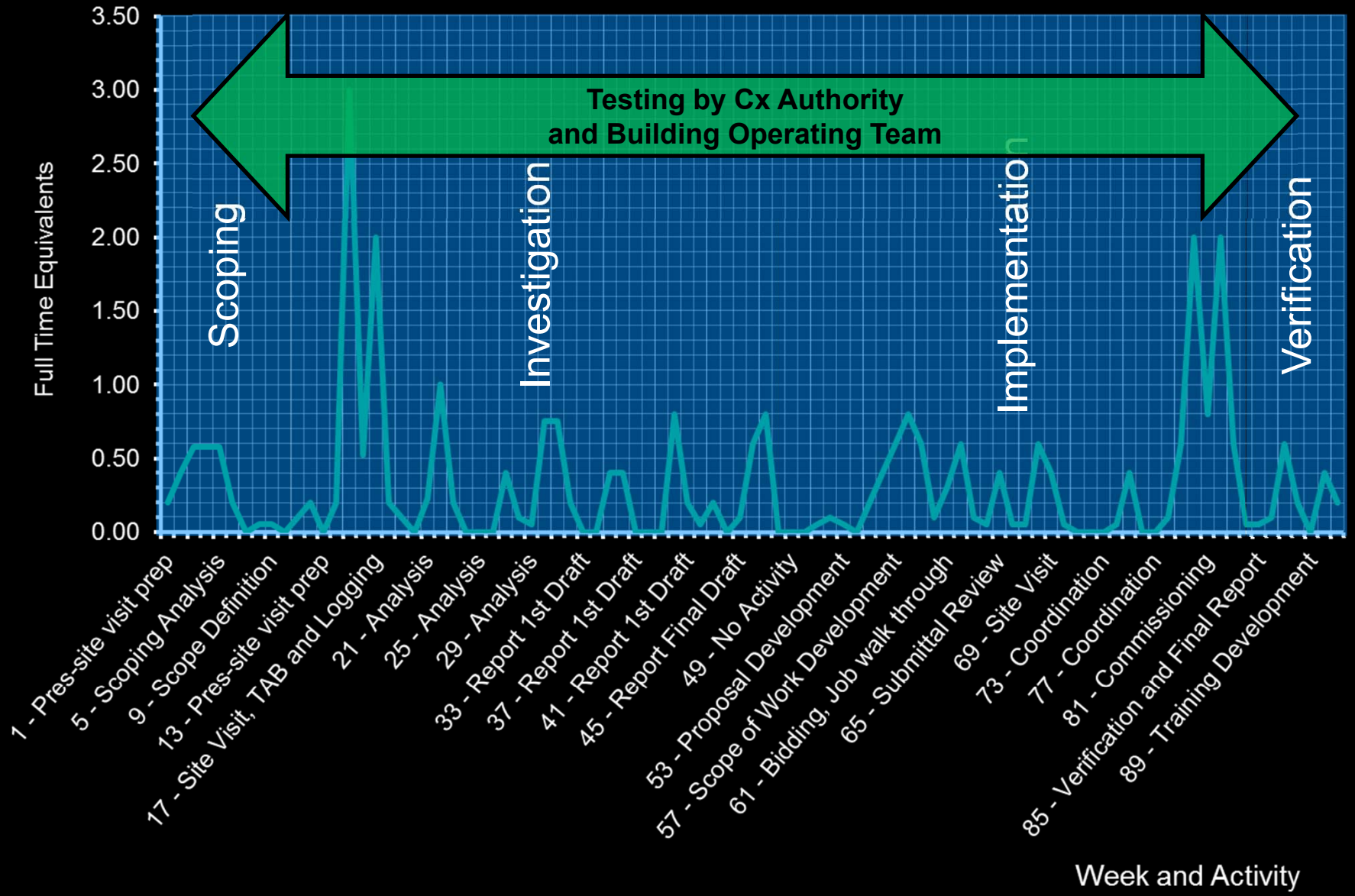
Generally speaking, successful completion of everything inside the red dotted line is required for system acceptance

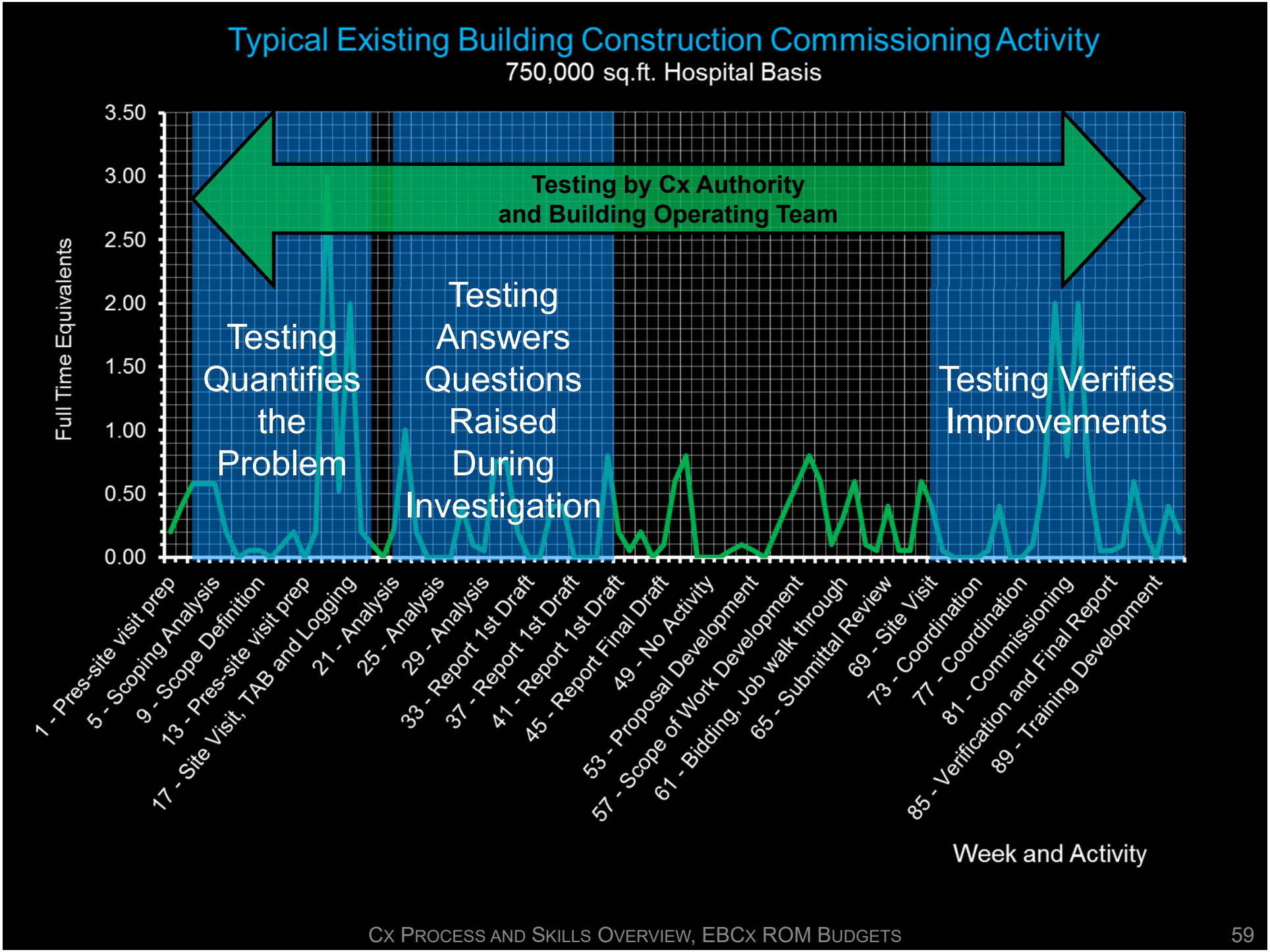
Steps in the Existing Building Commissioning Process

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
Testing by Cx Authority
and Building Operating Team
Scoping
Investigation
Implementation
Verification
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
69 - Site Visit
73 - Coordination
77 - Coordination
81 - Commissioning
85 - Verification and Final Report
89 - Training Development
Week and Activity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2.50
2.00
1.50
1.00
0.50
0.00
Testing by Cx Authority
and Building Operating Team
Testing Quantifies the Problem
Testing Answers Questions Raised During Investigation
Testing Verifies Improvements
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
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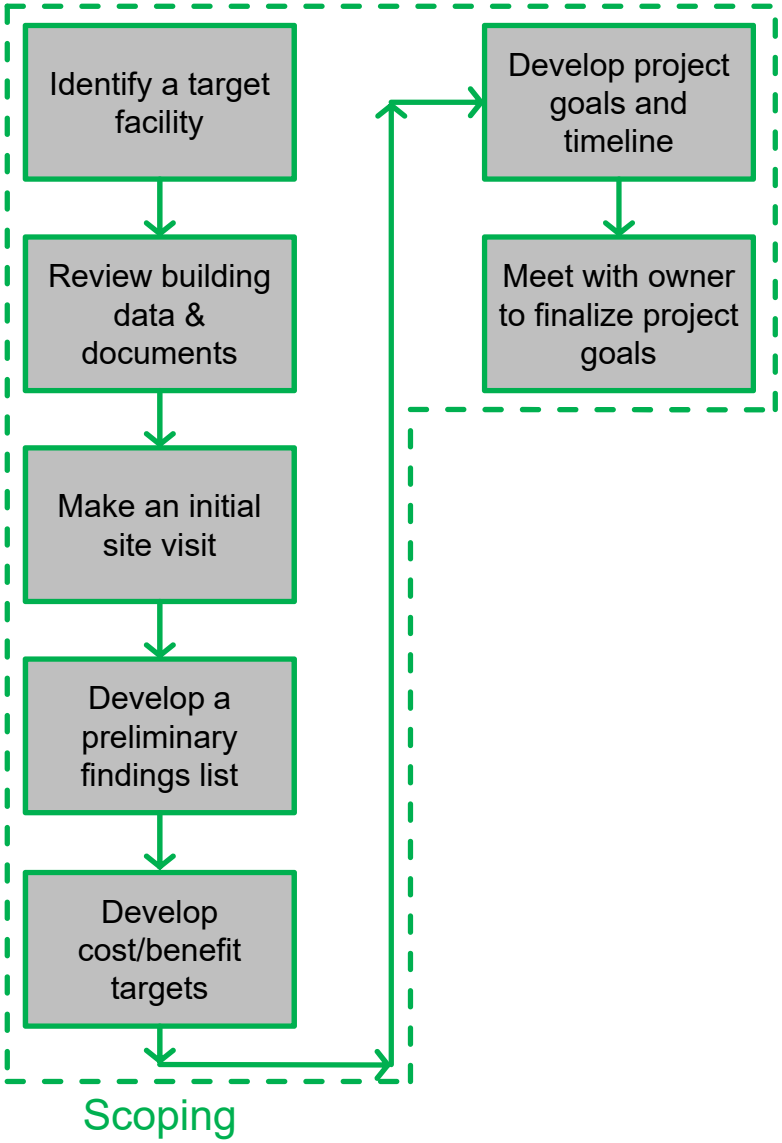
Week and Activity

A Typical EBCx Process



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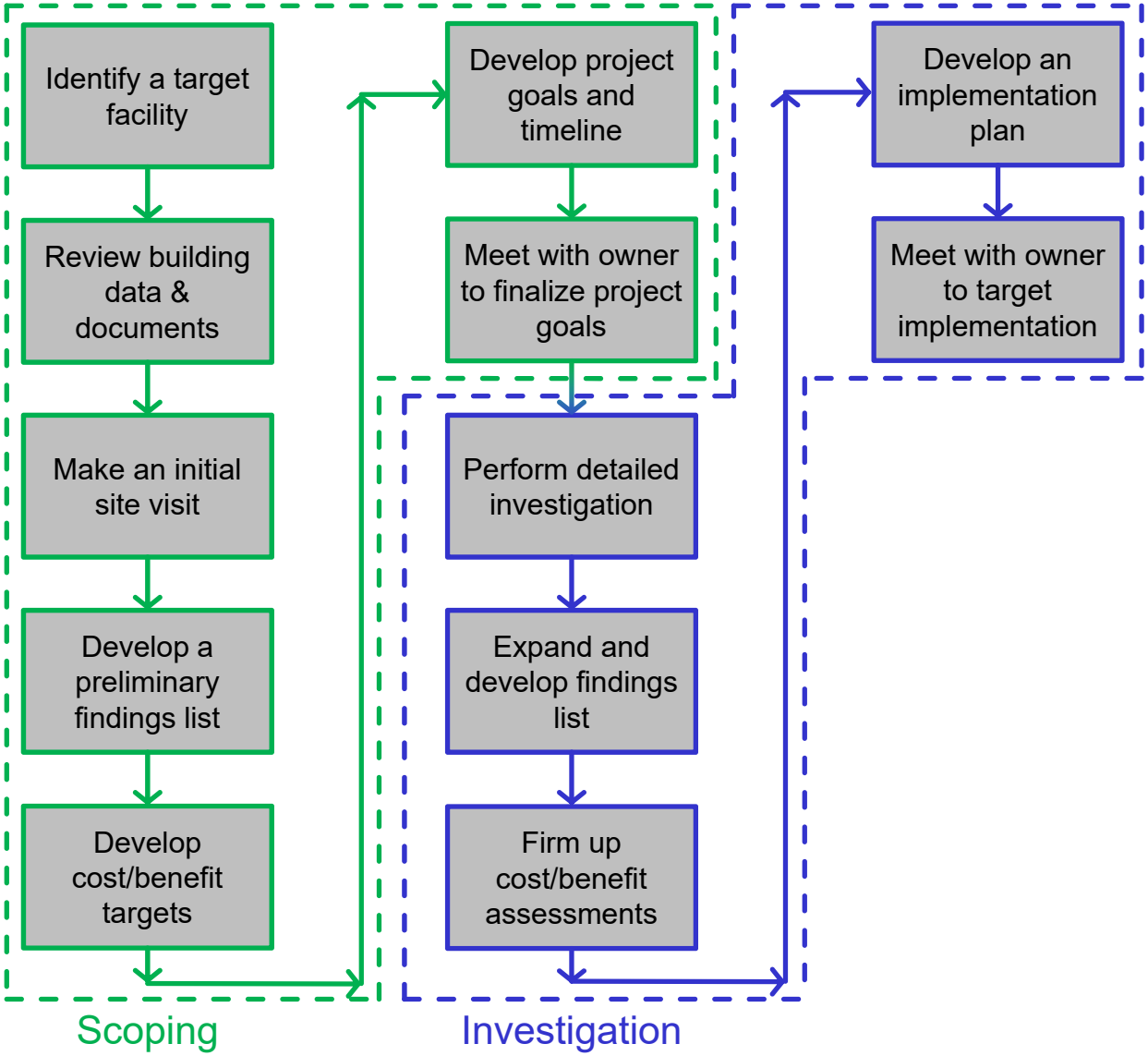

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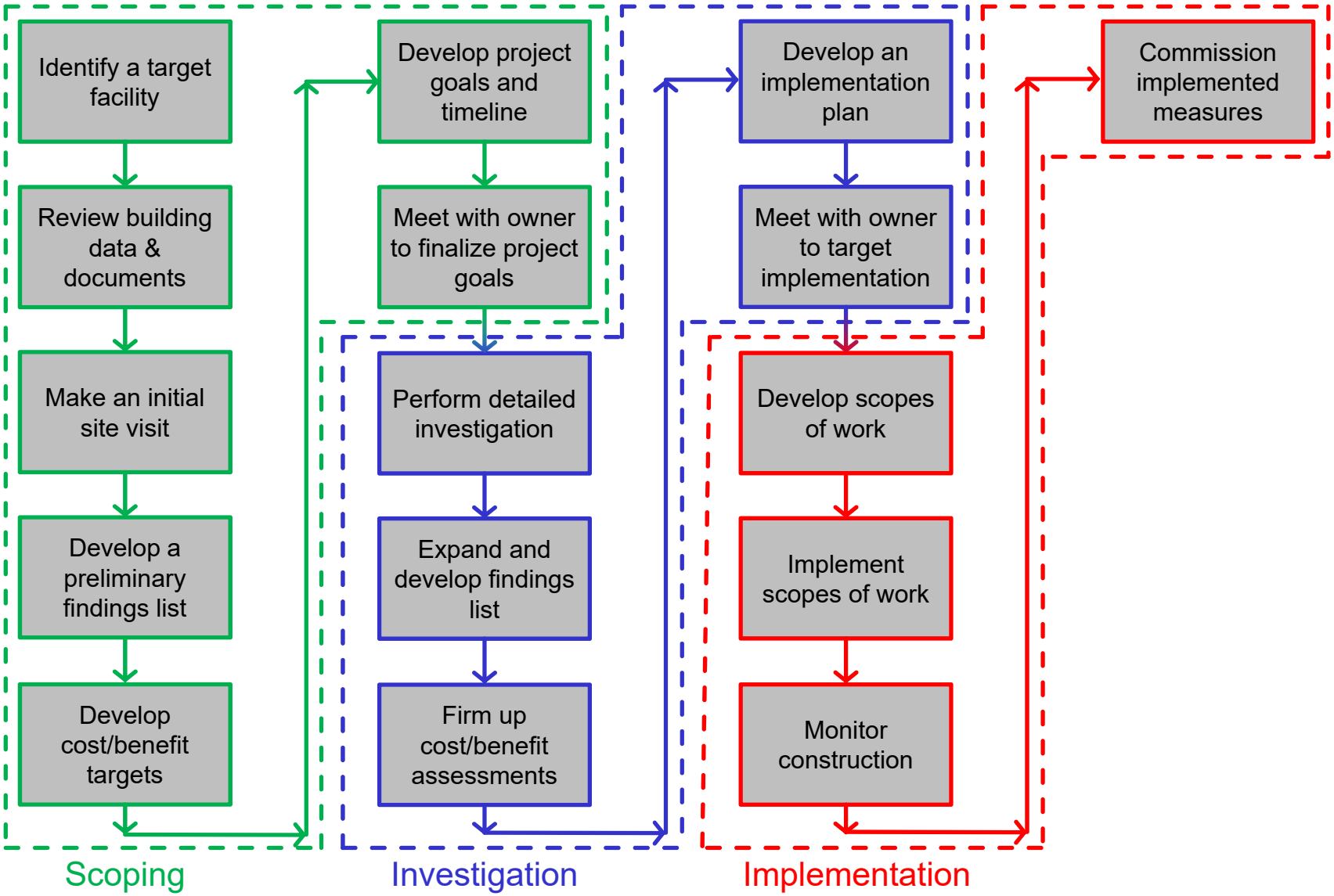

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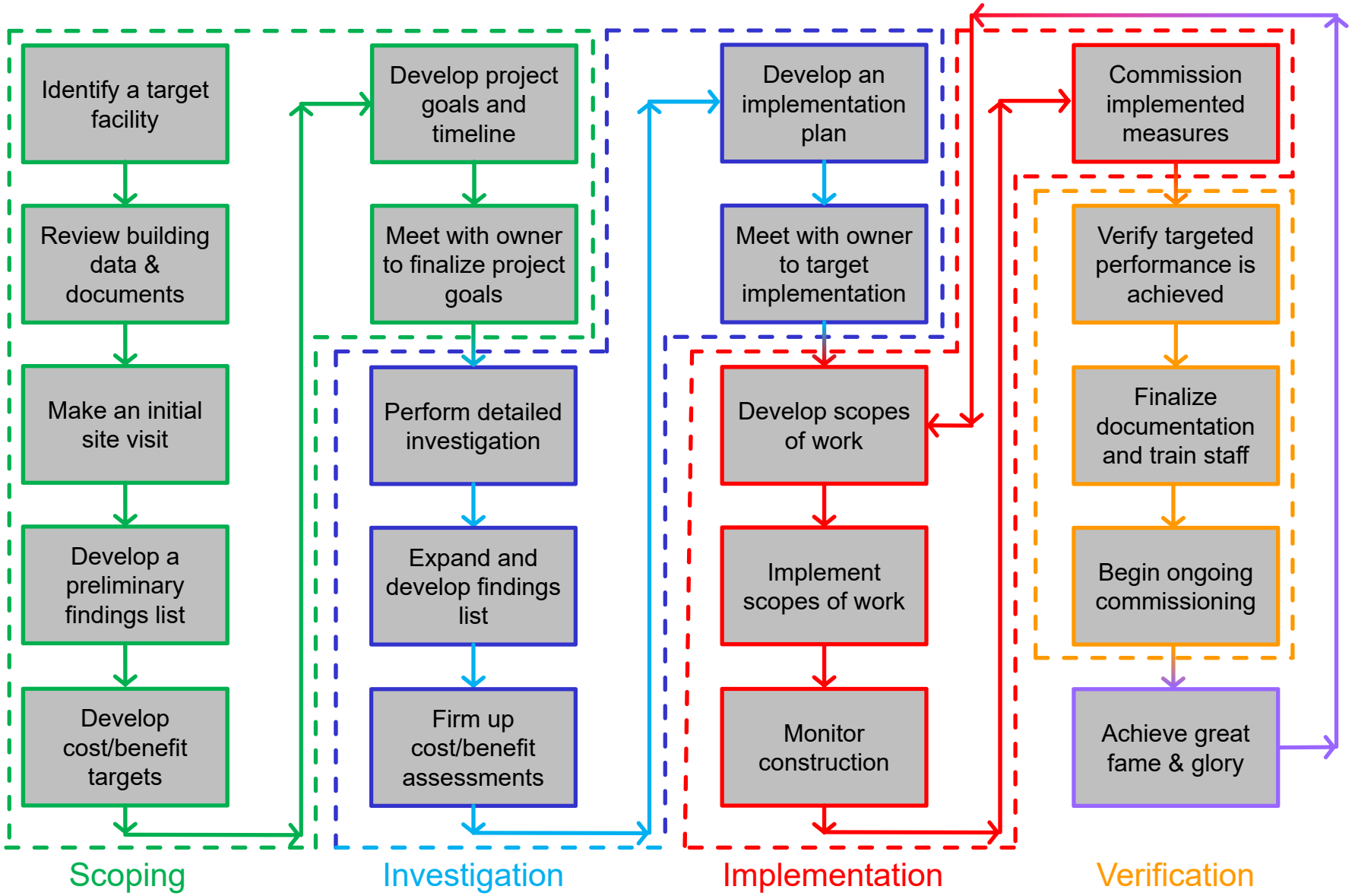
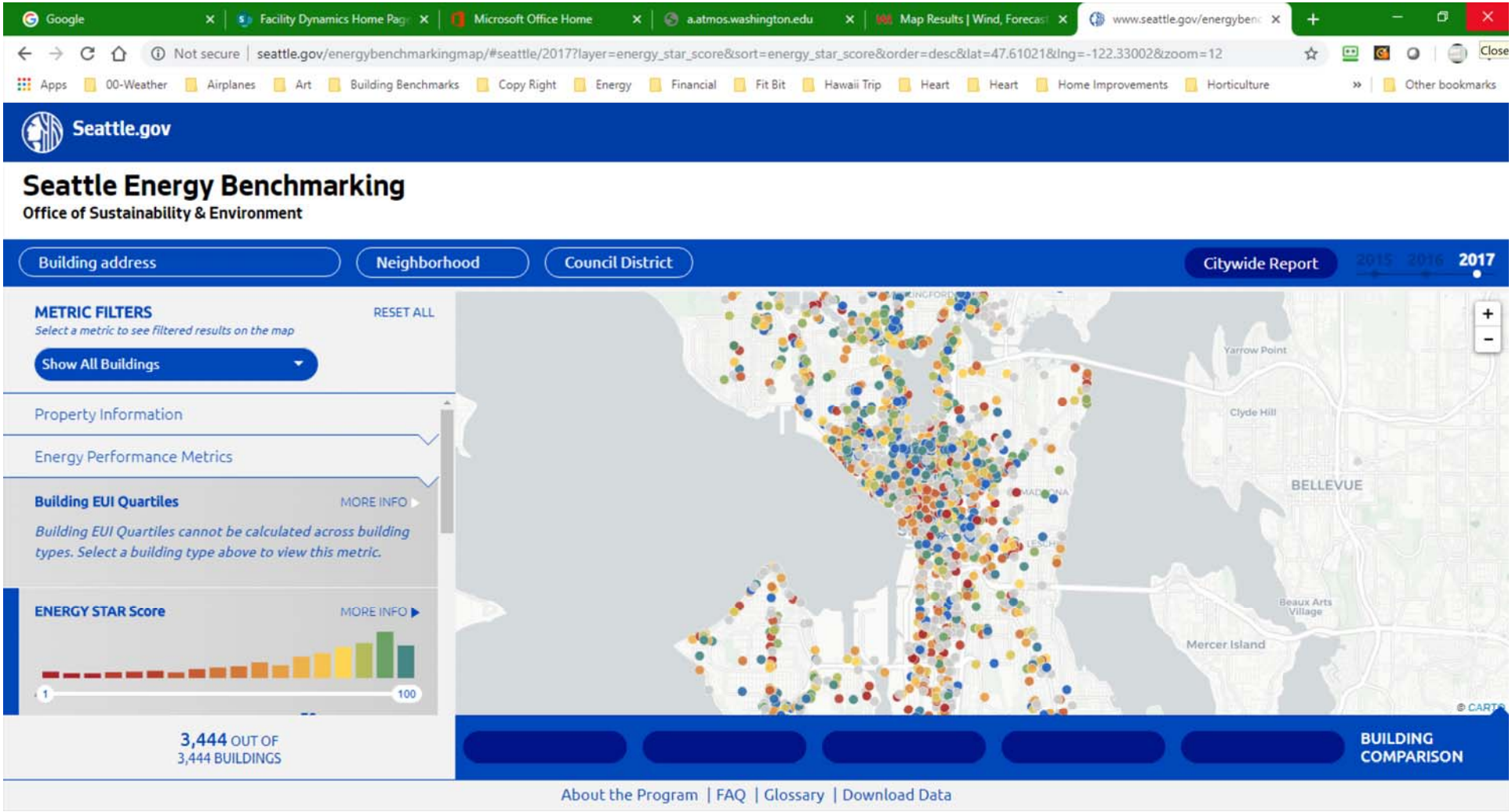


Utility Analysis, Benchmarking and EBCx Budgets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Facility Dynamics Home Pag
Microsoft Office Home
a.atmos.washington.edu
Map Results | Wind, Forecast
www.seattle.gov/energybenc
Not secure | seattle.gov/energybenchmarkingmap/#seattle/2017?layer=energy_star_score&sort=energy_star_score&order=desc&lat=47.61021&lng=-122.33002&zoom=12
Close
Apps
00-Weather
Airplanes
Art
Building Benchmarks
Copy Right
Energy
Financial
Fit Bit
Hawaii Trip
Heart
Heart
Home Improvements
Horticulture
Other bookmarks
Seattle.gov
Seattle Energy Benchmarking
Office of Sustainability & Environment
Building address
Neighborhood
Council District
Citywide Report
2015
2016
2017
METRIC FILTERS
Select a metric to see filtered results on the map
RESET ALL
Show All Buildings
Property Information
Energy Performance Metrics
Building EUI Quartiles
MORE INFO
Building EUI Quartiles cannot be calculated across building types. Select a building type above to view this metric.
ENERGY STAR Score
MORE INFO
1
100
3,444 OUT OF
3,444 BUILDINGS
Yarrow Point
Clyde Hill
BELLEVUE
Beaux Arts Village
Mercer Island
© CARTO
BUILDING COMPARISON
About the Program | FAQ | Glossary | Download Data

Compare buildings with Energy Star

A common approach

ENERGY STAR® Statement of Energy Performance

LEARN MORE AT energystar.gov

89

ENERGY STAR® Score[1]

100 California Street

Primary Property Type: Office
Gross Floor Area (ft²): 319,361
Built: 1960

For Year Ending: March 31, 2017
Date Generated: May 01, 2018

1. The ENERGY STAR score is a 1-100 assessment of a building's energy efficiency as compared with similar buildings nationwide, adjusting for climate and business activity.

Property & Contact Information

Property Address	Property Owner	Primary Contact
100 California Street 100 California Street San Francisco, California 94111	, (___)___-_____	, (___)___-_____

Property ID: 1099028

Energy Consumption and Energy Use Intensity (EUI)

Site EUI
61.3 kBtu/ft²

Annual Energy by Fuel

Electric - Grid (kBtu)	11,847,303 (61%)
Natural Gas (kBtu)	7,714,035 (39%)

National Median Comparison

National Median Site EUI (kBtu/ft²)	109
National Median Source EUI (kBtu/ft²)	252.5
% Diff from National Median Source EUI	-44%

Annual Emissions

Greenhouse Gas Emissions (Metric Tons CO2e/year)	1,308

Source EUI
141.8 kBtu/ft²

March 31, 2017

ENERGY STAR® Statement of Energy Performance

LEARN MORE AT energystar.gov

95

ENERGY STAR® Score[1]

100 California Street

Primary Property Type: Office
Gross Floor Area (ft²): 319,361
Built: 1960

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Property & Contact Information

Property Address	Property Owner	Primary Contact
100 California Street 100 California Street San Francisco, California 94111	, (___)___-_____	, (___)___-_____

Property ID: 1099028

Energy Consumption and Energy Use Intensity (EUI)

Site EUI
45.3 kBtu/ft²

Annual Energy by Fuel

Natural Gas (kBtu)	3,959,931 (27%)
Electric - Grid (kBtu)	10,507,836 (73%)

National Median Comparison

National Median Site EUI (kBtu/ft²)	100.3
National Median Source EUI (kBtu/ft²)	257.6
% Diff from National Median Source EUI	-55%

Annual Emissions

Greenhouse Gas Emissions (Metric Tons CO2e/year)	1,007

Source EUI
116.3 kBtu/ft²

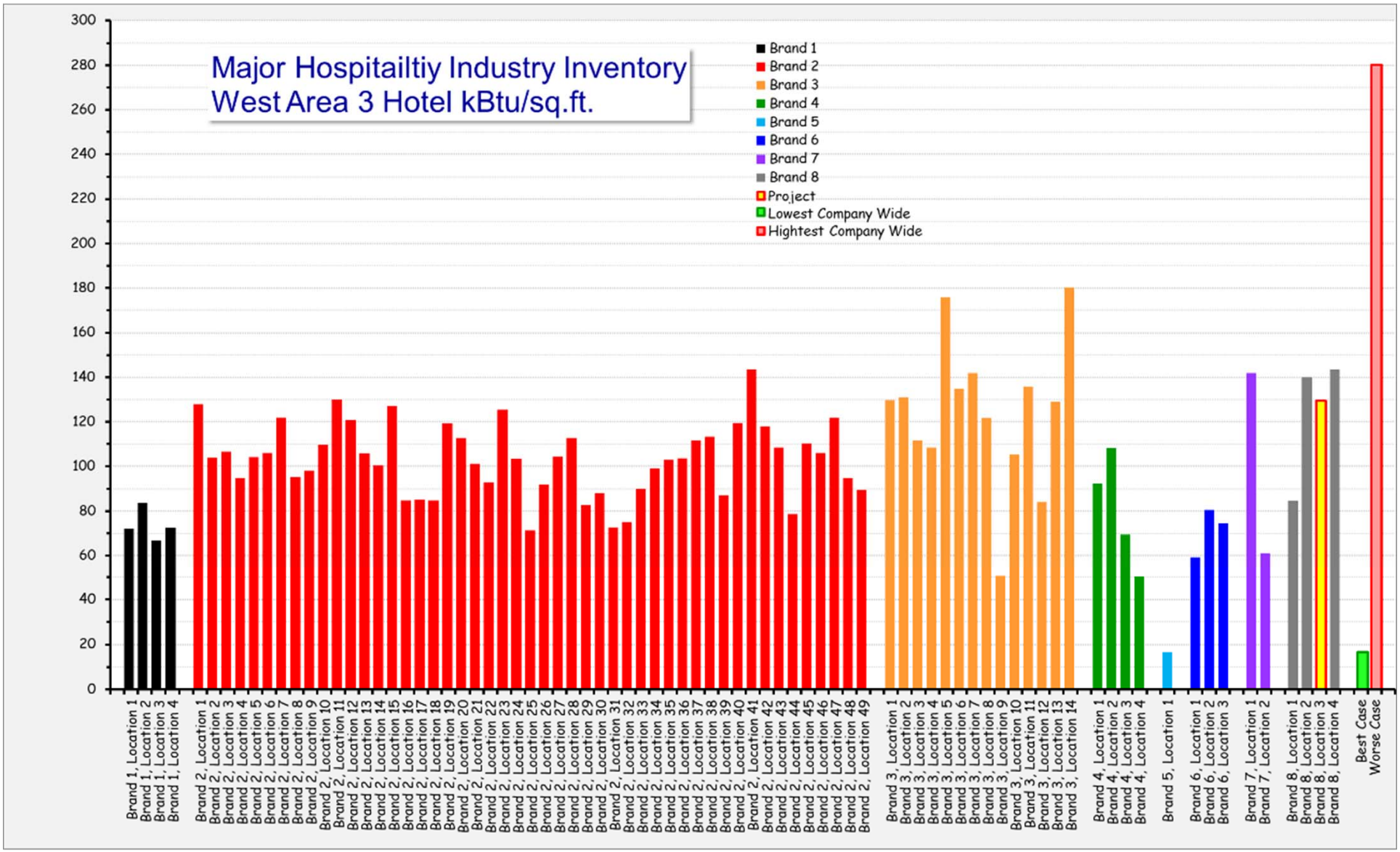
March 31, 2018

Take a Look across a Broad Spectrum

DOE building performance database

www.bpd.lbl.gov/

Some Owners have Internal Metrics



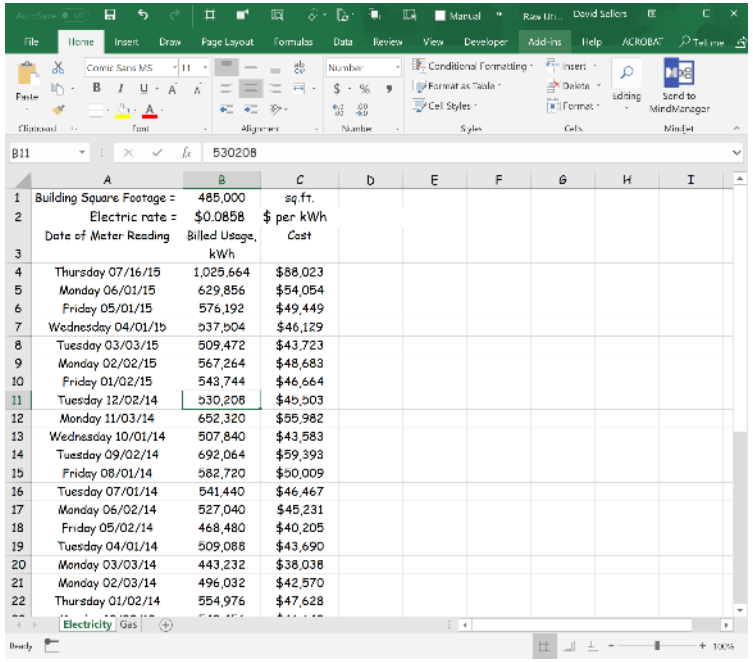
Energy Utilization Index (EUI)

$$EUI = \frac{((kWh_{Annual} \times 3,413) + Fuel_{Annual})}{(1,000 \times Area_{Building})}$$

Where:

EUI	=	Energy Use Intensity (some say Energy Use Index), typically in kBtu/sq.ft./year
kWh_{Annual}	=	Annual building electrical consumption in kWh
3,413	=	Unit conversion constant; there are 3,413 Btus per kWh
$Fuel_{Annual}$	=	Annual building fuel consumption in Btus; Note that you may have to convert the units of measure from what is used on the bill. For instance, gas is often billed as therms and there are 100,000 Btu per therm.
1,000	=	Unit conversion constant; there are 1,000 Btu per kilo-Btu
$Area_{Building}$	=	Building gross square footage

Let’s give it a try



	A	B	C
1	Building Square Footage =	485,000	sq.ft.
2	Electric rate =	$0.0858	$ per kWh
3	Date of Meter Reading	Billed Usage, kWh	Cost
4	Thursday 07/16/15	1,025,664	$88,023
5	Monday 06/01/15	629,856	$54,054
6	Friday 05/01/15	576,192	$49,449
7	Wednesday 04/01/15	537,504	$46,129
8	Tuesday 03/03/15	509,472	$43,723
9	Monday 02/02/15	567,264	$48,683
10	Friday 01/02/15	543,744	$46,664
11	Tuesday 12/02/14	530,208	$45,503
12	Monday 11/03/14	652,320	$55,982
13	Wednesday 10/01/14	507,840	$43,583
14	Tuesday 09/02/14	692,064	$59,393
15	Friday 08/01/14	582,720	$50,009
16	Tuesday 07/01/14	541,440	$46,467
17	Monday 06/02/14	527,040	$45,231
18	Friday 05/02/14	468,480	$40,205
19	Tuesday 04/01/14	509,088	$43,690
20	Monday 03/03/14	443,232	$38,038
21	Monday 02/03/14	496,032	$42,570
22	Thursday 01/02/14	554,976	$47,628

Example

Site Energy
Utilization Index

- 121 kBtu/sq.ft./year

Source Energy
Utilization Index

- 232 kBtu/sq.ft./year

Why So Different

Site Energy
Utilization Index

- **121** kBtu/sq.ft./year

Source Energy
Utilization Index

- **232** kBtu/sq.ft./year

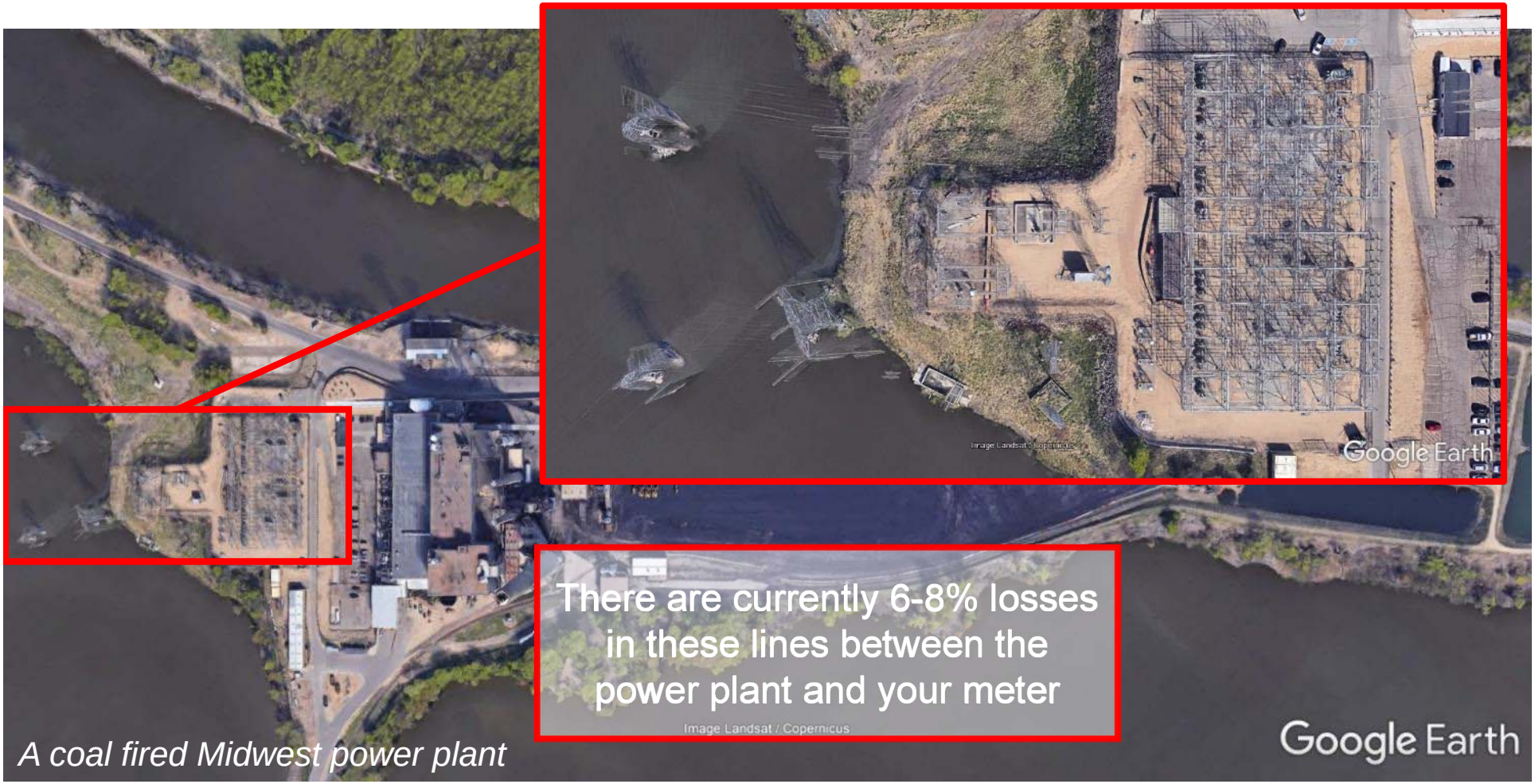
Site Energy

Energy that passes through your **meter**

Source Energy

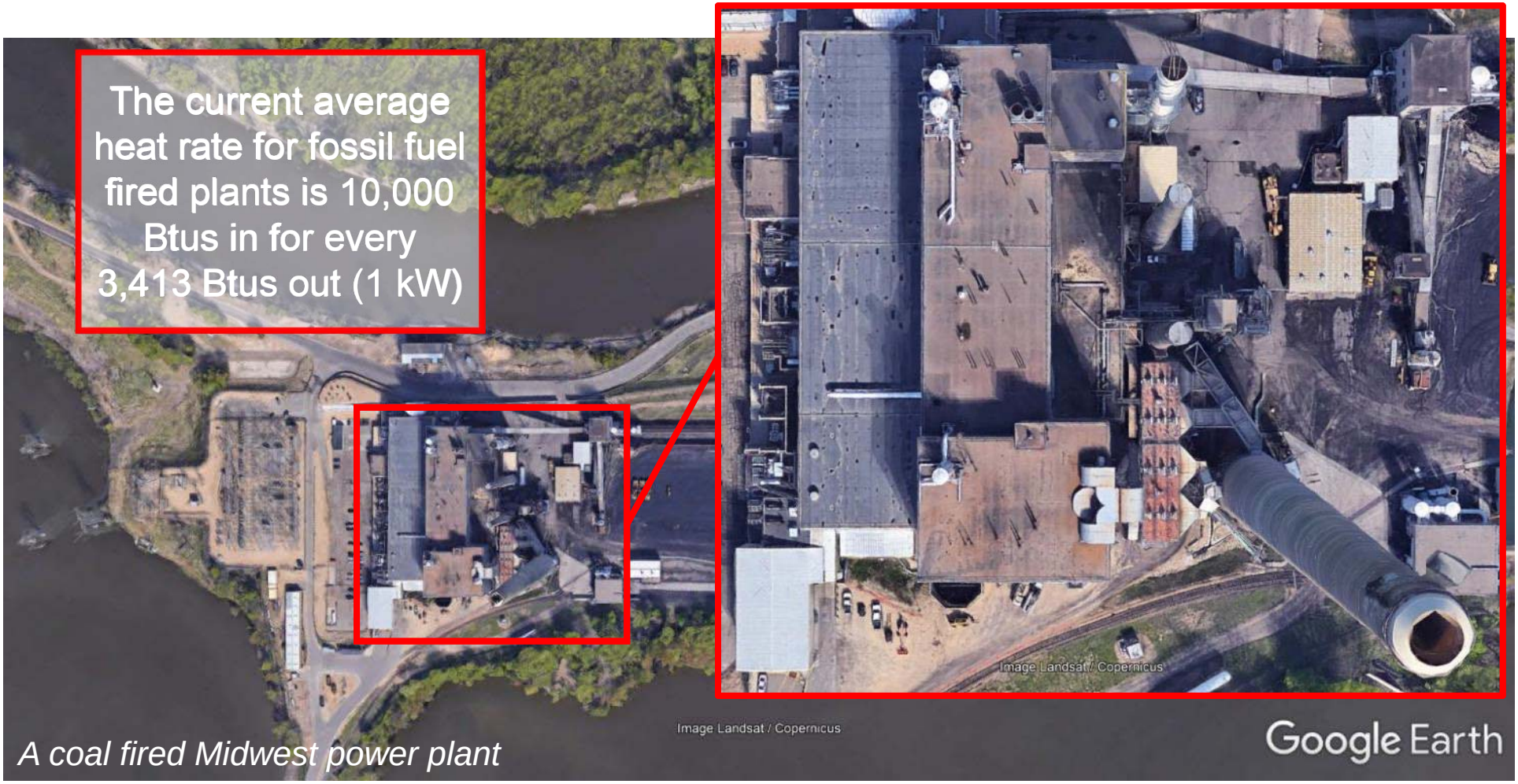
Energy that passed through the **power plant**

Transmission Losses are Significant



A coal fired Midwest power plant

Conversion Losses are Significant



A coal fired Midwest power plant

Physical Principles will Prevail

A coal fired Midwest power plant

Takeaways

- Generating power consumes finite resources and impacts the environment
- Looking at source energy provides a more holistic perspective on energy consumption and efficiency improvements

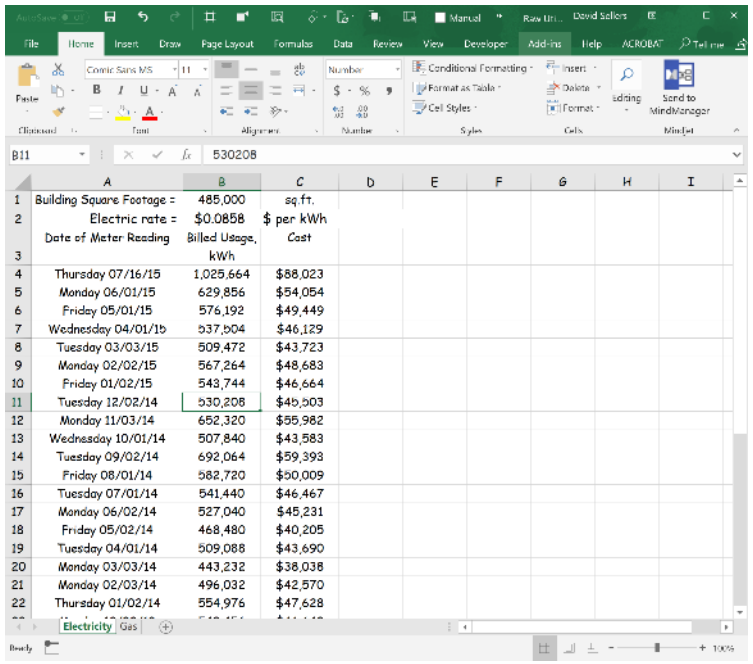
Utility Consumption Analysis

Provides clues to focus scoping

- More info than on monthly bill:
- Averaged over the number of days in the billing period
- Normalized for the calendar month
- Compare results to potential drivers
  - Heating or cooling degree days
  - Production
  - Occupancy

UCAT Makes it Easy

Let’s give it a try



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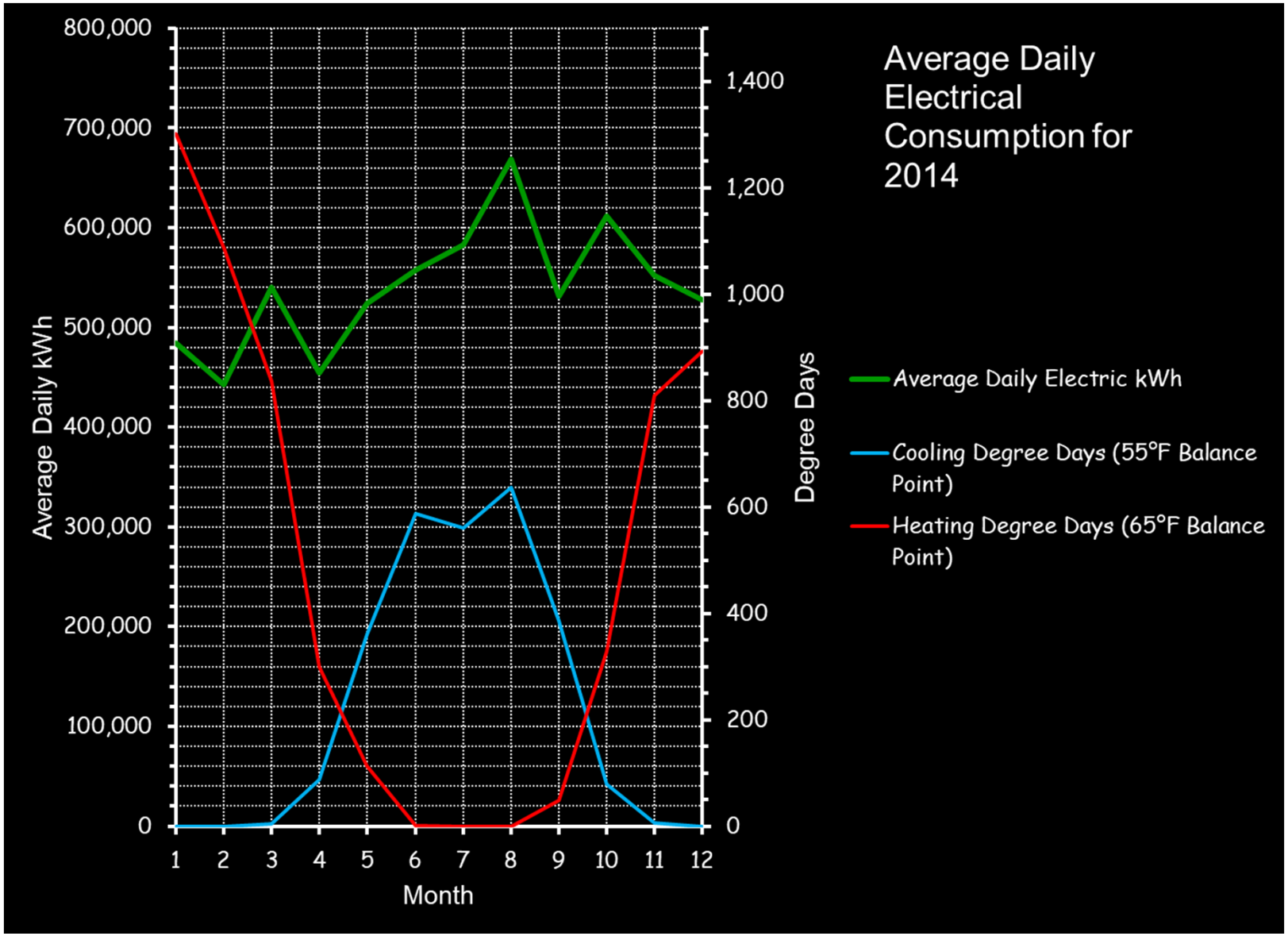
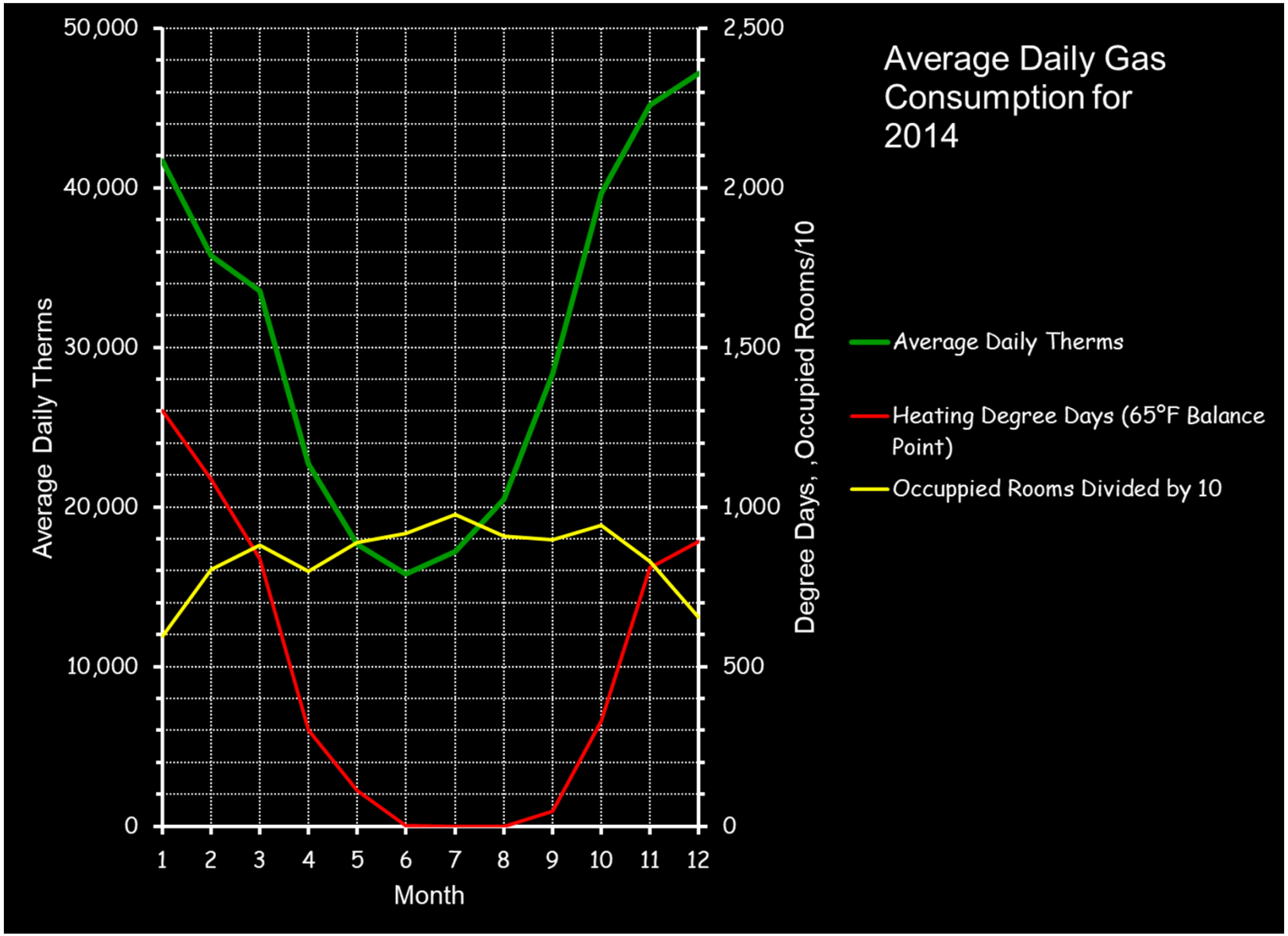
Clues to focus scoping based on *electrical* consumption patterns



Clues to focus scoping based on *gas* consumption patterns



If you thought that was exciting, try 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

Clouds can reveal important information about buildings

A Cloud Revealing Something About Buildings.
© JR Hott

Utility Data

- Clouds can reveal important information about buildings

Utilities are moving to Smart Meters

Smart meters read data:

- Daily
- Hourly
- Every 15 minutes

Utility Data

- Clouds can reveal important information about buildings

  Utilities are moving to Smart Meters

  This is called “interval data” and it provides a lot more insight into daily and seasonal load profile than your utility bill

Utility Data

- Clouds can reveal important information about buildings

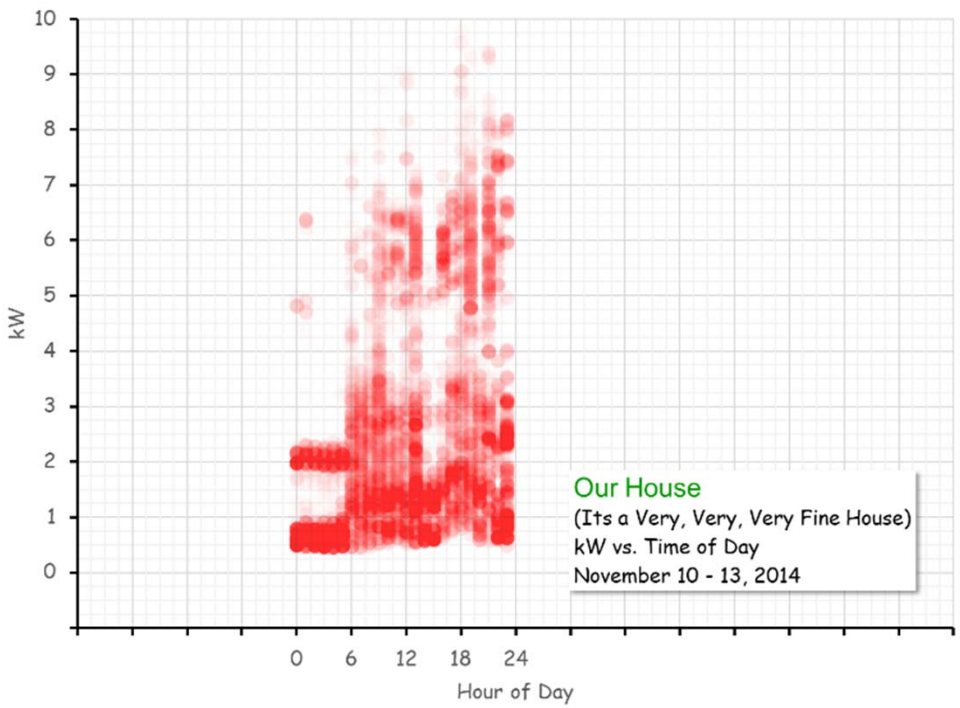
Regressions:

- Make you sound very smart
- Reveal patterns that can indicate opportunities
- Verify the results of improvements you make

Utility Data

- Clouds can reveal important information about buildings

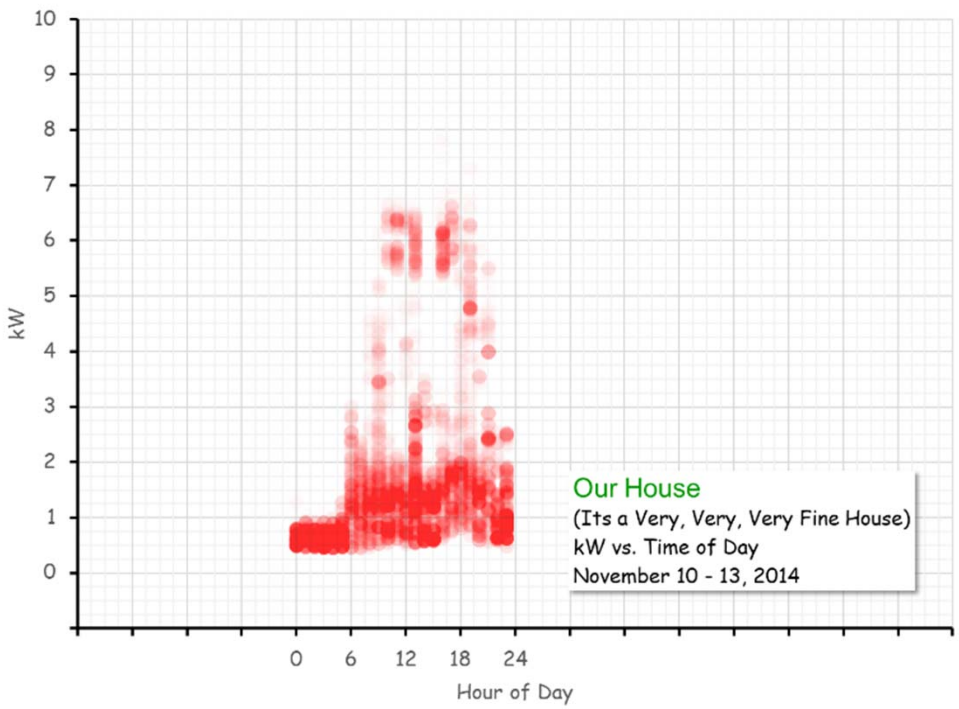
Our house, 15 second samples



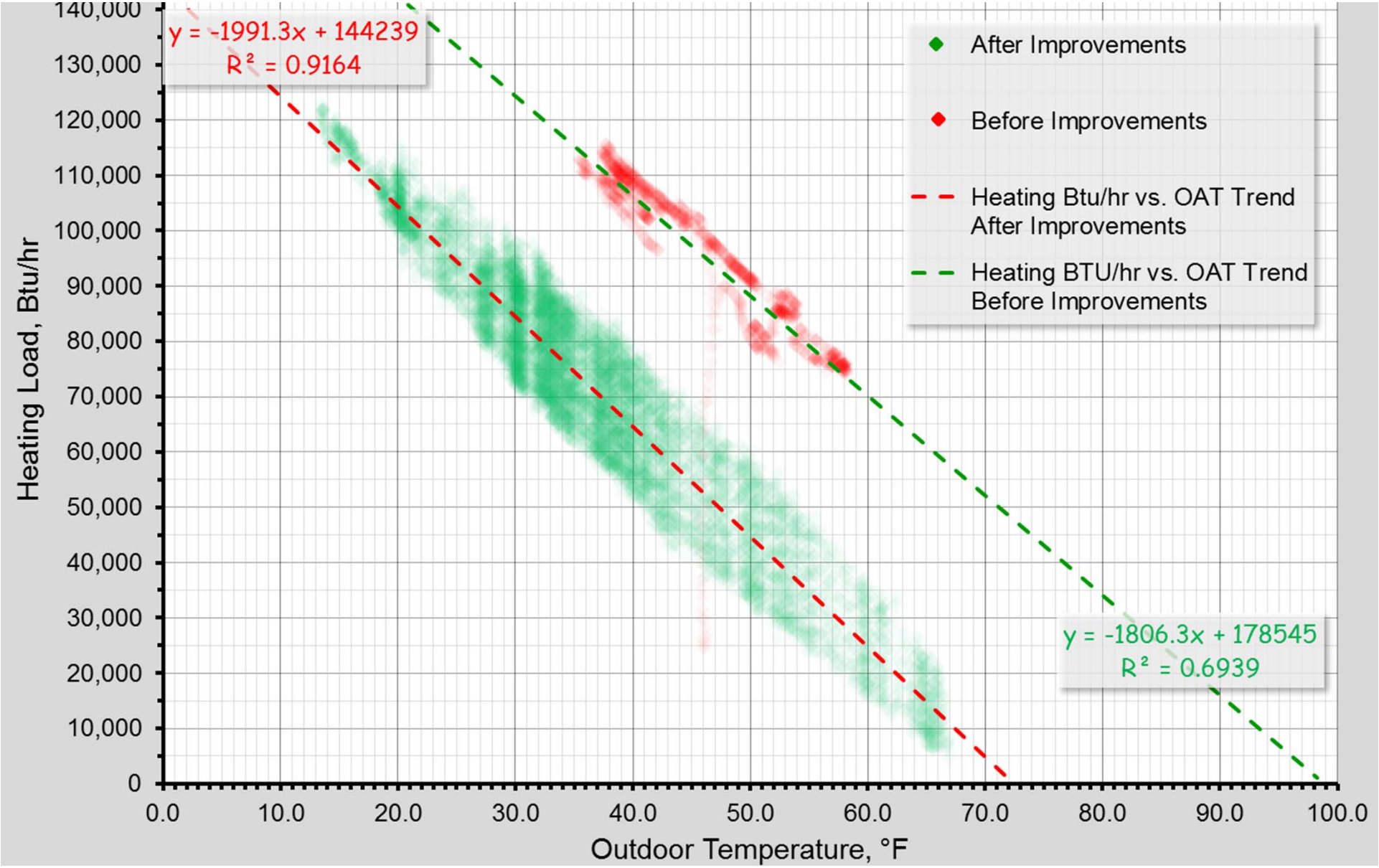
Utility Data

- Clouds can reveal important information about buildings

Our house; art studio and water heater filtered out



Regressions and Savings Assessments



Resource for Determining Savings

LBNL Report includes citable industry metrics:

- Different Cx processes
- Energy savings
- Dollar savings
- Non-energy benefit savings

THE COST-EFFECTIVENESS OF COMMERCIAL-BUILDINGS COMMISSIONING

A Meta-Analysis of Energy and Non-Energy Impacts in Existing Buildings and New Construction in the United States

EVAN MILLS[1]
HANNAH FRIEDMAN[2]
TEHESIA POWELL[3]
NORMAN BOURASSA[1]
DAVID CLARIDGE[3]
TUDI HAASL[2]
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December 15, 2004

LBNL – 56637 (Rev.)

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An electronic version of this document and data input forms are available at
http://eetd.lbl.gov/emills/PUBS/Cx-Costs-Benefits.html

http://cx.lbl.gov/cost-benefit.htmlhttp://cx.lbl.gov/cost-benefit.html

LBNL Metrics Relate Consumption to Savings

$$Savings_{EBCxPotential} = Consumption_{Annual} \times Metric_{LBNL}$$

Where:

$Savings_{EBCxPotential}$	=	Potential annual savings from a commissioning process in consistent units
$Consumption_{Annual}$	=	Annual resource consumption in consistent units
$Metric_{LBNL}$	=	Annual savings metric from the LBNL report; in consistent units; this could be median savings, minimum savings, maximum savings, etc. The selection should be tempered by engineering judgement and the results of a scoping effort

Owner Financial Metrics Relate Savings to Budget

$$Budget_{EBCx} = Savings_{EBCxPotential} \times Preference_{Owner}$$

Where:

$Budget_{EBCx}$	=	Nominal project budget in dollars
$Savings_{EBCxPotential}$	=	Potential annual savings from a commissioning process
$Preference_{Owner}$	=	The owner's financial preference expressed as a simple payback in years

Leveraging EUI and LBNL Metrics can Yield Perspective Early On

RCx Project Preliminary Savings and Budget Metrics		
Annual utility costs	Energy	Dollars
Electricity, kWh	6,477,564	$555,906
Gas, therms	365,139	$213,452
Total, kBtu	58,621,809	$769,358
Building square footage	485,000	sq.ft.
EUI, Site Energy Basis	121	kBtu/sq.ft./year
Energy Cost	$1.59	per square foot
LBNL Median Savings	16%	
Anticipated Savings Range After Scoping	10%	16%
	$76,936	$123,097
Owner's acceptable simple payback range, years	2	5
Projected project budget	$153,872	$615,487

Scoping can Firm Up the Initial Estimate of Savings Potential

34 findings identified in the initial scoping visit

- Broken economizers
- Simultaneous heating and cooling
- Scheduling

Number	Brief Description
1.	Many systems are operating 24/7 and could likely be scheduled.
2.	Auxilliary equipment supporting the chillers runs even if the chiller it serves is off-line
3.	Based on operator feedback, the econmizers are set to a fixed minimum outdoor air position
4.	All of the meeting rooms in a random sample demonstrated part of the room heating while the other part cooled to achieve set
5.	The corridor make up air system appears to be moving very little air causing the stairwells to be the make-up air path (see 6).
6.	The building is plauged by severe negative pressure problems in the winter, making the lobby particularly uncomfortable (see 5).
7.	There are issues with the distribution of domestic hot water to the showers at the end of the facility relative to the plant.
8.	Meeting room temperature control is a significant issue.
9.	There appears to be a water quality issue with the middle chiller; water is sort of milky looking.
10.	Meeting room lights appear to be on a lot when they could be scheduled
11.	The second chiller seems to be short cycling and may be starting when the lead chiller could manage the load with out it.
12.	N and S boilers "fight" each other; the S boiler short cycles; most of its time is spent in pre and post purge;
13.	There is a lot of lint and debris in the exhaust fan discharge area; possible fire hazard.
14.	There may be opportunities to optimize cooling for the elevator machine rooms.
15.	The AHU serving the maintenance floor has issues with the economzier dampers; RA and OA both basically closed.
16.	The AHU serving the maintenance floor is doing a lot of reheat that it probalby would not need to do.
17.	The IT/phone switch room cooling could be improved to save energy.
18.	The maintenance shop AHU CHW valve actuator has come loose from the valve body
19.	The shop AHU may not need to run a return fan.
20.	The valves in my guest room fan coil unit might have been leaking by; test inconclusive.
21.	Corridor MAU run-around system may benefit from optimization
22.	CHW and HHW distribution systems have heavily throttled valves in the return mains
23.	All chillers have heavily throttled valves on the evaporator lines
24.	Generally, the gauges intended to read pump dishargе pressure are improperly located; they are on the volute vent, not the
25.	The ice machine cooling loop may have throttled valves on the pump discharge.
26.	The Delta control system is not well understood and may benefit from upgrade or improvement and training on its use.
27.	The kitchen exhaust fan is constant speed and there may be an opportunity there to look at variable flow hoods
28.	There appear to be a number of abandone/failed VFDs associated with the central plant pumps
29.	The piping of the CHW distribution pump discharge header sets up some loads to get warm water
30.	The HW distribution loop to the guest rooms looks like it could do a reset but that may not be working.
31.	Being able to reset the HW temperature to the meeting rooms indepenently of the guest rooms could be an advantage
32.	Pneumatic terminal unit controllers for meeting rooms and ball rooms may not be served often enough to compentsate for drift
33.	Resolving item 32 along with zone level schedulling may justify a DDC upgrade to meeting and ball room terminal units.
34.	Existing domestic water booster pumps are conventional pumps with no VFDs; a VFD upgrade may make sense.

Bottom Line

- EUI Analysis is Becoming a Legal Requirement
- Average Daily Consumption Analysis "falls out" of the data you collect to generate an EUI
- The EUI data combined LNBL metrics and Owner preferences informs EBCx project decisions