RCx 101

Introduction to Commissioning, the 10 Skills, and Resources

Presented By:

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Senior Engineer

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Copyright Materials

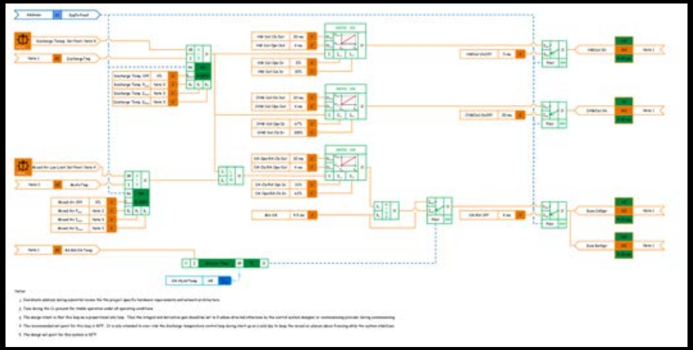
A Bit About Me

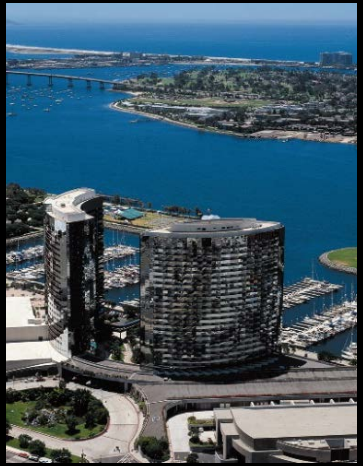
I intended to be an aircraft maintenance engineer

I'm doing something totally different

A Bit About Me

- HVAC field technician
- Control system designer
- HVAC designer
- MCC Powers system engineer
- Murphy Company controls and start-up engineer
- Project engineer
- Wafer fab facilities engineer and system owner
- A PECI technical support engineer and trainer
- FDE Senior Engineer





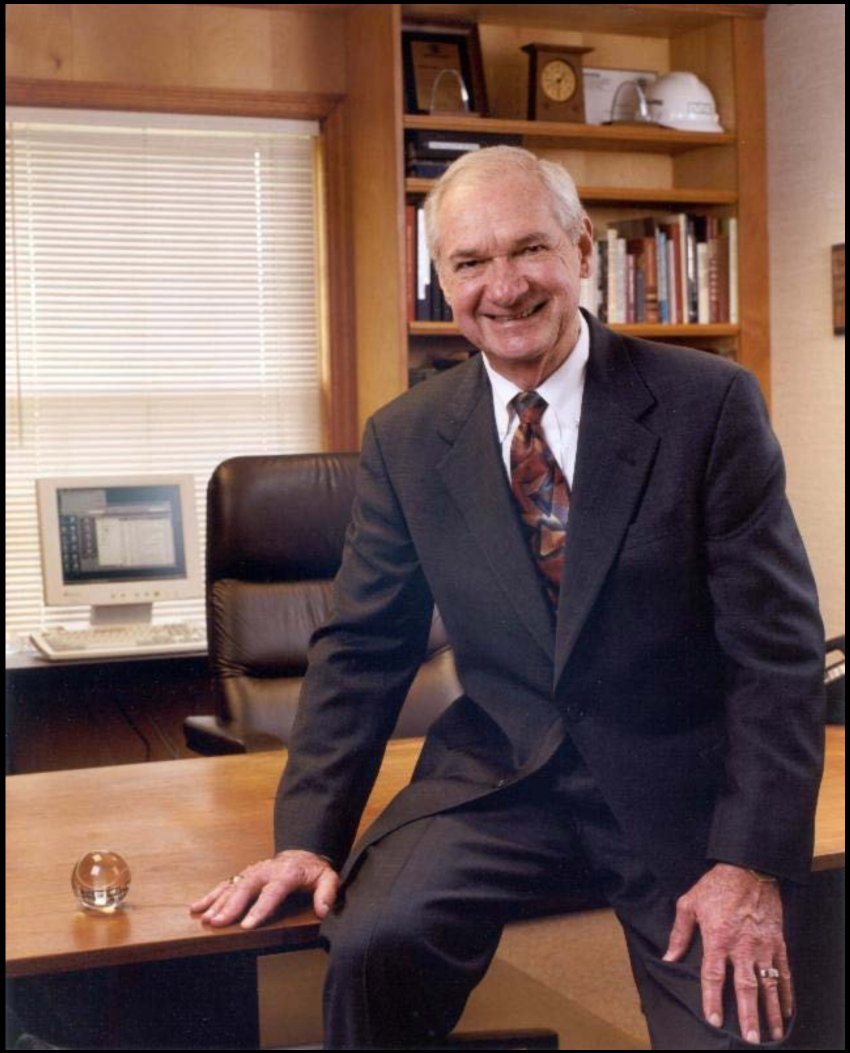
I’ve Had Great Mentors Along the Way

I’ve Had Great Mentors Along the Way

“… 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

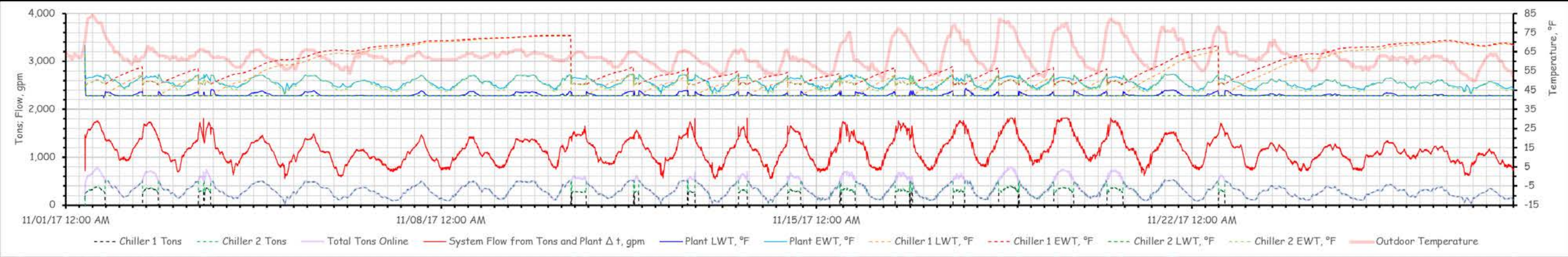
ASHRAE Journal, vol. 42, no. 7, p. 16-21



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

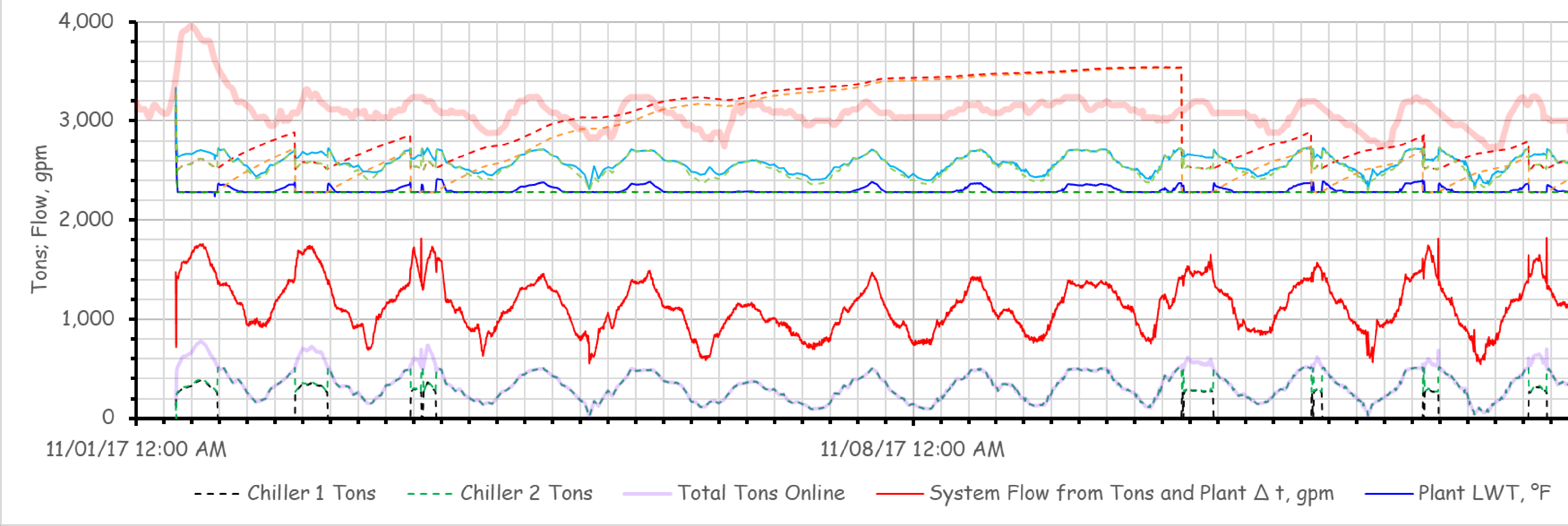
My Most Important Lession

It’s All About the Load Profile



My Most Important Lesson

It's All About the Load Profile



Tell Us a Bit About You

- Name, Company Affiliation (if you have one) and what you hope to gain from this course
- Where you are in the self study process? (Haven't started yet is O.K.)
- How do you plan to participate in the SketchUp model based activities later today?

https://tinyurl.com/PECRCx101GettingToKnowYou

Key EBCx Skills

1. Be able to benchmark and perform utility analysis
2. Be able to scope a facility for obvious indicators of opportunity
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 – Skill 3 is a BIG ONE!

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Key EBCx Skills – Skill 3 is a BIG ONE!

3. Be familiar with fundamental principles and building systems

   i. Saturated systems
   ii. Loads, psychrometrics and envelopes
   iii. Centrifugal machines
   iv. Refrigeration and cooling equipment
   v. Heating equipment
   vi. Piping systems
   vii. Variable flow water systems
   viii. Duct systems
   ix. Air and water side economizers
   x. Make up air systems and exhaust systems
   xi. Variable air volume systems
   xii. Control systems
   xiii. Electrical systems
   xiv. Life safety systems

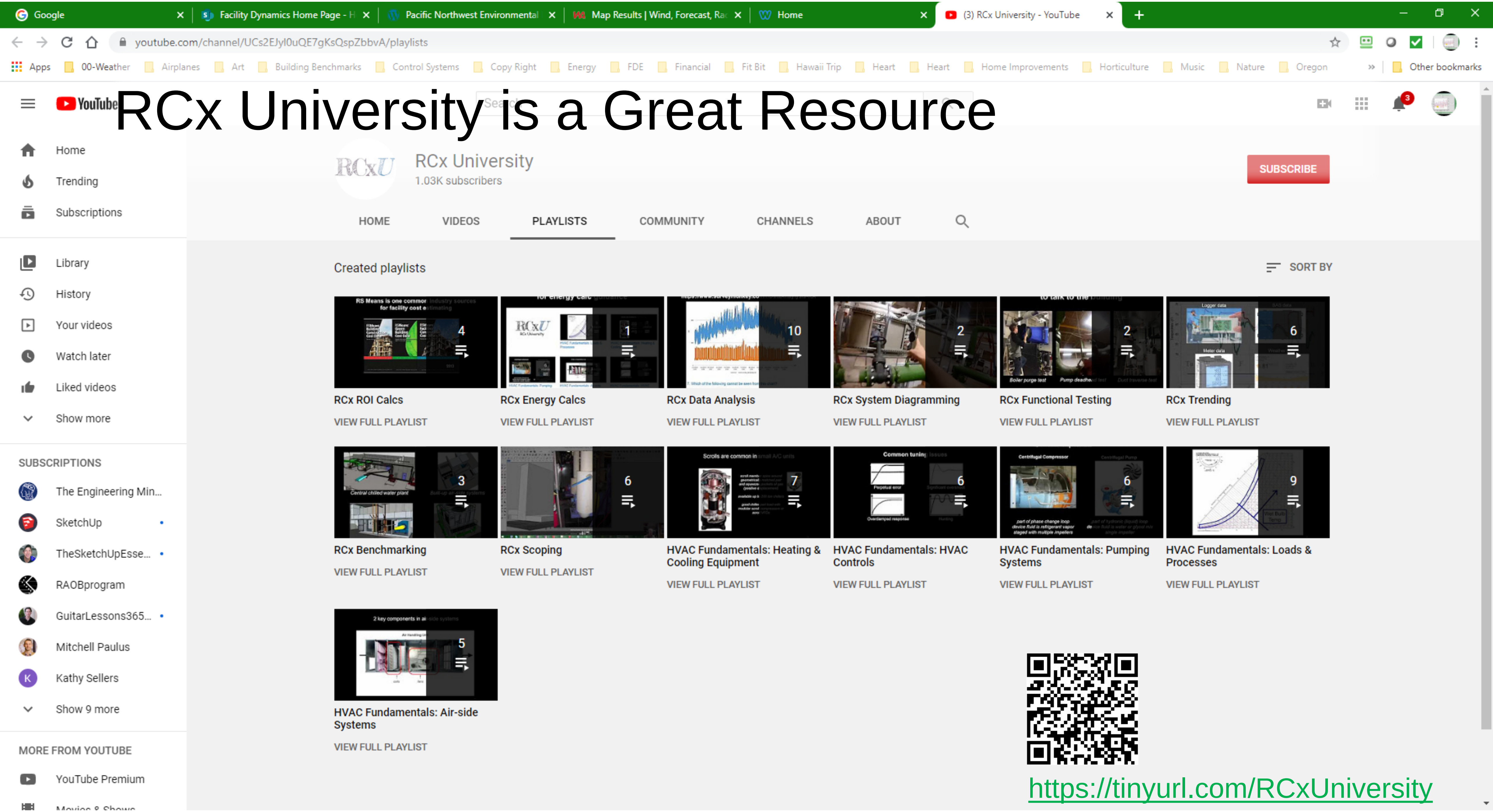
https://av8rdas.wordpress.com/2014/01/14/key-retrocommissioning-skills/

Bottom Line

There’s a lot to learn!

A Few Resources to Get You Started

RCx University is a Great Resource



https://tinyurl.com/RCxUniversity

The EBCx Skills Guidebook is Built Around the 10 Skills

http://www.av8rdas.com/ebcx-skills-guidebook.html

HOME BLOG RESOURCES TRAINING CONTACT

Existing Building Commissioning Skills Guidebook

The guidebook is organized using the 10 Key Commissioning Skills as a framework and provides:

- A description and example of why the skill is important;
- Learning objectives to help guide a self study effort;
- Links to primary resources that can be used to learn about the skill in a self study effort;
- Links to secondary resources that can be used to dig in deeper if you have a particular interest in a particular topic.

The *10 Skills Learning Objectives Checklist* is intended to complement the guidebook by providing a list of all of the learning objectives with a check-box that allows you to track your progress as you work your way through the guidebook in a self study effort.

EBCx Skills Guidebook (ebcx_technical_skills_guidebook_v2017-07-07_web.pdf)
Download File

10 Skills Learning Objectives Checklist (skills_table_web_v5.xlsx)
Download File

Facility Dynamics Engineering — *Existing Building Commissioning Guidebook*

Introduction

Over the years, Facility Dynamics has been involved with providing technical training with a focus on existing building commissioning in a number of different venues and for a number of different clients including the Pacific Energy Center, Marriott, and IMCOM. For those programs, I have frequently been the lead technical trainer.

As the training agendas evolved, it started to become clear that there were a number of key skills that it would be desirable to develop if you were going to pursue existing building commissioning. About 5 years ago, Russ Good and Barry Estes of Marriott International asked me to make a list of the ten most important skills and to complement it with a list of the three primary resources that were available were available to help develop each skill.

At that point in time, I had already compiled a list of technical resources that we used to support the classes, but it was about 40 pages long and always growing. So, it could be a bit overwhelming if you were just getting into this and Russ and Barry wanted me to figure out how to focus things a bit.

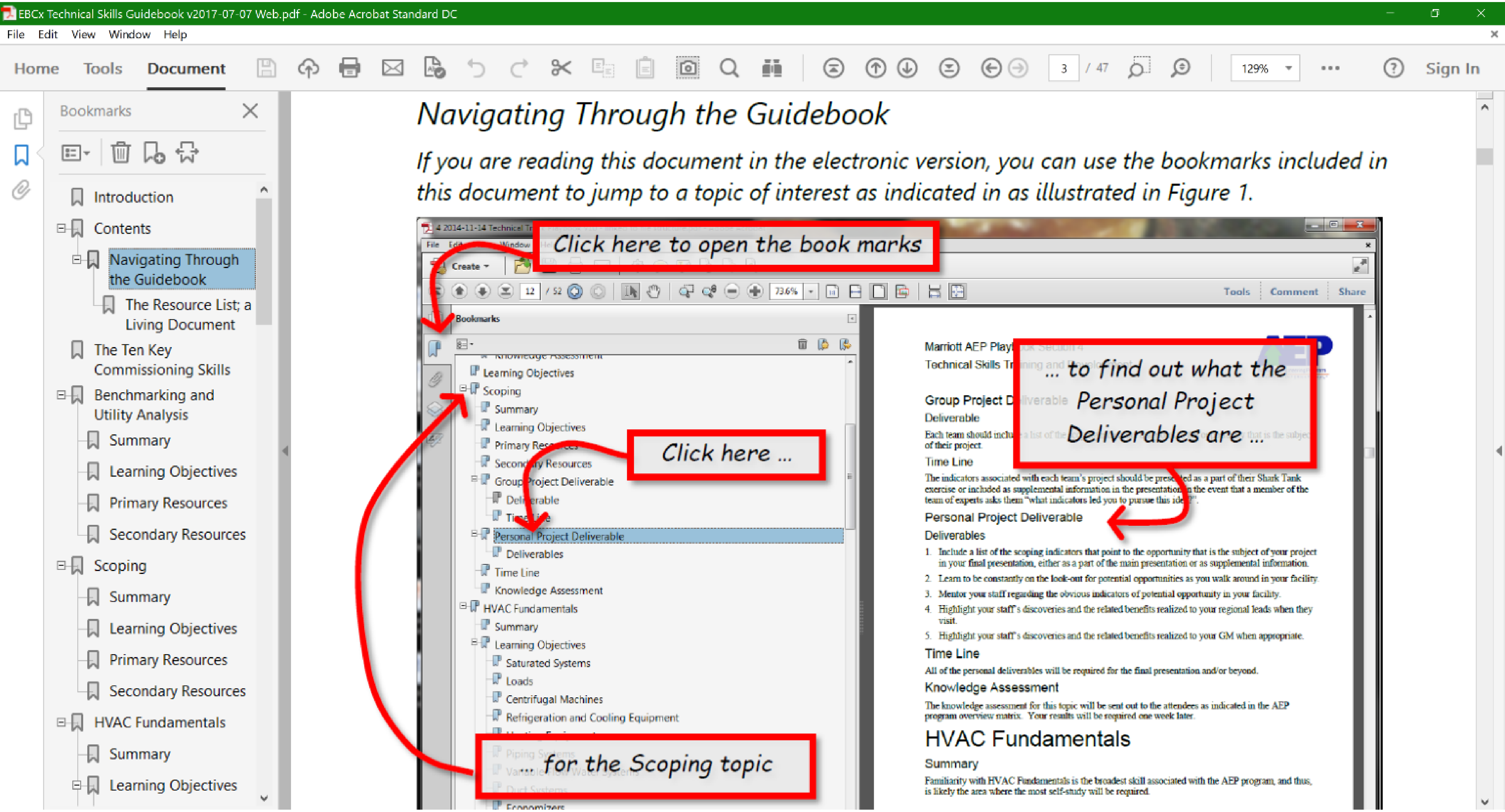
That forced me to think about what really mattered from a technical stand point if you are out in the field doing this sort of work. It was really hard for me to whittle the list down to only 10 skills, but Barry and Russ were pretty firm on that, and I finally pulled it off. Truth be told, I kind of cheated in a way because I made one of the skills Familiarity with HVAC fundamentals and then put 10 sub-skills under that.

But the exercise was a really good one and when I was finished, I realized that the list was a pretty good framework for organizing the technical side of any of the training classes and I have been using it ever since in that manner. In addition, I reorganized the resource list so that the resources were grouped under headings that correlated with the 10 skills.

I also should point out that while the driver for developing the list of the 10 skills was Existing Building Commissioning training, the skills really apply across the boards. In other words, you generally will use the same skills for new construction commissioning, ongoing commissioning, and general building operations.

In fact, one of my little jokes in class is that there are all sorts of names and acronyms applied to processes where you apply the 10 skills, including Existing Building Commissioning, EBCx, Retrocommissioning, RCx, Building Tune-ups, Ongoing Commissioning, NCx, Facility Operations, etc. I have had the opportunity to work on projects where all of those names have been applied to what I was doing.

But when I think about it, all of them generally are technically the same thing that I was doing back in 1976, when I first became involved with the industry. Back then, we just called it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Bookmarks
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The Resource List; a Living Document
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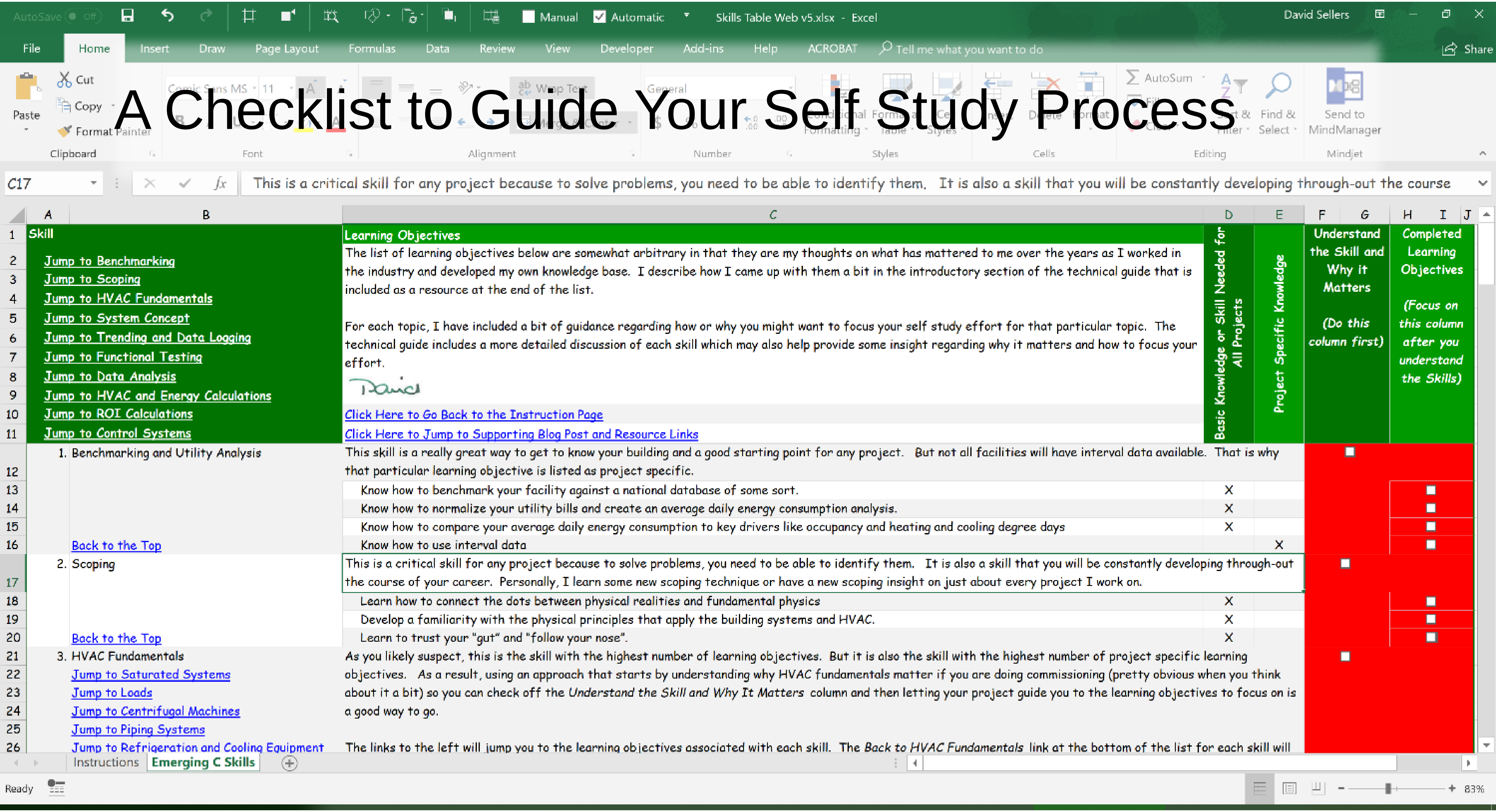
Secondary Resources
Scoping
Summary
Learning Objectives
Primary Resources
Secondary Resources
HVAC Fundamentals
Summary
Learning Objectives
Navigating Through the Guidebook
If you are reading this document in the electronic version, you can use the bookmarks included in this document to jump to a topic of interest as indicated in as illustrated in Figure 1.
Click here to open the book marks
Click here ...
... to find out what the Personal Project Deliverables are ...
... for the Scoping topic
Bookmarks
Learning Objectives
Scoping
Summary
Learning Objectives
Group Project Deliverable
Personal Project Deliverable
Deliverables
Time Line
Knowledge Assessment
HVAC Fundamentals
Summary
Learning Objectives
Saturated Systems
Loads
Centrifugal Machines
Refrigeration and Cooling Equipment
Tools Comment Share
Marriott AEP Play
Technical Skills Tr
Group Project D
Deliverable
Time Line
Personal Project Deliverable
Deliverables
1. Include a list of the scoping indicators that point to the opportunity that is the subject of your project in your final presentation, either as a part of the main presentation or as supplemental information.
2. Learn to be constantly on the look-out for potential opportunities as you walk around in your facility.
3. Mentor your staff regarding the obvious indicators of potential opportunity in your facility.
4. Highlight your staff's discoveries and the related benefits realized to your regional leads when they visit.
5. Highlight your staff's discoveries and the related benefits realized to your GM when appropriate.
Time Line
All of the personal deliverables will be required for the final presentation and/or beyond.
Knowledge Assessment
The knowledge assessment for this topic will be sent out to the attendees as indicated in the AEP program overview matrix. Your results will be required one week later.
HVAC Fundamentals
Summary
Familiarity with HVAC Fundamentals is the broadest skill associated with the AEP program, and thus, is likely the area where the most self-study will be required.

A Checklist to Guide Your Self Study Process



Skills Table Web v5.xlsx - Excel

C17 — 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 through-out the course

Skill	Learning Objectives	Basic Knowledge or Skill Needed for All Projects	Project Specific Knowledge	Understand the Skill and Why it Matters (Do this column first)	Completed Learning Objectives (Focus on this column after you understand the Skills)
Jump to Benchmarking Jump to Scoping Jump to HVAC Fundamentals Jump to System Concept Jump to Trending and Data Logging Jump to Functional Testing Jump to Data Analysis Jump to HVAC and Energy Calculations Jump to ROI Calculations Jump to Control Systems	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. 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. David Click Here to Go Back to the Instruction Page Click Here to Jump to Supporting Blog Post and Resource Links				
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 is why that particular learning objective is listed as project specific.			☐	
	Know how to benchmark your facility against a national database of some sort.	X			☐
	Know how to normalize your utility bills and create an average daily energy consumption analysis.	X			☐
	Know how to compare your average daily energy consumption to key drivers like occupancy and heating and cooling degree days	X			☐
Back to the Top	Know how to use interval data		X		☐
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 through-out the 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.			☐	
	Learn how to connect the dots between physical realities and fundamental physics	X			☐
	Develop a familiarity with the physical principles that apply the building systems and HVAC.	X			☐
Back to the Top	Learn to trust your "gut" and "follow your nose".	X			☐
3. HVAC Fundamentals Jump to Saturated Systems Jump to Loads Jump to Centrifugal Machines Jump to Piping Systems Jump to Refrigeration and Cooling Equipment	As you likely suspect, this is the skill with the highest number of learning objectives. But it is also the skill with the highest number of project specific learning objectives. As a result, using an approach that starts by understanding why HVAC fundamentals matter if you are doing commissioning (pretty obvious when you think about it a bit) so you can check off the *Understand the Skill and Why It Matters* column and then letting your project guide you to the learning objectives to focus on is a good way to go. The links to the left will jump you to the learning objectives associated with each skill. The *Back to HVAC Fundamentals* link at the bottom of the list for each skill will			☐	

Instructions | Emerging C Skills

The Resource List is Organized Around the 10 Skills

http://www.av8rdas.com/resource-list.html

Resource List

The list is organized by the ten key technical skills we thing are important for anyone who wants to work in the commissioning and building operations fields. If you want to know what we think those skills are and why, just click here.

If you turn on the bookmarks in the .pdf document (typically, you can do that by clicking on the little ribbon shaped icon on the left side of the Acrobat window), you will links that will let you easily and quickly move around in the document. The document also includes a description of how to navigate through it in a section that starts on page 2.

We try to update the document every year or so, adding new things we have found, removing items that are obsolete, and

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Resources and Reading List

Date: November 2, 2011, (*Revised October 9, 2014*)

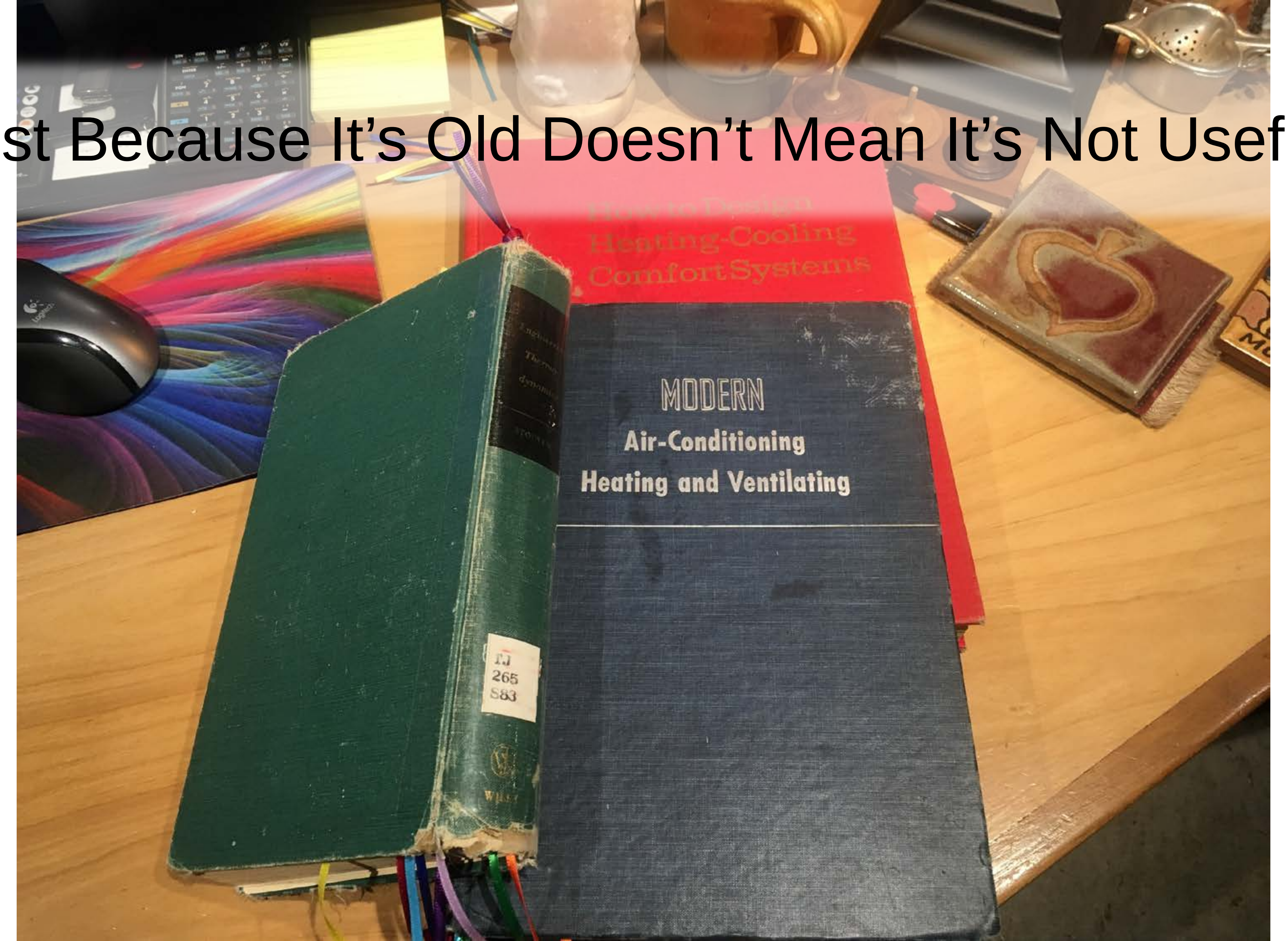
Overview

Over the years, one of the challenges we have faced in delivering technical classes for the Pacific Energy Center, the University of Wisconsin, SMUD, and other venues is to establish a common level of understanding of the fundamentals behind the topics to be discussed. Classes are often attended by people with a broad range of experience, including operators and facilities engineers who deal with technical issue and machinery on a day to day basis at one end of the technical spectrum and people new to the industry or who function more in management roles than technical roles at the other end. There can also be people with very deep knowledge in a focused area of expertise who have less depth in other areas.

Initially, we tried to address this by starting with the fundamentals and working our way up to the targeted content. But this tended to frustrate the more experienced attendees, reduced the time we had to spend on the intended topic, and could be overwhelming for the less experienced folks because we went at a pretty fast pace.

Over the past several years, we have successfully experimented with a different approach where-in we distribute a resource and reading list to attendees prior to class to allow them to self-educate where necessary. Typically, we supplement this list with a class specific cover memorandum to focus the pre-class preparation effort on topics we feel it is essential for you to understand to fully appreciate the class

Just Because It’s Old Doesn’t Mean It’s Not Useful



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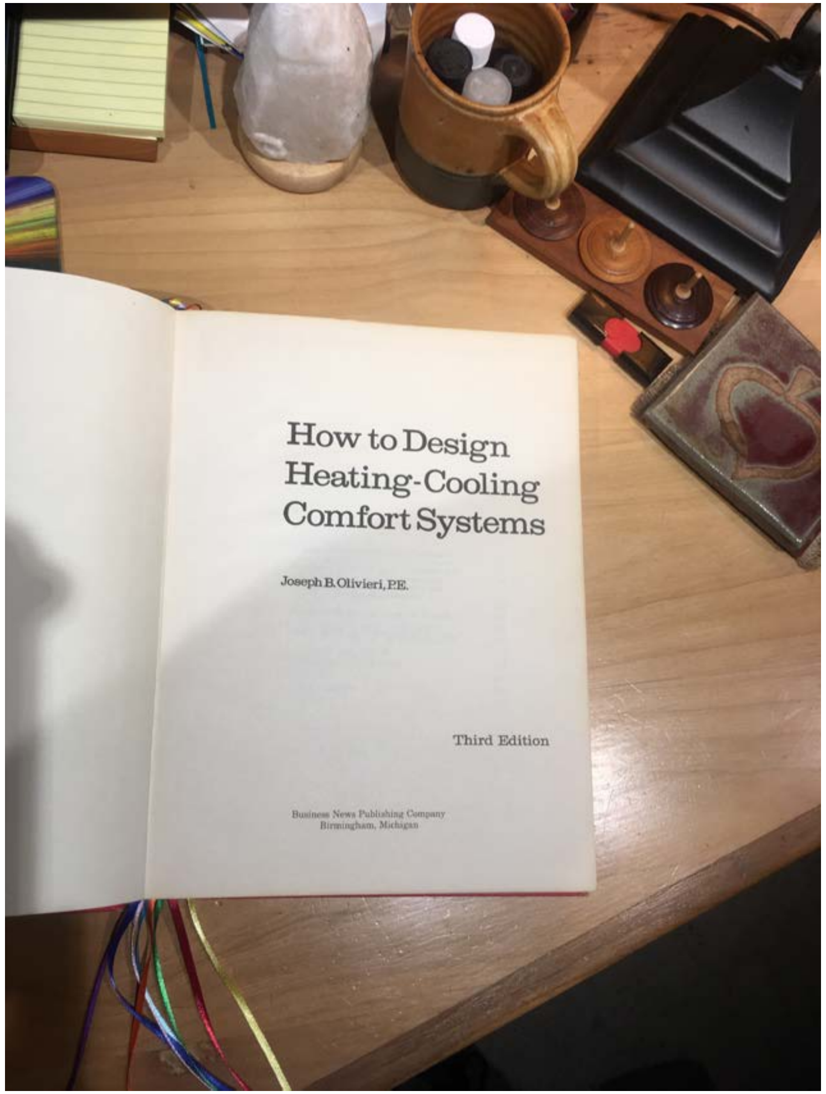

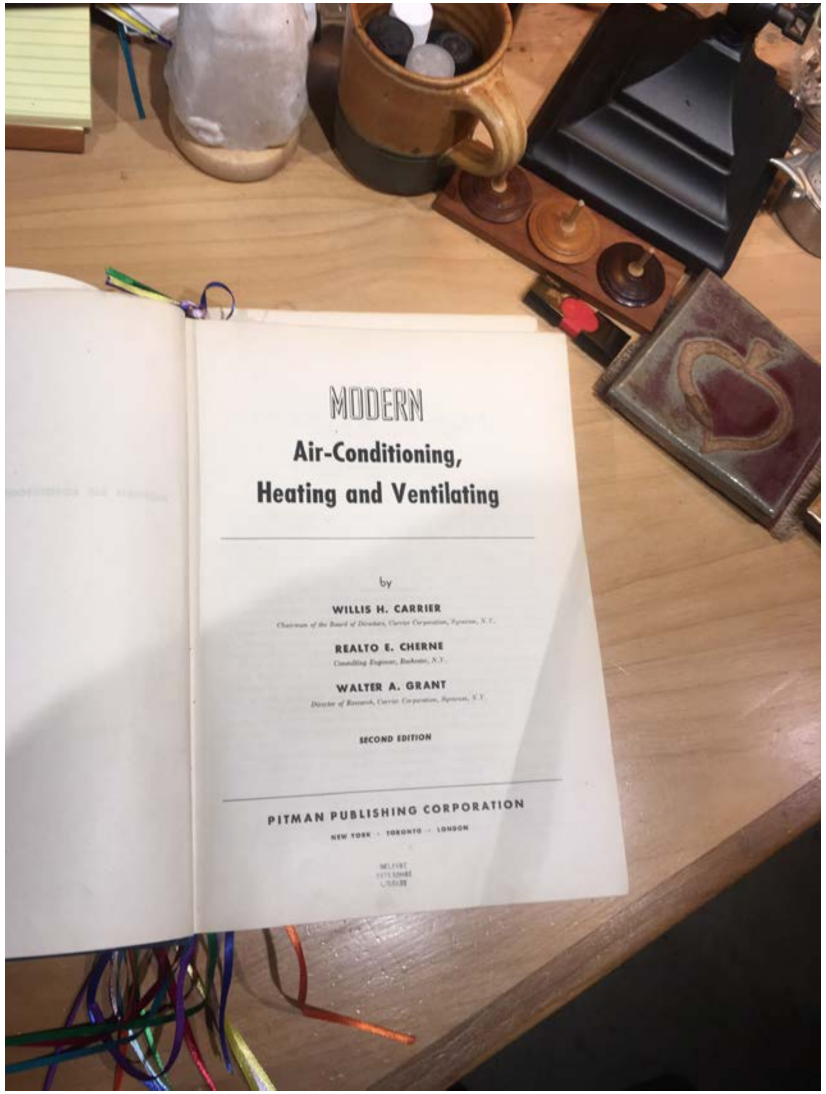

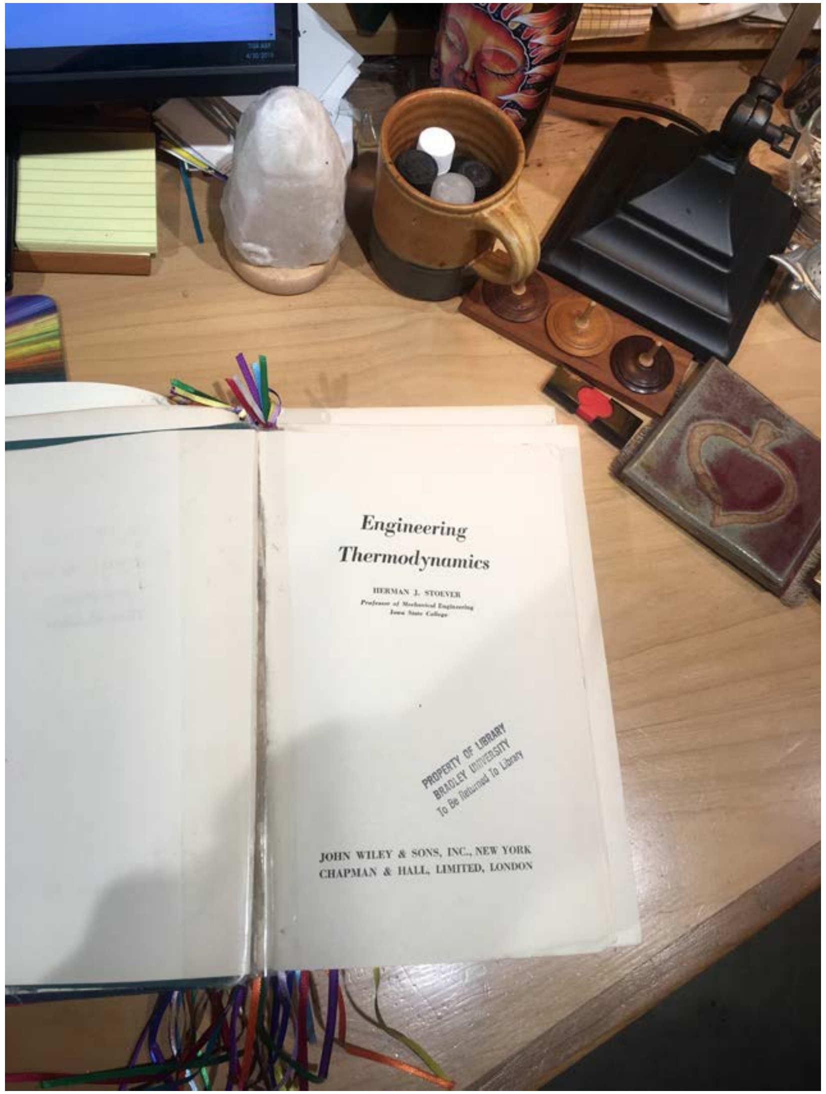

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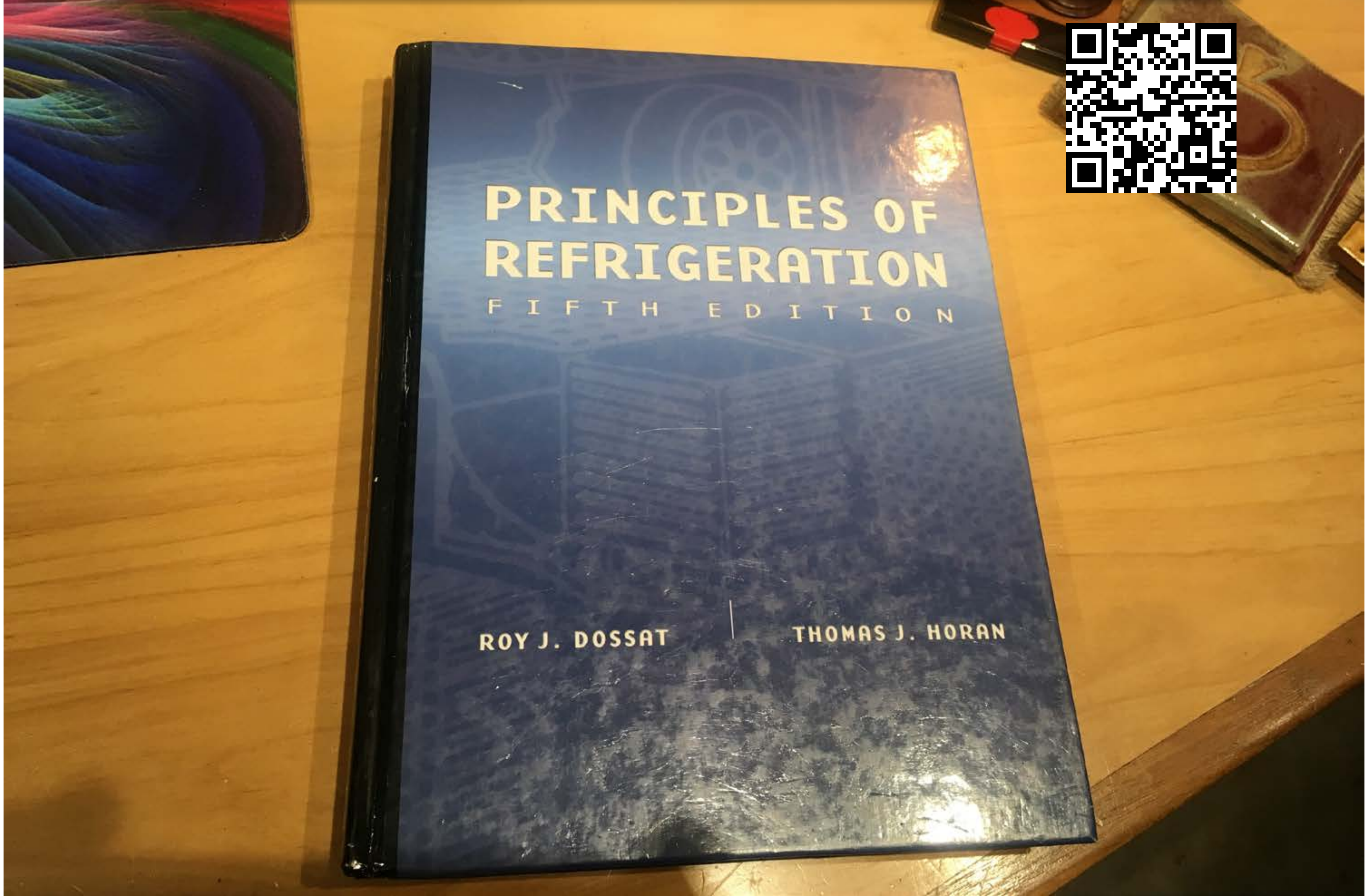
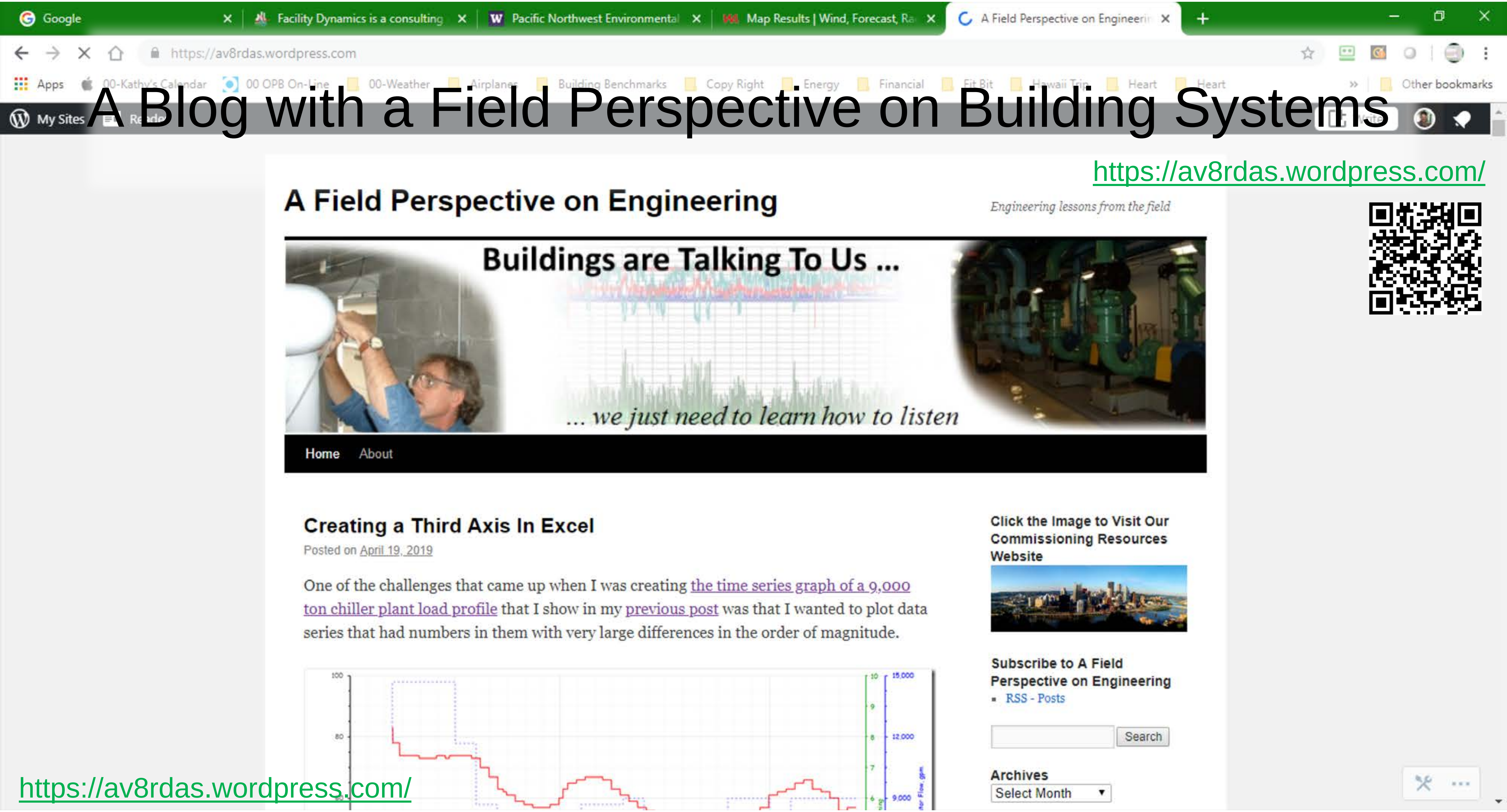


A Blog with a Field Perspective on Building Systems

https://av8rdas.wordpress.com/



https://av8rdas.wordpress.com/

A Commissioning Resources Web Site

http://www.av8rdas.com/

There’s Even a Cx Resource Built into Most Smart Phones

Flipping the Classroom

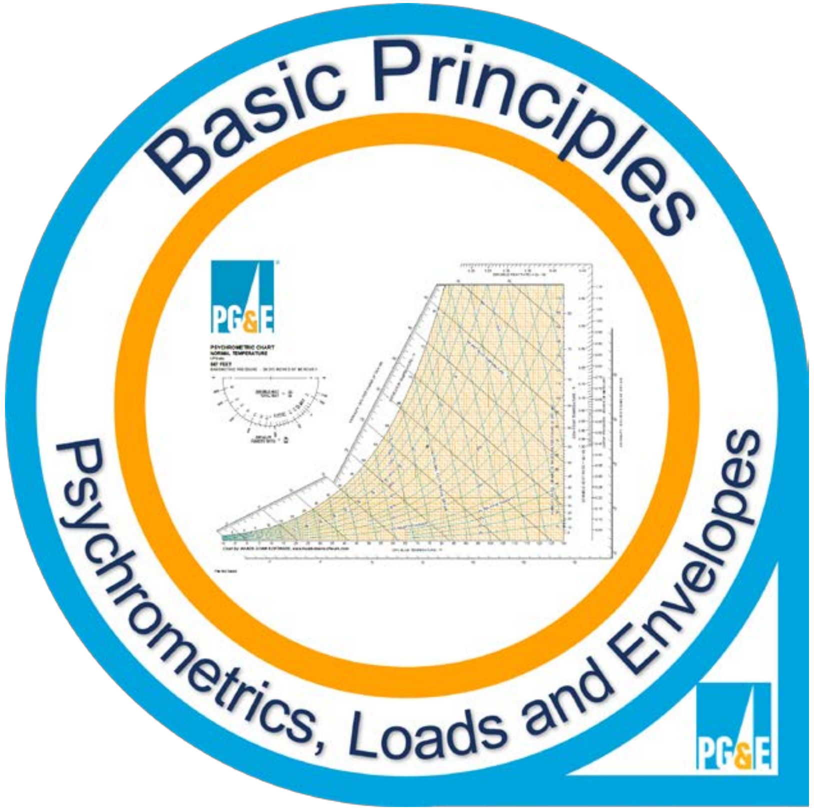
Our Learning Plan

Flip the Classroom

- Provide resources to allow self-paced self-study

Flip the Classroom

- Provide resources to allow self-paced self-study
- Use MS Form Base Quizzes to certify competence in the self study concepts
  - The Good News
    - You can try as many times as you need to
    - If you get a question wrong, you will be provided with a resource to help you get it right
    - One-on-one support will be available

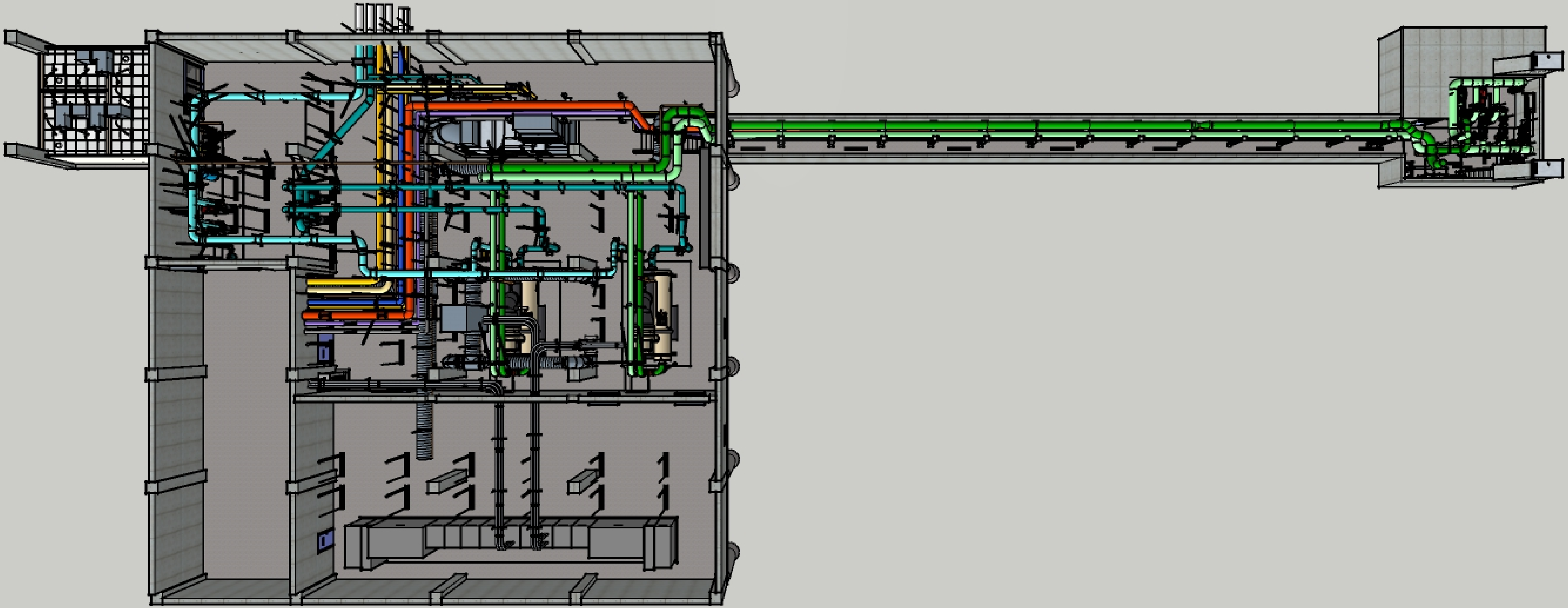


Flip the Classroom

- Use face to face and screen to screen time with the instructor for interactive exercises that apply the self study concepts

Flip the Classroom

SketchUp models will be used for virtual field experiences



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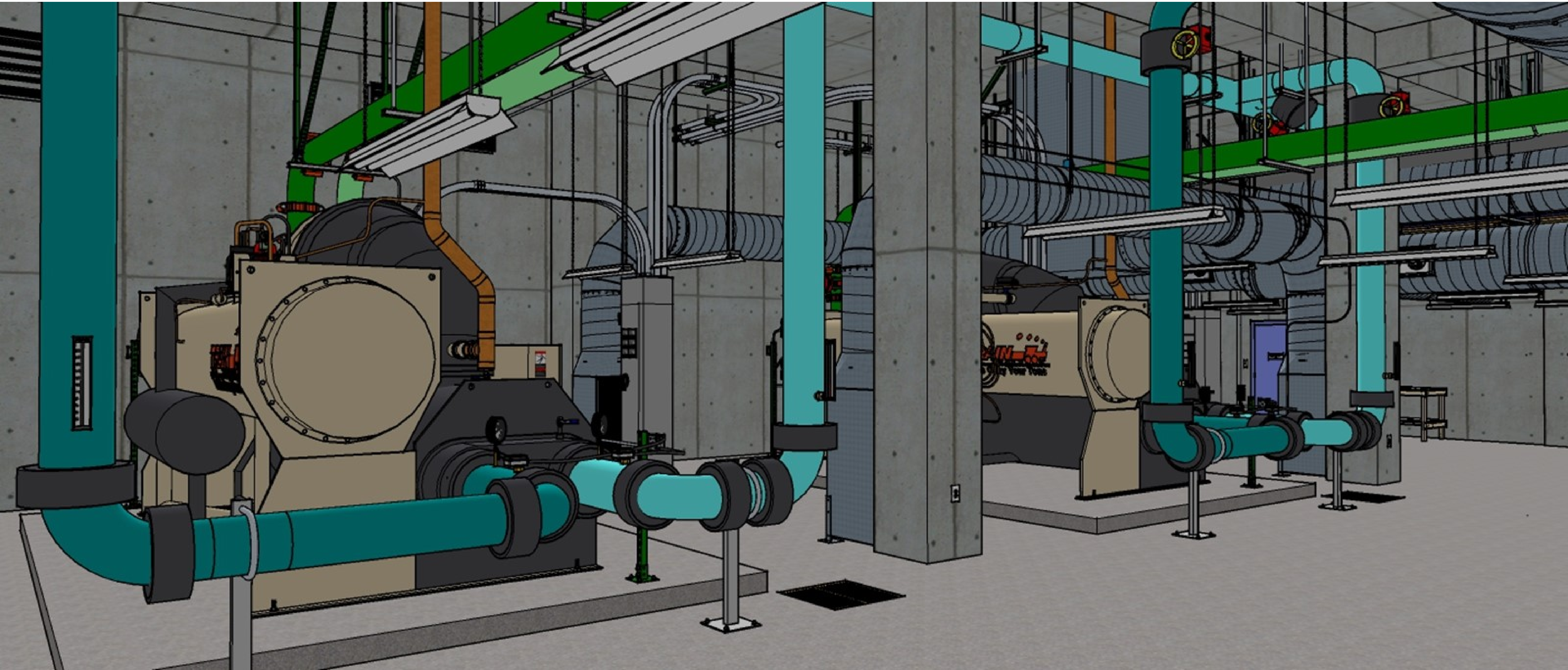

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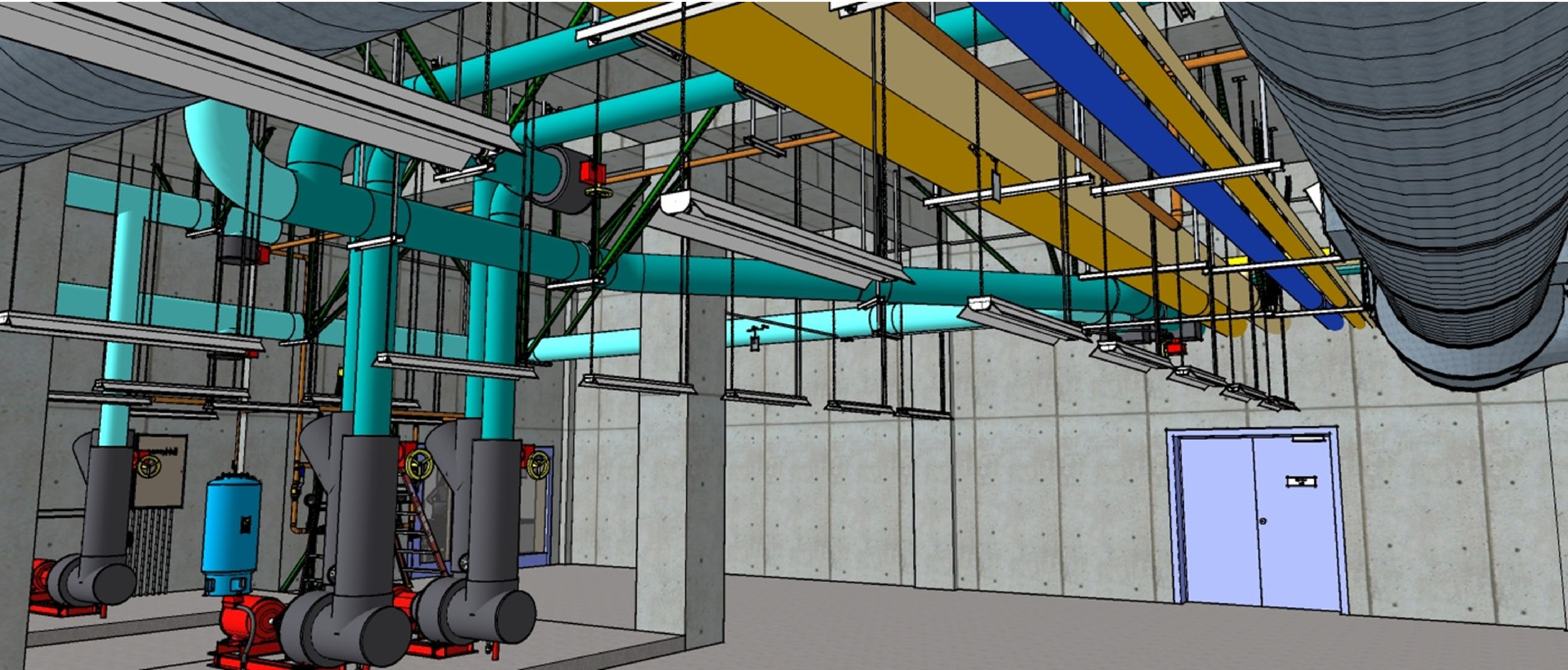

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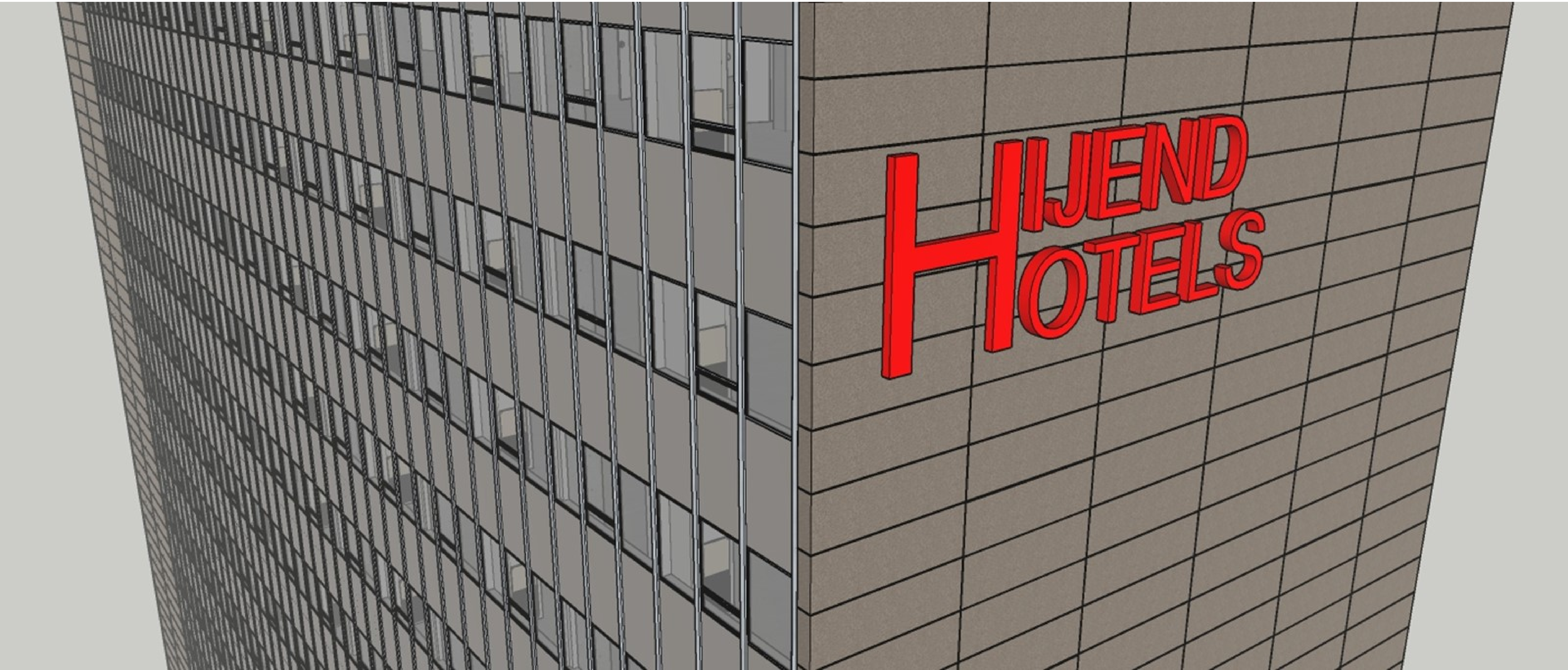

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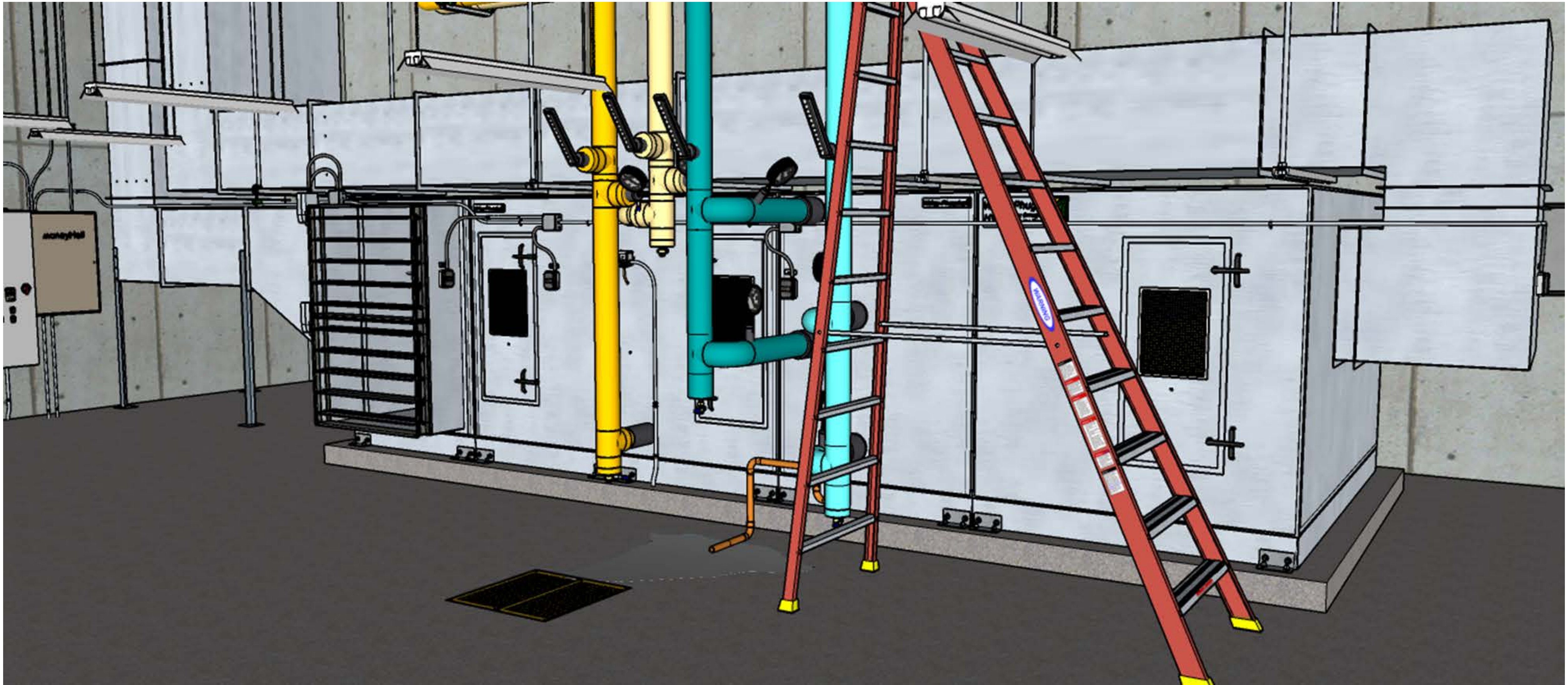
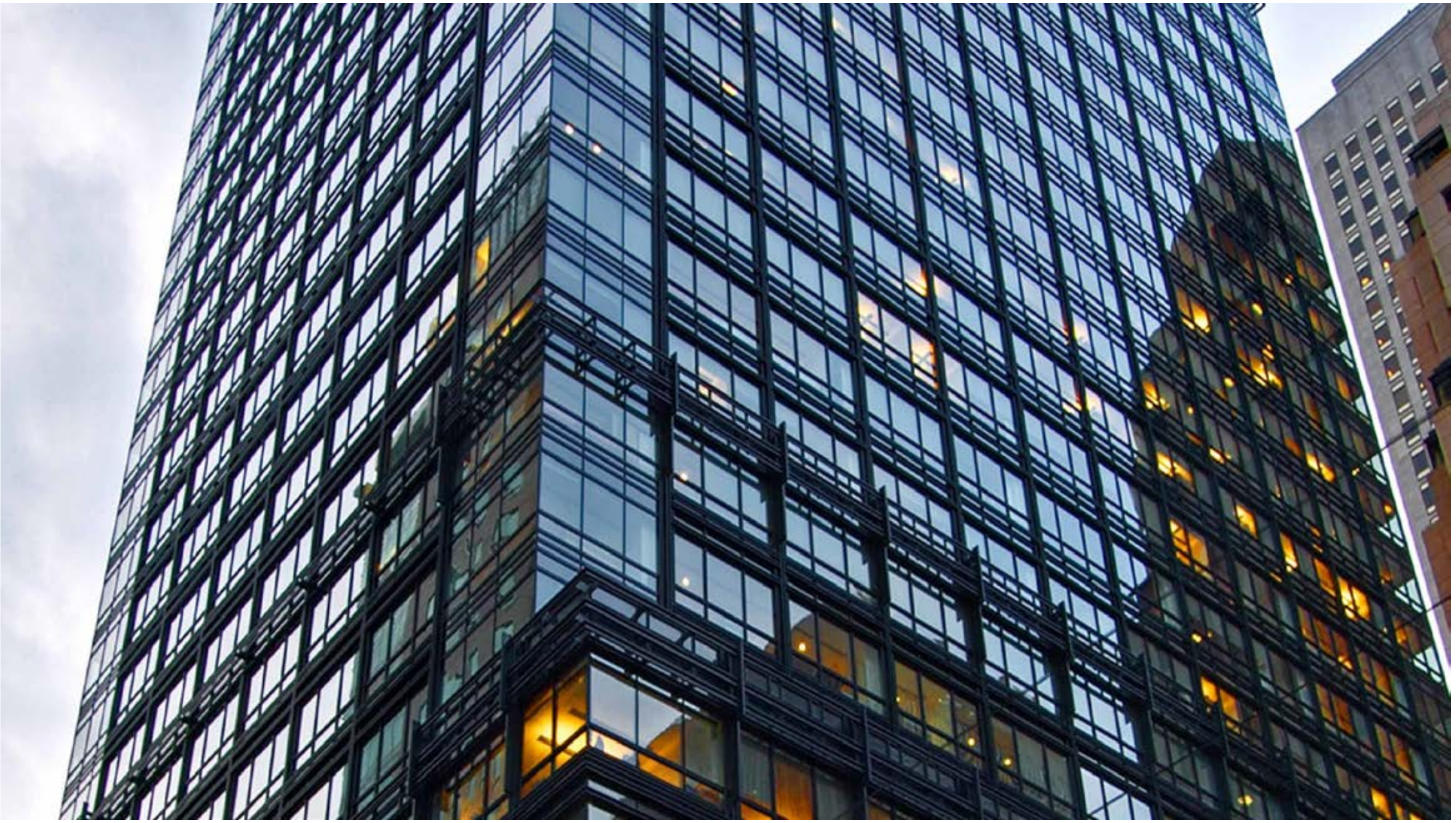


Flip the Classroom

- Use a personal project to apply the skills you learned and deliver improvements to your facility



What Is Building Commissioning?

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

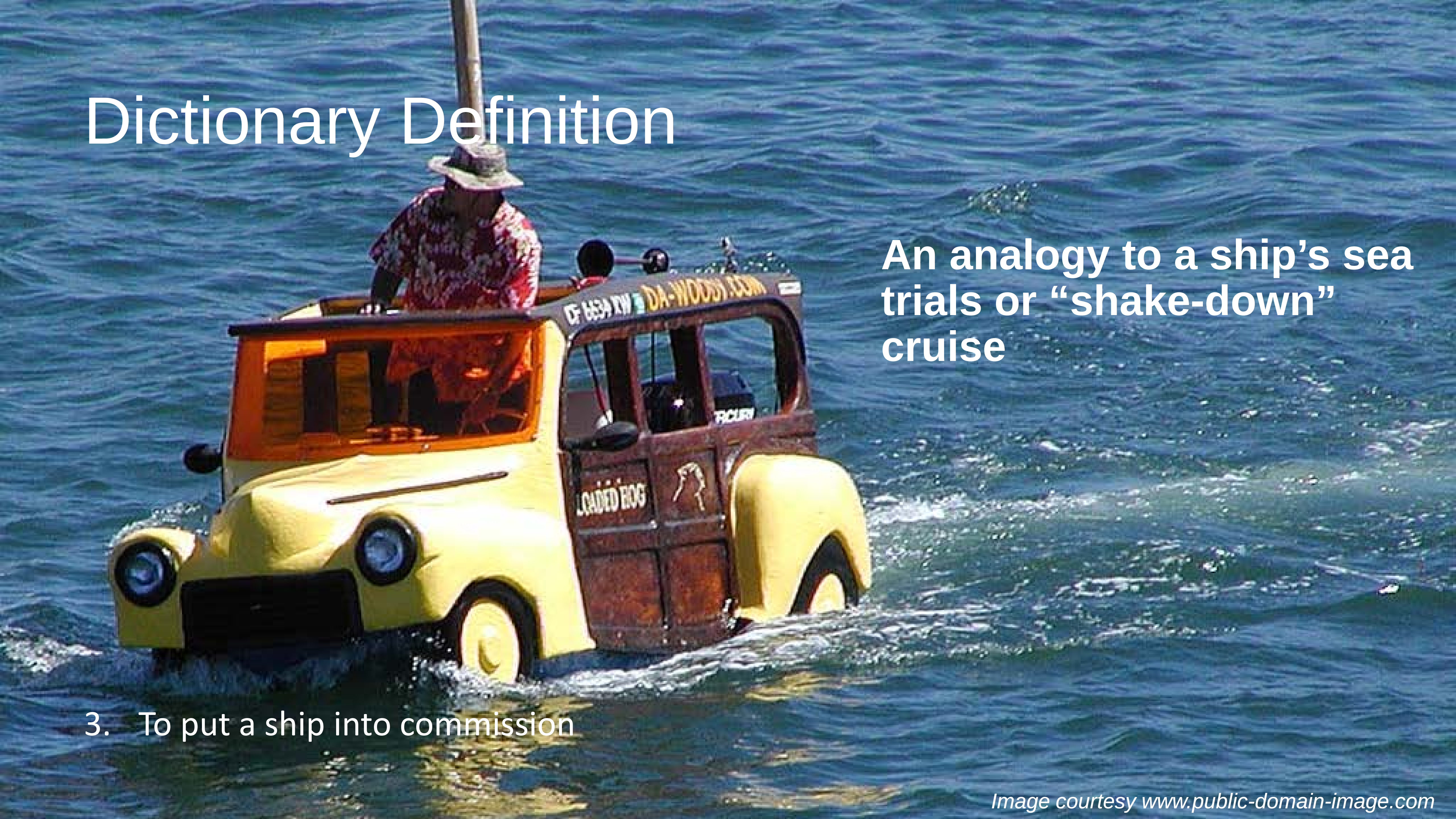
   synonyms: order, authorize, bespeak

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

   We had a few hiccups getting the heating equipment commissioned

3. To put a ship into commission

Dictionary Definition



An analogy to a ship's sea trials or "shake-down" cruise

3. To put a ship into commission

Image courtesy www.public-domain-image.com

Industry Definition

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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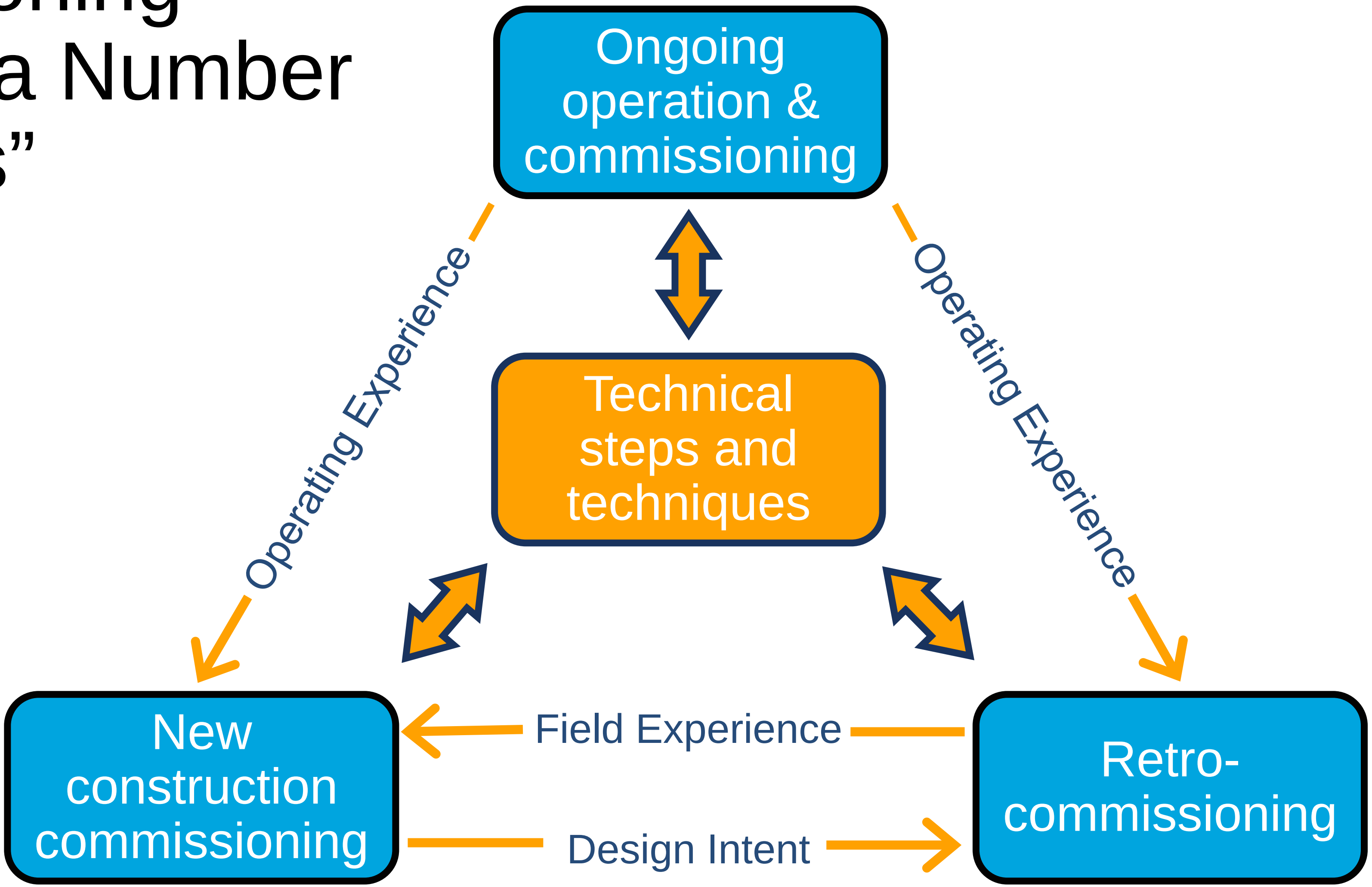
- Includes training
- Documents performance

Commissioning is about performance and integration

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

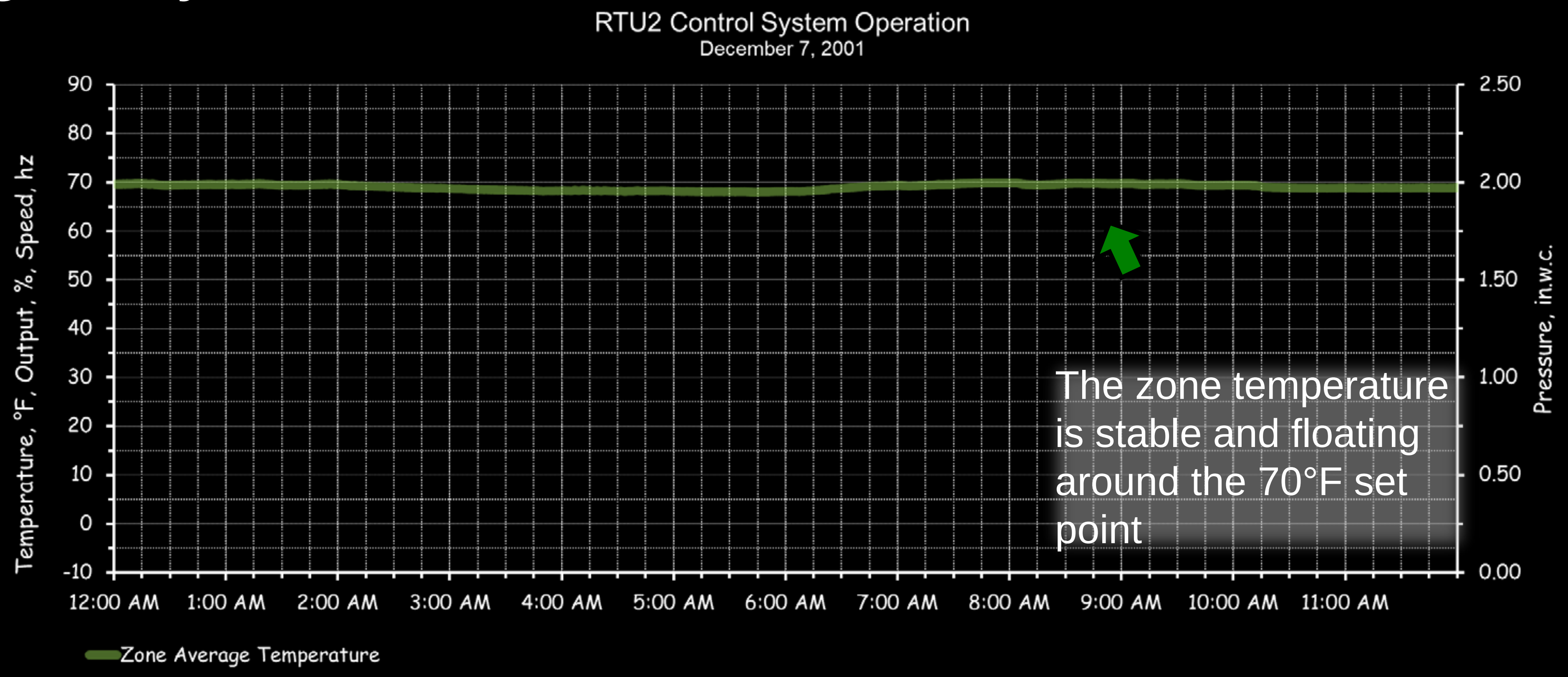
What folks called it when I started doing this stuff (1976)

You May Not Fully Comprehend the Situation

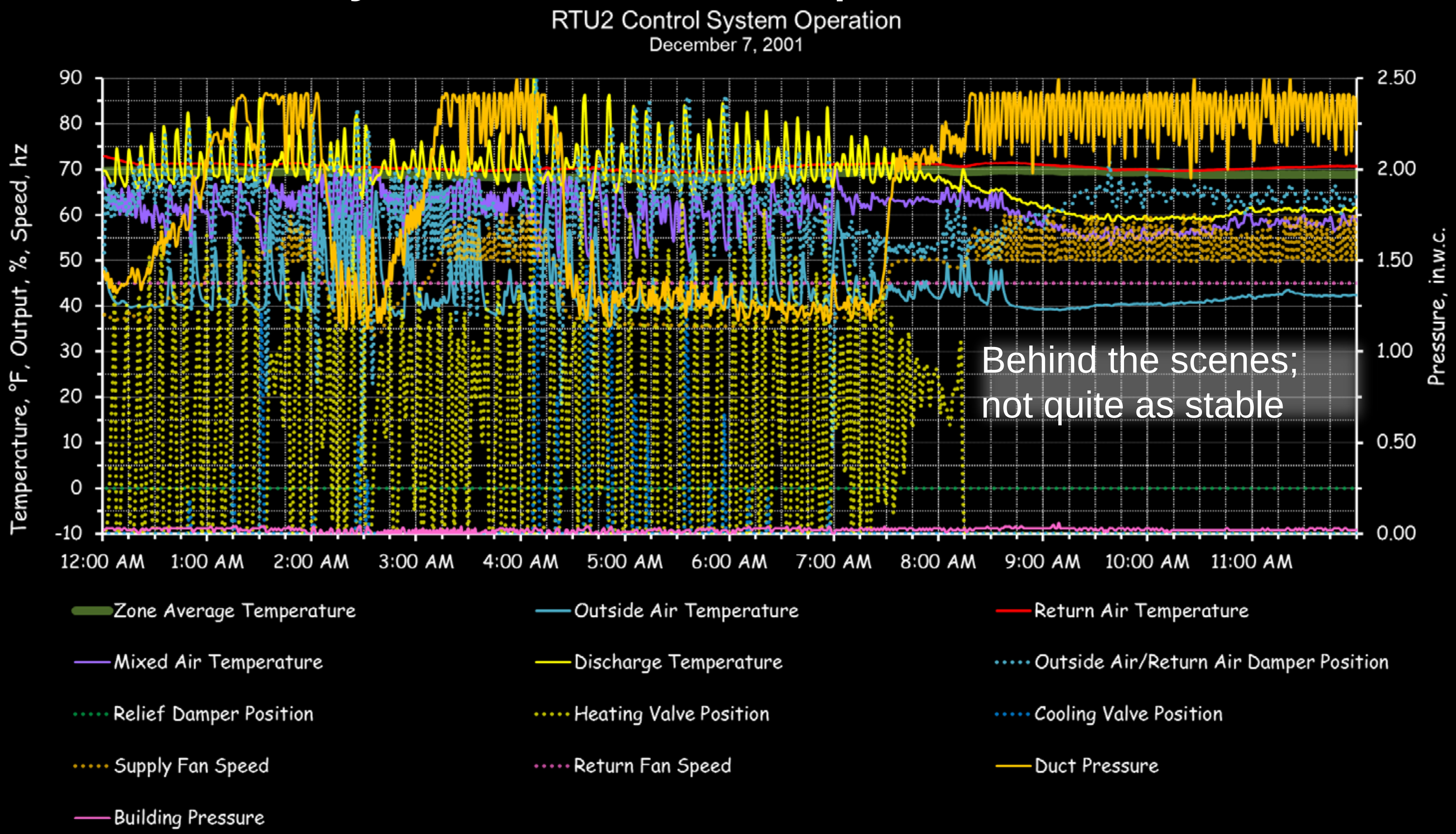
"… If you are piloting an untested vehicle on it's first test flight and that vehicle contains more propellant than was ever placed on a launch pad before and the vehicle was assembled by the low bidder and you aren't a little nervous, then you don't fully comprehend the situation"

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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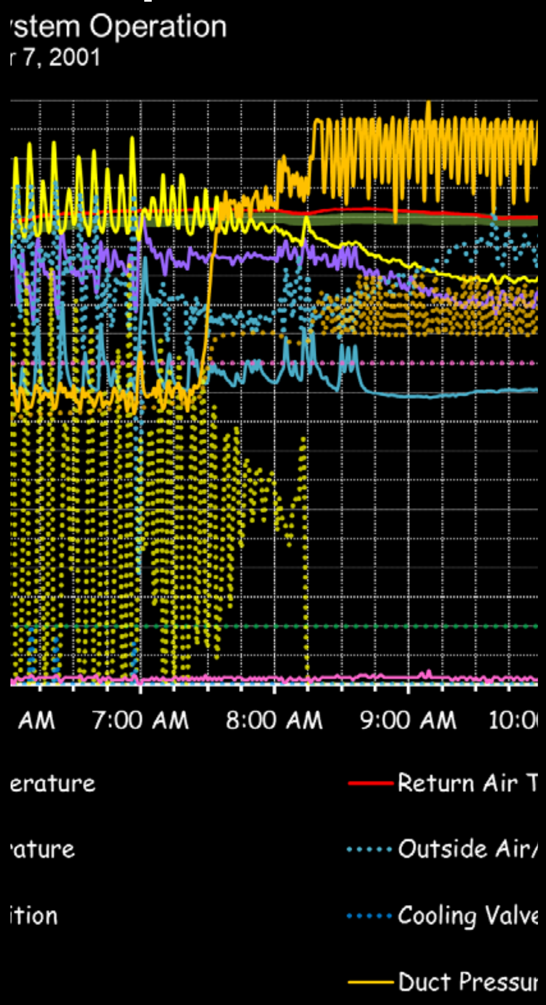
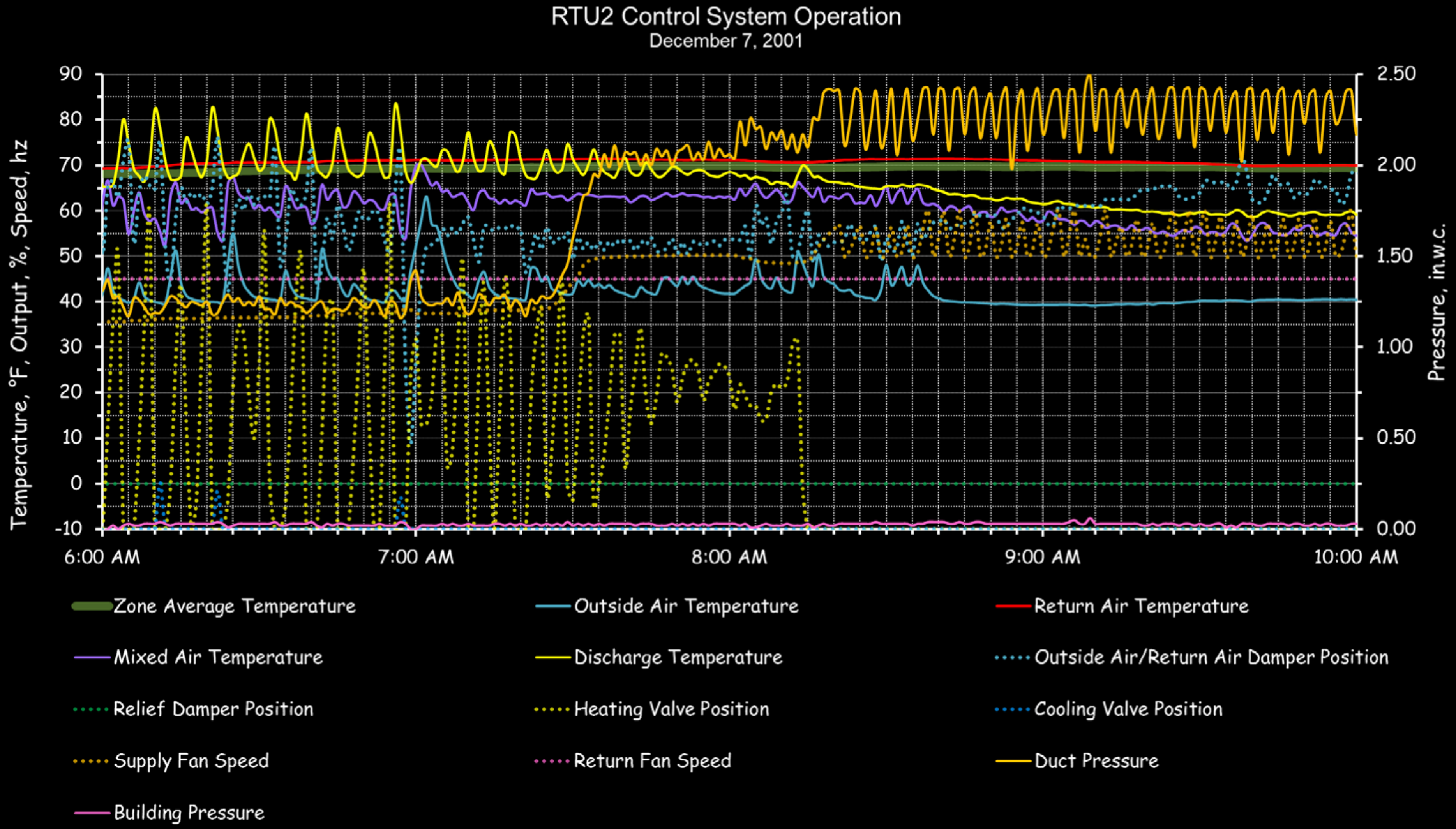
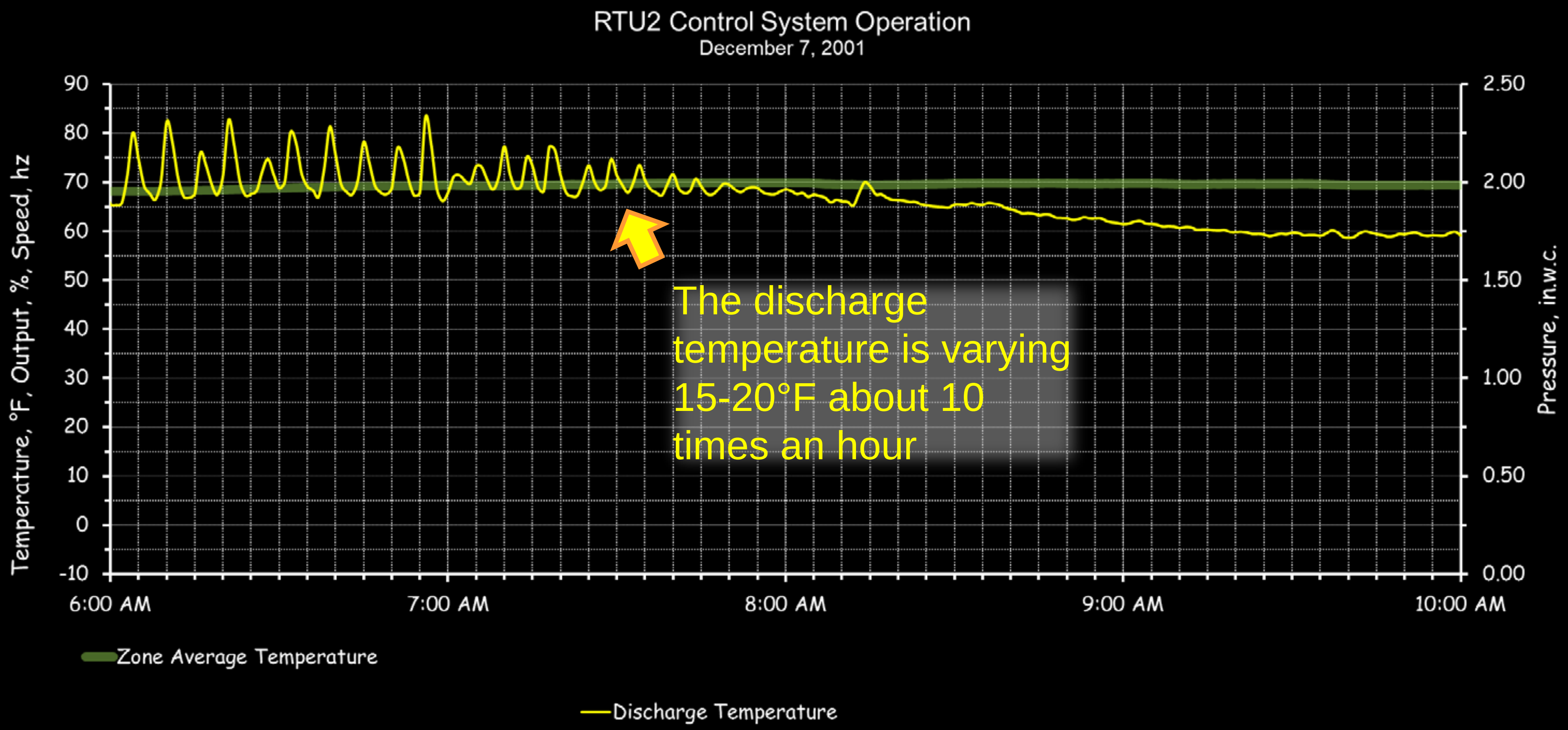


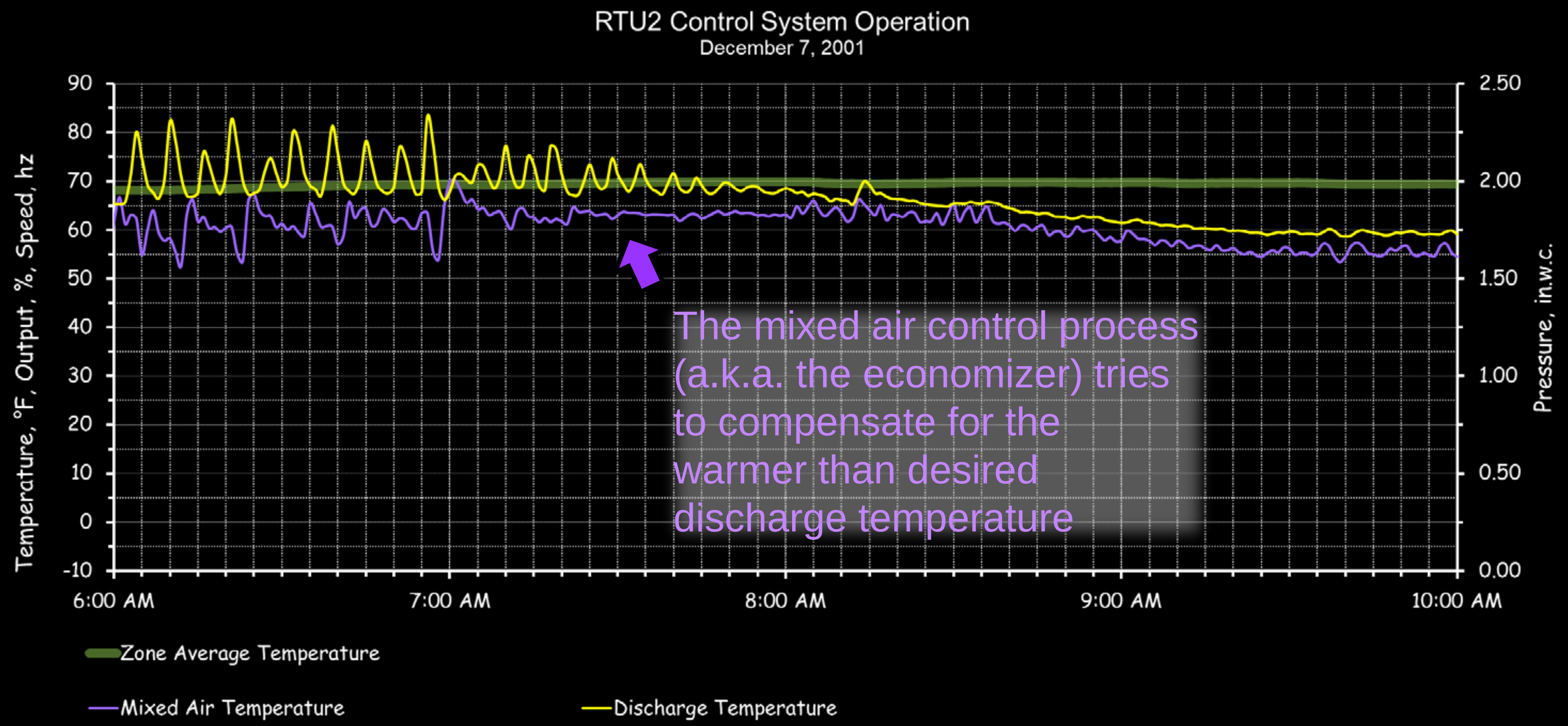
… and HVAC can be insidious



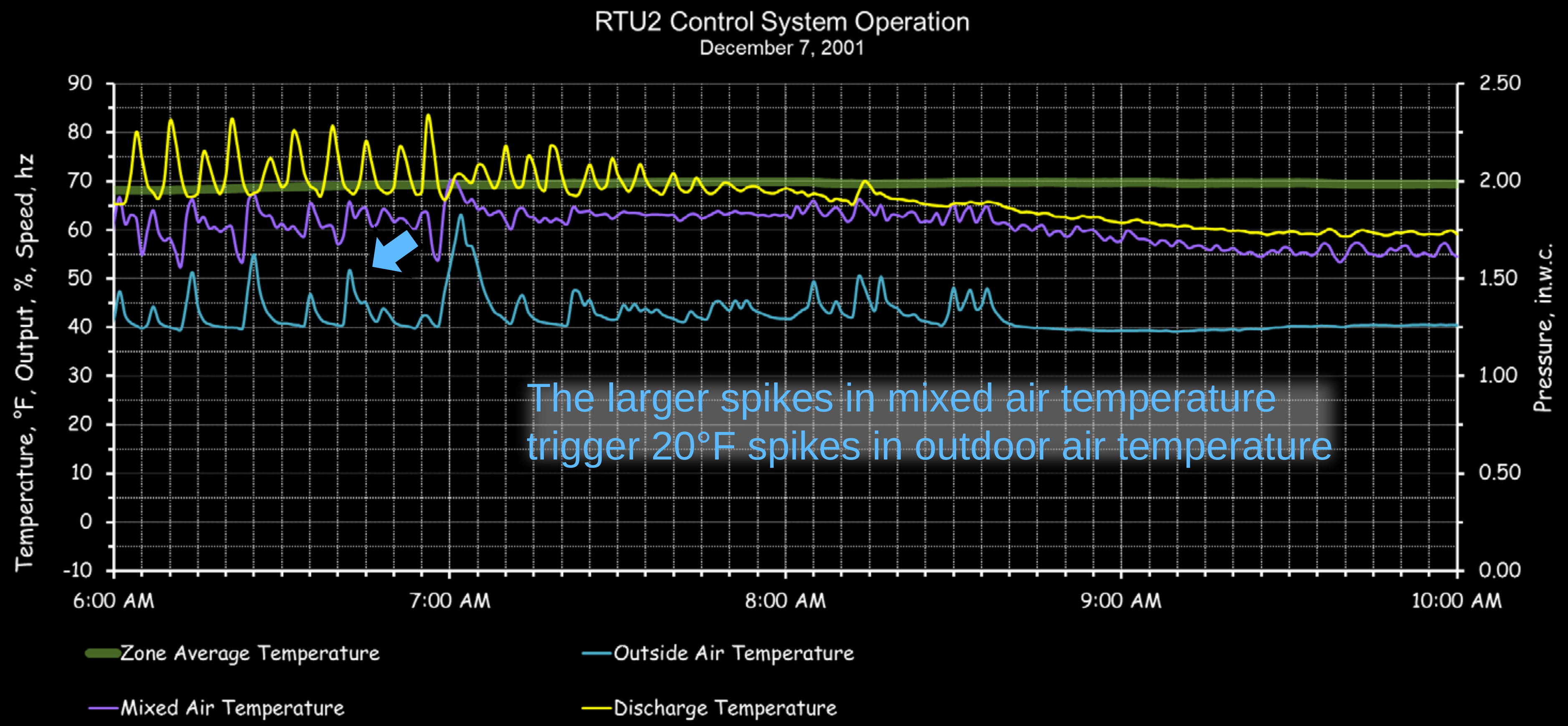
… and HVAC can be insidious



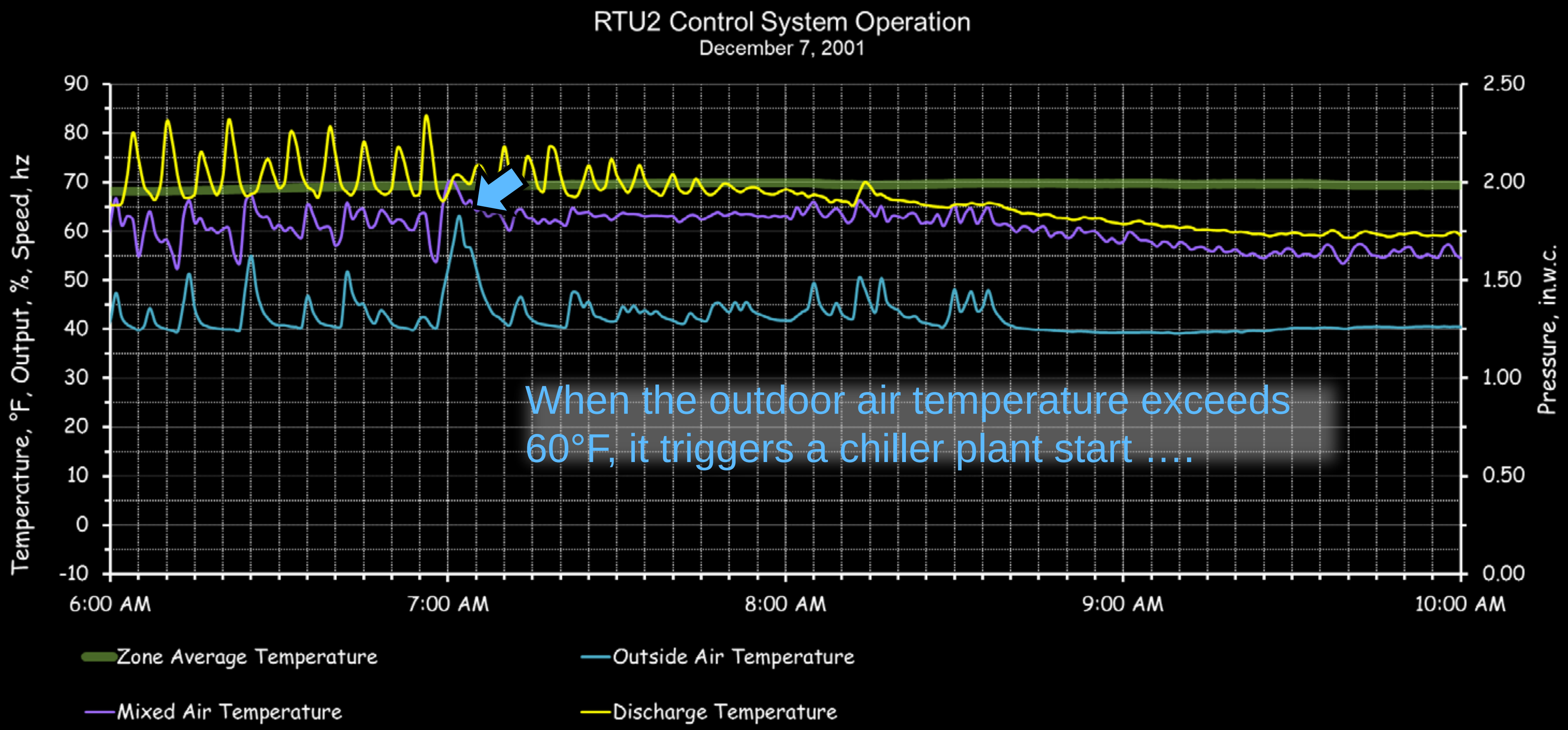
… and HVAC can be insidious



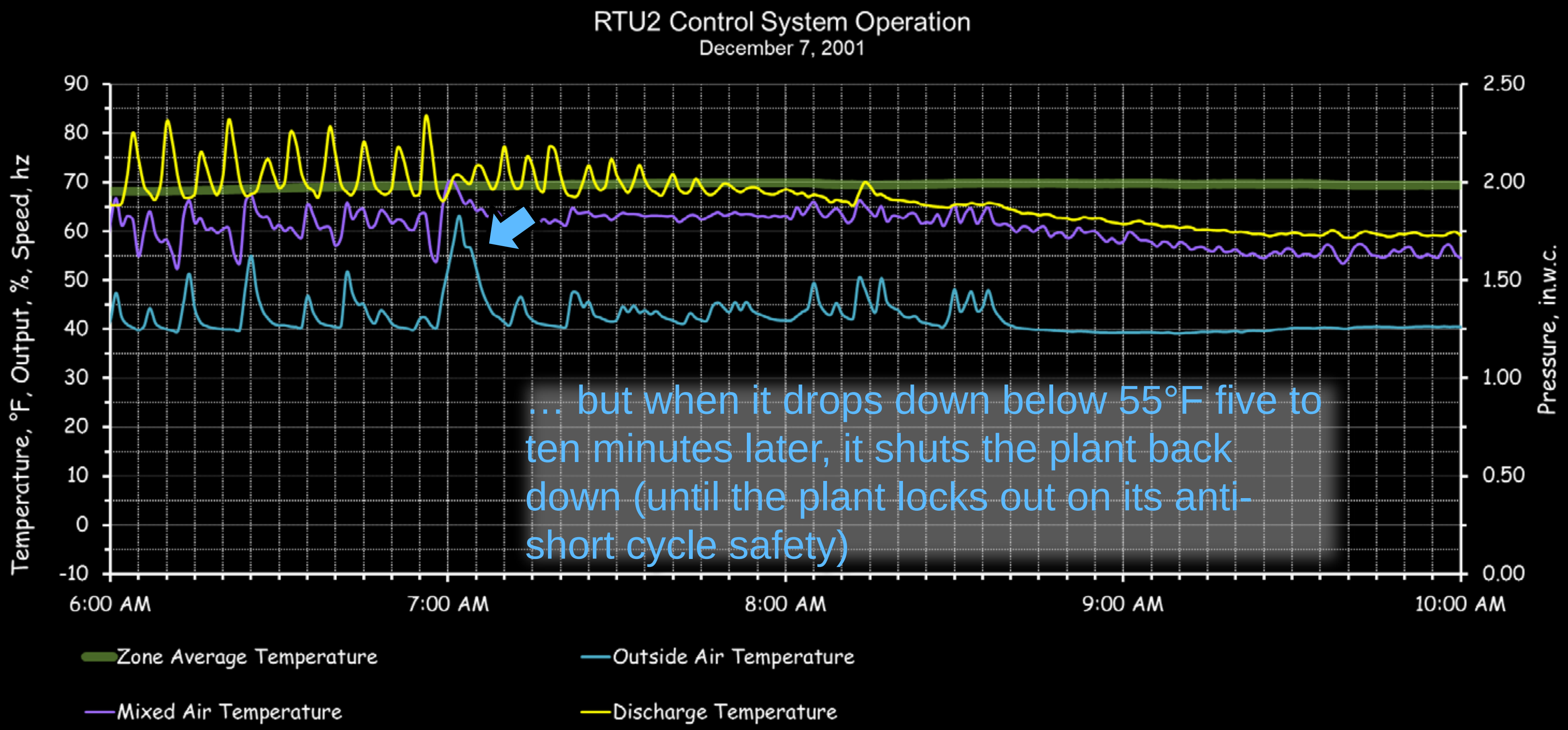
… and HVAC can be insidious



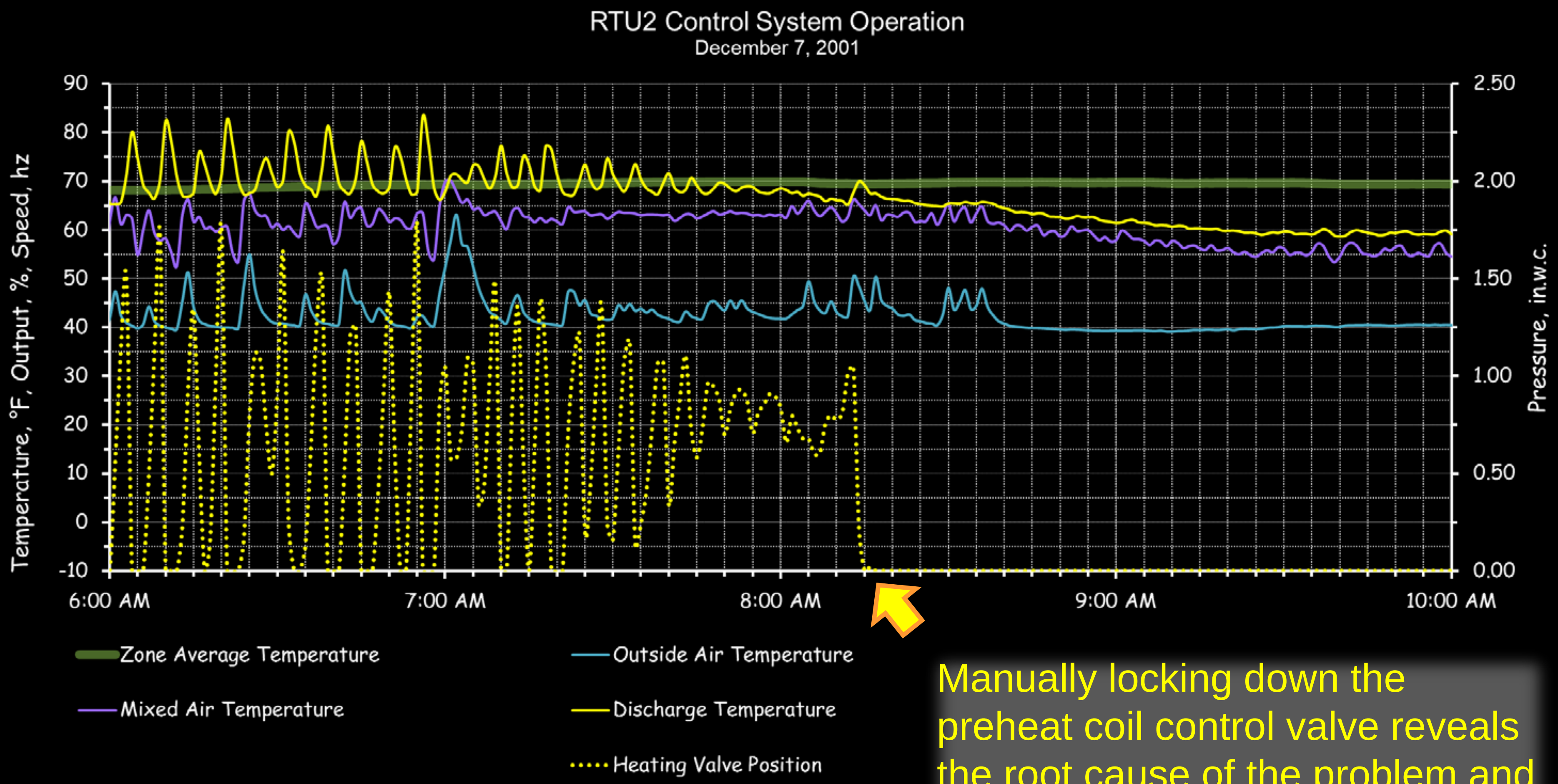
… and HVAC can be insidious



… and HVAC can be insidious

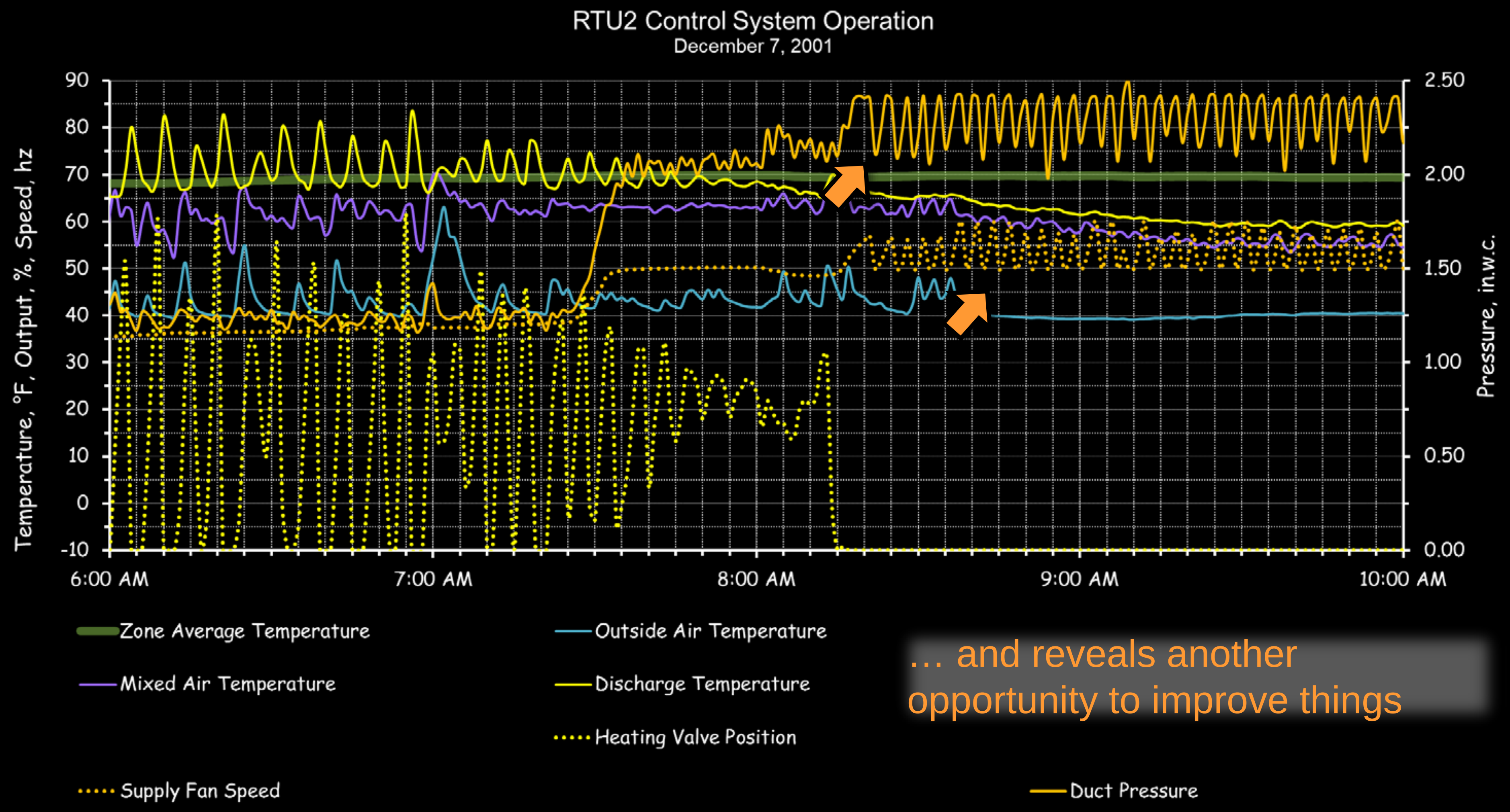


… and HVAC can be insidious



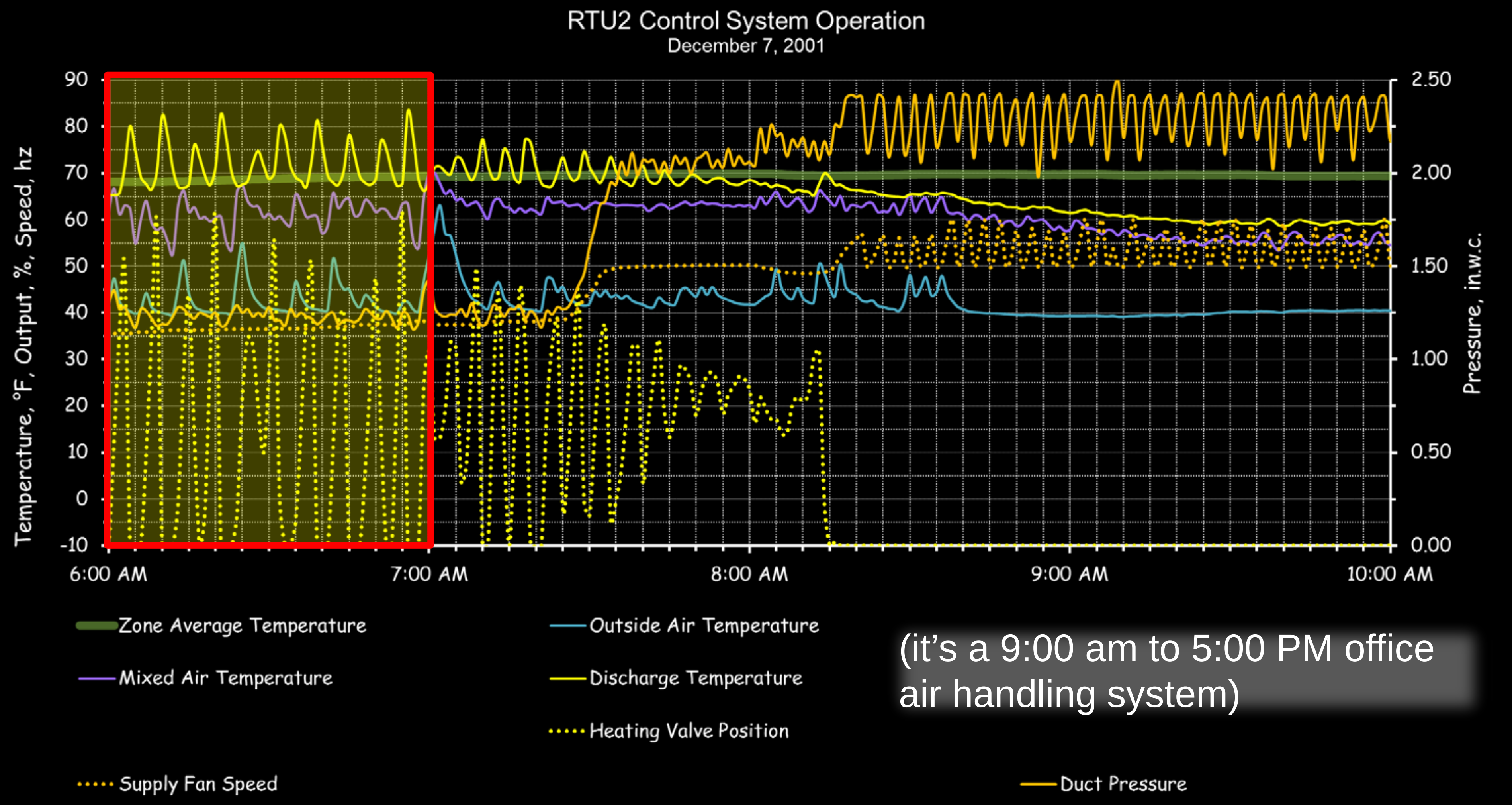
Manually locking down the preheat coil control valve reveals the root cause of the problem and how to solve it …

… 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)

HVAC System Fundamental Goals

- Keep the building comfortable
- Keep the people using the facility productive
- Keep the building safe
- Keep the building clean

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
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- Control sensor location
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Typical Existing Building Cx Issues

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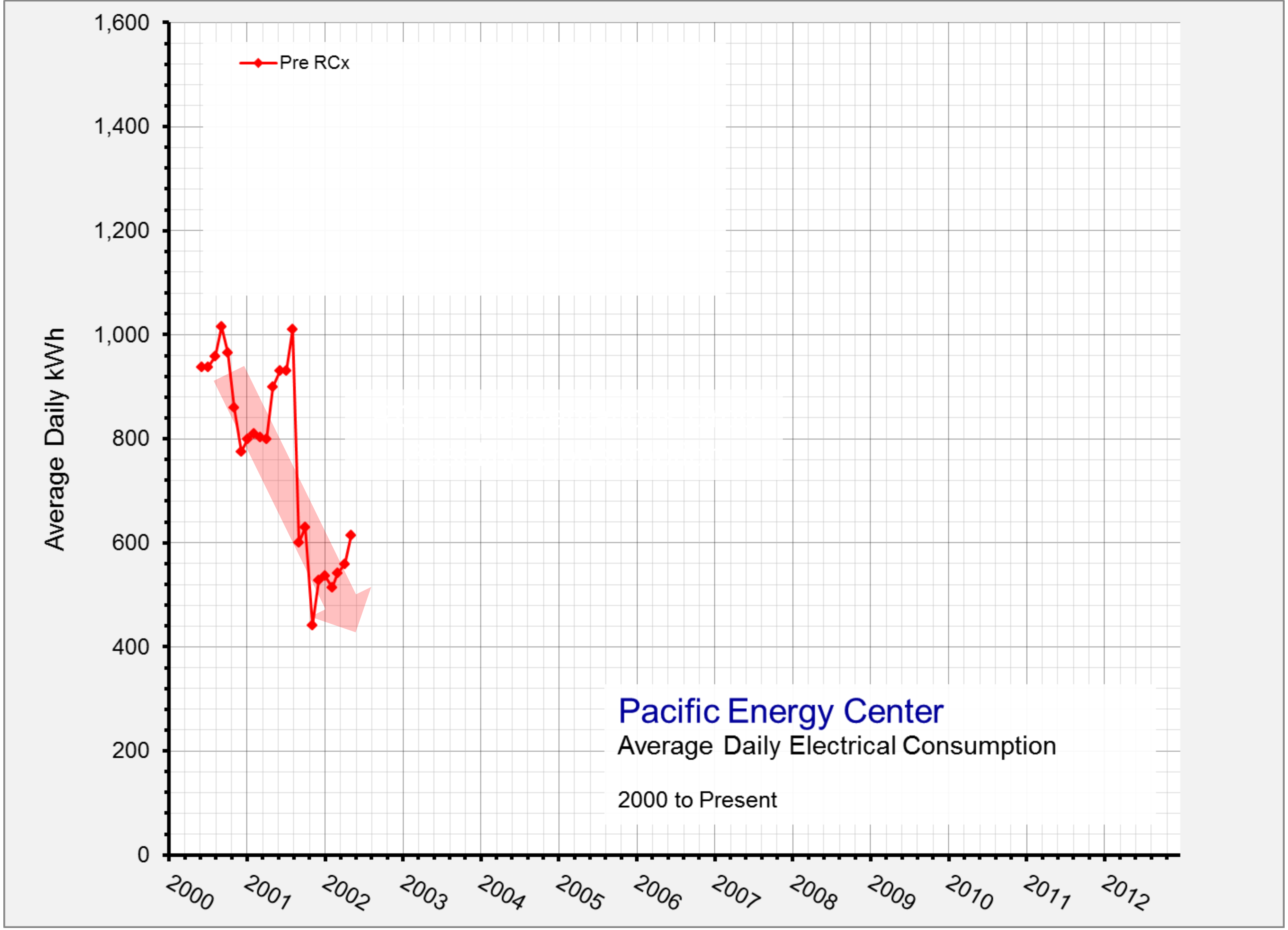
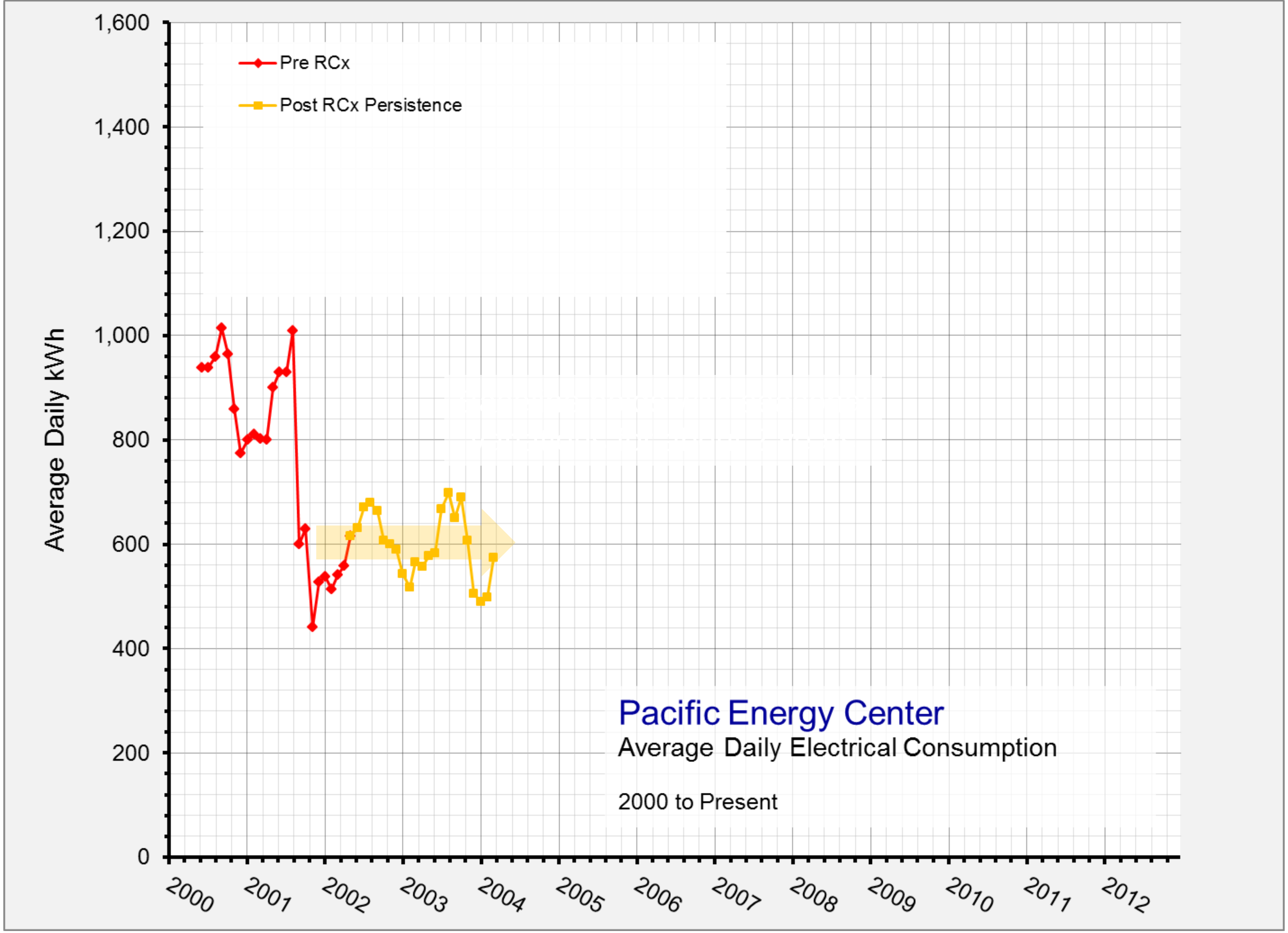
- Control sensor location
- Control system logic
- Control system design
- Schedules missing
- Equipment missing

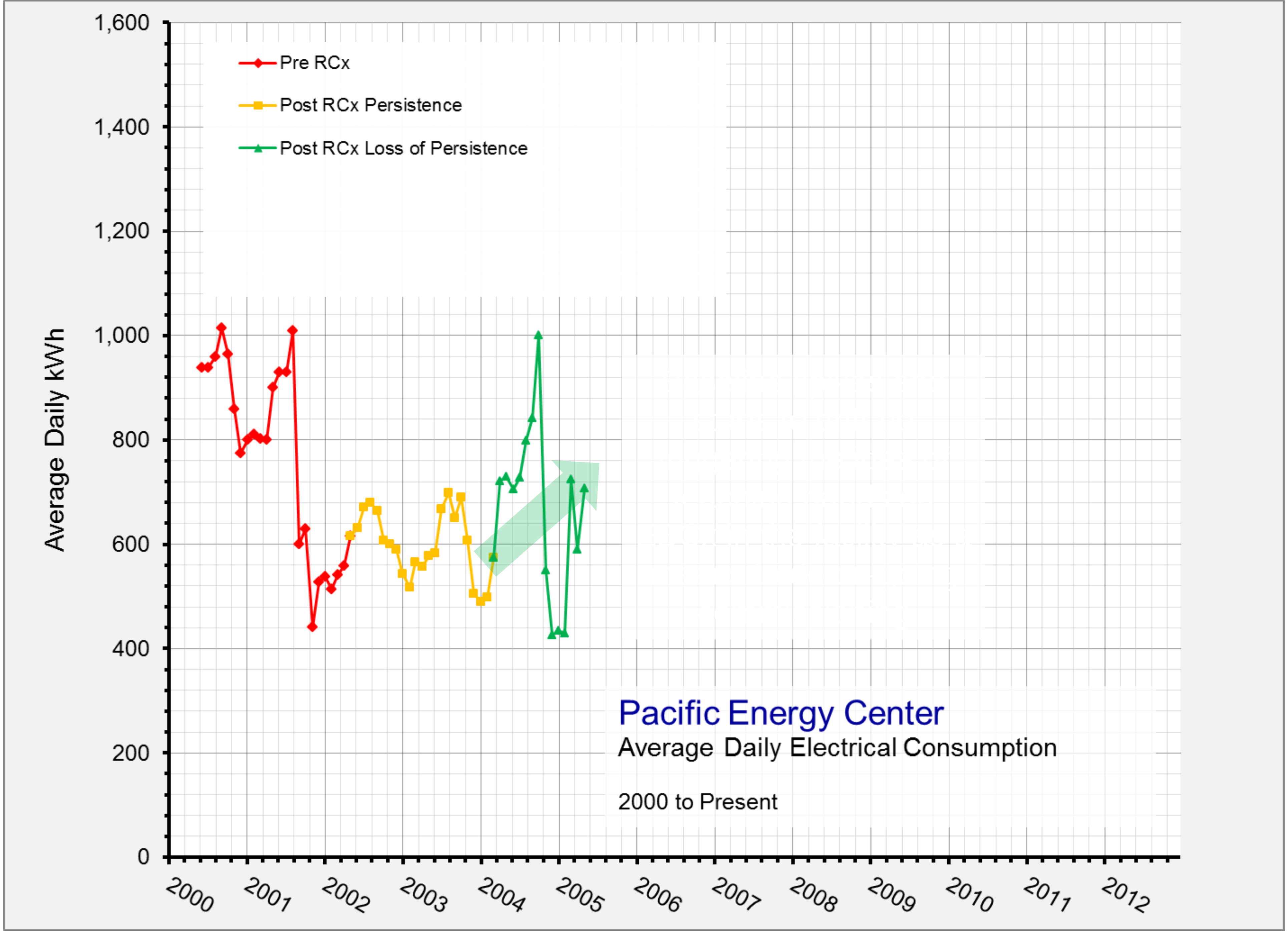
- Most existing building commissioning issues are unresolved new construction commissioning issues or design issues
- Existing building commissioning issues are excellent design review targets

Savings and Improvements vs. *Persistent* Savings and Improvements

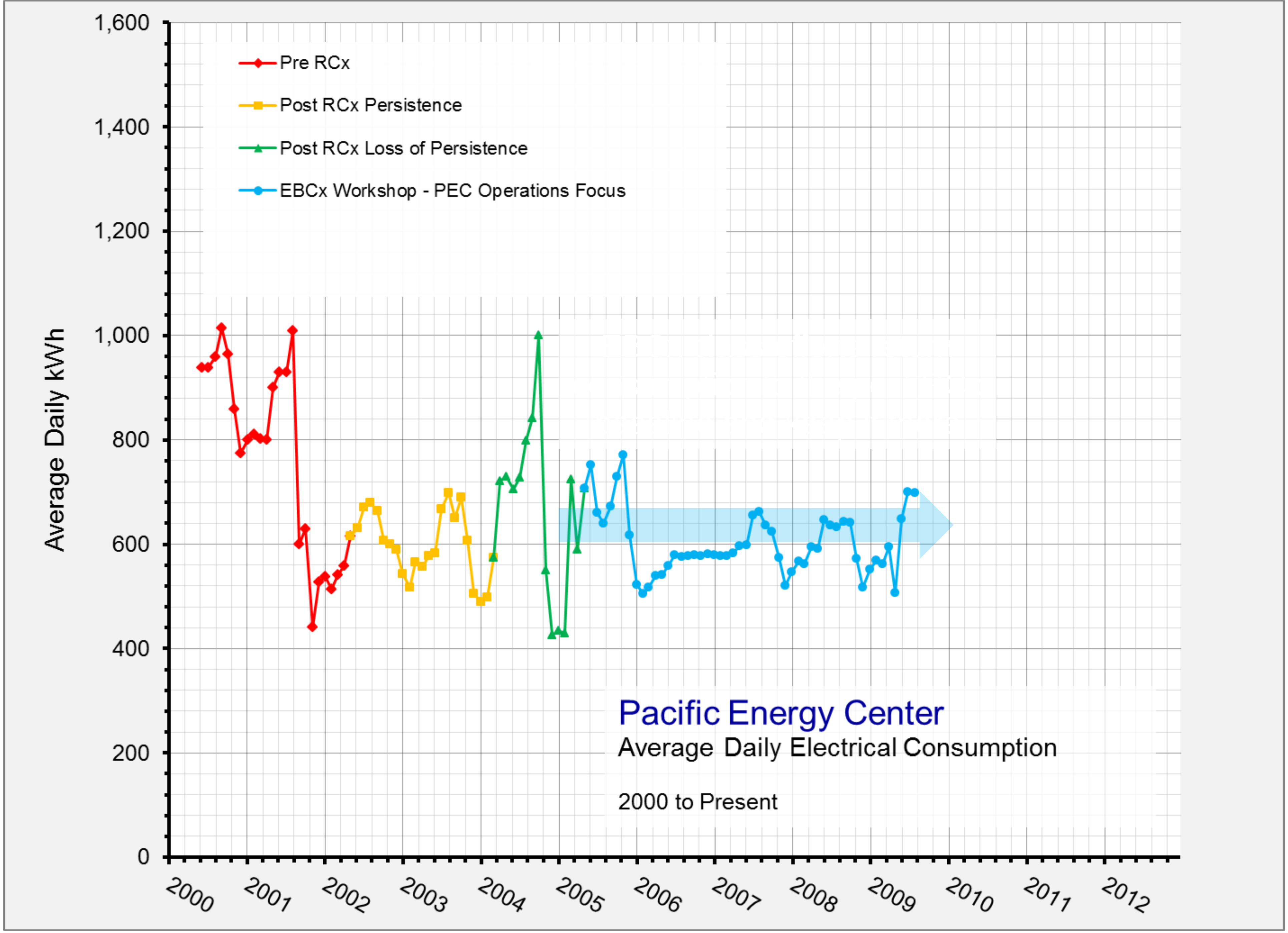


Pre RCx
Average Daily kWh
1,600
1,400
1,200
1,000
800
600
400
200
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Pacific Energy Center
Average Daily Electrical Consumption
2000 to Present

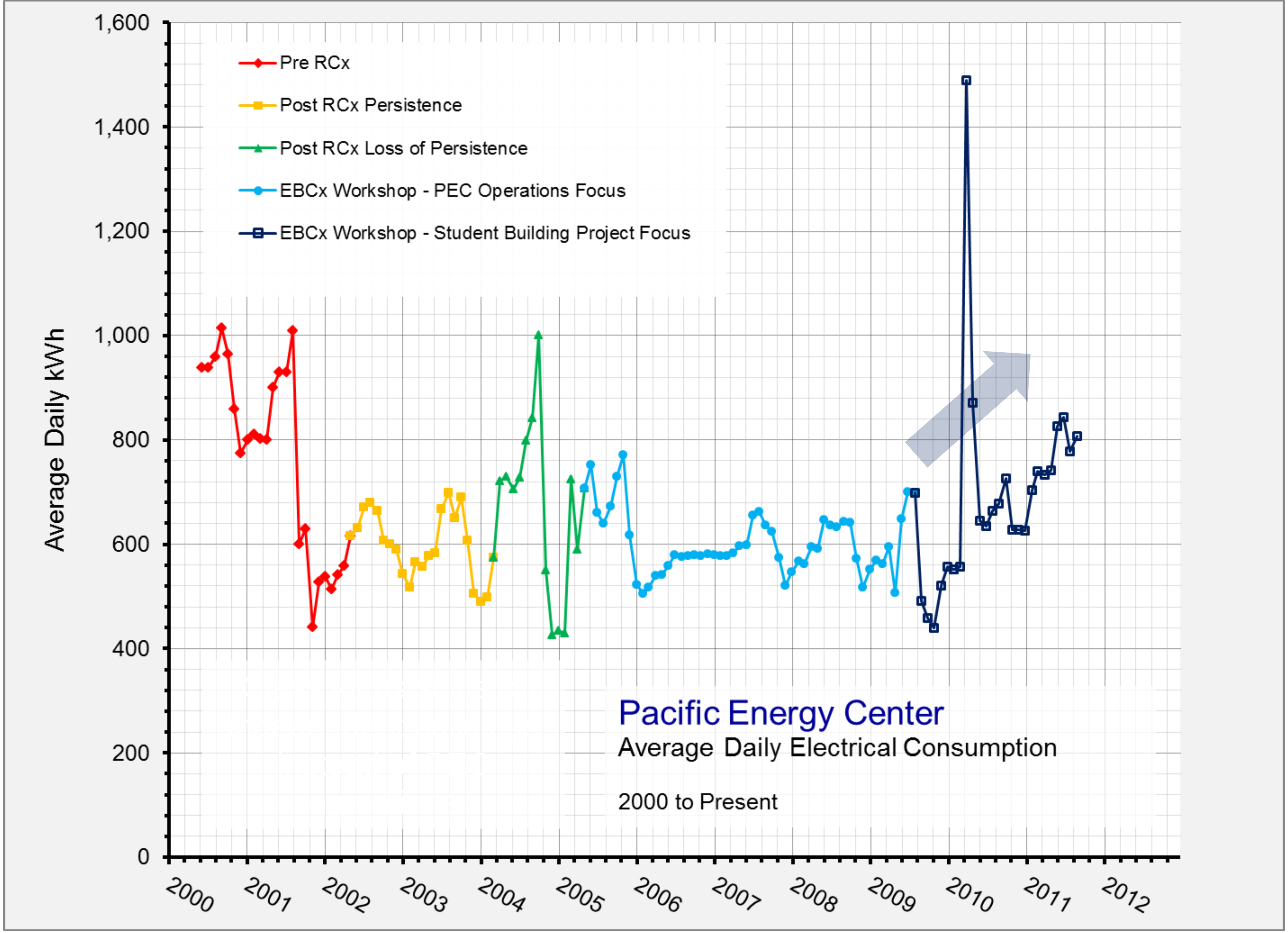

Pre RCx
Post RCx Persistence
Average Daily kWh
1,600
1,400
1,200
1,000
800
600
400
200
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Pacific Energy Center
Average Daily Electrical Consumption
2000 to Present



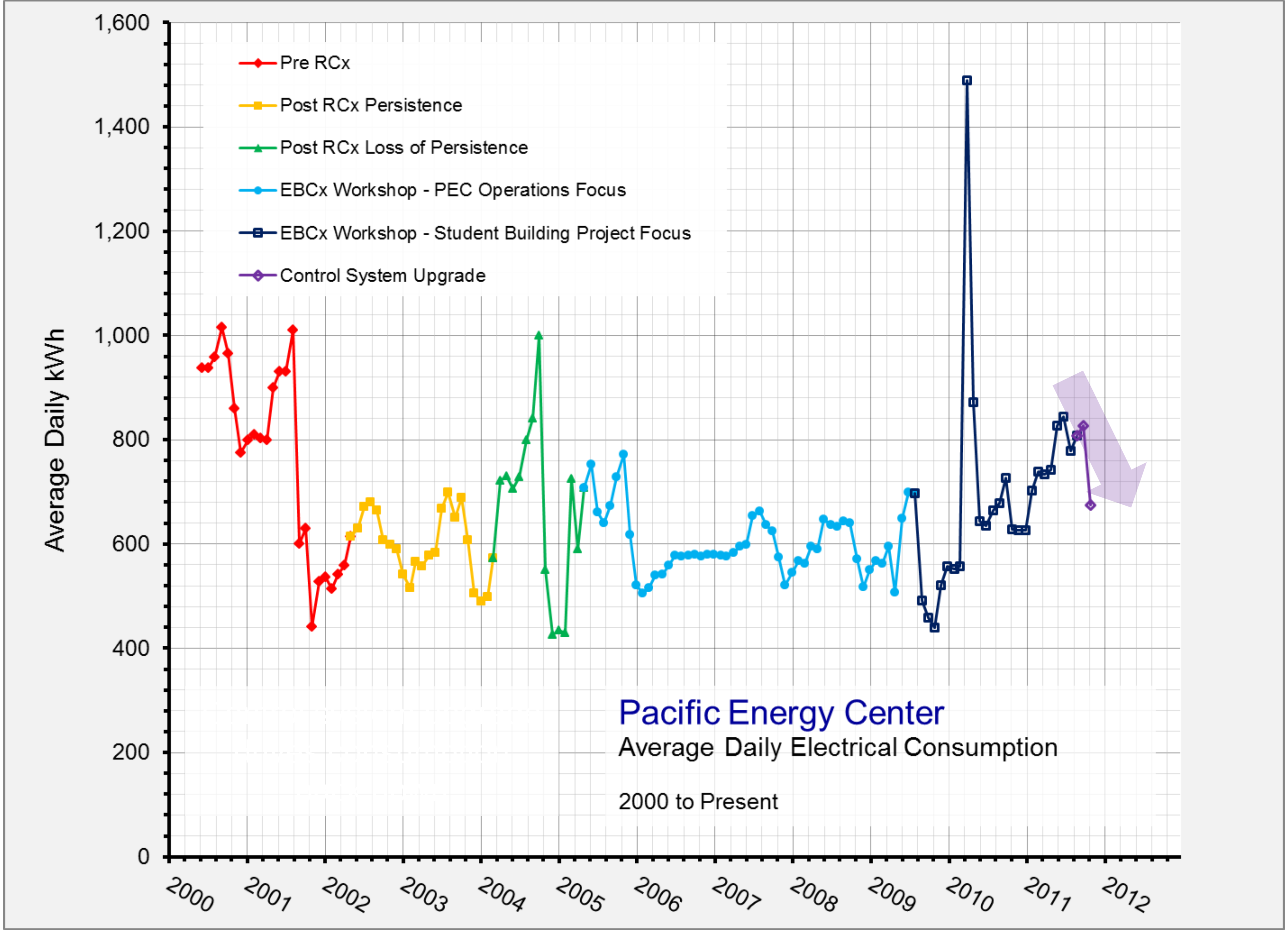
Pacific Energy Center
Average Daily Electrical Consumption
2000 to Present
Pre RCx
Post RCx Persistence
Post RCx Loss of Persistence
Average Daily kWh
1,600
1,400
1,200
1,000
800
600
400
200
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012



Pre RCx
Post RCx Persistence
Post RCx Loss of Persistence
EBCx Workshop - PEC Operations Focus
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
Post RCx Loss of Persistence
EBCx Workshop - PEC Operations Focus
EBCx Workshop - Student Building Project Focus
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
Pacific Energy Center
Average Daily Electrical Consumption
2000 to Present



Pre RCx
Post RCx Persistence
Post RCx Loss of Persistence
EBCx Workshop - PEC Operations Focus
EBCx Workshop - Student Building Project Focus
Control System Upgrade
Average Daily kWh
0
200
400
600
800
1,000
1,200
1,400
1,600
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
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

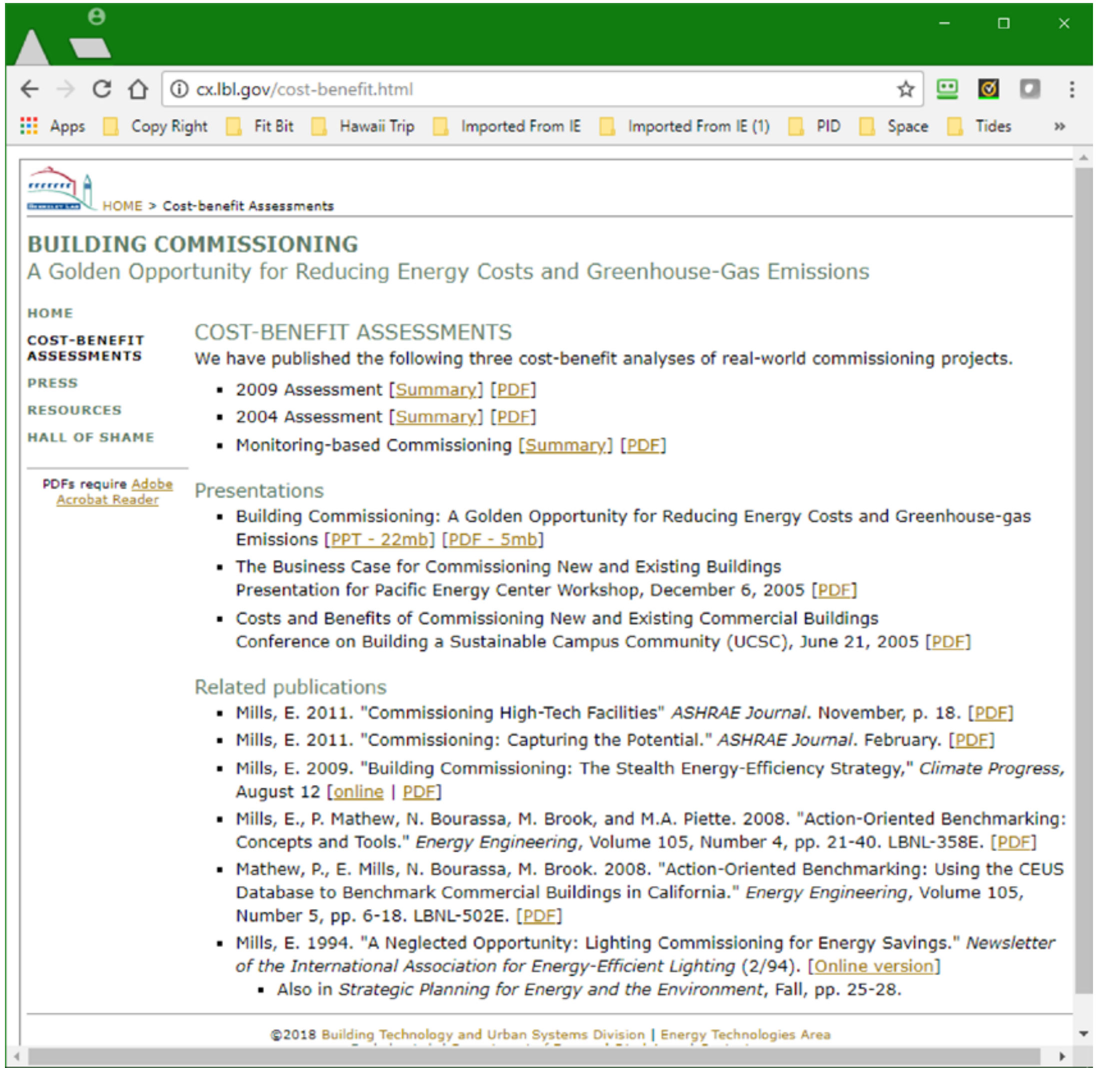
- Things wear
- Heat transfer characteristics change
- Things break
- People forget
- People make mistakes

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 in 2009 and 2019

  https://tinyurl.com/CxCostBenefitLBNL



HOME > Cost-benefit Assessments

BUILDING COMMISSIONING

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

HOME
COST-BENEFIT ASSESSMENTS
PRESS
RESOURCES
HALL OF SHAME

PDFs require Adobe Acrobat Reader

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]

Related publications

- Mills, E. 2011. "Commissioning High-Tech Facilities" *ASHRAE Journal*. November, p. 18. [PDF]
- Mills, E. 2011. "Commissioning: Capturing the Potential." *ASHRAE Journal*. February. [PDF]
- Mills, E. 2009. "Building Commissioning: The Stealth Energy-Efficiency Strategy," *Climate Progress*, August 12 [online | PDF]
- Mills, E., P. Mathew, N. Bourassa, M. Brook, and M.A. Piette. 2008. "Action-Oriented Benchmarking: Concepts and Tools." *Energy Engineering*, Volume 105, Number 4, pp. 21-40. LBNL-358E. [PDF]
- Mathew, P., E. Mills, N. Bourassa, M. Brook. 2008. "Action-Oriented Benchmarking: Using the CEUS Database to Benchmark Commercial Buildings in California." *Energy Engineering*, Volume 105, Number 5, pp. 6-18. LBNL-502E. [PDF]
- Mills, E. 1994. "A Neglected Opportunity: Lighting Commissioning for Energy Savings." *Newsletter of the International Association for Energy-Efficient Lighting* (2/94). [Online version]
  - Also in *Strategic Planning for Energy and the Environment*, Fall, pp. 25-28.

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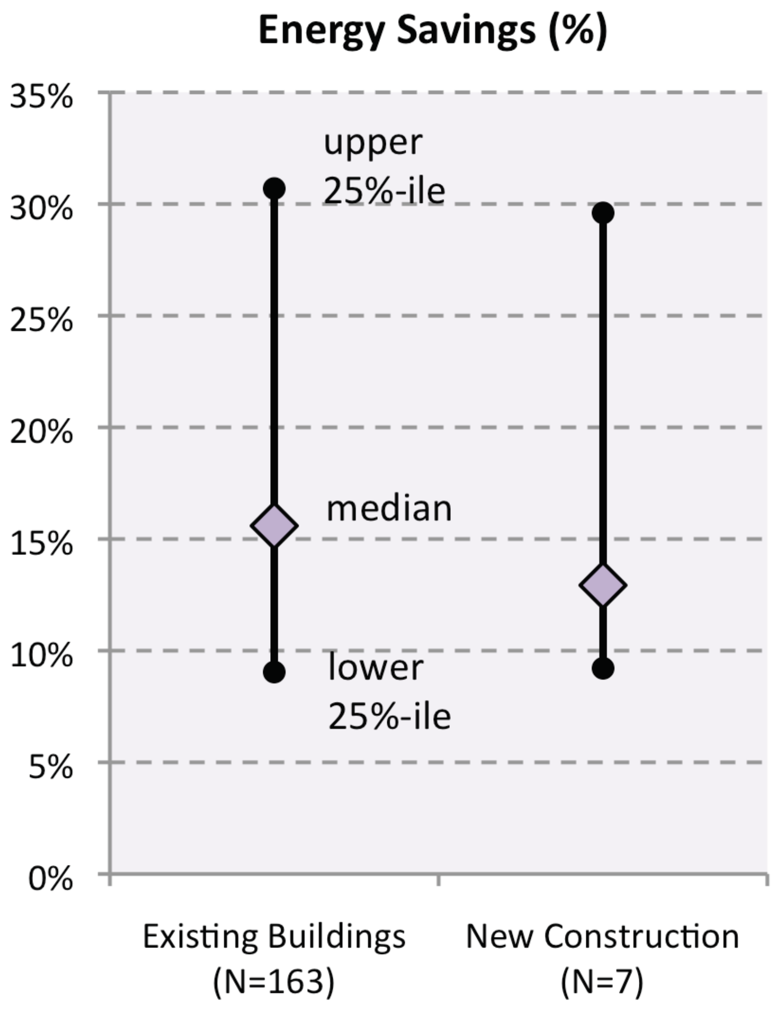
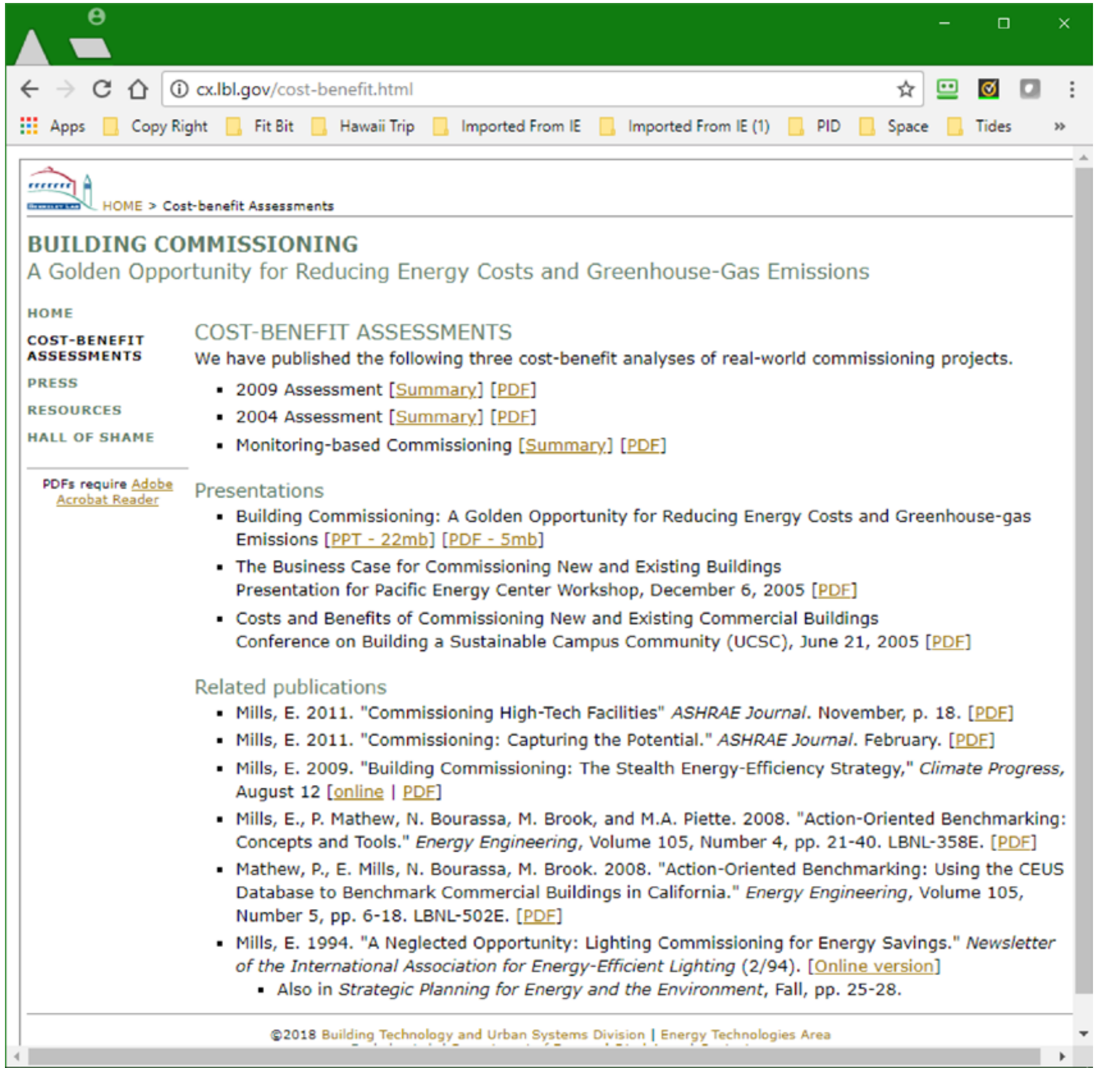
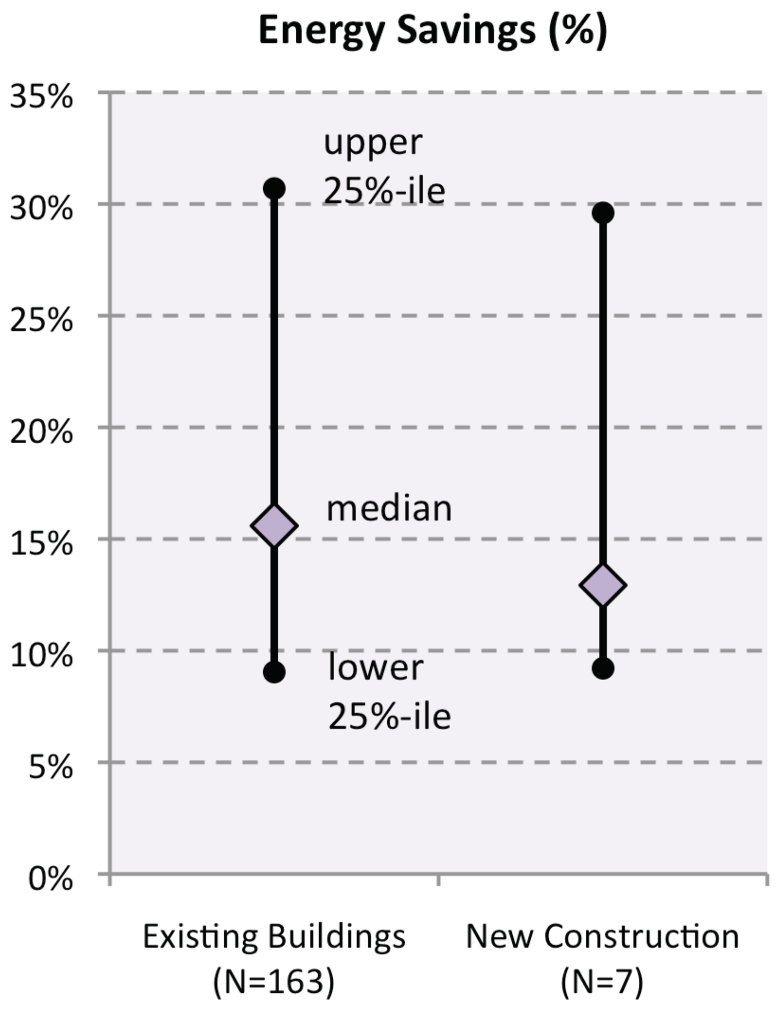
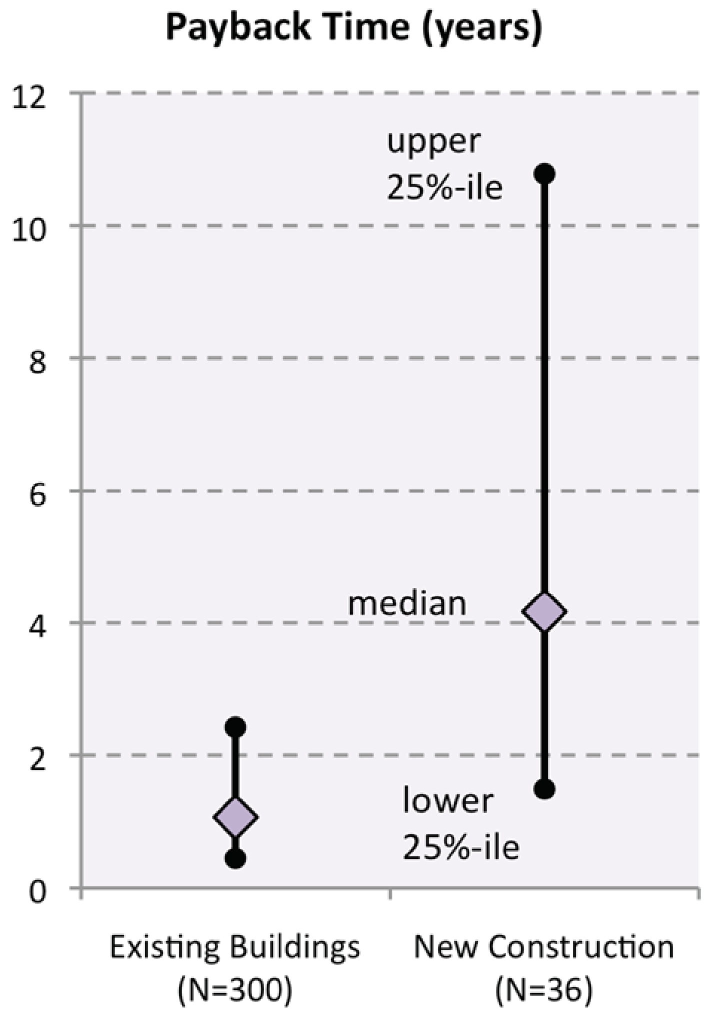
Achieving Persistence is Rewarding





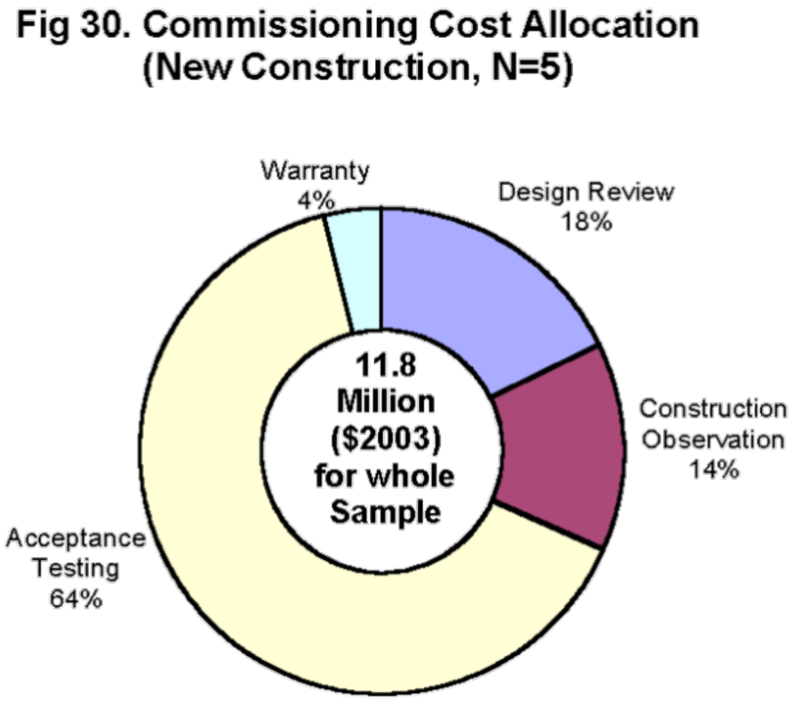
Achieving Persistence is Rewarding



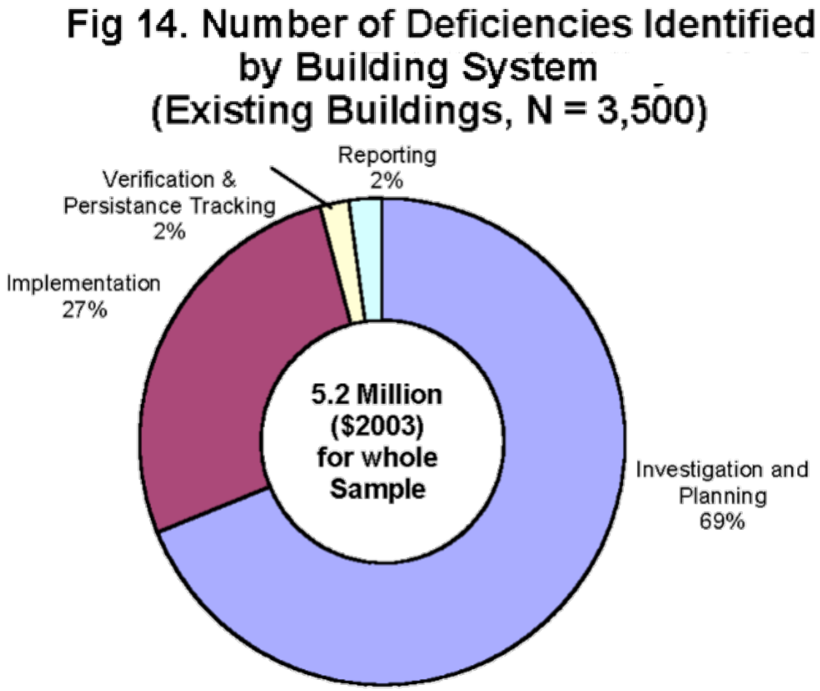


How the Budget is Spent

New Construction Cx

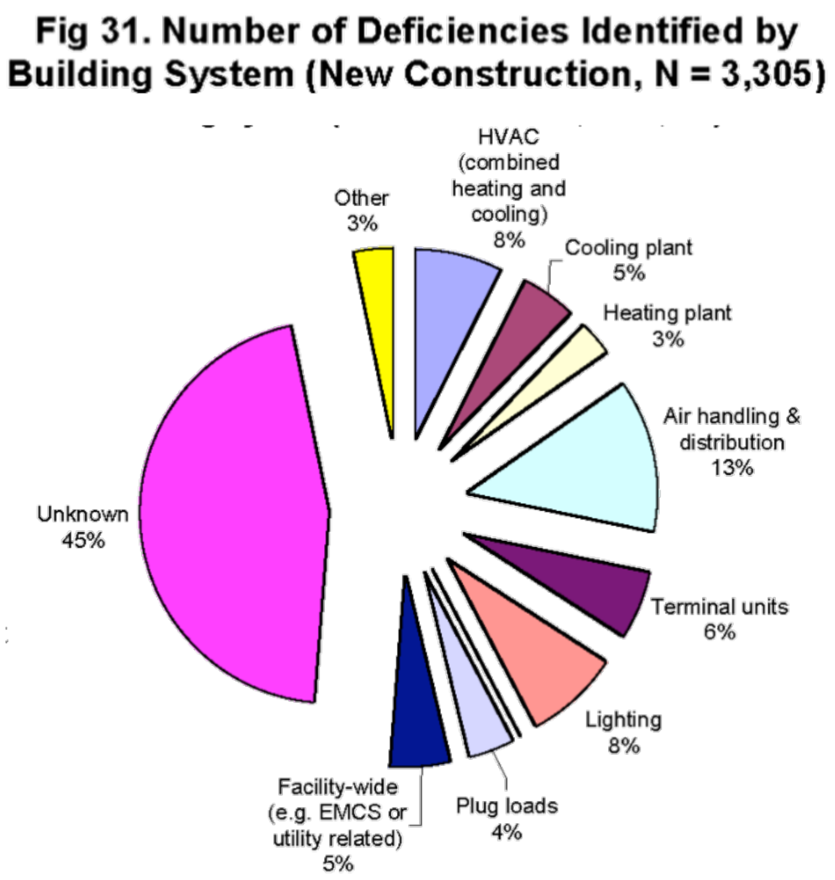


Existing Building Cx

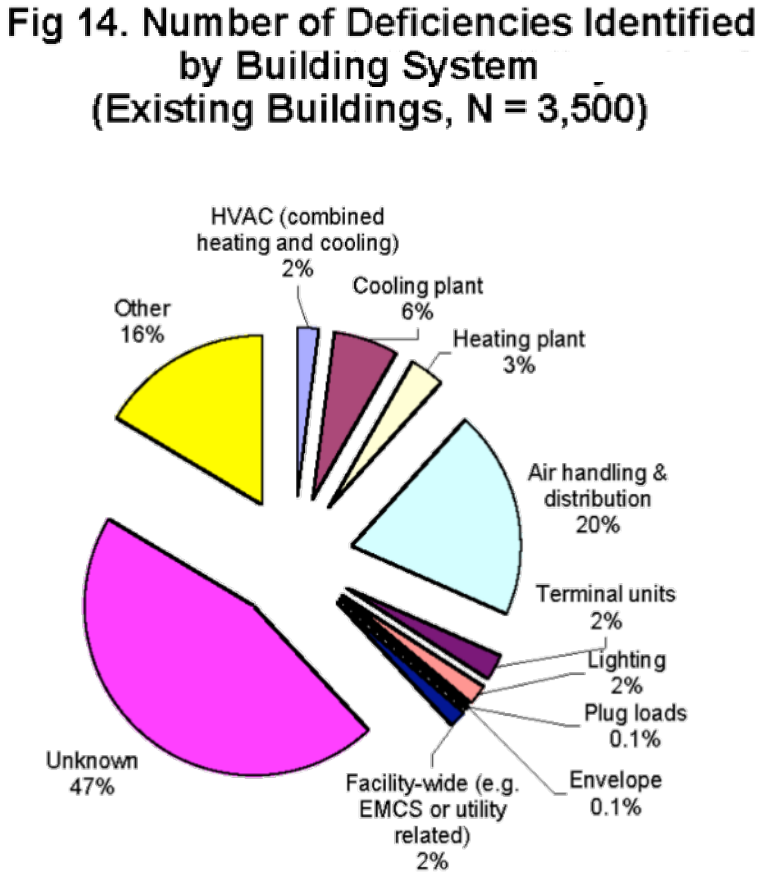


Where the Savings are Achieved

New Construction Cx



Existing Building Cx

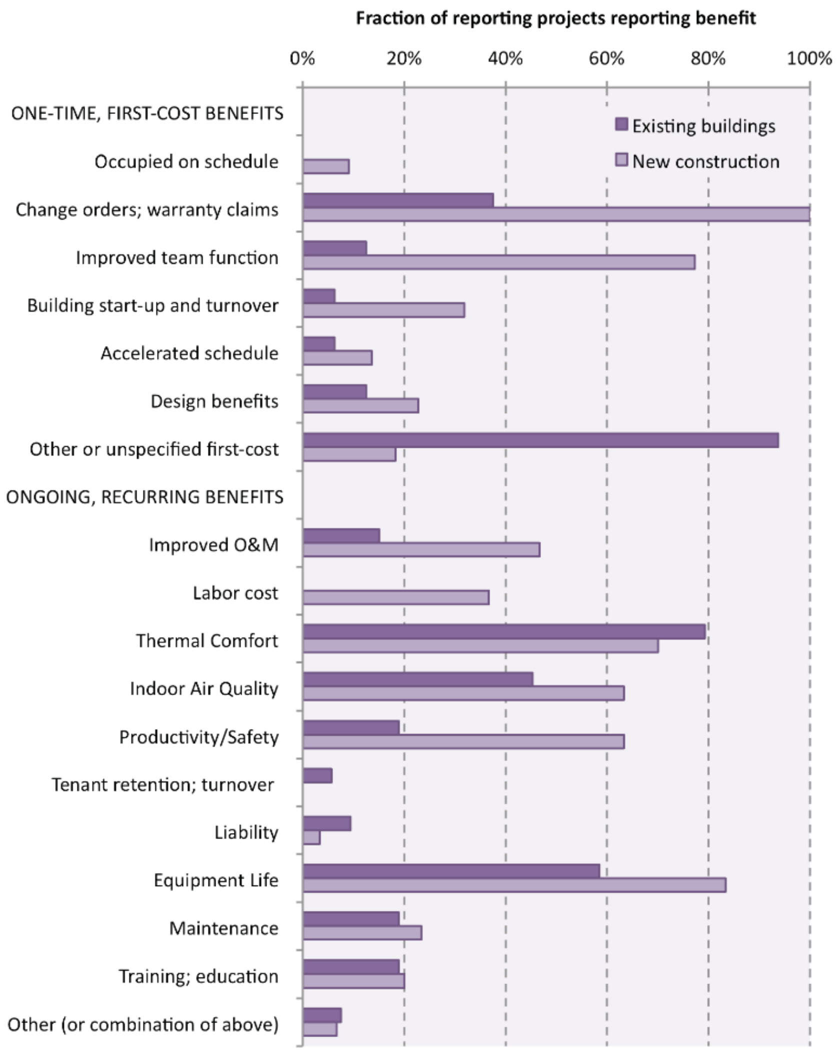


There's More to Save Than Energy

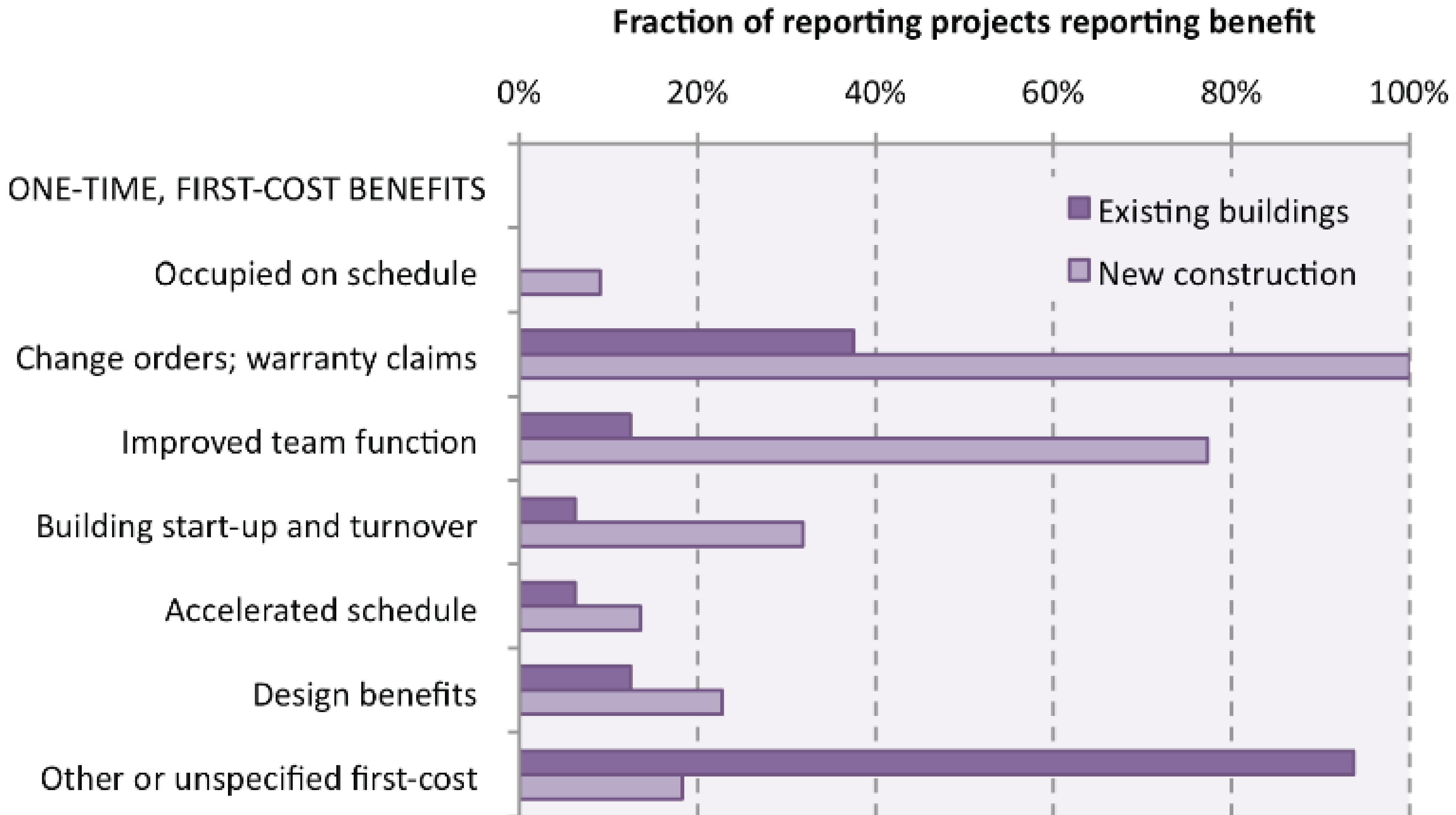
- From the 2004 LBNL Report:
- Median NCx energy savings
  $0.05 per square foot
- Median NCx NEB savings
  $1.24 per square foot
- Median EBCx energy savings
  $0.26 per square foot
- Median EBCx NEB savings
  $0.18 per square foot

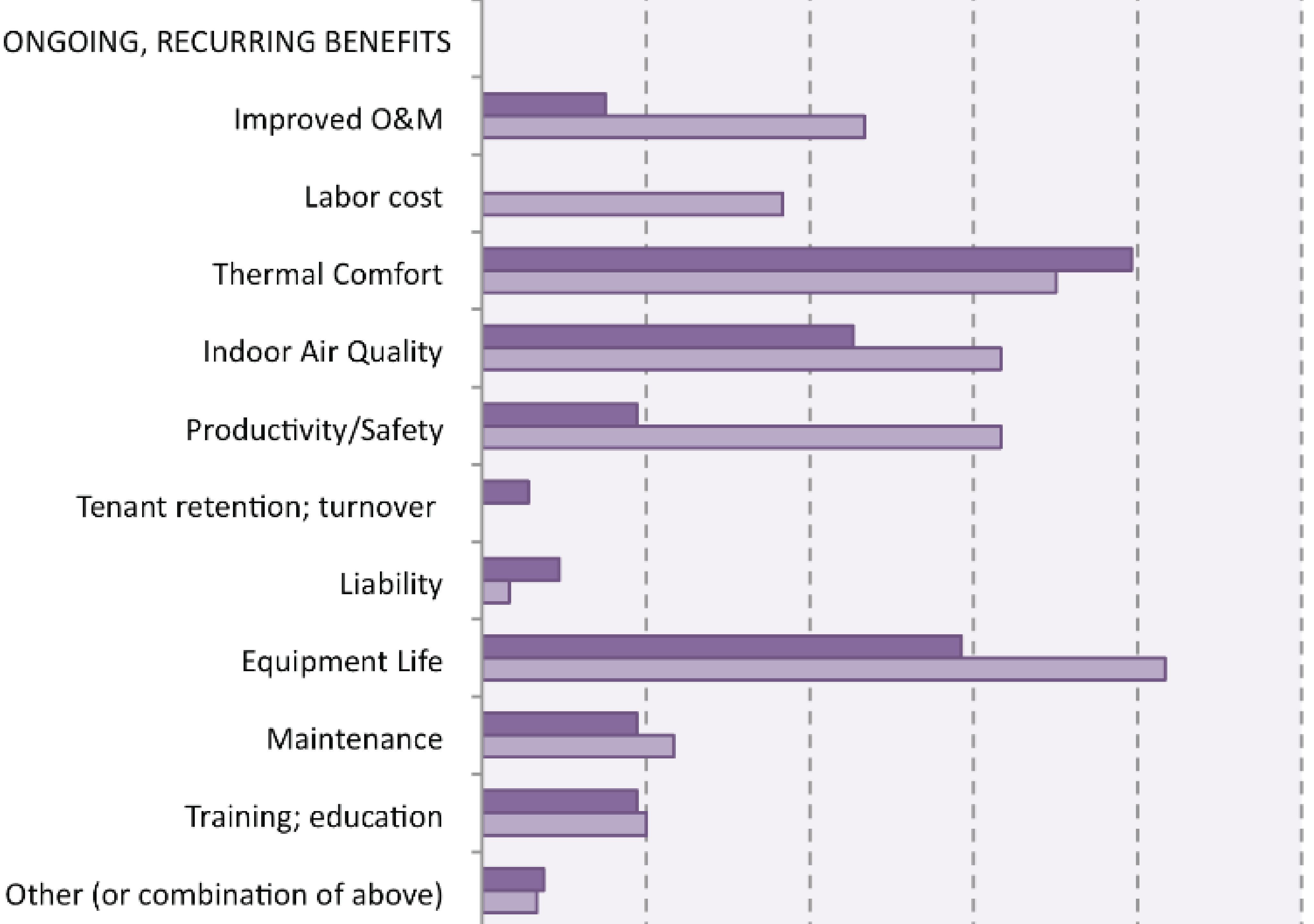
- *NEB = NEI = Non Energy Benefit or Impact*
- *NCx – New Construction Cx*
- *EBCx = Existing Building Cx*
- *Cx = Commissioning*
- *(from Rx as in a prescription)*

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



37


Fraction of reporting projects reporting benefit
0%
20%
40%
60%
80%
100%
ONE-TIME, FIRST-COST BENEFITS
Existing buildings
New construction
Occupied on schedule
Change orders; warranty claims
Improved team function
Building start-up and turnover
Accelerated schedule
Design benefits
Other or unspecified first-cost


ONGOING, RECURRING BENEFITS
Improved O&M
Labor cost
Thermal Comfort
Indoor Air Quality
Productivity/Safety
Tenant retention; turnover
Liability
Equipment Life
Maintenance
Training; education
Other (or combination of above)

Building Commissioning, Sustainability, and Electrification

California Releases Report Charting Path to 100 Percent Clean Electricity

If You:


CALIFORNIA ENERGY COMMISSION

HOME PROCEEDINGS RULES AND REGULATIONS PROGRAMS AND TOPICS

Home > Newsroom > News Releases > California Releases Report Charting Path to 100 Percent Clean Electricity

California Releases Report Charting Path to 100 Percent Clean Electricity

Save electricity or gas, you likely reduce your carbon footprint

If You:


CALIFORNIA
ENERGY COMMISSION

HOME | PROCEEDINGS | RULES AND REGULATIONS | PROGRAMS AND TOPICS

Home > Newsroom > News Releases > California Releases Report Charting Path to 100 Percent Clean Electricity

California Releases Report Charting Path to 100 Percent Clean Electricity

Reduce heat rejection requirements in a water-cooled central plant, you save water

If You:

Extend filter life cycles by adopting best life cycle cost based filter operation, you:

1. Reduce your waste stream
2. Free up labor hours to do other things
3. Reduce the non-energy resources you consume

The Bigger Picture

Why This Matters

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

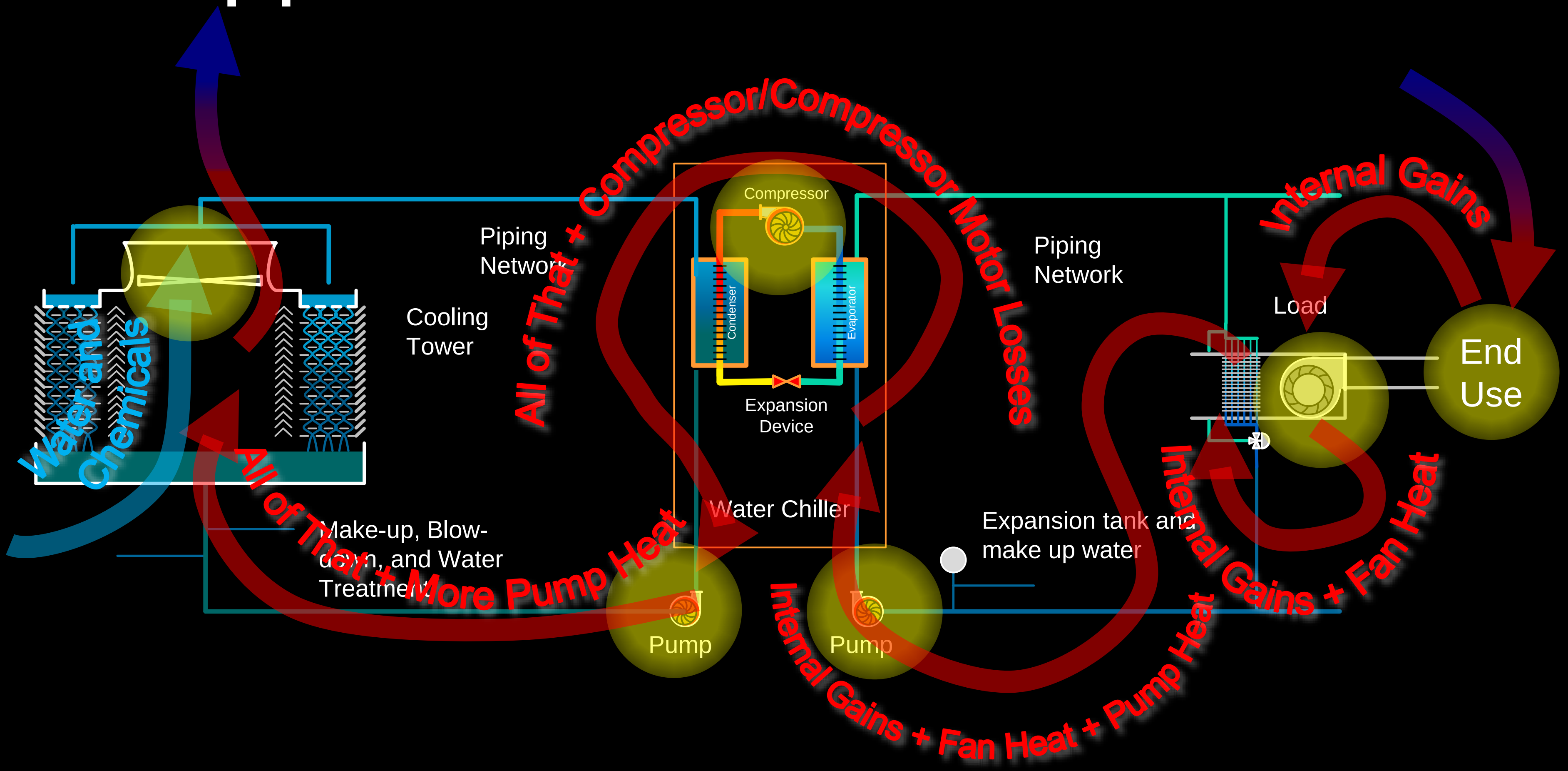
Gene Cernan

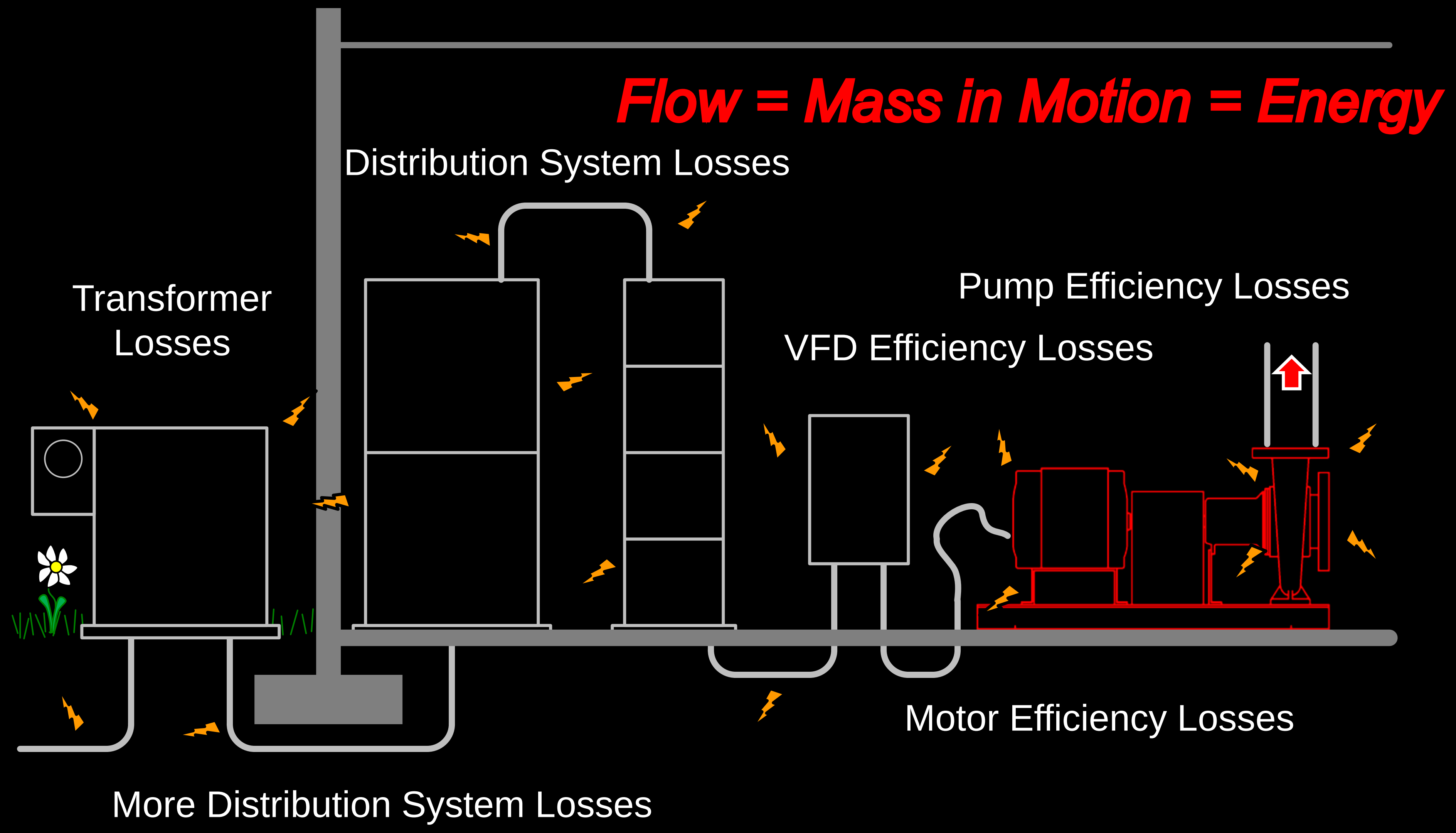
Apollo 17 Commander

Image courtesy NASA Image Archives; https://www.nasa.gov/multimedia/imagegallery/index.html


We don’t inherit the world from our ancestors,
we borrow it from our children
Unknown

Applying the Commissioning Tool Set can Have Ripple Effects





Flow = Mass in Motion = Energy
Distribution System Losses
Transformer Losses
Pump Efficiency Losses
VFD Efficiency Losses
Motor Efficiency Losses
More Distribution System Losses

A Definition

- Power Generation
  - A process that generates power by converting one form of energy into a different, more useful form for the task at hand

State	% of Total Electric Power Generation											Non-renewable + Nuclear Percent of Total	Renewable Percent of Total	Combustion Process Generated Percent of Total	Non-combustion Process Generated Percent of Total
	Non-Renewable					Renewable					Nuclear				
	Combustion Processes						Non-Combustion Processes								
	Coal	Oil	Gas	Other Fossil Fuel	Purchased, Fuel Generated	Biomass	Hydro	Wind	Solar	Geothermal					
CA	0.2%	0.0%	47.7%	0.8%	0.3%	3.0%	11.0%	7.0%	15.7%	5.9%	8.4%	57.4%	42.6%	52.0%	48.0%
DC	0.0%	0.0%	61.3%	0.0%	0.0%	31.4%	0.0%	0.0%	7.3%	0.0%	0.0%	61.3%	38.7%	92.7%	7.3%
DE	2.0%	0.2%	92.6%	2.8%	0.0%	1.4%	0.0%	0.1%	1.0%	0.0%	0.0%	97.6%	2.5%	99.0%	1.1%
HI	12.8%	67.8%	0.0%	0.0%	1.3%	5.0%	1.1%	6.4%	5.3%	0.1%	0.0%	81.9%	17.9%	86.9%	12.9%
IA	23.7%	0.2%	11.8%	0.0%	0.0%	0.3%	1.7%	57.3%	0.0%	0.0%	4.9%	40.6%	59.3%	36.0%	63.9%
NH	0.8%	0.3%	22.3%	0.0%	0.0%	5.6%	7.5%	3.2%	0.0%	0.0%	60.4%	83.8%	16.3%	29.0%	71.1%
NV	4.8%	0.0%	66.3%	0.0%	0.1%	0.1%	4.8%	0.7%	13.7%	9.4%	0.0%	71.2%	28.7%	71.3%	28.6%
OR	2.6%	0.0%	29.9%	0.0%	0.0%	1.6%	50.2%	13.8%	1.7%	0.3%	0.0%	32.5%	67.6%	34.1%	66.0%
RI	16.8%	49.9%	30.9%	0.0%	0.0%	0.0%	0.0%	0.8%	1.6%	0.0%	0.0%	97.6%	2.4%	97.6%	2.4%
WA	0.0%	0.1%	0.1%	0.0%	0.0%	21.3%	52.4%	17.8%	8.4%	0.0%	0.0%	0.2%	99.9%	21.5%	78.6%
WY	88.6%	0.3%	4.9%	0.1%	0.0%	0.0%	2.8%	3.3%	0.0%	0.0%	0.0%	93.9%	6.1%	93.9%	6.1%
Minimum	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.2%**	**2.4%**	**18.2%**	**1.1%**
Maximum	**88.6%**	**67.8%**	**93.0%**	**2.8%**	**1.3%**	**31.4%**	**65.8%**	**57.3%**	**15.7%**	**9.4%**	**60.4%**	**97.6%**	**99.9%**	**99.0%**	**81.9%**
Average	**19.8%**	**2.9%**	**36.2%**	**0.3%**	**0.1%**	**3.0%**	**10.2%**	**9.4%**	**2.3%**	**0.3%**	**15.4%**	**74.7%**	**25.3%**	**62.3%**	**37.7%**
US	19.3%	0.7%	40.5%	0.3%	0.1%	1.5%	7.0%	8.4%	2.2%	0.4%	19.6%	80.5%	19.5%	62.4%	37.6%

A Definition

- Power Generation
  - The heat can come from burning things like coal

State	% of Total Electric Power					
	Non-Renewable					
	Combustion Processes					
	Coal	Oil	Gas	Other Fossil Fuel	Purchased, Fuel Generated	Biomass
CA	0.2%	0.0%	47.7%	0.8%	0.3%	3.0%
DC	0.0%	0.0%	61.3%	0.0%	0.0%	31.4%
DE	2.0%	0.2%	92.6%	2.8%	0.0%	1.4%
HI	12.8%	67.8%	0.0%	0.0%	1.3%	5.0%
IA	23.7%	0.2%	11.8%	0.0%	0.0%	0.3%
NH	0.8%	0.3%	22.3%	0.0%	0.0%	5.6%
NV	4.8%	0.0%	66.3%	0.0%	0.1%	0.1%
OR	2.6%	0.0%	29.9%	0.0%	0.0%	1.6%
RI	16.8%	49.9%	30.9%	0.0%	0.0%	0.0%
WA	0.0%	0.1%	0.1%	0.0%	0.0%	21.3%
WY	88.6%	0.3%	4.9%	0.1%	0.0%	0.0%
Minimum	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Maximum	**88.6%**	**67.8%**	**93.0%**	**2.8%**	**1.3%**	**31.4%**
Average	**19.8%**	**2.9%**	**36.2%**	**0.3%**	**0.1%**	**3.0%**
US	19.3%	0.7%	40.5%	0.3%	0.1%	1.5%

A Definition

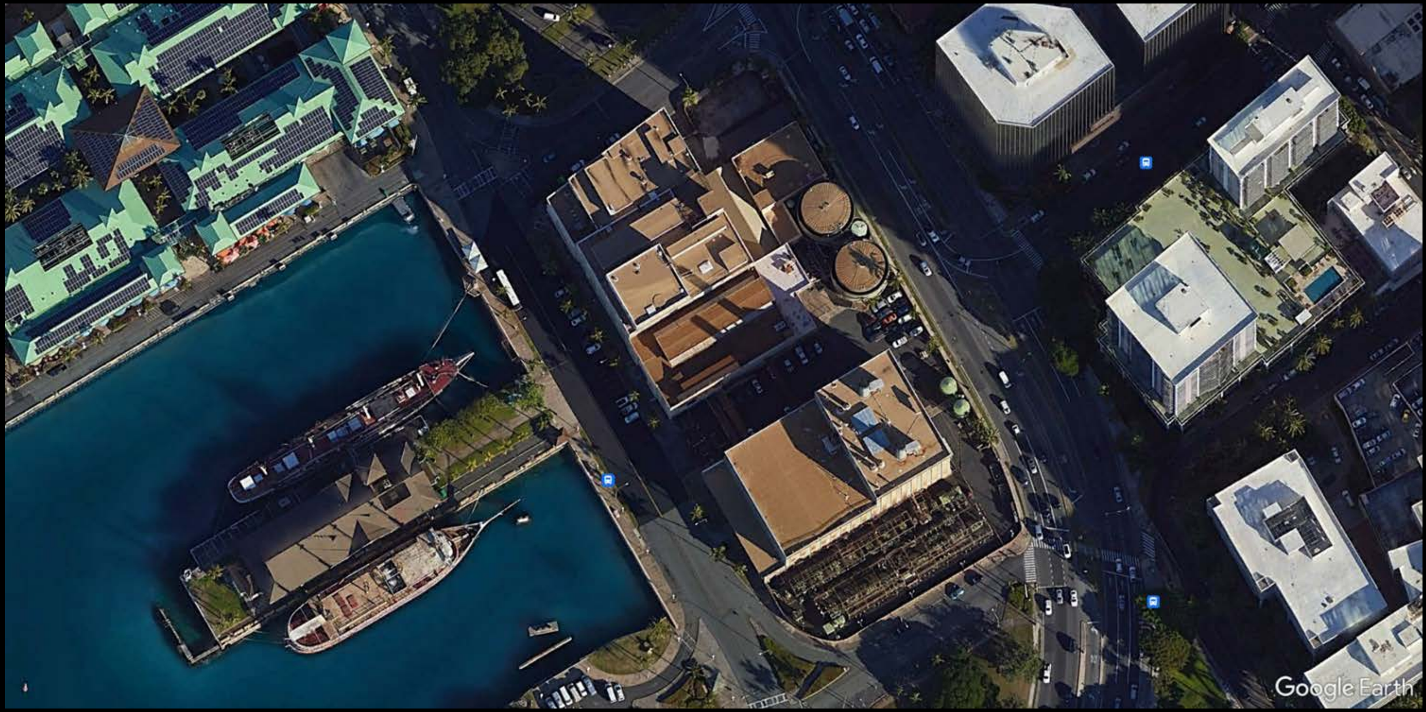
- Power Generation
  - The heat can come from burning things like coal, gas

State	% of Total Electric Power					
	Non-Renewable					
	Combustion Processes					
	Coal	Oil	Gas	Other Fossil Fuel	Purchased, Fuel Generated	Biomass
CA	0.2%	0.0%	47.7%	0.8%	0.3%	3.0%
DC	0.0%	0.0%	61.3%	0.0%	0.0%	31.4%
DE	2.0%	0.2%	92.6%	2.8%	0.0%	1.4%
HI	12.8%	67.8%	0.0%	0.0%	1.3%	5.0%
IA	23.7%	0.2%	11.8%	0.0%	0.0%	0.3%
NH	0.8%	0.3%	22.3%	0.0%	0.0%	5.6%
NV	4.8%	0.0%	66.3%	0.0%	0.1%	0.1%
OR	2.6%	0.0%	29.9%	0.0%	0.0%	1.6%
RI	16.8%	49.9%	30.9%	0.0%	0.0%	0.0%
WA	0.0%	0.1%	0.1%	0.0%	0.0%	21.3%
WY	88.6%	0.3%	4.9%	0.1%	0.0%	0.0%
Minimum	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Maximum	**88.6%**	**67.8%**	**93.0%**	**2.8%**	**1.3%**	**31.4%**
Average	**19.8%**	**2.9%**	**36.2%**	**0.3%**	**0.1%**	**3.0%**
US	19.3%	0.7%	40.5%	0.3%	0.1%	1.5%

A Definition

- Power Generation
  - The heat can come from burning things like coal, gas, oil

State	% of Total Electric Power					
	Non-Renewable					
	Combustion Processes					
	Coal	Oil	Gas	Other Fossil Fuel	Purchased, Fuel Generated	Biomass
CA	0.2%	0.0%	47.7%	0.8%	0.3%	3.0%
DC	0.0%	0.0%	61.3%	0.0%	0.0%	31.4%
DE	2.0%	0.2%	92.6%	2.8%	0.0%	1.4%
HI	12.8%	67.8%	0.0%	0.0%	1.3%	5.0%
IA	23.7%	0.2%	11.8%	0.0%	0.0%	0.3%
NH	0.8%	0.3%	22.3%	0.0%	0.0%	5.6%
NV	4.8%	0.0%	66.3%	0.0%	0.1%	0.1%
OR	2.6%	0.0%	29.9%	0.0%	0.0%	1.6%
RI	16.8%	49.9%	30.9%	0.0%	0.0%	0.0%
WA	0.0%	0.1%	0.1%	0.0%	0.0%	21.3%
WY	88.6%	0.3%	4.9%	0.1%	0.0%	0.0%
Minimum	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Maximum	**88.6%**	**67.8%**	**93.0%**	**2.8%**	**1.3%**	**31.4%**
Average	**19.8%**	**2.9%**	**36.2%**	**0.3%**	**0.1%**	**3.0%**
US	19.3%	0.7%	40.5%	0.3%	0.1%	1.5%



A Definitions

- Power Generation
  - The heat can come from burning things like coal, gas, oil, or biomass …

State	% of Total Electric Power					
	Non-Renewable					
	Combustion Processes					
	Coal	Oil	Gas	Other Fossil Fuel	Purchased, Fuel Generated	Biomass
CA	0.2%	0.0%	47.7%	0.8%	0.3%	3.0%
DC	0.0%	0.0%	61.3%	0.0%	0.0%	31.4%
DE	2.0%	0.2%	92.6%	2.8%	0.0%	1.4%
HI	12.8%	67.8%	0.0%	0.0%	1.3%	5.0%
IA	23.7%	0.2%	11.8%	0.0%	0.0%	0.3%
NH	0.8%	0.3%	22.3%	0.0%	0.0%	5.6%
NV	4.8%	0.0%	66.3%	0.0%	0.1%	0.1%
OR	2.6%	0.0%	29.9%	0.0%	0.0%	1.6%
RI	16.8%	49.9%	30.9%	0.0%	0.0%	0.0%
WA	0.0%	0.1%	0.1%	0.0%	0.0%	21.3%
WY	88.6%	0.3%	4.9%	0.1%	0.0%	0.0%
Minimum	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Maximum	**88.6%**	**67.8%**	**93.0%**	**2.8%**	**1.3%**	**31.4%**
Average	**19.8%**	**2.9%**	**36.2%**	**0.3%**	**0.1%**	**3.0%**
US	19.3%	0.7%	40.5%	0.3%	0.1%	1.5%

A Definition

- Power Generation
  - … or it can come non-combustion process-based sources like hydro,

Electric Power Generation						Non-renewable + Nuclear Percent of Total	Renewable Percent of Total	Combustion Process Generated Percent of Total	Non-combustion Process Generated Percent of Total
Renewable					Nuclear				
	Non-Combustion Processes								
Biomass	Hydro	Wind	Solar	Geothermal					
3.0%	11.0%	7.0%	15.7%	5.9%	8.4%	57.4%	42.6%	52.0%	48.0%
31.4%	0.0%	0.0%	7.3%	0.0%	0.0%	61.3%	38.7%	92.7%	7.3%
1.4%	0.0%	0.1%	1.0%	0.0%	0.0%	97.6%	2.5%	99.0%	1.1%
5.0%	1.1%	6.4%	5.3%	0.1%	0.0%	81.9%	17.9%	86.9%	12.9%
0.3%	1.7%	57.3%	0.0%	0.0%	4.9%	40.6%	59.3%	36.0%	63.9%
5.6%	7.5%	3.2%	0.0%	0.0%	60.4%	83.8%	16.3%	29.0%	71.1%
0.1%	4.8%	0.7%	13.7%	9.4%	0.0%	71.2%	28.7%	71.3%	28.6%
1.6%	50.2%	13.8%	1.7%	0.3%	0.0%	32.5%	67.6%	34.1%	66.0%
0.0%	0.0%	0.8%	1.6%	0.0%	0.0%	97.6%	2.4%	97.6%	2.4%
21.3%	52.4%	17.8%	8.4%	0.0%	0.0%	0.2%	99.9%	21.5%	78.6%
0.0%	2.8%	3.3%	0.0%	0.0%	0.0%	93.9%	6.1%	93.9%	6.1%
0.0%	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.2%**	**2.4%**	**18.2%**	**1.1%**
31.4%	**65.8%**	**57.3%**	**15.7%**	**9.4%**	**60.4%**	**97.6%**	**99.9%**	**99.0%**	**81.9%**
3.0%	**10.2%**	**9.4%**	**2.3%**	**0.3%**	**15.4%**	**74.7%**	**25.3%**	**62.3%**	**37.7%**
1.5%	7.0%	8.4%	2.2%	0.4%	19.6%	80.5%	19.5%	62.4%	37.6%

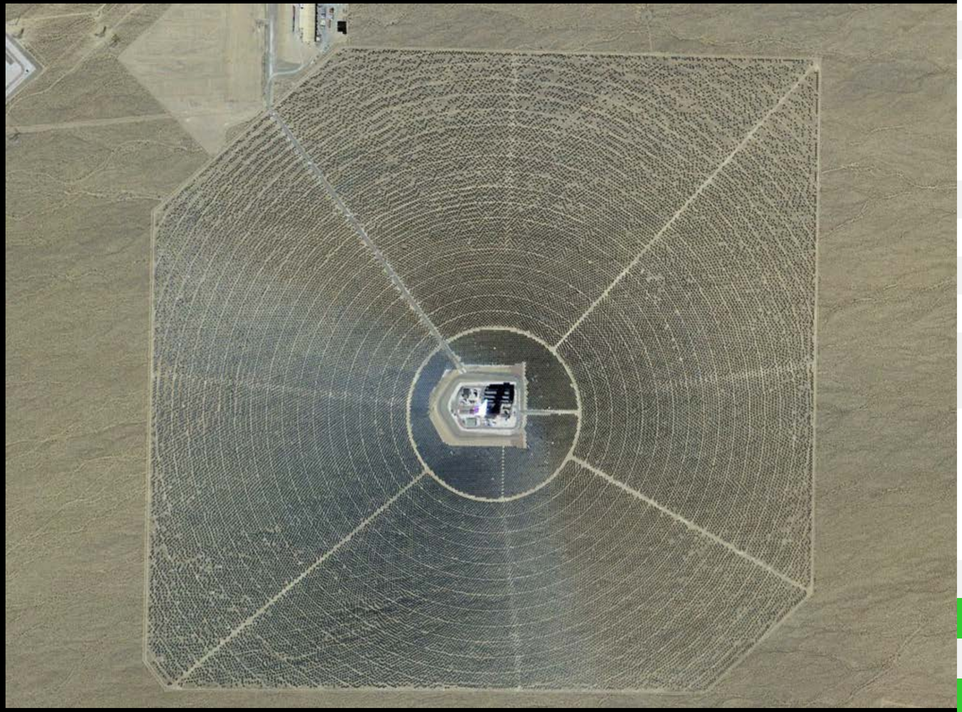
A Definition

- Power Generation
  - … or it can come non-combustion process-based sources like hydro, wind

Electric Power Generation						Non-renewable + Nuclear Percent of Total	Renewable Percent of Total	Combustion Process Generated Percent of Total	Non-combustion Process Generated Percent of Total
Renewable					Nuclear				
	Non-Combustion Processes								
Biomass	Hydro	Wind	Solar	Geothermal					
3.0%	11.0%	7.0%	15.7%	5.9%	8.4%	57.4%	42.6%	52.0%	48.0%
31.4%	0.0%	0.0%	7.3%	0.0%	0.0%	61.3%	38.7%	92.7%	7.3%
1.4%	0.0%	0.1%	1.0%	0.0%	0.0%	97.6%	2.5%	99.0%	1.1%
5.0%	1.1%	6.4%	5.3%	0.1%	0.0%	81.9%	17.9%	86.9%	12.9%
0.3%	1.7%	57.3%	0.0%	0.0%	4.9%	40.6%	59.3%	36.0%	63.9%
5.6%	7.5%	3.2%	0.0%	0.0%	60.4%	83.8%	16.3%	29.0%	71.1%
0.1%	4.8%	0.7%	13.7%	9.4%	0.0%	71.2%	28.7%	71.3%	28.6%
1.6%	50.2%	13.8%	1.7%	0.3%	0.0%	32.5%	67.6%	34.1%	66.0%
0.0%	0.0%	0.8%	1.6%	0.0%	0.0%	97.6%	2.4%	97.6%	2.4%
21.3%	52.4%	17.8%	8.4%	0.0%	0.0%	0.2%	99.9%	21.5%	78.6%
0.0%	2.8%	3.3%	0.0%	0.0%	0.0%	93.9%	6.1%	93.9%	6.1%
0.0%	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.2%**	**2.4%**	**18.2%**	**1.1%**
31.4%	**65.8%**	**57.3%**	**15.7%**	**9.4%**	**60.4%**	**97.6%**	**99.9%**	**99.0%**	**81.9%**
3.0%	**10.2%**	**9.4%**	**2.3%**	**0.3%**	**15.4%**	**74.7%**	**25.3%**	**62.3%**	**37.7%**
1.5%	7.0%	8.4%	2.2%	0.4%	19.6%	80.5%	19.5%	62.4%	37.6%

A Definition

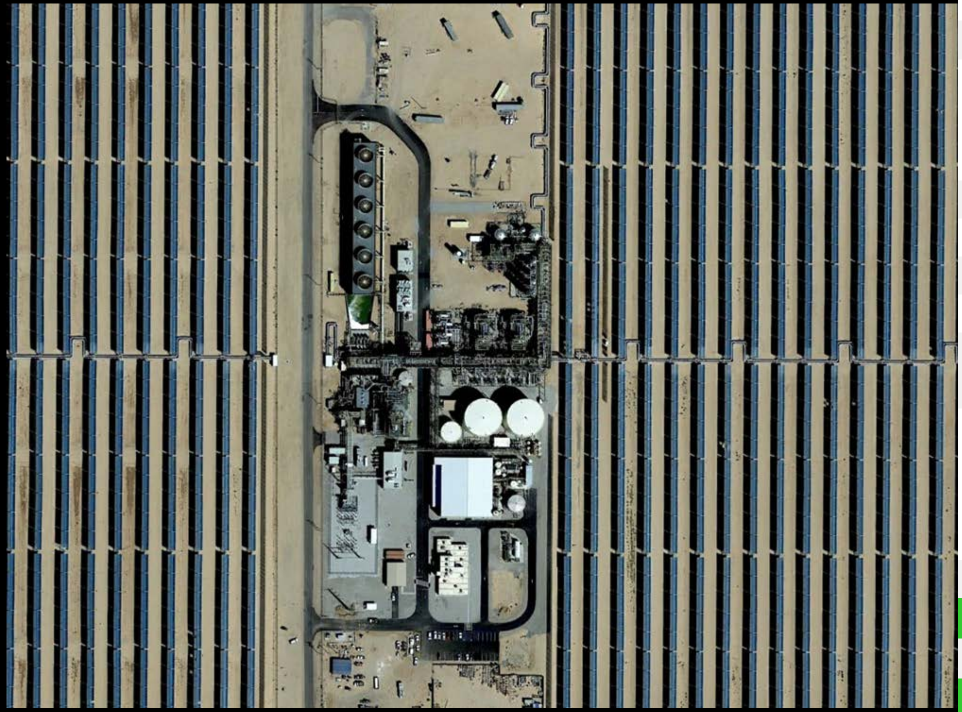
- Power Generation
  - … or it can come non-combustion process-based sources like hydro, wind, solar



Electric Power Generation									
Renewable					Nuclear	Non-renewable + Nuclear Percent of Total	Renewable Percent of Total	Combustion Process Generated Percent of Total	Non-combustion Process Generated Percent of Total
	Non-Combustion Processes								
Biomass	Hydro	Wind	Solar	Geothermal					
3.0%	11.0%	7.0%	15.7%	5.9%	8.4%	57.4%	42.6%	52.0%	48.0%
31.4%	0.0%	0.0%	7.3%	0.0%	0.0%	61.3%	38.7%	92.7%	7.3%
1.4%	0.0%	0.1%	1.0%	0.0%	0.0%	97.6%	2.5%	99.0%	1.1%
5.0%	1.1%	6.4%	5.3%	0.1%	0.0%	81.9%	17.9%	86.9%	12.9%
0.3%	1.7%	57.3%	0.0%	0.0%	4.9%	40.6%	59.3%	36.0%	63.9%
5.6%	7.5%	3.2%	0.0%	0.0%	60.4%	83.8%	16.3%	29.0%	71.1%
0.1%	4.8%	0.7%	13.7%	9.4%	0.0%	71.2%	28.7%	71.3%	28.6%
1.6%	50.2%	13.8%	1.7%	0.3%	0.0%	32.5%	67.6%	34.1%	66.0%
0.0%	0.0%	0.8%	1.6%	0.0%	0.0%	97.6%	2.4%	97.6%	2.4%
21.3%	52.4%	17.8%	8.4%	0.0%	0.0%	0.2%	99.9%	21.5%	78.6%
0.0%	2.8%	3.3%	0.0%	0.0%	0.0%	93.9%	6.1%	93.9%	6.1%
0.0%	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.2%**	**2.4%**	**18.2%**	**1.1%**
31.4%	**65.8%**	**57.3%**	**15.7%**	**9.4%**	**60.4%**	**97.6%**	**99.9%**	**99.0%**	**81.9%**
3.0%	**10.2%**	**9.4%**	**2.3%**	**0.3%**	**15.4%**	**74.7%**	**25.3%**	**62.3%**	**37.7%**
1.5%	7.0%	8.4%	2.2%	0.4%	19.6%	80.5%	19.5%	62.4%	37.6%

A Definition

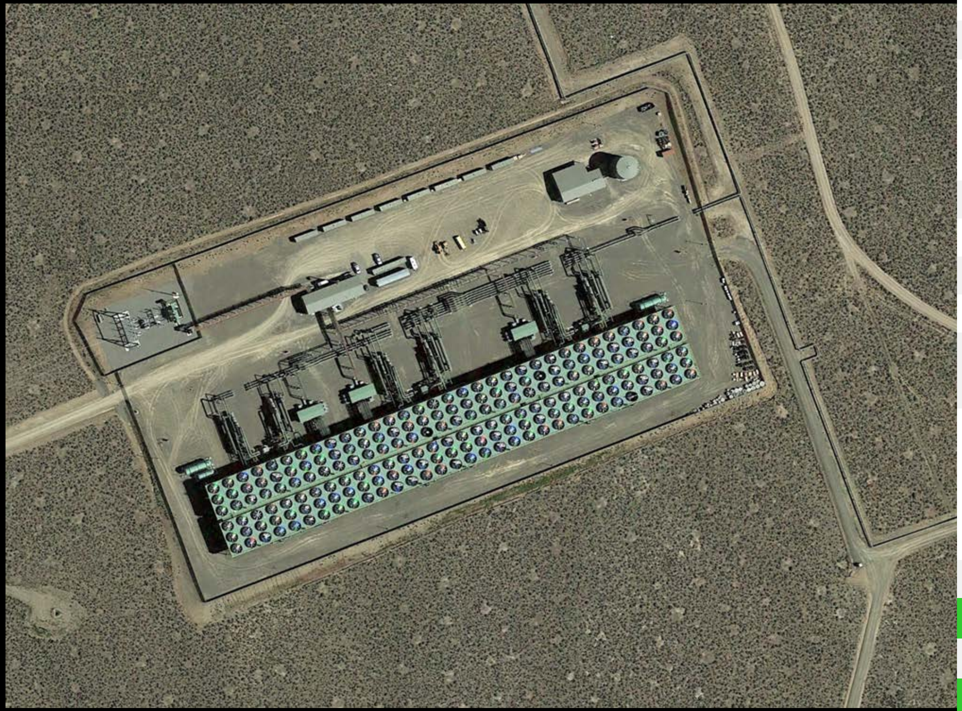
- Power Generation
  - … or it can come non-combustion process-based sources like hydro, wind, solar



Electric Power Generation						Non-renewable + Nuclear Percent of Total	Renewable Percent of Total	Combustion Process Generated Percent of Total	Non-combustion Process Generated Percent of Total
	Renewable				Nuclear				
	Non-Combustion Processes								
Biomass	Hydro	Wind	Solar	Geothermal					
3.0%	11.0%	7.0%	15.7%	5.9%	8.4%	57.4%	42.6%	52.0%	48.0%
31.4%	0.0%	0.0%	7.3%	0.0%	0.0%	61.3%	38.7%	92.7%	7.3%
1.4%	0.0%	0.1%	1.0%	0.0%	0.0%	97.6%	2.5%	99.0%	1.1%
5.0%	1.1%	6.4%	5.3%	0.1%	0.0%	81.9%	17.9%	86.9%	12.9%
0.3%	1.7%	57.3%	0.0%	0.0%	4.9%	40.6%	59.3%	36.0%	63.9%
5.6%	7.5%	3.2%	0.0%	0.0%	60.4%	83.8%	16.3%	29.0%	71.1%
0.1%	4.8%	0.7%	13.7%	9.4%	0.0%	71.2%	28.7%	71.3%	28.6%
1.6%	50.2%	13.8%	1.7%	0.3%	0.0%	32.5%	67.6%	34.1%	66.0%
0.0%	0.0%	0.8%	1.6%	0.0%	0.0%	97.6%	2.4%	97.6%	2.4%
21.3%	52.4%	17.8%	8.4%	0.0%	0.0%	0.2%	99.9%	21.5%	78.6%
0.0%	2.8%	3.3%	0.0%	0.0%	0.0%	93.9%	6.1%	93.9%	6.1%
0.0%	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.2%**	**2.4%**	**18.2%**	**1.1%**
31.4%	**65.8%**	**57.3%**	**15.7%**	**9.4%**	**60.4%**	**97.6%**	**99.9%**	**99.0%**	**81.9%**
3.0%	**10.2%**	**9.4%**	**2.3%**	**0.3%**	**15.4%**	**74.7%**	**25.3%**	**62.3%**	**37.7%**
1.5%	7.0%	8.4%	2.2%	0.4%	19.6%	80.5%	19.5%	62.4%	37.6%

A Definition

- Power Generation
  - … or it can come non-combustion process-based sources like hydro, wind, solar, geothermal



Electric Power Generation						Non-renewable + Nuclear Percent of Total	Renewable Percent of Total	Combustion Process Generated Percent of Total	Non-combustion Process Generated Percent of Total
Renewable					Nuclear				
	Non-Combustion Processes								
Biomass	Hydro	Wind	Solar	Geothermal					
3.0%	11.0%	7.0%	15.7%	5.9%	8.4%	57.4%	42.6%	52.0%	48.0%
31.4%	0.0%	0.0%	7.3%	0.0%	0.0%	61.3%	38.7%	92.7%	7.3%
1.4%	0.0%	0.1%	1.0%	0.0%	0.0%	97.6%	2.5%	99.0%	1.1%
5.0%	1.1%	6.4%	5.3%	0.1%	0.0%	81.9%	17.9%	86.9%	12.9%
0.3%	1.7%	57.3%	0.0%	0.0%	4.9%	40.6%	59.3%	36.0%	63.9%
5.6%	7.5%	3.2%	0.0%	0.0%	60.4%	83.8%	16.3%	29.0%	71.1%
0.1%	4.8%	0.7%	13.7%	9.4%	0.0%	71.2%	28.7%	71.3%	28.6%
1.6%	50.2%	13.8%	1.7%	0.3%	0.0%	32.5%	67.6%	34.1%	66.0%
0.0%	0.0%	0.8%	1.6%	0.0%	0.0%	97.6%	2.4%	97.6%	2.4%
21.3%	52.4%	17.8%	8.4%	0.0%	0.0%	0.2%	99.9%	21.5%	78.6%
0.0%	2.8%	3.3%	0.0%	0.0%	0.0%	93.9%	6.1%	93.9%	6.1%
0.0%	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.2%**	**2.4%**	**18.2%**	**1.1%**
31.4%	**65.8%**	**57.3%**	**15.7%**	**9.4%**	**60.4%**	**97.6%**	**99.9%**	**99.0%**	**81.9%**
3.0%	**10.2%**	**9.4%**	**2.3%**	**0.3%**	**15.4%**	**74.7%**	**25.3%**	**62.3%**	**37.7%**
1.5%	7.0%	8.4%	2.2%	0.4%	19.6%	80.5%	19.5%	62.4%	37.6%

A Definition

- Power Generation
  - … or it can come non-combustion process-based sources like hydro, wind, solar, geothermal, and nuclear energy

Electric Power Generation						Non-renewable + Nuclear Percent of Total	Renewable Percent of Total	Combustion Process Generated Percent of Total	Non-combustion Process Generated Percent of Total
Renewable					Nuclear				
	Non-Combustion Processes								
Biomass	Hydro	Wind	Solar	Geothermal					
3.0%	11.0%	7.0%	15.7%	5.9%	8.4%	57.4%	42.6%	52.0%	48.0%
31.4%	0.0%	0.0%	7.3%	0.0%	0.0%	61.3%	38.7%	92.7%	7.3%
1.4%	0.0%	0.1%	1.0%	0.0%	0.0%	97.6%	2.5%	99.0%	1.1%
5.0%	1.1%	6.4%	5.3%	0.1%	0.0%	81.9%	17.9%	86.9%	12.9%
0.3%	1.7%	57.3%	0.0%	0.0%	4.9%	40.6%	59.3%	36.0%	63.9%
5.6%	7.5%	3.2%	0.0%	0.0%	60.4%	83.8%	16.3%	29.0%	71.1%
0.1%	4.8%	0.7%	13.7%	9.4%	0.0%	71.2%	28.7%	71.3%	28.6%
1.6%	50.2%	13.8%	1.7%	0.3%	0.0%	32.5%	67.6%	34.1%	66.0%
0.0%	0.0%	0.8%	1.6%	0.0%	0.0%	97.6%	2.4%	97.6%	2.4%
21.3%	52.4%	17.8%	8.4%	0.0%	0.0%	0.2%	99.9%	21.5%	78.6%
0.0%	2.8%	3.3%	0.0%	0.0%	0.0%	93.9%	6.1%	93.9%	6.1%
0.0%	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.2%**	**2.4%**	**18.2%**	**1.1%**
31.4%	**65.8%**	**57.3%**	**15.7%**	**9.4%**	**60.4%**	**97.6%**	**99.9%**	**99.0%**	**81.9%**
3.0%	**10.2%**	**9.4%**	**2.3%**	**0.3%**	**15.4%**	**74.7%**	**25.3%**	**62.3%**	**37.7%**
1.5%	7.0%	8.4%	2.2%	0.4%	19.6%	80.5%	19.5%	62.4%	37.6%

Why Electrification?

The traditional approach to generating heat has been to burn fossil fuels

- Good News
  - Fairly simple
  - High grade heat
  - Fairly inexpensive

Why Electrification?

The traditional approach to generating heat has been to burn fossil fuels

- Good News
- Fairly simple
- High grade heat
- Fairly inexpensive

Bad News

- CO_2 Intensive

CO_2 Emissions for Different Fuels

Fuel	lb CO_2 per million Btu Burned	lb CO_2 per million Btu Delivered						
		Boiler Efficiency						
		95%	90%	85%	80%	75%	70%	65%
Natural Gas	117	123	130	137	146	156	167	179
Propane	139	146	154	163	173	185	198	213
Oil	163	172	182	192	204	218	234	251
Coal	212	223	235	249	265	282	303	326

Emmissions Factor Source - https://www.eia.gov/environment/emissions/co2_vol_mass.php

The Goal

Stop burning fossil fuels by switching to an all-electric grid powered by renewable resources

The Challenges

1. Currently about 60-63% of our electricity is generated by burning something

The Challenges

2. Heat rates (efficiencies) for our power plants are not particularly high …

Heat Rates for Different Types of Power Plants

Generating Station Type	Typical Heat Rate				Emissions	lb CO_2 per kWh Generated	
	Minimum		Maximum		lb CO_2 per million Btu	Minimum	Maximum
	Btu/kWh	Efficiency	Btu/kWh	Efficiency			
Natural Gas with Cogeneration	5,000	68%	6,500	53%	117	0.58	0.76
Natural Gas Combined Cycle	6,200	55%	8,000	43%	117	0.72	0.93
Natural Gas Reciprocating Engine	7,500	46%	8,500	40%	117	0.87	0.99
Natural Gas Combustion Turbine	8,000	43%	10,000	34%	117	0.93	1.17
Coal Steam Turbine	9,000	38%	11,000	31%	212	1.91	2.33
Natural Gas Steam Turbine	10,000	34%	12,000	28%	117	1.17	1.40
Nuclear Power Plant	10,446	33%	10,459	33%	0	0.00	0.00
Heat Rate Source -	https://energyknowledgebase.com/topics/heat-rate.asp						
Emmissions Factor Source -	https://www.eia.gov/environment/emissions/co2_vol_mass.php						

2. Heat rates (efficiencies) for our power plants are not particularly high and CO_2 emissions potentially would not be much different

Heat Rates for Different Types of Power Plants

Generating Station Type	Typical Heat Rate				Emissions	lb CO_2 per kWh Generated	
	Minimum		Maximum		lb CO_2 per million Btu	Minimum	Maximum
	Btu/kWh	Efficiency	Btu/kWh	Efficiency			
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Heat Rate Source - https://energyknowledgebase.com/topics/heat-rate.asp

CO_2 Emissions for Different Fuels

Fuel	lb CO_2 per million Btu Burned	lb CO_2 per million Btu Delivered by Boilers							lb CO_2 per Million Btu Delivered as Electric Resistance Heat *
		Boiler Efficiency							
		95%	90%	85%	80%	75%	70%	65%	
Natural Gas	117	123	130	137	146	156	167	179	214
Propane	139	146	154	163	173	185	198	213	
Oil	163	172	182	192	204	218	234	251	
Coal	212	223	235	249	265	282	303	326	

Emmissions Factor Source - https://www.eia.gov/environment/emissions/co2_vol_mass.php

Heat Rate Source - "Heat Rates" tab of this spreadsheet

* This is the average value for the various fossil fuel power plants listed in the "Heat Rates" tab

The Challenges

3. Distribution losses are in the range of 5-6% between the switch yard at the power plant and your meter

Heat Rates for Different Types of Power Plants

Generating Station Type	Typical Heat Rate				Emissions	lb CO_2 per kWh Generated	
	Minimum		Maximum		lb CO_2 per million Btu	Minimum	Maximum
	Btu/kWh	Efficiency	Btu/kWh	Efficiency			
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Heat Rate Source - https://energyknowledgebase.com/topics/heat-rate.asp

Emmissions Factor Source - https://www.eia.gov/environment/emissions/co2_vol_mass.php

The Challenges

4. It will take a very significant investment in additional infrastructure to support the distribution required for an all-electric renewable energy supplied grid

Heat Rates for Different Types of Power Plants

Generating Station Type	Typical Heat Rate				Emissions	lb CO_2 per kWh Generated	
	Minimum		Maximum		lb CO_2 per million Btu	Minimum	Maximum
	Btu/kWh	Efficiency	Btu/kWh	Efficiency			
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Heat Rate Source - https://energyknowledgebase.com/topics/heat-rate.asp
Emmissions Factor Source - https://www.eia.gov/environment/emissions/co2_vol_mass.php

The Challenges

4. Energy storage systems will also be needed with related investments


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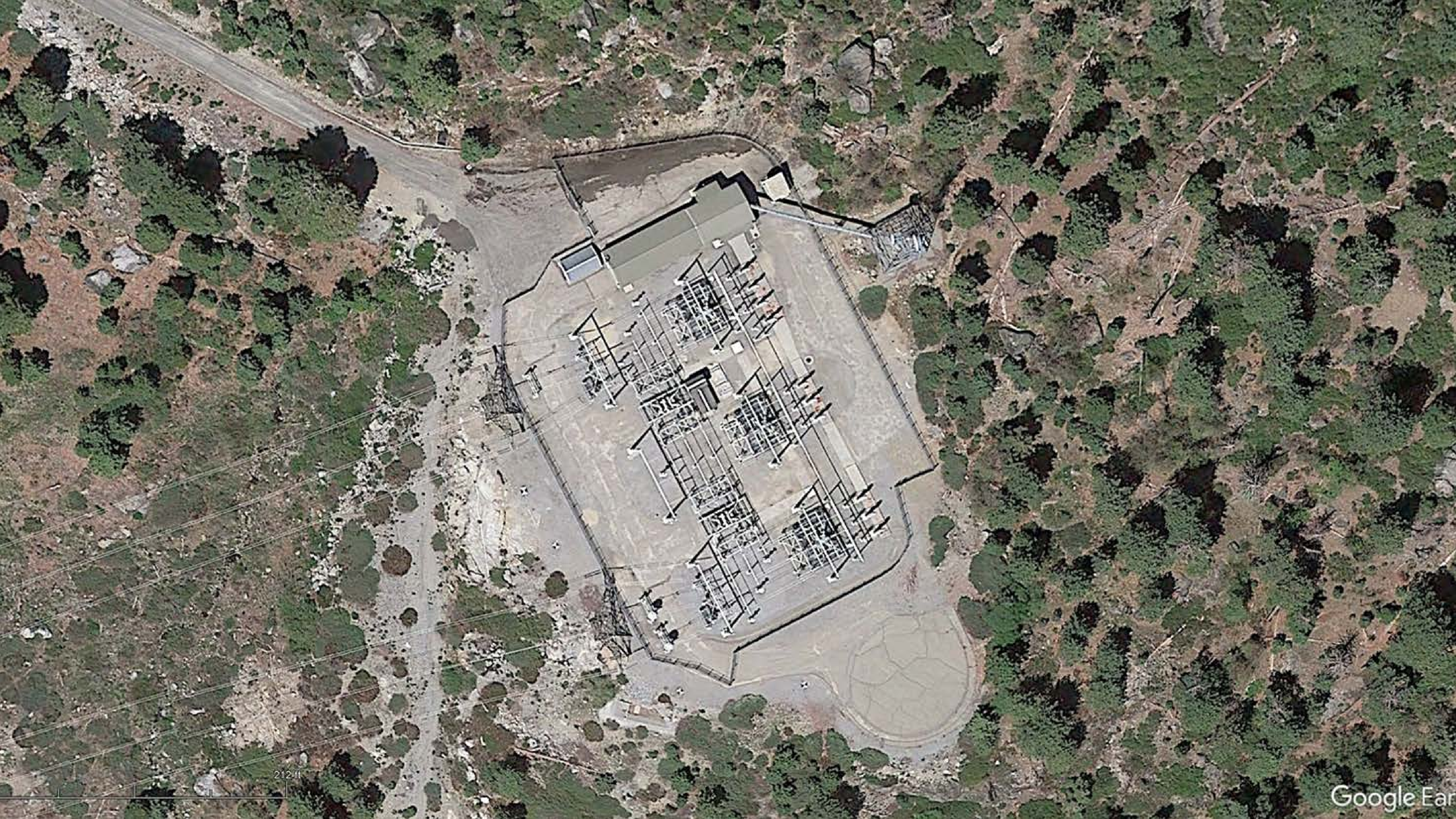
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Google Earth


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Google Earth


Google Earth

The Challenges

5. There may be things going on that we have yet to fully appreciate

The relative contribution of waste heat from power plants to global warming

R. Zevenhoven[a,*], A. Beyene[b]

[a] Department of Chemical Engineering, Thermal and Flow Engineering Laboratory, Åbo Akademi University, Biskopsgatan 8, FI-20500 Åbo/Turku, Finland
[b] Department of Mechanical Engineering, San Diego State University, 5500 Campanile Drive, San Diego, CA, USA

A R T I C L E I N F O

Article history:
Received 2 March 2010
Received in revised form
26 August 2010
Accepted 6 October 2010
Available online 3 November 2010

Keywords:
Global warming
Thermal power plant
Greenhouse gases
Waste heat

A B S T R A C T

Evidence on global climate change, being caused primarily by rising levels of greenhouse gases in the atmosphere, is perceived as fairly conclusive. It is generally attributed to the enhanced greenhouse effect, resulting from higher levels of trapped heat radiation by increasing atmospheric concentrations of gases such as CO_2 (carbon dioxide). Much of these gases originate from power plants and fossil fuel combustion. However, the fate of vast amounts of waste heat rejected into the environment has evaded serious scholarly research. While 1 kWh electricity generation in a typical condensing coal-fired power plant emits around 1 kg of CO_2, it also puts about 2 kWh energy into the environment as low grade heat. For nuclear (fission) electricity the waste heat release per kWh is somewhat higher despite much lower CO_2 releases. This paper evaluates the impact of waste heat rejection combined with CO_2 emissions using Finland and California as case examples. The immediate effects of waste heat release from power production and radiative forcing by CO_2 are shown to be similar. However, the long-term (hundred years) global warming by CO_2-caused radiative forcing is about twenty-five times stronger than the immediate effects, being responsible for around 92% of the heat-up caused by electricity production.

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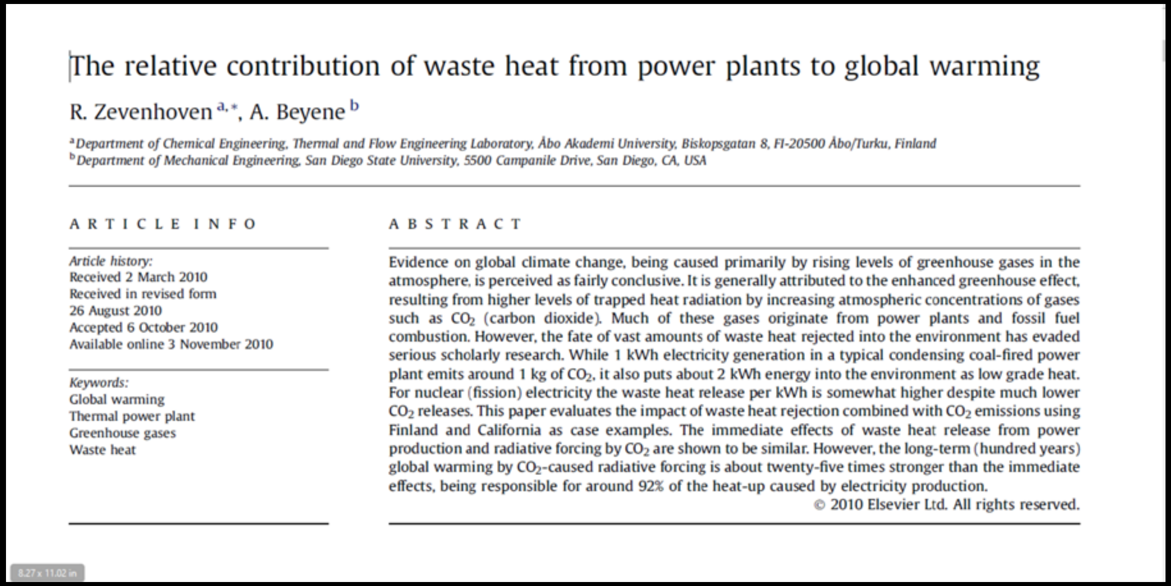
The Challenges

5. There may be things going on that we have yet to fully appreciate



The relative contribution of waste heat from power plants to global warming

R. Zevenhoven [a,*], A. Beyene [b]

[a] Department of Chemical Engineering, Thermal and Flow Engineering Laboratory, Åbo Akademi University, Biskopsgatan 8, FI-20500 Åbo/Turku, Finland
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ABSTRACT

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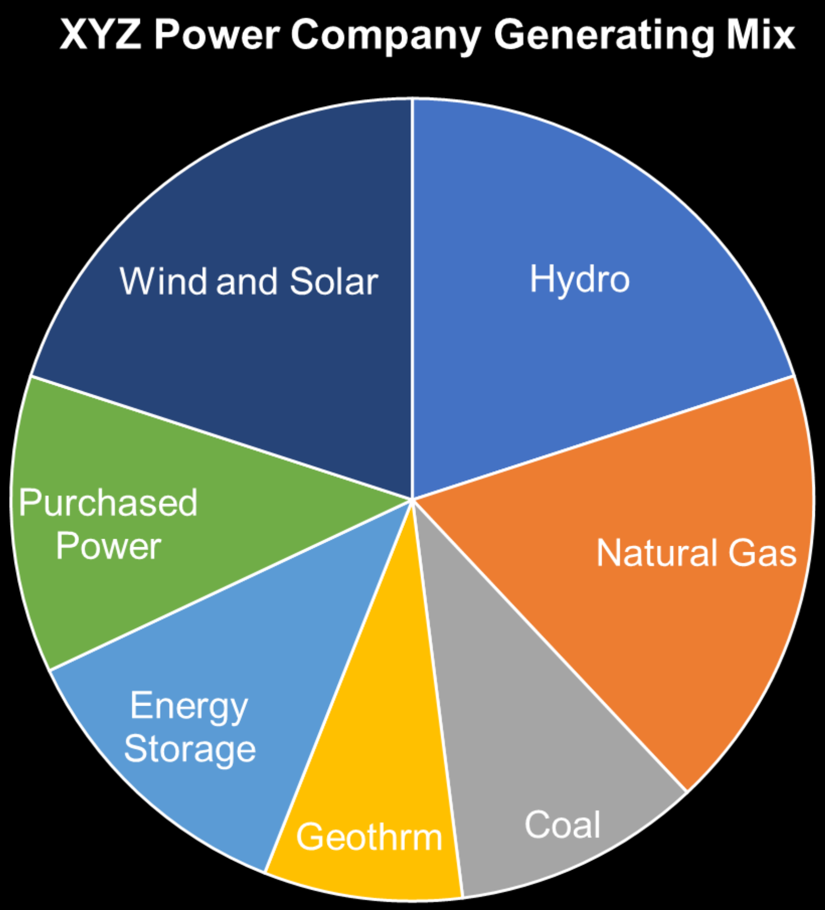
Reducing Atmospheric Impacts

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

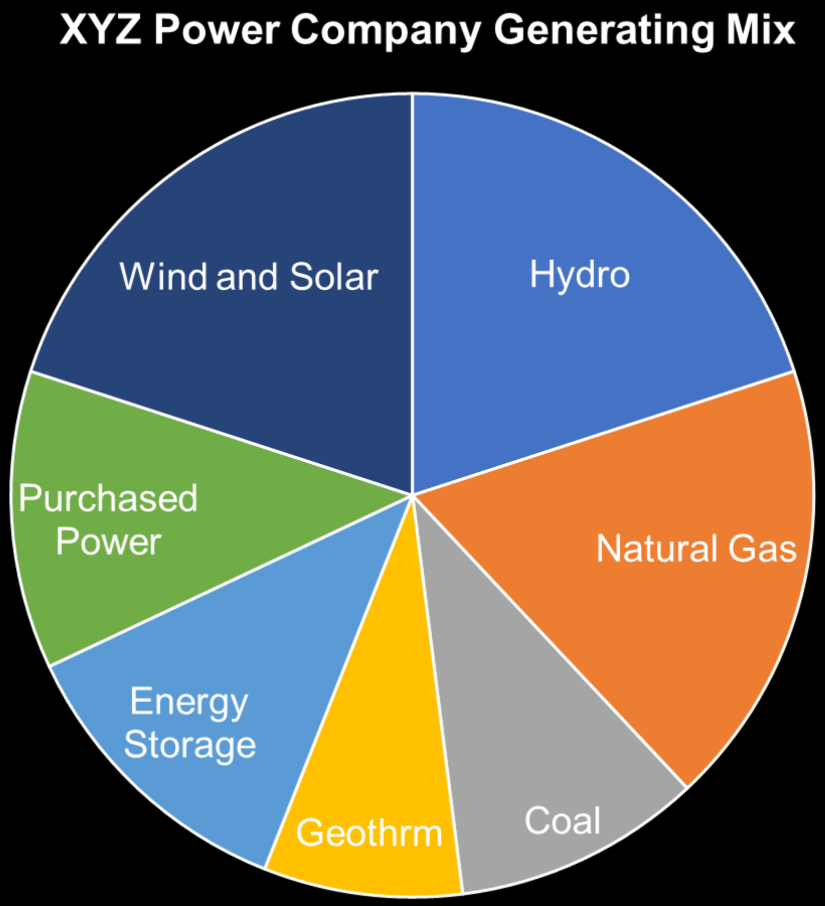
Moving away from carbon fuels is a common, long-term goal for many utilities



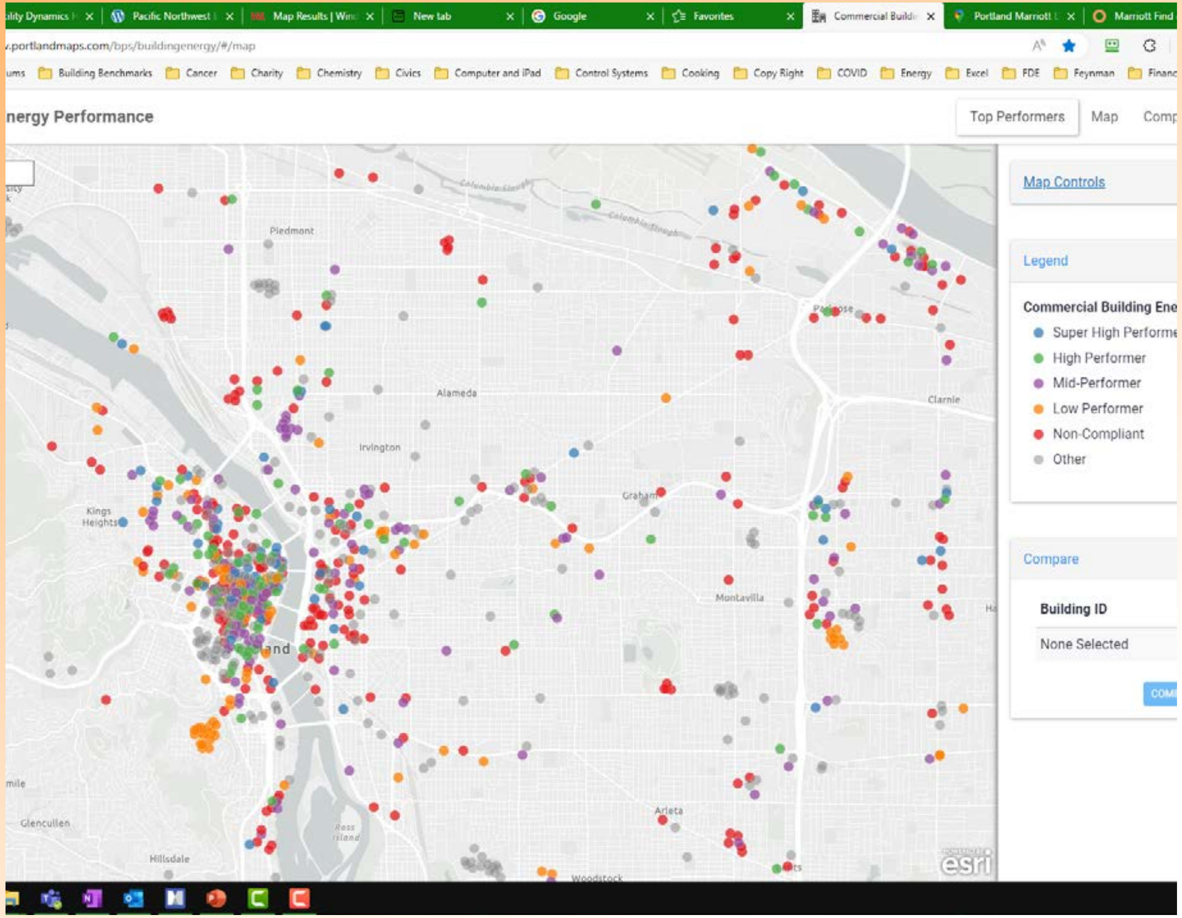
Reducing Atmospheric Impacts

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

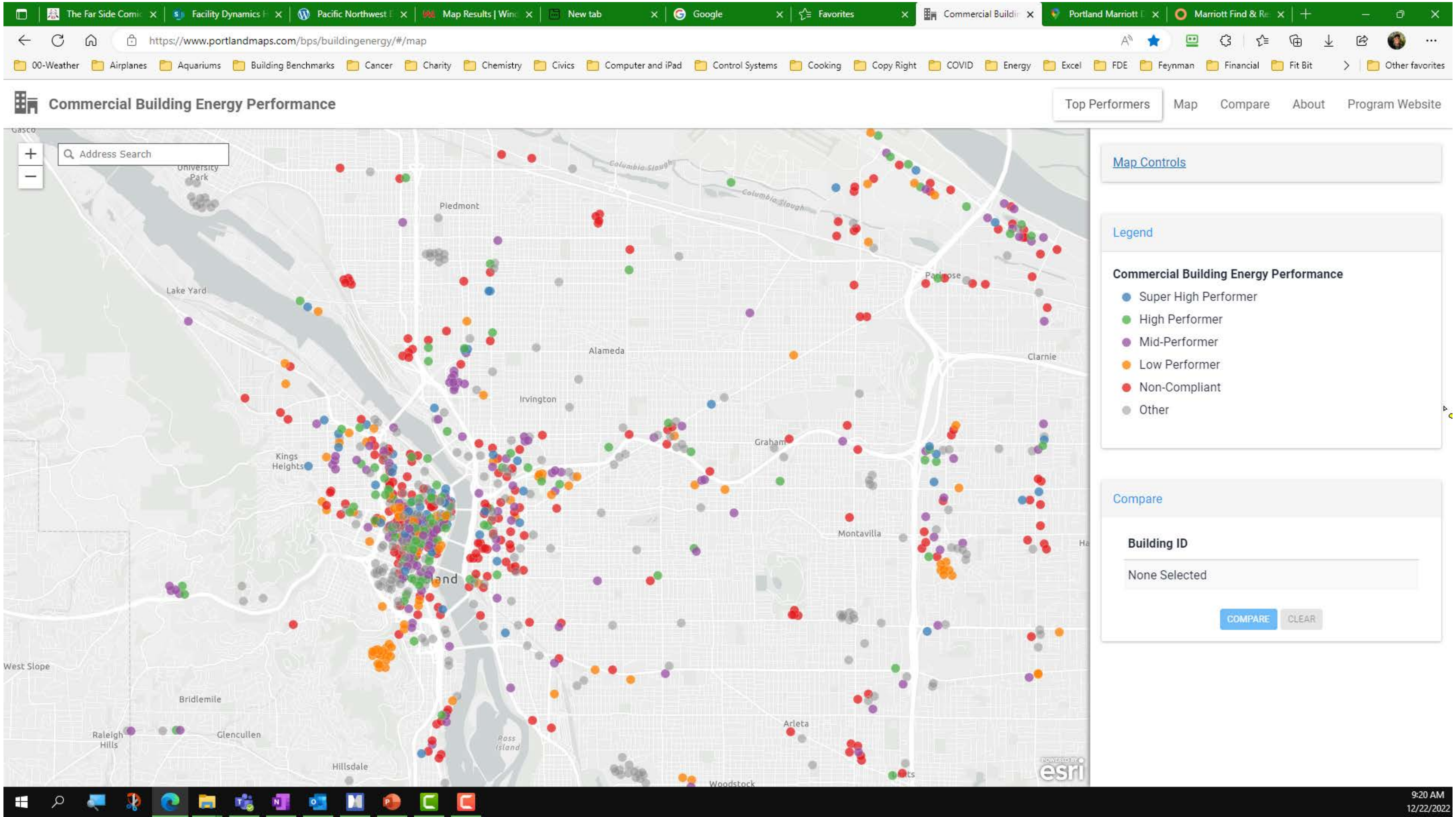
It's a win-win situation



What is Benchmarking?



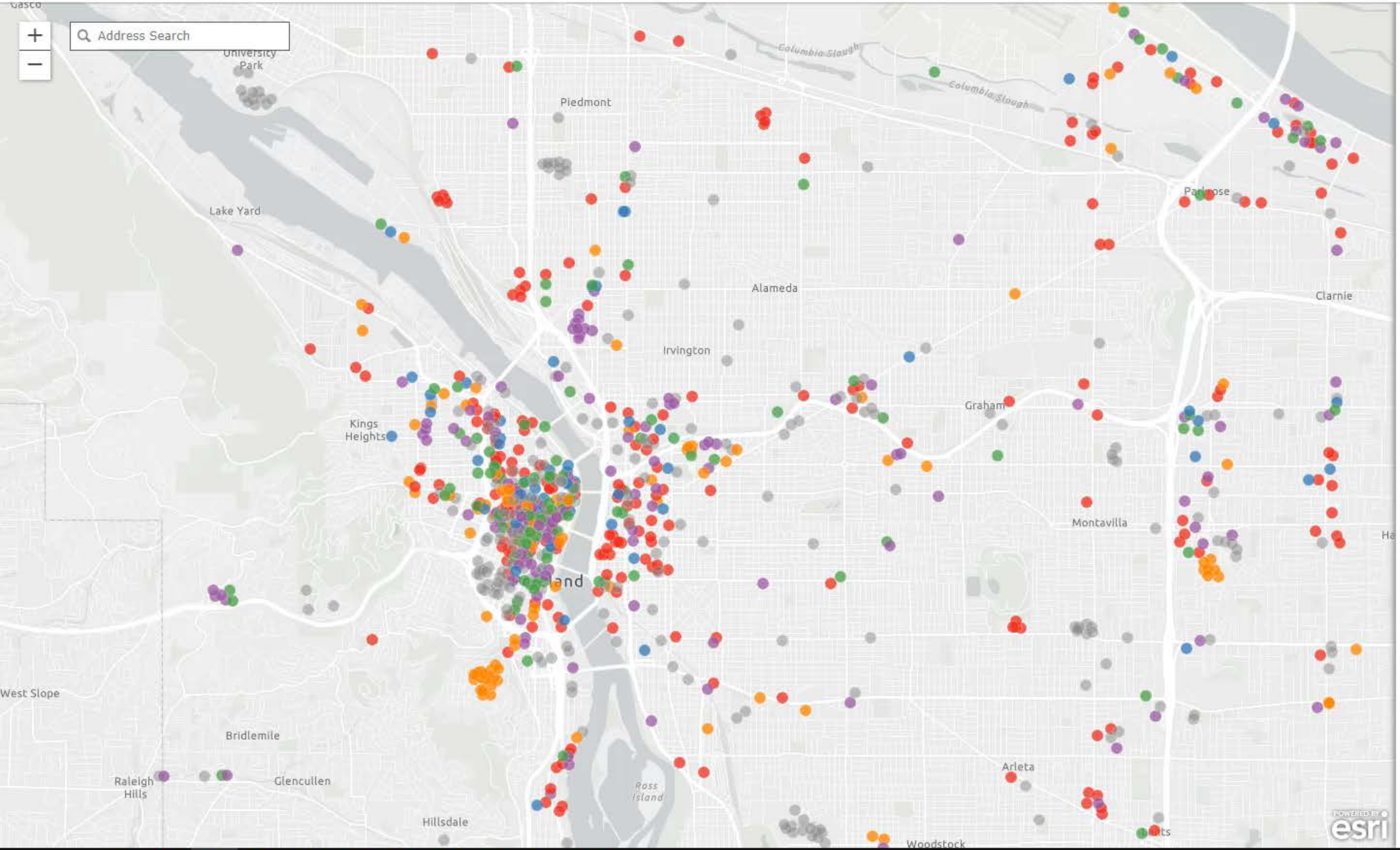
Benchmarking is Comparing Your Building's Efficiency to Your Peers



https://www.portlandmaps.com/bps/buildingenergy/#/map

Commercial Building Energy Performance

Top Performers | Map | Compare | About | Program Website



Map Controls

Legend

Commercial Building Energy Performance

- Super High Performer
- High Performer
- Mid-Performer
- Low Performer
- Non-Compliant
- Other

Compare

Building ID

None Selected

COMPARE CLEAR

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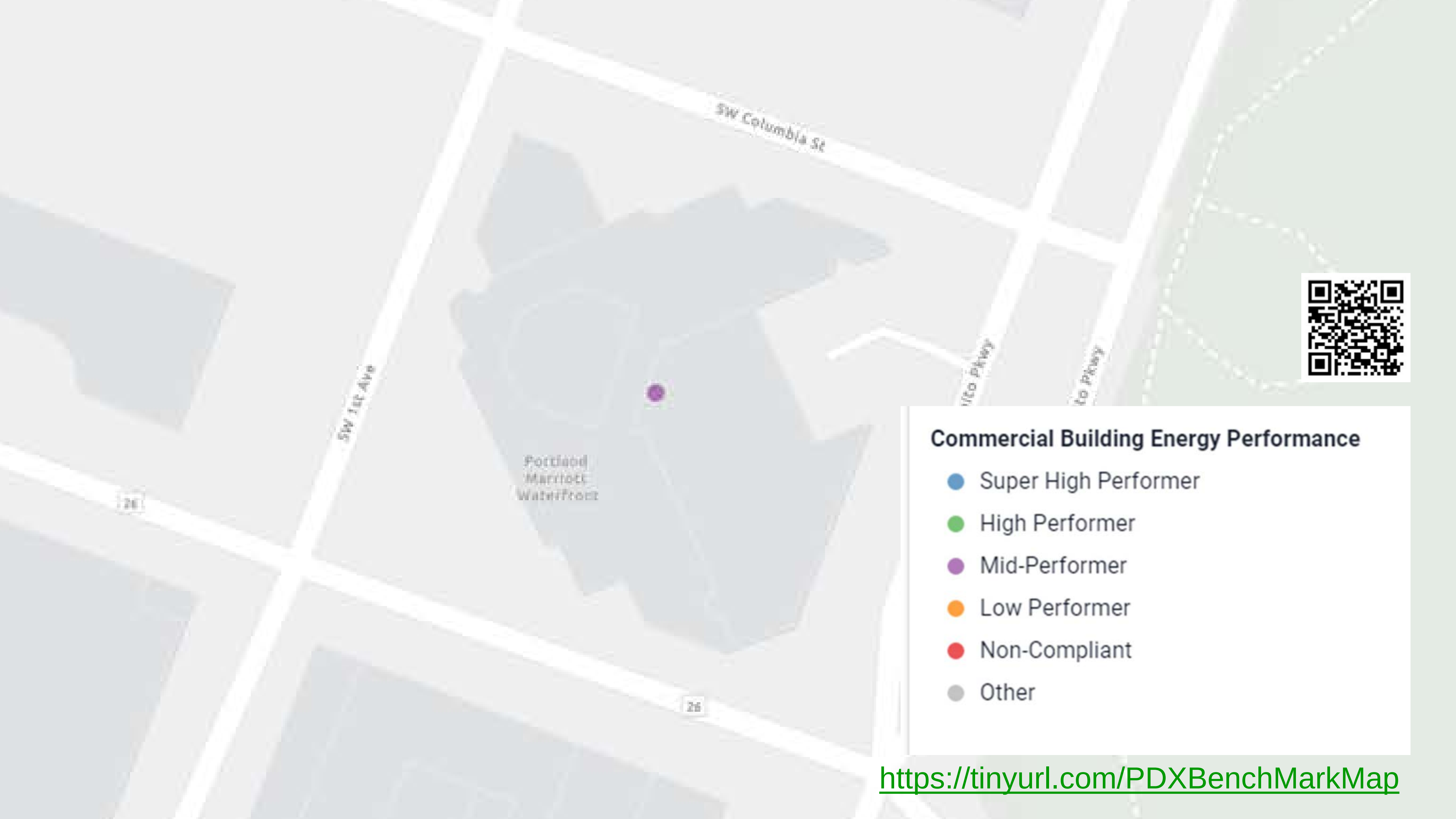

https://tinyurl.com/PDXBenchMarkMap

Benchmarking with Energy Star

March 31, 2017

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, 2018

ENERGY STAR® Statement of Energy Performance

LEARN MORE AT energystar.gov

95

ENERGY STAR® Score[1]

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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

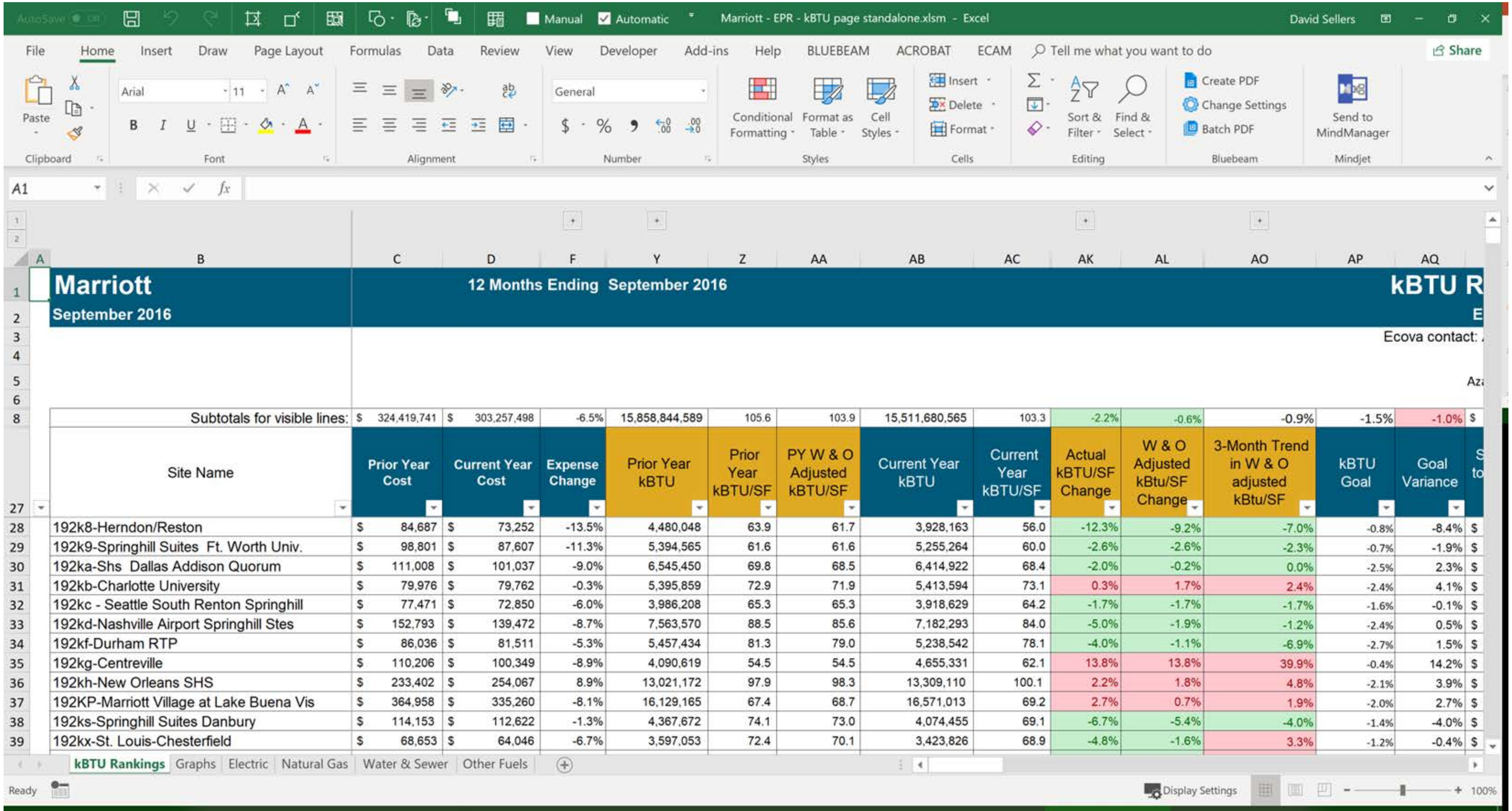
https://tinyurl.com/ENRGStarBenchMark

Benchmarking with the DOE Building Performance Database

https://bpd.lbl.gov/

Benchmarking with Marriott's EPR-kBtu Spreadsheet

https://tinyurl.com/EPRkBtu01



Marriott
September 2016
12 Months Ending September 2016
kBTU R
Ecova contact:

Site Name	Prior Year Cost	Current Year Cost	Expense Change	Prior Year kBTU	Prior Year kBTU/SF	PY W & O Adjusted kBTU/SF	Current Year kBTU	Current Year kBTU/SF	Actual kBTU/SF Change	W & O Adjusted kBtu/SF Change	3-Month Trend in W & O adjusted kBtu/SF	kBTU Goal	Goal Variance
Subtotals for visible lines:	$ 324,419,741	$ 303,257,498	-6.5%	15,858,844,589	105.6	103.9	15,511,680,565	103.3	-2.2%	-0.6%	-0.9%	-1.5%	-1.0%
192k8-Herndon/Reston	$ 84,687	$ 73,252	-13.5%	4,480,048	63.9	61.7	3,928,163	56.0	-12.3%	-9.2%	-7.0%	-0.8%	-8.4%
192k9-Springhill Suites Ft. Worth Univ.	$ 98,801	$ 87,607	-11.3%	5,394,565	61.6	61.6	5,255,264	60.0	-2.6%	-2.6%	-2.3%	-0.7%	-1.9%
192ka-Shs Dallas Addison Quorum	$ 111,008	$ 101,037	-9.0%	6,545,450	69.8	68.5	6,414,922	68.4	-2.0%	-0.2%	0.0%	-2.5%	2.3%
192kb-Charlotte University	$ 79,976	$ 79,762	-0.3%	5,395,859	72.9	71.9	5,413,594	73.1	0.3%	1.7%	2.4%	-2.4%	4.1%
192kc - Seattle South Renton Springhill	$ 77,471	$ 72,850	-6.0%	3,986,208	65.3	65.3	3,918,629	64.2	-1.7%	-1.7%	-1.7%	-1.6%	-0.1%
192kd-Nashville Airport Springhill Stes	$ 152,793	$ 139,472	-8.7%	7,563,570	88.5	85.6	7,182,293	84.0	-5.0%	-1.9%	-1.2%	-2.4%	0.5%
192kf-Durham RTP	$ 86,036	$ 81,511	-5.3%	5,457,434	81.3	79.0	5,238,542	78.1	-4.0%	-1.1%	-6.9%	-2.7%	1.5%
192kg-Centreville	$ 110,206	$ 100,349	-8.9%	4,090,619	54.5	54.5	4,655,331	62.1	13.8%	13.8%	39.9%	-0.4%	14.2%
192kh-New Orleans SHS	$ 233,402	$ 254,067	8.9%	13,021,172	97.9	98.3	13,309,110	100.1	2.2%	1.8%	4.8%	-2.1%	3.9%
192KP-Marriott Village at Lake Buena Vis	$ 364,958	$ 335,260	-8.1%	16,129,165	67.4	68.7	16,571,013	69.2	2.7%	0.7%	1.9%	-2.0%	2.7%
192ks-Springhill Suites Danbury	$ 114,153	$ 112,622	-1.3%	4,367,672	74.1	73.0	4,074,455	69.1	-6.7%	-5.4%	-4.0%	-1.4%	-4.0%
192kx-St. Louis-Chesterfield	$ 68,653	$ 64,046	-6.7%	3,597,053	72.4	70.1	3,423,826	68.9	-4.8%	-1.6%	3.3%	-1.2%	-0.4%

kBTU Rankings | Graphs | Electric | Natural Gas | Water & Sewer | Other Fuels

Benchmarks Use Energy Use Intensity (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

A tool to help you start benchmarking - https://tinyurl.com/BenchMarkSpreadsheet

What is the Difference Between Site and Source Energy?

Site Energy

Energy that passes through *<u>your</u>* meter

Source Energy

Energy that passes through *your* meter

Energy that passed through the *power plant* meter

The Source Energy Perspective Takes Energy Conversion Losses Into Consideration

State	% of Total Electric Power Generation											Non-renewable + Nuclear Percent of Total	Renewable Percent of Total	Combustion Process Generated Percent of Total	Non-combustion Process Generated Percent of Total
	Non-Renewable					Renewable					Nuclear				
	Combustion Processes						Non-Combustion Processes								
	Coal	Oil	Gas	Other Fossil Fuel	Purchased, Fuel Generated	Biomass	Hydro	Wind	Solar	Geothermal					
CA	0.2%	0.0%	47.7%	0.8%	0.3%	3.0%	11.0%	7.0%	15.7%	5.9%	8.4%	57.4%	42.6%	52.0%	48.0%
DC	0.0%	0.0%	61.3%	0.0%	0.0%	31.4%	0.0%	0.0%	7.3%	0.0%	0.0%	61.3%	38.7%	92.7%	7.3%
DE	2.0%	0.2%	92.6%	2.8%	0.0%	1.4%	0.0%	0.1%	1.0%	0.0%	0.0%	97.6%	2.5%	99.0%	1.1%
HI	12.8%	67.8%	0.0%	0.0%	1.3%	5.0%	1.1%	6.4%	5.3%	0.1%	0.0%	81.9%	17.9%	86.9%	12.9%
IA	23.7%	0.2%	11.8%	0.0%	0.0%	0.3%	1.7%	57.3%	0.0%	0.0%	4.9%	40.6%	59.3%	36.0%	63.9%
NH	0.8%	0.3%	22.3%	0.0%	0.0%	5.6%	7.5%	3.2%	0.0%	0.0%	60.4%	83.8%	16.3%	29.0%	71.1%
NV	4.8%	0.0%	66.3%	0.0%	0.1%	0.1%	4.8%	0.7%	13.7%	9.4%	0.0%	71.2%	28.7%	71.3%	28.6%
OR	2.6%	0.0%	29.9%	0.0%	0.0%	1.6%	50.2%	13.8%	1.7%	0.3%	0.0%	32.5%	67.6%	34.1%	66.0%
RI	16.8%	49.9%	30.9%	0.0%	0.0%	0.0%	0.0%	0.8%	1.6%	0.0%	0.0%	97.6%	2.4%	97.6%	2.4%
WA	0.0%	0.1%	0.1%	0.0%	0.0%	21.3%	52.4%	17.8%	8.4%	0.0%	0.0%	0.2%	99.9%	21.5%	78.6%
WY	88.6%	0.3%	4.9%	0.1%	0.0%	0.0%	2.8%	3.3%	0.0%	0.0%	0.0%	93.9%	6.1%	93.9%	6.1%
Minimum	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.2%**	**2.4%**	**18.2%**	**1.1%**
Maximum	**88.6%**	**67.8%**	**93.0%**	**2.8%**	**1.3%**	**31.4%**	**65.8%**	**57.3%**	**15.7%**	**9.4%**	**60.4%**	**97.6%**	**99.9%**	**99.0%**	**81.9%**
Average	**19.8%**	**2.9%**	**36.2%**	**0.3%**	**0.1%**	**3.0%**	**10.2%**	**9.4%**	**2.3%**	**0.3%**	**15.4%**	**74.7%**	**25.3%**	**62.3%**	**37.7%**
US	19.3%	0.7%	40.5%	0.3%	0.1%	1.5%	7.0%	8.4%	2.2%	0.4%	19.6%	80.5%	19.5%	62.4%	37.6%

Data taken from https://www.epa.gov/egrid

The Source Energy Perspective Takes Energy Conversion Losses Into Consideration

% of Total Electric Power Generation									Non-renewable + Nuclear Percent of Total	Renewable Percent of Total	Combustion Process Generated Percent of Total	Non-combustion Process Generated Percent of Total
		Renewable						Nuclear				
sses			Non-Combustion Processes									
Fossil uel	Purchased, Fuel Generated	Biomass	Hydro	Wind	Solar	Geothermal						
8%	0.3%	3.0%	11.0%	7.0%	15.7%	5.9%	8.4%	57.4%	42.6%	52.0%	48.0%
0%	0.0%	31.4%	0.0%	0.0%	7.3%	0.0%	0.0%	61.3%	38.7%	92.7%	7.3%
8%	0.0%	1.4%	0.0%	0.1%	1.0%	0.0%	0.0%	97.6%	2.5%	99.0%	1.1%
0%	1.3%	5.0%	1.1%	6.4%	5.3%	0.1%	0.0%	81.9%	17.9%	86.9%	12.9%
0%	0.0%	0.3%	1.7%	57.3%	0.0%	0.0%	4.9%	40.6%	59.3%	36.0%	63.9%
0%	0.0%	5.6%	7.5%	3.2%	0.0%	0.0%	60.4%	83.8%	16.3%	29.0%	71.1%
0%	0.1%	0.1%	4.8%	0.7%	13.7%	9.4%	0.0%	71.2%	28.7%	71.3%	28.6%
0%	0.0%	1.6%	50.2%	13.8%	1.7%	0.3%	0.0%	32.5%	67.6%	34.1%	66.0%
0%	0.0%	0.0%	0.0%	0.8%	1.6%	0.0%	0.0%	97.6%	2.4%	97.6%	2.4%
0%	0.0%	21.3%	52.4%	17.8%	8.4%	0.0%	0.0%	0.2%	99.9%	21.5%	78.6%
1%	0.0%	0.0%	2.8%	3.3%	0.0%	0.0%	0.0%	93.9%	6.1%	93.9%	6.1%
0%	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.2%**	**2.4%**	**18.2%**	**1.1%**
8%	**1.3%**	**31.4%**	**65.8%**	**57.3%**	**15.7%**	**9.4%**	**60.4%**	**97.6%**	**99.9%**	**99.0%**	**81.9%**
3%	**0.1%**	**3.0%**	**10.2%**	**9.4%**	**2.3%**	**0.3%**	**15.4%**	**74.7%**	**25.3%**	**62.3%**	**37.7%**
3%	0.1%	1.5%	7.0%	8.4%	2.2%	0.4%	19.6%	80.5%	19.5%	62.4%	37.6%

The Source Energy Perspective Takes Energy Conversion Losses Into Consideration

Heat Rates for Different Types of Power Plants							
Generating Station Type	Typical Heat Rate				Emissions	lb CO_2 per kWh Generated	
	Minimum		Maximum		lb CO_2 per million Btu	Minimum	Maximum
	Btu/kWh	Efficiency	Btu/kWh	Efficiency			
Natural Gas with Cogeneration	5,000	68%	6,500	53%	117	0.58	0.76
Natural Gas Combined Cycle	6,200	55%	8,000	43%	117	0.72	0.93
Natural Gas Reciprocating Engine	7,500	46%	8,500	40%	117	0.87	0.99
Natural Gas Combustion Turbine	8,000	43%	10,000	34%	117	0.93	1.17
Coal Steam Turbine	9,000	38%	11,000	31%	212	1.91	2.33
Natural Gas Steam Turbine	10,000	34%	12,000	28%	117	1.17	1.40
Nuclear Power Plant	10,446	33%	10,459	33%	0	0.00	0.00
Heat Rate Source -	https://energyknowledgebase.com/topics/heat-rate.asp						
Emmissions Factor Source -	https://www.eia.gov/environment/emissions/co2_vol_mass.php						

https://tinyurl.com/EIACO2EmissionFactors

https://tinyurl.com/EIACO2EmissionFactors

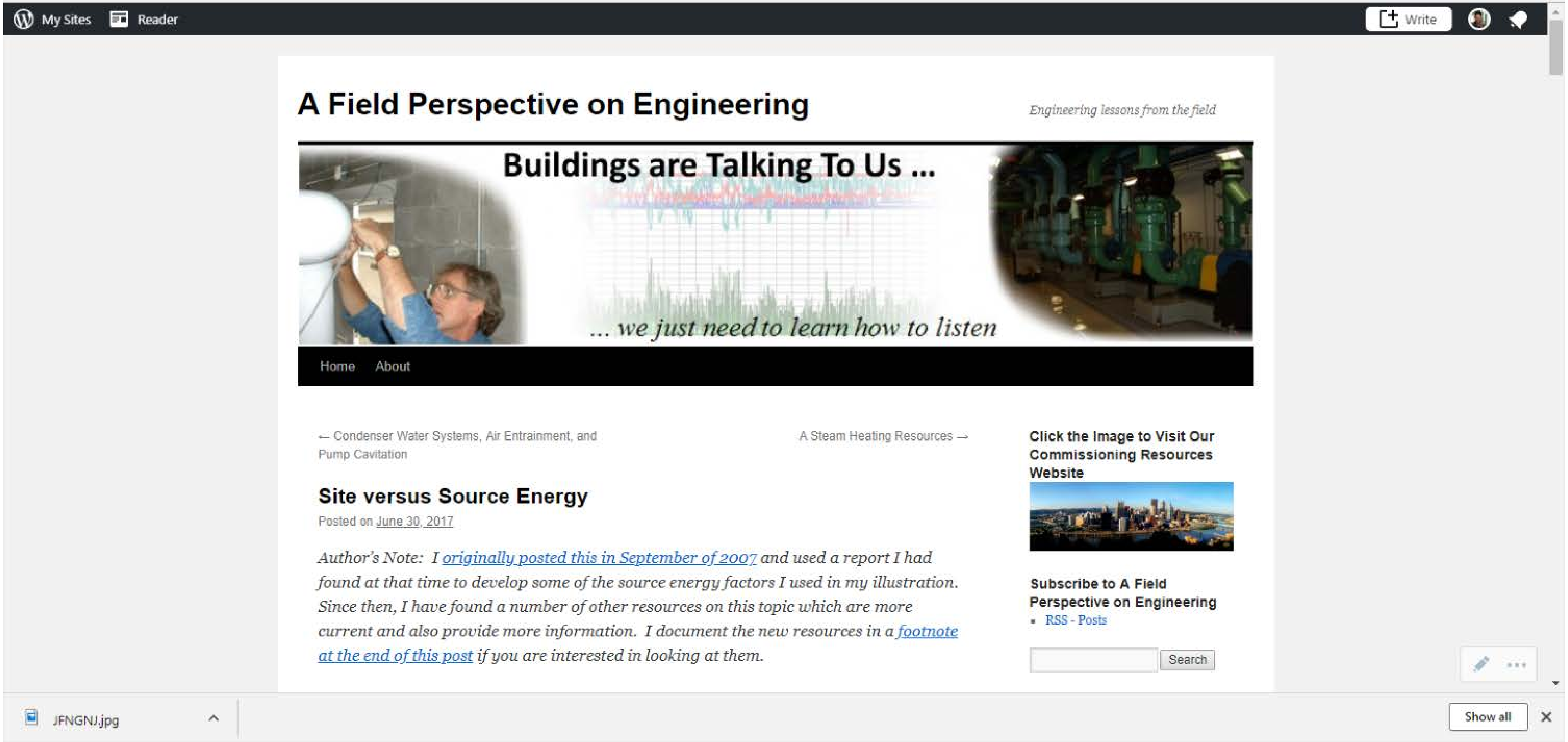
Physical Principles Will Prevail

A coal fired Midwest power plant

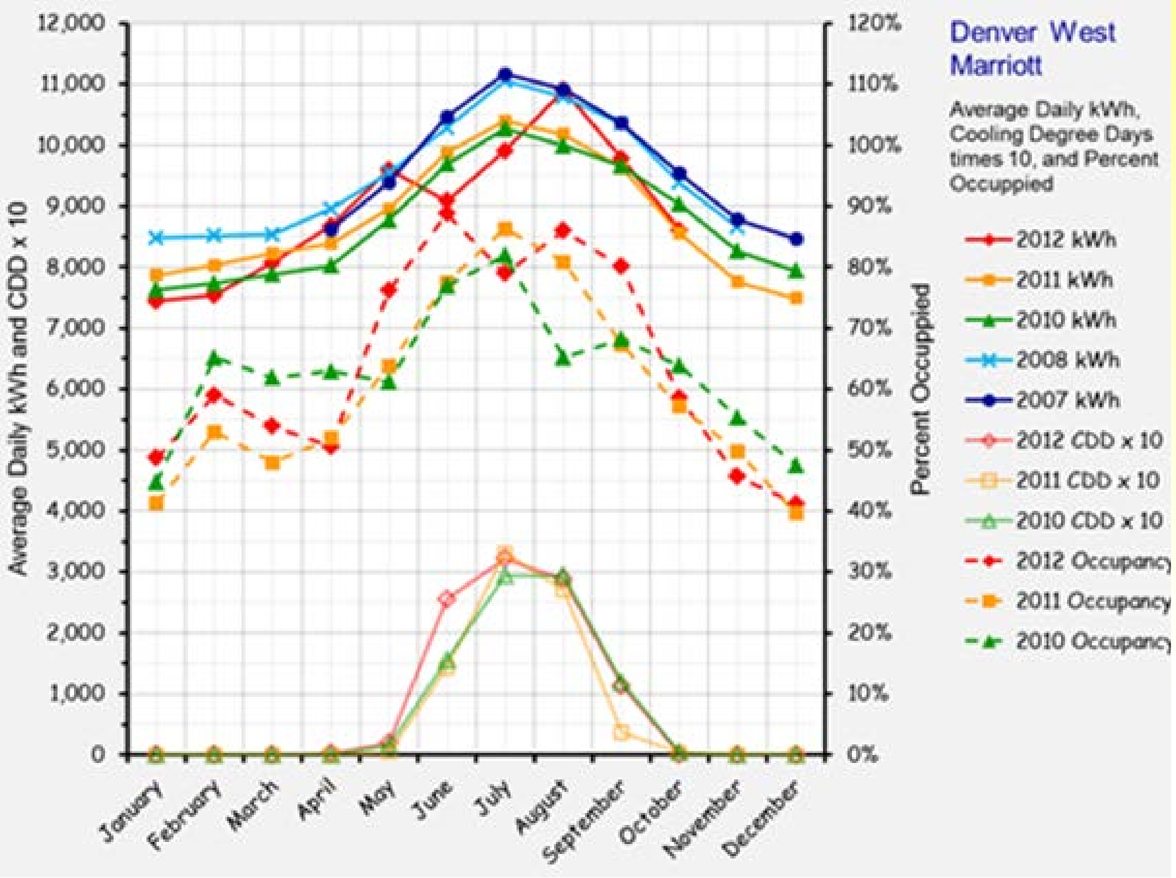
Transmission Losses are Also Considered

More on Site vs. Source Energy

https://tinyurl.com/SitevsSourcEnergy

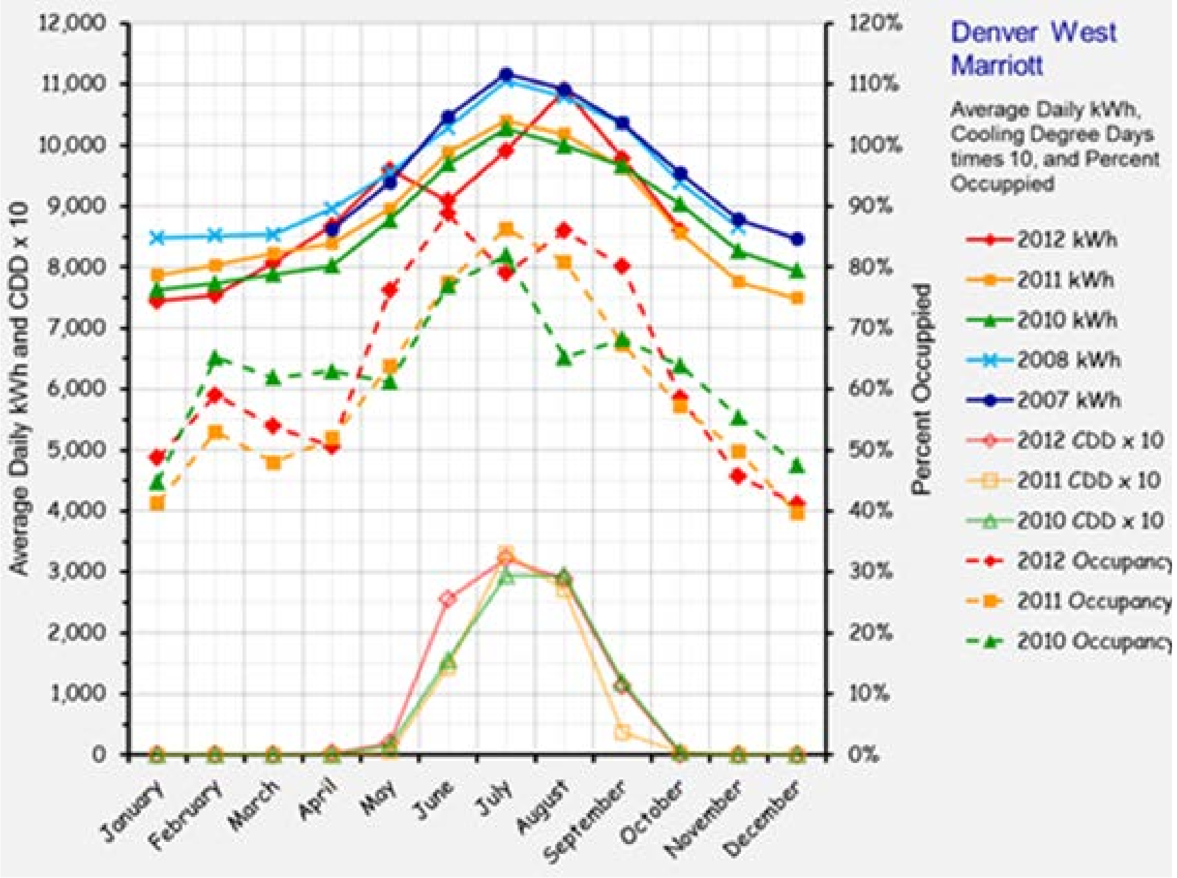


What is Utility Consumption Analysis?



What is Utility Consumption Analysis?

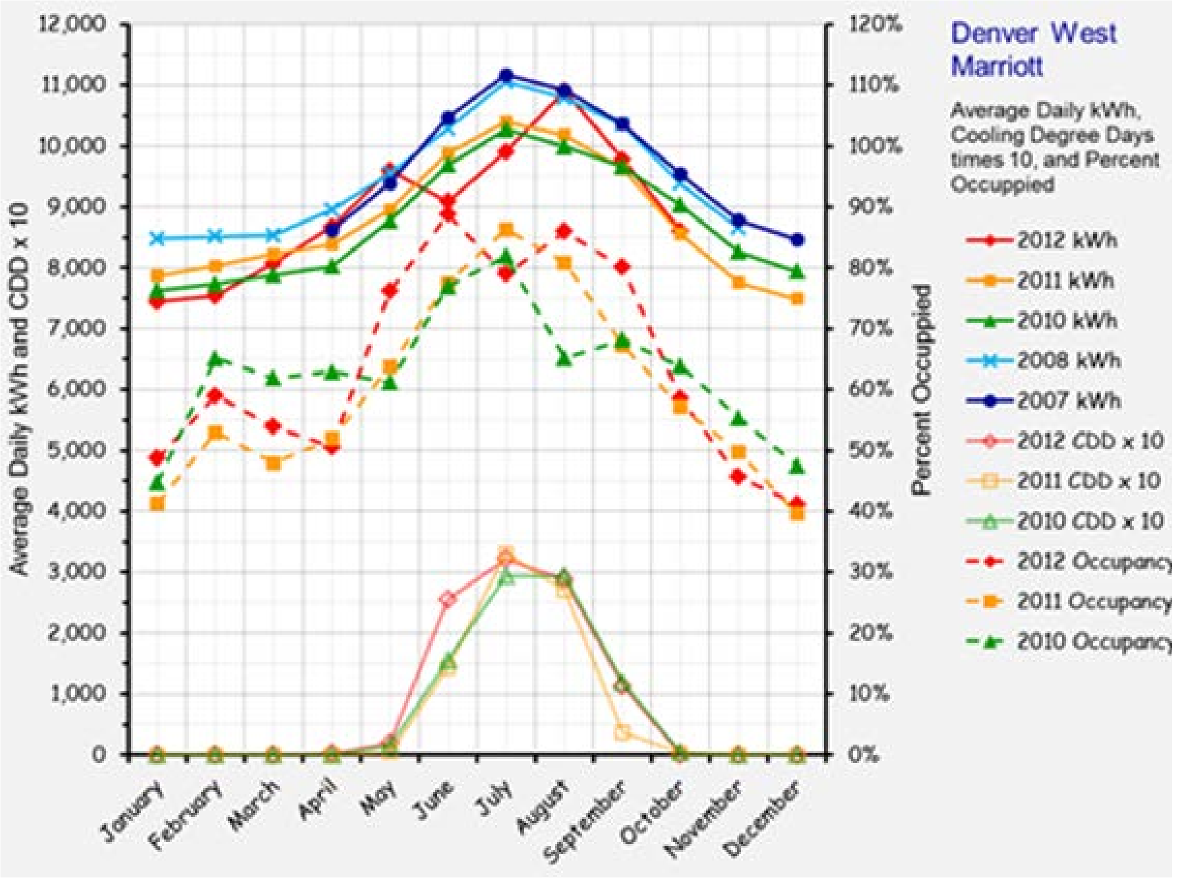
Utility consumption analysis looks for trends in utility consumption patterns that are indicators of opportunities to save resources. These patterns are also indicators of the persistence of benefits provided by past projects



What is Utility Consumption Analysis?

Compare average monthly patterns to potential drivers

- Heating and cooling degree days
- Occupancy patterns
- Production



Heating and Cooling Degree Day Resource - https://tinyurl.com/HDDandCDD

What is Utility Consumption Analysis?

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

Using Utility Bills and Average Daily Energy Consumption to Target Commissioning Efforts and Track Building Performance

By: David Sellers, Senior Engineer, Portland Energy Conservation Inc, Portland, Oregon

ABSTRACT

This paper discusses using basic utility data that is readily available from utility bills to both focus and target commissioning efforts. It also discusses how to use this information to spot emerging problems related to how the building is using energy. This sort of analysis can be done using relatively simple techniques such as a hand calculation or a spreadsheet and is the type of thing that any facility engineer or operator could handle and would be interested in. Techniques are also discussed which allow the data to be further refined to target specific energy uses.

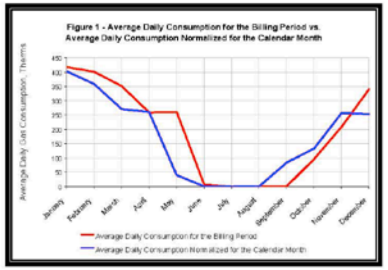
INTRODUCTION

Most Facilities Departments and Commissioning Agents are privy to the utility bills associated with the facilities they are operating or otherwise involved with. Usually, Facilities Departments review the bills for approval purposes and many groups track billing period consumption from month to month for record and comparison. Commissioning agents use this information for similar purposes as well as to understand building consumption patterns and flag potential areas requiring attention. In many cases, little analysis is done beyond looking at the information as presented in the billing statement, and a great deal of benefit can be realized by simply reviewing the information in this manner. However, by a little bit of additional analysis via hand calculations or a simple spreadsheet it is possible to glean even more information about the building and its energy use patterns from the utility data. By looking at the data on an average daily consumption basis, normalized to match the calendar months, it is possible to identify patterns that will not be noticed by simply tracking total consumption per billing period or even average daily consumption per billing period. Once developed, the techniques and calculations required for this additional work would quite literally require only a few minutes of an operator's or engineer's time. But the insights gained can often save thousands of dollars in utility costs and commissioning labor either by identifying an abnormal consumption pattern early on or by more finely focussing commissioning efforts funded from a limited budget.

WHY TAKE THE EXTRA STEPS?

Operators and commissioning agents who already are monitoring monthly consumption or even average daily consumption for the billing period (many utilities have started to present this information as a standard part of their bill) may wonder what additional value is to be gained by further refining the information. The benefits are as follows:

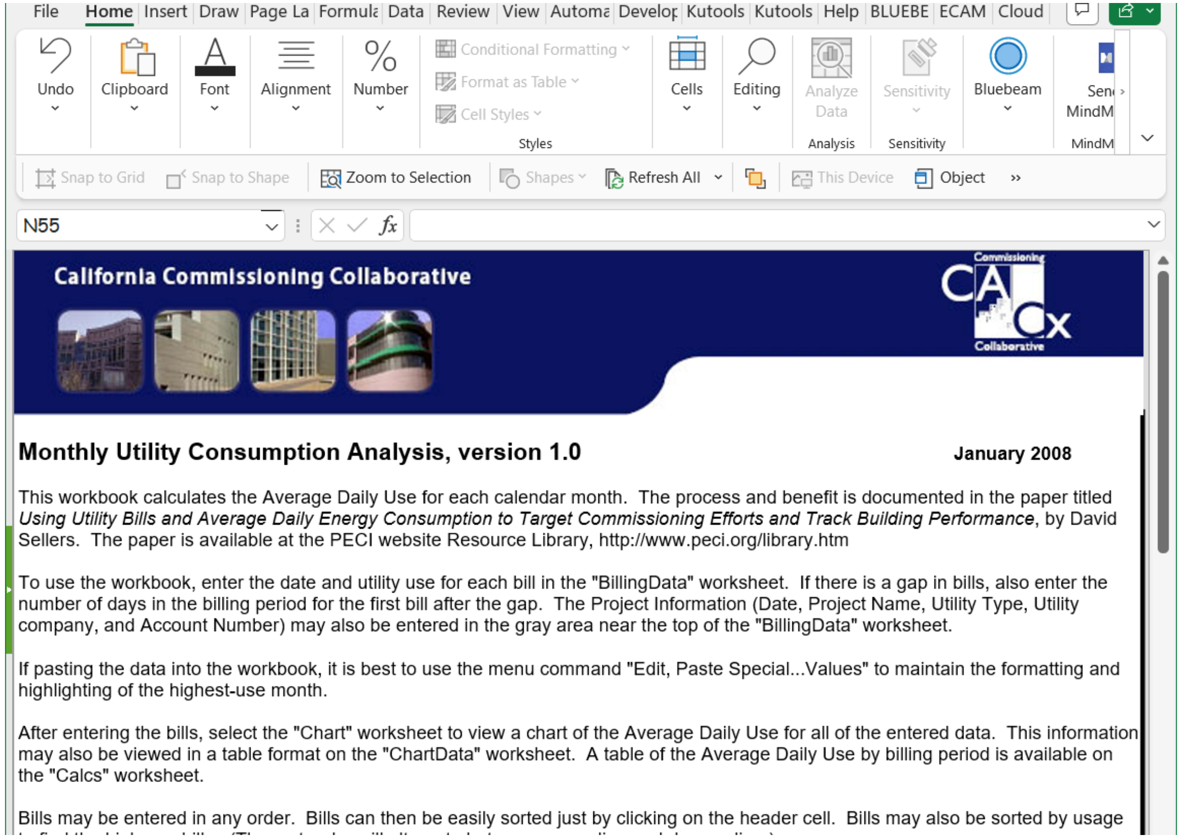
- Gross billing period consumption data, while somewhat related to season, is also influenced by the length of the billing period and the dates the meter is read. Meters are often read on a specific *day* of the month rather than on a regular interval based on a certain number of days. This means that two months with identical operating schedules, weather patterns and other factors, but differing numbers of days would show different consumption totals. This would simply be because one billing period had more days than the other, not because of any particular pattern associated with the season or building.
- Meter reading dates seldom fall on the first day of the month, thus the consumption data usually is related to two different calendar months. For instance, a bill for a meter reading taken on the 10th of May and received later that month would most likely be posted as the May consumption. In fact, from a calendar basis, it is more likely that it reflects energy utilization patterns associated with the weather and use of the building in April rather than May. But, the information is also influenced by what happened in May since the reading was taken on the 10th of the month. Attempting to correlate this data to weather and utilization information for either of the calendar months could be misleading and may be irrelevant. Even if the data is looked at as average



What is Utility Consumption Analysis?

Critical considerations

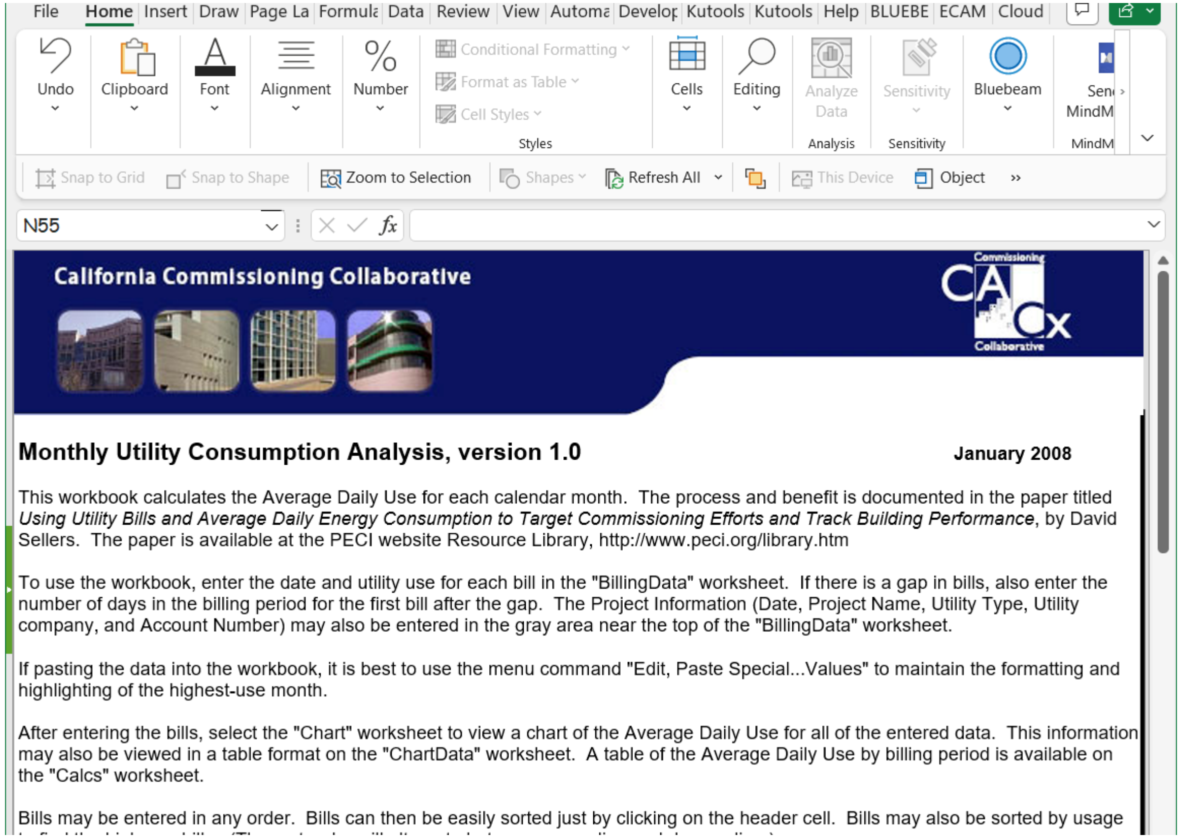
- Data needs to be averaged over the days in the billing period
- Data needs to be normalized to the month not the billing period
- The Utility Consumption Analysis Tool (UCAT) will do the work for you



UCAT and Related Paper - https://tinyurl.com/UCATToolAndPaper

Leverage Benchmarks, UCAT and Industry Metrics to Project Savings and Budgets

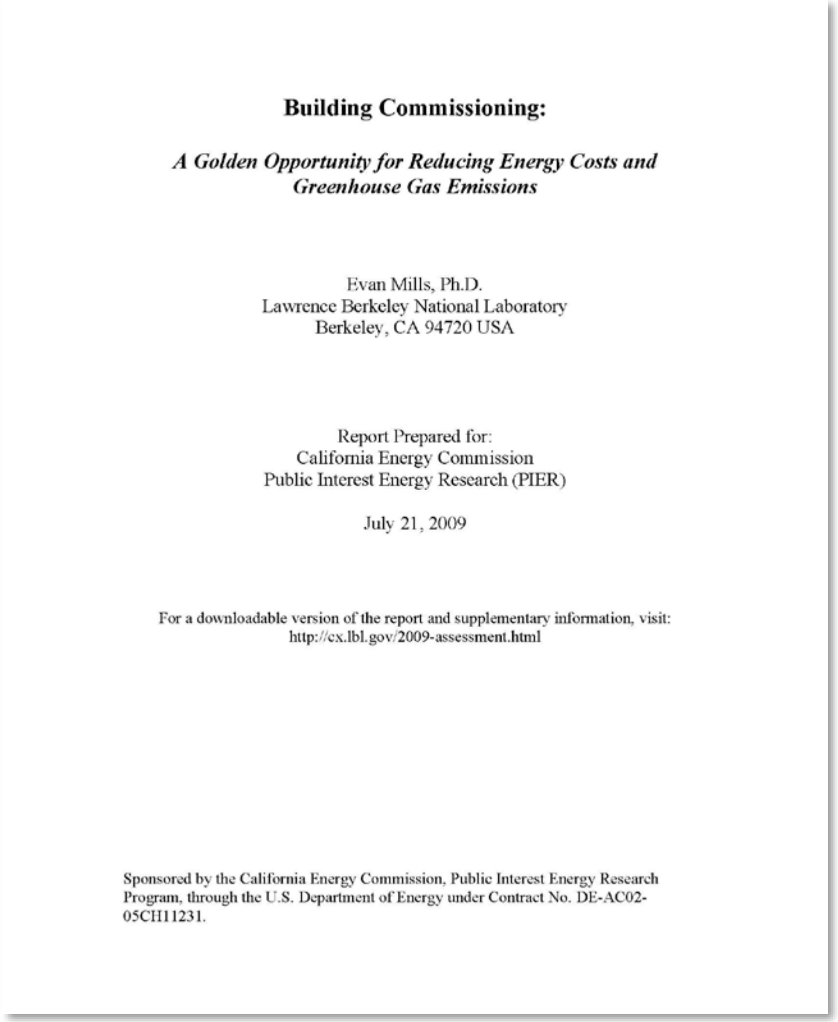
- Benchmarks and UCAT provide insight into annual consumption patterns and costs



Leverage Benchmarks, UCA and Industry Metrics to Project Savings and Budgets

- Benchmarks and UCA provide insight into annual consumption patterns and costs
- LBNL cost/benefit metrics provide savings potential based on utility consumption

https://tinyurl.com/LBLCxCostBenefit



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)

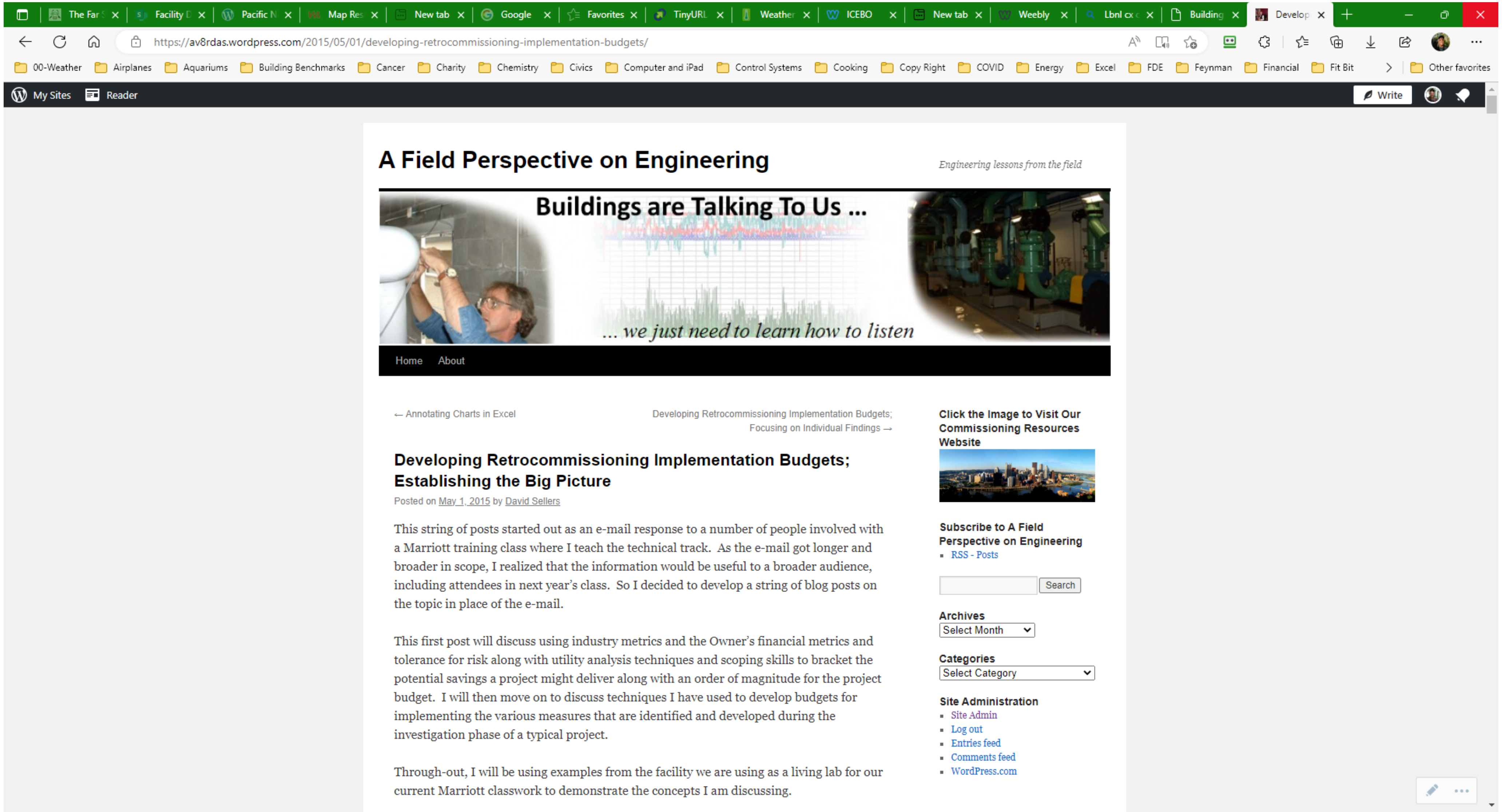
July 21, 2009

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.

More on Budget and Savings Projections

https://tinyurl.com/EBCxBudgetGeneral



https://av8rdas.wordpress.com/2015/05/01/developing-retrocommissioning-implementation-budgets/

My Sites Reader Write

A Field Perspective on Engineering

Engineering lessons from the field

Buildings are Talking To Us ...

... we just need to learn how to listen

Home About

← 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 by David Sellers

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 budget. I will then move on to discuss techniques I have used to develop budgets for implementing the various measures that are identified and developed during the investigation phase of a typical project.

Through-out, I will be using examples from the facility we are using as a living lab for our current Marriott classwork to demonstrate the concepts I am discussing.

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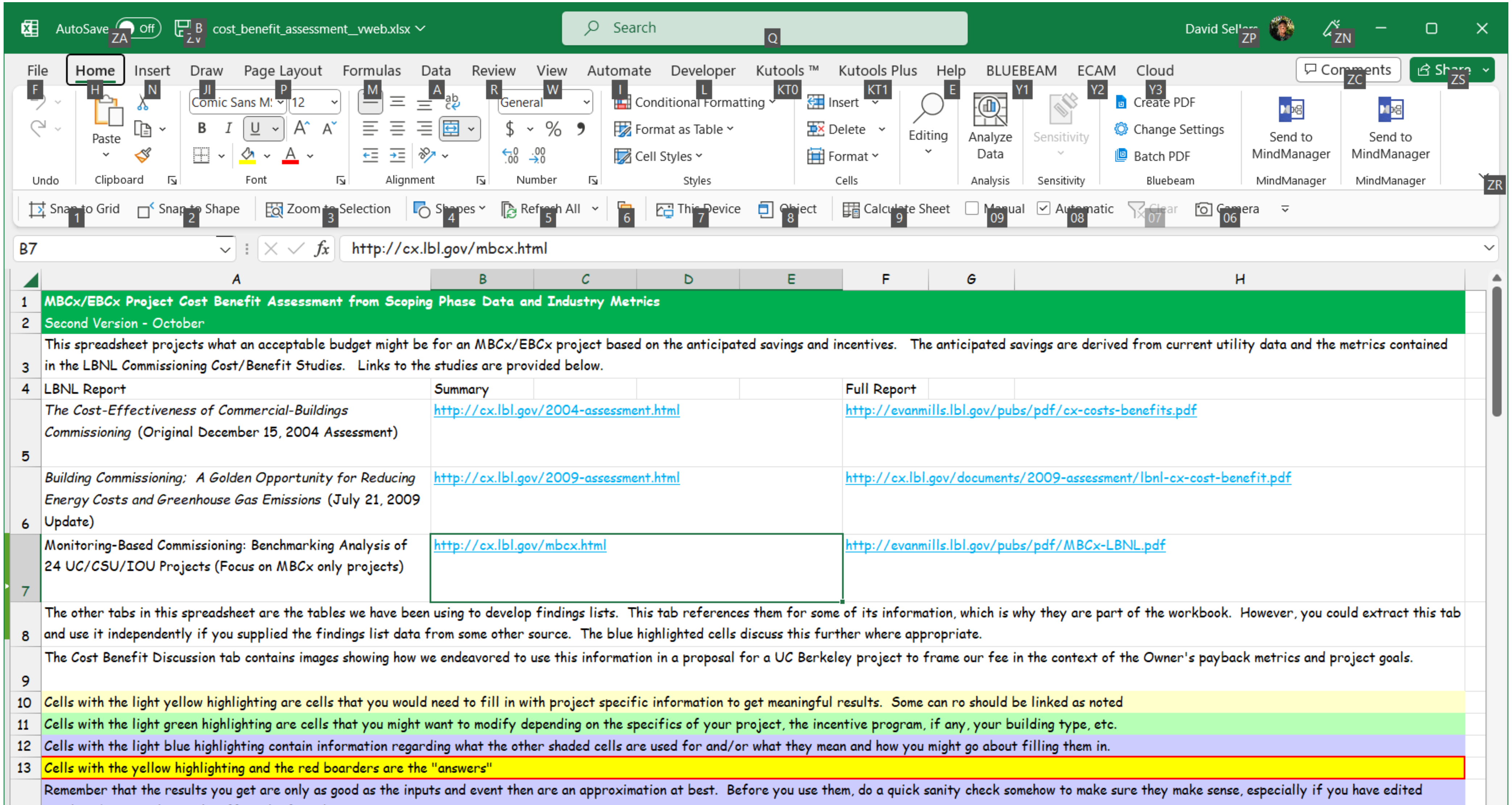
More on Budget and Savings Projections

https://tinyurl.com/EBCxCostBenefitSpreadsheet



What is Scoping?

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

Gary Larson

The Far Side

February 2, 1983

Scoping is Seeking Out the Obvious

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?

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

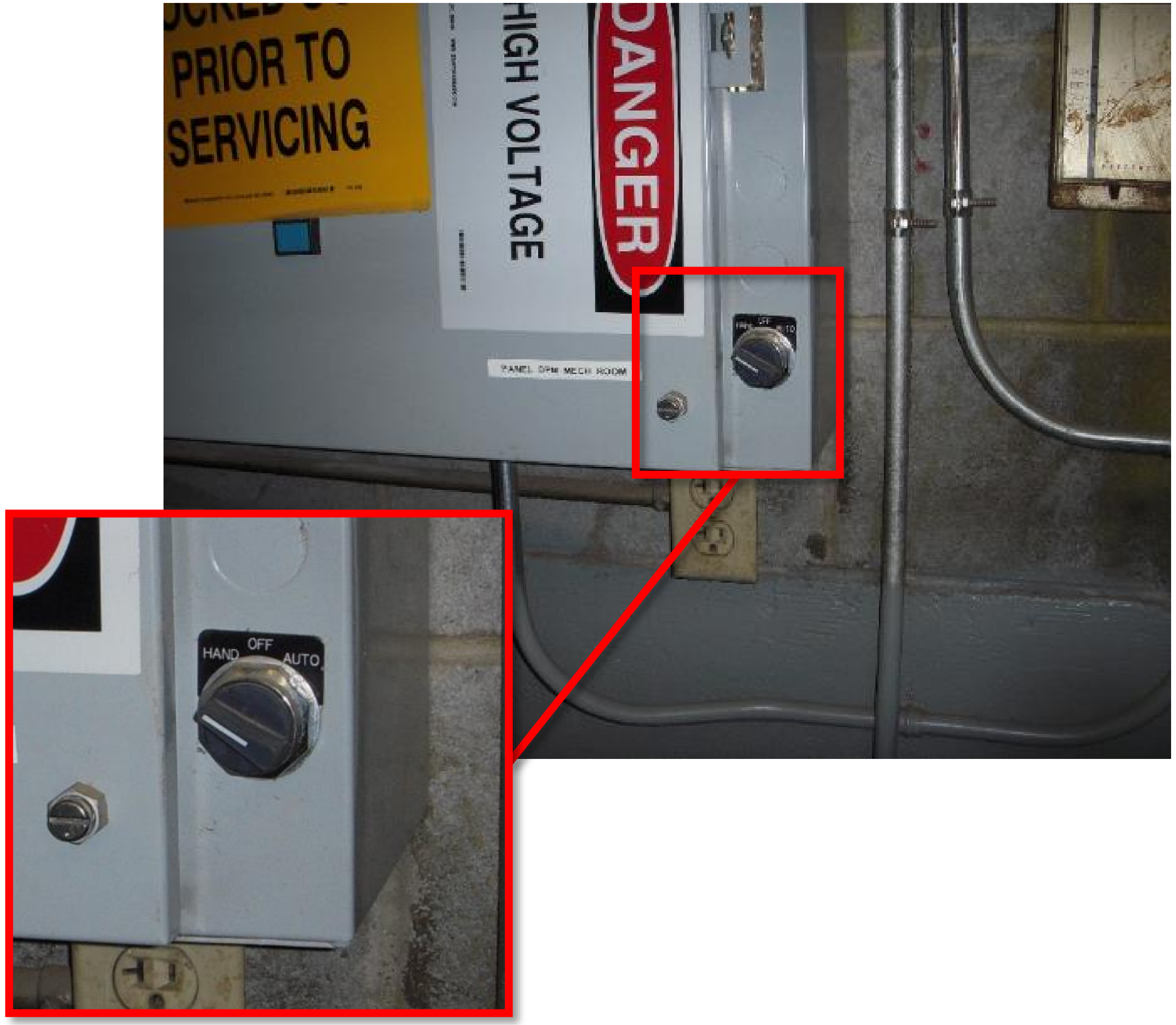
Gary Larson

The Far Side

February 2, 1983

Scoping is Seeking Out the Obvious

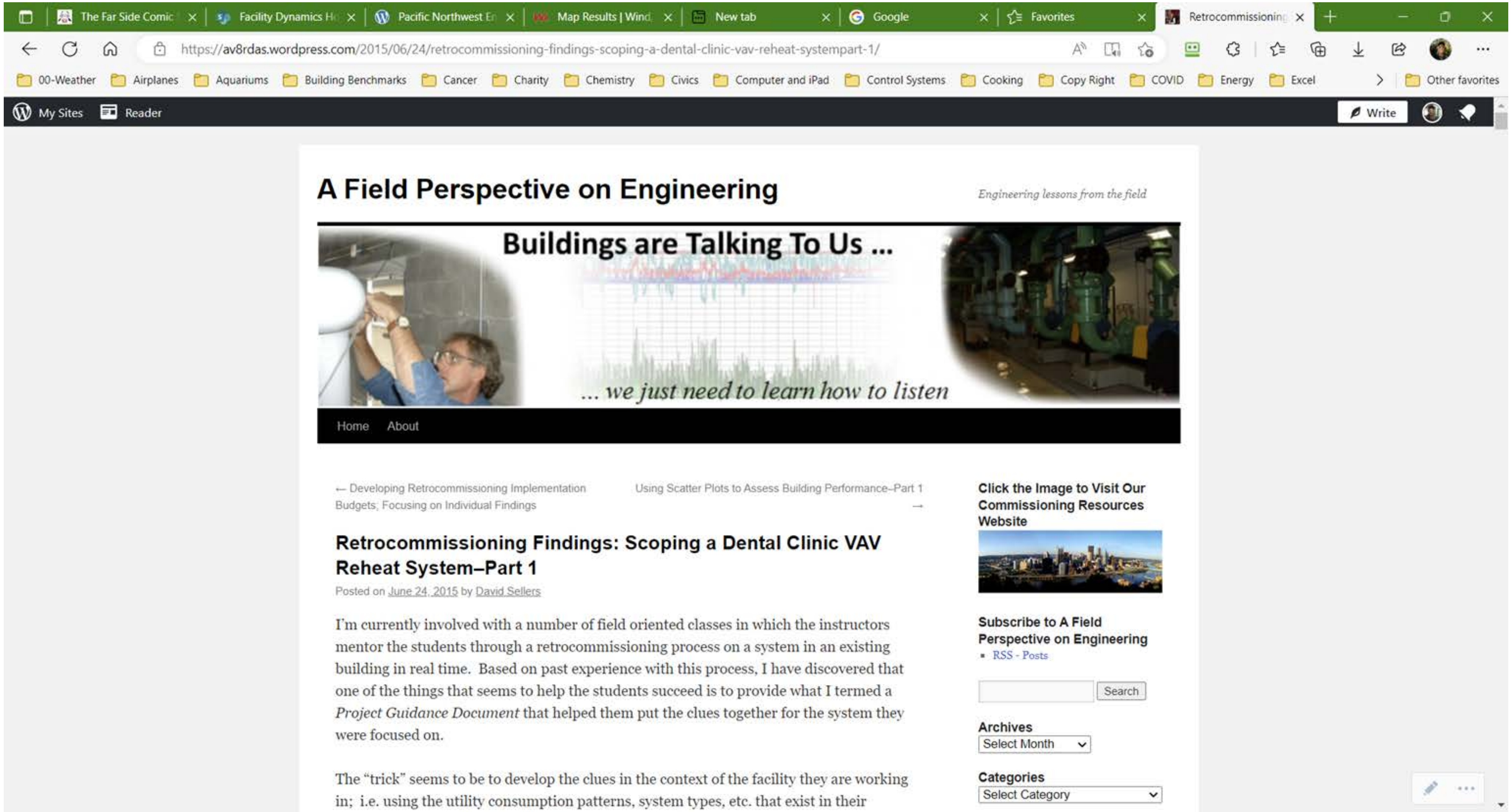
- Do things make sense?
- Should the outdoor air dampers be open or closed given the current conditions?
- Should the chilled water coil be active given the current conditions?
- Are things running when they don’t need to run?



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

A Scoping Example

https://tinyurl.com/ClinicScoping



What is a Findings List?

Number	Brief Description	Total Savings $		Incentive, $		Impl P
		Low End	High End	Low End	High End	Low
1.		To Be Determined	To Be Determined	None Offered	None Offered	
2.		To Be Determined	To Be Determined	None Offered	None Offered	
3.		To Be Determined	To Be Determined	None Offered	None Offered	
4.		To Be Determined	To Be Determined	None Offered	None Offered	
5.		To Be Determined	To Be Determined	None Offered	None Offered	
6.		To Be Determined	To Be Determined	None Offered	None Offered	
7.		To Be Determined	To Be Determined	None Offered	None Offered	
8.		To Be Determined	To Be Determined	None Offered	None Offered	
9.		To Be Determined	To Be Determined	None Offered	None Offered	
10.		To Be Determined	To Be Determined	None Offered	None Offered	
11.		To Be Determined	To Be Determined	None Offered	None Offered	
12.		To Be Determined	To Be Determined	None Offered	None Offered	
TOTALS		To Be Determined	To Be Determined	None Offered	None Offered	To Deter

What is a Findings List

- A list of potential EBCx opportunities
- A way to keep track of the opportunities you discover
- A way to present them to the owner
- A living document

Number	Brief Description	Total Savings $		Incentive, $		Implementation Cost Projections, $		Implementatio After Incentiv	
		Low End	High End	Low End	High End	Low End	High End	Low End	Hig
1.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
2.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
3.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
4.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
5.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
6.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
7.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
8.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
9.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
10.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
11.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
12.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
TOTALS		To Be Determined	To Be Determined	None Offered	None Offered	To Be Determined	To Be Determined	To Be Determined	T Dete

Number	Brief Description	Total Savings $		Incentive, $		Implementation Cost Projections, $		Implementation After Incentiv	
		Low End	High End	Low End	High End	Low End	High End	Low End	Hig
1.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
2.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
3.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
4.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
5.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
6.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
7.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
8.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
9.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
10.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
11.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
12.		To Be Determined	To Be Determined	None Offered	None Offered			$0	

						Projections, $		[illegible]	
		Low End	High End	Low End	High End	Low End	High End	Low End	Hig
1.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
2.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
3.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
4.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
5.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
6.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
7.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
8.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
9.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
10.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
11.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
12.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
TOTALS		To Be Determined	To Be Determined	None Offered	None Offered	To Be Determined	To Be Determined	To Be Determined	T Det

Number	Brief Description	Total Savings $		Incentive, $		Implementation Cost Projections, $		Implementatio After Incenti	
		Low End	High End	Low End	High End	Low End	High End	Low End	Hi
1.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
2.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
3.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
4.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
5.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
6.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
7.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
8.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
9.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
10.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
11.		To Be Determined	To Be Determined	None Offered	None Offered			$0	
12.		To Be Determined	To Be Determined	None Offered	None Offered			$0	

Implementation Cost Projections, $		Implementation Cost After Incentives, $		Simple Payback Range After Incentives, Years		Electricity						
						kWh savings				kW savings		
						Low end		High end		Low End	High End	Low
Low End	High End	Low End	High End	Low End	High End	kWh	$	kWh	$			Therm
		$0	$0	To Be Determined	To Be Determined	0	$0	0	$0	0.0	0.0	0
		$0	$0	To Be Determined	To Be Determined	0	$0	0	$0	0.0	0.0	0
		$0	$0	To Be Determined	To Be Determined	0	$0	0	$0	0.0	0.0	0
		$0	$0	To Be Determined	To Be Determined	0	$0	0	$0	0.0	0.0	0
		$0	$0	To Be Determined	To Be Determined	0	$0	0	$0	0.0	0.0	0
		$0	$0	To Be Determined	To Be Determined	0	$0	0	$0	0.0	0.0	0
		$0	$0	To Be Determined	To Be Determined	0	$0	0	$0	0.0	0.0	0
		$0	$0	To Be Determined	To Be Determined	0	$0	0	$0	0.0	0.0	0
		$0	$0	To Be Determined	To Be Determined	0	$0	0	$0	0.0	0.0	0
		$0	$0	To Be Determined	To Be Determined	0	$0	0	$0	0.0	0.0	0
		$0	$0	To Be Determined	To Be Determined	0	$0	0	$0	0.0	0.0	0
		$0	$0	To Be Determined	To Be Determined	0	$0	0	$0	0.0	0.0	0

	Gas				Other Savings						Notes
s	Therm Savings										
n End	Low end		High end		Low end			High end			
	Therm	$	Therms	$	Amount	Units	$	Amount	Units	$	
).0	0	$0	0	$0	None	N/A	$0	None	N/A	$0	
).0	0	$0	0	$0	None	N/A	$0	None	N/A	$0	
).0	0	$0	0	$0	None	N/A	$0	None	N/A	$0	
).0	0	$0	0	$0	None	N/A	$0	None	N/A	$0	
).0	0	$0	0	$0	None	N/A	$0	None	N/A	$0	
).0	0	$0	0	$0	None	N/A	$0	None	N/A	$0	
).0	0	$0	0	$0	None	N/A	$0	None	N/A	$0	
).0	0	$0	0	$0	None	N/A	$0	None	N/A	$0	
).0	0	$0	0	$0	None	N/A	$0	None	N/A	$0	
).0	0	$0	0	$0	None	N/A	$0	None	N/A	$0	
).0	0	$0	0	$0	None	N/A	$0	None	N/A	$0	
).0	0	$0	0	$0	None	N/A	$0	None	N/A	$0	

This Template is Included with the Cost Benefit Analysis Tool in the Working Table tab

Number	Brief Description	Total Savings $		Incentive, $		Implementation Cost Projections, $		Implementation Cost After Incentives, $		Simple Payback Range After Incentives, Years		Electricity						Gas				Other Savings						Notes
												kWh savings				kW savings		Therm Savings										
												Low end		High end		Low End	High End	Low end		High end		Low end			High end			
		Low End	High End	Low End	High End	Low End	High End	Low End	High End	Low End	High End	kWh	$	kWh	$			Therm	$	Therms	$	Amount	Units	$	Amount	Units	$	
1.		To Be Determined	To Be Determined	None Offered	None Offered			$0	$0	To Be Determined	To Be Determined	0	$0	0	$0	0.0	0.0	0	$0	0	$0	None	N/A	$0	None	N/A	$0	
2.		To Be Determined	To Be Determined	None Offered	None Offered			$0	$0	To Be Determined	To Be Determined	0	$0	0	$0	0.0	0.0	0	$0	0	$0	None	N/A	$0	None	N/A	$0	
3.		To Be Determined	To Be Determined	None Offered	None Offered			$0	$0	To Be Determined	To Be Determined	0	$0	0	$0	0.0	0.0	0	$0	0	$0	None	N/A	$0	None	N/A	$0	
4.		To Be Determined	To Be Determined	None Offered	None Offered			$0	$0	To Be Determined	To Be Determined	0	$0	0	$0	0.0	0.0	0	$0	0	$0	None	N/A	$0	None	N/A	$0	
5.		To Be Determined	To Be Determined	None Offered	None Offered			$0	$0	To Be Determined	To Be Determined	0	$0	0	$0	0.0	0.0	0	$0	0	$0	None	N/A	$0	None	N/A	$0	
6.		To Be Determined	To Be Determined	None Offered	None Offered			$0	$0	To Be Determined	To Be Determined	0	$0	0	$0	0.0	0.0	0	$0	0	$0	None	N/A	$0	None	N/A	$0	
7.		To Be Determined	To Be Determined	None Offered	None Offered			$0	$0	To Be Determined	To Be Determined	0	$0	0	$0	0.0	0.0	0	$0	0	$0	None	N/A	$0	None	N/A	$0	
8.		To Be Determined	To Be Determined	None Offered	None Offered			$0	$0	To Be Determined	To Be Determined	0	$0	0	$0	0.0	0.0	0	$0	0	$0	None	N/A	$0	None	N/A	$0	
9.		To Be Determined	To Be Determined	None Offered	None Offered			$0	$0	To Be Determined	To Be Determined	0	$0	0	$0	0.0	0.0	0	$0	0	$0	None	N/A	$0	None	N/A	$0	
10.		To Be Determined	To Be Determined	None Offered	None Offered			$0	$0	To Be Determined	To Be Determined	0	$0	0	$0	0.0	0.0	0	$0	0	$0	None	N/A	$0	None	N/A	$0	
11.		To Be Determined	To Be Determined	None Offered	None Offered			$0	$0	To Be Determined	To Be Determined	0	$0	0	$0	0.0	0.0	0	$0	0	$0	None	N/A	$0	None	N/A	$0	
12.		To Be Determined	To Be Determined	None Offered	None Offered			$0	$0	To Be Determined	To Be Determined	0	$0	0	$0	0.0	0.0	0	$0	0	$0	None	N/A	$0	None	N/A	$0	
TOTALS		To Be Determined	To Be Determined	None Offered	None Offered	To Be Determined	To Be Determined	To Be Determined	To Be Determined	To Be Determined	To Be Determined	To Be Determined	To Be Determined	To Be Determined	To Be Determined	To Be Determined	To Be Determined	To Be Determined	To Be Determined	To Be Determined	To Be Determined			To Be Determined			To Be Determined	

https://tinyurl.com/EBCxCostBenefitSpreadsheet

I Was Told There Would Be No Math Involved

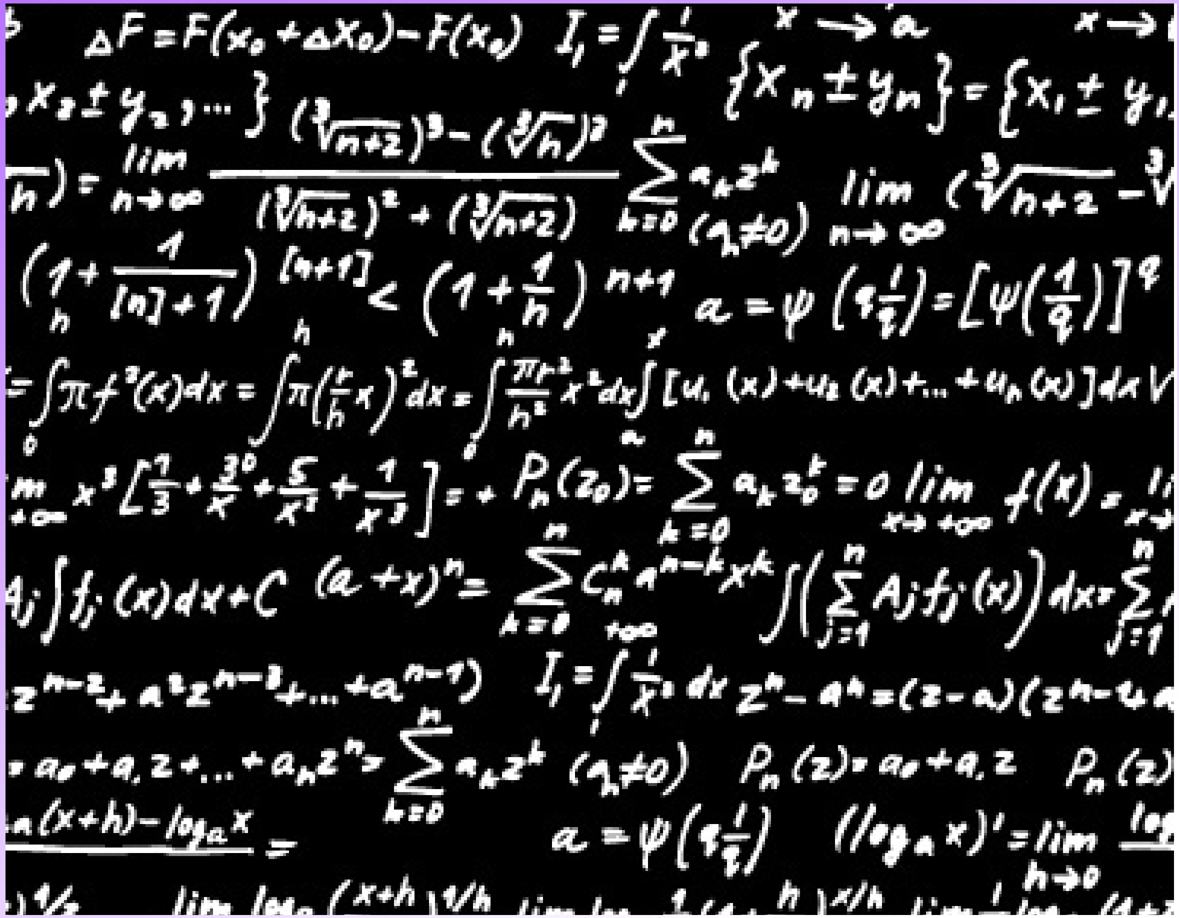
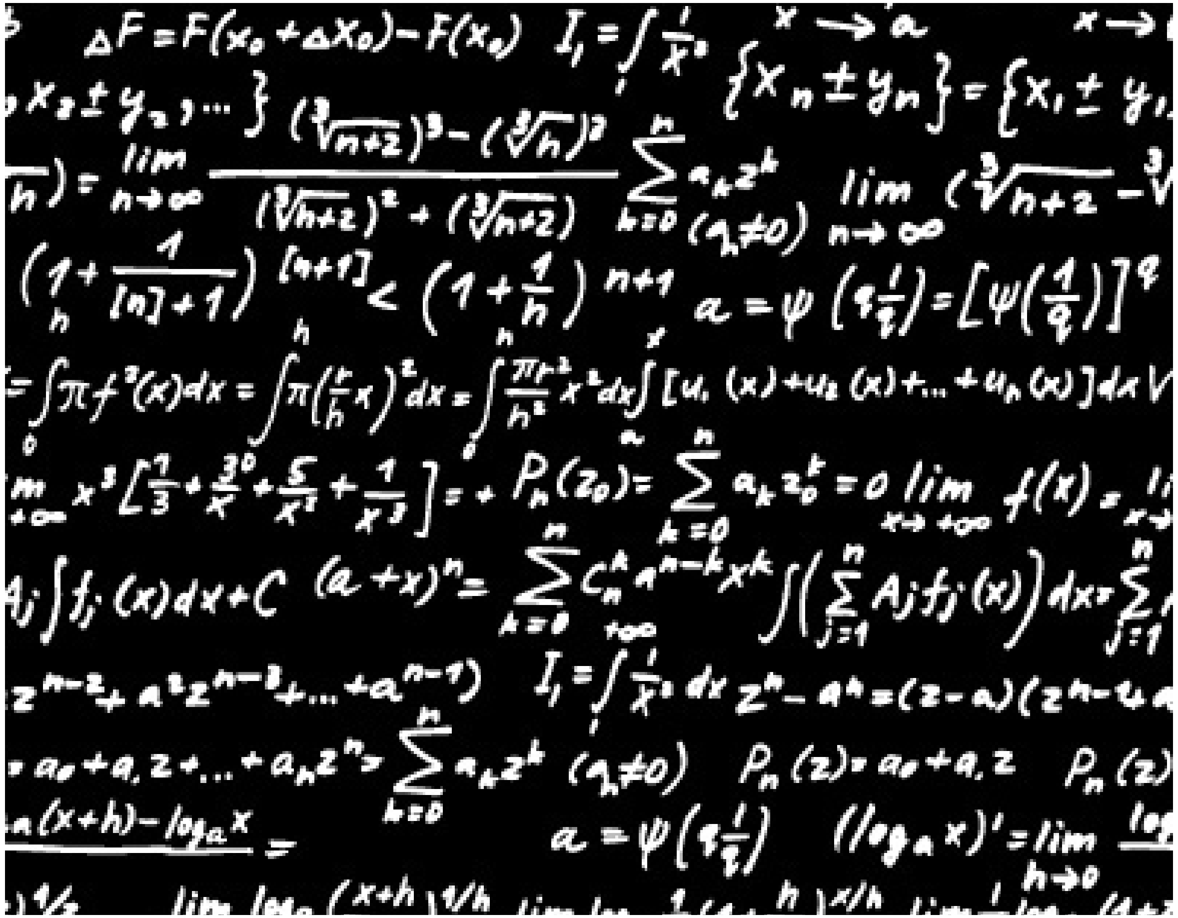


Image courtesy https://auntiebswax.blogspot.com/2010/10/no-one-told-me-there-would-be-math.html

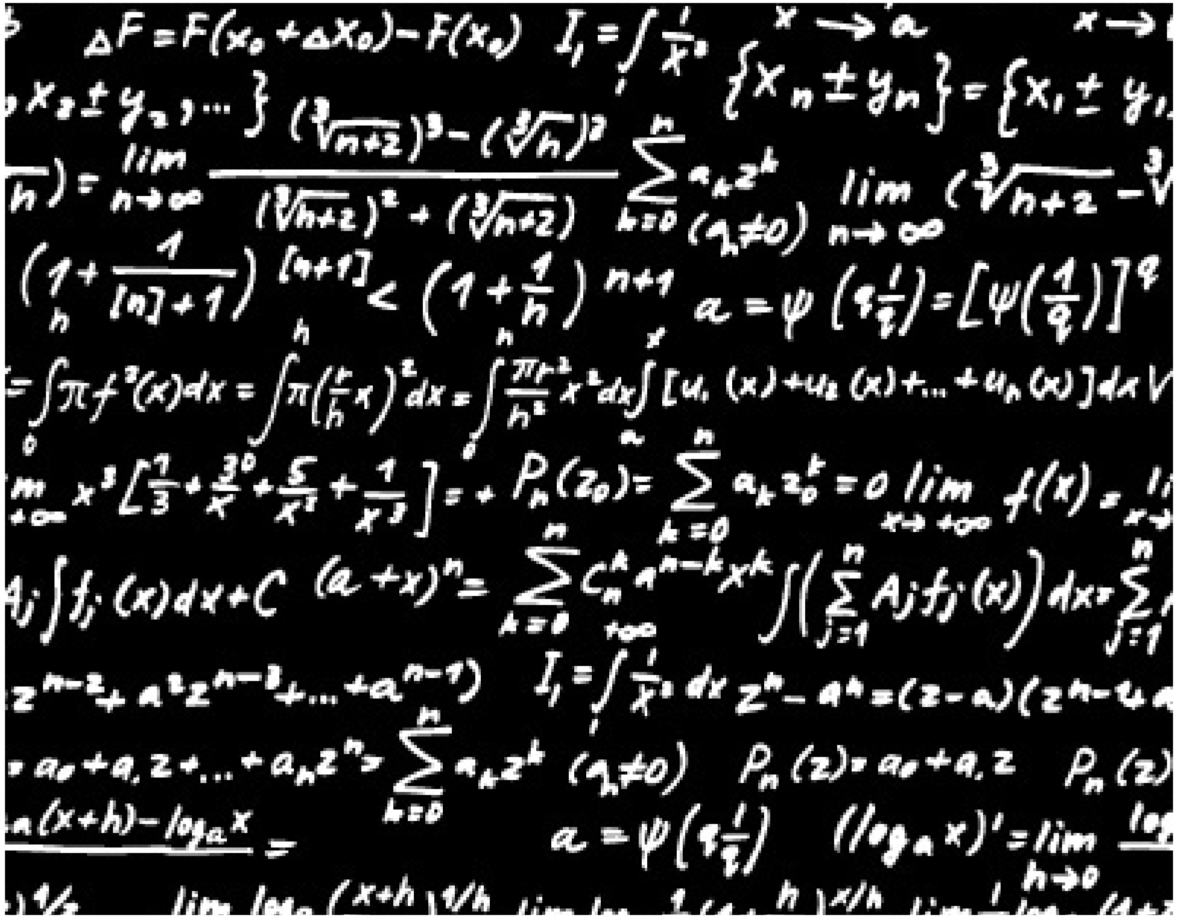
I Was Told There Would Be No Math Involved

1. Nobody actually said that



I Was Told There Would Be No Math Involved

1. Nobody actually said that
2. Stay calm and continue to breath normally



I Was Told There Would Be No Math Involved

1. Nobody actually said that
2. Stay calm and continue to breath normally
3. The math involved is not complex
4. The math involved can be informative

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

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

The Math Involved can be Informative

This equation tells us that if you reduce the flow rate, you could save energy

- Could you use this relationship with logged data to figure out the energy wasted by a variable volume system that was not varying volume?
- Could you use this relationship with design and field data to figure out if a system was oversized?

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

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

The Math Involved can be Informative

It also tells us that if you reduce the temperature change, you could save energy

- Could you use this relationship with design data and trend data to understand if you were supplying air that was hotter or colder than needed?
- Could you use this relationship with field data to understand the savings potential achieved via a reset schedule?

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

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

Other (Potentially) Informative Relationships

This relationship tells us similar things about how energy use is impacted by the flow rate and the change in enthalpy – i.e. total energy content of the air stream - across a coil

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

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 design or TAB data

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

Other (Potentially) Informative Relationships

This relationship tells us that the energy transferred to or from the water flowing through a coil is a function of the flow rate and the temperature change

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

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

Other (Potentially) Informative Relationships

This relationship tells us that the power used by a pump is directly related to the flow and head it produces and inversely related to the pump, motor and drive system efficiency

$$kW = \left(\frac{Flow_{gpm} \times Head_{ft.w.c.}}{3{,}960 \times \eta_{Pump} \times \eta_{Motor} \times \eta_{VSD}} \right) \times .746$$

Where:

kW	=	Input to the system to produce the flow and head
$Flow$	=	Flow rate in gallons per minute
$Head$	=	The pump head in ft.w.c. water column
3,960	=	A units conversion constant that is good for water between 40°F and 220°F
η_{Pump}	=	Pump efficiency.
η_{Motor}	=	Motor efficiency
η_{VSD}	=	Variable speed drive efficiency
.746	=	Horsepower to kW conversion constant

Other (Potentially) Informative Relationships

This very similar relationship tells us that the power used by a fan is directly related to the flow and static pressure it produces and inversely related to the fan, motor, belt, and drive system efficiency

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

Where:

kW	=	Input to the system to produce the flow and static pressure
$Flow$	=	Flow rate in cubic feet per minute
$Static$	=	The fan static pressure in inches water column
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
η_{Belts}	=	Belt efficiency. Well adjusted V belts typically have an efficiency of 97-98%.
η_{Motor}	=	Motor efficiency
η_{VSD}	=	Variable speed drive efficiency
.746	=	Horsepower to kW conversion constant.

Other (Potentially) Informative Relationships

This very similar relationship tells us that the power used by a fan is directly related to the flow and static pressure it produces and inversely related to the fan, motor, belt, and drive system efficiency

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

A resource for learning more about HVAC equations and other HVAC fundamentals topics

https://tinyurl.com/HVACEquations

Next Steps for Your Self-Study Effort

Next Steps for Your Self-Study Effort

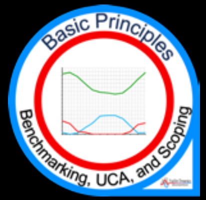
Review the Self Study Videos and Related Exercises

- https://tinyurl.com/SSBenchmarkUCAScoping
- https://tinyurl.com/SSLoadsAndPsych
- https://tinyurl.com/SSSystemDgmIntro

Next Steps for Your Self-Study Effort

Collect your merit badges

- https://tinyurl.com/SSBenchmarkUCAScoping



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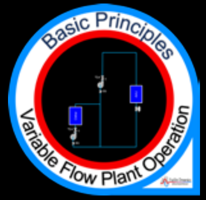

Next Steps for Your Self-Study Effort

Reach Out to Ryan to Register for the EBCx Workshop

r2s2@pge.com

Next Steps for Your Self-Study Effort

Identify a Project Building

- Begin to fill out the building information form Ryan will provide
- Benchmark the building
  - EnergyStar
  - DOE Building Performance Database
- Start a Utility Consumption Analysis
- Make a site visit to scope it and start a findings list

Applying the EUI Concept (and Getting Acquainted)

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

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

Given:

- The EUI relationship

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

Where:

EUI	$=$	Energy Use Intensity (some say Energy Use Index), typically in kBtu/sq.ft./year
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$1,000$	$=$	Unit conversion constant; there are 1,000 Btu per kilo-Btu
$Area_{Building}$	$=$	Building gross square footage

Given:

- The EUI relationship
- The Exercise 01 Resources provided in the Utility Data folder (Unzipped from the zip file)
- Calculate the site EUI for the facility for 2014
  - There are 3,413 Btu/kWH
  - There are 100,000 Btu/therm
  - The building square footage is 485,000 sq.ft.

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

Where:

EUI	=	Energy Use Intensity (some say Energy Use Index), typically in kBtu/sq.ft./year
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3,413	=	Unit conversion constant; there are 3,413 Btus per kWh
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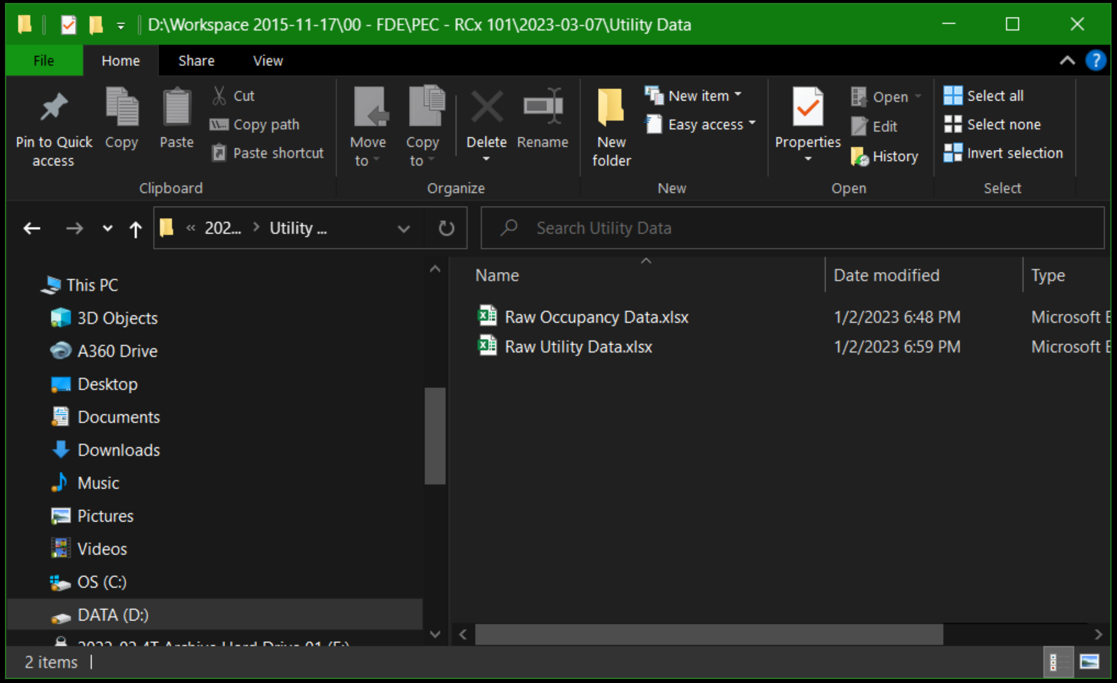
1,000	=	Unit conversion constant; there are 1,000 Btu per kilo-Btu
$Area_{Building}$	=	Building gross square footage



Leveraging the Data

Project Energy Metrics - Source as indicated					
Electric rate -	$0.09	$/kWh			
Thermal energy rate -	$0.58	$ per therm			
Electrical incentive -	$0.00	$ per kWh			
Thermal incentive -	$0.00	$ per therm			
Building square footage -	485,000	From Benchmarking Data			
Site energy electrical energy conversion factor -	3,413	Btu/kWh			
Source energy electrical energy conversion factor -	11,485	Btu/Kwh			
Source energy thermal energy conversion factor -	1.050	Therms at the well head per therm delivered			
Annual Consumption - From a baseline report, utility bills, utility meters, etc.					
	Energy	$			
Electricity - kWh/$ per year	6,477,564	$555,906			
Thermal at the Central Plant - Therms/$ per year	365,139	$213,452			
TOTAL		$769,358	$ per year		
		$1.59	$/sq.ft. /yr		
EUI Factors	Site Energy	Source Energy			
Electrical Energy	46	153	kBtu/sq.ft./yr.		
Thermal Energy	75	79	kBtu/sq.ft./yr.		
Total	121	232	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 Use			
	Low End	High End			
Potential savings range for the purposes of our discussion -	10%	16%			
Potential annual savings -	$76,936	$123,097	$ per year		
Percentage of the annual savings to be allocated electricity -	50%				
Percentage of the annual savings to be allocated to thermal -	50%				
Potential electrical savings -	448,238	717,181	kWh per year		
Potential thermal savings -	65,805	105,287	Therms per yr.		
Projected EUIs Post Implementation					
	Low End		High End		
	Site Energy	Source Energy	Site Energy	Source Energy	
Electrical Energy	42	143	41	136	kBtu/sq.ft./yr
Thermal Energy	62	65	54	56	kBtu/sq.ft./yr
Total	104	208	94	193	kBtu/sq.ft./yr
	Low End	High End			
Expenditure Justified by Anticipated Savings					
Simple payback time frame -	2	years	5	years	
Savings range -	Low End	High End	Low End	High End	
Energy savings after the indicated interval, 2013 $ -	$153,872	$246,195	$384,679	$615,487	
Incentive, 2013 $ -	$0	$0	$0	$0	
Total, 2013 $ -	$153,872	$246,195	$384,679	$615,487	

Adding Things Up

Project Energy Metrics - Source as indicated			
Electric rate -	$0.09	$/kWh	
Thermal energy rate -	$0.58	$ per therm	
Electrical incentive -	$0.00	$ per kWh	
Thermal incentive -	$0.00	$ per therm	
Building square footage -	485,000	From Benchmarking Data	
Site energy electrical energy conversion factor -	3,413	Btu/kWh	
Source energy electrical energy conversion factor -	11,485	Btu/Kwh	
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Annual Consumption - From a baseline report, utility bills, utility meters, etc.			
	Energy	$	
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Thermal at the Central Plant - Therms/$ per year	365,139	$213,452	
TOTAL		$769,358	$ per year
		$1.59	$/sq.ft. /yr
EUI Factors	Site Energy	Source Energy	
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Projecting Savings

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	Low End		High End		
	Site Energy	Source Energy	Site Energy	Source Energy	
Electrical Energy	42	143	41	136	kBtu/sq.ft./y
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Projecting Savings

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Total, 2013 $ -	$153,872	$246,195	$384,679	$615,487

Taking Things to the Next Level

California Commissioning Collaborative

Calculation of Average Daily Utility Use

Utility Usage Data

Project Information

Date:	January 3, 2023
Project Name:	ABC Tower
Utility Type	Electricity
Utility Units	kWh
Utility Company	Pacific Gas and Electric
Account Number:	XXX-XXX-XXX

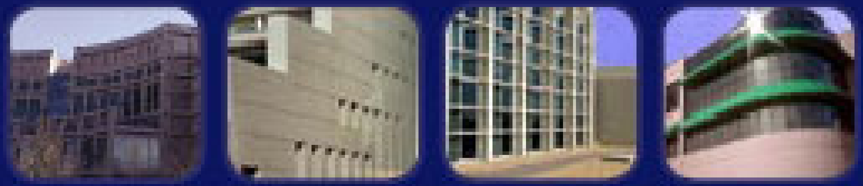
Date, or Date & Time	Billed Usage, kWh	Input Duration in Days

The analysis process and benefit is documented in the paper, *Using Utility Bills and Average Daily Energy Consumption to Target Commissioning Efforts and Track Building Performance*, by David Sellers:

http://www.peci.org/library/PECI_UtilBills1_1002.pdf

Utility Consumption Analysis

California Commissioning Collaborative



Calculation of Average Daily Utility Use

Utility Usage Data

Project Information

Date:	January 3, 2023
Project Name:	ABC Tower
Utility Type	Electricity
Utility Units	kWh

Utility Consumption Analysis

Any Volunteers?

Calculation of Average Daily Utility Use

Utility Usage Data

Project Information

Date:	January 3, 2023
Project Name:	ABC Tower
Utility Type	Electricity
Utility Units	kWh
Utility Company	Pacific Gas and Electric
Account Number:	XXX-XXX-XXX

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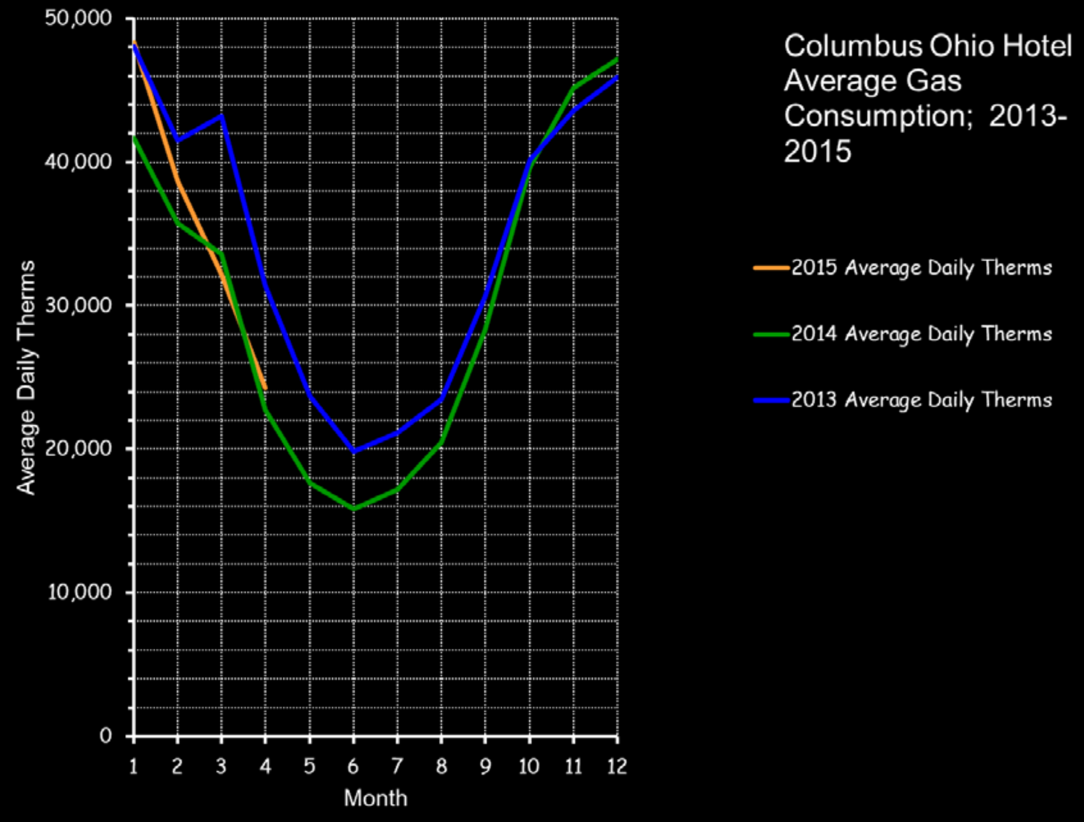
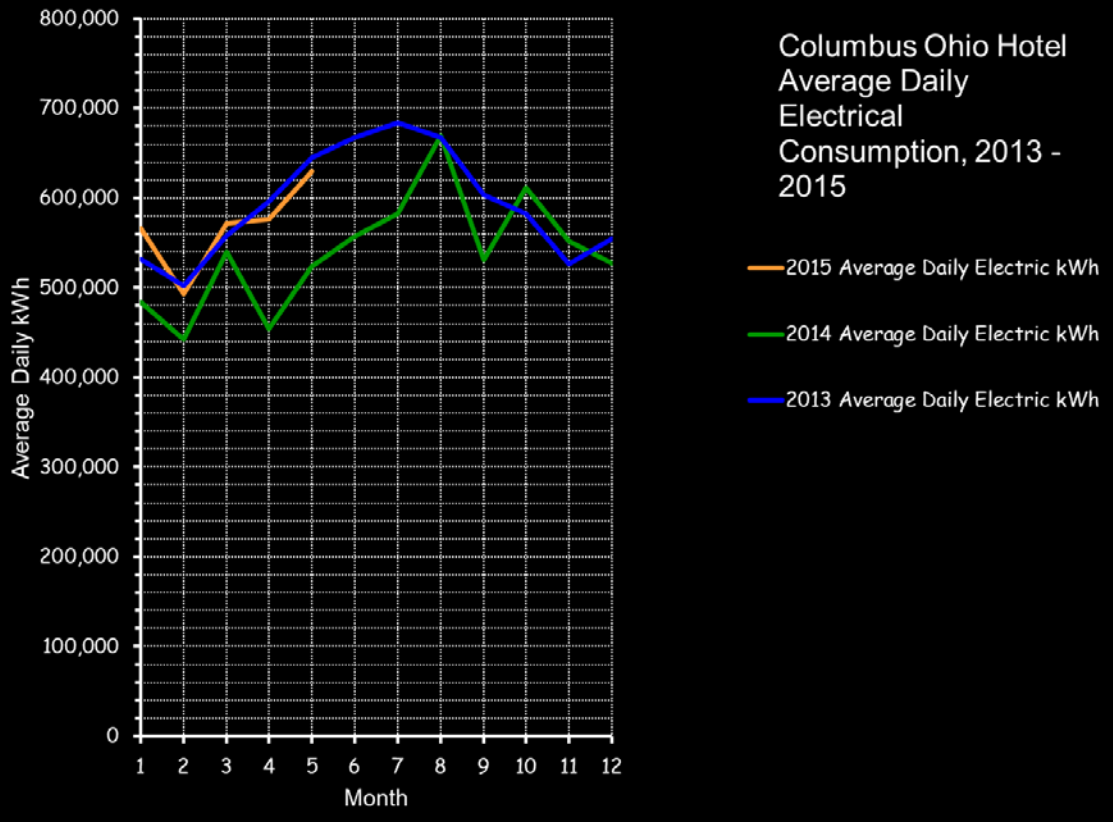
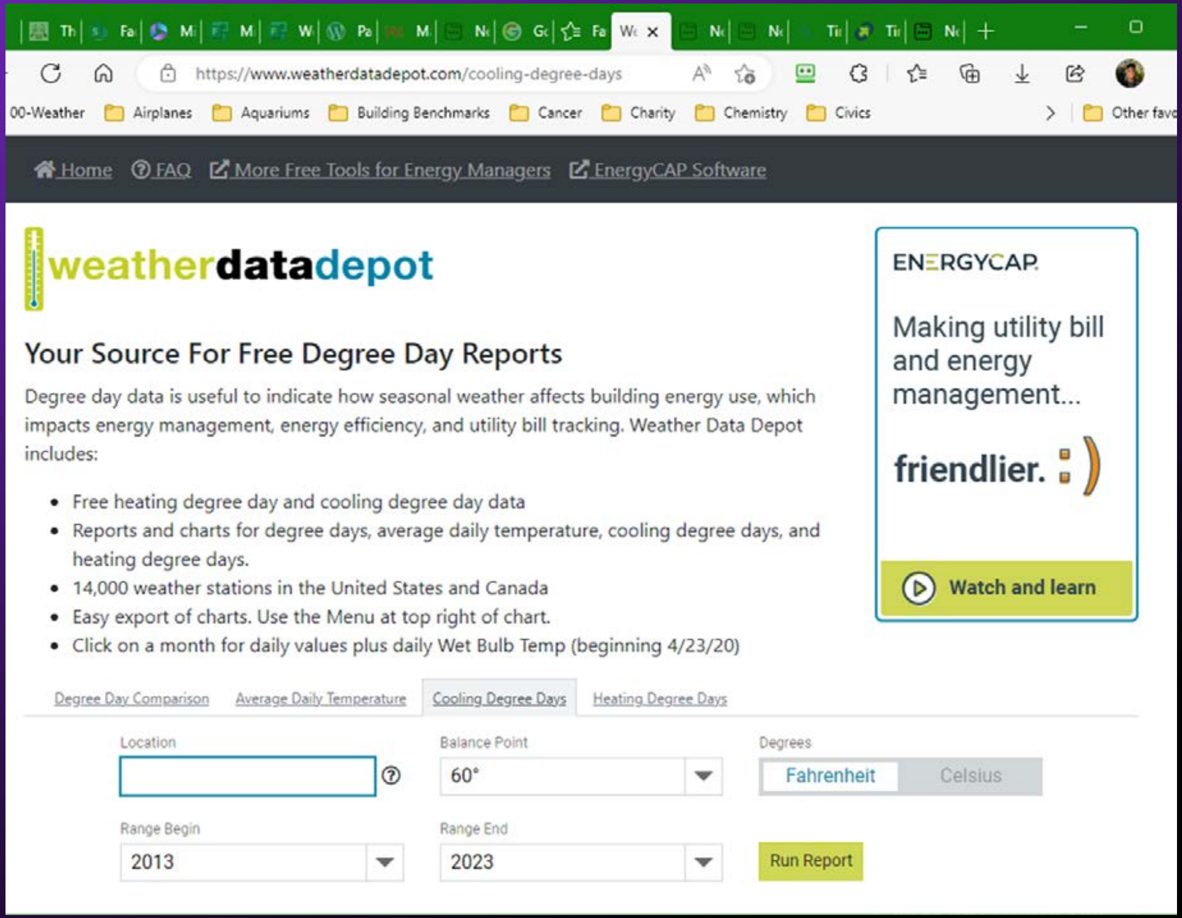
Utility Consumption Analysis

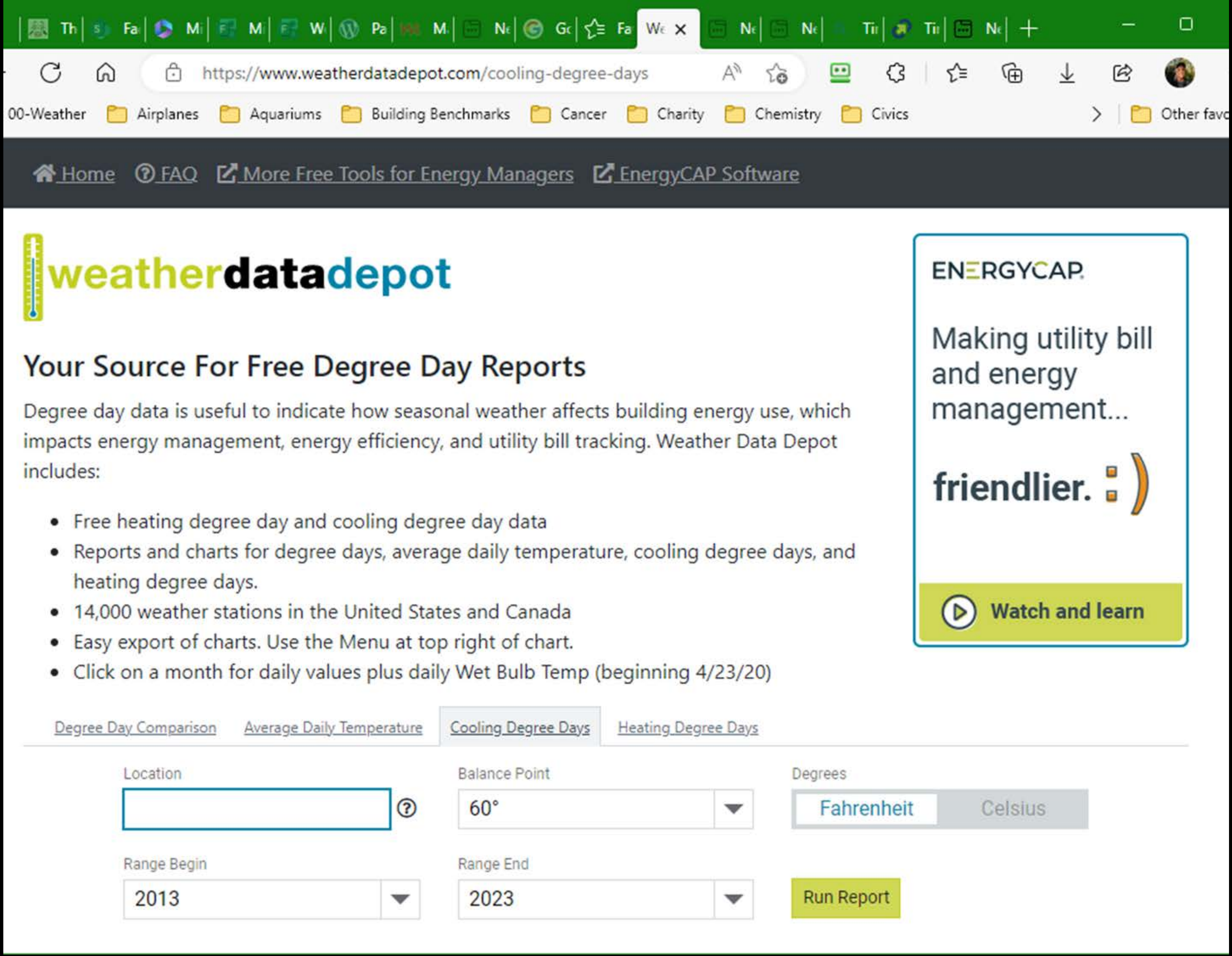




Looking at Drivers



Climate Drivers



https://www.weatherdatadepot.com/cooling-degree-days

00-Weather Airplanes Aquariums Building Benchmarks Cancer Charity Chemistry Civics Other favo

Home FAQ More Free Tools for Energy Managers EnergyCAP Software

weatherdatadepot

Your Source For Free Degree Day Reports

Degree day data is useful to indicate how seasonal weather affects building energy use, which impacts energy management, energy efficiency, and utility bill tracking. Weather Data Depot includes:

- Free heating degree day and cooling degree day data
- Reports and charts for degree days, average daily temperature, cooling degree days, and heating degree days.
- 14,000 weather stations in the United States and Canada
- Easy export of charts. Use the Menu at top right of chart.
- Click on a month for daily values plus daily Wet Bulb Temp (beginning 4/23/20)

Degree Day Comparison | Average Daily Temperature | Cooling Degree Days | Heating Degree Days

Location

Balance Point: 60°

Degrees: Fahrenheit Celsius

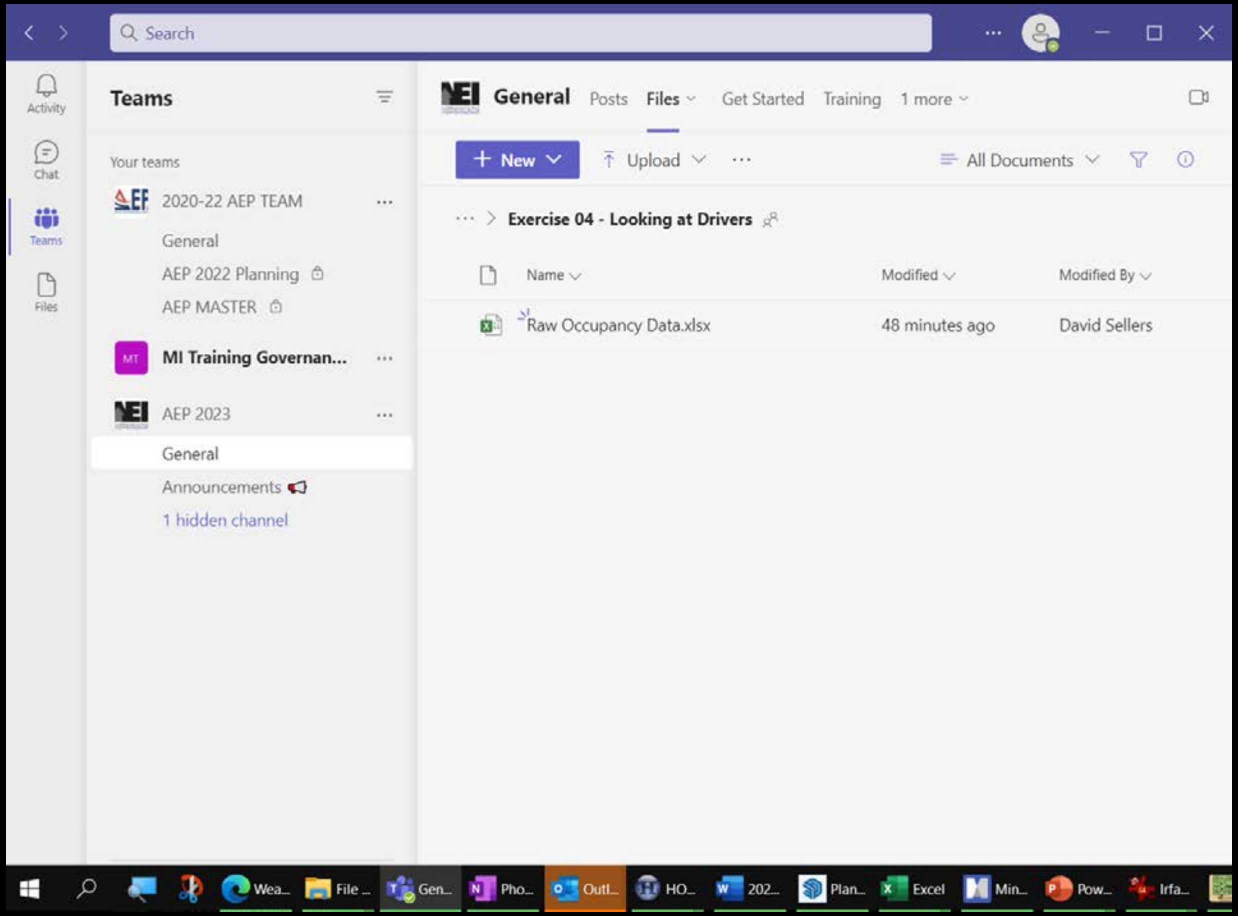
Range Begin: 2013

Range End: 2023

Run Report

Utility Consumption Analysis

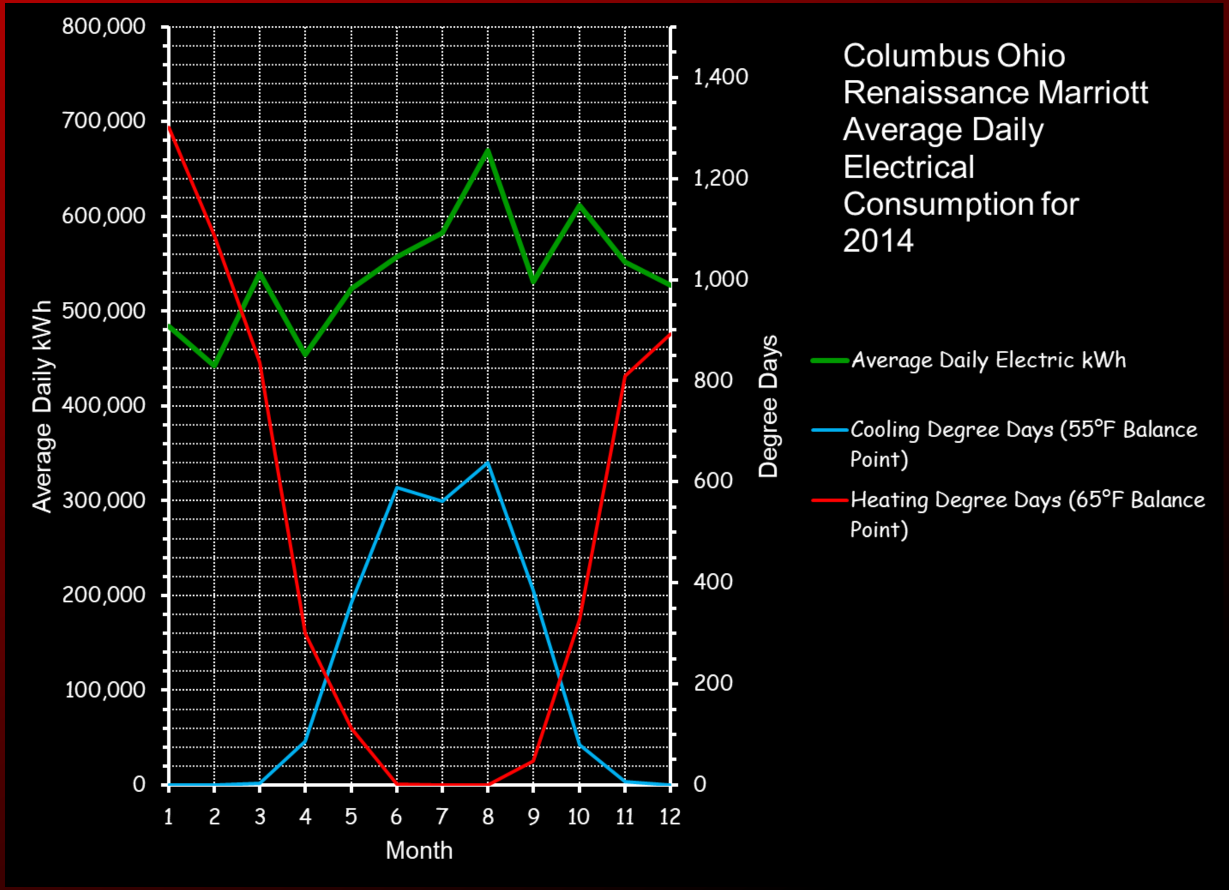
If you want to work along, the resources are in the Exercise 04 – Looking at Drivers

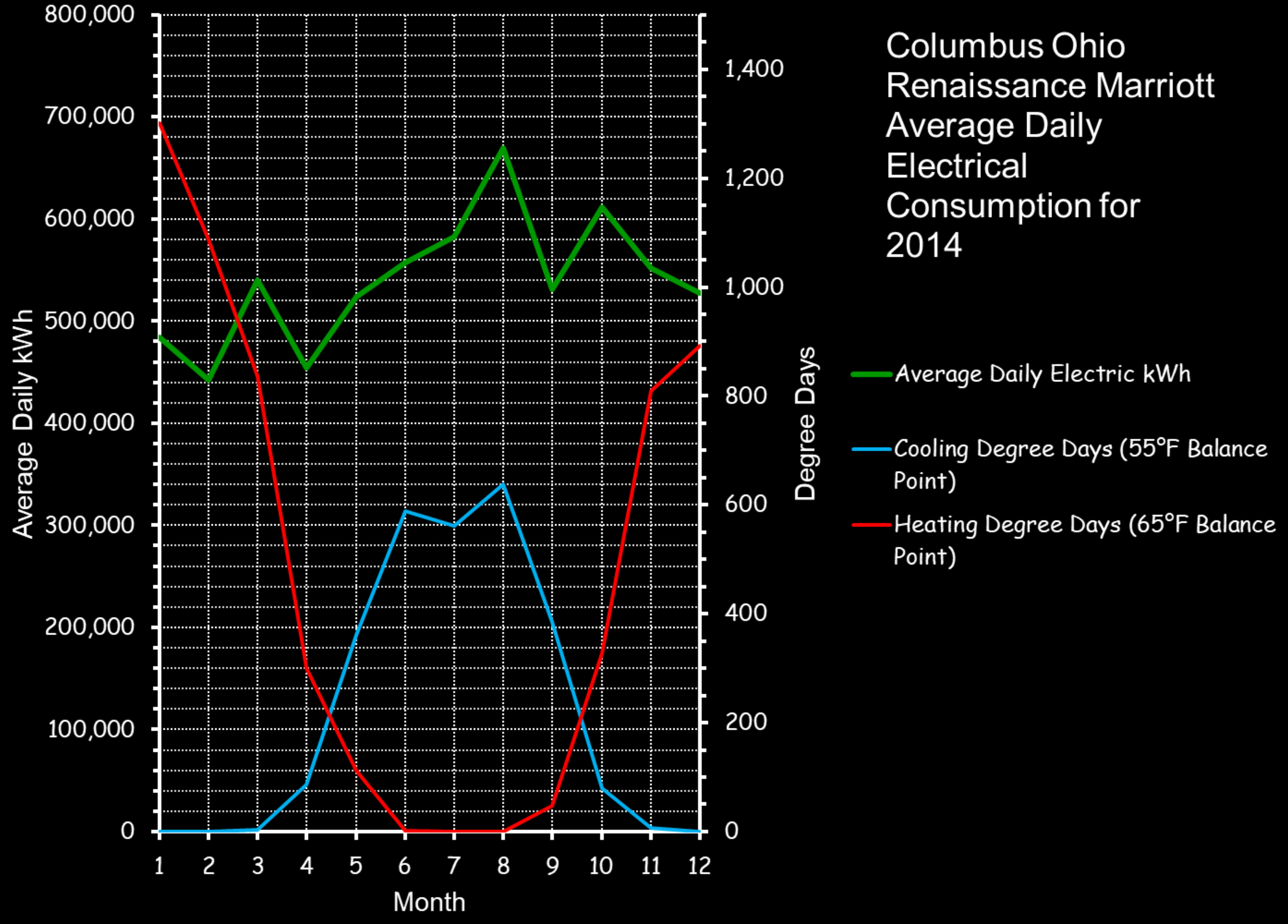


Occupancy as a Driver

Total Available Rooms -		408
Month	Occupied Rooms	
2013-01	6,393	
2013-02	8,835	
2013-03	9,038	
2013-04	9,890	
2013-05	9,224	
2013-06	9,871	
2013-07	9,473	
2013-08	10,037	
2013-09	9,008	
2013-10	10,235	
2013-11	7,819	
2013-12	6,660	
2014-01	5,961	
2014-02	8,047	
2014-03	8,815	
2014-04	7,971	
2014-05	8,899	
2014-06	9,162	
2014-07	9,760	
2014-08	9,077	
2014-09	8,967	

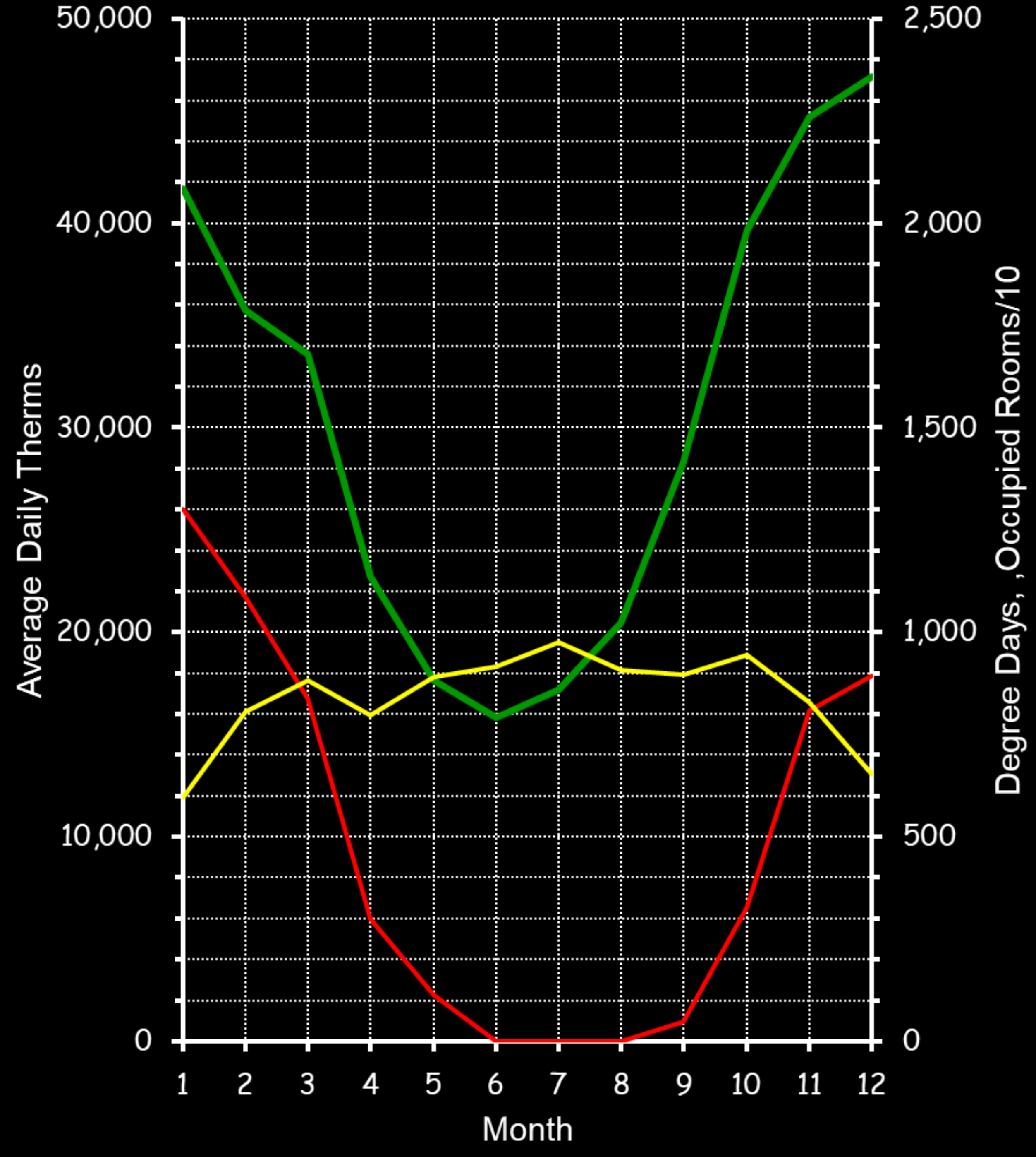
Connecting Some Dots

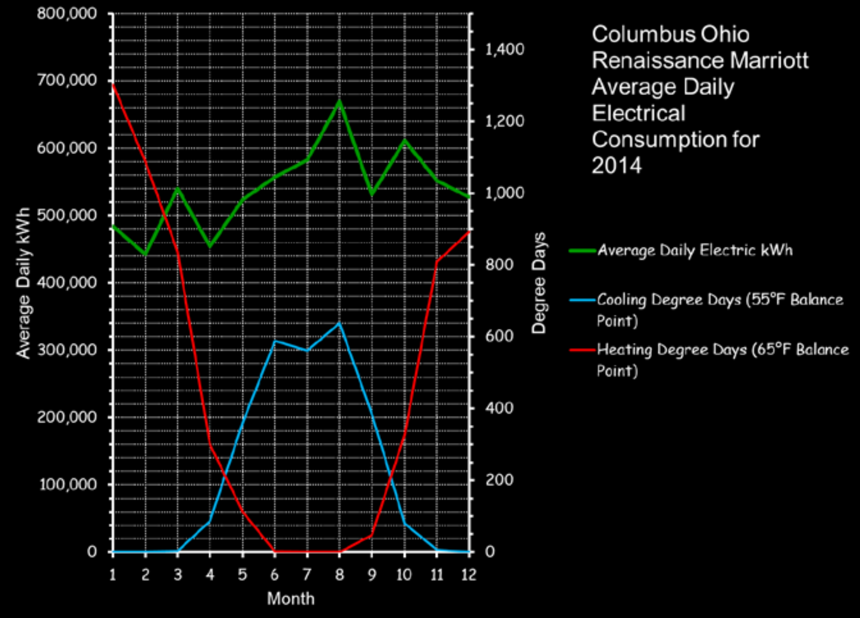




Columbus Ohio
Renaissance Marriott
Average Daily
Electrical
Consumption for
2014
Average Daily kWh
Degree Days
Month
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1,400
1,200
1,000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12
Average Daily Electric kWh
Cooling Degree Days (55°F Balance Point)
Heating Degree Days (65°F Balance Point)

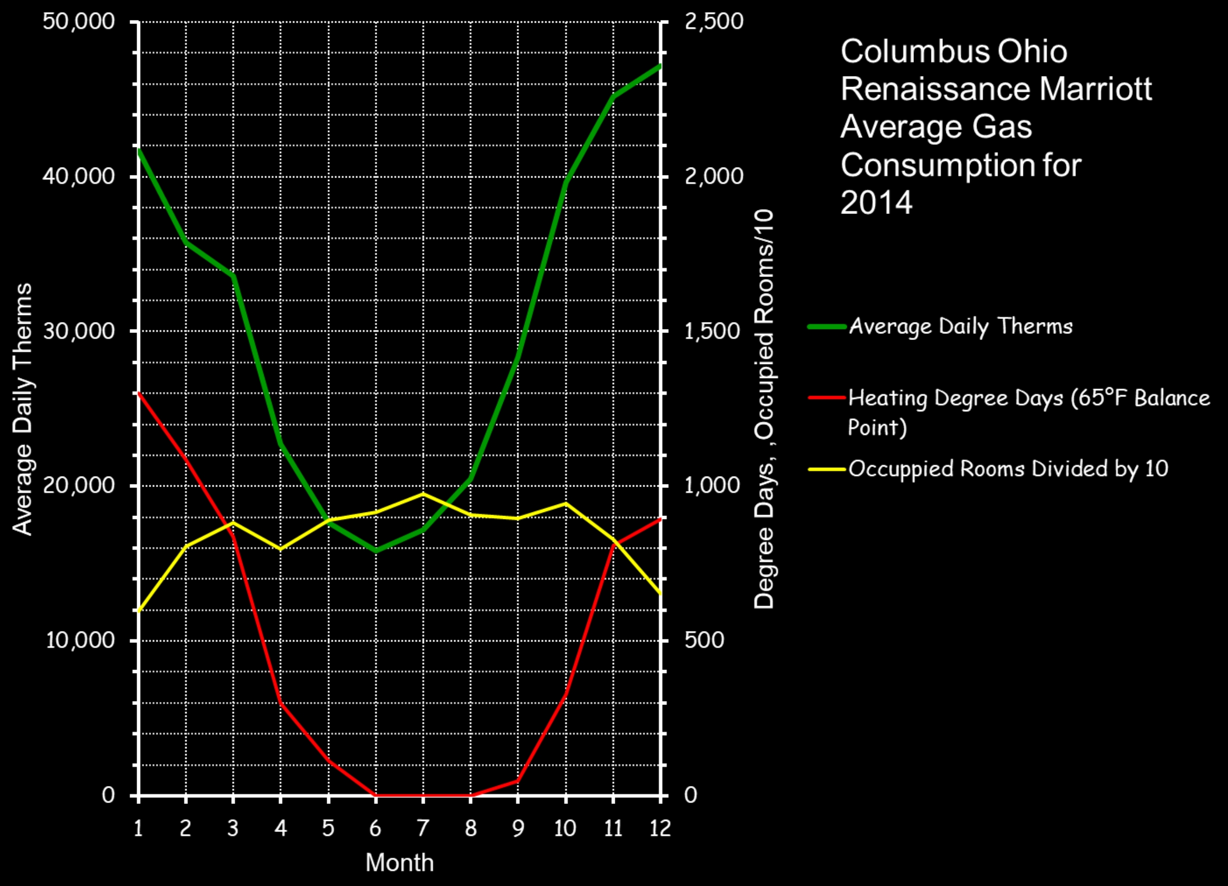
Columbus Ohio Renaissance Marriott Average Gas Consumption for 2014

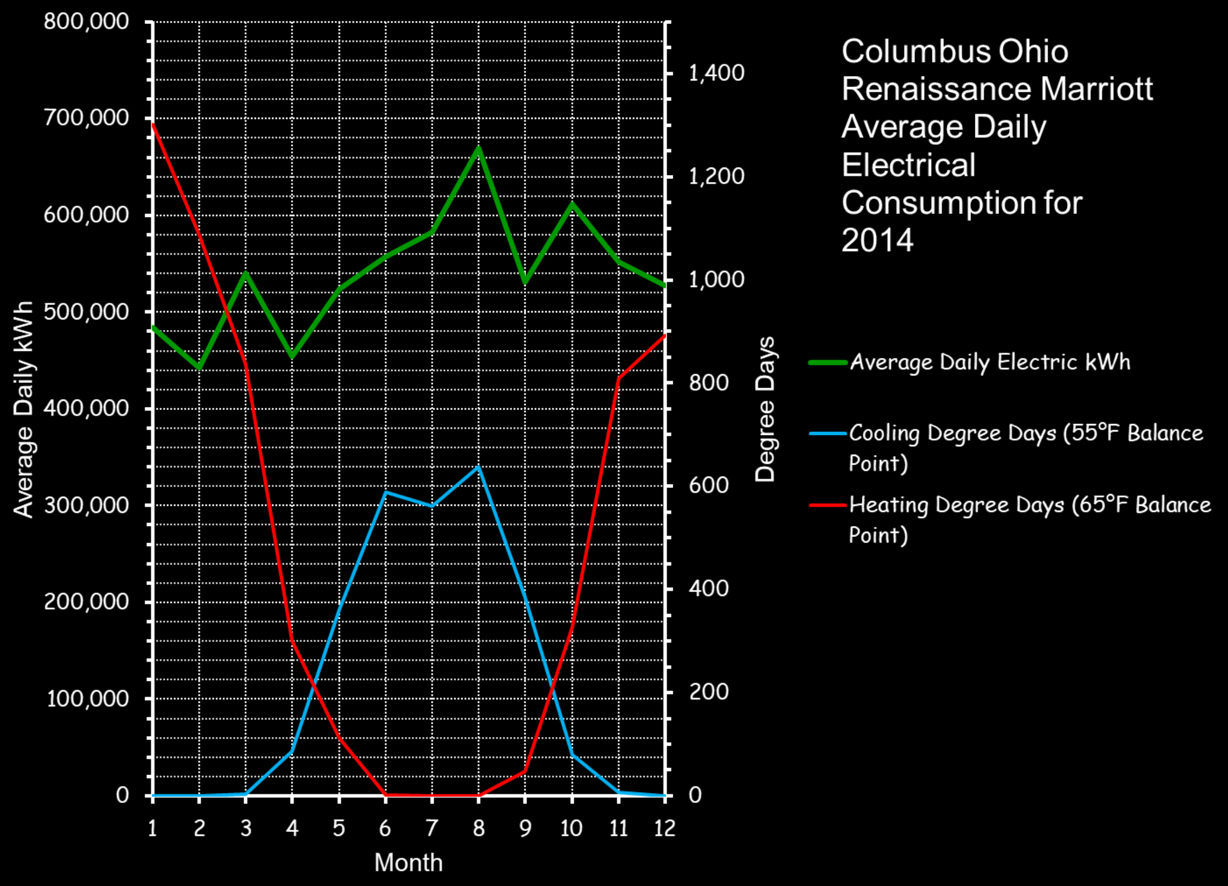




Think About It

It Will Come Up in the Next Webinar





I Was Told There Would Be No Math Involved

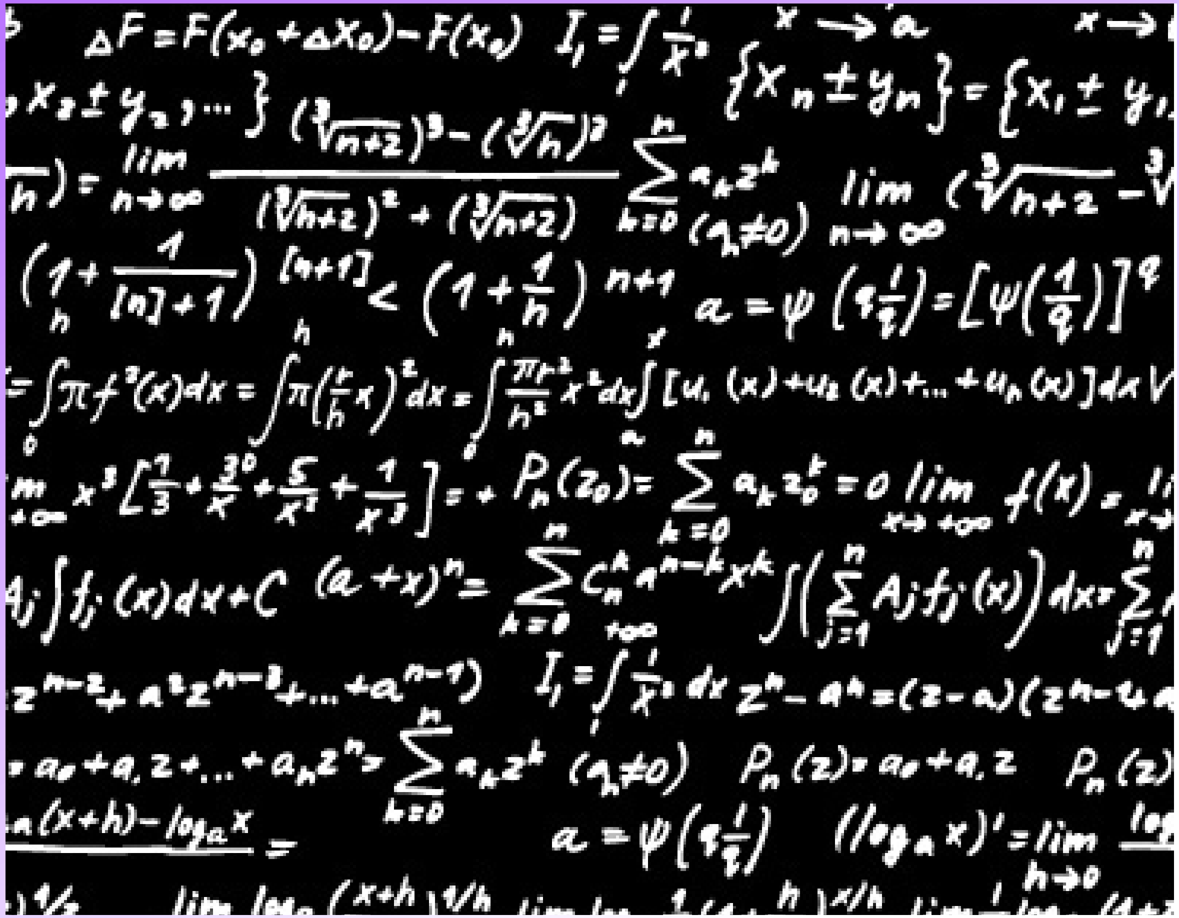


Image courtesy https://auntiebswax.blogspot.com/2010/10/no-one-told-me-there-would-be-math.html

A (Potentially) Informative Relationship

This relationship tells us that the power used by a pump is directly related to the flow and head it produces and inversely related to the pump, motor and drive system efficiency

$$kW = \left(\frac{Flow_{gpm} \times Head_{ft.w.c.}}{3,960 \times \eta_{Pump} \times \eta_{Motor} \times \eta_{VSD}} \right) \times .746$$

Where:

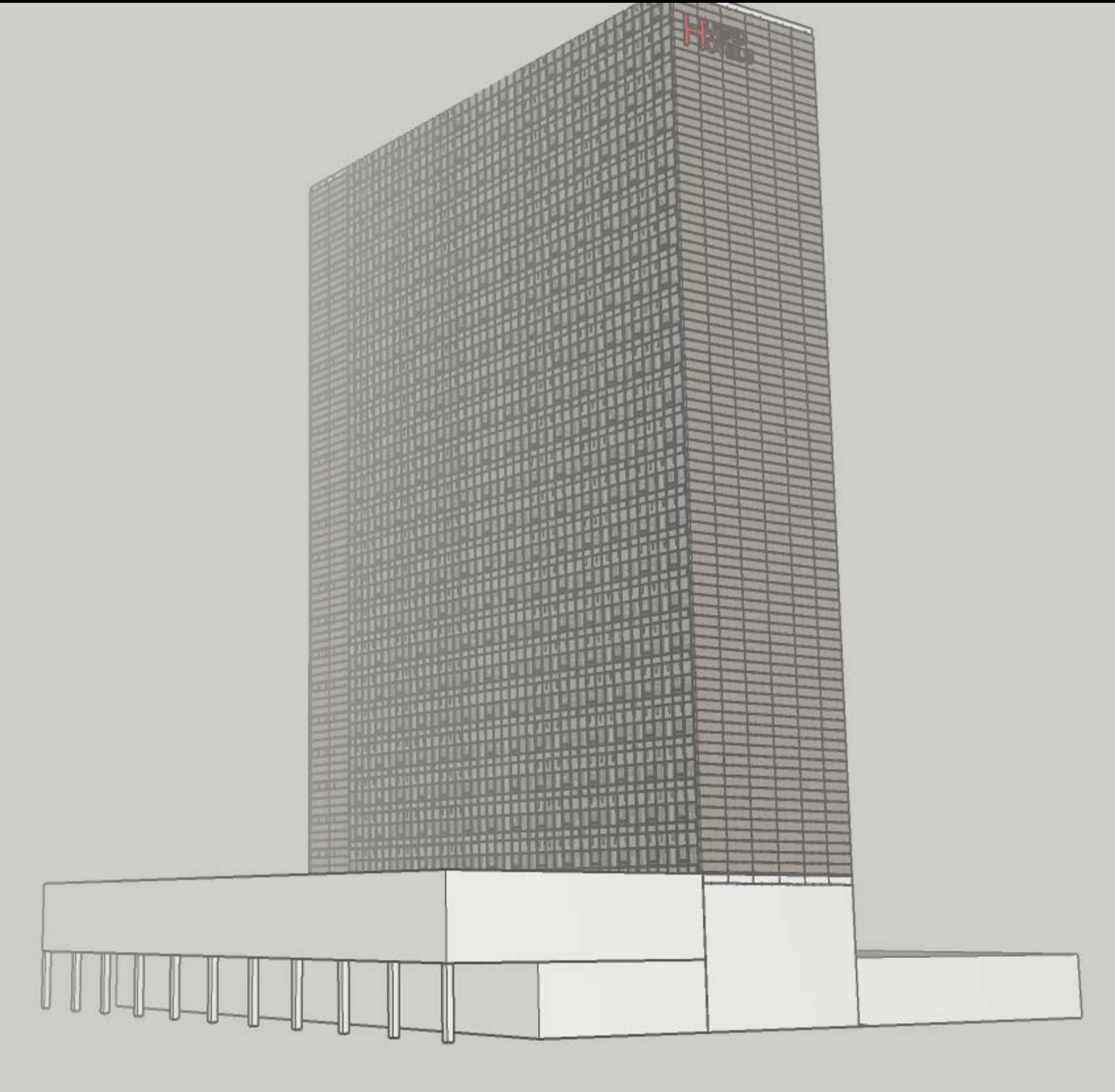
kW	=	Input to the system to produce the flow and head
$Flow$	=	Flow rate in gallons per minute
$Head$	=	The pump head in ft.w.c. water column
3,960	=	A units conversion constant that is good for water between 40°F and 220°F
η_{Pump}	=	Pump efficiency.
η_{Motor}	=	Motor efficiency
η_{VSD}	=	Variable speed drive efficiency
.746	=	Horsepower to kW conversion constant

Let’s Apply the Concept

Current Conditions

Current Conditions

- Foggy
- Furnace running at home when you left
- Low 50’s °F through early afternoon, then clearing and sunny with a high of 68-70°F anticipated
- Hotel at 84% occupancy
- Major conference happening
  - Main ball room in use
  - Meeting rooms and Junior Ball Room in use
  - Spaces under control at design target of 72°F/50% RH
  - Ballroom MOA settings recently verified



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AEP 2023