AABC Commissioning Group

AIA Provider Number 50111116

ASHRAE 90.1-2016, Energy Standard for Buildings – Review of Changes

Course Number: CXENERGY1725

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Course Description

The presentation will focus on the updates to the ASHRAE 90.1-2016 Energy Standard for Commercial Buildings including envelope, mechanical, lighting and performance modeling changes relative to ASHRAE 90.1-2013.

It will also include some overall background on the standard and its overall impact on Building Energy Efficiency and Design.

In addition reference sources for further information and implementation will be provided

Learning Objectives

At the end of the this course, participants will be able to:

1. Understand the scope of the 125 addenda contained in the 2016 ANSI/ASHRAE/IES Standard 90.1 and how to identify how these items impact current projects.

2. Learn about the new provisions of the standard that affect building envelope exterior walls, fenestration and opaque doors, and verification.

3. Learn about the new provisions of the standard that affect lighting controls, modification of exterior and interior lighting power densities impacted by LED lights.

4. Learn about the new provisions of the standard that result in significant changes in energy cost budget (ECB) and modeling.

United Technologies – Climate Controls and Security

Commercial HVAC&R Systems and Subsystems Efficiency Imitative

Richard Lord

Sr. Fellow

3-24-2017

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Introduction

- For several years investigations work and discussions have been occurring and several groups have been evaluating ways to consider system and subsystem for future efficiency improvements and for metrics
  - AHRI Systems Steering Committee
  - ASHRAE 90.1 Hydronic Working Group
  - ASHRAE Advanced Energy Standards Committee
  - Alliance to Save Energy
  - Title 24
  - New Building Institute
  - Pacific Northwest Laboratory
  - European Fist and Second Directive
  - CSA C873 Standard
  - Singapore Systems Standards
  - Company Initiatives
- At the same time there is also considerable activity on connected equipment and how smart connected systems could help with Energy Savings especially for sustained energy savings

Intent is to give a quick overview of where things are going, with a focus on the chilled water initiative that we discussed last year

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Background

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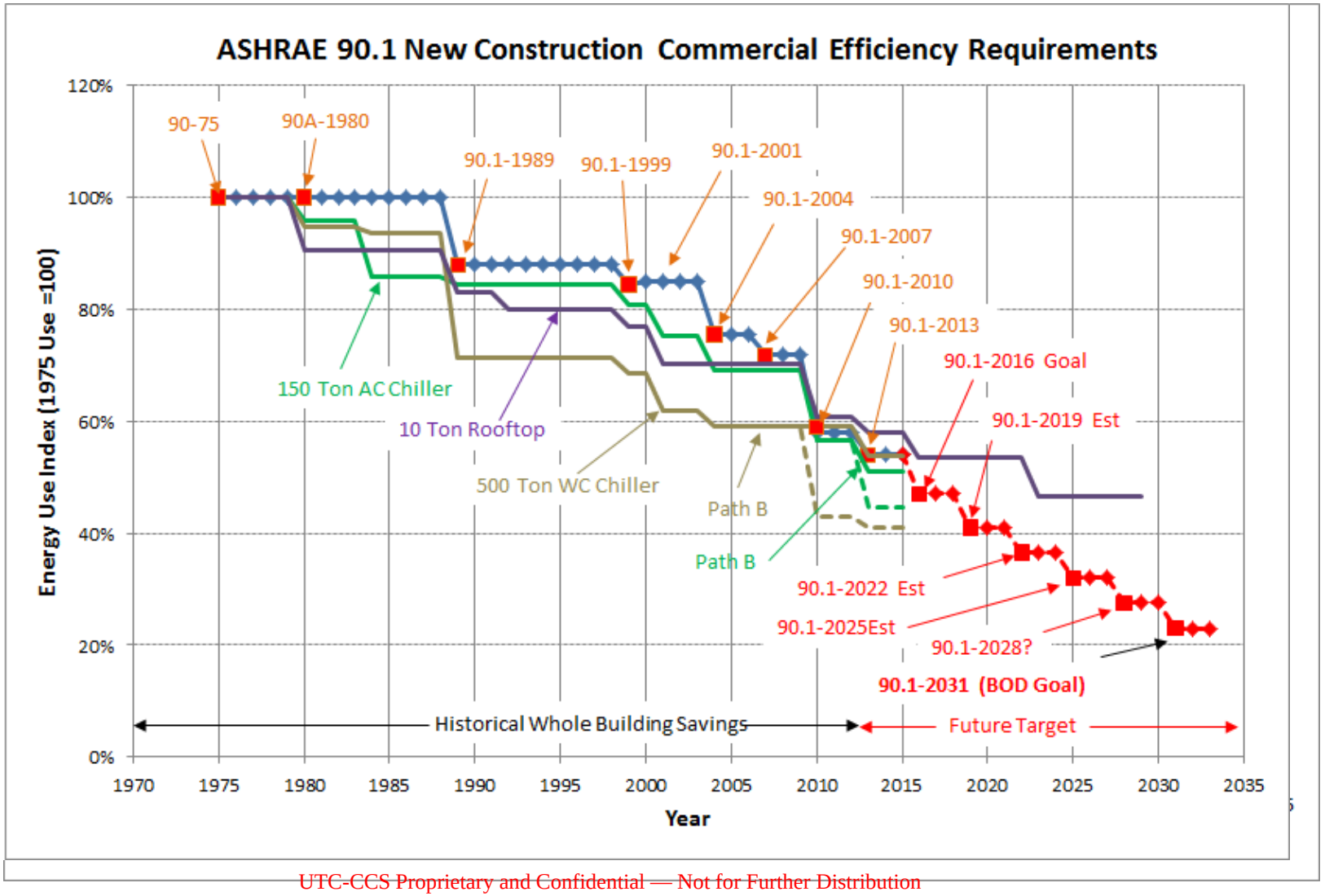
Background – Commercial Building Efficiency

Great progress has been made in overall commercial building efficiency, but we are seeing signs that equipment component efficiencies will not meet future goals



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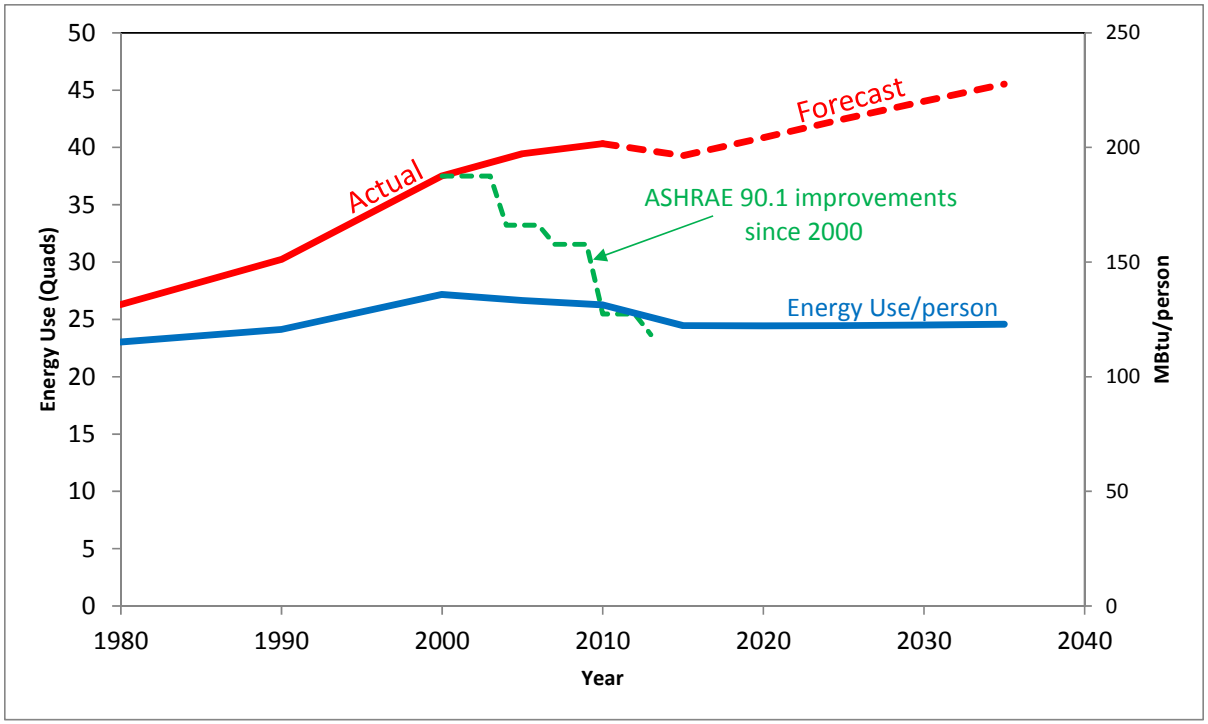
Mechanical Efficiency Improvements

But overall building energy is still increasing?



Why is to occurring

- Population growth and increased building
- Regulation focus on just new construction
- Focus is on design and not operation
- Delay in state adoption of new standards (non-enforcement)
- Demand for energy increasing due to plug and miscellaneous loads
- Lack of a total systems approach and items that are not regulated or evaluated

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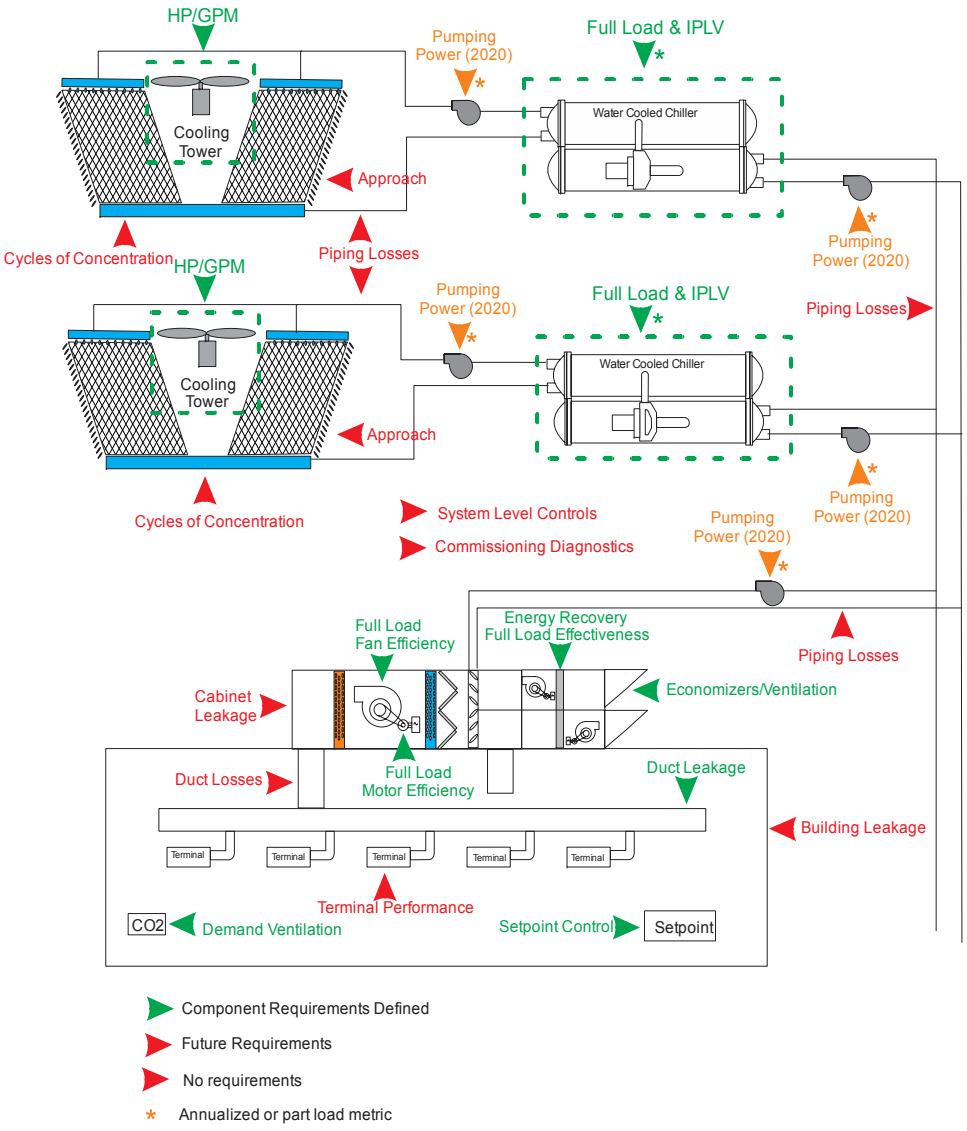
Current Mechanical System Metric

- Current metrics are based on appliance approach and focused on components and prescriptive design requirements
- Metrics are primary focused on design day loads and temperature but there is some movement to annualized and part load
- Typically only 1 common metric is used for the US
- Overall systems are not typically evaluated or optimized at a system level
- Creative solutions are not always rewarded for their beneficial improvement (i.e.. Economizers, hybrid systems, duct design, etc.,)
- No real focus on sustained performance



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Equipment Efficiency Improvements

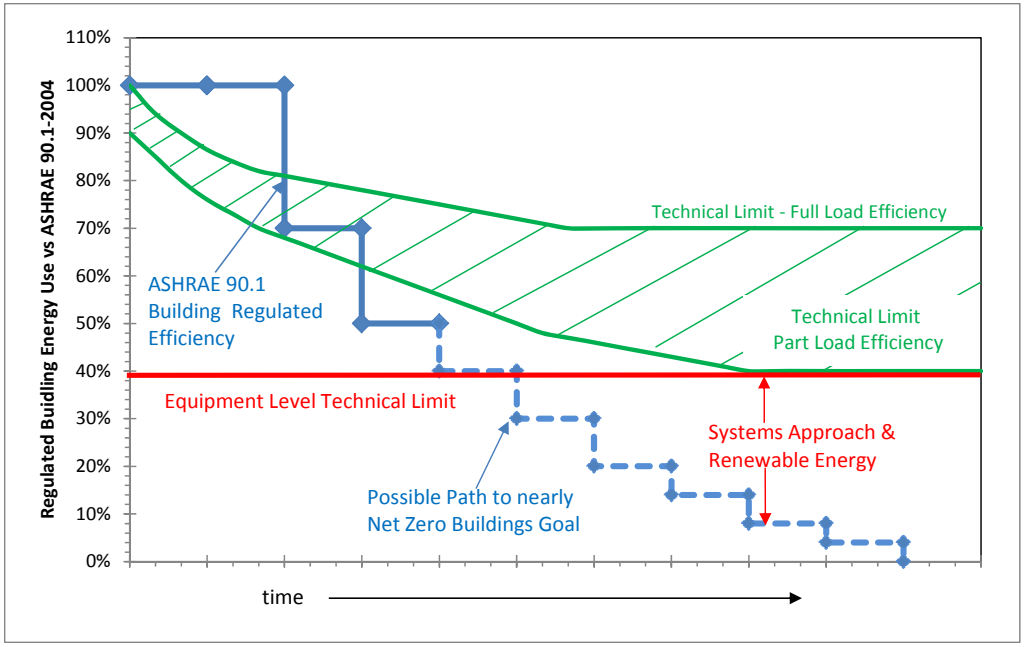
There are limits on efficiency improvements due to fundamental laws of thermodynamics (first and second law, Carnot cycle and component limit

There are also limits on economic payback and very long paybacks can actual have a negative impact on efficiency

Not all products are at the same point on the curve

Some believe there will be new technology and the same trend will continue

Others believe that when a product reaches ***"Max Tech"*** that DOE and ASHRAE will stop



Chiller Efficiencies is where the industry is close to ***"Max Tech"*** and no work or discussions at a typical equipment level metric are being planned other than possible global regional annualized efficiency metrics (IPLV)

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Systems and Subsystems Conceptual Approach

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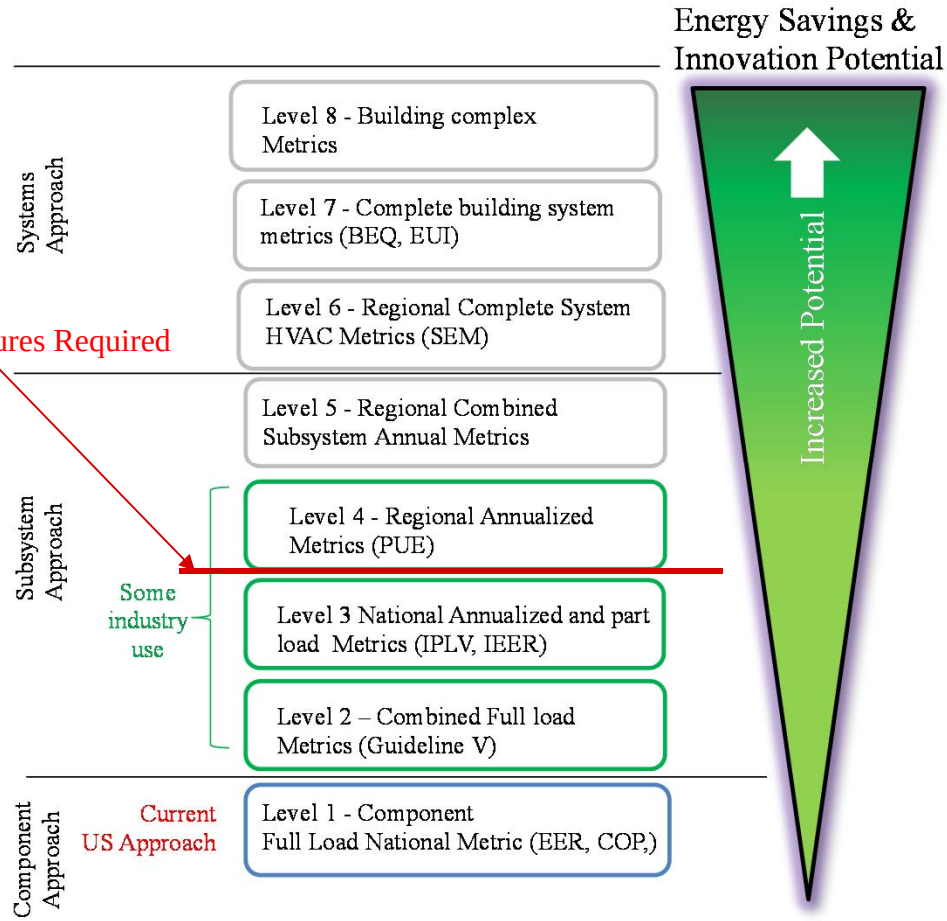
What is a Systems Approach

- Alliance to Save Energy Definition - A building system has been defined "*as a combination of equipment, operations, controls, accessories, and means of interconnection that uses energy to perform a specific function*"

- The intent of a mechanical systems approach will be to move up the scale where we believe more energy savings can be obtained

- But conventional tools and ratings metrics will need to be revised to allow for this approach

- It also will likely enable and result in a move to regional requirements which for chillers is already occurring globally



It also should be noted that a systems approach should also includes commissioning, monitoring, reporting and maintenance and factor in benefits of connected equipment

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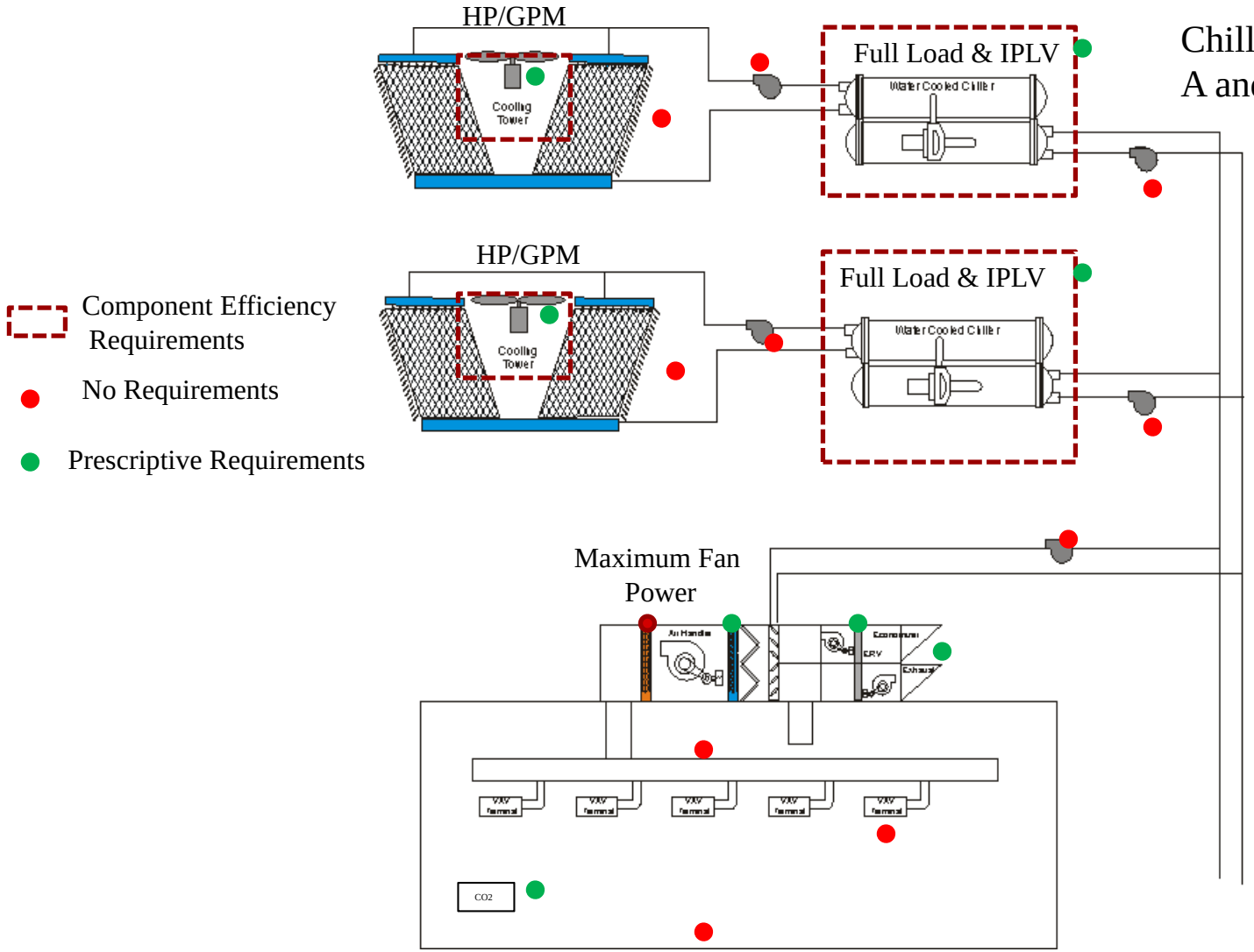
Defining System Boundaries – Chilled Water

Current ASHRAE 90.1 Chilled Water Regulations (Prescriptive Approach)



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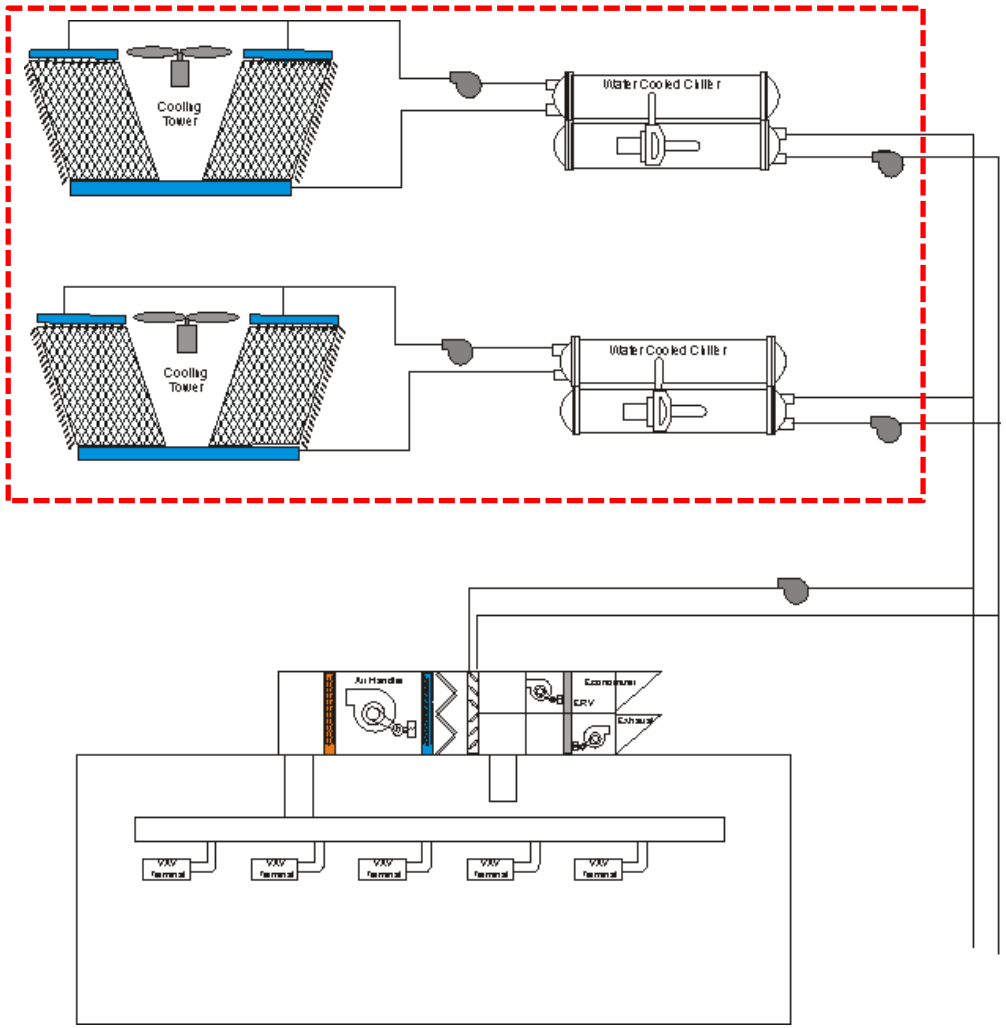
Chilled Water System/Subsystem Example

Possible Proposed Sub-Systems Approach

Option A1 – Chilled Water Subsystem



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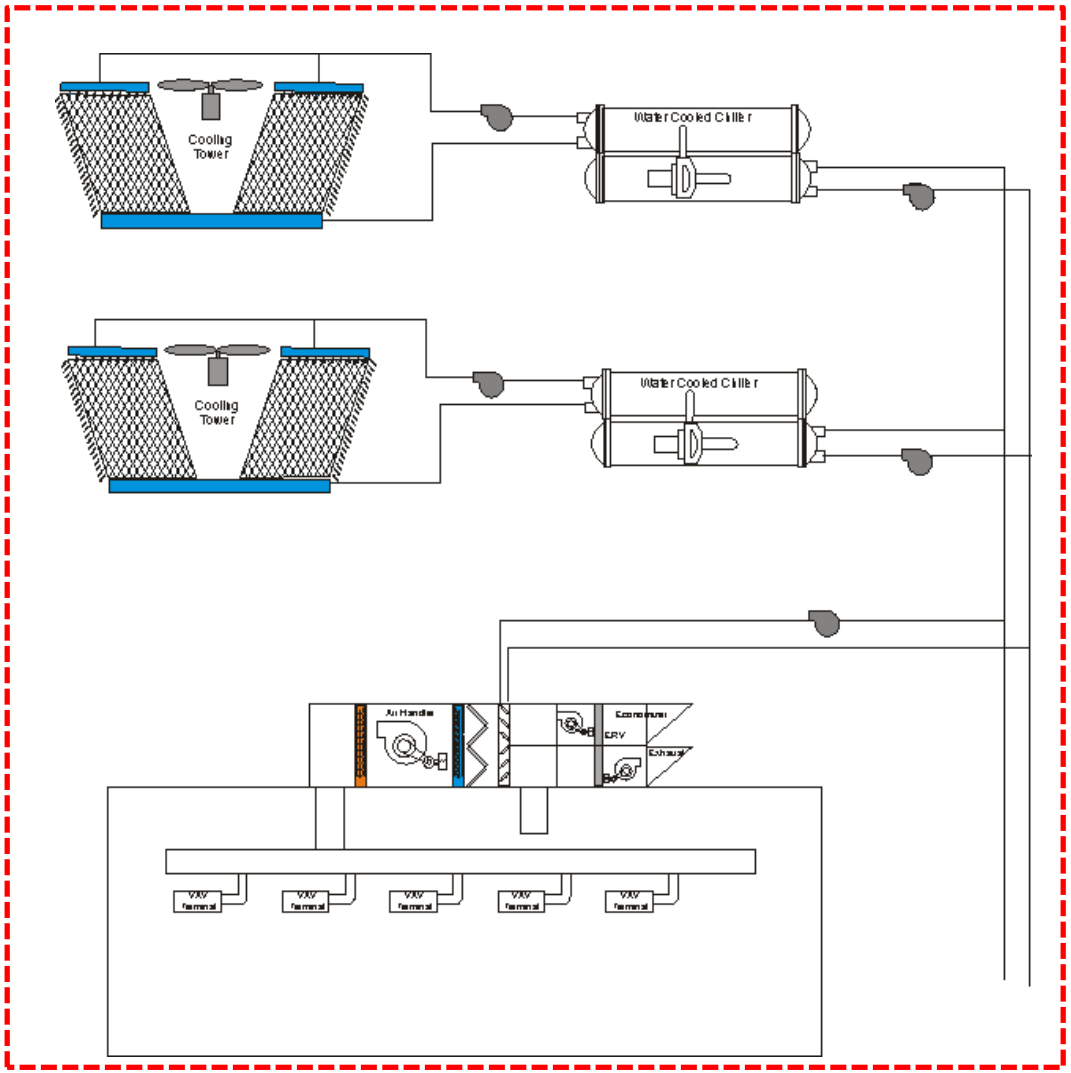
Chilled Water System/Subsystem Example

Proposed Systems Approach

Option A2 – Complete System



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Other System Initiatives

- There are other subsystem and system initiatives underway
  - AHRI proof of concept evaluation for chilled water systems, rooftop systems and supermarket systems
  - AHRI new annualized metrics and regional metrics for VRF, Chillers
  - Updated metrics including SEER2, IEER2, CEF, WSHP part load and more
  - Alliance Strategic Plan and a possible Sensate Bill Proposal
  - Second European Directive
  - Canada System Metrics and Tool Development
  - Diagnostics, connected equipment and standard codes

We can expand on these at future meetings but we will focus today on the chilled water system

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Strategy for Chilled Water System including Tools, Procedures and Standard Changes

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Need for Tools and Procedures

- Once we get beyond the simple full and part load metrics like EER, SEER, SEER2, IPLV and IEER, which generally are done at fixed ratings points and for average buildings, new tools and procedures will be required

- The tools and procedures are needed for many reasons
  - Full product map ratings are required
  - Need to factor in the building load and building type
  - Need to factor in the ambient conditions

- The industry has been discussing these tools, but work has been slow due to concerns with further secondary regulations and the fact that the industry is already highly regulated. The industry is also extremely busy due to new regulations, pending refrigerant changes and other regulatory burden with occupies more than 60% of the current resources and soon all resources with new refrigerant changes and 2023 efficiency changes for rooftops and residential products

- But there has been considerable work underway to develop the tools and supporting structure as well determine how to interface certification programs and to implement a subsystem and systems approach.

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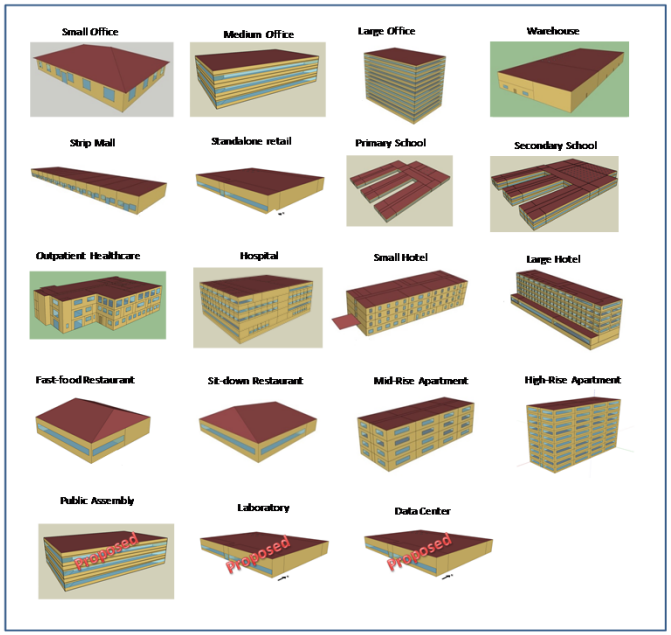
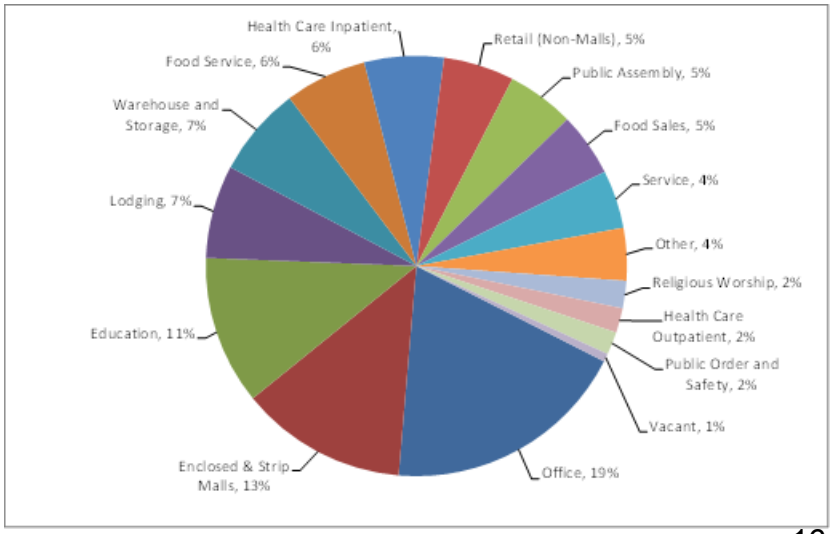
Commercial Building Types

- There are many commercial buildings and the loads and operation can vary significantly



- Work has been done by ASHRAE and PNNL to develop standardized benchmark buildings to cover about 85% of the market, but getting new updates has been difficult due to funding issues from DOE and Carrier has been trying to work on this



- **This will be a critical enabler to a systems approach in the future**

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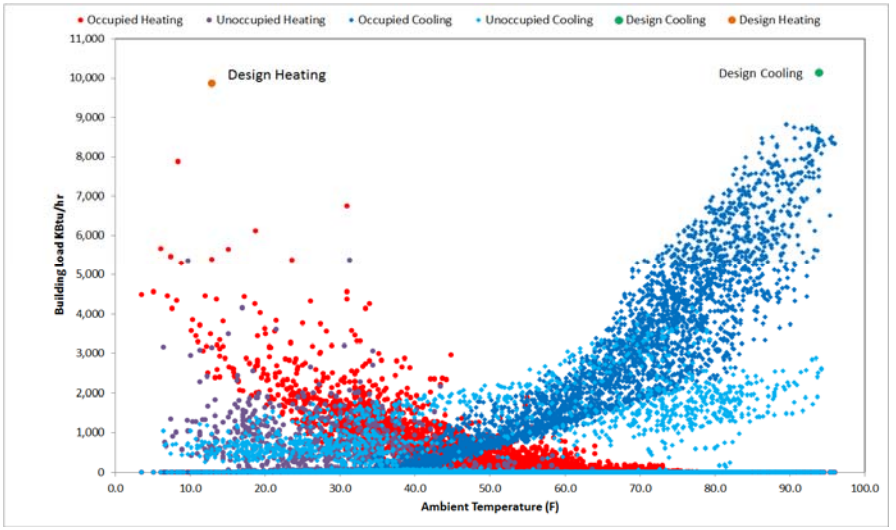
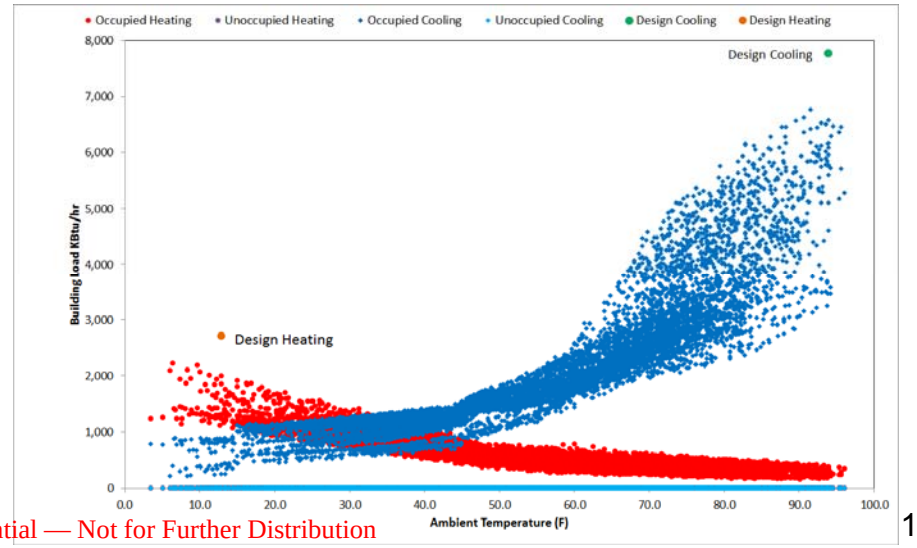
Mechanical System Loads

- Most mechanical systems efficiency are highly dependent on building loads
- They **spend very little time**, if any at **full load** and design ambient, which is where we focus on energy efficiency metrics
- Building loads vary significantly by building type and needs to be considered in a systems approach
- They are different than residential load profiles and can have simultaneous heating and cooling

Large Office Building, Baltimore Zone 4a



Hospital, Baltimore Zone 4a



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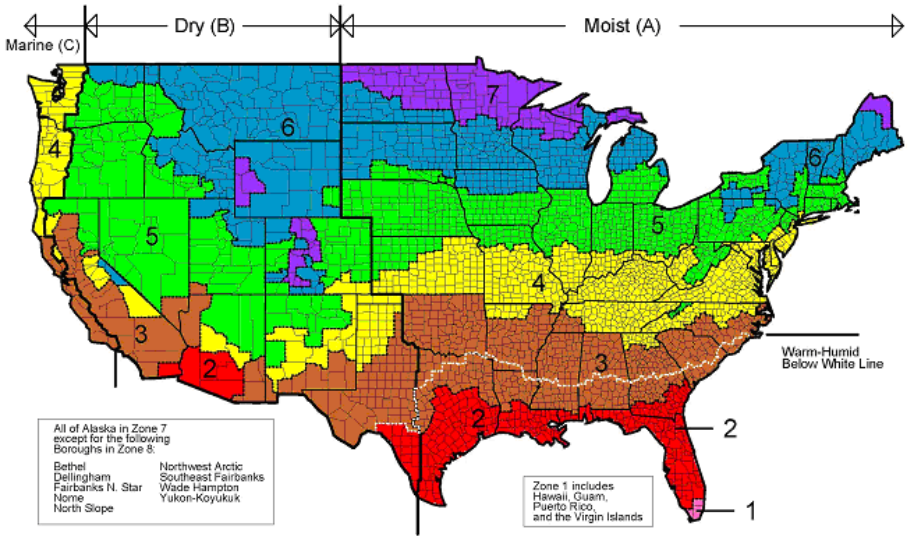
New US Climate Zones (ASHRAE 169)

OLD



NEW

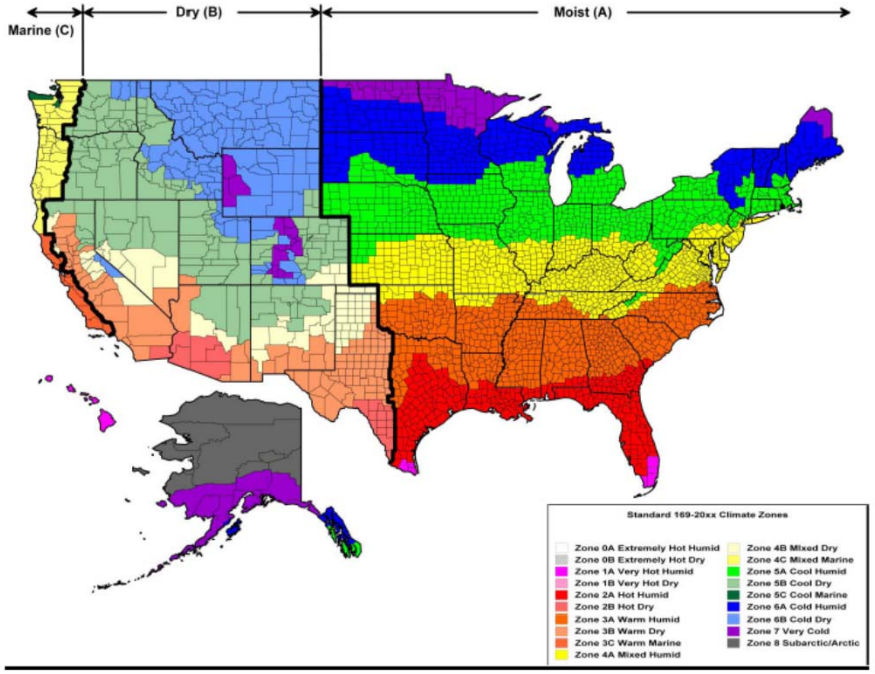


Figure B-1 Climate Zones for United States Counties

In general climate zone boarders have moved north. Note that the colors are not the same

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Global Climate Zones (ASHRAE 169-2013)

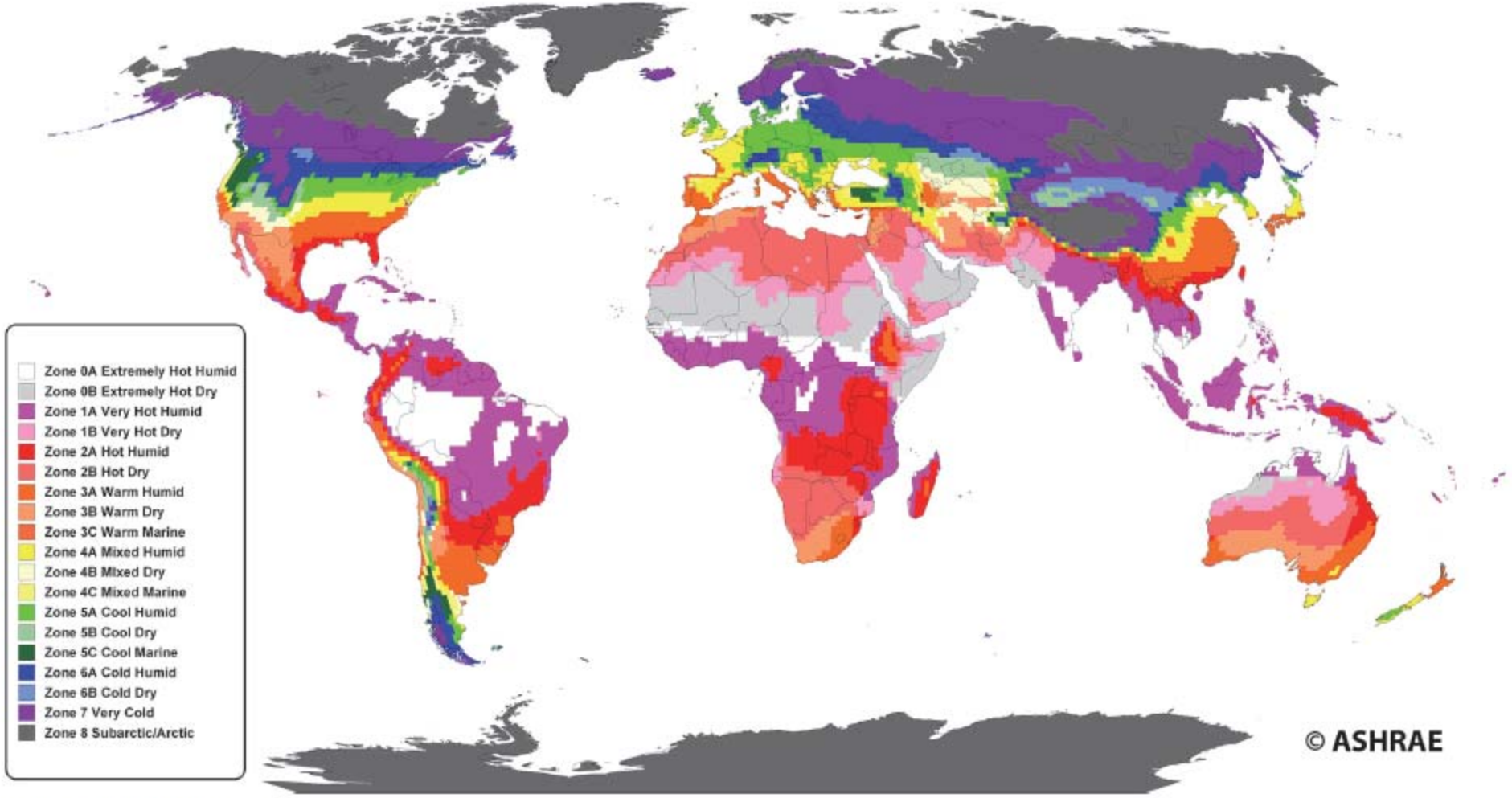

FIGURE C-2 World climate zones map.

We often get feedback that the ASHRAE 169 climate zones do not address the world but that is not true and in fact the 20 climates zones are mapped to the world

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Tool Development Status

- A key part of the implementation of a system approach is models for the equipment and we have been working on a new **ASHRAE Standard 205** which is very close to be released for a first public review

- This is a new standard that will develop complete **system map** models for equipment and chillers and rooftops are in the first release

- Also a critical part of the implementation is a tool that will allow for **integrating the equipment**, system and then running it vs a **building load profile for a given weather file**

- Carrier Innovation and Research group is in the process of evaluating a proof of concept tool using preliminary ASHRAE 205 models and other models for the equipment including evaluation of new visual user friendly modeling approach

- We had hoped to get some industry funding for a development of an industry tool but with all the other priorities for refrigerants and DOE efficiencies as well as new administration budget cuts we have not had much success

- Because there is a strong interest from ASHRAE 90.1 for chiller system approach Carrier I&R is proceeding internal development of a tool that will then be given to ASHRAE 90.1 for using in a systems approach implementation

- We also could provide this tool for a CEE rebate program.

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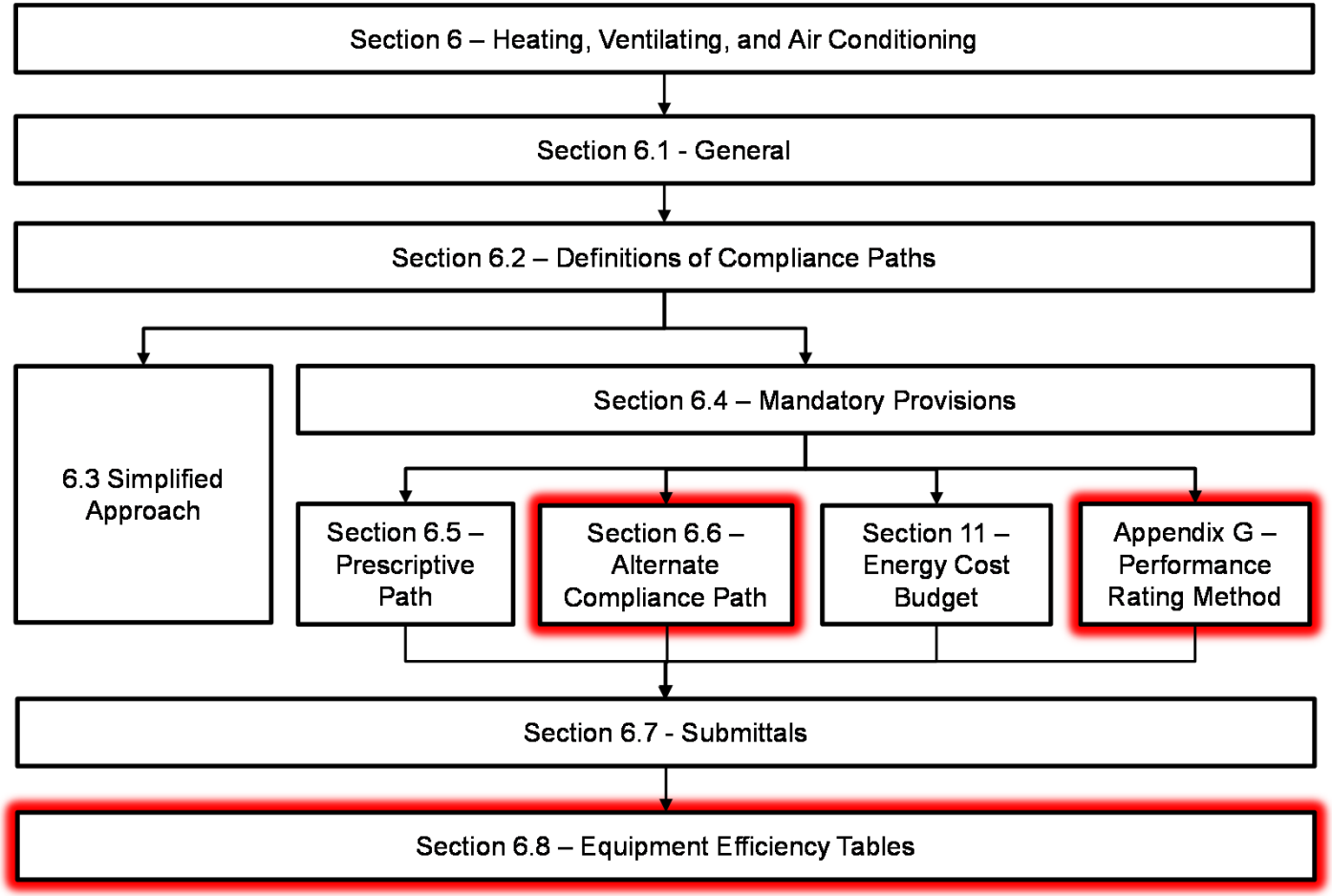
Chiller Subsystem and Tool Implementation

- ASHRAE 90.1 already includes a section 6.6 for implementation of concepts like the subsystems approach and has done so for data centers and PUE



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Current ASHRAE 90.1-2016 Section 6.6

6.6 **Alternative Compliance Path**

6.6.1 Computer Rooms Systems HVAC systems serving the heating, cooling, or ventilating needs of a computer room shall comply with Sections 6.1, 6.4, 6.6.1.1 or 6.6.1.2, 6.6.1.3, 6.7, and 6.8.

6.6.1.1 The computer room PUE1 shall be less than or equal to the values listed in Table 6.6.1. Hourly simulation of the proposed design, for purposes of calculating PUE1, shall be based on the ASHRAE Standard 90.1 Appendix G simulation methodology.

Exception to Section 6.6.1.1
This compliance path is not allowed for a proposed computer room design utilizing a combined heat and power system.

6.6.1.2 The **computer room PUE0** is less than or equal to the values listed in Table 6.6.1, shall be the highest value determined at outdoor cooling design temperatures, and shall be limited to systems only utilizing electricity for an energy source. PUE0 shall be calculated for two conditions: 100% design IT equipment energy and 50% design IT equipment energy.

6.6.1.3 Documentation shall be provided, including a breakdown of energy consumption or demand by at least the following components: IT equipment, power distribution losses external to the IT equipment, HVAC systems, and lighting.

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ASHRAE 90.1 Section 6.6 PUE Metrics

Table 6.6.1 Power Usage Effectiveness (PUE) Maximum

Climate Zone	PUE[a]
0A	1.64
1A	1.61
2A	1.49
3A	1.41
4A	1.36
5A	1.36
6A	1.34
0B	1.62
1B	1.53
2B	1.45
3B	1.42
4B	1.38
5B	1.33
6B	1.33
3C	1.39
4C	1.38
5C	1.36
7	1.32
8	1.30

a. PUE_0 and PUE_1 shall not include energy for battery charging.

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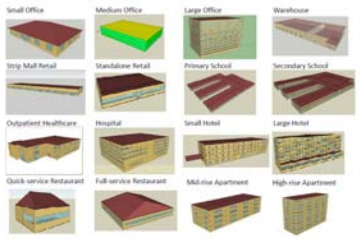
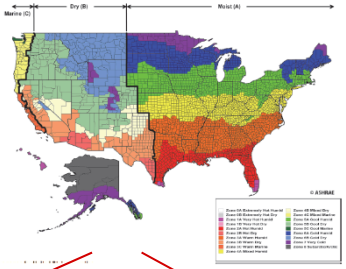
Chiller Systems Implementation Approach

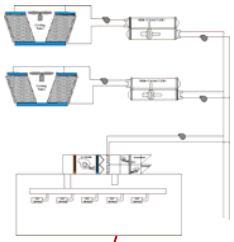
Benchmark Buildings



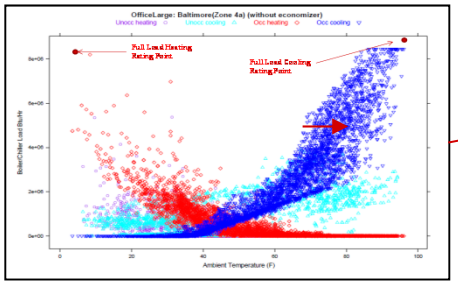
Benchmark Cities and Weather Data

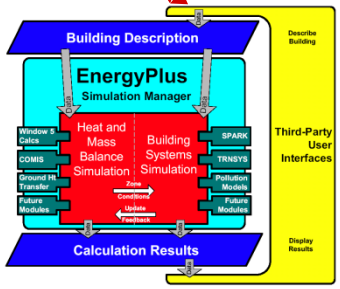


Proposed Chiller water System Design

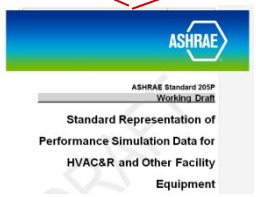


Typical Building Load Profile (pre-run and stored)

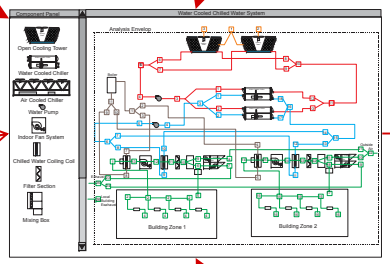




Used to pre-run Building models



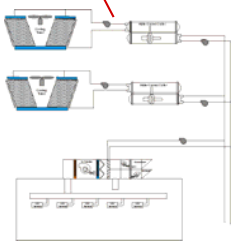
Equipment Models/Data (ASHRAE 205)



Approval

< Minimum metric established by climate zone and building and Tier

Visual Simulation Tool **(compliance tool)**



Baseline System Defined by ASHRAE 90.1

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Example AC Chiller System Level Metrics

Larger Office Building Cooling Example

- The following example shows what the targets might look like for a typical large office building using an air cooled chiller including pumps, and air handler power as well as economizer
- Concept is to use the ratio of the proposed annual efficiency relative to a baseline system metric

400 Ton Office Building with Dual Air Cooled Chillers (Cooling EER, no heating)

Zone	CITY	OPERATING HRS		ECONOMIZER	ANNUAL BUIDLING LOAD	HVAC SYSTEM POWER	HVAC SYSTEM ANNUAL EER
		COOLING	MECHANICAL				
		hrs	hrs	-	Tons	Mw-hrs	Btu/watt
		1	2	3		4	
1A	Miami	5878	5878	no	872461.7	1287.0	8.13
1B	Riyadh	6859	6859	no	762687.6	1503.8	6.09
2A	Houston	5336	4262	yes	684886.9	954.0	8.61
2B	Phoenix	5887	4593	yes	492643.4	856.8	6.90
3A	Memphis	5147	3420	yes	531100.1	724.3	8.80
3B	El Paso	5404	3538	yes	652380.0	909.7	8.61
3C	San Francisco	5014	1853	yes	342041.5	284.6	14.42
4A	Baltimore	4785	2464	yes	386684.1	482.4	9.62
4B	Albuquerque	5138	2502	yes	482625.2	660.8	8.76
4C	Salem	4659	1675	yes	319272.2	323.9	11.83
5A	Chicago	4586	1918	yes	341031.3	399.1	10.25
5B	Boise	4821	1862	yes	403843.9	486.0	9.97
5C	Vancouver	4614	1203	yes	319515.7	228.0	16.82
6A	Burlington	4420	1683	yes	294689.9	306.0	11.56
6B	Helena	4801	1373	yes	442209.4	479.9	11.06
7	Duluth	4443	1122	yes	268881.6	221.2	14.59
8	Fairbanks	4016	803	yes	232382.0	144.3	19.33

Base 200 Ton AC Chiller has an 11.1 EER and 14.0 IPLV

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Efficiency Standard & Guideline Minimum

Concept would be to set relative energy use metrics relative to a fixed established baseline by climate zone and building type using benchmark buildings and cities

Standard Efficiency Table - Tier 1 (ASHRAE 90.1)

Building Type	Climate Zone Annual Efficiency Ratio vs Baseline System																
	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Small Office	0.95	0.93	0.92	0.92	0.90	0.89	0.89	0.87	0.87	0.87	0.86	0.86	0.86	0.84	0.84	0.81	0.81
Medium Office	0.90	0.88	0.87	0.87	0.86	0.85	0.85	0.83	0.83	0.83	0.82	0.82	0.82	0.80	0.80	0.77	0.77
Large Office	0.86	0.84	0.83	0.83	0.81	0.80	0.80	0.79	0.79	0.79	0.78	0.78	0.78	0.76	0.76	0.73	0.73
Warehouse	0.97	0.95	0.94	0.94	0.92	0.91	0.91	0.89	0.89	0.89	0.88	0.88	0.88	0.86	0.86	0.83	0.83
Strip Mall	0.90	0.88	0.87	0.87	0.86	0.85	0.85	0.83	0.83	0.83	0.82	0.82	0.82	0.80	0.80	0.77	0.77
Standalone Retail	0.94	0.92	0.91	0.91	0.89	0.88	0.88	0.86	0.86	0.86	0.85	0.85	0.85	0.83	0.83	0.80	0.80
Primary School	0.84	0.82	0.81	0.81	0.79	0.78	0.78	0.77	0.77	0.77	0.76	0.76	0.76	0.74	0.74	0.71	0.71
Secondary School	0.84	0.82	0.81	0.81	0.79	0.78	0.78	0.77	0.77	0.77	0.76	0.76	0.76	0.74	0.74	0.71	0.71
Outpatient Healthcare	0.74	0.72	0.72	0.72	0.70	0.69	0.69	0.68	0.68	0.68	0.67	0.67	0.67	0.65	0.65	0.63	0.63
Hospital	0.67	0.65	0.65	0.65	0.63	0.62	0.62	0.61	0.61	0.61	0.60	0.60	0.60	0.59	0.59	0.57	0.57
Small Hotel	0.86	0.84	0.83	0.83	0.81	0.80	0.80	0.79	0.79	0.79	0.78	0.78	0.78	0.76	0.76	0.73	0.73
Large Hotel	0.86	0.84	0.83	0.83	0.81	0.80	0.80	0.79	0.79	0.79	0.78	0.78	0.78	0.76	0.76	0.73	0.73
Quick Serve Restaurant	0.74	0.72	0.72	0.72	0.70	0.69	0.69	0.68	0.68	0.68	0.67	0.67	0.67	0.65	0.65	0.63	0.63
Full Service Restaurant	0.74	0.72	0.72	0.72	0.70	0.69	0.69	0.68	0.68	0.68	0.67	0.67	0.67	0.65	0.65	0.63	0.63
Mid-Rise Apartment	0.90	0.88	0.87	0.87	0.86	0.85	0.85	0.83	0.83	0.83	0.82	0.82	0.82	0.80	0.80	0.77	0.77
High Rise Apartment	0.86	0.84	0.83	0.83	0.81	0.80	0.80	0.79	0.79	0.79	0.78	0.78	0.78	0.76	0.76	0.73	0.73
Data Center	0.60	0.59	0.58	0.58	0.57	0.56	0.56	0.55	0.55	0.55	0.54	0.54	0.54	0.53	0.53	0.51	0.51
Public Assembly	0.86	0.84	0.83	0.83	0.81	0.80	0.80	0.79	0.79	0.79	0.78	0.78	0.78	0.76	0.76	0.73	0.73

The above numbers are only examples but the concept would be to fix the baseline and then as technology advances revise the tables for new targets for minimum as well as higher tier rebate levels

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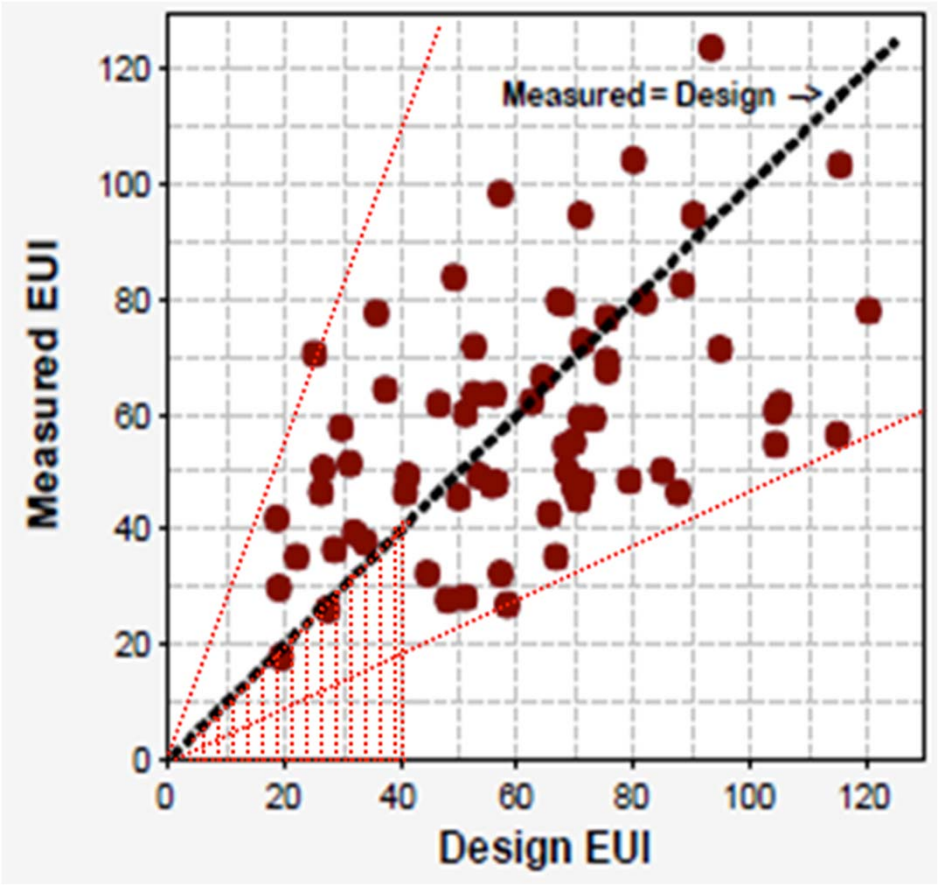
Why not Use Absolute Energy Use

- Studies have been conducted by ASHRAE, National Labs and standards like CSA 873
- The curve to the right shows the results of a study conducted to compare modeled total building energy vs measured energy
- This is why all standards do not attempt to predict absolute energy and instead use a baseline building as defined by standards like ASHRAE appendix G
- But there are some that are proposing EUI metrics



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New ASHRAE 90.1 Appendix G Whole Building Metrics

TABLE 4.2.1.1 Building Performance Factor (BPF)

Building Area Type[a]	Climate Zone																
	0A and 1A	0B and 1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Multifamily	0.73	0.73	0.71	0.69	0.74	0.73	0.68	0.78	0.81	0.81	0.76	0.80	0.81	0.76	0.79	0.74	0.80
Healthcare/ hospital	0.64	0.56	0.60	0.56	0.60	0.56	0.54	0.57	0.53	0.55	0.59	0.52	0.55	0.57	0.52	0.56	0.56
Hotel/motel	0.64	0.65	0.62	0.60	0.63	0.65	0.64	0.62	0.64	0.62	0.60	0.61	0.60	0.59	0.61	0.57	0.58
Office	0.58	0.62	0.57	0.62	0.60	0.64	0.54	0.58	0.60	0.58	0.60	0.61	0.58	0.61	0.61	0.57	0.61
Restaurant	0.62	0.62	0.58	0.61	0.60	0.60	0.61	0.58	0.55	0.60	0.62	0.58	0.60	0.63	0.60	0.65	0.68
Retail	0.52	0.58	0.53	0.58	0.54	0.62	0.60	0.55	0.60	0.60	0.55	0.59	0.61	0.55	0.58	0.53	0.53
School	0.46	0.53	0.47	0.53	0.49	0.52	0.50	0.49	0.50	0.49	0.50	0.50	0.50	0.49	0.50	0.47	0.51
Warehouse	0.51	0.52	0.56	0.58	0.57	0.59	0.63	0.58	0.60	0.63	0.60	0.61	0.65	0.66	0.66	0.67	0.67
All others	0.62	0.61	0.55	0.57	0.56	0.61	0.59	0.58	0.57	0.61	0.57	0.57	0.61	0.56	0.56	0.53	0.52

a. In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply

Note this is a total building metric and is based on a baseline of ASHRAE 2004

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Connected Equipment Consideration

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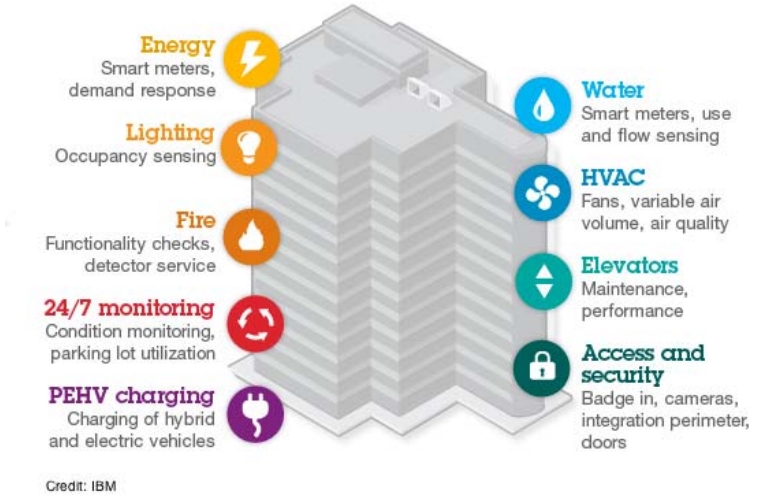
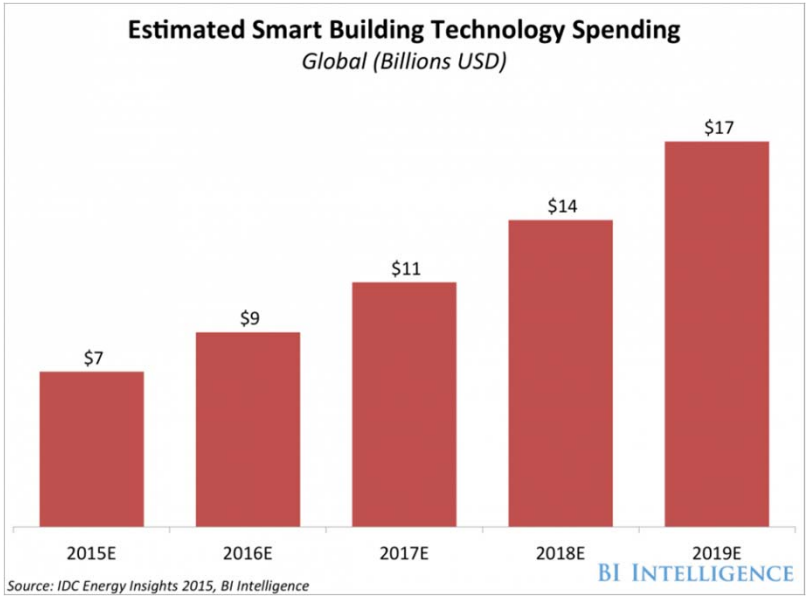
System Efficiency Metric Credits

- Current standards as well as CEE guidelines assume that all equipment works properly and is properly commissioned and maintained
- But we know this is not the case and it varies based on the equipment, commissioning, owner, service and if the equipment in monitored
- With connected equipment and buildings there are new opportunities to insure high performance buildings and equipment maintenance
- Some energy standards are now starting to explore this and offer credits to efficiency metrics for connected equipment, commissioning, monitoring and peak load management and we see this as a possible factor that could be added to the previous tables to enable and encourage their use





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FDD & Connected Credit Examples

The following is a very preliminary Title 24 proposal of some credits to efficiency metrics for FDD and there are others being considered for peak load and connected equipment

Four Proposed Compliance Options that can be Modeled in CBECC-RES

Case	EER Multiplier	Notes
No refrigerant charge	90%	Prescriptive CZ 1, 3-7, 16
FDD	94%	CZ 1, 3-7, 16 only
Refrigerant charge OR Temperature split OR Weigh-in method	96%	Prescriptive CZ 2, 8-15
FID OR FDD & refrigerant charge or FDD & temperature split	98%	All CZ's

CALIFORNIA ENERGY CODES & STANDARDS
A STATEWIDE UTILITY PROGRAM

DRAFT

4

FDD = fault detection device
FID = fault indication device

Also in EnergyStar they now give a 5% credit in efficiency for a connected unit

Table 4: Connected Allowance**

Product Type	CEERAdder_Connected[2]
All RAC types covered in Tables 1, 2 and 3[1]	0.05 x CEERBASE

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Summary and Next Step

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Summary and Next Step

- The focus is on a chilled water system implementation thru ASHRAE 90.1 as these products are at close to “max tech” and there is interest from ASHRAE 90.1
- This could also align with our discussions of last year about an aligned system rebate program
- We still have a lot of work to do and is a focus this year.
  - Complete and release ASHRAE 205
  - Develop chillers models for use with ASHRAE 205
  - Define the scope of the system for a chilled water system
  - Update baseline building models and add new models
  - Develop and validate visual chilled water system modeling tool
  - Define chilled water baseline system thru ASHRE 90.1 committee
  - Define minimum efficiency metrics for chilled water system by building and climate zone
  - Validation and proof of concept
  - Develop addendum for ASHRAE 90.1 for 2019 standard
  - Next Step with CEE

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Questions and Discussion

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This concludes The American Institute of Architects
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