WHAT'S YOUR EUI?

Douglas Zentz
Emeriti Professor
Ferris State University

DL Program

- Please no commercialism
- DL Program is “special”
- Please fill out the DL forms
- Try to expand your thinking
- Feel free to ask questions

AIA Continuing Education Provider

ASHRAE is a Registered Provider with The American Institute of Architects Continuing Education Systems. Credit earned on completion of this program will be reported to CES Records for AIA members. Certificates of Completion for non-AIA members are available on request.

This program is registered with the AIA/CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product. Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

EDUCATION PARTNER

What's Your EUI?

By Douglas F Zentz

GBCI cannot guarantee that course sessions will be delivered to you as submitted to GBCI. However, any course found to be in violation of the standards of the program, or otherwise contrary to the mission of GBCI, shall be removed. Your course evaluations will help us uphold these standards.

Course ID:

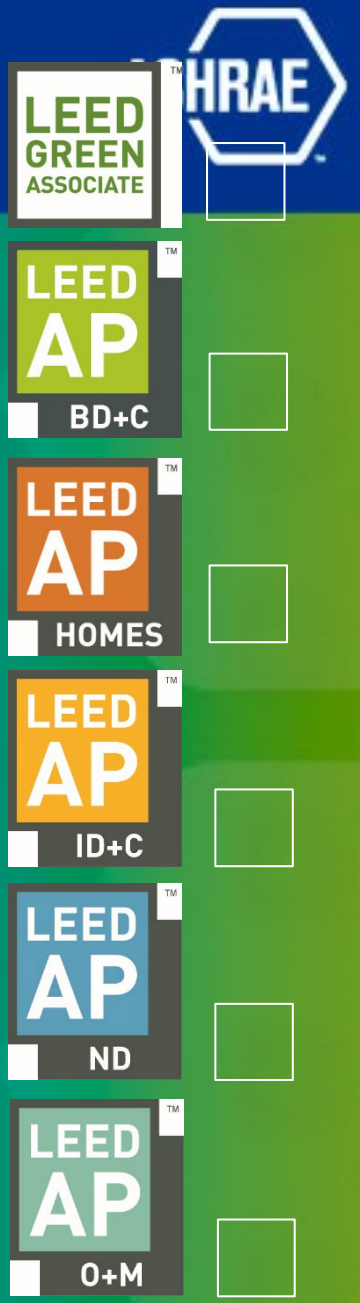
Approved for:

1

General CE hours

1

LEED-specific hours



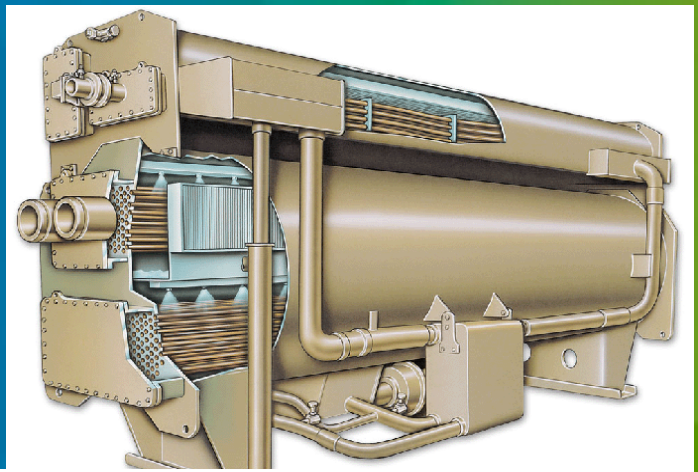
Efficiency?

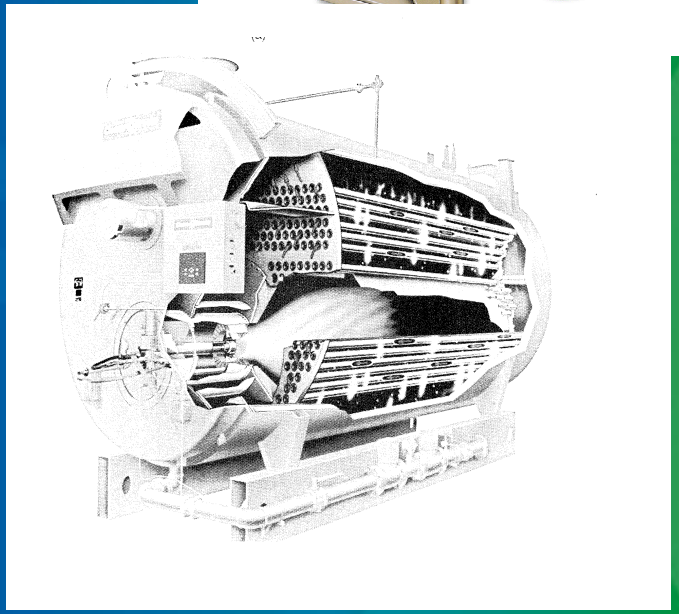
- What's the most common measurement?

- Transportation - MPG

What About HVAC?

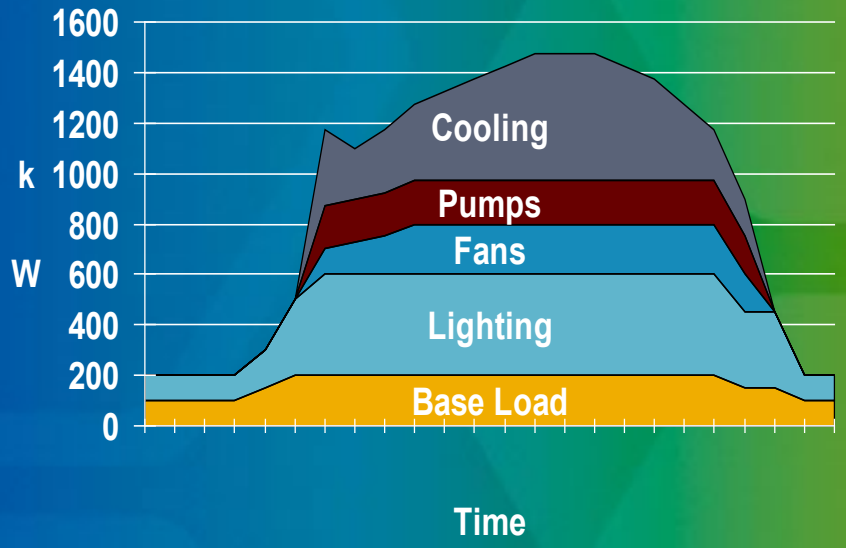
- **We have many measurements!**
  - COP
  - EER
  - kW/ton
  - Percent Efficient





Design vs. Actual

- Design
  - Full load conditions
- Actual
  - Seasonal conditions
  - Part-load ratings
  - Other than design condition
- Building Owner



Commercial Buildings

- What's the means for measurement?
- What's the Benchmark?
- How is this related to Energy Codes?
- How will this effect building owners?
- What is the future?

What's the Means of Measurement

Energy Usage Index

- S------ and Associates
  - Energy Auditing Firm – Ohio

- Using data obtained from your utility bills, usage is expressed in British Thermal Units (BTU) to compare energy consumption from year to year to similar building types or to track consumption from year to year in the same building.

Energy Intensity Index

- U.S. Department of Energy
  - www1.eere.energy.gov/ba/pba/intensityindicators/total_commercial.html
  - Measured from a Baseline level of annual energy consumption - kBtus/ft^2

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Planning, Budget, & Analysis

Energy Utilization Index

- The Blank (government) Astrophysics Data System
  - Method for predicting building annual energy use
  - Measured in Btu/sf-yr
- Public Schools (western state)
  - SB1149 provides funding for public school annual energy savings measured in Btu/sf-yr

Energy Use Intensity

- Energy Star –
  - (www.energystar.gov/index.cfm?fuseaction=buildingcontest.eui)
  - Measured in annual kBtus per square foot of building area
- ASHRAE
  - Measured in kBtus/ft^2 (MJ/m^2) of annual energy consumption

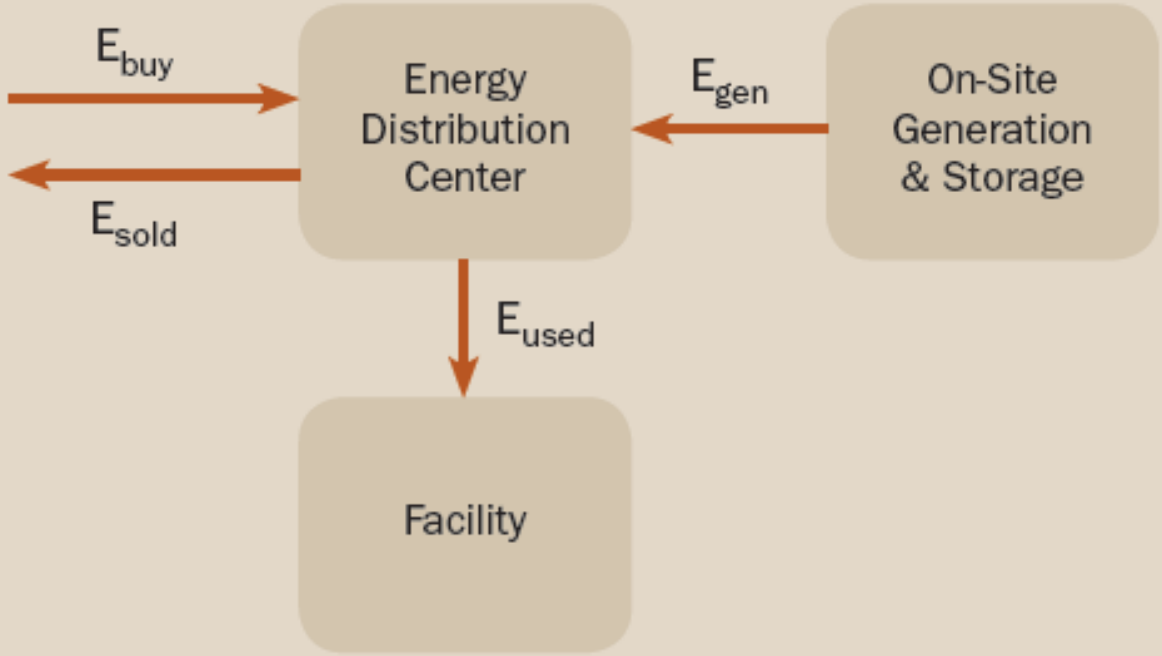
Common Definition

THE COMMON DEFINITION
OF BUILDING EUI IS:

$$\frac{\text{Annual Building Energy Use (kBtus or MJ)}}{\text{Building Area } (\text{ft}^2 \text{ or } \text{m}^2)} = \text{EUI}$$

Net Energy Flow

FIGURE 1 **TOTAL AND NET ENERGY FLOWS**



$$E_{total} = E_{used} = E_{buy} + E_{gen} - E_{sold}$$

$$E_{net} = E_{buy} - E_{sold}$$

Factors Influencing EUI

- Energized Systems
- Non-Energized Systems
- Human Systems

Energized Systems

- HVAC systems
- Lighting systems
- Domestic water heating systems
- People moving systems
- Cooking systems
- Data and communication systems
- Building emergency systems
- Electrical plug loads

Non-Energized Systems

- Building shell
- Building location
- Building surroundings & site
- Mother Nature
- Utility (?)

Human Systems

- People Activity
- Densities
- Schedules
- Comfort factors (?)
- Building Owner/Manager
  - Maintenance
  - Sustainable practices

What Should You Use?

- CBECS
  - (www.eia.doe.gov/emeu/cbecs)
  - The *"Commercial Buildings Energy Consumption Survey"*
  - Done by the EIA (Energy Information Administration) every 3 or 4 years since 1979
  - Sample size is 5,000 to 7,000 buildings nationwide

Target Population

- Any building that is not residential, agricultural or manufacturing

- Exclusions from CBECS:
  - Buildings less than 1,000 square feet
  - Parking garages
  - Buildings on military bases
  - Other restricted-access buildings
  - Buildings on manufacturing facilities

2003 Survey

Form EIA-871A

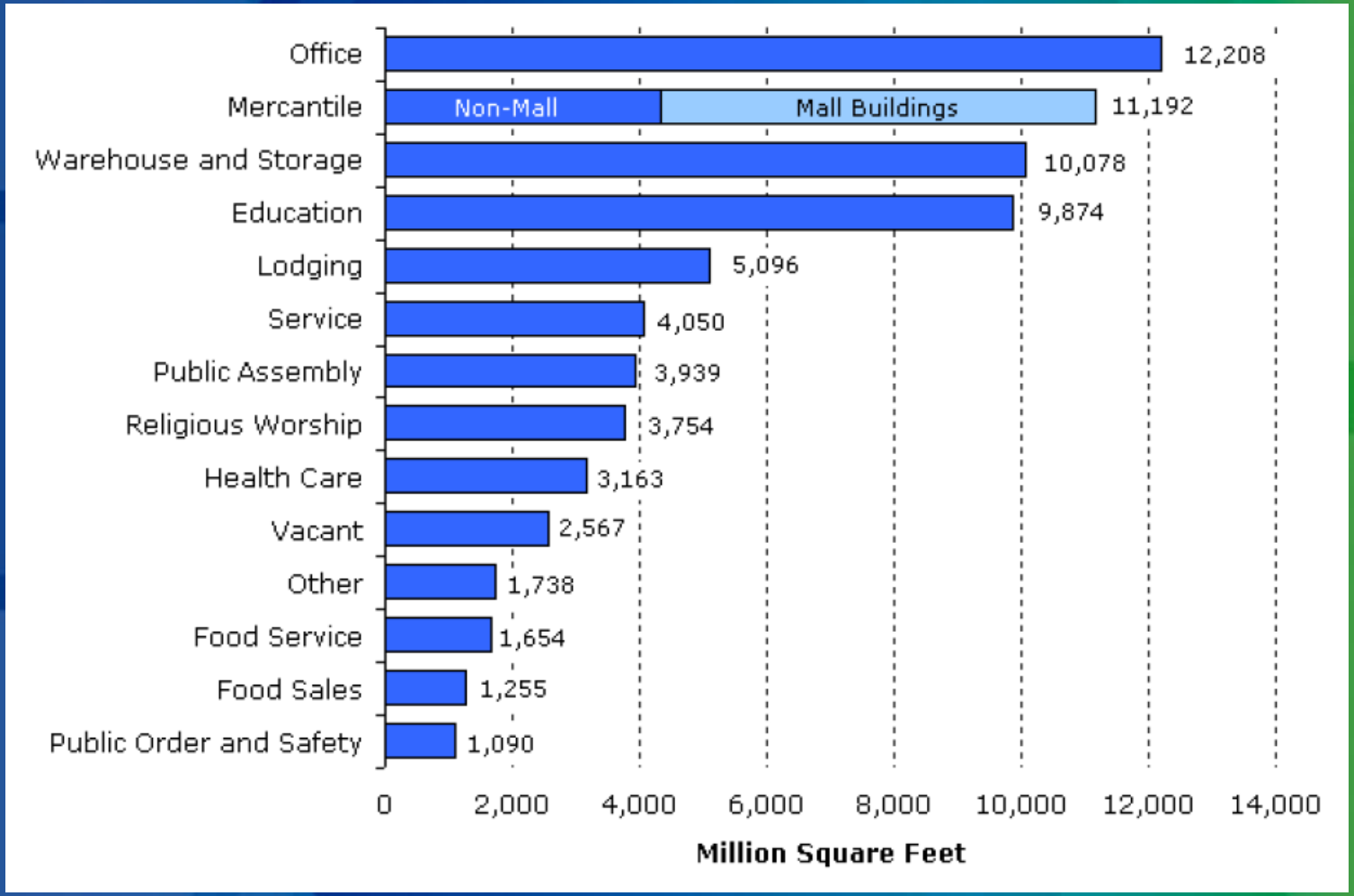
Form Approval
OMB No.: 1905-0145
Expires: 06/30/2006

U.S. Department of Energy

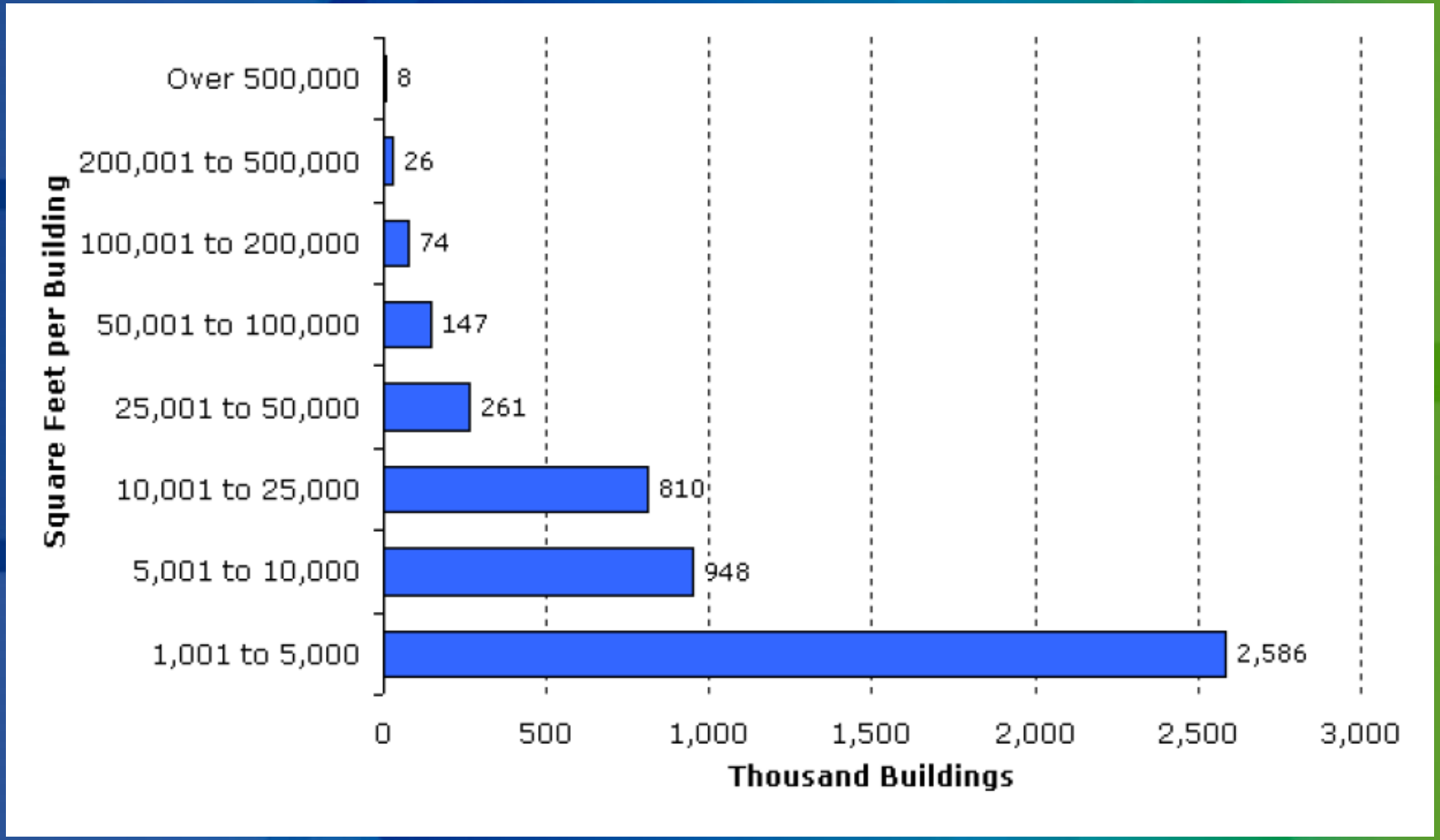
Commercial Buildings Energy Consumption Survey for 2003

BUILDING QUESTIONNAIRE

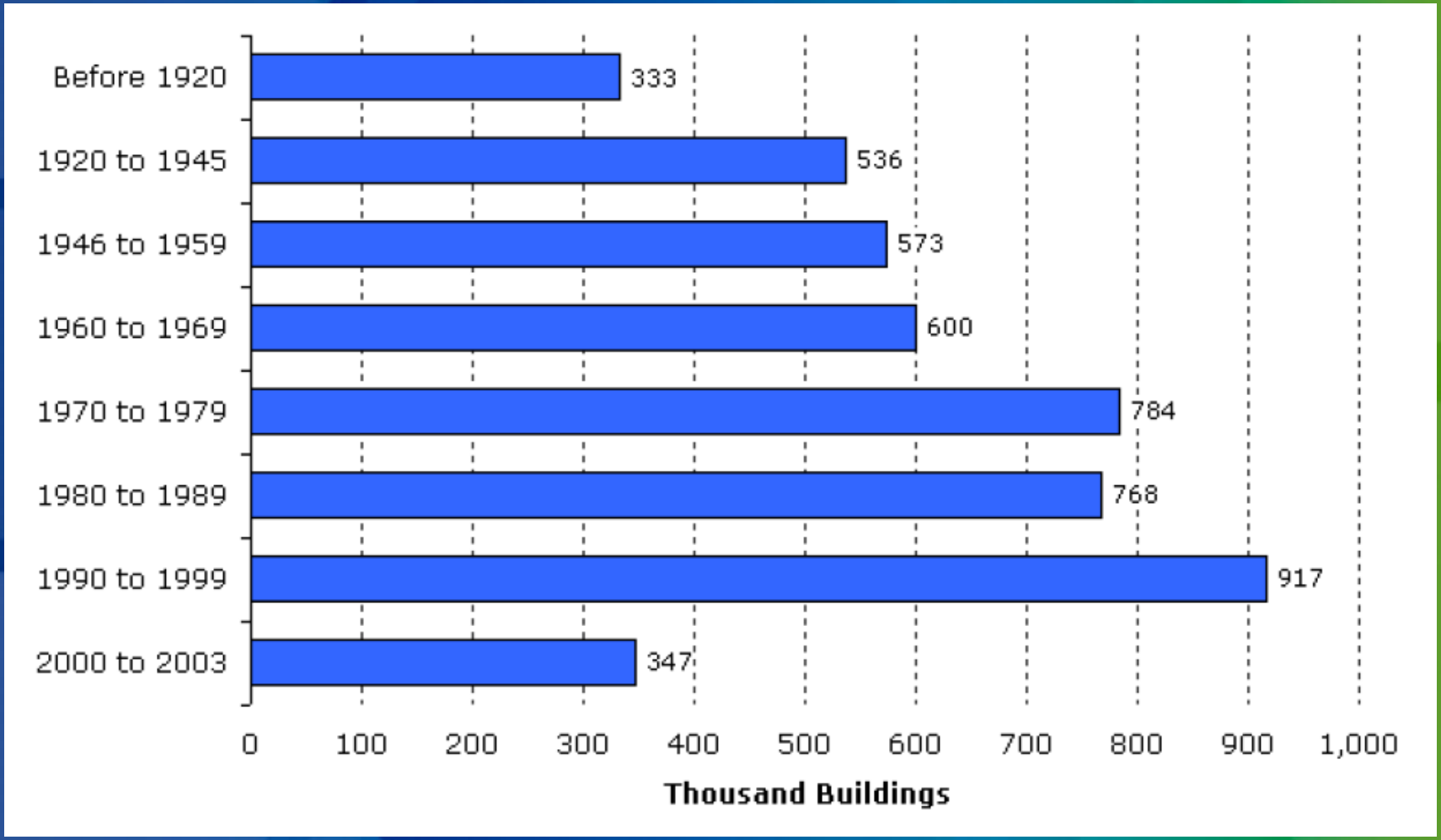
Building Types



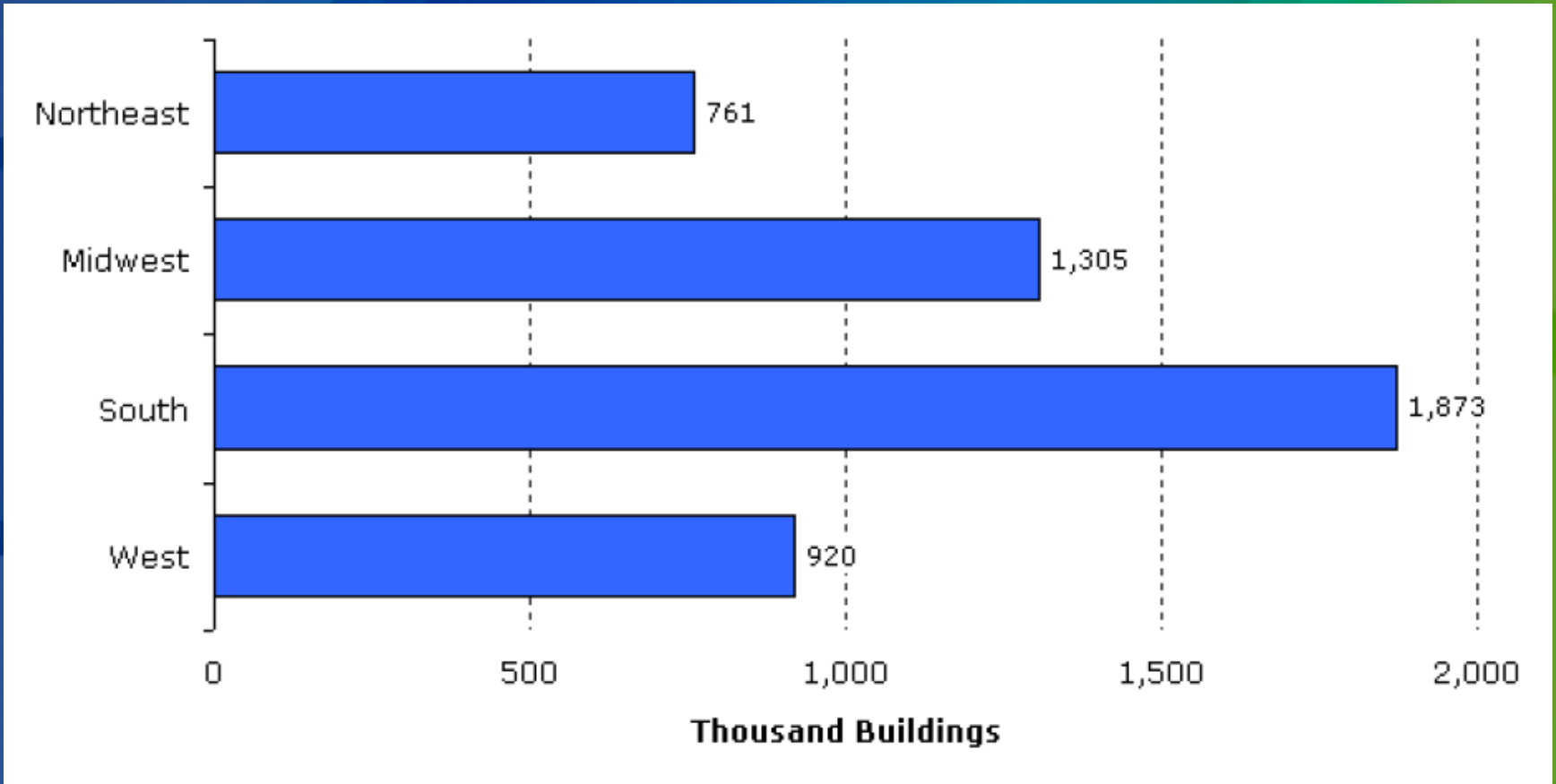
Building Sizes



Building Age



Building Locations



2003 CBECS Details

- Information can be obtained at the following:
  - http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html#enduse03
  - Total of 152 separate charts

CBECS 2003 Mean Intensities

Table 3. 2003 CBECS[6] Weighted Mean Energy Use Intensities by Subsector and Climate Zone: IP Units kBtu/ft^2-yr

Subsectors	Climate Zones														
	All	1A	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	6A	6B	7
All	90	74	72	114	89	70	62	95	108	99	104	87	89	97	71
Office/professional	93	42	82	72	88	70	58	97	143	95	107	66	110	114	68
Nonrefrigerated warehouse	42	22	16		22	21	20	39	29	37	79	60	37	58	33
Education	83	52	73	160	62	74	105	102	38	58	87	79	90	90	84
Retail (except malls)	74	61	93	129	60	50	31	65	100		88	80	93	97	102
Public assembly	94	75	60		112	48	45	110	44	249	103	97	88	102	97
Service	77	60	53		49	61	27	82	83		80	101	88	99	65
Religious worship	44		31		28	31		47	56		52	39	53	34	
Lodging	94	81	91		98	57		92	264	545	89	65	108	93	68
Food services	258	393	208		423	393	82	234		260	258	228	203	236	192
Inpatient health care	249	200	246	360	205	257	204	248	163		294	245	240	235	256
Public order and safety	116		91		160	79		129			108	94	126	148	
Food sales	200		166		212	183	120	242			203	147	242		199
Outpatient health care	95	19	77		55	106		70	190		111	120	112	91	166
Vacant	21		4	47	4	6	0	40	3	60	21	93	22		55
Other	79		48		100	175		71	26		94	92	69	85	57
Skilled nursing	125		71		84	85		148			148	153	118	134	
Laboratory	305				242	170		600			370		268	115	
Refrigerated warehouse	99							120			68	51	62		

End User Intensities

Load Element	Office Bldg	Education	Retail	Health Care
Space Heating	32.8	39.4	24.8	91.8
Cooling	8.9	8	5.9	18.6
Ventilation	5.2	8.4	3.7	20
Water Heating	2	5.8	1.1	48.4
Lighting	23.1	11.5	25.7	40.1
Cooking	0.3	0.8	0.6	5.6
Refrigeration	2.9	1.6	5	2
Office Equipment	2.6	0.4	0.6	1.1
Computers	9	4	5.6	18.1
Other	6.1	3.4	1	3.9
Total	92.9	83.1	73.9	249.2

Consumption vs. Age

3.1.9 2003 Commercial Delivered Energy Consumption Intensities, by Principal Building Type and Vintage (1)

Building Type	Consumption (kBtu/SF) Pre-1959	1960-1989	1990-2003	Building Type	Consumption (kBtu/SF) Pre-1959	1960-1989	1990-2003
Health Care	178.1	216.0	135.7	Education	77.7	88.3	80.6
Inpatient	230.3	255.3	253.8	Service	62.4	86.0	74.8
Outpatient	91.6	110.4	84.4	Food Service	145.2	290.1	361.2
Food Sales	205.8	197.6	198.3	Religious Worship	46.6	39.9	43.3
Lodging	88.2	111.5	88.1	Public Order & Safety	N.A.	101.3	110.6
Office	93.6	94.4	88.0	Warehouse & Storage	N.A.	38.9	33.3
Mercantile	80.4	91.8	94.4	Public Assembly	61.9	107.6	119.7
Retail (Non-Malls)	74.1	63.7	86.4	Vacant	21.4	23.1	N.A.
Retail (Malls)	N.A.	103.9	99.5	Other	161.3	204.9	125.3

Note(s): 1) See Table 3.1.3 for primary versus delivered energy consumption.

Source(s): EIA, 2003 Commercial Buildings Energy Consumption and Expenditures: Consumption and Expenditures Tables, Oct. 2006, Table C12a.

Energy Independence and Security Act of 2007

- Title IV – Energy Savings in Buildings and industry, Subtitle C – High Performance Buildings, Sec. 433 – Federal Building Energy Efficiency Performance Standards

- Mandatory Energy Savings from 2003 baseline
  - **2010 – 55%**
  - **2015 – 65%**
  - **2020 – 80%**
  - **2025 – 90%**
  - **2030 – 100%**

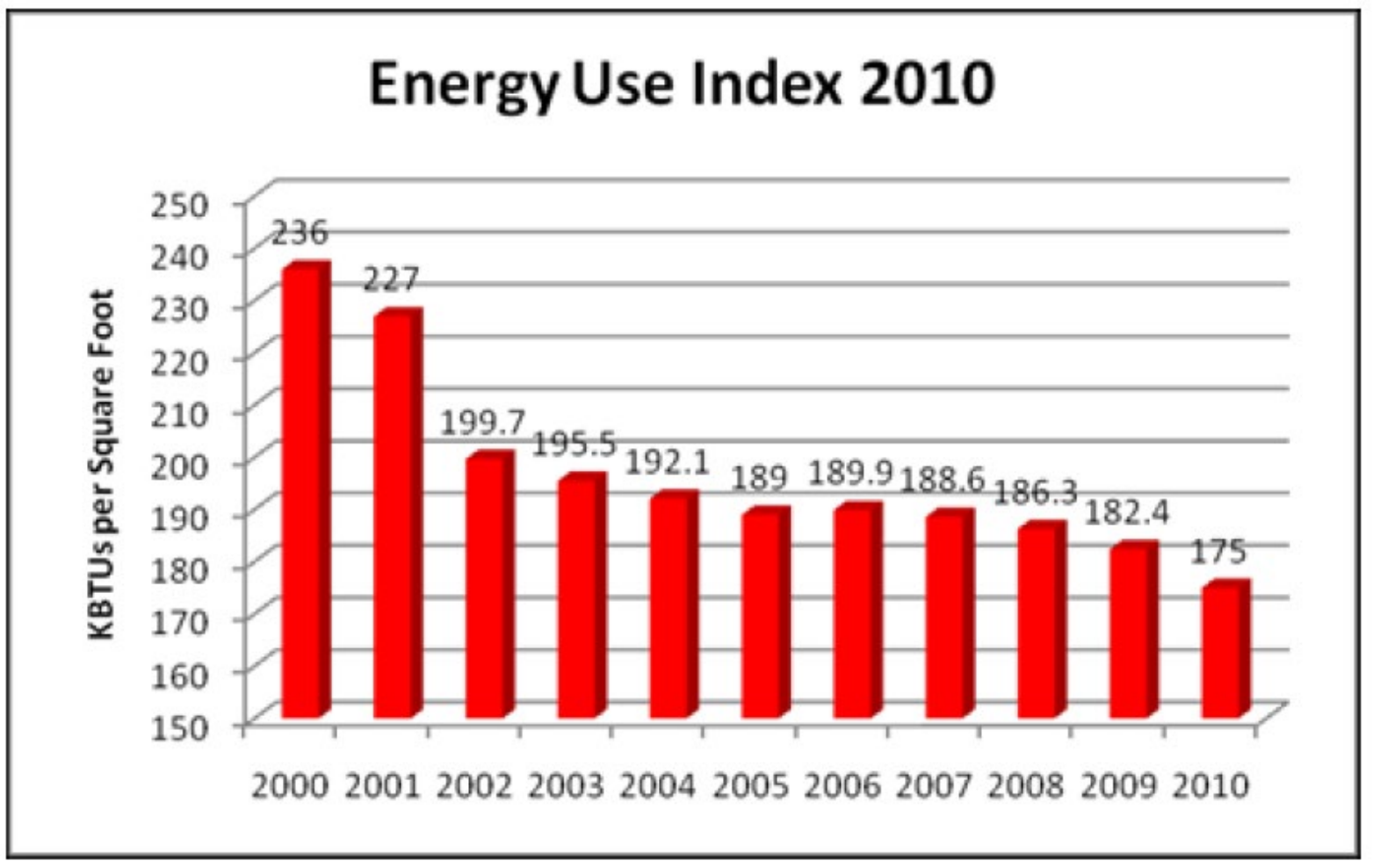
New Federal Construction Benchmarks

City	Miami	Houston	Phoenix	Atlanta	Los Angeles	Las Vegas	San Francisco	Baltimore	Albuquerque	Seattle	Chicago	Denver	Minneapolis	Helena	Duluth	Fairbanks
Climate Zone	1A	2A	2b	3A	3B	3B	3C	4A	4B	4C	5A	5B	6A	6B	7	8
Large Office	38	40	38	38	32	34	35	40	34	37	43	36	46	40	47	39
Medium Office	39	42	40	41	33	37	38	45	38	42	48	41	54	48	57	77
Small Office	44	44	43	41	33	39	35	46	41	42	51	45	57	51	61	83
Warehouse	30	19	19	18	14	18	15	21	20	18	24	23	29	27	33	52
Stand-alone Retail	62	63	60	61	44	56	50	72	61	65	81	69	93	83	104	145
Strip Mall	56	58	57	62	44	57	53	74	64	69	85	72	99	89	111	156
Primary School	57	57	55	55	46	52	51	61	54	54	65	58	75	66	79	113
Secondary School	56	57	55	57	42	54	50	68	58	61	76	64	89	77	97	141
Supermarket	158	167	159	170	153	158	166	184	168	181	195	179	208	197	223	266
Quick Service Restaurant	535	549	538	561	496	541	524	609	567	575	657	604	713	663	765	949
Full Service Restaurant	404	423	409	440	374	418	415	488	447	467	527	481	570	532	617	763
Hospital	145	147	138	142	137	135	142	148	127	139	148	130	153	137	155	185
Outpatient Facility	280	279	278	274	254	277	241	278	274	247	271	271	280	275	279	324
Small Hotel	71	71	69	71	62	68	64	75	70	69	80	74	87	80	92	112
Large Hotel	99	108	100	116	105	105	113	127	119	124	138	131	150	144	163	196
Mid-Rise Apartment	39	39	38	38	31	36	33	42	37	38	47	41	54	48	59	76

Zone 5a Comparison

	North America		New DOE Standard	
	Kbtuh/square foot		Kbtuh/square foot	
Building Type	ALL	Zone 5a	ALL	Zone 5a
All (average)	90	104	-	-
Office	93	107	50	43
Education	83	87	70	76
Retail	74	88	73	81
Lodging	94	89	85	80
Health Care	249	294	150	148

Campus Consumption

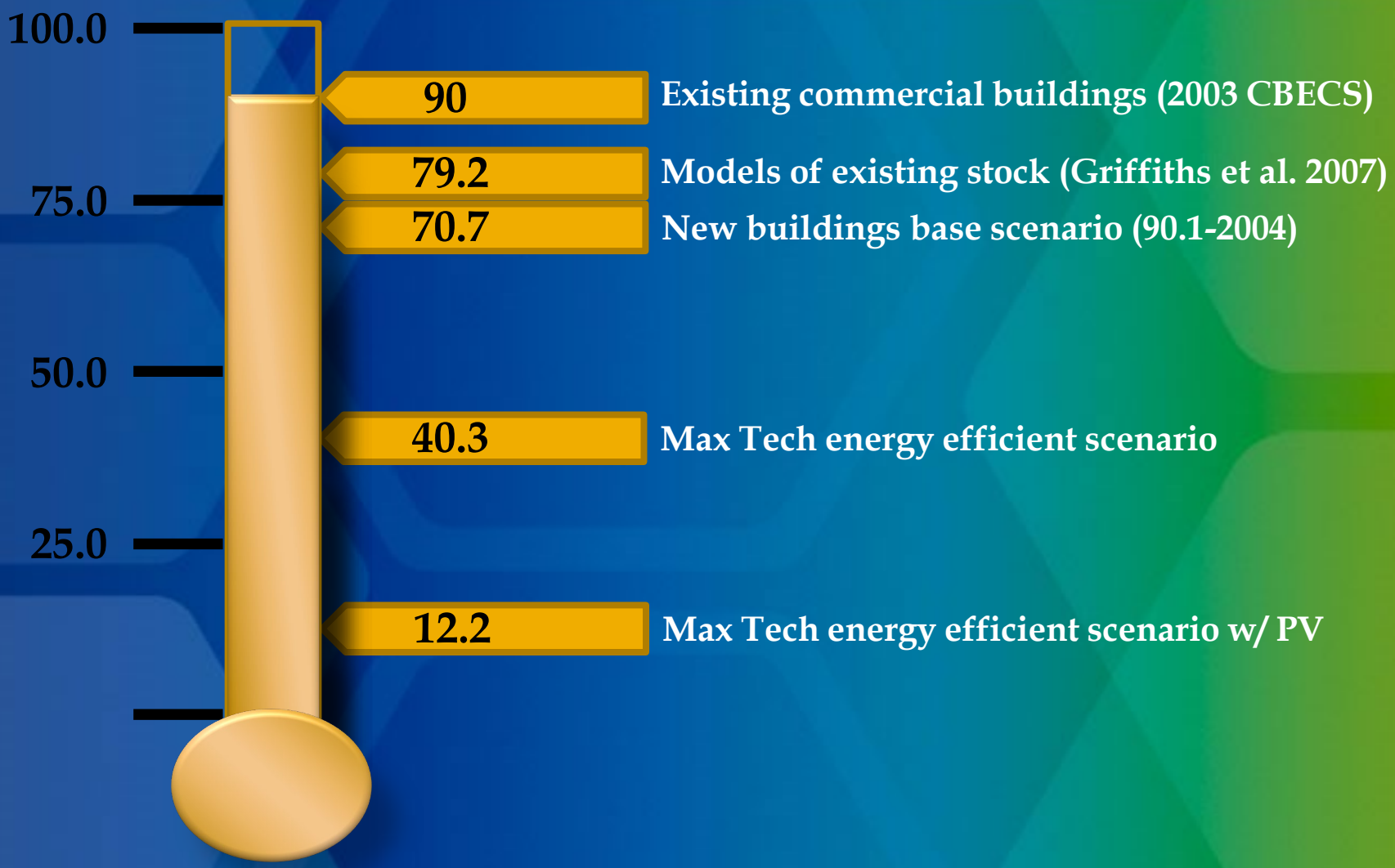


Public Schools

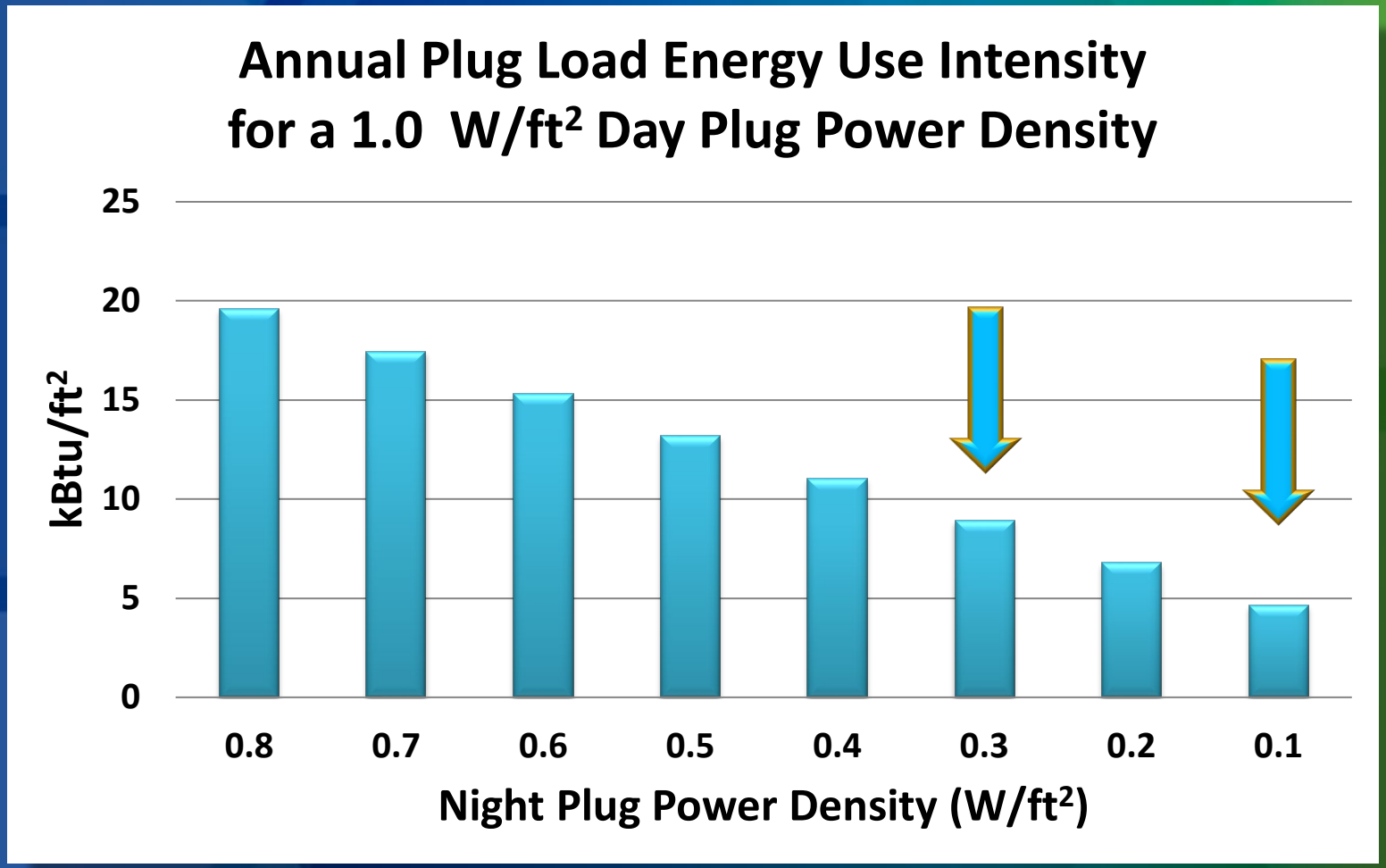
- SB1149 School Program

Region	School Type	Target Range	Typical Operating Hours
Western	Elementary School	37,800 - 43,200 Btu/sf-yr	2,400 Hours
	Middle School	39,900 - 45,600 Btu/sf-yr	2,600 Hours
	High School	44,800 - 51,200 Btu/sf-yr	3,200 Hours
Eastern	Elementary School	47,600 - 54,400 Btu/sf-yr	2,400 Hours
	Middle School	46,900 - 53,600 Btu/sf-yr	2,600 Hours
	High School	46,900 - 53,600 Btu/sf-yr	3,200 Hours

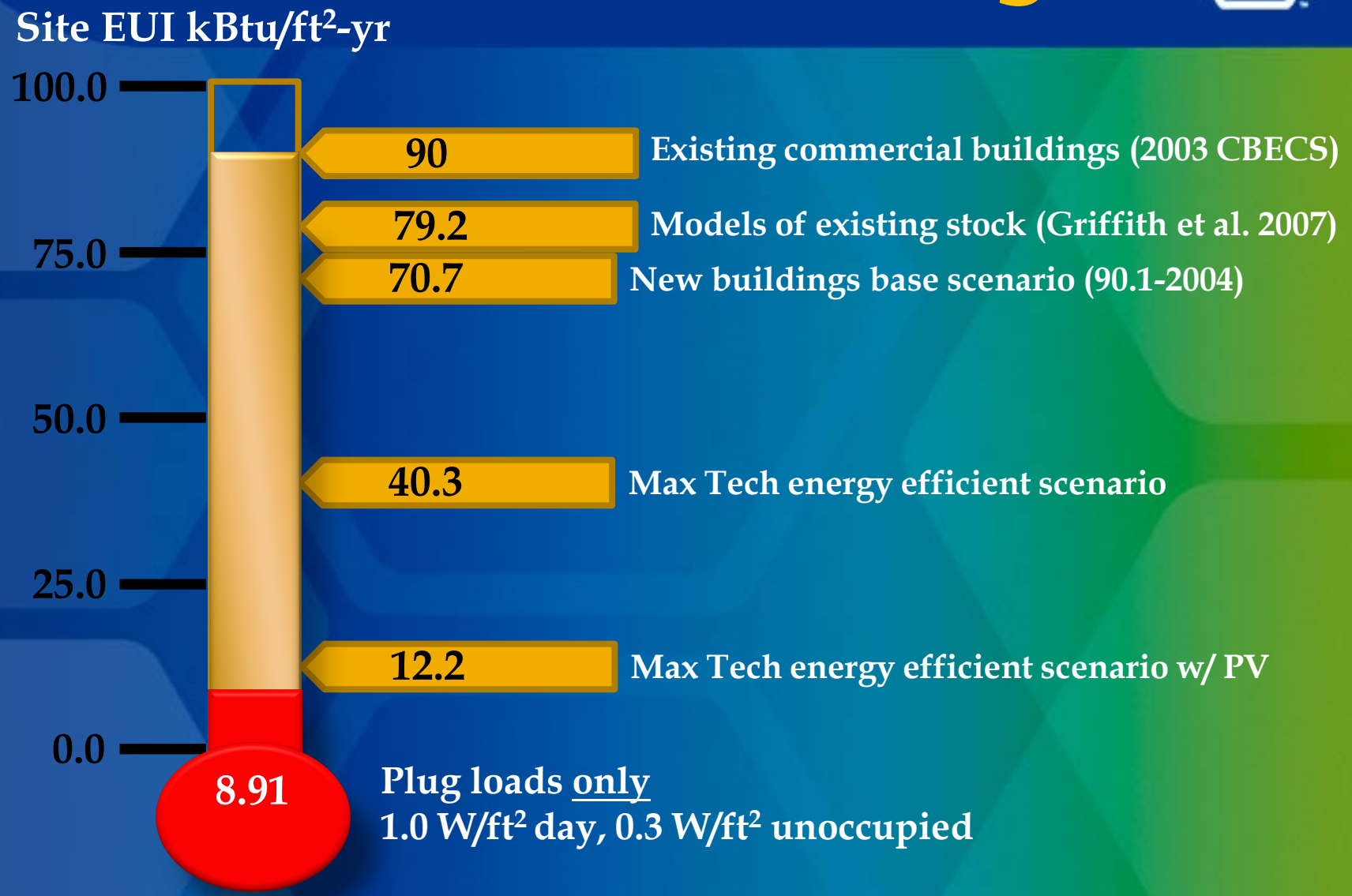
Commercial Buildings



Plug Load Energy Use

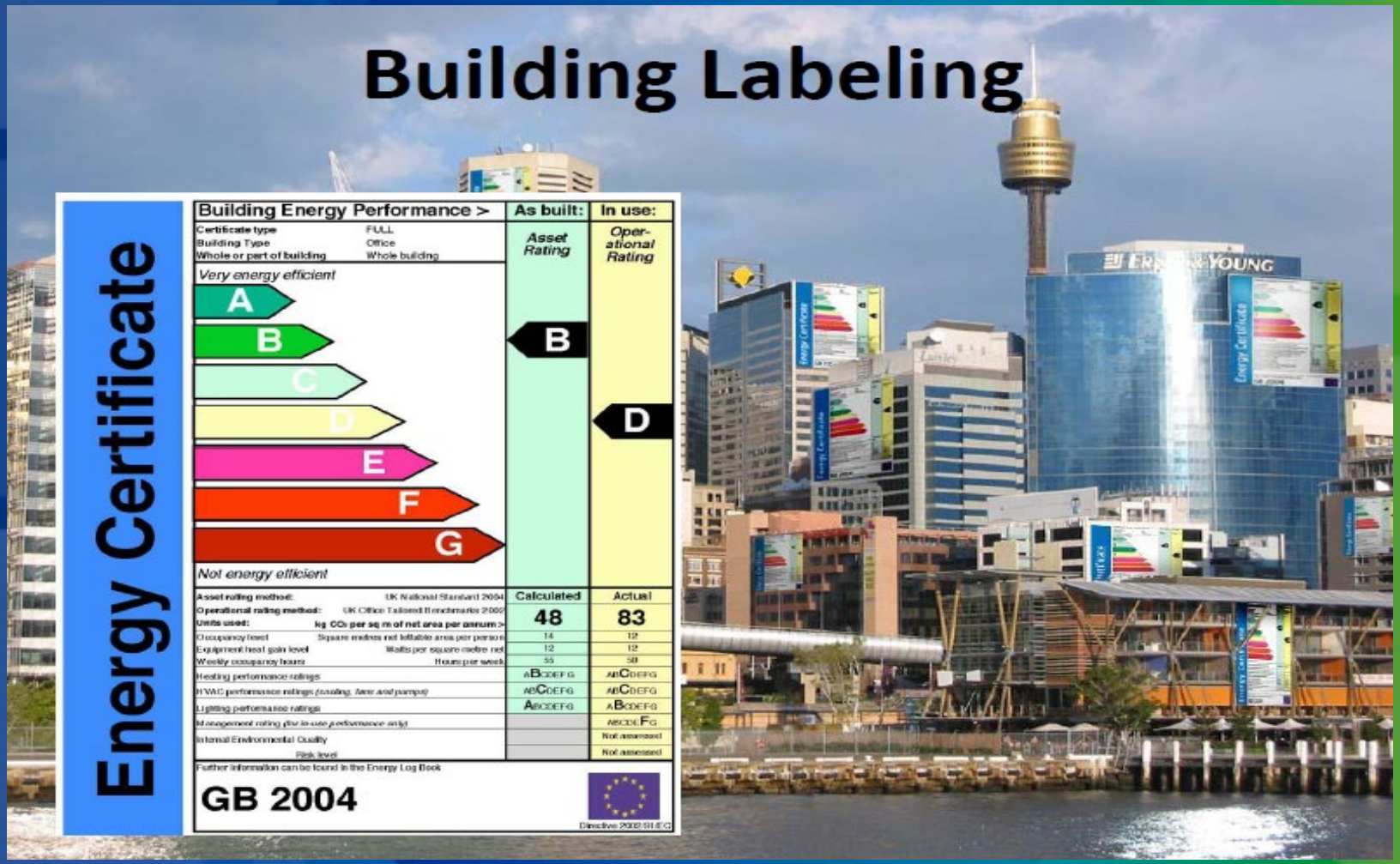


Commercial Buildings



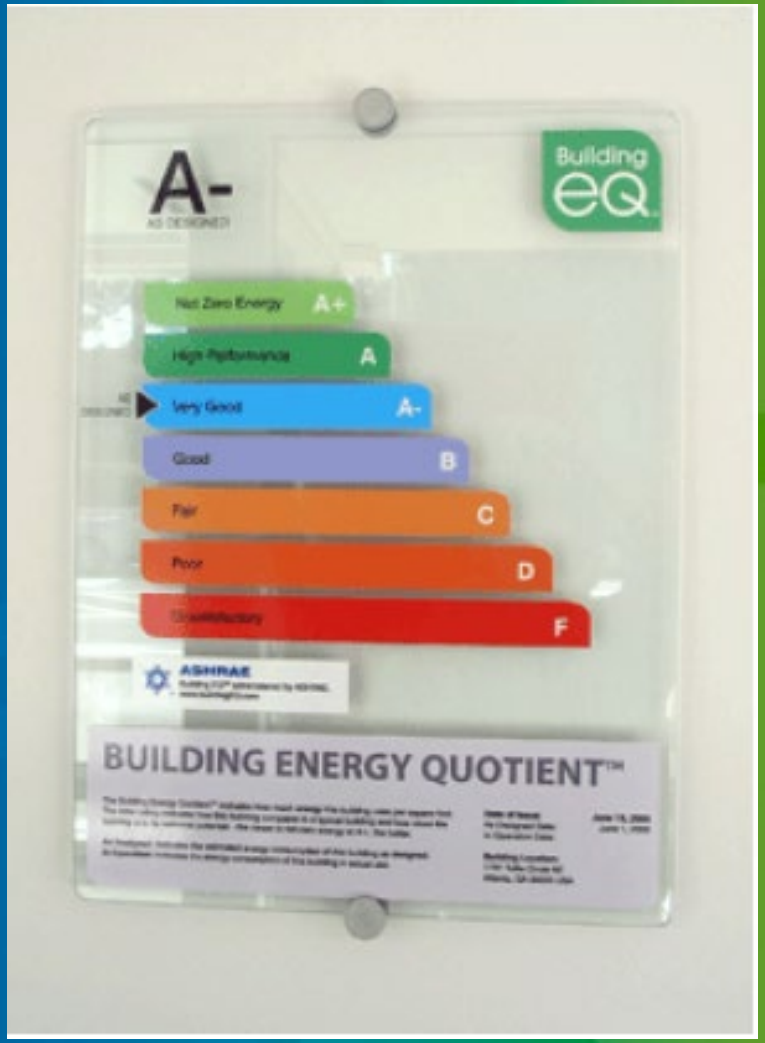
European Union

European Union Program

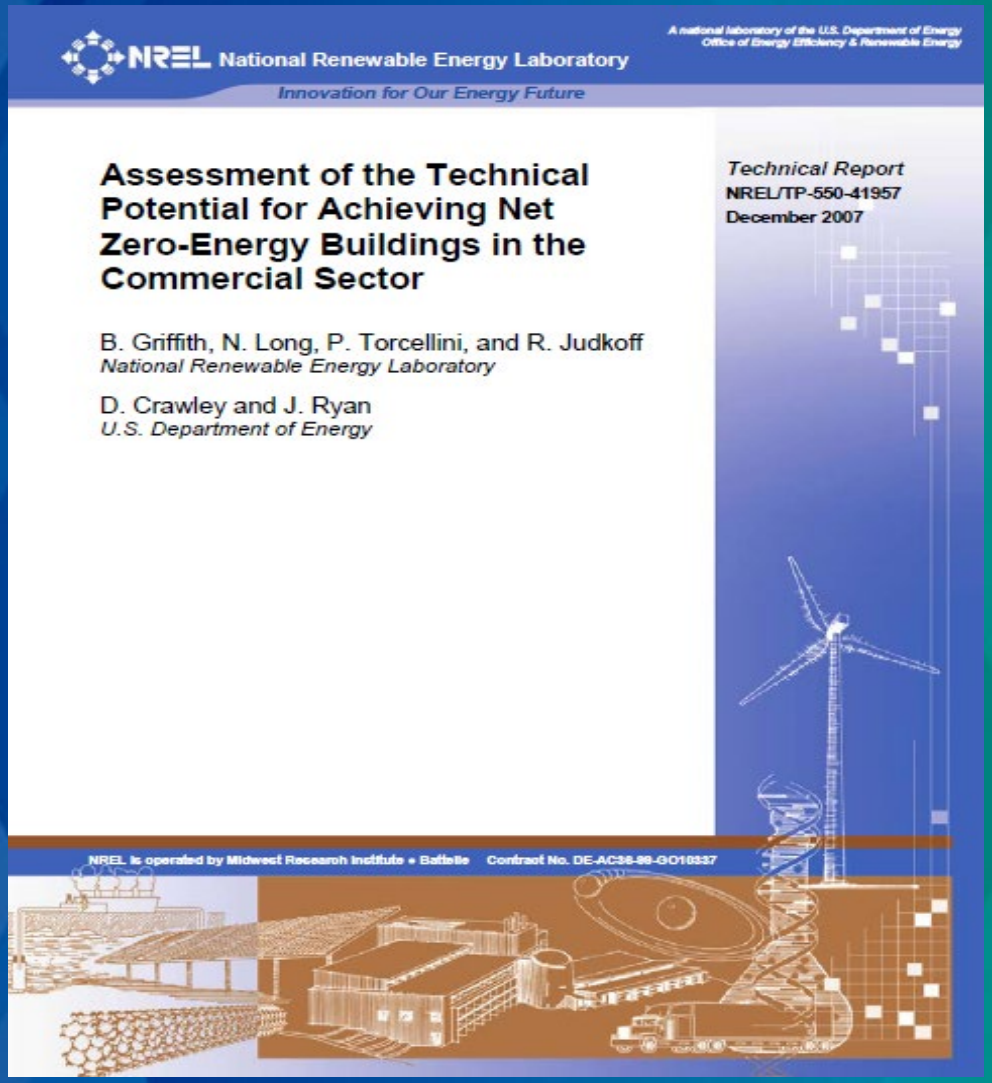


ASHRAE Building EQ

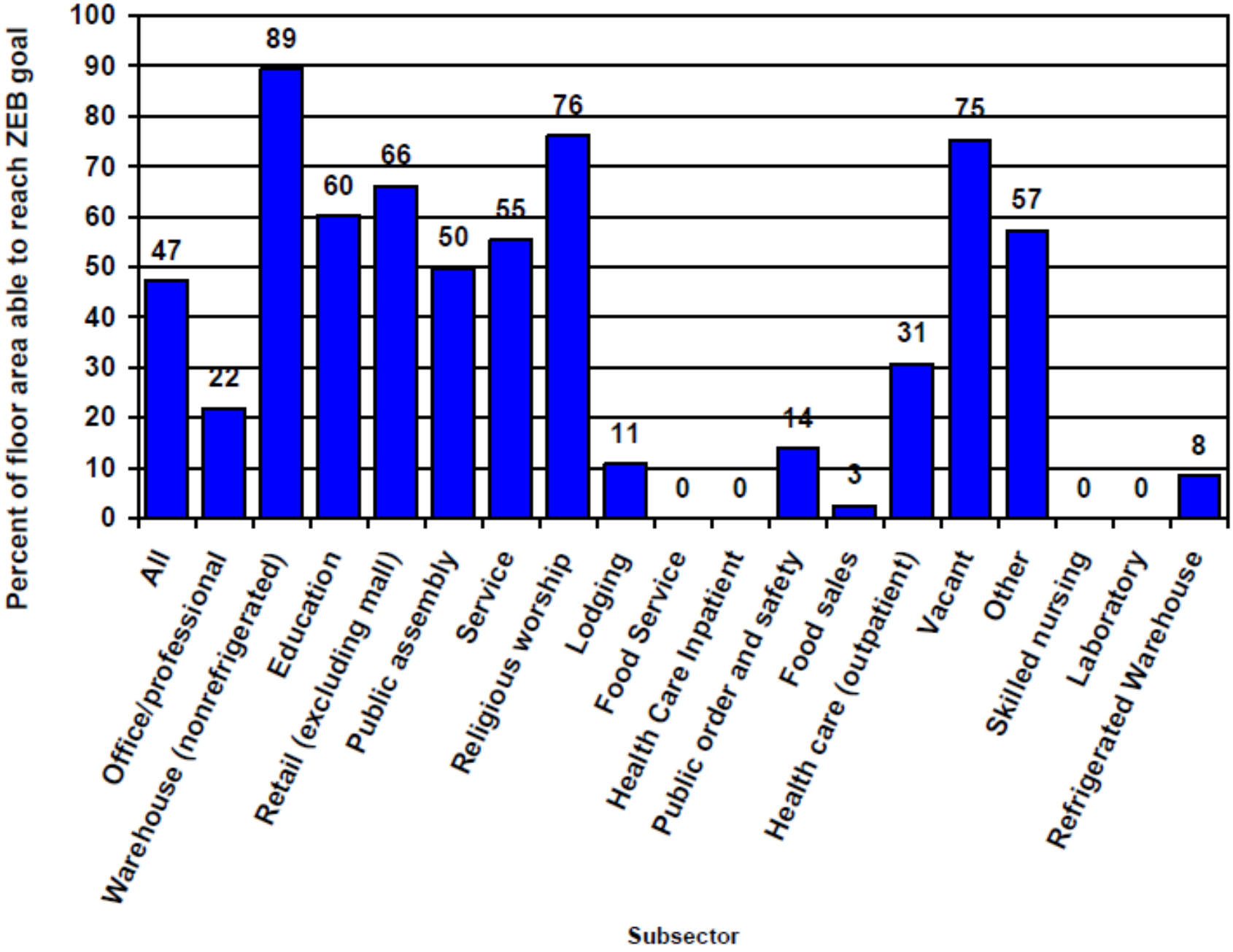
- Voluntary Approach
- DOE Version – yet to come?



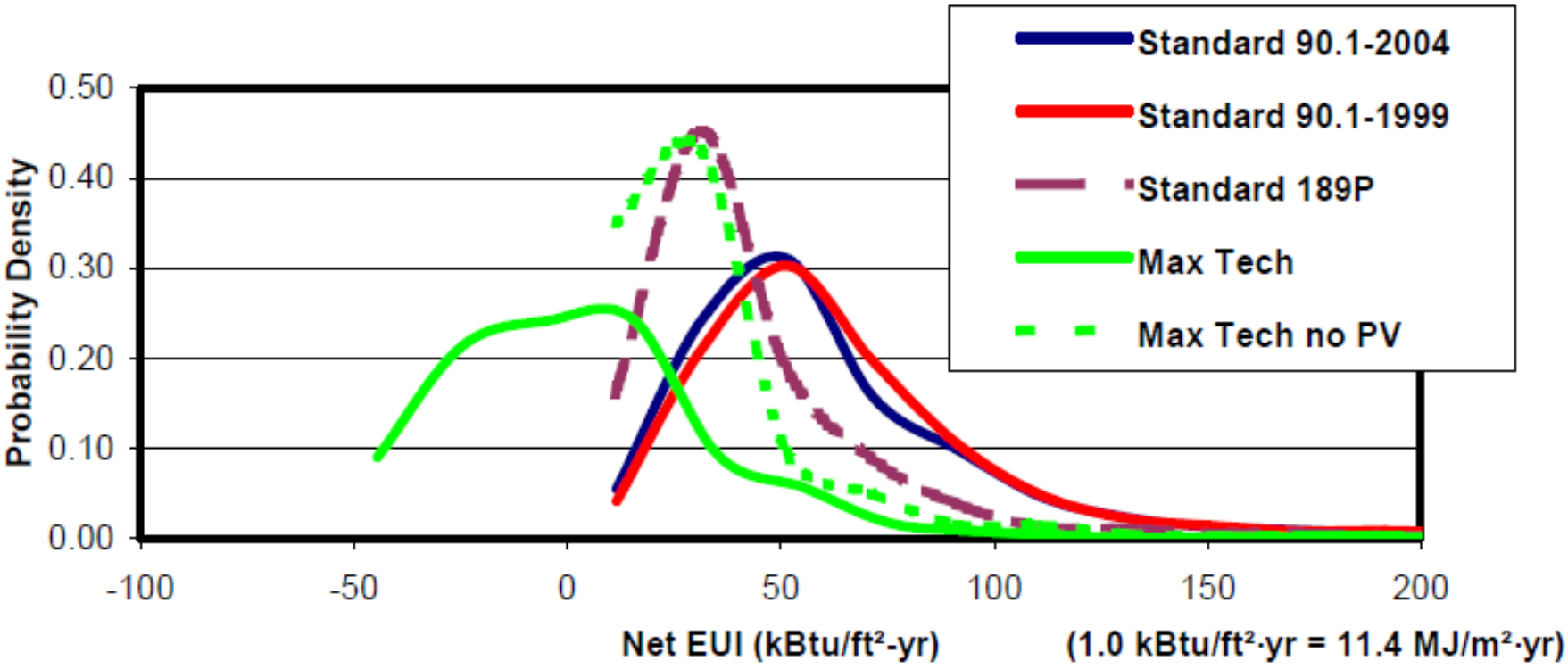
NREL Study on CBECS



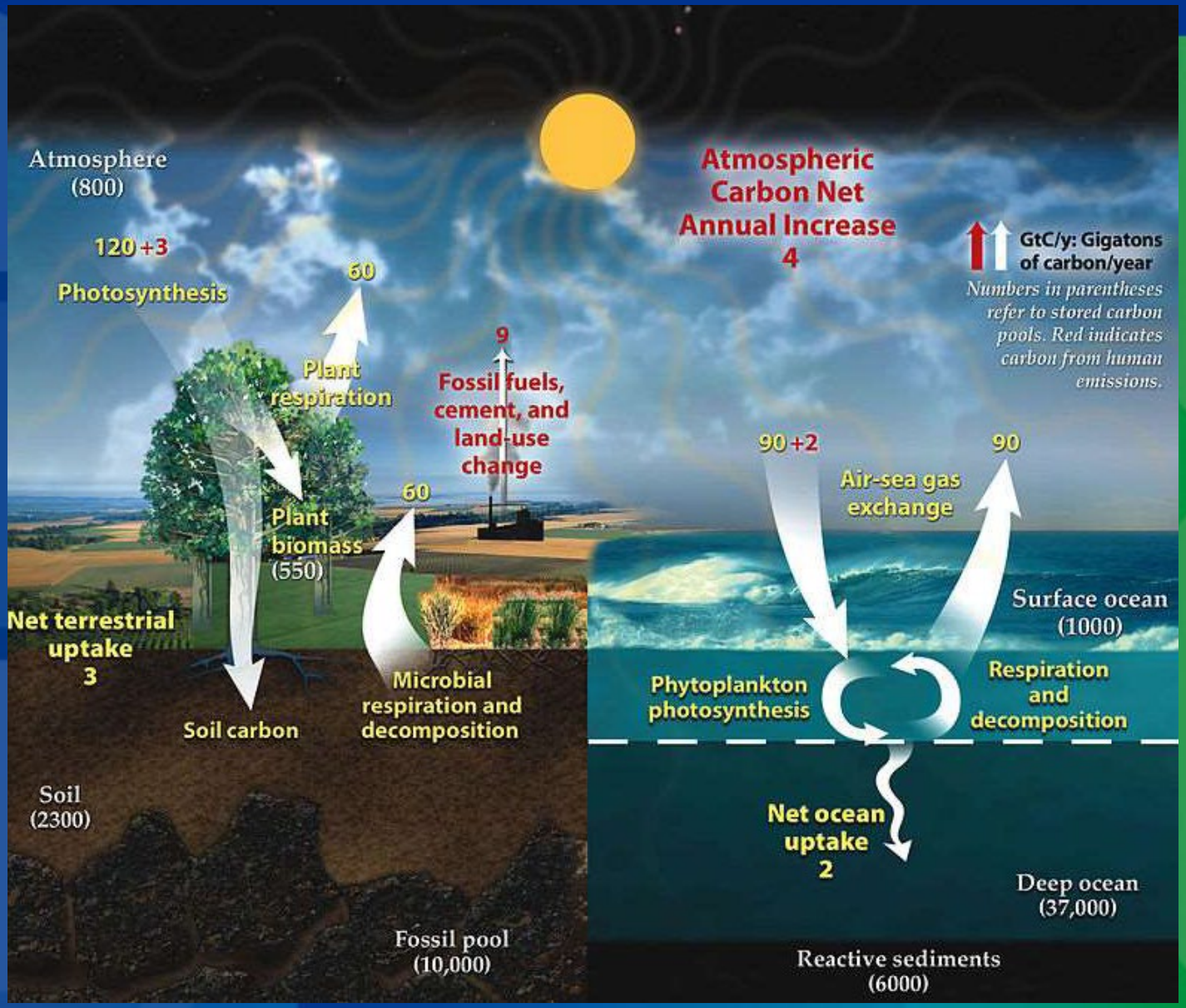
Subsector	Climate Zone														
	All	1A	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	6A	6B	7
All	12.2	19.8	7.4	9.4	13.4	2.9	27.3	13.6	-8.0	15.5	18.5	1.5	13.9	-2.0	12.7
Office/professional	14.2	17.9	12.3	-7.6	8.0	7.0	23.0	18.9	20.6	19.5	17.1	4.4	12.0	-8.6	15.0
Nonrefrigerated warehouse	-20.7	-40.9	-28.8		-32.0	-27.6	-33.9	-22.4	-26.5	-12.7	-16.3	-13.6	-8.9	-25.4	2.9
Education	-6.0	36.5	-10.2	-25.5	-16.7	-15.2	1.8	0.0	-31.5	-4.7	2.1	-18.2	-0.3	-11.9	-5.4
Retail (excluding mall)	-8.5	-31.3	-2.6	-23.3	-19.0	-16.8	4.3	-7.6	-23.0		-0.7	-10.0	1.0	-7.7	2.1
Public assembly	1.7	-2.4	-4.4		8.6	-10.2	-10.5	3.8	-30.5	19.2	2.5	-11.1	8.2	10.7	-2.6
Service	-0.3	19.7	-2.4		-19.4	-18.9	-29.5	5.6	-8.7		6.6	-2.5	0.1	-9.5	6.8
Religious worship	-13.1		-23.3		-22.5	-22.9		-11.5	-23.4		-4.5	-23.7	-3.2	-26.1	
Lodging	14.1	25.7	18.1		10.9	3.8		17.4	23.5	7.9	16.9	0.4	14.6	-16.7	9.7
Food services	276.2	425.0	255.7		277.0	288.6	287.5	272.8		356.7	288.3	254.4	278.2	151.2	253.0
Health care (inpatient)	61.1	68.5	64.1	71.9	54.7	61.5	50.5	58.3	54.1		70.9	51.9	56.1	52.5	88.7
Public order and safety	20.1		18.4		1.1	20.9		18.0			27.5	20.0	18.7	48.7	
Food sales	66.7		66.0		71.8	45.6	58.8	72.1			64.7	74.9	68.1		77.2
Health care (outpatient)	11.7	10.4	13.1		1.0	19.9		8.7	-5.0		21.3	-1.8	11.5	8.1	26.6
Vacant	-17.0		-42.2	-4.5	-31.4	-24.6	-19.3	-2.6	-22.1	-11.0	-17.1	-34.1	-8.6		14.8
Other	-1.3		2.9		-18.2	-11.8		-2.7	-42.4		4.4	-25.6	7.9	-9.3	-10.7
Skilled nursing	61.5		65.4		54.4	30.9		75.7			73.9	21.9	55.6	34.7	
Laboratory	272.9				290.0	286.4		205.9			274.2		234.4	261.0	
Refrigerated warehouse	15.6							11.2			31.9	1.1	16.8		


Percent of floor area able to reach ZEB goal
100
90
80
70
60
50
40
30
20
10
0
47
22
89
60
66
50
55
76
11
0
0
14
3
31
75
57
0
0
8
All
Office/professional
Warehouse (nonrefrigerated)
Education
Retail (excluding mall)
Public assembly
Service
Religious worship
Lodging
Food Service
Health Care Inpatient
Public order and safety
Food sales
Health care (outpatient)
Vacant
Other
Skilled nursing
Laboratory
Refrigerated Warehouse
Subsector

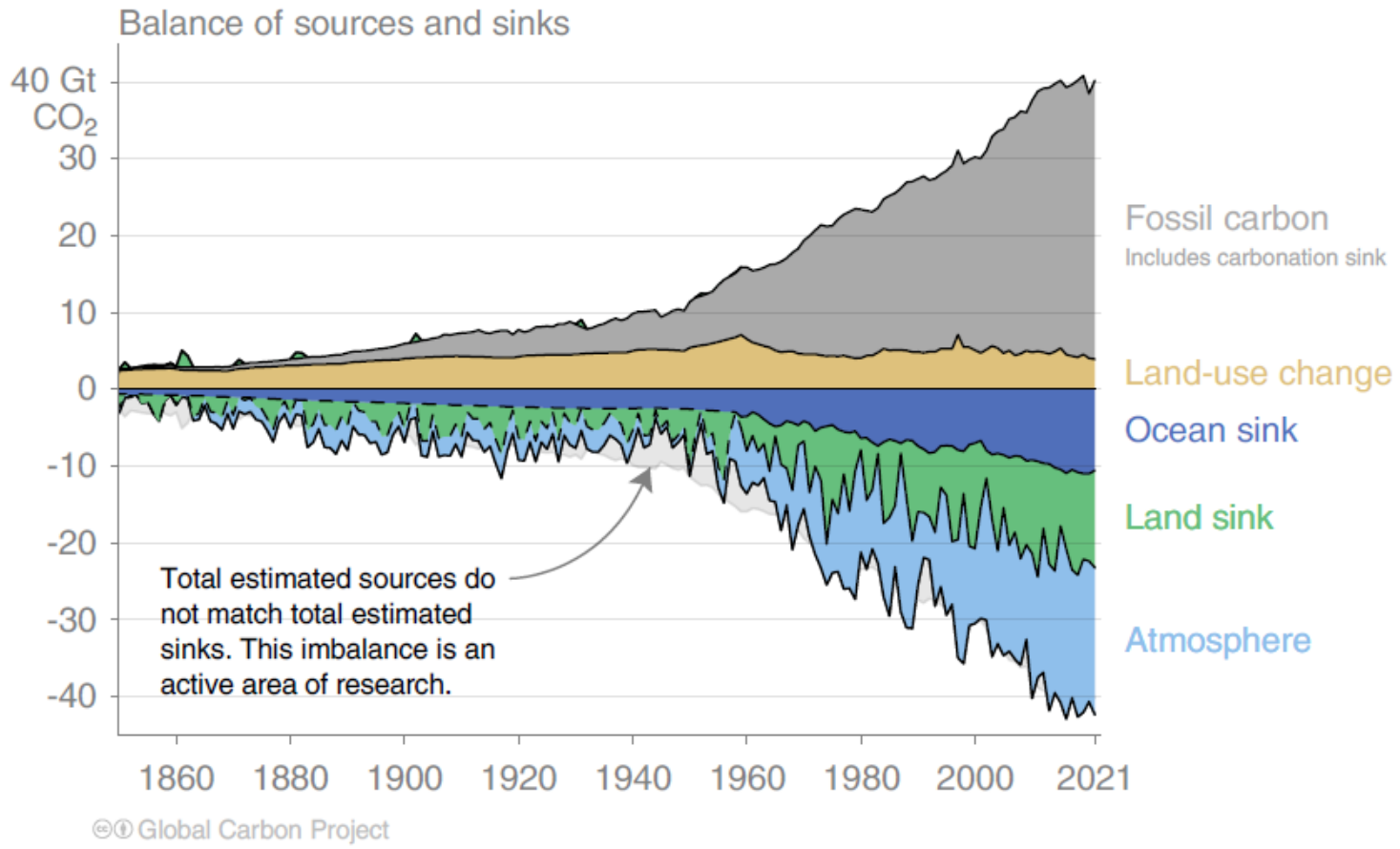
ASHRAE Standards – EUI



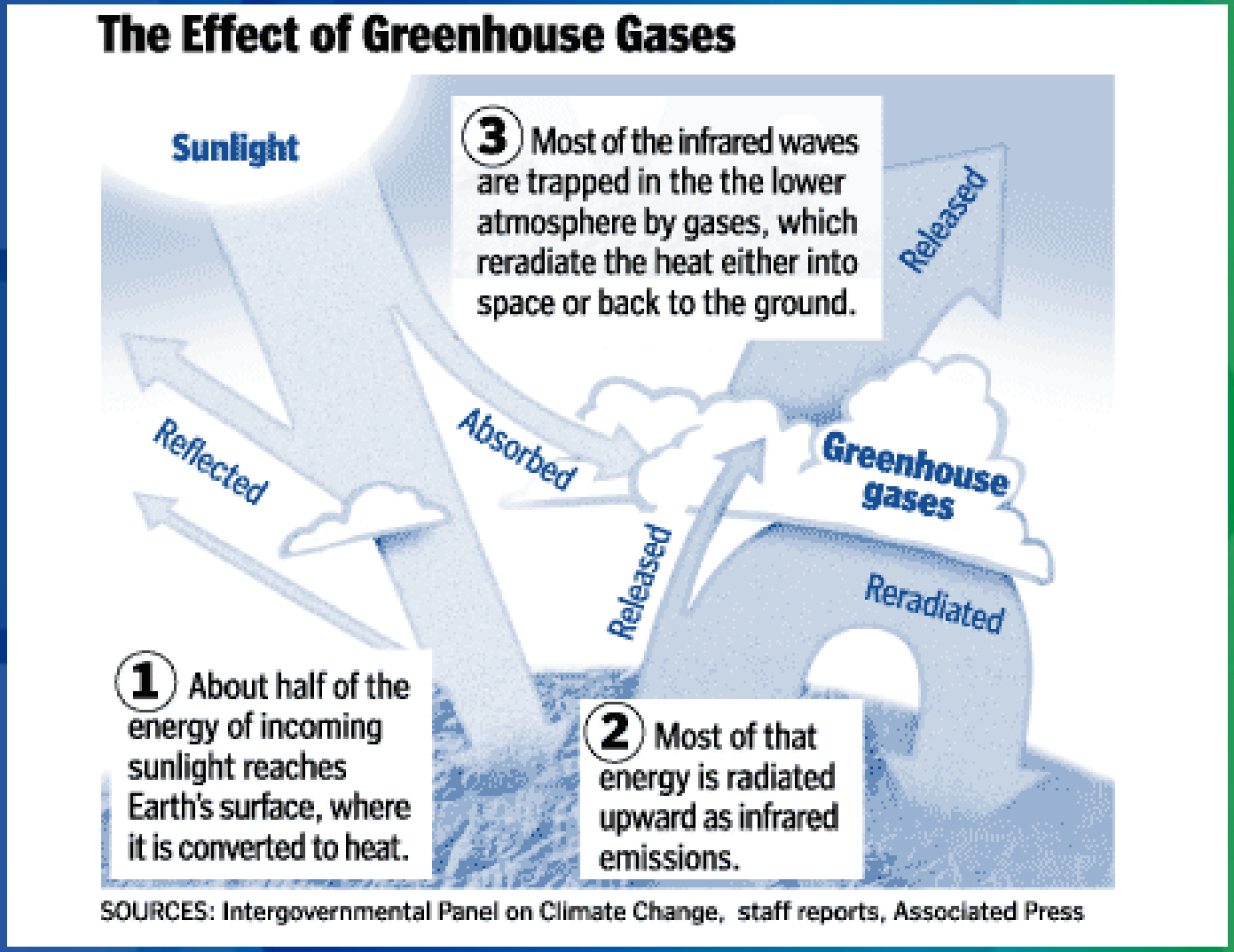
The Carbon Cycle



Why is there an Imbalance

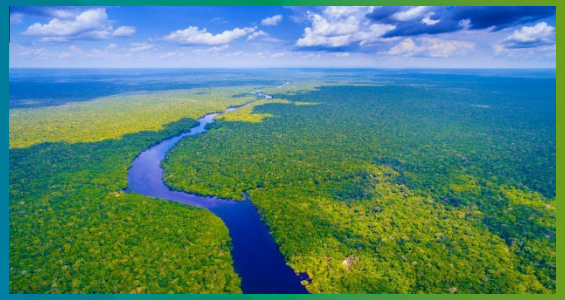


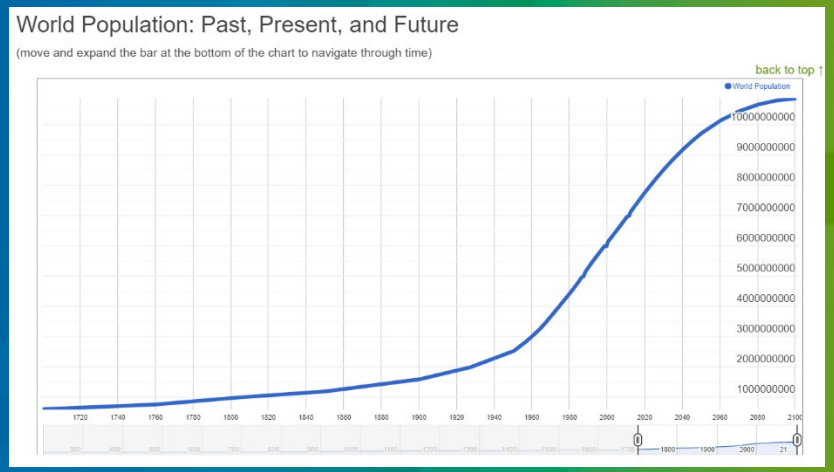
Greenhouse Effect

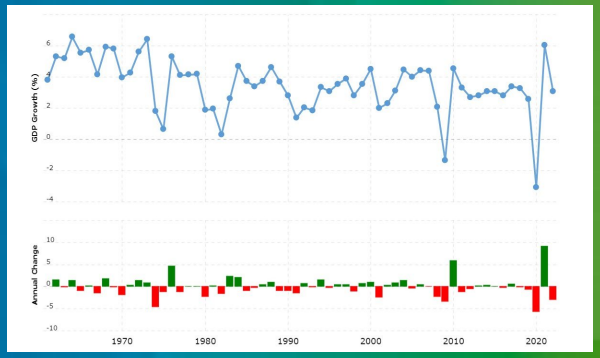


Other Elements

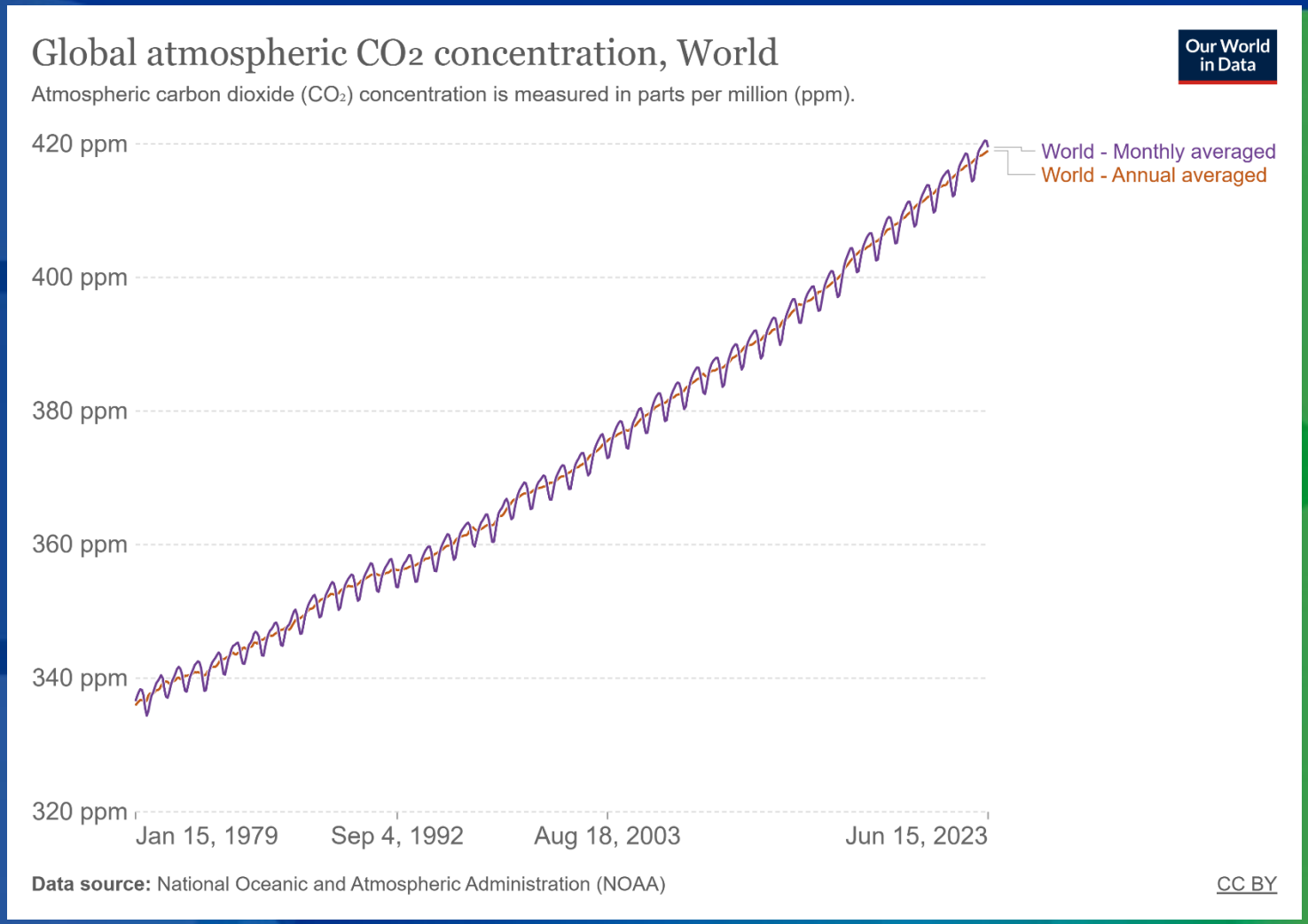
- Beef Craze
- Land Use
- Population Growth
- World Wealth
- Be Like the USA







Global Concentration of CO_2



IPCC and Their Report

- The IPCC (International Panel on Climate Change) within the United Nations latest report on Climate Change illustrate:
  - The world is on a track to reach up to six degrees C rise in global average temperature rise by the end of this century if nothing is done to curb Carbon Emissions
    - 2 C rise potentially by 2040
    - 3 C rise potentially by 2060
    - 4 C rise potentially by 2075
    - 5 C rise potentially by 2090
    - 6 C rise potentially by 2100

1 C Rise Elements

- Shifts in Global Weather Patterns, the Jet Stream, the amount of moisture in the air and overall local weather conditions will change globally to shift the perceived new "climate normal" for most local areas of the globe (many have already experienced this).
- Past evidence of similar weather changes around the period of 1100 – 1300 AD indicates the climate in many regions had dry land and trees where lakes and rivers exist today.
- Currently the European Alps are experiencing the melting of permafrost in higher elevations, which have not been seen before in recorded history. This results in falling rock/earth with ice melt.
- In the past changes in localized climate change took centuries (not decades) and the plant & animal survival in many cases cannot adjust fast enough in today's world of climate change. It has been stated that by the time we get to 2 C rise, 20% of all plant and animal life will be extinct

2 C Rise Elements

- The oceans will continue to see more effects to not only temperature rise, but to an increase in PH, becoming more acidic! This change will result in a reduction in life forms within the oceans.
- Farming and food generation globally will be a challenge due to rising temperatures and changes in rain/weather patterns. The result will create hardship and potentially shifts in where crops can be harvested, and where farm animals can be raised.
- The Northern hemisphere permafrost tipping point is about 2.7 C rise in global temperature rise, so at about 2 degrees C this will be seen in some parts of the northern hemisphere. Global Warming elements of Methane gas and Carbon Dioxide (currently frozen within the ground) will be released into the atmosphere (more than what mankind has created since 1850 AD)!

3 C Rise Elements

- Due to global glaciers melting completely, winter snow caps melting in the spring will result in periods on a yearly cycle where rivers potentially run dry of natural waterflow (we are seeing this potential now in the western mountain ranges of the United States). The result of this will include great hardship on people, crop reduction/elimination, and erosion of landscape.
- Hurricanes will become more frequent and will appear in places where they haven't appeared in recorded history (Europe, South America, and Southern Africa). There will be an increase in average hurricane intensity (6-8 % predicted) which means more CAT 4 & 5 Hurricanes!
- **Big picture changes to the world include, a) Europe - having storms unseen in modern history, b) Africa - having intense heat beyond what has been seen in modern history, c) North America - more cycles of intense weather changes (drought and flood cycles), d) South America - losing parts of the Amazon, and e) The Permafrost will melt to fully release trapped Greenhouse Gases.**

4 C Rise Elements

- World Glaciers and ice packs will be almost 100% gone!
- Methane Hydrate in the oceans could create tipping point events
- The oceans will absorb more of this energy, which will lead to a "net expansion" of the water within all oceans. As to what the rise in ocean levels will be is difficult to estimate; however, estimates vary from 1 meter to over 25 meters in global ocean sea rise! Think of all seaside cities globally with an altitude less than 25 meters (82 feet) as to what this could do to millions of people. Potential cities in trouble include:

New Orleans – 0-59 feet
Charleston, SC – 10-16 feet
Miami, FL – 2-10 feet
Tampa, FL – 10-62 feet
Houston, TX – 10-82 feet
New York, NY – 20-62 feet
Honolulu, HI – 7-32 feet
London, England – 14 meters
Tokyo, Japan – 6 meters
Copenhagen, Denmark – 10 meters
Dublin, Ireland – 8 meters
Amsterdam, Netherlands – (-2) meters
Bangkok, Thailand – 1 meter
Cairo, Egypt – 22 meters

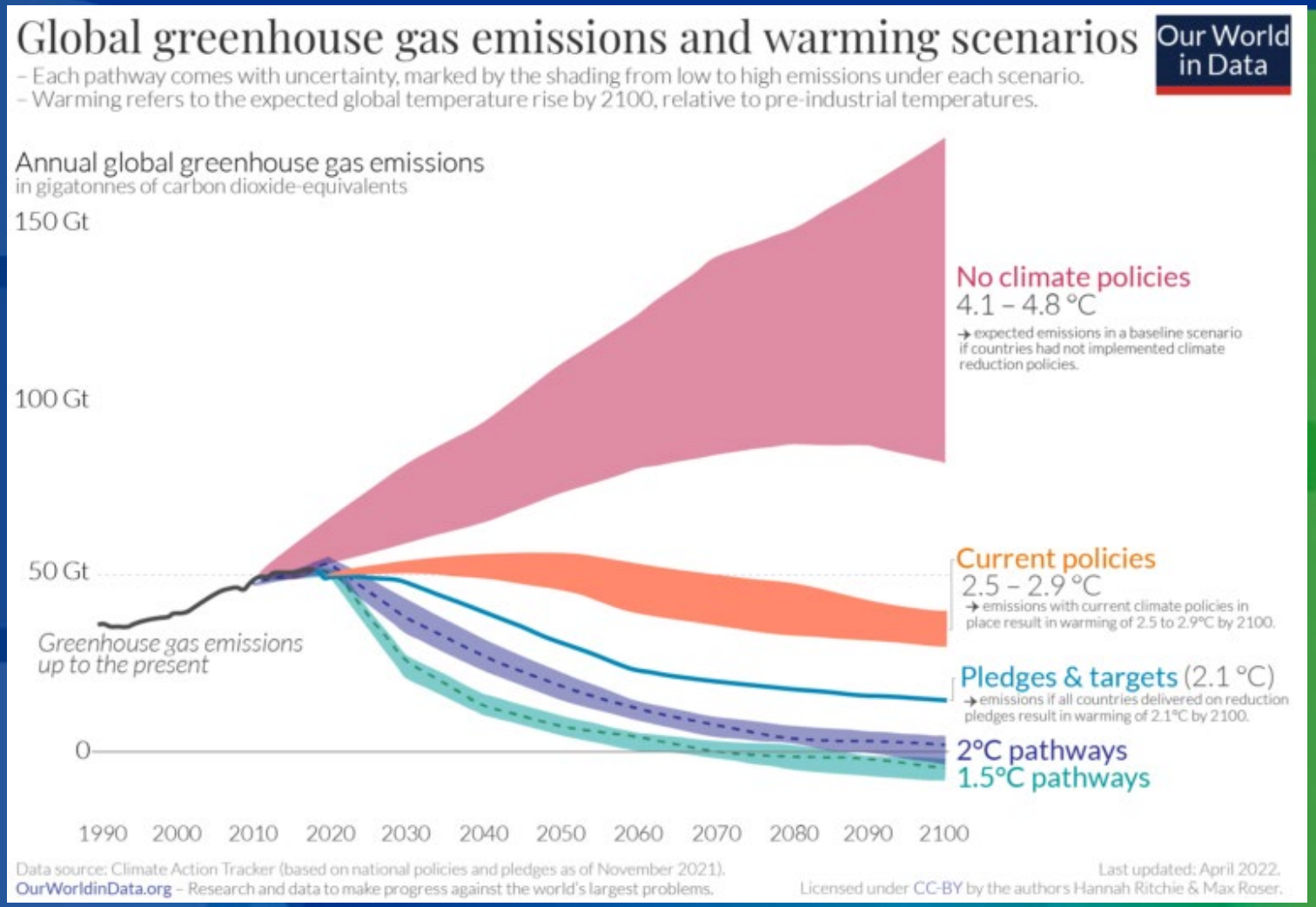
5 C Rise Elements

- When we get to 5 C rise in global temperature the earth will have gone through many changes, examples include:
  - The “rain forests” will be in danger of existence due to the lack of water and extreme heat build-up.
  - Most coastal cities will be drastically impacted by sea level rise.
  - Evaporation into the atmosphere will increase such that continued cycles of drought and downpours create tremendous erosion around the world away from the equator.
  - Desert areas around the world will expand, especially those close to the equator, making them uninhabitable.
  - Many areas of the world will need to use deep drilling techniques (like oil drilling) to find fresh water.
- Changes in weather conditions could result in challenges for crop growth and farm animal management (mostly due to freshwater availability and drought).

6 C Rise Elements

- Computer modeling has little information for 6 C rise in global temperature rise, so like the IPCC, one must rely on geological information about extreme episodes in earth's past. Here are some examples of what could occur based on earth's history (geological evidence).
- Like some movie and television productions, the "***following could be offensive to some viewers***".
- People will continue to move away from the equator for survival, and to both raise crops and have animals for food as deserts will move to more northern latitudes in the northern hemisphere and southern latitudes in the southern hemisphere (example: beyond the 45th parallel for the northern hemisphere).
- With the oceans rising, more than 20% of what is dry land (globally) today will be underwater at this time.

The Future?


Global greenhouse gas emissions and warming scenarios
– Each pathway comes with uncertainty, marked by the shading from low to high emissions under each scenario.
– Warming refers to the expected global temperature rise by 2100, relative to pre-industrial temperatures.
Our World in Data
Annual global greenhouse gas emissions
in gigatonnes of carbon dioxide-equivalents
150 Gt
100 Gt
50 Gt
0
Greenhouse gas emissions up to the present
No climate policies
4.1 – 4.8 °C
→ expected emissions in a baseline scenario if countries had not implemented climate reduction policies.
Current policies
2.5 – 2.9 °C
→ emissions with current climate policies in place result in warming of 2.5 to 2.9°C by 2100.
Pledges & targets (2.1 °C)
→ emissions if all countries delivered on reduction pledges result in warming of 2.1°C by 2100.
2°C pathways
1.5°C pathways
1990 2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
Data source: Climate Action Tracker (based on national policies and pledges as of November 2021).
OurWorldinData.org – Research and data to make progress against the world's largest problems.
Last updated: April 2022.
Licensed under CC-BY by the authors Hannah Ritchie & Max Roser.

Hope and the Built Environment

- Earth and mankind do not have to complete the pathway to 6 C global temperature rise, we can still avoid the dramatic hardships and disasters illustrated above. However, change must occur, and most humans resist change. Thus, the following is important if we collectively wish to avoid the 6 C rise.
- Remember that the **Built Environment represents about 39% of all greenhouse gas emissions globally**; thus, drastic reductions in building energy consumption would directly lower global greenhouse gas emissions. This focus needs to "start now" as our window to drastically slow or even stop global temperature rise will end sooner than many expect.
- **High Performance ZEB buildings should be the goal of "new construction buildings."**
- Using lessons learned for converting existing buildings to low energy consumption should have some form of incentive (government, taxes, etc..) and demanded by code changes (use of penalties, or higher energy costs **– make it financially painful - $**).

HVAC

- Old habits, ideas & methods need to be updated – **Stop repeating 1950s-1980s Engineering practices!**
- Look to water-based systems, instead of air systems to transfer energy (water is 1 Btu/lbs. and air is 0.24 Btu/lbs.). Also, pumps are more efficient than fans to transfer fluids (water verses air movement).
- DOAS systems are common to most High-Performance HVAC Systems, and they can be integrated with many different types of HVAC building systems. The use of DOAS with energy recovery has been proven via energy analysis to be more energy efficient.
- Utilize heat pump systems and **look to centralized geothermal** if possible! Centralized Geothermal has a much better life cycle value and has potential for first cost savings!

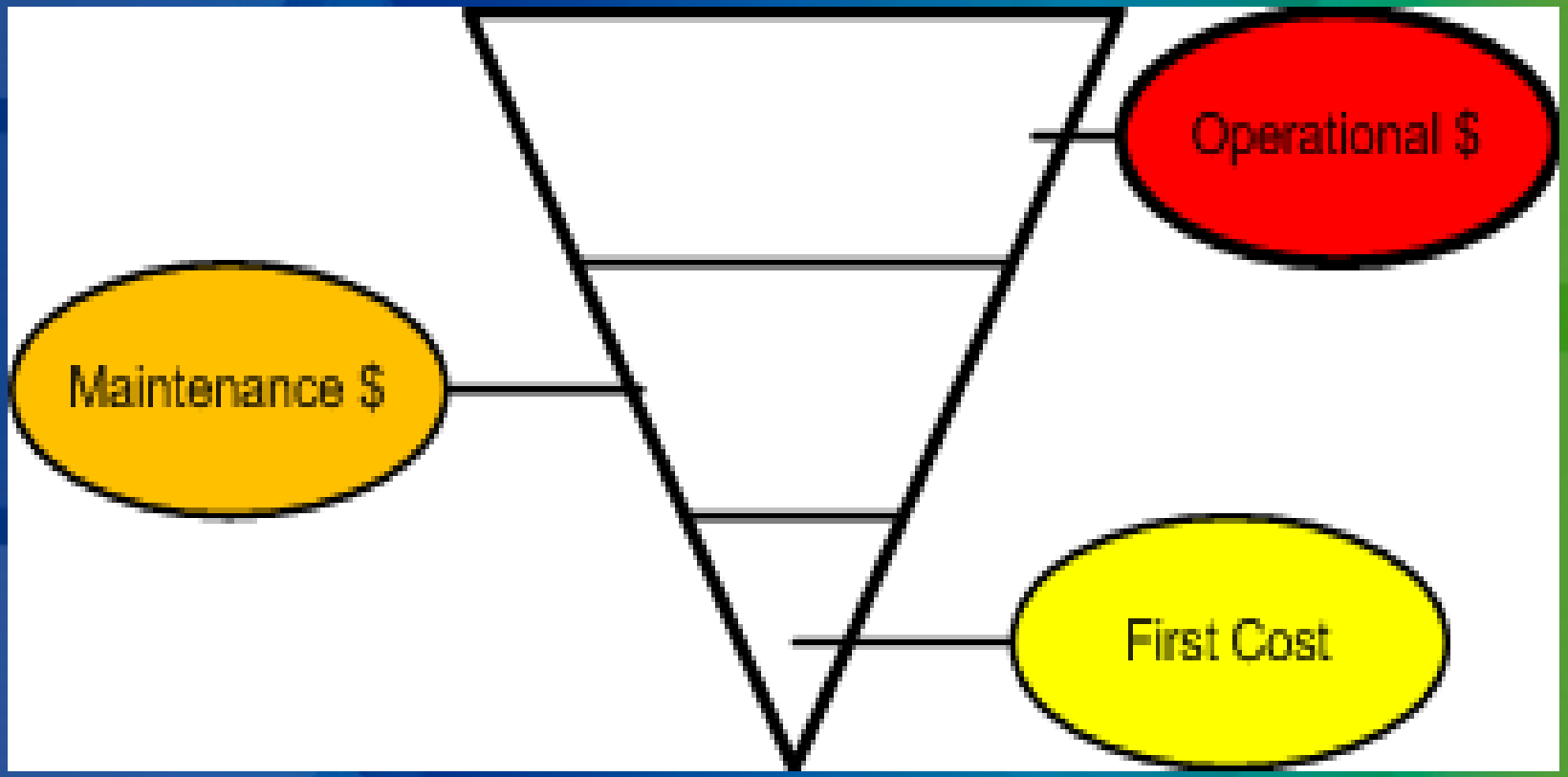
Suggestions

- Per Standard 189.1, embrace 50-year life cycle (Chapter 10) thinking for decisions on building system choices (architectural, mechanical, electrical, etc..). We need to look to Europe where they measure the life of a building in centuries and not decades! When this occurs, decisions as to the best building systems are much easier to justify and understand!
- For us to get to as close to **ZEB** as the norm, we will need to innovate as an industry, so don't be afraid of innovation!
- Rethink "**Bid Day**" mentality, and advocate for a "**Team (or integrated) Approach**".
- When sizing air handling equipment, **oversize** them one size (min.) to slow down the airflow within the unit and lower static pressures (overall performance of the unit will go up as energy transfer is better and air pressure drops are drastically reduced).

References

- "*How to Avoid A Climate Disaster*", by Bill Gates – 2021
- "*Climate Chaos*", by Brian Fagan & Nadia Durrani – 2021
- "*Saving Us – A Climate Scientist's Case for Hope and Healing in a Divided World*", by Katharine Hayhoe – 2021
- "*Six Degrees – Our Future on A Hotter Planet*", by Mark Lynas – 2008
- "*Breaking Ground – The Science of Our Planet*", by Johan Rockstrom & Owen Gaffney – 2021
- "*The Physics of Climate Change*", by Lawrence Kraus – 2021
- "OurWorldData.org"

Upside Down Pyramid



What's Your EUI?

Q & A