Why Buildings Matter:
and
The Role of ASHRAE 90.1

R. Christopher Mathis
MC^2 - Mathis Consulting Company

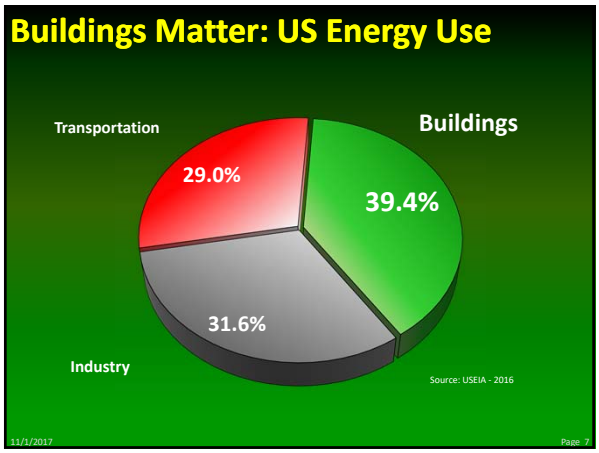
The End in Mind

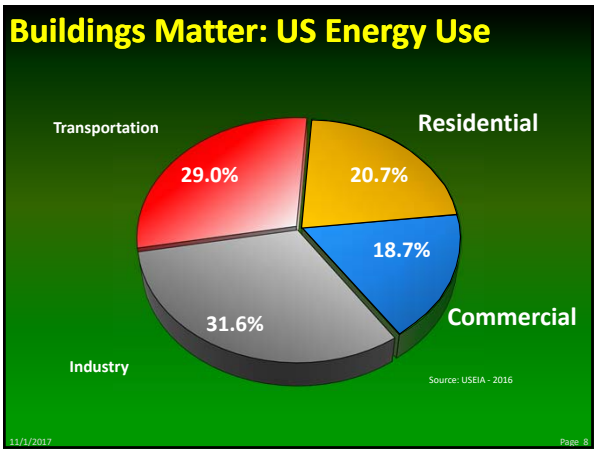
- **Buildings Matter!**
  - More than we know…
- **Major Trends Impacting Building Decisions**
  - Energy, Power, Water, etc.
- **What Does the Future Hold**
  - ASHRAE 90.1 Update
  - Building Envelope Priorities
  - Implications for Building Professionals
    - Engineers, Architects, Code Officials

Who Am I?

- **Building Scientist for 35+ years**
- **Author, Educator**
- **Standards Developer and User**
  - ASHRAE Member – 30+ years
    - 90.1, 90.2, 189.1, Distinguished Lecturer
  - ASTM Member 30+ years
    - Insulation, Fenestration, Commissioning
- **Code Developer**
  - IECC, IGCC, State Codes, Federal Codes, etc.
- **Beekeeper**

First,
Some Context…


Buildings Matter: US Energy Use
Transportation
Buildings
29.0%
39.4%
31.6%
Industry
Source: USEIA - 2016
11/1/2017
Page 7


Buildings Matter: US Energy Use
Transportation
Residential
29.0%
20.7%
18.7%
Commercial
31.6%
Industry
Source: USEIA - 2016
11/1/2017
Page 8

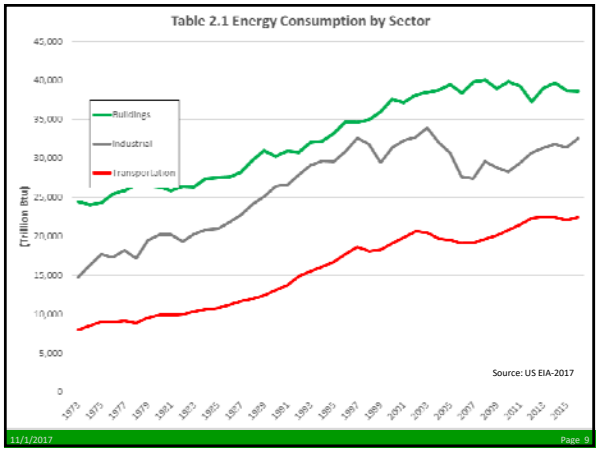
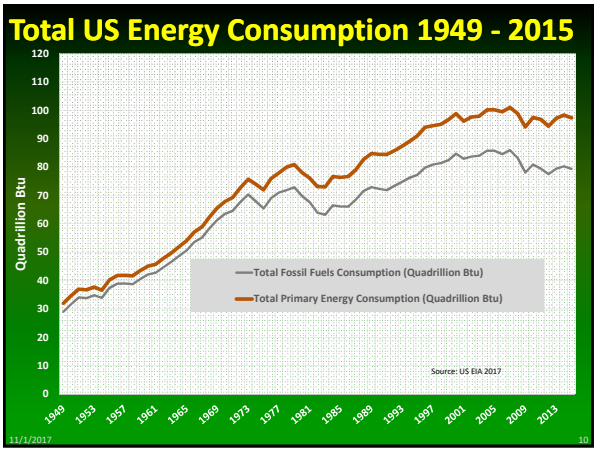
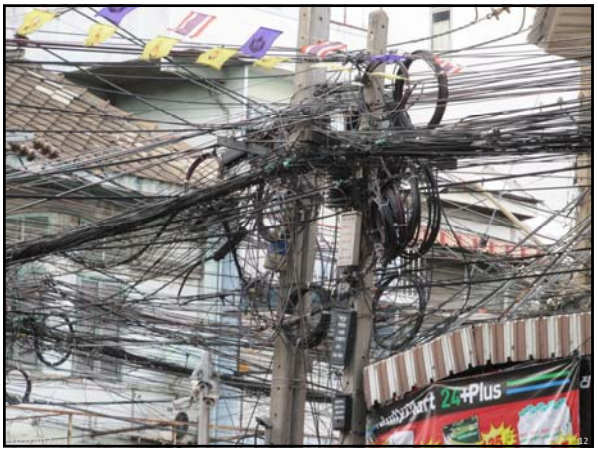
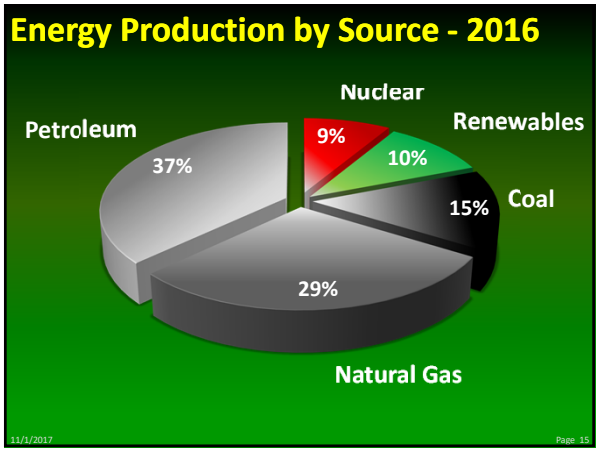
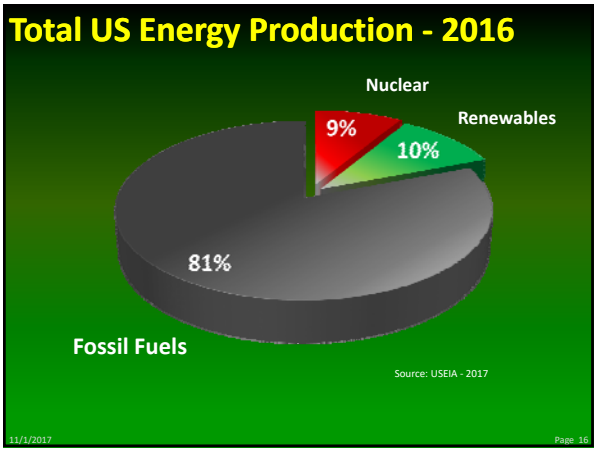


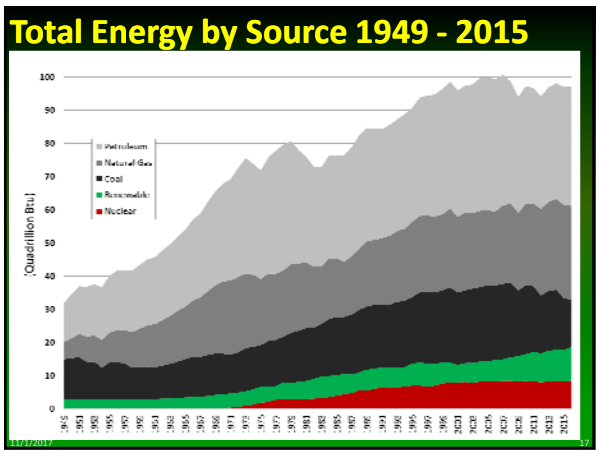
Table 2.1 Energy Consumption by Sector
(Trillion Btu)
Buildings
Industrial
Transportation
Source: US EIA-2017
11/1/2017
Page 9

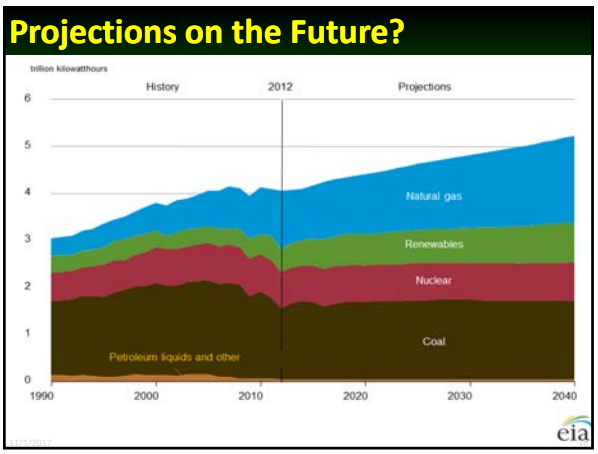

Total US Energy Consumption 1949 - 2015
Quadrillion Btu
Total Fossil Fuels Consumption (Quadrillion Btu)
Total Primary Energy Consumption (Quadrillion Btu)
Source: US EIA 2017
11/1/2017
10




Energy Production by Source - 2016
Nuclear
Petroleum
Renewables
9%
10%
37%
15%
Coal
29%
Natural Gas
11/1/2017
Page 15

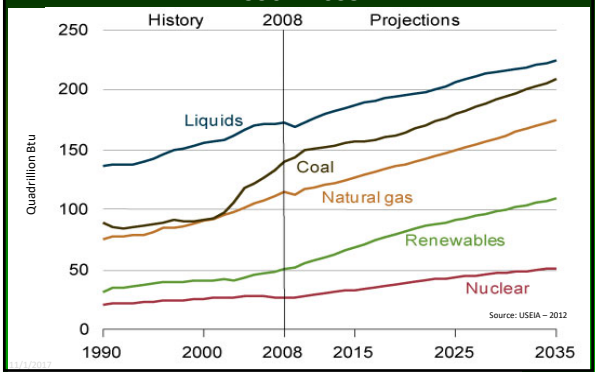

Total US Energy Production - 2016
Nuclear
Renewables
9%
10%
81%
Fossil Fuels
Source: USEIA - 2017
11/1/2017
Page 16


Total Energy by Source 1949 - 2015
Quadrillion Btu
Petroleum
Natural Gas
Coal
Renewables
Nuclear


Projections on the Future?
trillion kilowatthours
History
2012
Projections
Natural gas
Renewables
Nuclear
Coal
Petroleum liquids and other
1990
2000
2010
2020
2030
2040
eia

World Energy Consumption by Fuel

1990 – 2035

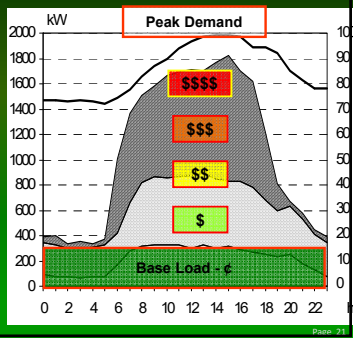


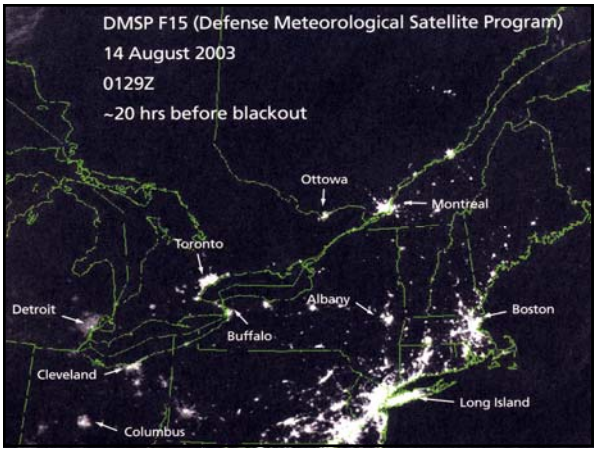
The Energy Megatrend

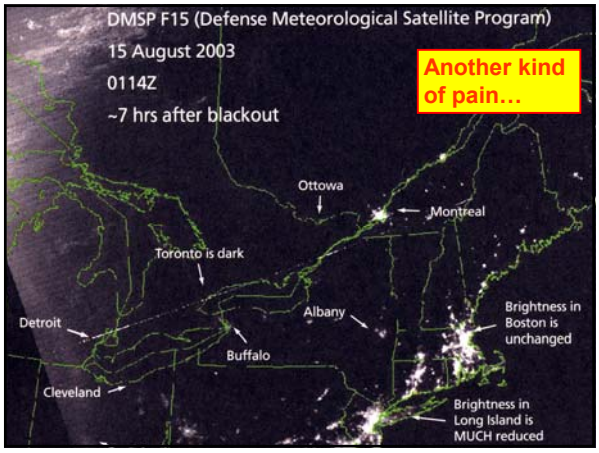
- Increasing demand
- Supply challenges
- Peak power issues
- Economic security
- Population change
- Water demand
- Available resources

Utility Concerns

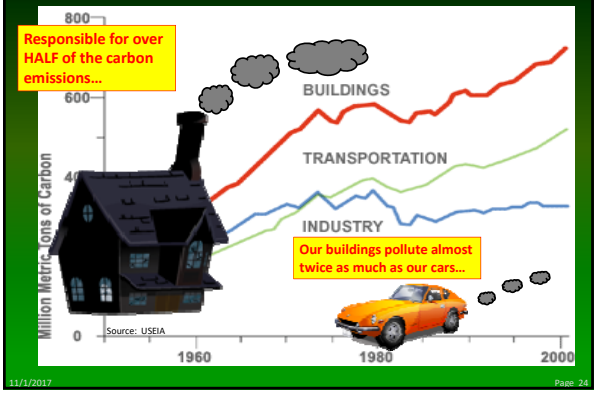
- The "Timing" of our Demand
  - Base Load
  - Peak Demand
  - Cooling Driven
  - Lighting Driven

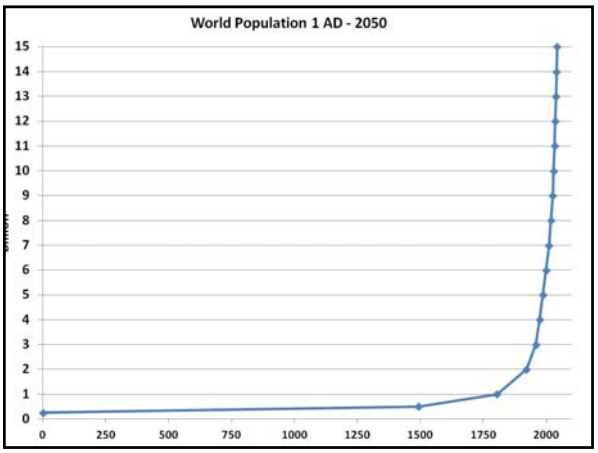


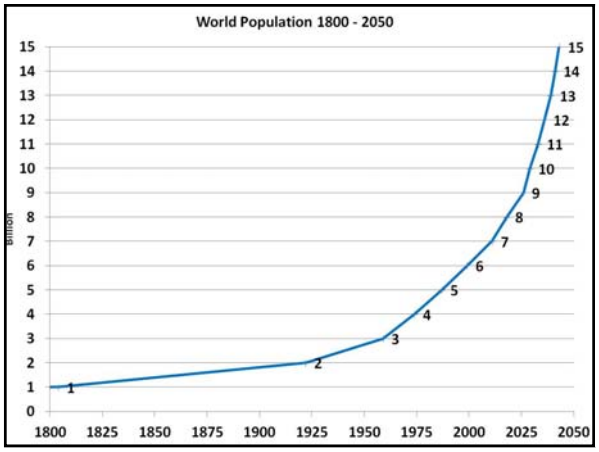


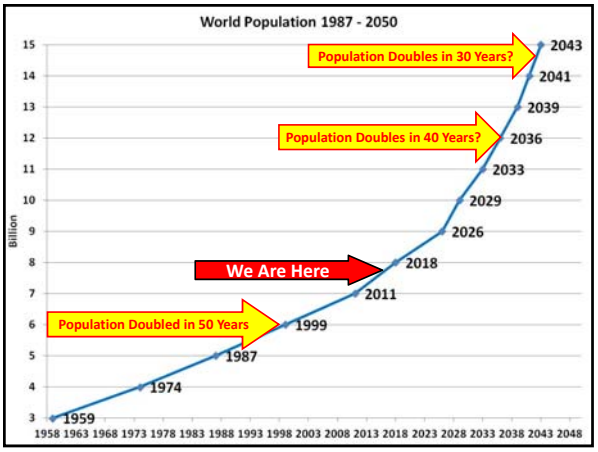


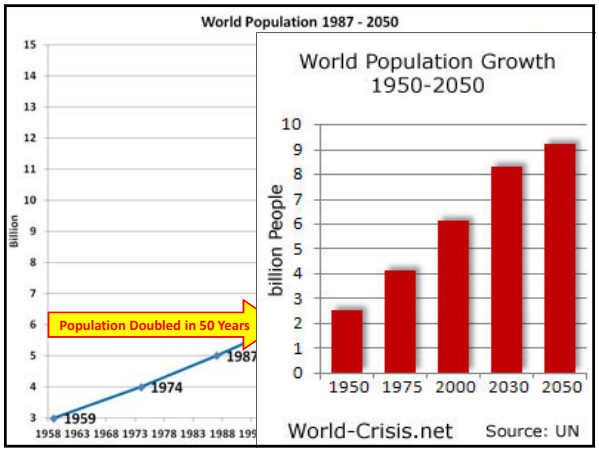
Climate Change? Buildings Matter!

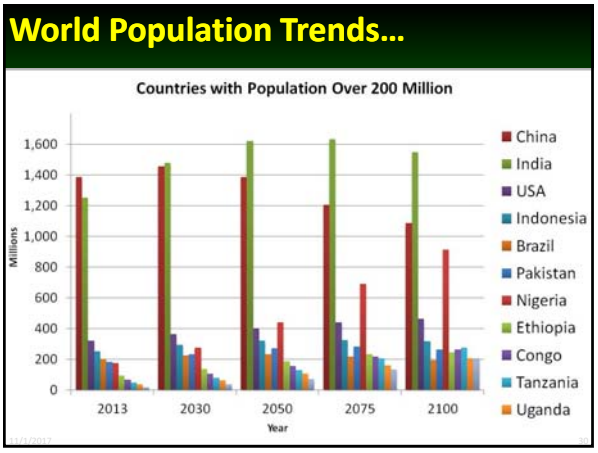


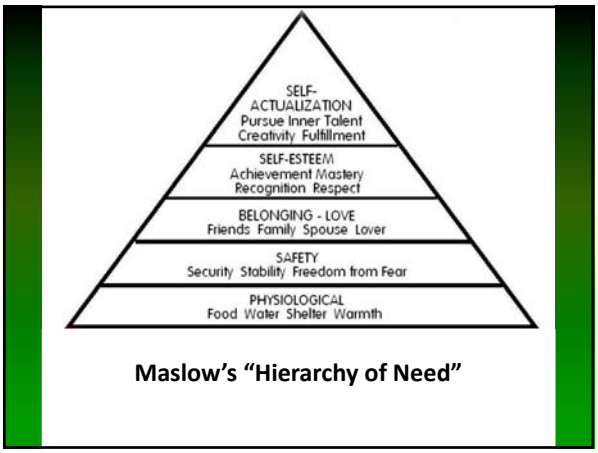

World Population 1 AD - 2050
Billion
0 250 500 750 1000 1250 1500 1750 2000


World Population 1800 - 2050
Billion
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
1800 1825 1850 1875 1900 1925 1950 1975 2000 2025 2050


World Population 1987 - 2050
Billion
Population Doubles in 30 Years?
Population Doubles in 40 Years?
We Are Here
Population Doubled in 50 Years
1959 1974 1987 1999 2011 2018 2026 2029 2033 2036 2039 2041 2043
1958 1963 1968 1973 1978 1983 1988 1993 1998 2003 2008 2013 2018 2023 2028 2033 2038 2043 2048


World Population 1987 - 2050
Billion
Population Doubled in 50 Years
1959 1974 1987
World Population Growth
1950-2050
billion People
1950 1975 2000 2030 2050
World-Crisis.net
Source: UN


World Population Trends...
Countries with Population Over 200 Million
Millions
2013 2030 2050 2075 2100
Year
China
India
USA
Indonesia
Brazil
Pakistan
Nigeria
Ethiopia
Congo
Tanzania
Uganda



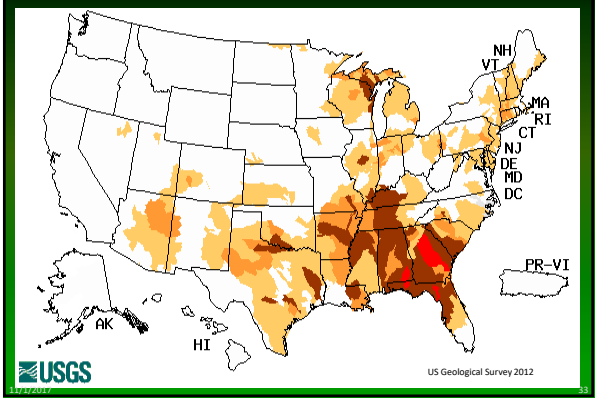
Maslow's "Hierarchy of Need"

Energy and Water

Worst US drought in decades deepens to cover 60 percent of lower 48 states

11/1/2017 US News, 11/22/2012 32

Water Implications…



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Power and Water

- US thermoelectric facilities use over 200 billion gallons of water a day.

Over half of the withdrawn water in the US…

Sources: Union of Concerned Scientists 2011, USGS 2012

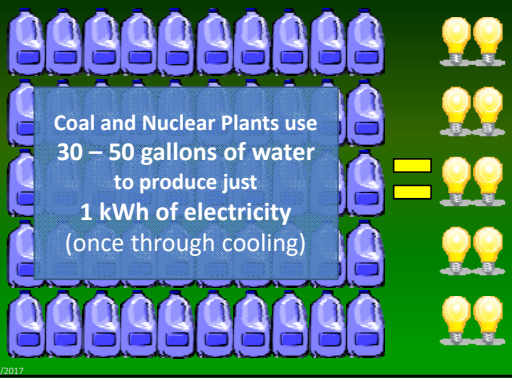
11/1/2017 Page 34

Niagara Falls

The volume of water flowing through America's electric utilities is 3 TIMES the amount flowing over Niagara Falls!

Niagara Falls State Park and USGS

Water and Power Connection…



Coal and Nuclear Plants use
30 – 50 gallons of water
to produce just
1 kWh of electricity
(once through cooling)

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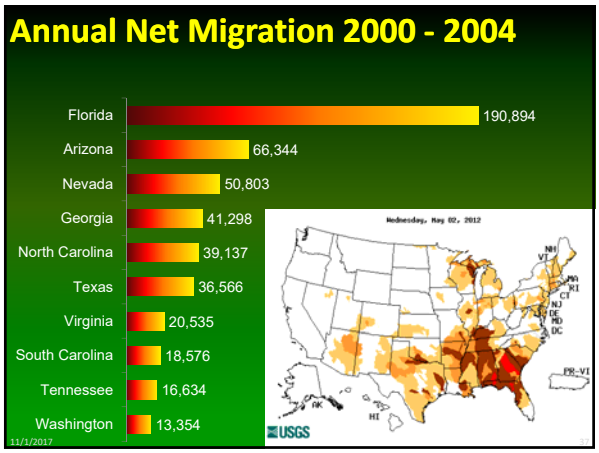
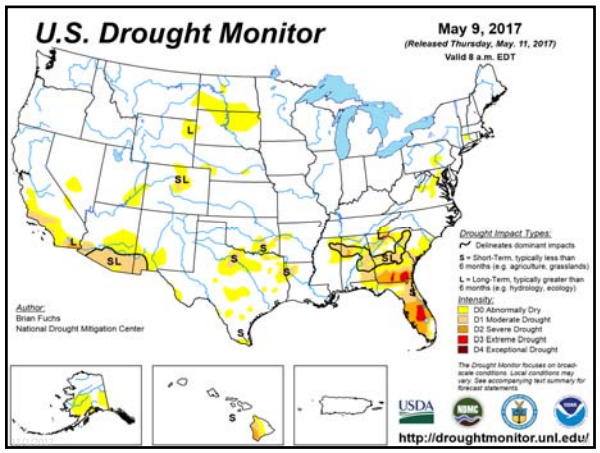
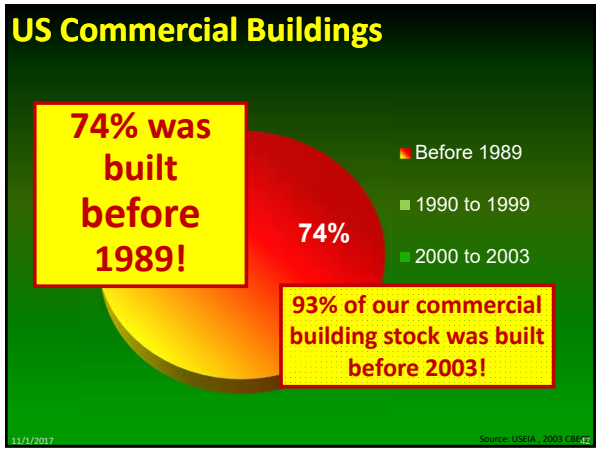
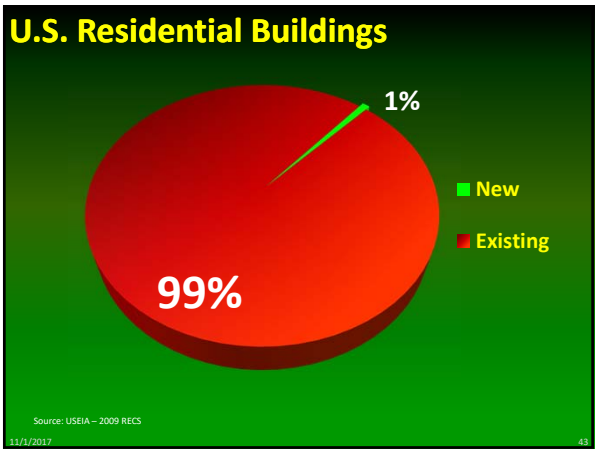

Annual Net Migration 2000 - 2004
Florida 190,894
Arizona 66,344
Nevada 50,803
Georgia 41,298
North Carolina 39,137
Texas 36,566
Virginia 20,535
South Carolina 18,576
Tennessee 16,634
Washington 13,354
USGS
11/1/2017

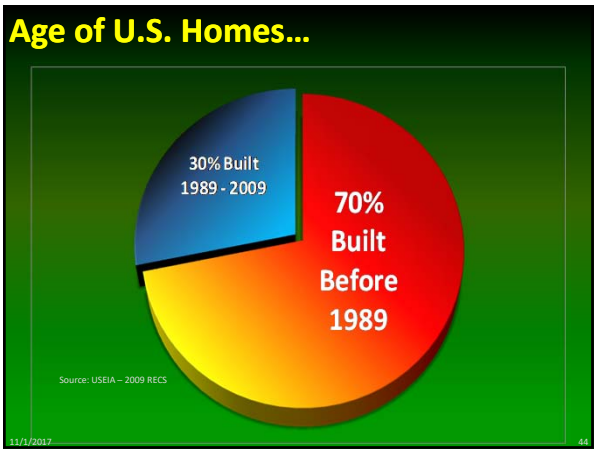

U.S. Drought Monitor
May 9, 2017
(Released Thursday, May. 11, 2017)
Valid 8 a.m. EDT
Author:
Brian Fuchs
National Drought Mitigation Center
Drought Impact Types:
Intensity:
D0 Abnormally Dry
D1 Moderate Drought
D2 Severe Drought
D3 Extreme Drought
D4 Exceptional Drought
USDA
http://droughtmonitor.unl.edu/

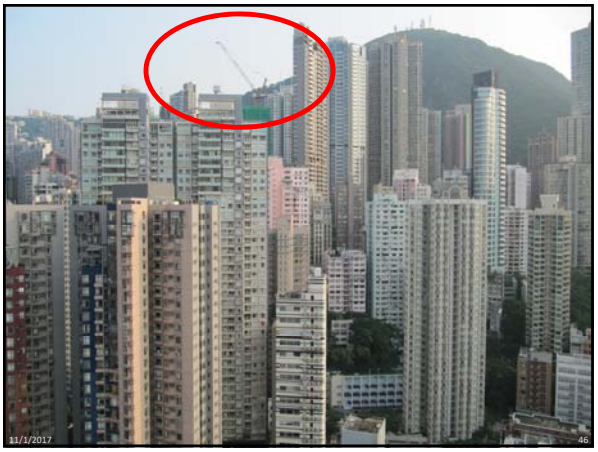

US Commercial Buildings
74% was built before 1989!
74%
Before 1989
1990 to 1999
2000 to 2003
93% of our commercial building stock was built before 2003!
11/1/2017
Source: USEIA , 2003 CBECS

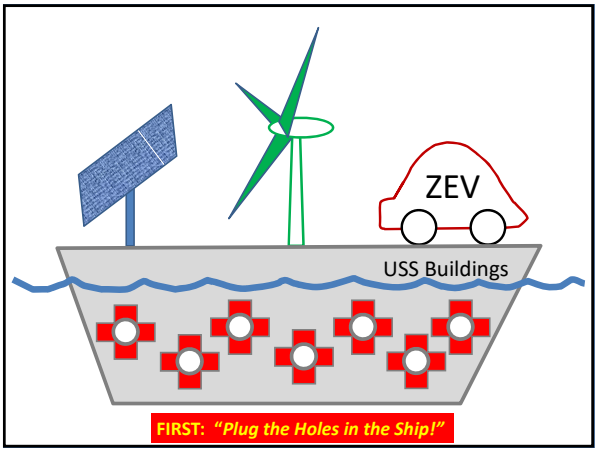
U.S. Residential Buildings



Age of U.S. Homes…







Some Trends…

U.S. Commercial Construction

Built Environment Trends - 1

- More severe climate events
  - "Superstorms"
  - Extreme cold - "Polar Vortex"
  - Extreme heat

August 22, 2015

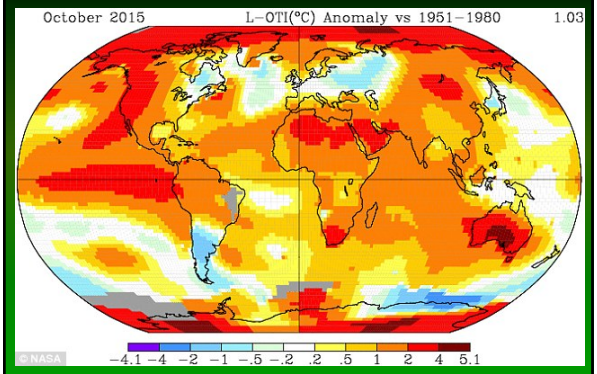

World breaks new heat records in July – US scientists

Trends - 2

October smashes record for global warmth: Last month keeps 2015 on track to be the hottest year since 1880

- Global temperatures last month were 1.04°C above long-term average
- This figure is the greatest increase of any month since record began
- There is 99.9% chance this year will beat 2014 as the warmest year ever
- Scientists blame increase in greenhouses gases and a strong El Niño

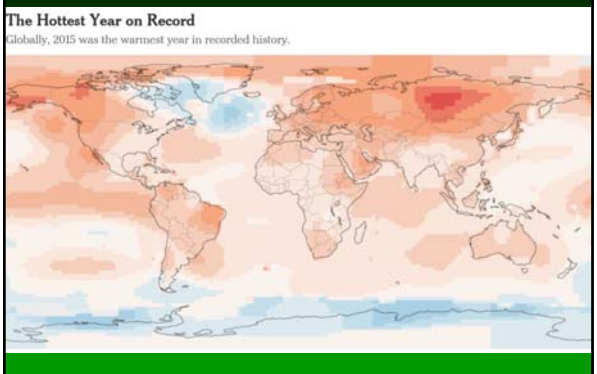
Hottest October Since 1880…



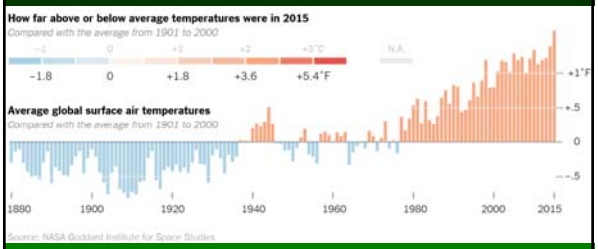
Legacy of 2015…

US: 2015 was hottest on Earth by a wide margin

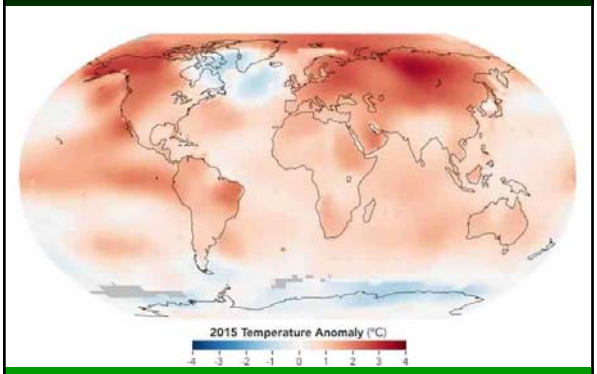
The World is Getting Warmer…

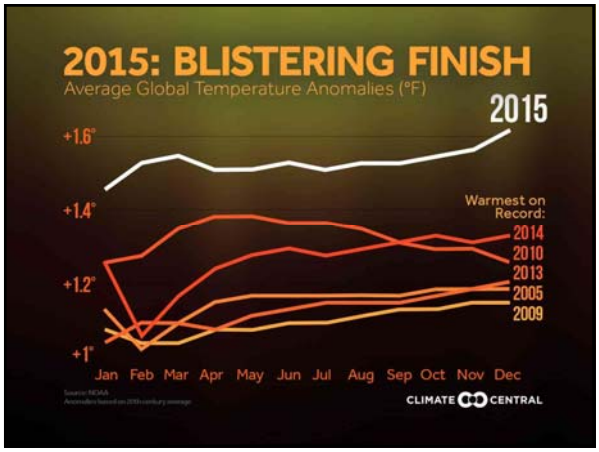


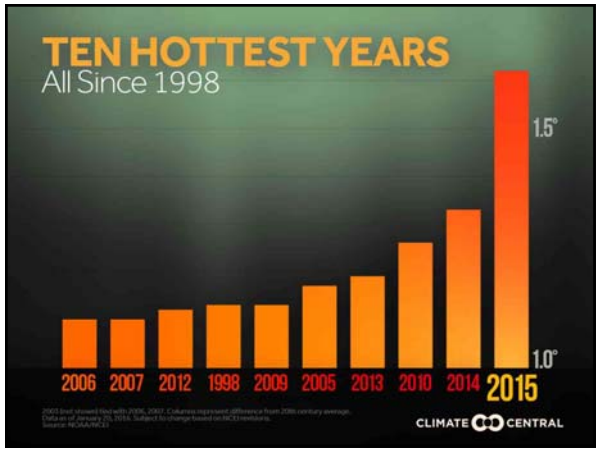
2015: Warmest Year in Modern Record Keeping



How Far From "Normal"?





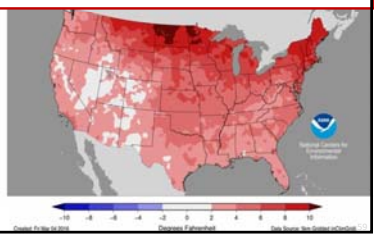


3/9/16…

Winter Tops Charts As Warmest on Record For U.S.

U.S. breaks record for hottest winter — nearly 5 degrees above normal

THE ASSOCIATED PRESS / Wednesday, March 9, 2016, 8:57 AM



4/20/16…

Science Home Archaeology Air & Space Planet Earth Wild Nature Natural Science Dinosaurs Slideshows

CLIMATE

March set even more global temperature records, NOAA reports

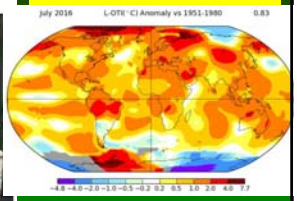
The month of March broke temperature records, making it the eleventh month in a row to do so, the National Oceanic and Atmospheric Association reported Tuesday, with North America having the warmest March ever since records began in 1910.

Globally in March, the average temperature across the land and oceans smashed the record, measuring 2.2 degrees Fahrenheit above the 20th-century average, NOAA said. That measurement breaks last year's record for March by over half a degree Fahrenheit, making it the warmest average temperature for the month across the globe since 1880.

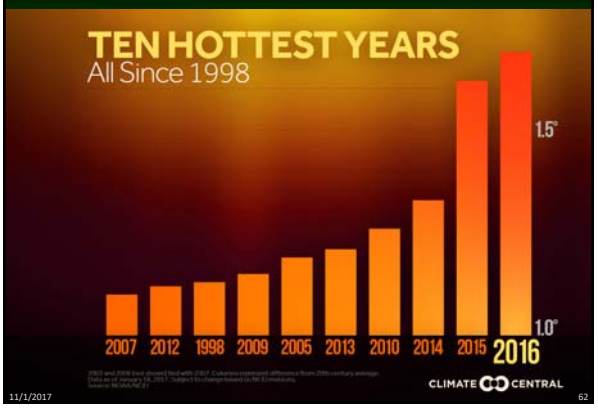
July 2016

July was Earth's hottest month in recorded history — the 10th record hot month in a row: NASA

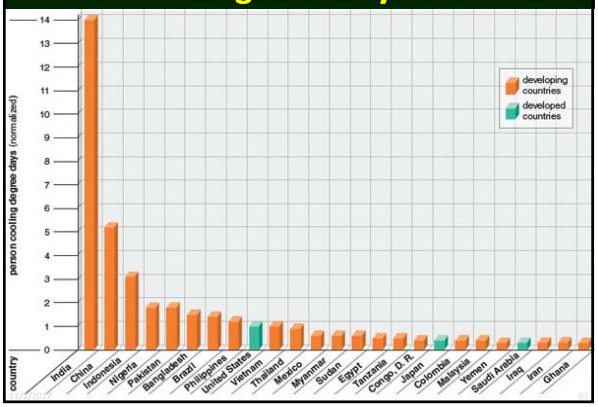
Hottest month in recorded history…



2016: The Trend Continues...



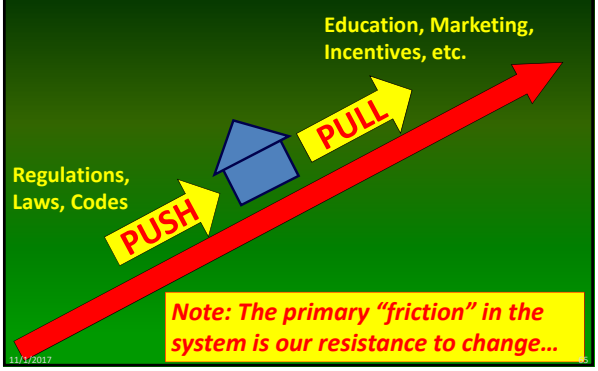
Air Conditioning for Everyone?



Built Environment Trends - 3

- **Increased expectations for building performance**
  - Energy
  - Health and IEQ
  - Safety
  - Durability
  - Resilience – especially against changing climate
  - Sustainable
  - For how long?

Market Transformation…



But we've got the building codes to handle these issues…

Right?

What is the Code?

- Least safe…
- Least strong…
- Least energy efficient…

- …building allowed by law.

We're not allowed to build it any crappier…

Disaster Breeds Codes

Disaster Breeds Codes…

- **Code of Hammurabi – 1750 BC**
  - 6th King of Babylonia
  - Over 3750 years ago…
  - Contains five key elements designed to protect the occupants

"Regulatory Simplicity"

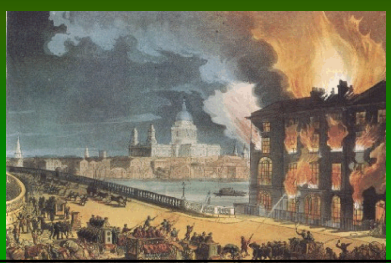
- **"If a builder build a house for a man and do not make its construction firm and the house which he has built collapse and cause the death of the owner of the house, the builder shall be put to death…"**

Disaster Breeds Codes…

- **The Burning of Rome – 64 AD**
  - Nero didn't like the slums and stench
  - Established fire safety and sanitation requirements for all buildings following the fire

Europe Learns…

- **The Great London Fire – 1666**
  - Black Plague, raw sewage, tightly spaced buildings
  - Two-thirds of the city destroyed
  - "London Building Act" adopted after the fire



US Code Milestones…

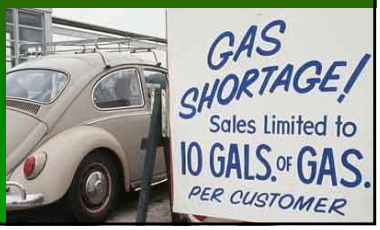
- **The Chicago Fire – 1871**
  - Mrs. O'Leary's cow…
  - Destroyed 17,000 buildings
  - Killed 250 people
  - Left 100,000 homeless
  - Bankrupted the insurance industry
  - New code adopted in 1875 regulating building construction and fire prevention.

More US Code Milestones

- **The San Francisco Earthquake – 1906**
  - What the earthquake didn't get, the fire did
  - One of the major influencers of today's structural, fire and life safety codes

First Energy Code Milestone

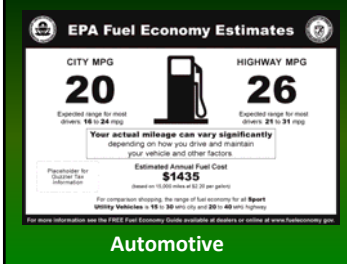
- **Arab Oil Embargo – 1973-4**
  - President Carter's Fireside Chat ("Turn your thermostat down to 65 and wear a sweater" and "Drive 55")
  - Precipitated the first energy codes for buildings – ASHRAE 1975



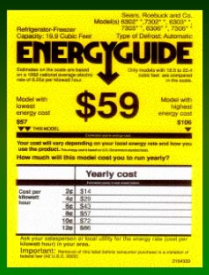
What Did We Do After 1973?

- **Tried to Save Energy**
  - Developed Standards and Ratings
    - Insulation, Appliances, Cars
- **Innovated (developed new technologies)**
  - Insulation, Glazing Technologies, HVAC, Lighting
- **Adopted our FIRST Energy Codes**
- **New Market Forces Evolved**
  - Utility Programs, Rebates, etc.

Why Standards?



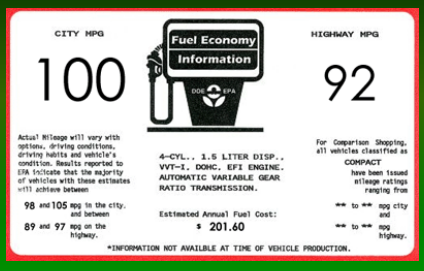
Automotive



Appliances

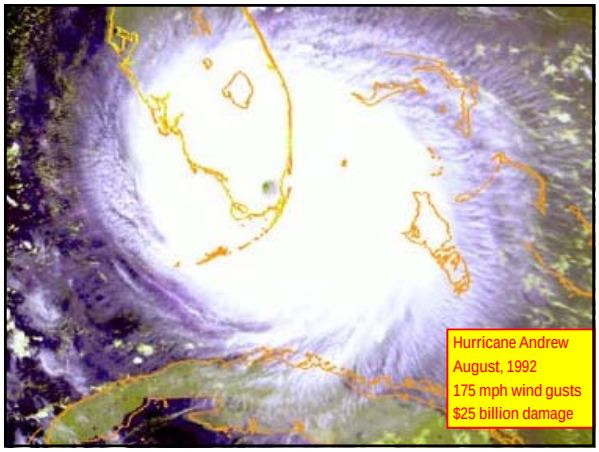
Consumer Signals About Energy!
A Means of Comparison…

What's Possible?



Energy Code Evolution…

Early Energy Code Solutions



Recent Code Milestones

- **Hurricane Andrew – 1992 AD**
  - 90% of all homes in Dade County Florida had roof damage
  - 117,000 homes were destroyed or had major damage
  - Primary driver of today's hurricane protection codes

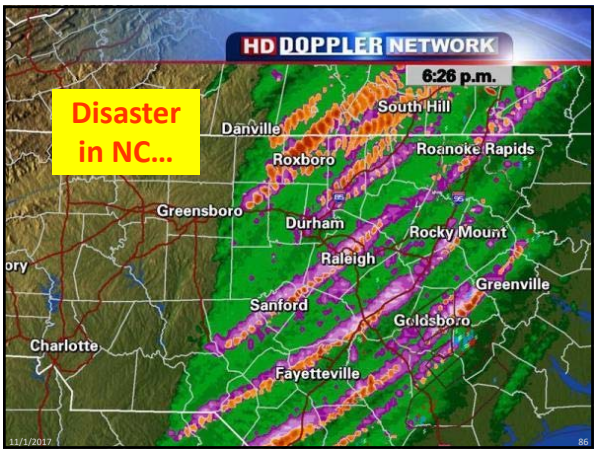
Perspective…

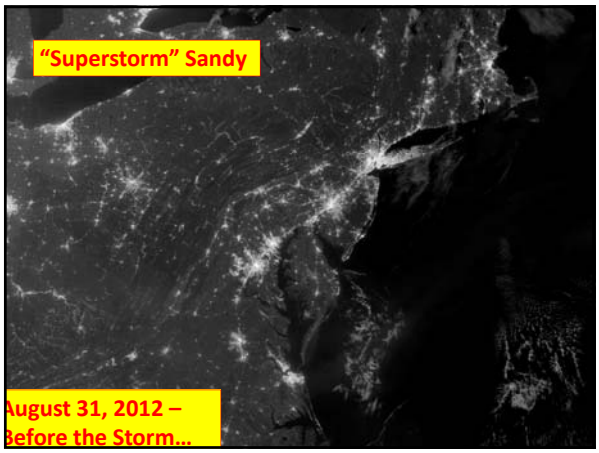
Katrina…

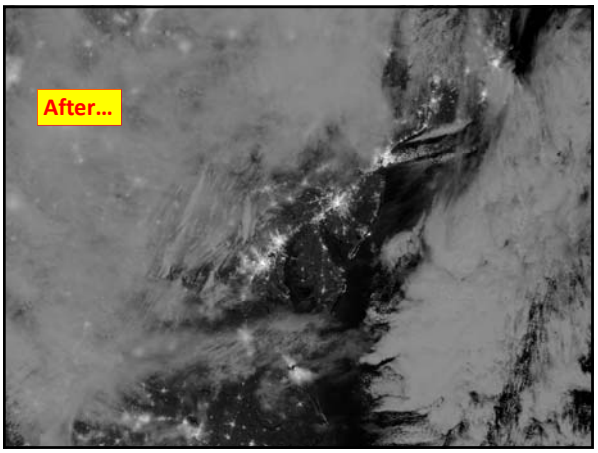
Katrina's Legacy…

- **Hurricane Katrina – 2005**
  - Costliest hurricane in US history – est. $80 billion
  - Over 1300 confirmed deaths
  - 3200 still missing

Following Katrina, Louisiana and Mississippi adopted their first codes…




"Superstorm" Sandy
August 31, 2012 –
Before the Storm…


After…


Route 35/Ocean Blvd
Mantoloking Bridge
August 31, 2012 –
Before the Storm…

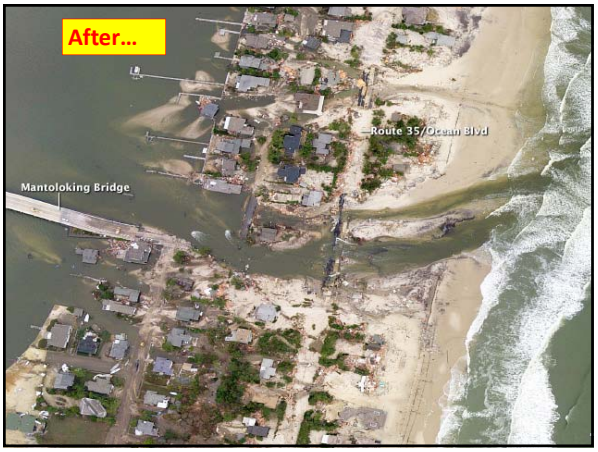

After…
Route 35/Ocean Blvd
Mantoloking Bridge


Photo taken by Iwan Baan

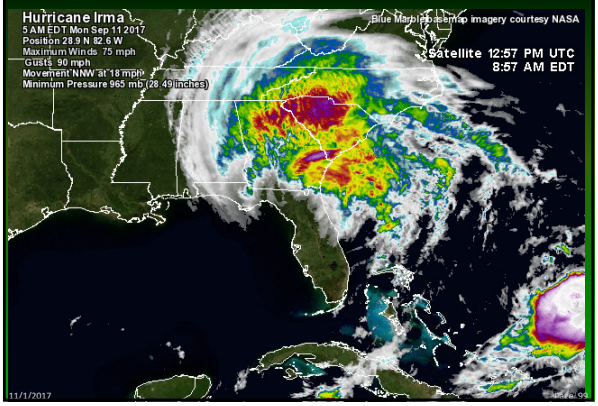

Hurricane Sandy
110 mph wind gusts (Category 1)
Estimated $20-$30 billion damage
>6 million people without power

Perspective:

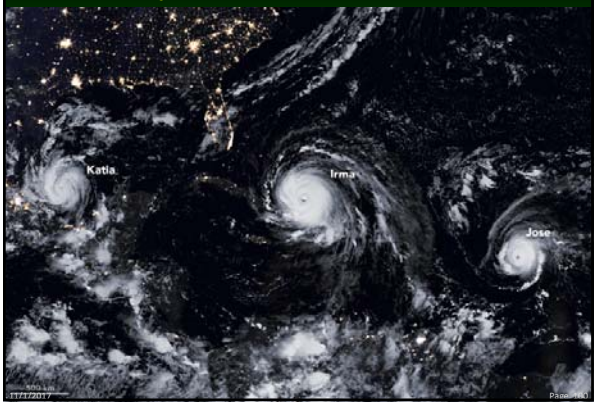
When the grid went down in India, over 350,000,000 people were without power…

Harvey…

Irma…

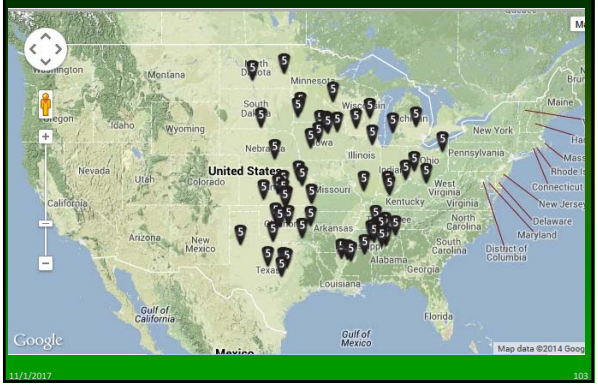


"More Frequent Severe Storm Events…"

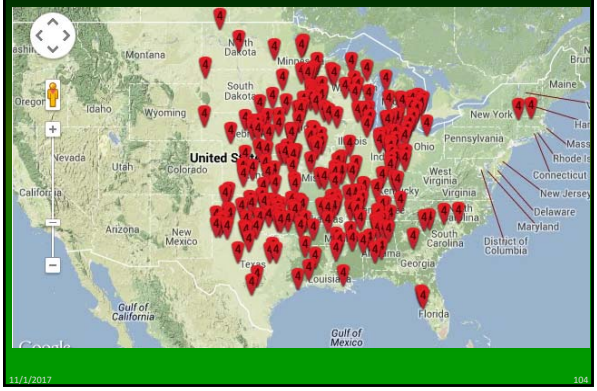


Moore, Oklahoma…

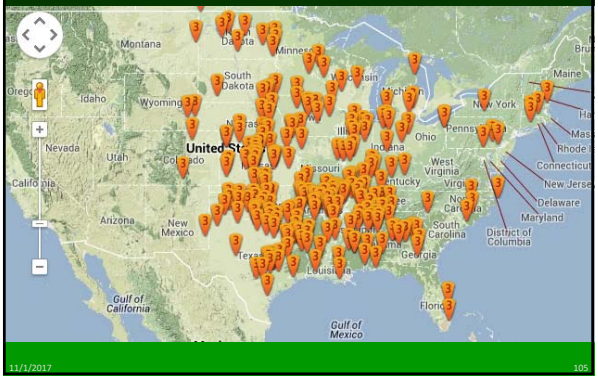
F5 Tornadoes Since 1950…



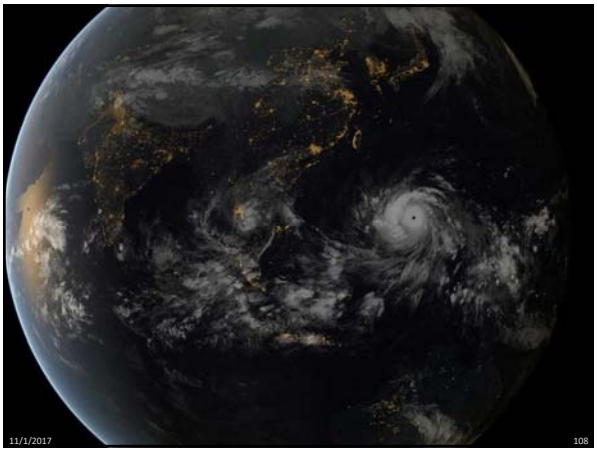
F4 Tornadoes Since 1950



F3s…

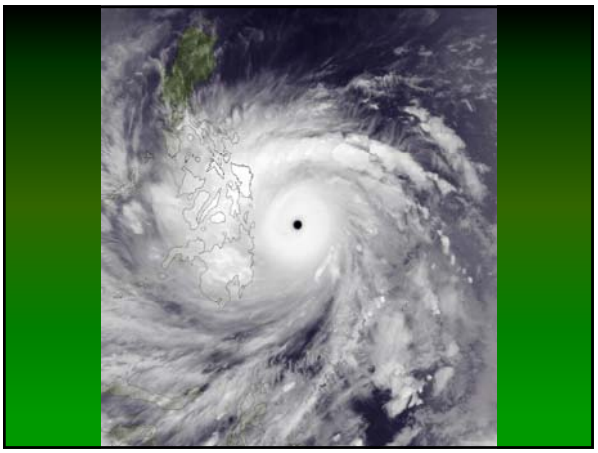


F2s…



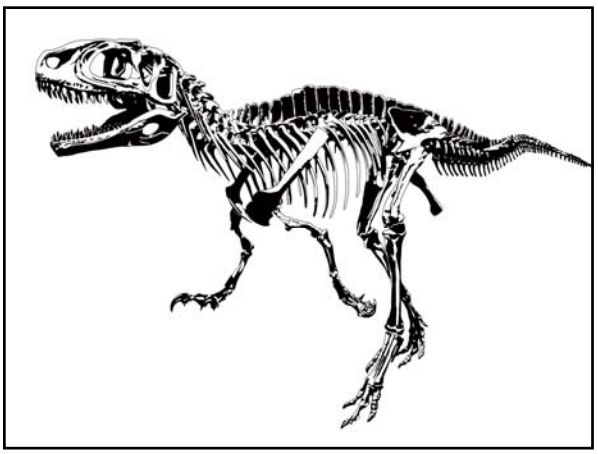
"Super Typhoon" Haiyan: 2013

- **The strongest storm in recorded history**
  - Category 5 Event
  - Sustained winds of over 96 mph for several hours
  - Wind speeds in excess of 260 mph
- **Storm surge alone estimated to be responsible for over 10,000 deaths**
- **The same area experienced 7.1 magnitude earthquake less than a month before…**
- **What lessons will we learn?**



History has shown that we wait for disaster before we act…

There are consequences to waiting…



Our ASHRAE Leadership Role

ASHRAE Mission

To advance the arts and sciences of heating, ventilating, air conditioning and refrigerating to serve humanity and promote a sustainable world.

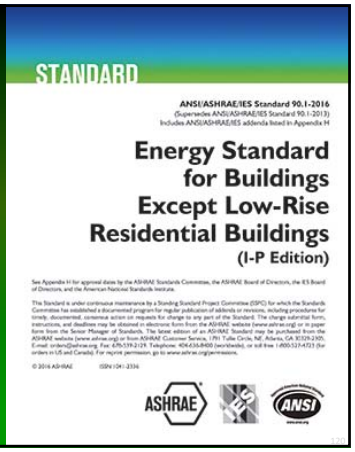
ASHRAE Vision

ASHRAE will be the global leader, the foremost source of technical and educational information, and the primary provider of opportunity for professional growth in the arts and sciences of heating, ventilating, air conditioning and refrigerating.

ASHRAE 90.1

Our Model Energy Code

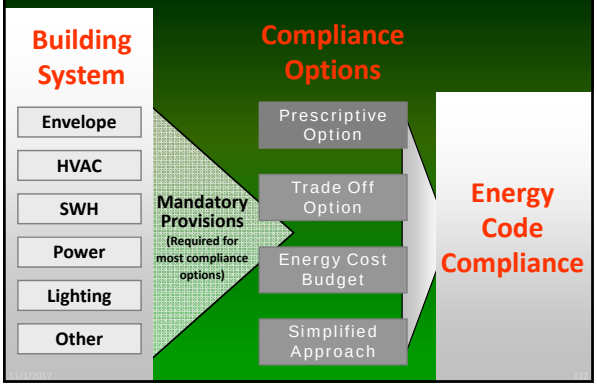
90.1-2016



Our Flagship Standard: 90.1

- The US "Model Energy Code"
  - Referenced in the Energy Policy Act of 1992
  - The Standard against which all state commercial energy codes are evaluated
- Defines the Minimum Energy Efficiency for
  - Commercial buildings
  - High-rise residential
  - Semi-conditioned
- On "Continuous Maintenance"
  - Updated every 3 years
  - Current edition – 2016

Compliance Approaches

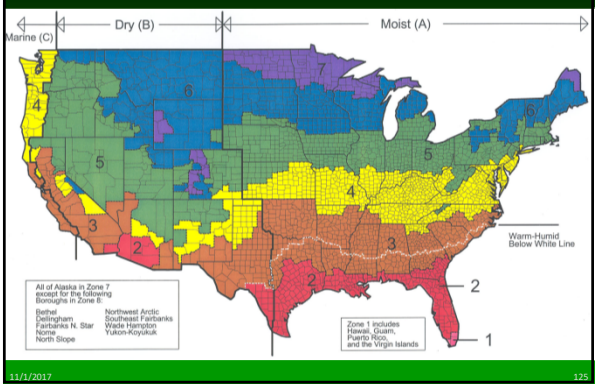


Improvements in EUI: 1975 to Present

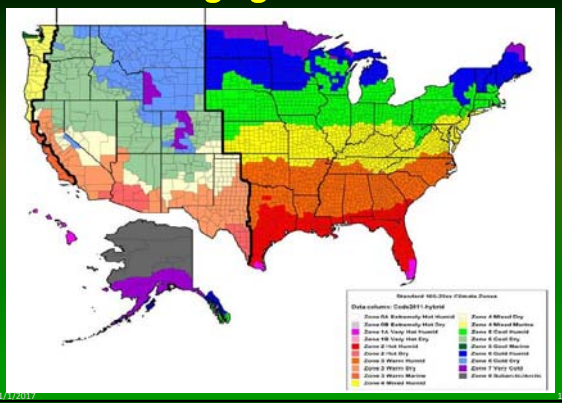
Latest Version of 90.1-2016

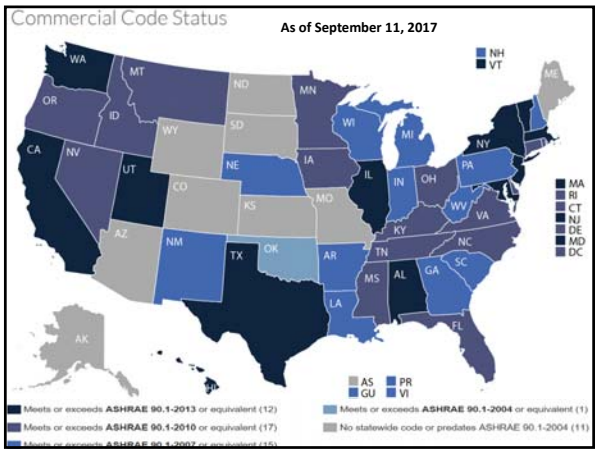
- Published October 2016
- Goal was to be 50% more efficient than 2004
  - Didn't get there most places
  - Some improvements in each climate zone
- A few big changes…
  - Many impact architects and engineers
    - Envelopes, Air sealing, Lighting, Commissioning
  - Pay particular attention to building envelope changes since 2007...

Climate Zones (Current)

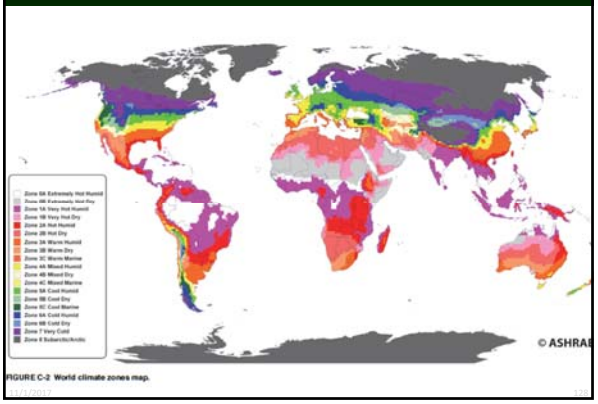


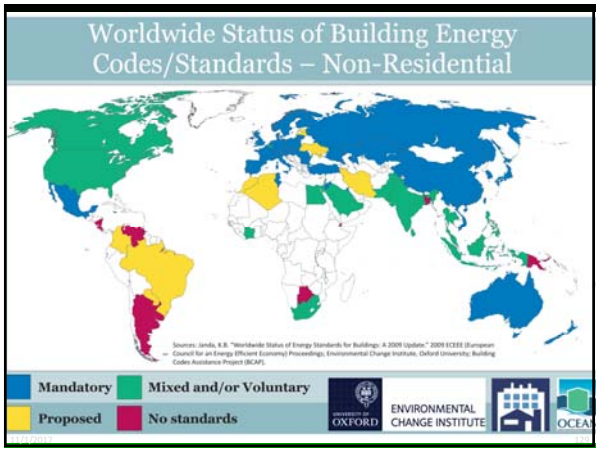
Climates Changing? New Standard 169





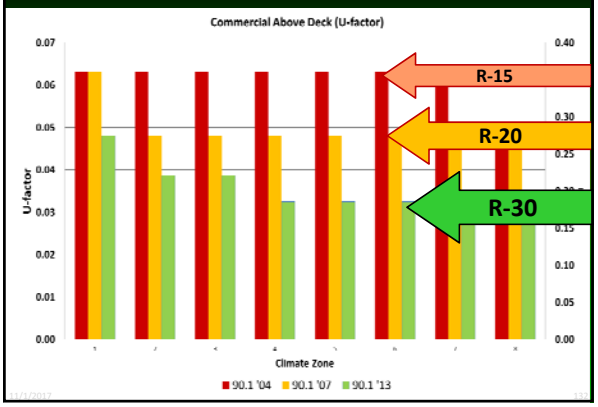
ASHRAE 169-2013



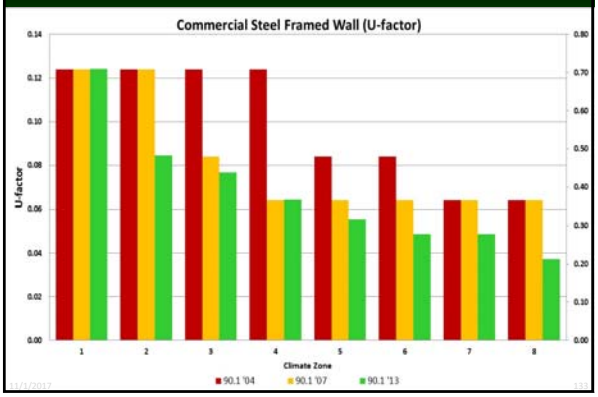


Building Thermal Envelope: Prescriptive Tables and Changes

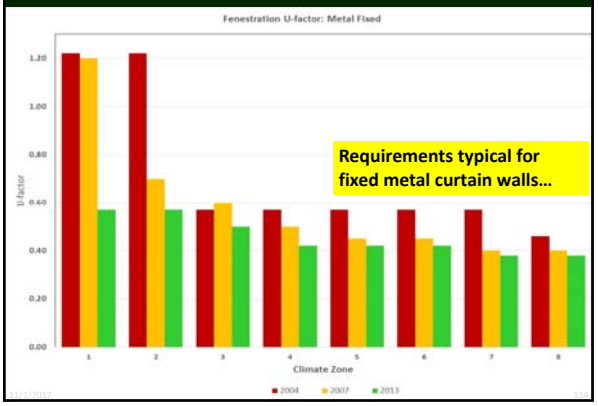
2004 to 2016: Roofs



2004 versus 2016: Walls

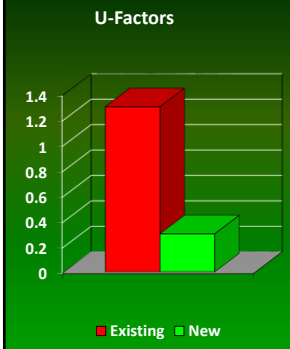


Fenestration U-factor: 2004 - 2016



Requirements typical for fixed metal curtain walls…

Heat Loss (winter)



- Common aluminum-framed, single glazed windows **lose 3 to 4 times** more heat in winter than today's most basic energy efficient technologies
- Cold glass surfaces with recurring condensation
- BIG impact on comfort
- BIG impact on heating costs

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Even with Efficiency Increases…

Compare the Heat Transfer…

	Steel-framed Walls	Curtain Wall (metal, fixed)	
CZ 5	0.055	0.38	6.9 times
CZ 6	0.049	0.36	7.3 times
CZ 7	0.049	0.33	6.7 times

ASHRAE 90.1-2016

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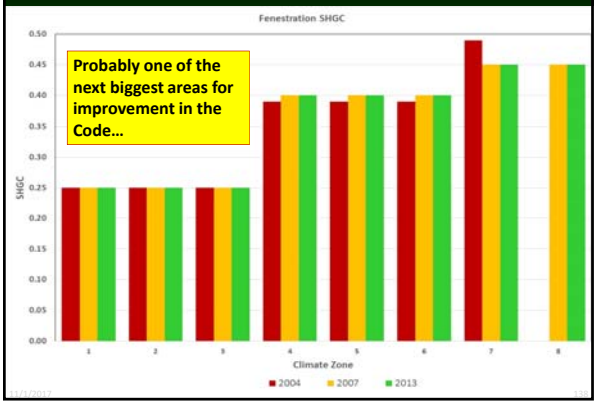
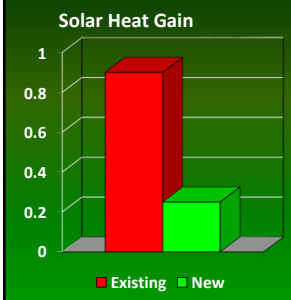
Solar Heat Gain Coefficient



Probably one of the next biggest areas for improvement in the Code…

Heat Gain (summer)



- Air conditioning energy is very expensive
- New window technologies are **over three times** more efficient at blocking unwanted heat gain than common aluminum-framed, single glazed windows
- Windows generally drive the air conditioning load (residential)
- Windows generally determine the perimeter load (commercial)

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Fenestration Decisions Matter!

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Controlling Envelope Air Leakage

- **2004/7 – General language about minimizing air leakage, sealing cracks, specific references to window and door leakage**
- **2010/13 – A FOCUS on controlling and limiting air leakage**
  - Requires a continuous air barrier
  - Lists approved materials and assemblies
  - Revised vestibule requirements, loading docks
- **2016/19 Biggest envelope improvement focus**
  - Air leakage testing or air barrier commissioning
  - Maximum leakage: 0.4 cfm/sq.ft.

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Engineers:

What do these new envelope requirements mean for your load calculations, equipment sizing and selection?

- **Does your favorite architect know about these new (now old) code requirements?**

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Architects:

What do these new envelope requirements mean for your decisions about amount of glass, wall insulation system, and air sealing plans?

- Does your favorite engineer know about these new (now old) code requirements?

Other Major Improvements

- Lighting Power Densities
- Lighting and Daylighting Controls
- Improved Equipment Efficiencies
- Improved Equipment Controls
  - Deadbands, setbacks, off-hour, damper controls, etc.
- Economizers (that actually function)
- Heat Recovery
- Refined Energy Modeling Rules
- Commissioning of Critical Systems - !!

Thinking about those recent load calcs again?

The Code Changes...

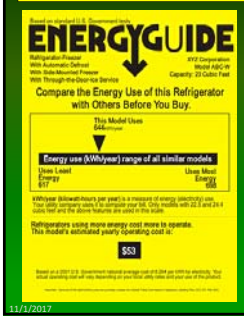
The 70s – "The Insulation Decade"

1970 — 1980

- Oil Embargo 1973
- ASHRAE 1975
- FTC R-Value Rule 1978

The 80s – "The Appliance Decade"

1980 — 1990



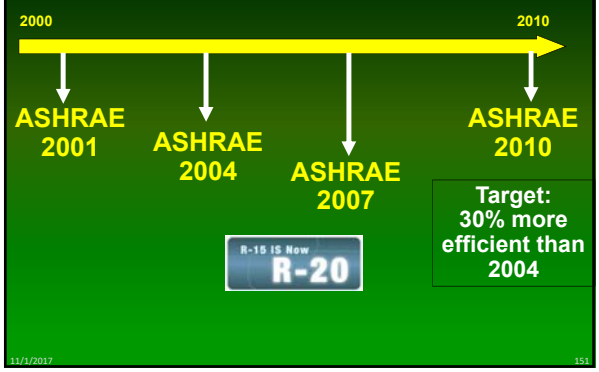
- NAECA 1985
- ASHRAE 1989

The 90s – "The Window Decade"

1990 — 2000

- Energy Policy Act of 1992
- ASHRAE 1999

2000-2010 – "The 30% Decade"



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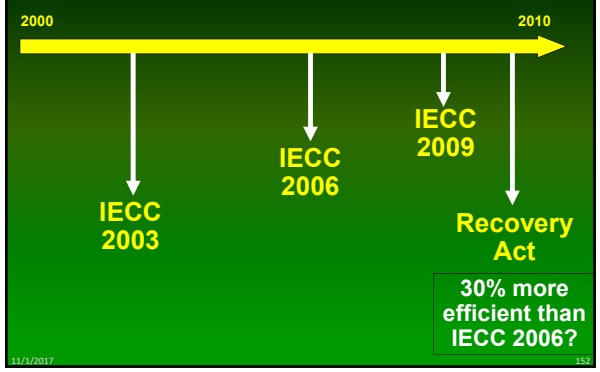
"The 30% Decade" - Residential



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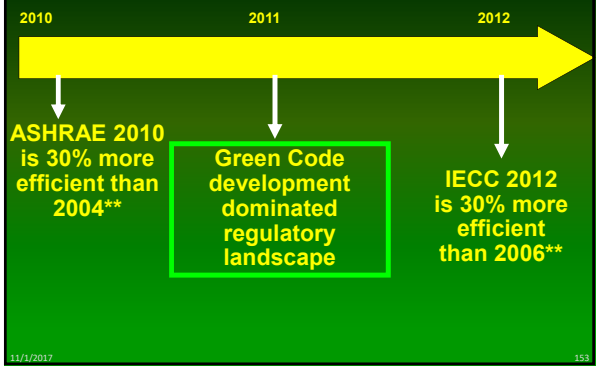
Evolving Regulatory Landscape



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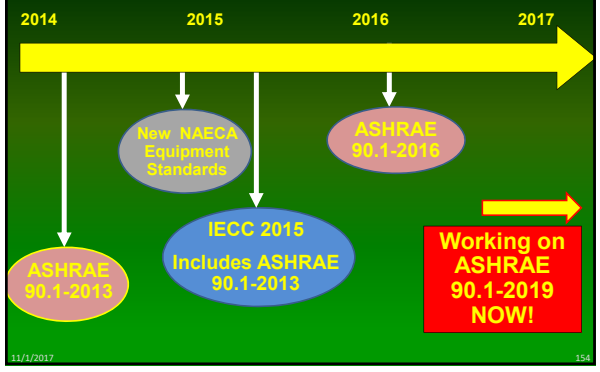
Recent Regulatory Landscape



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What Does the Future Look Like? (1)

- **Better Building Envelopes**
  - The 90.1-2013/16 Envelope tables look very different than 2004 or 2007 or 2010
    - You should already be familiar with these changes
- **Greater focus on reducing uncontrolled air leakage**
  - Continuous air barrier
  - Testing or commissioning
  - (Note: This focus is continuing for the 2019 edition of the Standard)

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What Does the Future Look Like? (2)

- **More daylighting and daylighting controls**
  - Better management of fenestration heat gain
  - Greater visible light availability and utilization
  - More sophisticated controls
- **Improvements to HVAC Systems**
  - Equipment efficiencies
  - Commissioning critical syatems and controls
- **Expansion to More Climate Zones**
  - Climate Zone zero!

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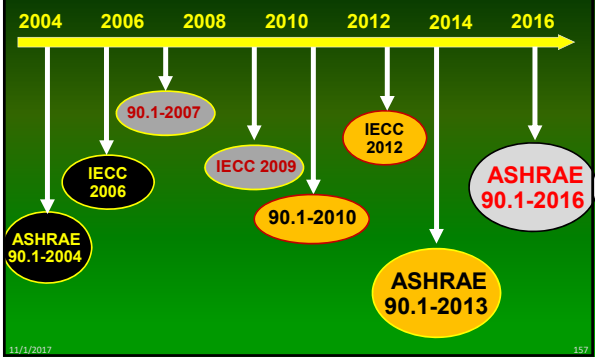
Where is Your Code Now?



Think About What We Are Building...

Think About What We Are Building...

How much energy? For how long?

What are our responsibilities as knowledgeable building professionals?

Recap: What is the Code?

- Least safe…
- Least strong…
- Least energy efficient…

…building allowed by law.

We're not allowed to build it any crappier…!

What the Code is NOT

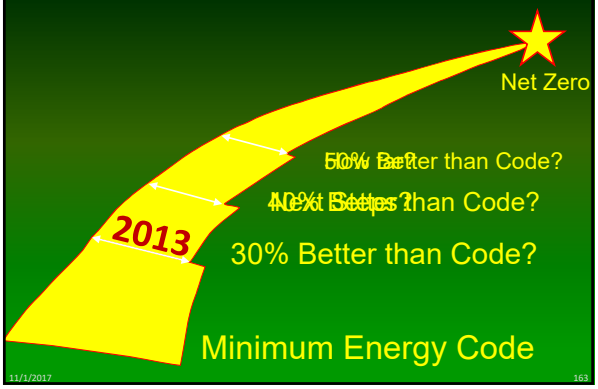
- Not leading edge
- Not superior performance
- Not exemplary
- Not green
- Not sustainable
- Not differentiating

It is the starting point for all differentiation…

The Starting Point for

- Energy Star
- LEED
- Green Globes
- Building America
- Houses That Work
- And every other "beyond code" program…

The Road to "Net Zero"



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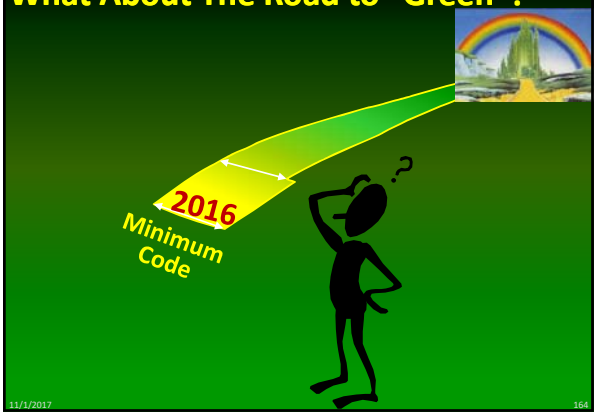
What About The Road to "Green"?



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Everybody Wants to be Green…

- ASHRAE 189
- ICC International Green Construction Code

- "It ain't easy…"
  - Standards
  - Ratings
  - Metrics
  - Boundary Conditions
  - How long?

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Example Problems with "Green"

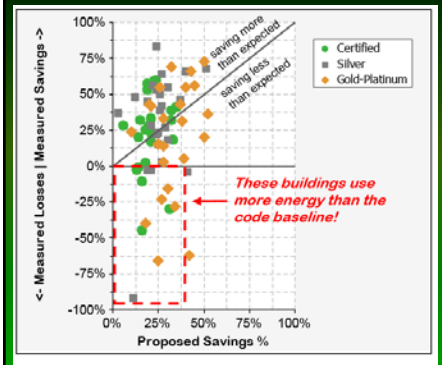

Figure 20: Measured versus Proposed Savings Percentages

LEED

Measured vs. Proposed Energy Savings

Source: Source: New Buildings Institute/USGBC's energy performance of LEED for new construction buildings

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What About Those Other Objectives?

- Durability?
- Resilience?
- IEQ?
- Comfort?
- Water Savings?
- Carbon?

- For how long?

- Are we appropriately engaged in the important long-term decision-making?

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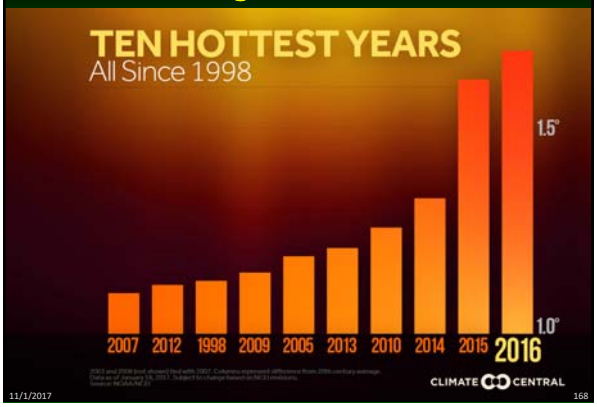
Sometimes change doesn't wait on us…



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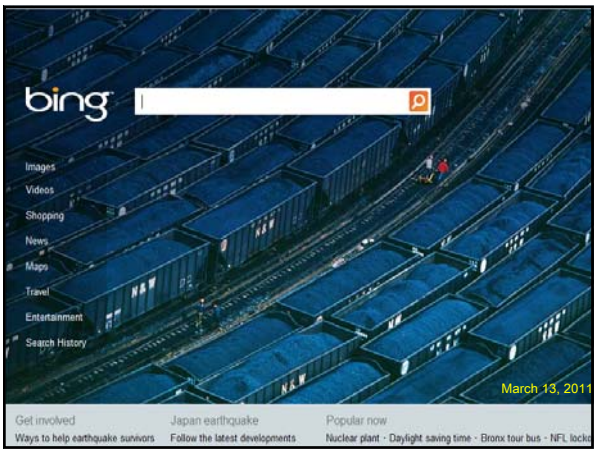
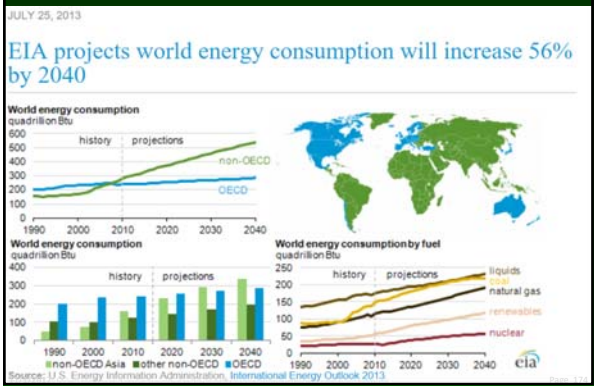
Our Leadership Responsibility

- **Get engaged!**
  - Get engaged in local code adoption and compliance
  - Support local building performance education
  - Collaborate! Architects, Building Officials, Developers, Product Suppliers, etc.
- **Commission Stuff!**
  - Envelopes, HVAC, Lighting systems, Controls
- **Measure stuff!**
  - Leakage, comfort conditions, air flows, radiant asymmetry, water use, energy use, etc.
- **New and Existing Buildings!**
  - Commercial AND Residential



Recent Scary Numbers



The End in Mind

- **Buildings Matter!**
  - It is up to knowledgeable building industry professionals to deliver this message.
- **Major Trends Impacting Building Decisions**
  - Environmental Trends
  - Human Expectation Trends
  - Population, Water, Power…
- **The Latest Energy Code**
  - The Starting Point for Building Performance
  - Major Implications for Building Professionals
  - Critical Step in Building Industry Leadership

Thank You!

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