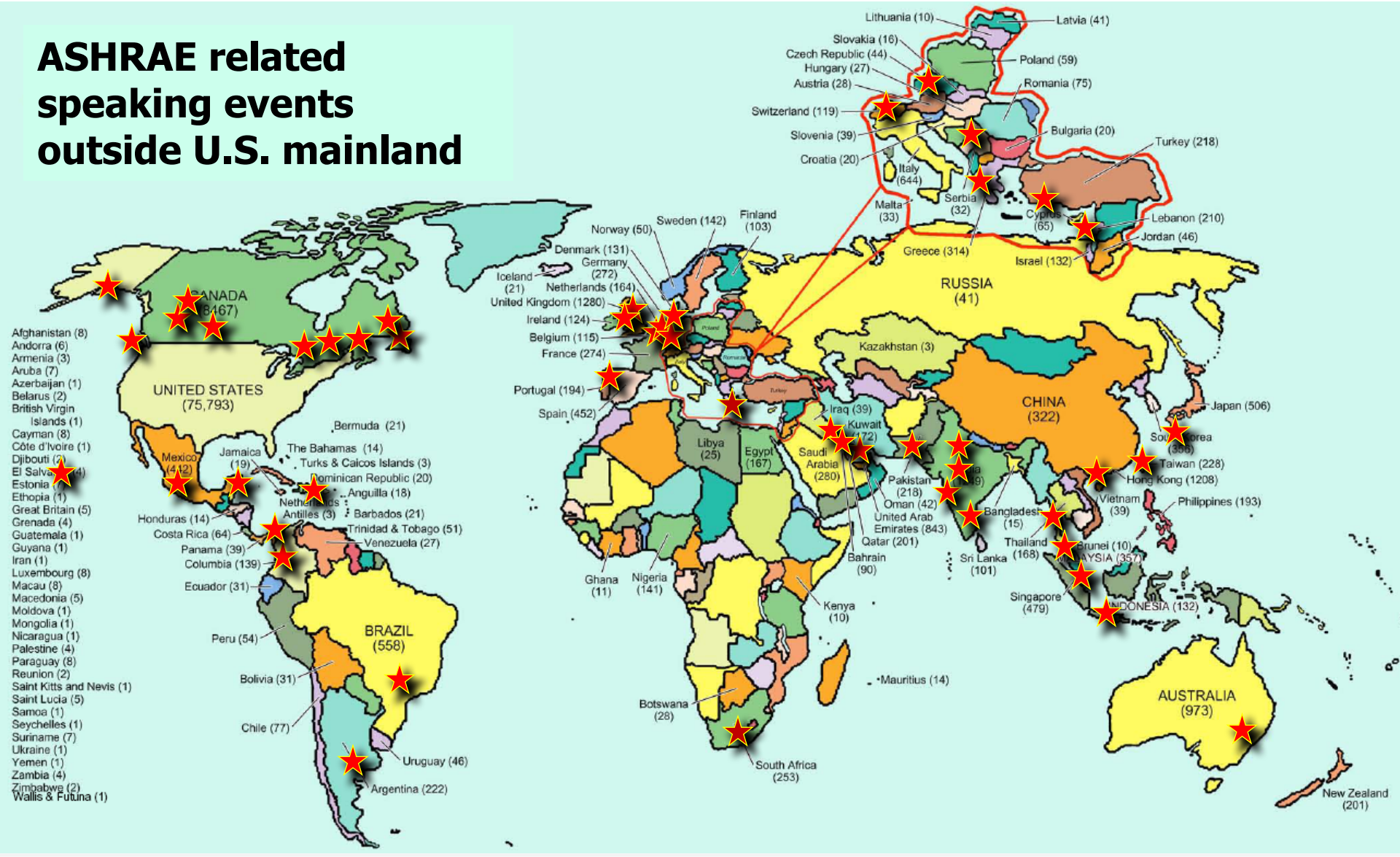
# HIGH PERFORMANCE BUILDING DESIGN: WHAT THE FUTURE HOLDS FOR THE DIRECTION FOR OUR INDUSTRY

Dr. Tom Lawrence, PE, LEED®-AP, F. ASHRAE
lawrence@engr.uga.edu

ASHRAE

College of Engineering
UNIVERSITY OF GEORGIA

# ASHRAE related speaking events outside U.S. mainland




**High Performance Green Buildings and related topics are becoming a big focus around the globe**

# Introduction and Topics Covered

- What is a “high-performance” building?
- Steps toward net-zero energy buildings
  *and consideration for more than just energy*
- What future trends might be in store
  - Smart grid, smart buildings
  - “Future proofing” the design
  - Resiliency
  - Performance versus promise

# HIGH-PERFORMANCE BUILDING DESIGN: GENERALIZATIONS

# What is a High-Performance Green Building, Anyway?

- Low energy consumption?  (Nearly Net-Zero?)
- Low water consumption?
- High return-on-investment for the owner?
- “Performance” of the occupants?
- The building’s impact on the surrounding locality (performance of its “neighbors”)?
- Smooth operations and maintenance?
- Does it make the cover of a famous architectural magazine?

# What is a High-Performance Green Building, Anyway?

*'High-performance building' means a building that integrates and optimizes on a life cycle basis all major high performance attributes, including energy conservation, environment, safety, security, durability, accessibility, cost-benefit, productivity, sustainability, functionality and operational considerations.*

***U.S. Energy Independence and Security Act, 2007***

# What is a High-Performance Green Building, Anyway?

***Sustainability is not sustainable, unless it is cost competitive.***

***Cost competitive is a vague term and can be interpreted many ways …***

# How Green Building Practices Evolved

- Guidelines
  - Suggestions for design (ASHRAE Advanced Energy Design Guides, CIBSE Guides A-M)
- Rating systems (BREEAM, LEED)
  - Generally voluntary, match design to specific credits
- Standards
  - Criteria recognized as meeting acceptable requirements for a level of performance
- Codes and Reporting
  - Legally enforcable, minimum criteria

# Future Trends

- **In U.S. -** ASHRAE Standard 189.1 and IgCC will merge in 2018
  - 'Unofficial' goals for cost-effective nearly net zero
- **In EU** – (EPBD)
  - 2020 goals of 20%🡻 in GHG emissions (1990 base); 20% share of renewable energy and 20% 🡹 overall energy efficiency
  - Setting goals for 2030 of 40%🡻 in GHG emissions; 27% share of renewable energy and 27% 🡹 overall energy efficiency

**Comparison**

- EU: More overall focus on energy, more stringent
- US: Overall, whole building approach (+ indoor air quality, water efficiency, materials, etc.)

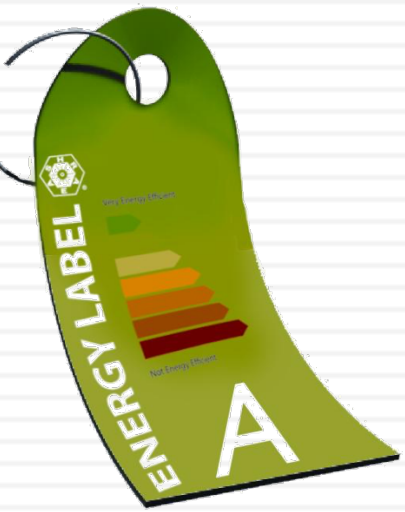
# NET-ZERO ENERGY BUILDINGS

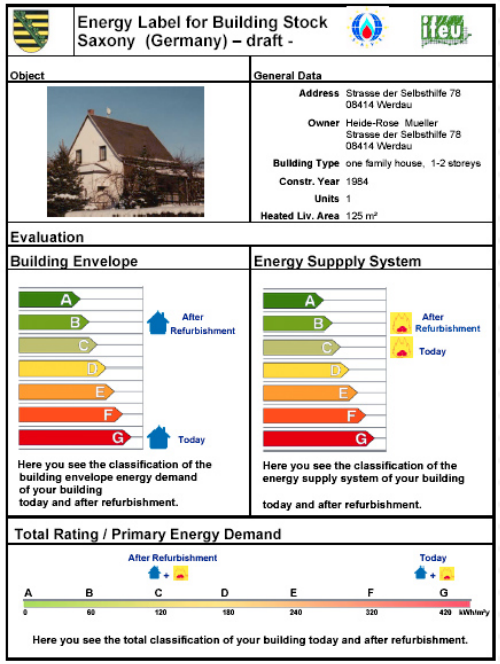
***Or Net-Zero Energy Communities?***

# Defining Net-Zero Energy Buildings (NZEBs)

- What qualifies a building as Net-Zero?
  - Multiple ways to quantify building energy performance
  - Multiple ways to quantify energy sources

**Need common quantifiable metrics to compare NZEBs**




# What is EUI, NEUI?

$$\text{Total Energy Use Intensity (EUI)} = \frac{TotalAnnualEnergyUse}{GrossFloorArea} \text{ kBtu/ft}^2\text{ yr (kWh/m}^2\text{ yr)}$$

$$\text{Net Energy Use Intensity (NEUI)} = \frac{NetAnnualEnergyUse}{GrossFloorArea} \text{ kBtu/ft}^2\text{ yr (kWh/m}^2\text{ yr)}$$

**Total Energy = All energy consumed in this building annually**

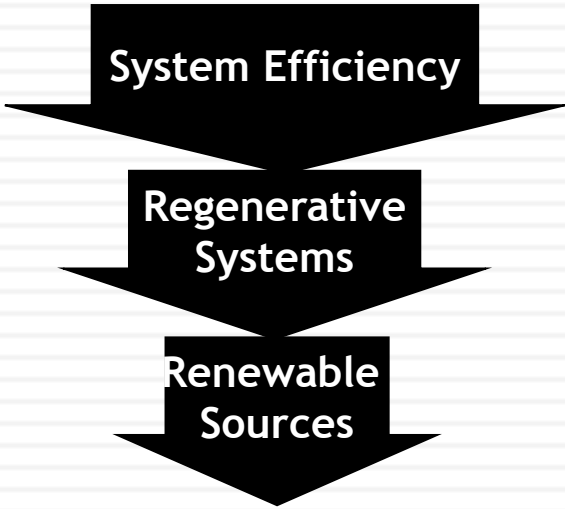
**Net Energy = Total Energy - Amount generated by on-site renewable energy systems**

***Source: ASHRAE Technology Council Ad Hoc Committee on Energy Targets (June 2010)***

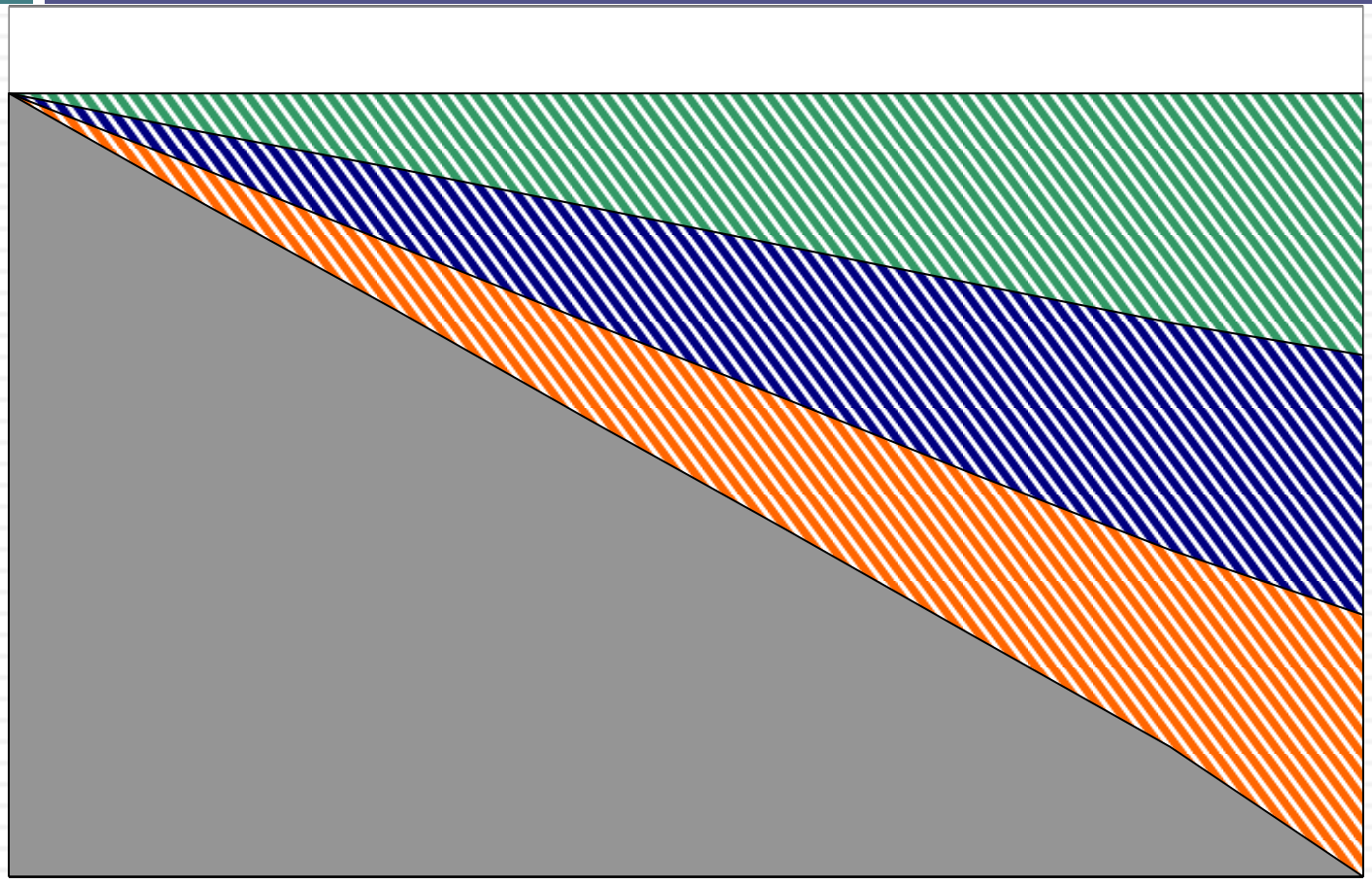
# Energy Efficiency and Renewables

## The 4-Rs

- **Reduce: First, limit amount required**
- **Reuse: Look for potential energy recovery opportunities**
- **Renewables: Only then include on-site renewable energy systems**
- **Rethink: The design process (actually is FIRST!)**




# Three Steps or "Wedges"



# Some Common Characteristics of (Nearly) Net-Zero Energy Buildings

- Shape, orientation, thermal mass
- Envelope improvements
- Daylighting – Shading; Lighting Efficiency
- ***Efficient ventilation*** ✓
- Energy recovery, pre-heating or cooling
- Good solar (or other renewable) resource
- Occupant "buy-in" and cooperation
- Incentives/mandates to make it net-zero
- Integrated design, sufficient design/analysis resources

# Some Common Characteristics of (Nearly) Net-Zero Energy Buildings

- Shape, orientation, thermal mass
- Envelope improvements
- Daylighting – Shading; Lighting Efficiency
- Efficient ventilation
- ***Energy recovery, pre-heating or cooling*** ✓
- Good solar (or other renewable) resource
- Occupant "buy-in" and cooperation
- Incentives/mandates to make it net-zero
- Integrated design, sufficient design/analysis resources

# Some Common Characteristics of (Nearly) Net-Zero Energy Buildings

- Shape, orientation, thermal mass
- Envelope improvements
- Daylighting – Shading; Lighting Efficiency
- Efficient ventilation
- Energy recovery, pre-heating or cooling
- ***Good solar (or other renewable) resource*** ✓
- Occupant "buy-in" and cooperation
- Incentives/mandates to make it net-zero
- Integrated design, sufficient design/analysis resources

# Some Common Characteristics of (Nearly) Net-Zero Energy Buildings

- Shape, orientation, thermal mass
- Envelope improvements
- Daylighting – Shading; Lighting Efficiency
- Efficient ventilation
- Energy recovery, pre-heating or cooling
- Good solar (or other renewable) resource
- ***Occupant "buy-in" and cooperation*** ✓
- Incentives/mandates to make it net-zero
- Integrated design, sufficient design/analysis resources

# Some Common Characteristics of Net-Zero Energy Buildings

- Shape, orientation, thermal mass
- Envelope improvements
- Daylighting – Shading; Lighting Efficiency
- Efficient ventilation
- Energy recovery, pre-heating or cooling
- Good solar (or other renewable) resource
- Occupant “buy-in” and cooperation
- Incentives/mandates to make it net-zero
- Integrated design, sufficient design/analysis resources ✓

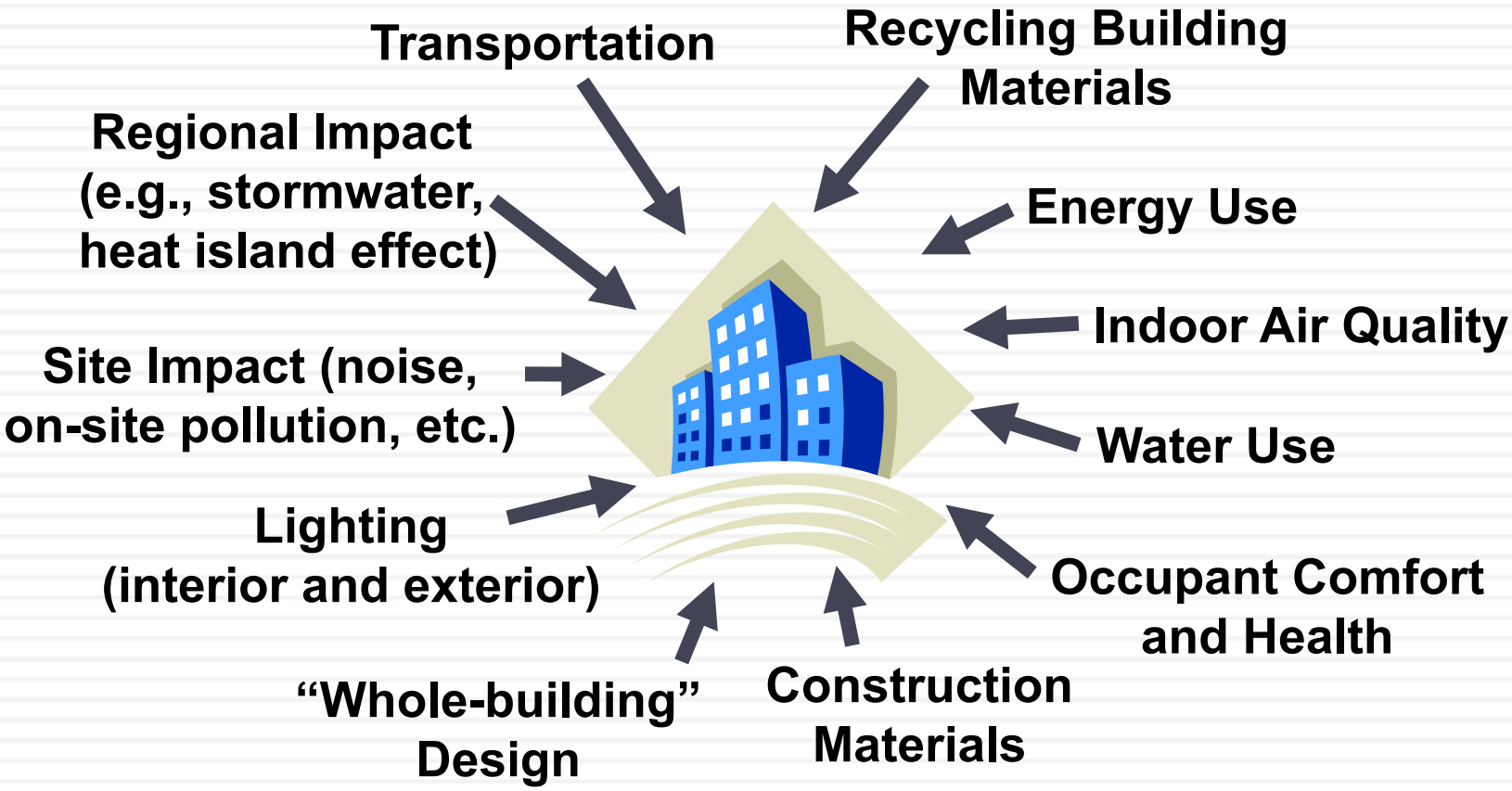
# Location Does Matter

- Climatic “sweet spots”
  - San Francisco versus Chicago in the U.S.
  - Marseille versus Prague
- Dense urban high-rise versus low density, low-rise development

# HIGH PERFORMANCE IS NOT JUST NET-ZERO ENERGY!

*Moving beyond that simple way of thinking*

# Issues Involved in High Performance, Green Buildings

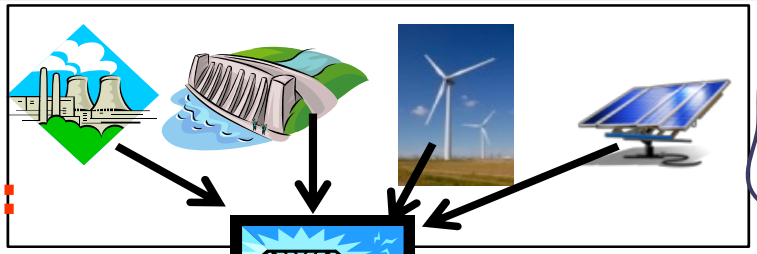


# SMART GRID, SMART BUILDINGS AND DEMAND RESPONSE MANAGEMENT

# What is the "Smart Grid"?

- Modernized electrical grid using information and technology to more efficiently produce, transmit and use electricity
- Each sector of the electricity supply chain has different goals and objectives for the smart grid

# The Grand Challenge



Electricity generation, and the "smart-grid"

Renewable: Some initial work on integration

Utilities: Good development so far

Prior (*solid line*): Power

New (*dashed line*): Power , information exchanged - sensitized objects, smart grid and information system

INFORMATION SYSTEM

*Human interaction and control*

*On-site renewable energy, combined heat/cooling/power systems*

*Sensor and flow networks*

BUILT ENVIRONMENT


Energy using devices:
"The Internet of Energy Things"

*Sensitized objects*

Built Environment: LOTS OF WORK STILL

# Vision for Model Predictive Control

*Smart grid interaction, such as demand response requests*

**Recent historical data and current day operation:**
- Real time energy price
- Weather
- Building loads
- Energy storage
- Renewable energy production

**Forecast Data [Source]:**
- Real time price [Model predicted]
- Weather [Forecast]
- Building loads [Energy models]
- Building occupancy [Scheduling]
- Human Factors and Thermal comfort impacts [Modeling]
- Renewable energy production [Correlation model]

**Model Predictive Controller**

**Recommended System Operation (today and the coming 24-48 hours):**
- HVAC System Setpoints, Schedules

***Goal is to minimize:***
- Cost to operate
- Total energy consumption
- $CO_2$ footprint
- Negative impact on thermal comfort, other operations

**Energy Systems & Buildings Operations**

***Current operation status***

***Current operation status (for adaptive learning)***

**System Monitoring**

***Fault Detection and Diagnostics***

***Feedback to refine model predictions (adaptive learning)***

***Feed forward model inputs***

***MPC output; system operation inputs***

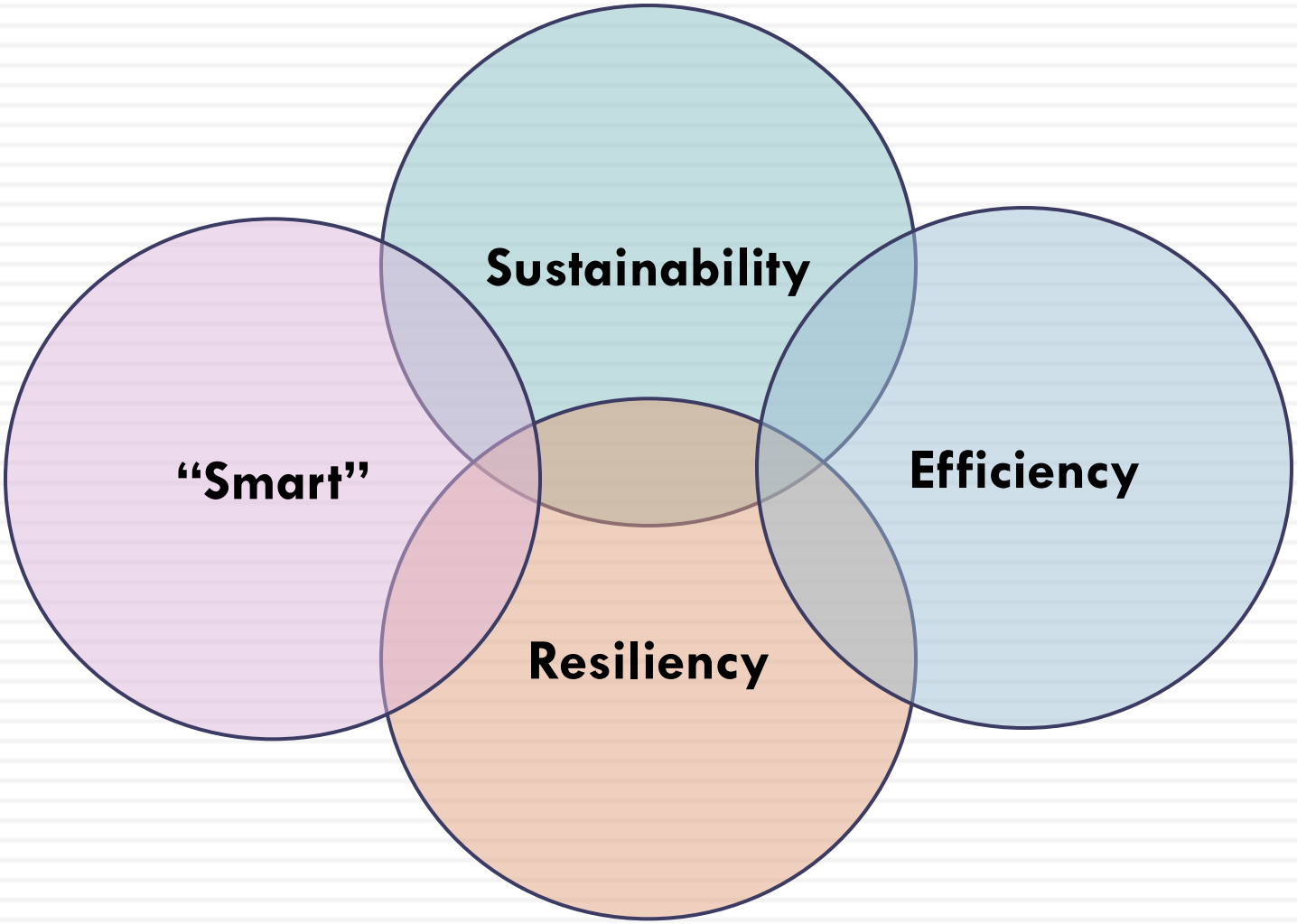
# From Smart Grid to a Neural Grid?

- Smart Grid 1.0
  - Some pockets of connectivity
- Currently evolving into Smart Grid 2.0
  - Widespread connectivity, communication and automation (building systems evolving in parallel)
- Future neural grid (and buildings?) 3.0
  - “Everything Belongs”
  - Distributed energy assets and generation, storage
  - Cloud based AI evaluation, control
  - Self-healing and learning

# Human Factor Considerations

- Thus far, development of smart grid, smart buildings has focused on larger industrial or commercial scale technologies
- But it is human beings who will interact and control this technology
- Smart grid concepts are also coming (or could be coming) to developing countries as well, without the evolutionary aspects as in U.S.

# Sustainability, Resiliency, Efficiency and "Smart" – The Interrelationship



# Monitoring in Smart Grid can Improve Recovery Time

- Utilities can detect and address grid outages

## New Smart Grid Means Fewer Outages For Georgia Power Customers

Georgia Power announced investments in "smart grid" technologies which can help avoid 17 million minutes of potential power outages.

By De Castillo (Patch Staff) - Updated August 31, 2016 2:50 pm ET

**My house after Trop. Storm Irma, Sept. 11, 2017**

# IAQ benefits are worth more than energy savings



- Value of the health and productivity of building occupants can be more than an order of magnitude greater than the cost of the energy it consumes
- **Annual energy cost: USD $10 - $30/m$^2$**
- **Annual functional costs: USD $800 - $6000/m$^2$**

# Developing a High-Performance Building

- "Future proofing" if possible
  - Changing climate
  - Changing energy systems
  - Changing demographics

# Monitoring, Measurement and Verification

- During building design process, you only can ensure the following:
  - Tools are in place to do necessary monitoring (design for disaggregation and monitoring)
  - Operational planning is done (what and how)

# Thank you!

- Comments, questions, concerns, advice …

**Dr. Tom Lawrence, P.E., LEED®-AP, F. ASHRAE**

**lawrence@engr.uga.edu**