

THE COMING AGE OF A SMART GRID AND SMART BUILDINGS

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Course Description

The smart grid is arriving rapidly, and with new era buildings will be interacting even more with the electric utilities. The communication will be in both directions, as the utility works to balance the grid supply and demand in collaboration with their customers through methods such as signaling requests for demand response measures, real-time price adjustments, etc. This is a new and evolving field and, while there are some differences in the need for and how a smart grid might function in the various regions of the world, there are some common factors as well. This seminar provides an overview of the smart grid particularly as it relates to buildings and their systems.

Learning Objectives

- Understand the concept of a smart grid and the purposes for why this is being developed
- Describe key methods on how a building can participate in electrical demand response programs
- Recognize how demand response measures are being incorporated into high-performance green building standards and rating systems
- Understand the role of HVAC systems in implementing demand response programs and some of the issues to watch for in demand response implementation.
- Identify some of the issues that building system designers need to consider in creating a smart building capable of interacting with a smart grid.

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The Coming Age of a Smart Grid and Smart Buildings

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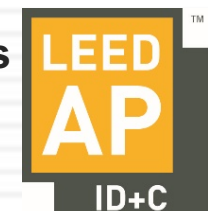
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General CE hours



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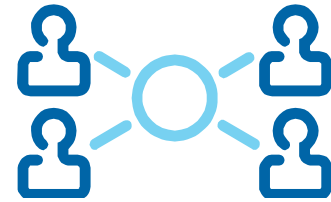
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Give Back to ASHRAE



GROW



NETWORK

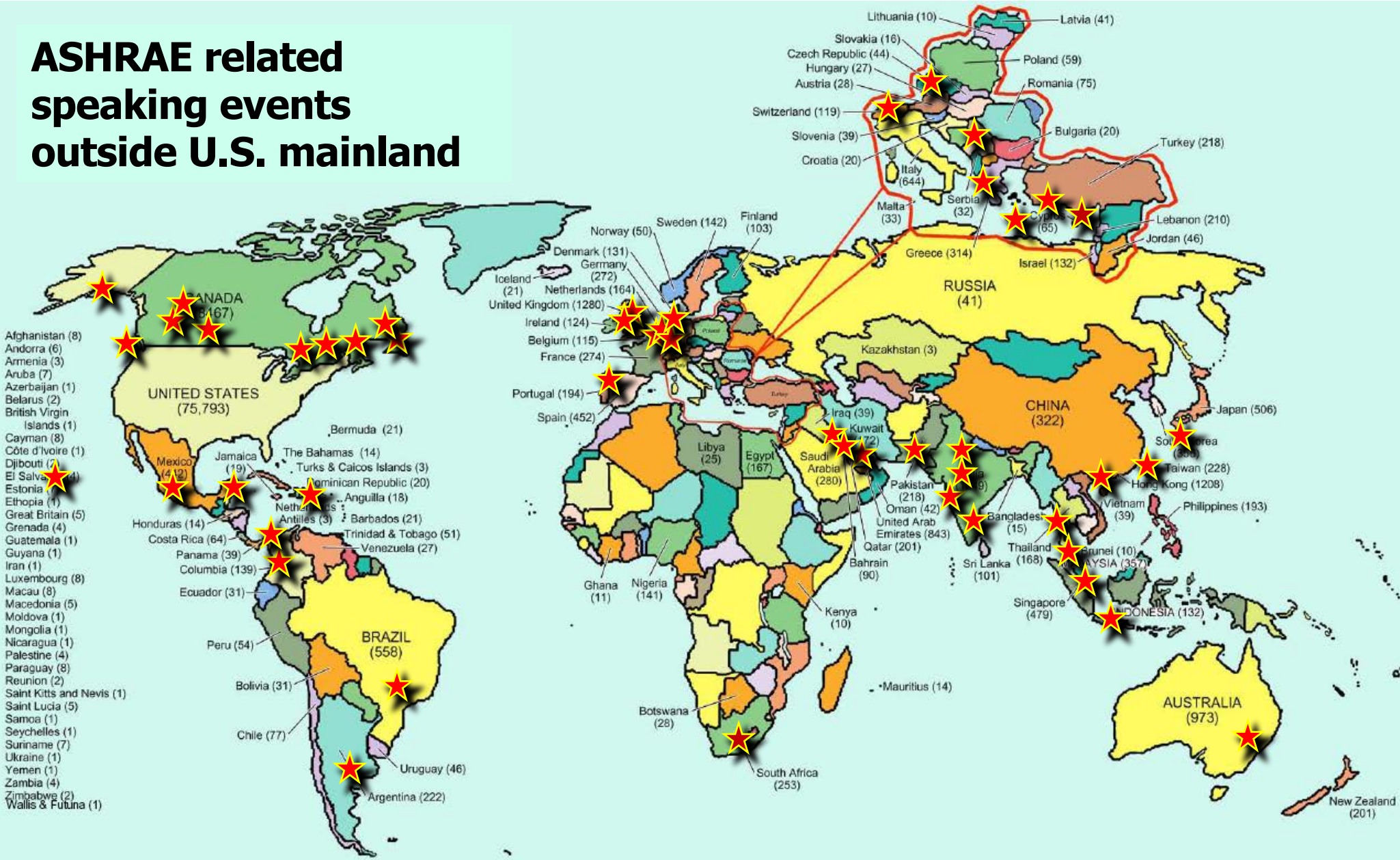
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Topics Covered

- What is the smart grid and a smart building?
- The Grand Challenge of a smart grid integration
- Demand response and methods buildings can implement demand response
- Smart aspects that increase overall resilience
 - ▣ Smart buildings, fault detection & diagnostics
 - ▣ Microgrids
 - ▣ Renewable energy, distributed generation integration
 - ▣ Monitoring
 - ▣ A future “neural grid”?
- Other issues and observations

Smart Grid: Definition and Composition

What is the “Smart Grid”?

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- 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
- A “smart grid” could also apply to other utility supplies (natural gas, fuel oil, gasoline, water) where smart controls can help alleviate disruptions

Why Should I Care?

As an ASHRAE, CIBSE or related similar society member, this is important because...

- ▣ The “smart grid” (in some form) is here regardless
- ▣ Buildings (commercial and residential), as well as industrial, will be affected in the future
- ▣ Building systems such as HVAC and lighting will be most involved with communicating energy use and adjusting demand based on the grid requirements
- ▣ It potentially opens up a new discipline specialty beyond just “energy efficiency” to “load management”
- ▣ Equipment and software suppliers already are converting their products

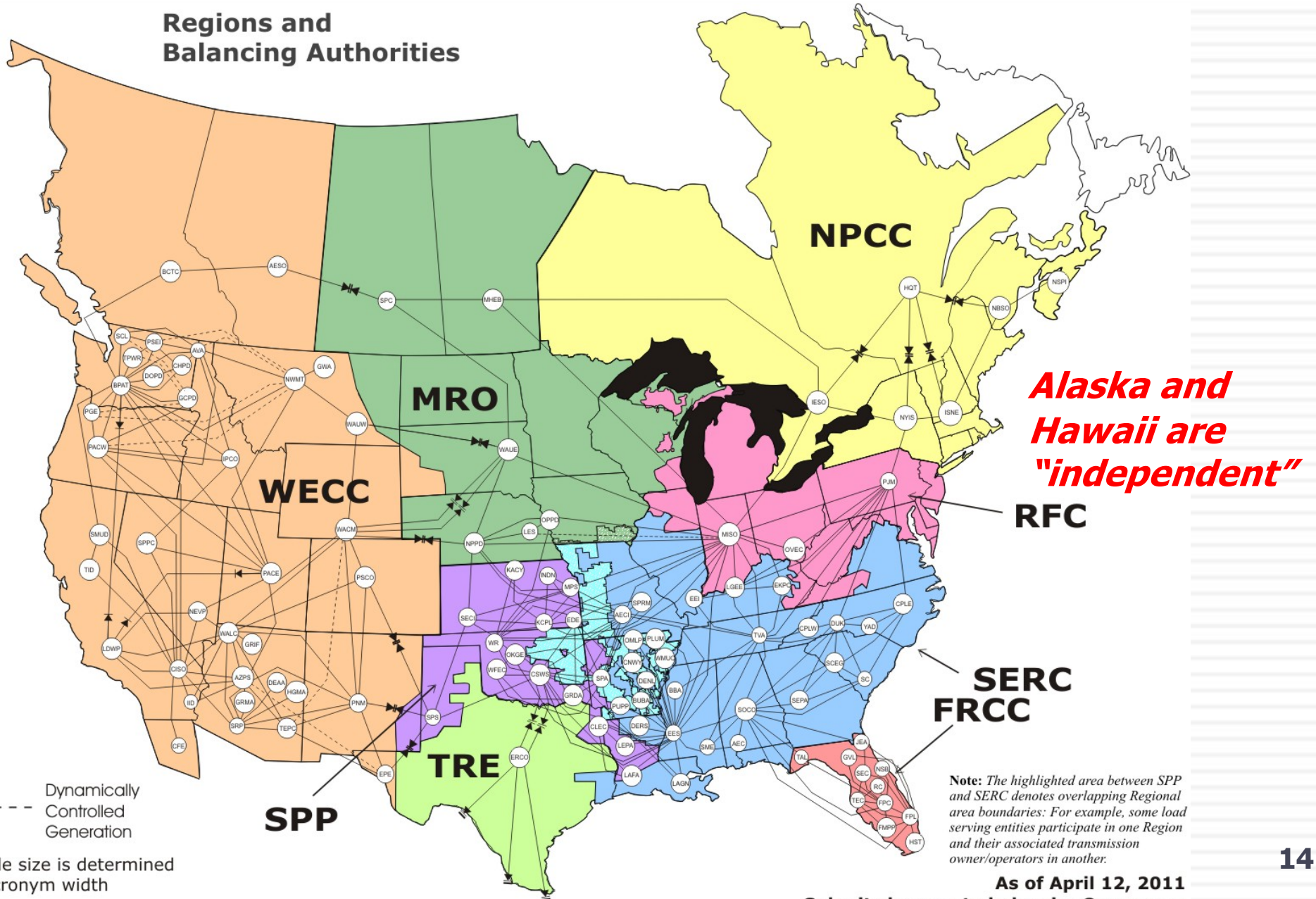
Smart Grid Components

(Already Here in Some Form)

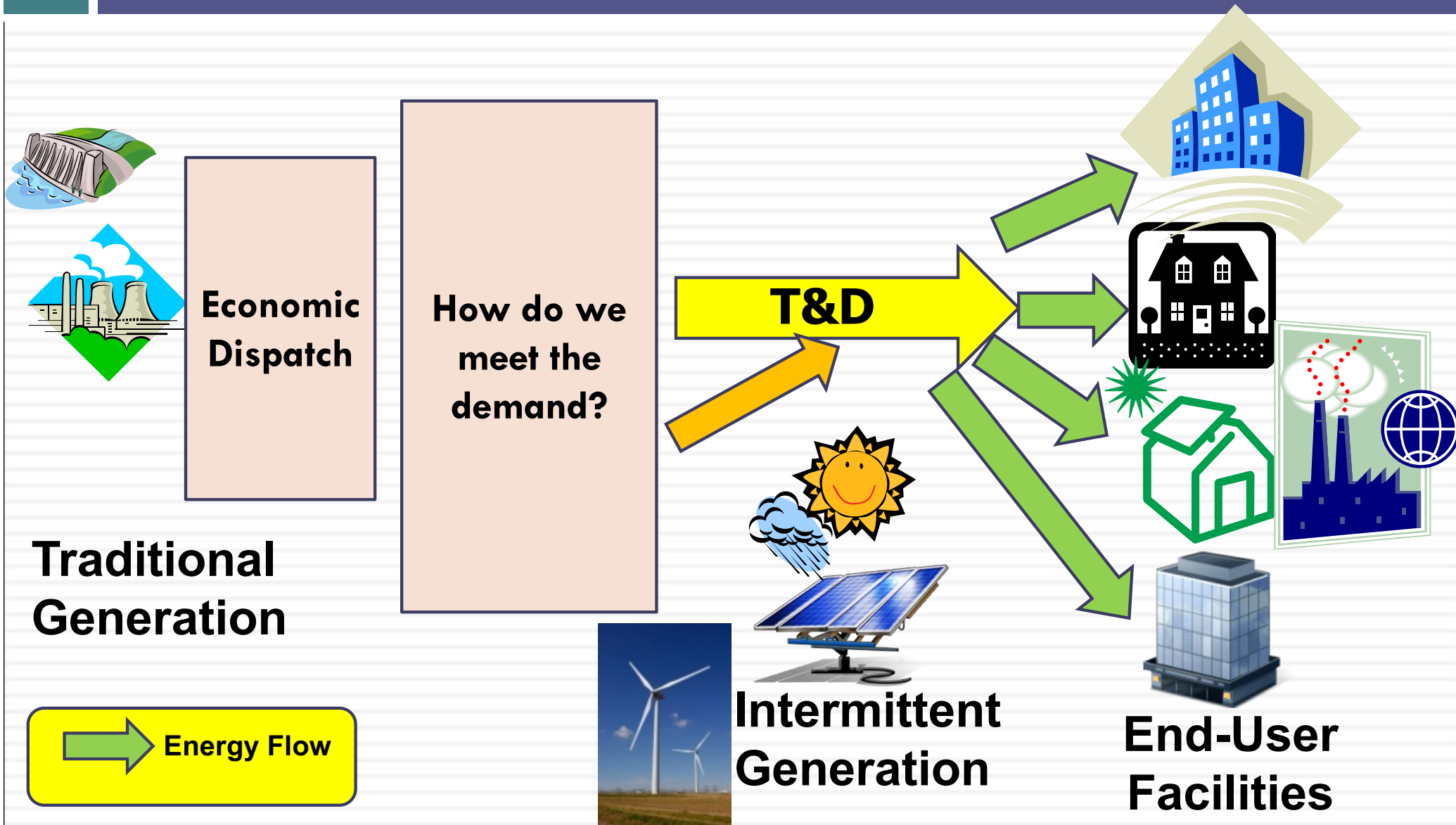
- Smart meters
- Two-way communication between utility and users (devices/buildings/industrial/transportation)
- Grid management logic and software
- Demand management logic and software
- Information flow, technology
- Load management through energy storage, use scheduling
- “Smart” end-use equipment or appliances

The U.S. and Canadian Electric Grid

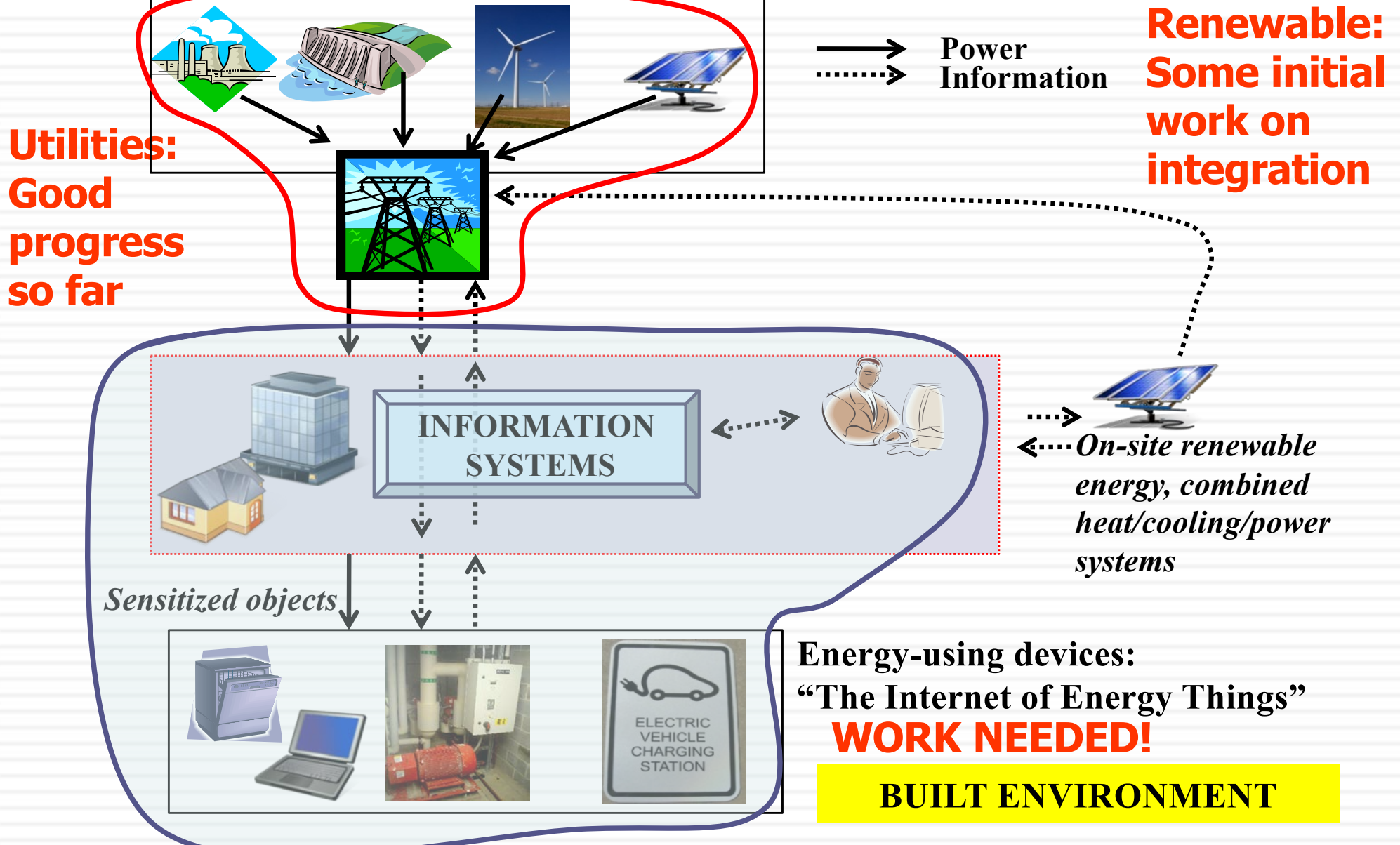
Regions and Balancing Authorities



How Grid Integration is Done Today (Without Demand Response)



The Grand Challenge



Demand Response and Management

Electric Peak Demand Management

(A First Step Toward a True Smart Grid)

- **Demand Response has been referred to as the “killer app” for the Smart Grid by one Federal Energy Regulatory Commission (FERC) commissioner**

Demand Response Scenarios

A. High Demand Relative to Supply:

- ▣ Reduce peak demand during high load conditions or grid “stress”
- ▣ Typically a summer cooling issue (occasionally in winter heating in some locations)

B. High or Variable Supply Relative to Demand:

- ▣ How to manage peak production from distributed generation systems (renewable, CHP)?
- ▣ Germany in June 2013 and continued this year
- ▣ Becoming more common in parts of U.S. (at night, wind)

C. Managing for Low Carbon Energy Production:

- ▣ An issue particularly for UK and EU now, others in future?
- ▣ Management of demand to match type of supply available

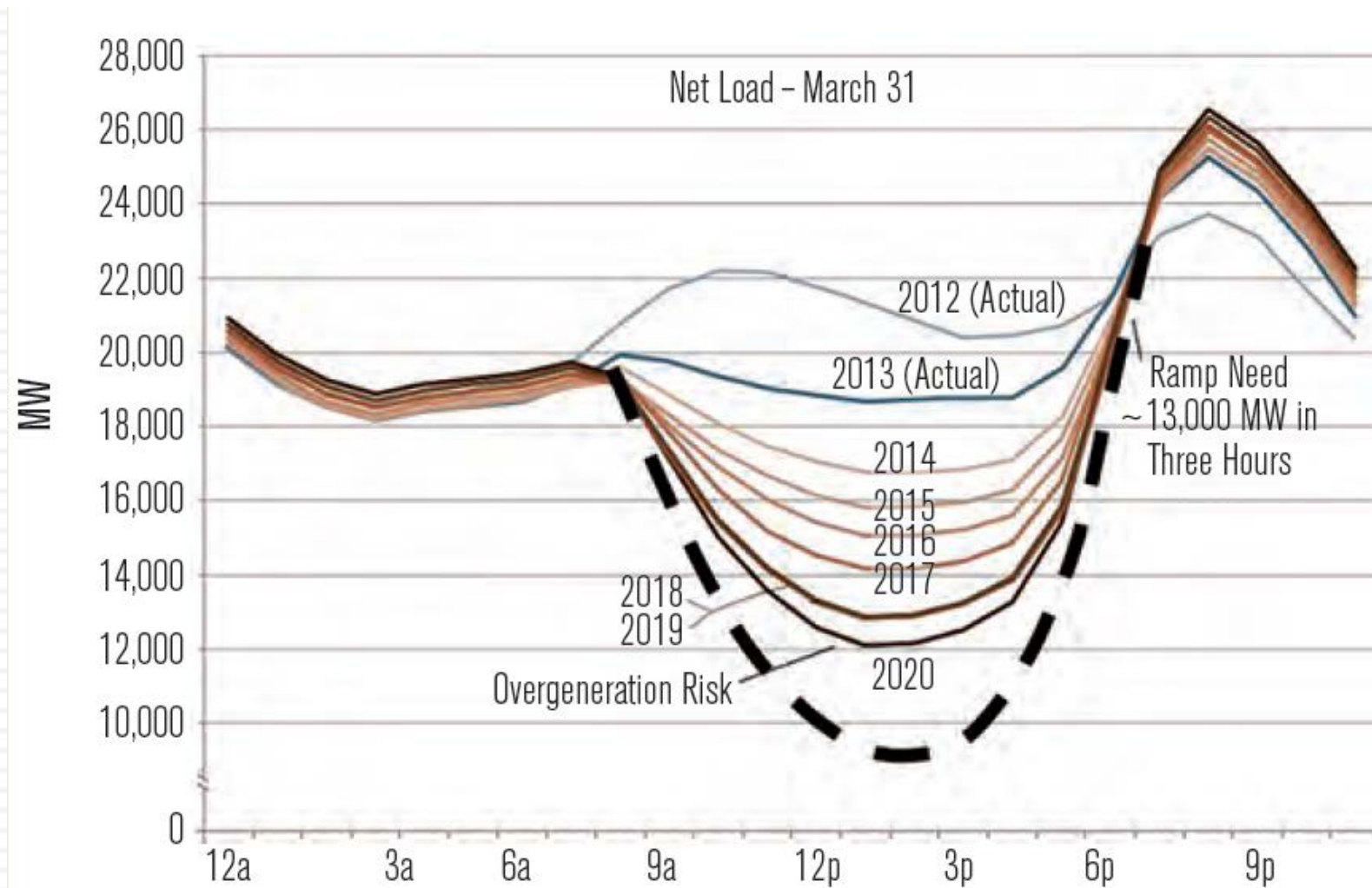
Common Types of Demand Response (DR) Programs

Price-based DR Programs: Higher prices used to induce demand reduction	
Time of Use (TOU) rates	Rates with fixed price blocks that differ by time of day.
Critical Peak Pricing (CPP)	Rates that include a pre-specified, extra-high rate that is triggered by the utility and is in effect for a limited number of hours.
Real Time Pricing (RTP)	Rates that vary continually (typically hourly) in response to wholesale market prices.
Incentive- or Event-based Programs: Incentives provided to induce demand reduction	
Direct load control	Customers receive incentive payments for allowing the utility a degree of control over certain equipment.
Demand bidding/buyback programs	Customers offer bids to curtail load when wholesale market prices are high or identify how much they would be willing to curtail at posted prices.
Emergency demand response programs	Customers receive incentive payments for load reductions when needed to ensure reliability, but curtailments are voluntary.
Capacity market programs	Customers receive incentive payments or rate discounts/bill credits for providing load reductions as substitutes for system capacity.
Interruptible/curtailable programs	Customers receive a discounted rate or bill credit for agreeing to reduce load upon request. If participants do not curtail when requested, they can be penalized.
Ancillary services market programs	Customers receive payments from a grid for ancillary services provided. Require that customers are able to adjust load quickly.

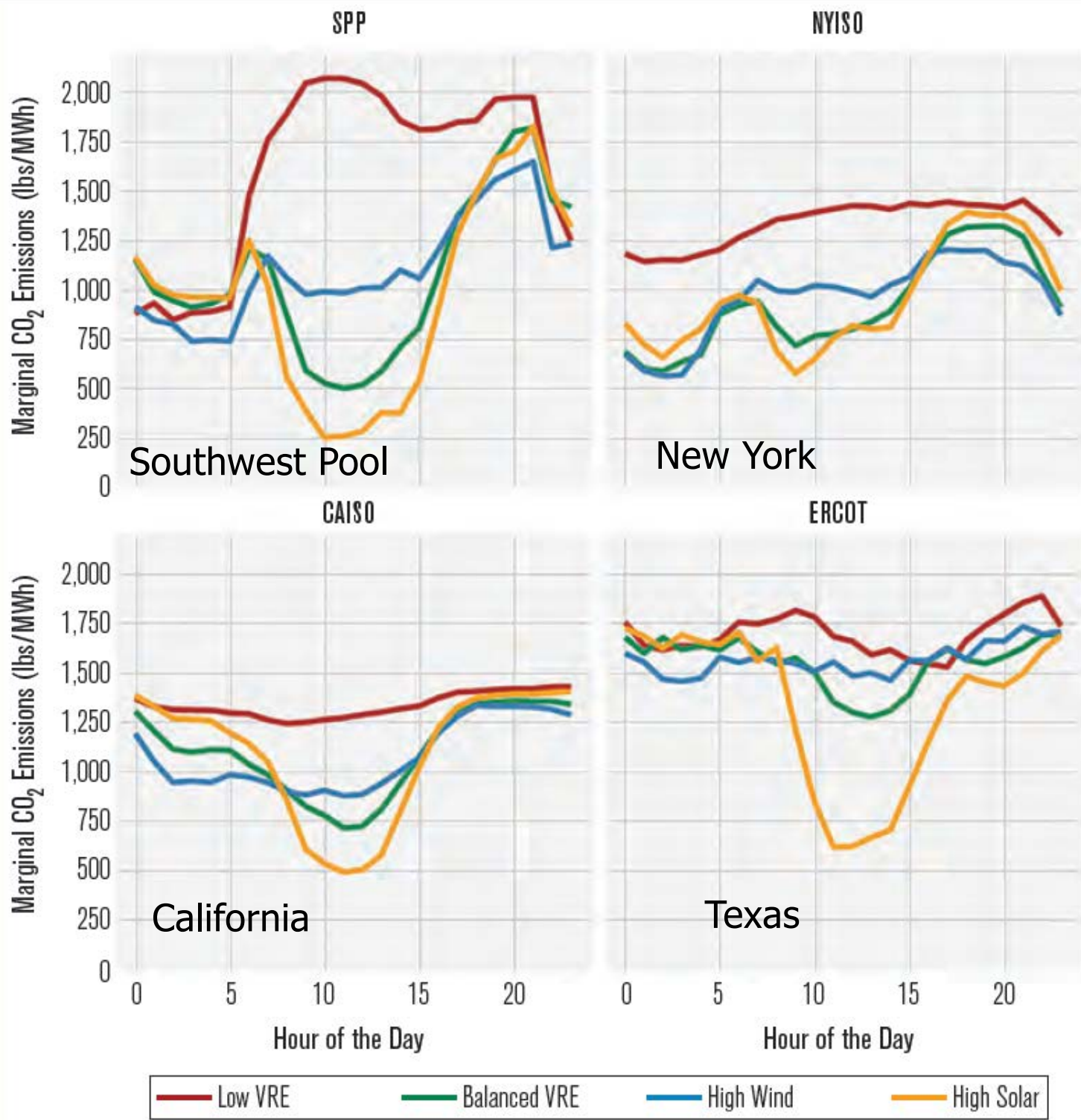
The Future is Coming (or Here)



The “Duck” Curve of California’s Energy Use *(California ISO, in MW)*



D. Nall, 2018. "Grid Coordination for Net Zero Energy Projects", ASRHAE Journal Oct. 2018



CO2 Emissions Rate Varies with Renewable Energy Availability

(VRE = variable renewable energy)

Nall, 2018

New Trends with DR Management

- Increased distributed generation by buildings adds to the problem that utilities need to address
- Building energy storage in parallel with utility scale storage
- ***Communication of the utility with buildings will help alleviate the “duck curve” problems***

New Trends with DR (Cont'd)

- Utilities are now targeting DR in more disaggregated manner to offload congestion at specific points, rather than system wide
 - ▣ *Zip code level*
 - ▣ *Specific streets or locations*
- Fast-acting DR to provide more short-term responses
- “Reverse demand response” to increase load when it makes sense to avoid ‘wasting’ solar or wind generation

Demand Response for Buildings and Their Systems

Demand response becoming more a requirement (LEED, Std. 189.1, IgCC)

Implementing demand response in buildings: new and/or existing

Example of a test case

LEED v4 EA Credit: Demand Response

Building project can opt to pursue the following credit options

- Case 1: Demand Response Program Available (2 pts)
 - ▣ Participate in the program through contract
 - ▣ Design system with capability for automate DR (Semi-automated allowed in practice)
 - ▣ Include DR in the commissioning

- Case 2: DR Program NOT Available (1 pt)
 - ▣ Provide infrastructure to take advantage of a future DR program, including meters and developing a comprehensive plan for load shedding of at least 10%

Demand Response is Becoming “Code” (IgCC/Standard 189.1)

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- Automated demand response capability to allow communication with utility, to receive demand response signals and implement load adjustments to HVAC and lighting as appropriate.
- During automated DR
 - ▣ HVAC setpoints adjusted by minimum of 3° F
 - ▣ Ramp up and down logic to avoid rebound and large peak.
 - ▣ VFD controllers to 90% of maximum
 - ▣ Lighting adjustments by 15% for those with centralized control systems

California (Title 24)

SECTION 120.2 – REQUIRED CONTROLS FOR SPACE-CONDITIONING SYSTEMS

- (h) **Automatic Demand Shed Controls.** HVAC systems with DDC to the Zone level shall be programmed to allow centralized demand shed for non-critical zones as follows:
1. The controls shall have a capability to remotely setup the operating cooling temperature set points by 4 degrees or more in all non-critical zones on signal from a centralized contact or software point within an Energy Management Control System (EMCS).
 2. The controls shall have a capability to remotely setdown the operating heating temperature set points by 4 degrees or more in all non-critical zones on signal from a centralized contact or software point within an EMCS.
 3. The controls shall have capabilities to remotely reset the temperatures in all non-critical zones to original operating levels on signal from a centralized contact or software point within an EMCS.
 4. The controls shall be programmed to provide an adjustable rate of change for the temperature setup and reset.
 5. The controls shall have the following features:
 - A. Disabled. Disabled by authorized facility operators; and
 - B. Manual control. Manual control by authorized facility operators to allow adjustment of heating and cooling set points globally from a single point in the EMCS; and
 - C. Automatic Demand Shed Control. Upon receipt of a demand response signal, the space-conditioning systems shall conduct a centralized demand shed, as specified in Sections 120.2(h)1 and 120.2(h)2, for non-critical zones during the demand response period.

Building Electric Peak Demand Management

- Peak demand management and response are becoming more important in building systems and control
- May not have much impact on the individual building total energy use, but important for overall societal energy and environmental management
- Considerations go beyond just one building's energy cost and utilization

Implementing Demand Response in Buildings

- What types of actions are possible?
- Planning for a new building versus retrofitting in an old building
- Case study example
- Communication protocols needed

What “tools” are available for DR?

- The obvious first choices:
 - ▣ HVAC systems
 - Setpoints
 - Thermal energy storage
 - ▣ Lighting
- Perhaps you have considered:
 - ▣ Plug load management
 - ▣ General overall energy conservation effects
- Other more unique considerations
 - ▣ Non-traditional thermal energy storage

Execution of Demand Response

- Buildings typically contain both deferrable and non-deferrable electric loads for the same end-users.
- Key questions to answer:
 - ▣ What to curtail?
 - ▣ How long?
 - ▣ How to verify (and who does the verifying)?
 - ▣ Comfort considerations
 - ▣ Safety, security concerns
 - ▣ Control and monitoring
- Externally generated versus internally created events:
 - ▣ External by utility or outside agent
 - ▣ Internal at owner's discretion (demand limiting or peak shaving) - May be more effective

Example: Implementing Demand Response in an Existing Campus

- Project goals: Study how could automated demand response measures be implemented in existing campus of buildings with wide range of technologies available and real-time price tariff
- First example of test case: Saturday 7 June 2014 (low occupancy, limited 'risk')
 - ▣ Changed zone set points by +3° F
 - ▣ Changed supply air set point also +3° F
 - ▣ Changed upper limit for AHU fan speed from 100% to 90% of maximum (when possible)
 - ▣ Thermal comfort survey

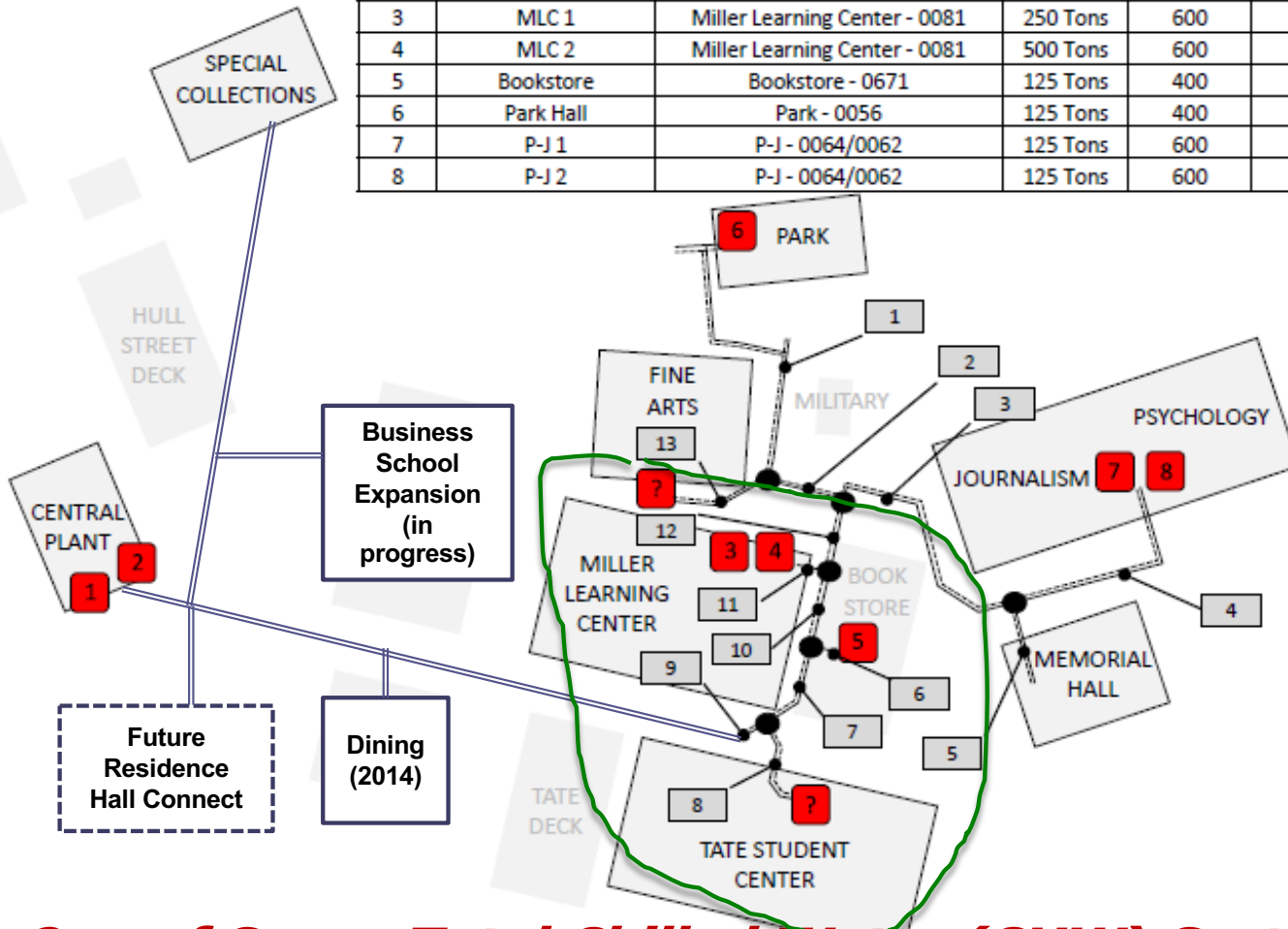
District Chilled Water Loop #1



Central District - Chiller Table

Dwg #	Chiller	Location	Rated Capacity	CT Size (Amps)	Staging	Heat Exchanger (y/n)
1	Central Plant 1	District Energy Plant #1 - 0741	420 Tons	1000	TBD	TBD
2	Central Plant 2	District Energy Plant #1 - 0741	500 Tons	1000	TBD	TBD
3	MLC 1	Miller Learning Center - 0081	250 Tons	600	TBD	TBD
4	MLC 2	Miller Learning Center - 0081	500 Tons	600	TBD	TBD
5	Bookstore	Bookstore - 0671	125 Tons	400	TBD	TBD
6	Park Hall	Park - 0056	125 Tons	400	TBD	TBD
7	P-J 1	P-J - 0064/0062	125 Tons	600	TBD	TBD
8	P-J 2	P-J - 0064/0062	125 Tons	600	TBD	TBD

Central District - Chilled Water Piping

Pipe Segment Number	Pipe Dia. (in)	Approx. Length (ft)
1	8	600
2	10	130
3	10	420
4	10	400
5	6	150
6	6	35
7	18	165
8	10	165
9	20	10
10	18	135
11	8	60
12	16	125
13	6	190



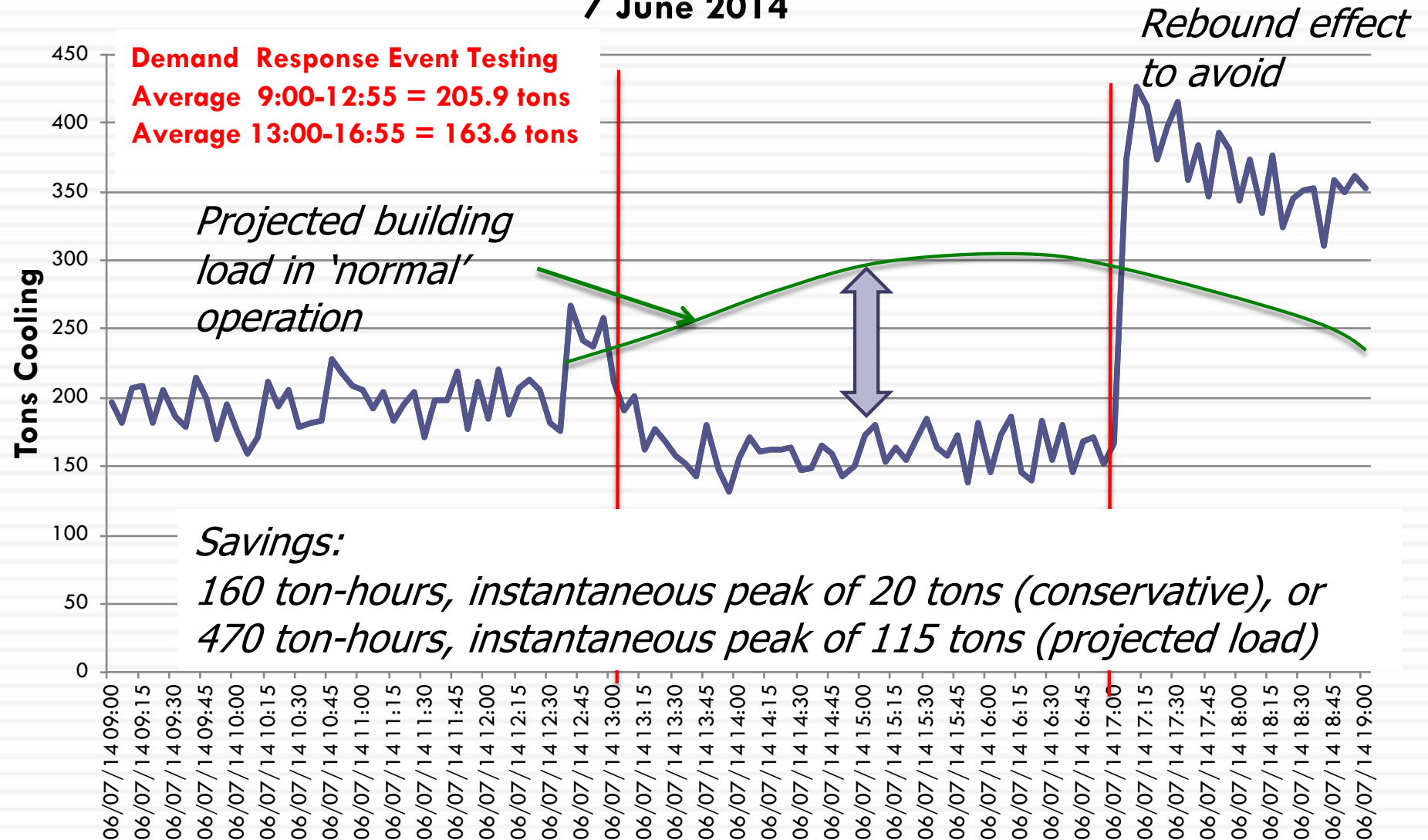
 Approximate Building Footprint
 Approximate Chiller Location



One of Seven Total Chilled Water (CHW) Systems on Campus

Initial Test in 2014: Demand Reduction Potential

MLC Building Chilled Water Measured Tons of Cooling –
7 June 2014

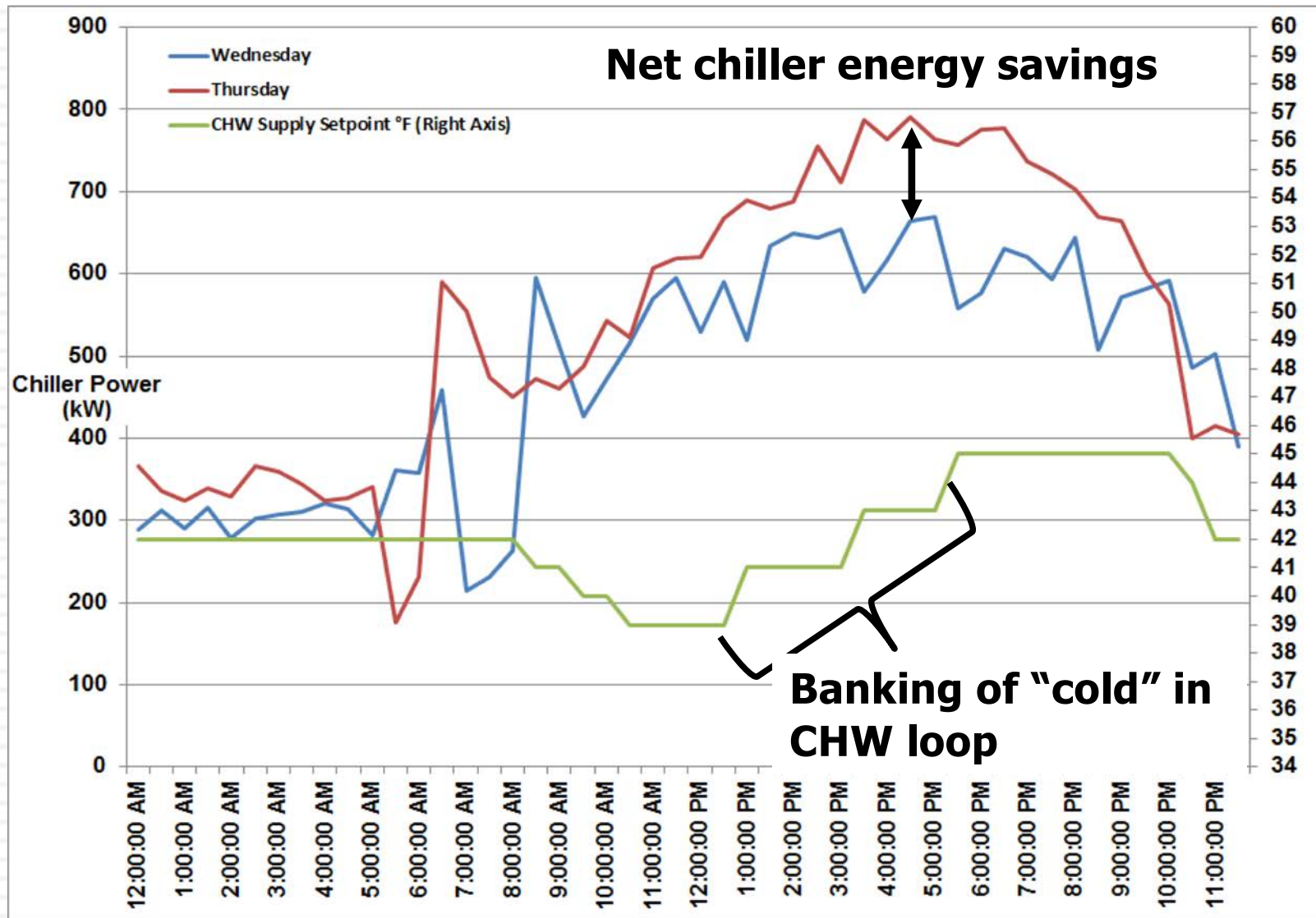


Thermal Comfort Survey Results

- *No real difference in perceived thermal comfort (both cases were ‘good’); statistically ‘close’*

June 7 (ADR Test Date)			June 19 (Control)		
PREDICTED MEAN VOTE ESTIMATOR			PREDICTED MEAN VOTE ESTIMATOR		
<u>"COMFORT"</u>	<u>#Votes</u>	<u>Score</u>	<u>"COMFORT"</u>	<u>#Votes</u>	<u>Score</u>
Cold	1	-3	Cold	2	-6
Cool	0	0	Cool	0	0
Slightly Cool	0	0	Slightly Cool	0	0
Neutral	20	0	Neutral	51	0
Slightly Warm	0	0	Slightly Warm	0	0
Warm	0	0	Warm	0	0
Hot	6	18	Hot	5	15
Total	27	15	Total	58	9
	PMV=	0.555556		PMV=	0.1551724
	PPD =	11.5%		PPD =	5.5%

Combined CHW and Air Side Test



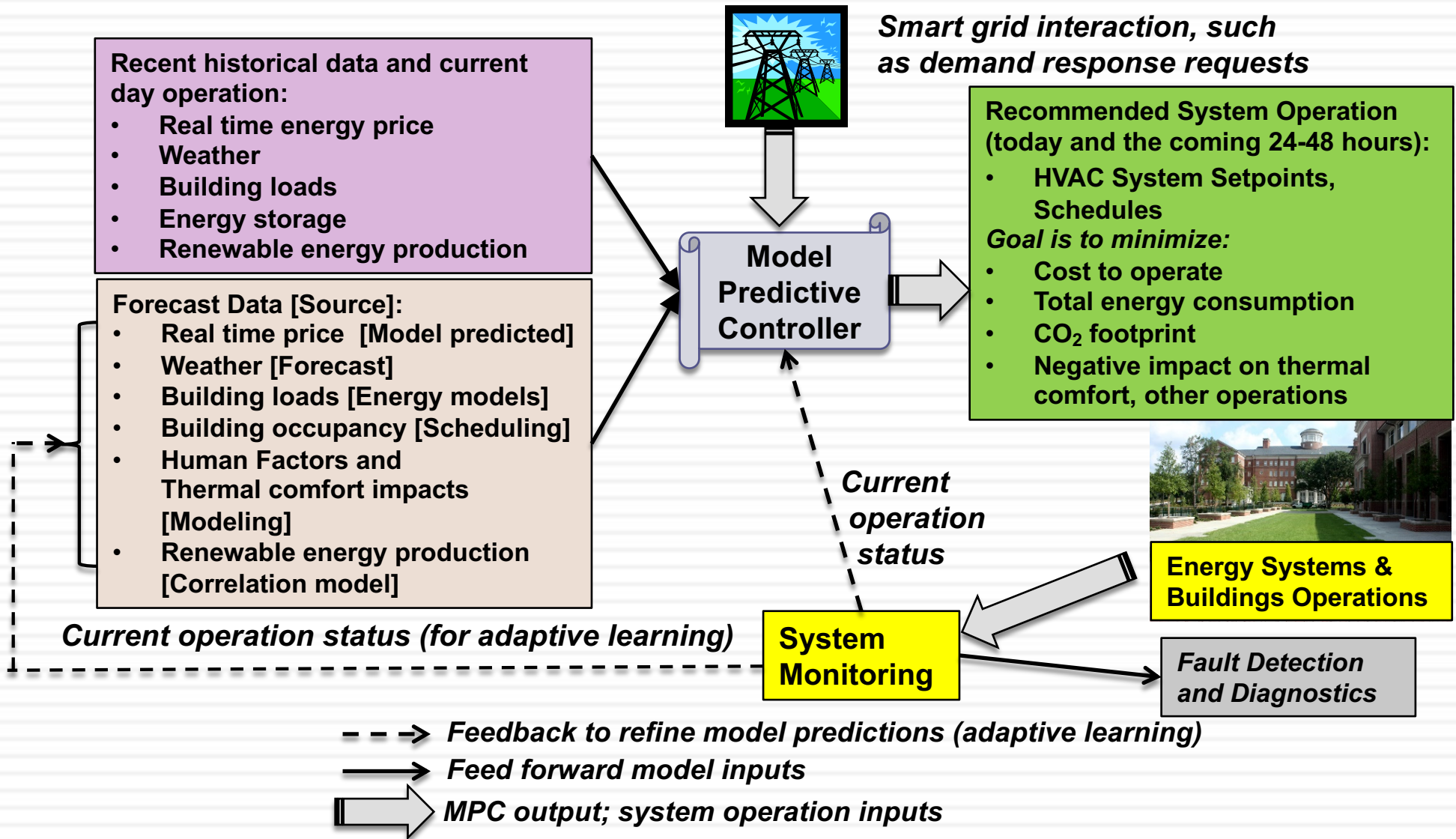
**August
26-27,
2015**

Day	Total kWh	Peak kW	% Compared to Test Day		
			Total kWh	Peak kW	High T (°F)
Monday	42,507	2,447	129.0%	128.0%	92.6
Tuesday	36,109	2,211	109.6%	115.7%	90.0
Wednesday	32,939	1,911	-	-	86.9
Thursday	36,584	2,132	111.1%	111.5%	87.0

Lessons Learned from this Test

- Perhaps temperature setpoints overall could be altered, or at least during higher cost time periods?
- Timing and scheduling
 - ▣ What are the optimal setpoint changes?
 - ▣ What times to start and stop?
 - ▣ How to avoid the rebound effect ('soft-start')?
- Most difficult... Need to be adaptable to the technologies in place
 - ▣ How to implement with automation and controls not designed for 'automated' demand response

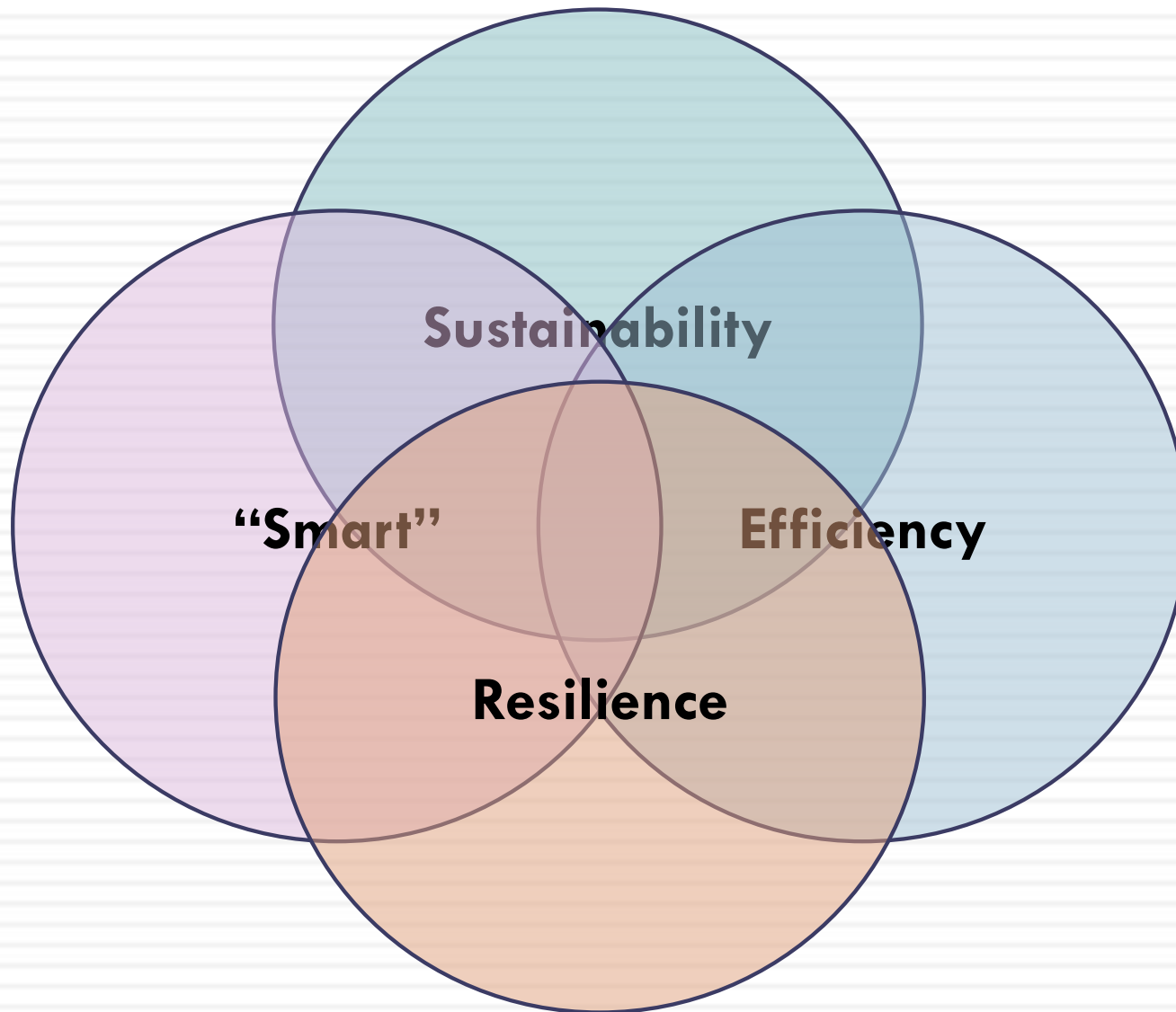
Vision for Model Predictive Control



A Smart Grid Increases Resilience of the Built Environment

- Smart buildings and their equipment
- Microgrids
- Distributed generation (CHP, renewables)
- Energy storage
- Grid monitoring and control
- Smart grid to neural grid evolution

Sustainability, Resilience, Efficiency and “Smart” – The Interrelationship

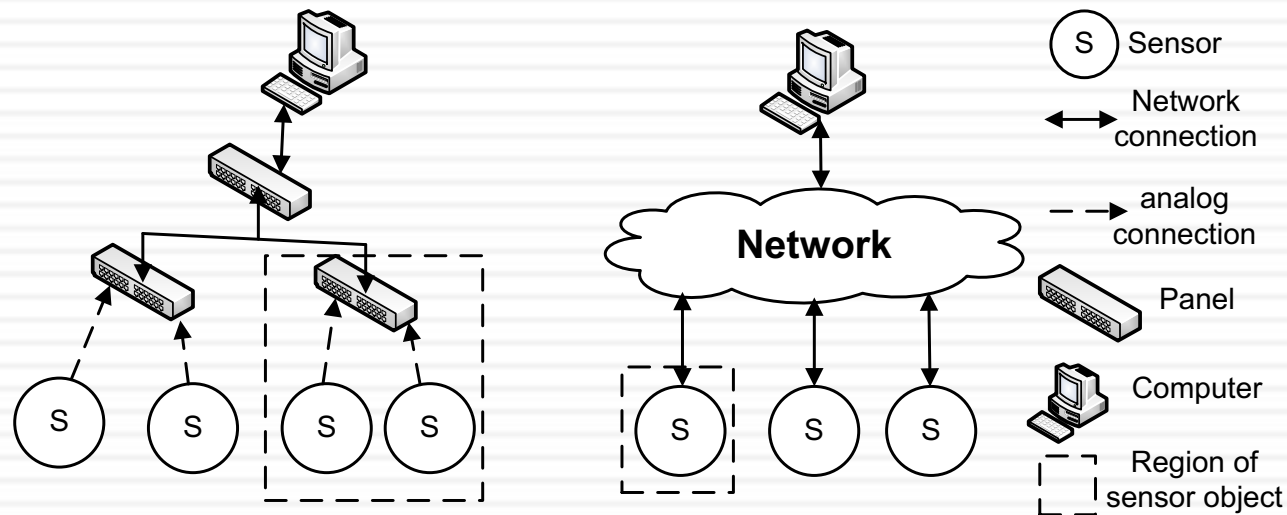


Smart Building Systems

- ASHRAE Handbook Chapter on Smart Buildings, Smart Grid (Applications Ch. 61, 2015)
 - ▣ Automated Fault Detection and Diagnostics
 - ▣ Sensing and actuating systems
 - ▣ Smart grid interactions

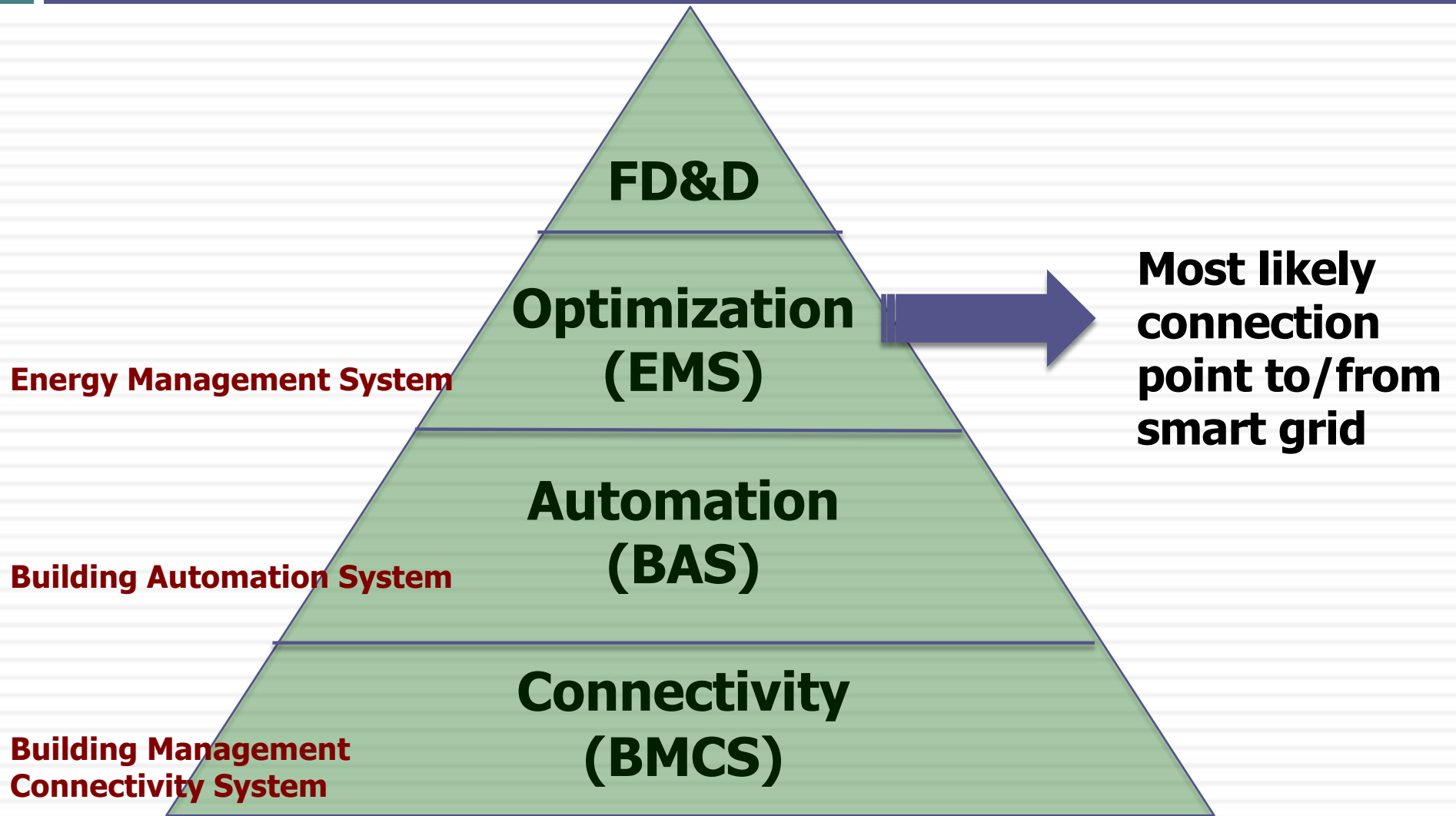
Sensing and Actuating Systems

- Moving beyond the traditional connection of sensors controlling and displaying locally and connected with “twisted pairs” of wires.
- Newer systems using more networked intelligence or web automation



*From draft copy of new ASHRAE Handbook Chapter
"Smart Building Systems"*

Building Controls Pyramid Featured in Operation and Interactions with Grid



Microgrids are a Natural Outgrowth from Traditional “Standby Generator”

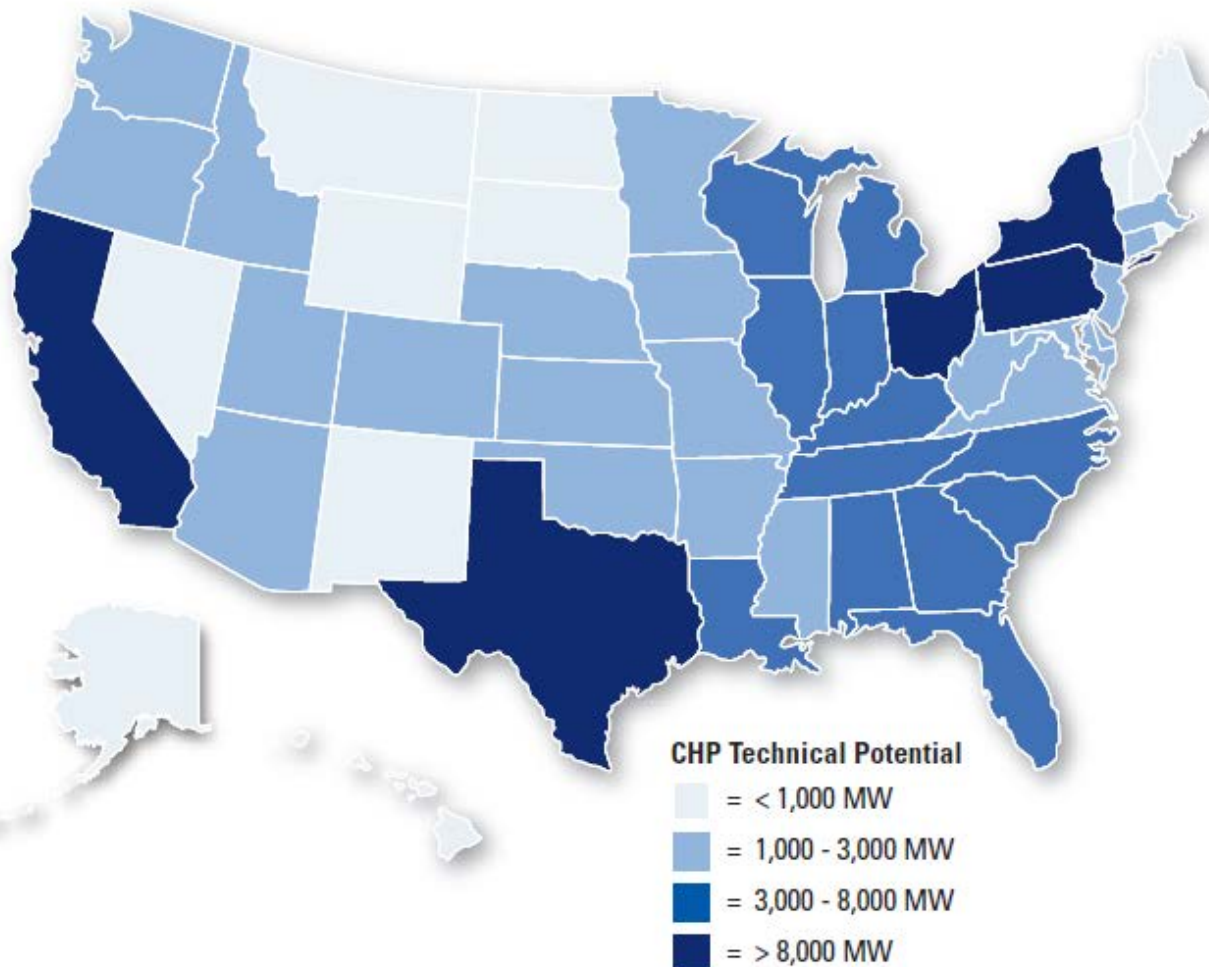
- Serve multiple buildings
- Good candidates for consideration are a medical complex, university or large corporate campus, and military bases
- Can be integrated with multiple generation sources of traditional and renewable energy
- Well suited for combined heat-cooling-power systems

Microgrid Types

- Microgrid operation modes:
 - ▣ Local generation (when grid is operational or not)
 - ▣ Local load management (demand response, etc.)
 - ▣ Parallel operation with grid/market interaction (possibly sending excess power to grid depending on real-time market conditions)
 - ▣ Island mode (allows independent operation if grid down for long period of time)
- Types:
 - ▣ Grid-tied utility distribution microgrids (UDMs)
 - ▣ Direct current microgrids (DC)
- A key to future growth is with greater creativity in both the public policy and business model arenas.

CHP as Distributed Generation

Remaining Technical CHP Potential



Nearly 9% of total U.S. generation capacity is in the form of CHP systems

Energy Storage

The Need for Energy Storage

“Storage will be critical for large scale implementation of sustainable energy.”

- The November 2007 California ISO report “Integration of Renewable Resources”

Principle Challenges for Energy Storage Growth

- Cost competitive technology needed
 - ▣ Life-cycle cost and overall performance (efficiency, energy density, cycle life, etc.)
- Validated reliability and safety
- Equitable regulatory environment
 - ▣ Reducing institutional and regulatory hurdles to similar that of other grid resources
- Industry acceptance
 - ▣ Must have confidence that it can be deployed as expected and it delivers as promised
- **Some of that storage can/could/should be imbedded into building systems**

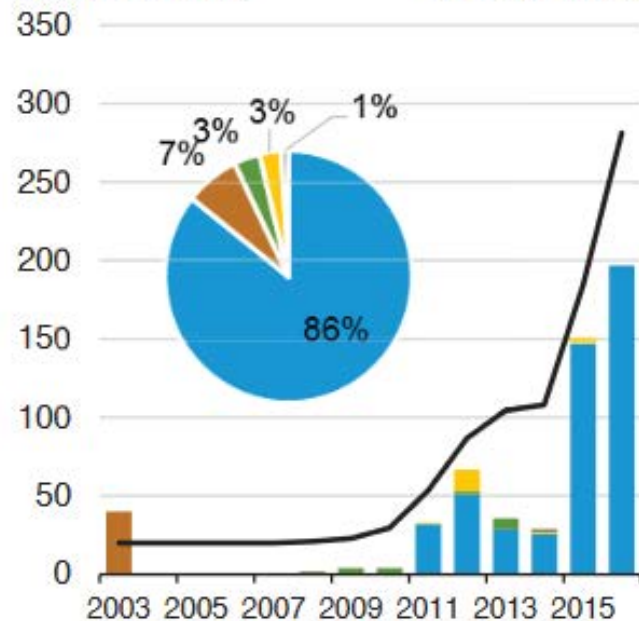
U.S. Grid Related Energy Storage in Rapid Growth Mode

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- Only 10% in 2014 was “behind the meter”, but by 2019 expected to be 45%
- Mostly thus far in PJM (13 states and D.C.) and California
- Europe and Japan have higher fractions of the total grid capacity as storage

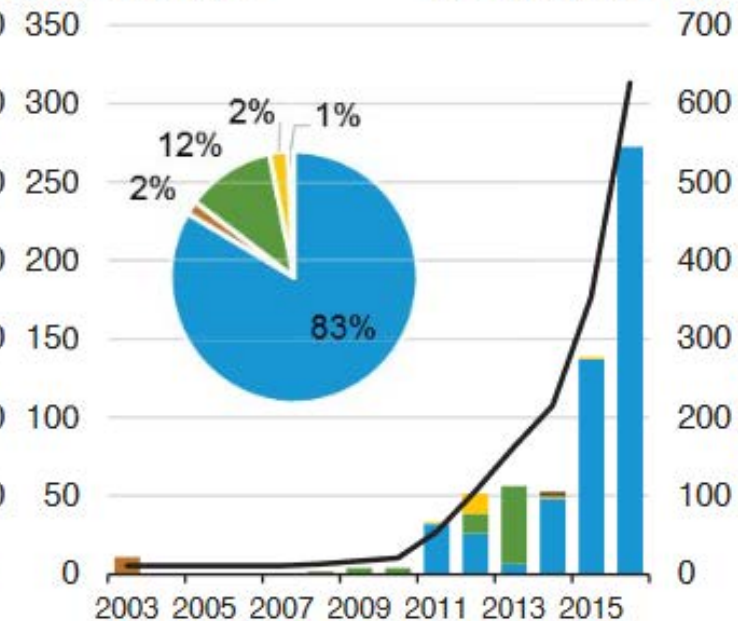
power capacity
megawatts

annual additions



energy capacity
megawatthours

annual additions

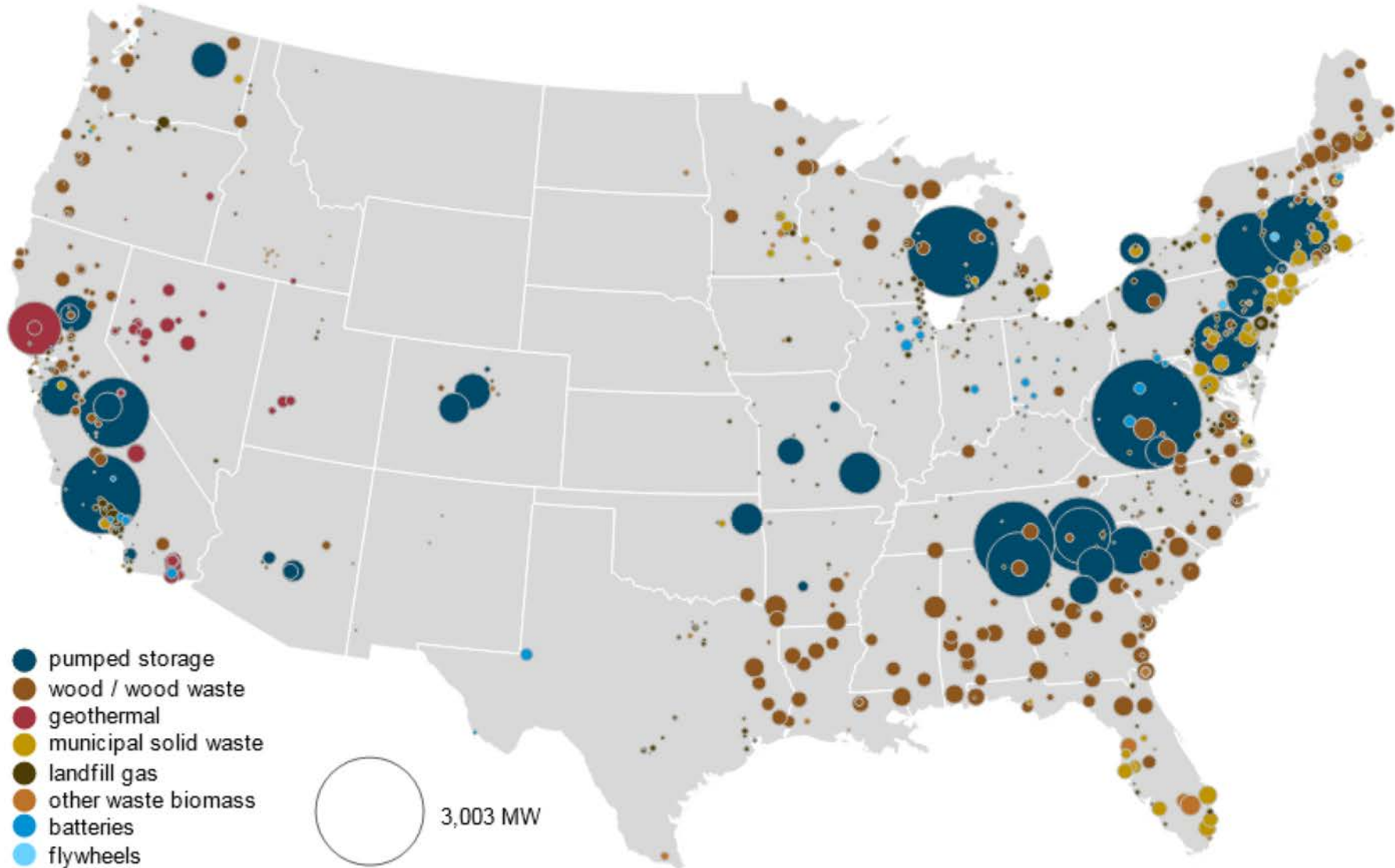


lithium-ion
nickel-based
sodium-based
lead-acid
other

Source: U.S. Energy Information Administration, Form EIA-860, *Annual Electric Generator Report*

Regional Variations in U.S.

Distribution of energy storage and other renewable power plants in the Lower 48 states



Other Methods for Energy Storage as Supplement to Grid Energy

- Potential for chilled water or hot water to be used as a means to supplement grid electrical storage *similar to thermal energy storage systems for buildings:*

Defined as “**Grid Interactive Thermal Storage**”

- Integrating electric vehicles into the grid

Energy Storage at Residential Scale

- Salt River Project in Arizona, test case with 4,500 houses coordinated by NREL



<https://www.nrel.gov/news/program/2018/arizona-utility-and-nrel-launch-home-energy-storage-study.html>

Observations on Energy Storage

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- Will energy storage negate the need for demand response measures?
- Increased emphasis on resilience will be a big driver for energy storage
- Utility scale grid storage or distributed (building scale) storage?

Monitoring in Smart Grid can Improve Recovery

- Utilities can detect and address grid outages faster

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



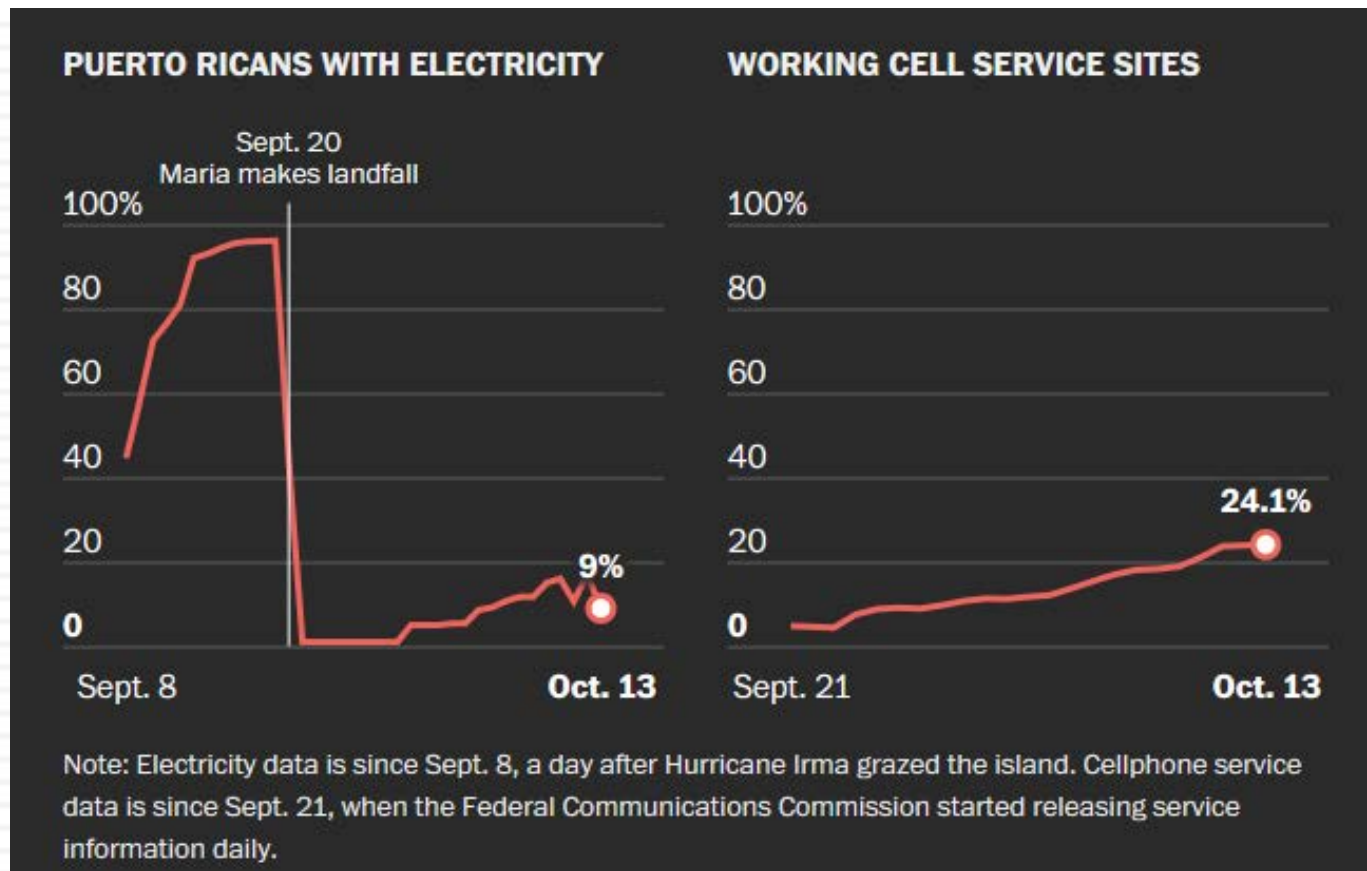
My house after Trop. Storm Irma, Sept. 11, 2017

Lessons from Puerto Rico



- The island was devastated by Hurricane Maria on September 20, 2017 (also damaged earlier by Irma on September 8)
- Essentially entire island power grid down (>85%); very slow recovery, estimated at least six months

Puerto Rico One-Two Punch and Recovery



Source: Washington Post. 2017. https://www.washingtonpost.com/graphics/2017/national/puerto-rico-hurricane-recovery/?utm_term=.876578f45c89.

Rebuild a Better Way?

- Why rebuild to the old, outdated standard a grid that did not function well to begin with?
- Desired to rebuild new with:
 - ▣ Distributed generation (solar and wind)
 - ▣ Microgrids
 - ▣ Energy storage
- Only 2% of island-wide generation from renewables in FY 2017
- New legislation set targets for 100% renewables by 2050 and ramping up energy efficiency

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?)
 - ▣ “Everything Belongs”
 - ▣ Distributed energy assets and generation, storage
 - ▣ Cloud based AI evaluation, control
 - ▣ Self-healing and learning

Other Issues, Observations

The Need for Cybersecurity

- The 800 pound (400 kg) gorilla in the room ...

Building Designers

Need to Now Consider ...

- System considerations:
 - ▣ On-site renewable energy
 - ▣ Other distributed generation (CHP, etc.)
 - ▣ Advanced building automation systems
 - ▣ Integrated system concepts
 - ▣ Energy measurement and metering
 - ▣ Electric vehicle charging stations
 - ▣ Ease of use, interoperability with existing technologies
- Demand response adaptations:
 - ▣ HVAC control and operation strategies

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.
- Next slide provides insight into the human factor considerations

Demand Response Discussion

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- Does your firm/organization participate in a demand response program?
- What has been your experience with demand response?
- What are the barriers to implementation of demand response that you see:
 - ▣ Your firm/organization?
 - ▣ Residential market?
 - ▣ Society as a whole?
- Planning for a new building versus retrofitting an old building

Questions, Answers



- What is the one key difference between a smart grid with distributed renewable energy systems and the traditional grid?
- What are some of the key technology components of the smart grid and buildings?
- What is the “duck curve” and why is that a potential problem for utilities?
- What types of demand response measures are possible and practical in a typical commercial building?
- What is the rebound effect with a potential demand response measure and how might that be prevented?
- What are some things that building designers need to be aware of when planning for smart buildings interacting with a smart grid?

Questions, Answers



- What is the one key difference between a smart grid with distributed renewable energy systems and the traditional grid?

Instead of just energy supplied and a bill sent each month, energy is supplied by the utility and other distributed locations (utility or other entities) and information exchanged between all agents.

- What are some of the key technology components of the smart grid and buildings?

This would include things like smart meters, two-way communication systems between utilities and building systems, software that can automatically control building systems, smart end use equipment.

- What is the “duck curve” and why is that a potential problem for utilities?

The daily variation in power input to grid related to solar feed-in, and serving the large ramp up in electrical energy demand in the late afternoon and evening hours has to be provided.

Questions, Answers



- What types of demand response measures are possible and practical in a typical commercial building?
HVAC system setpoints for zone temperatures, supply air temperatures, maximum supply air flow rates, plug load control, possibly lighting control.
- What is the rebound effect with a potential demand response measure and how might that be prevented?
If zone temperature setpoints are quickly returned to normal, the system will likely draw a high peak power demand to get back to normal. Need to “soft start” return to normal operation.
- What are some things that building designers need to be aware of when planning for smart buildings interacting with a smart grid? *Control systems with communication capability with the grid operator, advanced building energy management systems, integrated system controls, building occupant considerations, ease of maintenance and operation, demand response measures, to name a few.*

Thank You!

- Other comments, questions, concerns, advice ...

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