Quadrennial Technology Review-2015

Chapter 5: Enabling Modernization of the Electricity Delivery System

Public Webinar

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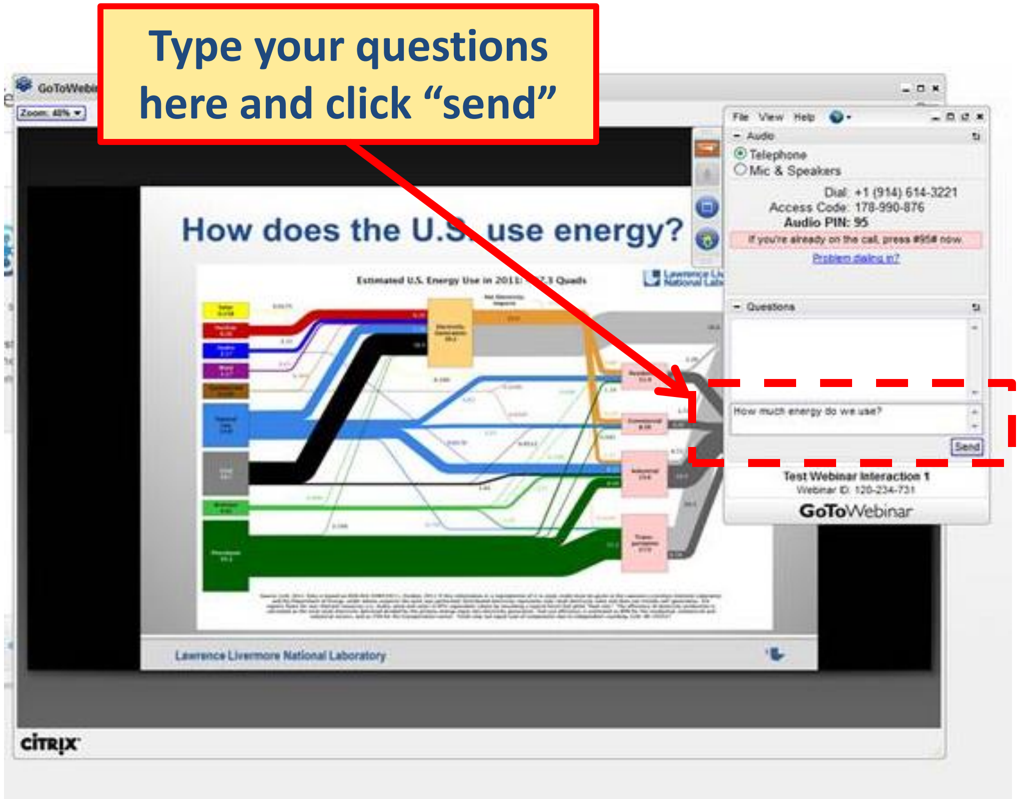
Webinar Logistics

- Due to the large number of expected participants, the audio and video portions of this webinar will be a “one way” broadcast. Only the organizers and QTR authors will be allowed to speak.
- Submit clarifying questions using the GoToWebinar control panel. Moderators will respond to as many questions as time allows. Substantial input regarding chapter content should be submitted by email to: DOE-QTR2015@hq.doe.gov



QTR 2015 Chapter Outline

Introduction

1. Energy Challenges
2. What has changed since QTR 2011
3. Energy Systems and Strategies

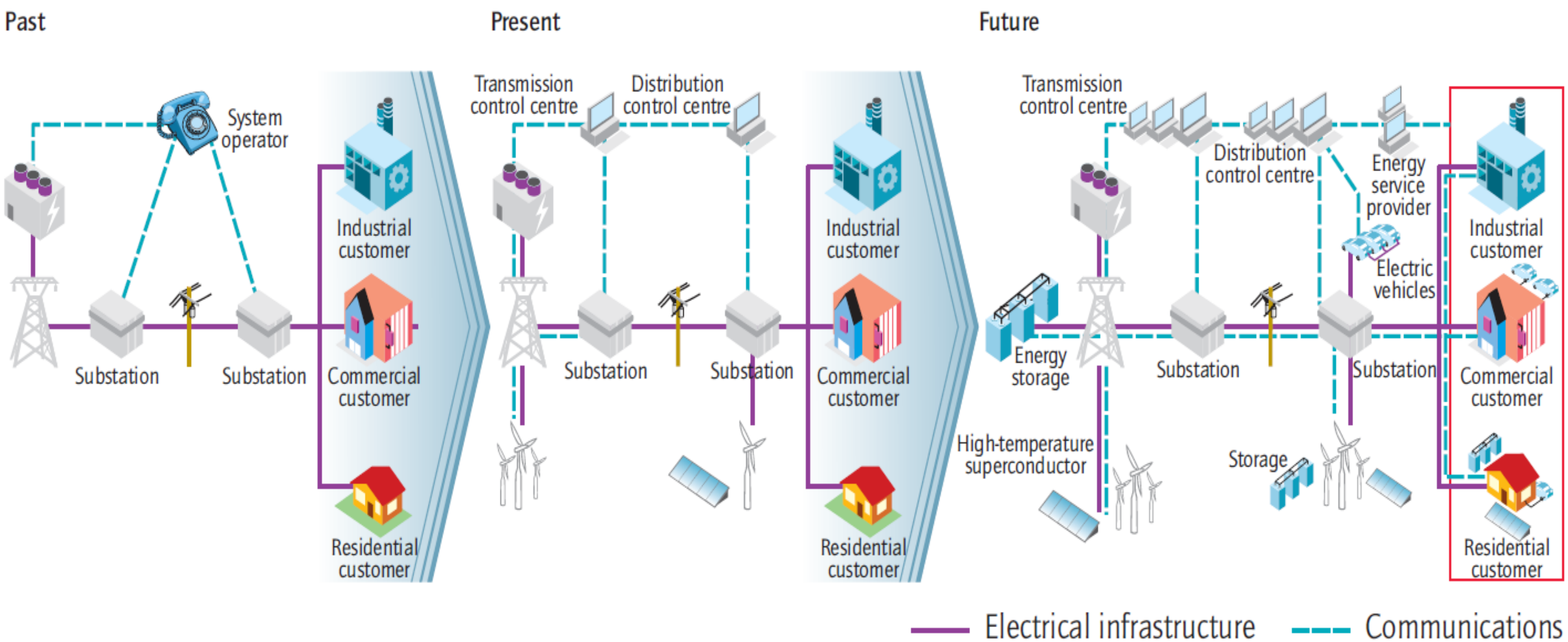
Assessments

4. Advancing Systems and Technologies to Produce Cleaner Fuels
5. **Enabling Modernization of Electricity Delivery Systems**
6. Advancing Clean Electric Power Technologies
7. Increasing Efficiency of Buildings Systems and Technologies
8. Increasing Efficiency and Effectiveness of Industry and Manufacturing
9. Advancing Clean Transportation and Vehicle Systems and Technologies
10. Enabling Capabilities for Science and Energy

Integrated Analysis

11. U.S. Competitiveness
12. Integrated Analysis
13. Accelerating Science and Energy RDD&D
14. Action Agenda and Conclusions; Web-Appendices
    Web Appendices

Chapter 5 Overview – Electricity Delivery Systems



Drivers of Change

- Integration of digital devices for managing power systems
- Changing mix of electricity supply
- Expectations for greater reliability and resilience
- Customer participation in electricity markets

Systems Approach – New Architecture for Electricity Delivery

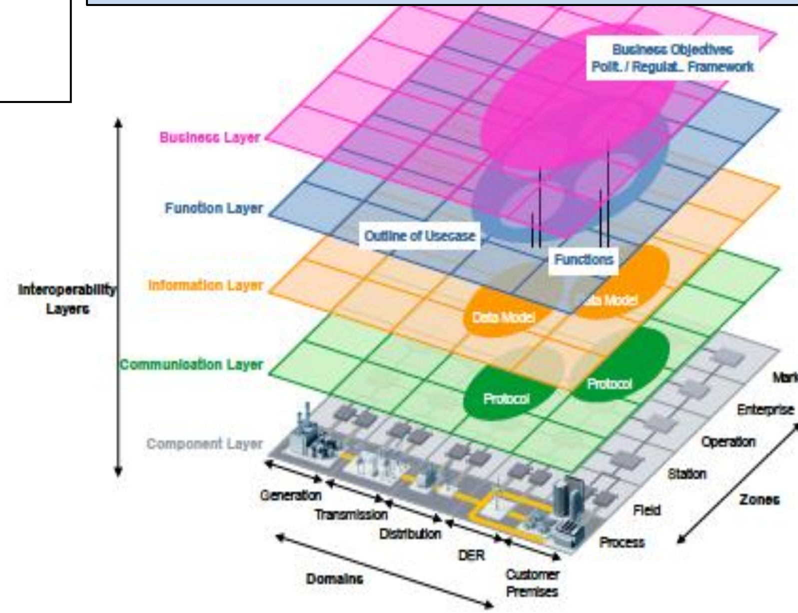
Historical	Emerging
• Rotational Inertia • Dispatchable Generation • Passive / Predictable Loads • "Static" T&D Infrastructure	• Reduced Stability / Faster Dynamics • Stochastic Generation • Engaged Consumers • "Adaptive" T&D Infrastructure
Operator-Based Grid Management *Centralized Control* *SCADA Measurements* *Off-Line Analysis / Limit Setting*	*Flexible and Resilient Systems* *Multi-Level Coordination* *PMU Measurements* *Faster-than-Real-Time Analysis*

New Requirements Need New Capabilities

- **Changing requirements create need for new capabilities**
  - **As new technologies for generation, delivery, and end-use get connected, they become part of a bigger "machine"; new interactions and power system behaviors are emerging**
  - **Integration of IT and high-bandwidth communications is a key to more modern grids, as they enable multi-level coordination to enhance flexibility and resilience**

Modern Grid Architecture

- **The architecture is a system-level model covering multiple facets of the electrical infrastructure; it facilitates coordination of technologies, policies, and institutional structures**
- **A paradigm shift is needed in the way new systems are designed, built, and operated**
- **Success requires innovations while simultaneously maintaining compatibility with legacy systems**
- **An architecture provides for structured transition**



Source: CEN-CENELEC-ETSI Smart Grid Coordination Group

Chapter Outline

1. **Introduction** (importance of electricity to the economy, key drivers, federal role)
2. **Moving from Traditional to Modern Electricity Delivery Systems** (characteristics of traditional and modern grids, new architectures for modern grids)
3. **R&D Needs for Modernization of Electricity Delivery**
   1. ***Control Systems for Electric Transmission***
   2. ***Control Systems for Electric Distribution***
   3. ***Distributed Energy Resources***
   4. ***Planning Tools***
   5. ***T&D Components***
   6. ***Electrical Energy Storage Systems***
   7. ***Cyber and Physical Security***

Technology Assessments

- **Transmission and Distribution Components:** focuses on technologies that are responsible for physically delivering electricity and controlling electric power flows
- **Electrical Energy Storage:** focuses on technologies that enable the bi-directional storage and provision of electricity
- **Measurements, Communications, and Controls:** focuses on technologies that support the real-time operations of the grid, coordinating balance between generation and load
- **Cyber and Physical Security:** focuses on technologies that enhance the security of the cyber and physical aspects of the electric power system
- **Flexible and Distributed Energy Resources:** focuses on technologies for loads, generators, or integrated systems located at the edges of the grid that can support real-time operations
- **Designs, Architectures, and Concepts:** focuses on technologies that help redesign and rethink what the electric power system could be and how the various pieces fit and work together

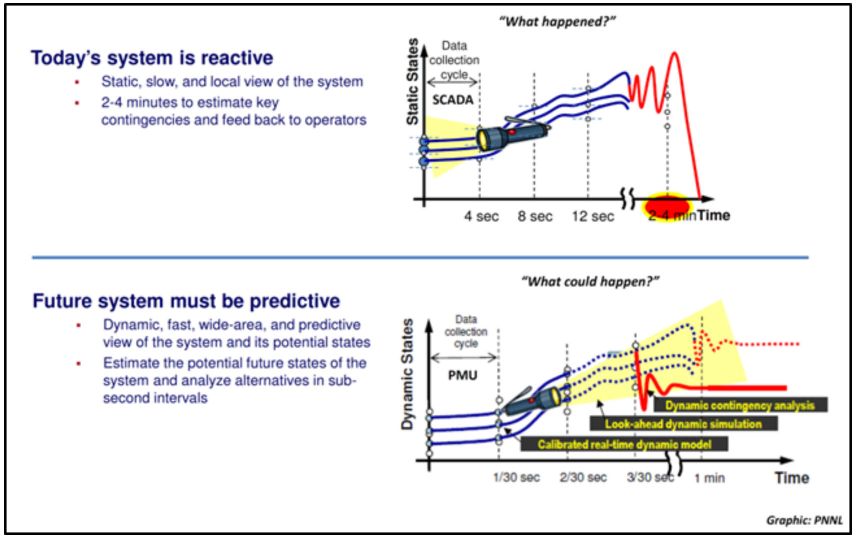
These assessments, separate from the main report, will contain the data and analysis that supports the technology discussion in the chapter. They will be available on the web.

3.1 Control Systems for Electric Transmission

Table 1. Key Monitoring and Control Attributes for the Evolving Power System			
Traditional		**Modern**	
Observability	**Controllability**	**Observability**	**Controllability**
Static, slow, and local view: weather, flows on key lines, voltages on key buses, tie flows, line status, generator status and real-power output	*Reactive (deterministic) high-level control:* balancing and load-following; discretized demand response [Eliminate and/or Avoid Risk]	*Dynamic, fast, and global perspective:* resource forecasts, grid stress, grid robustness, dangerous oscillations, frequency instability, voltage instability, reliability margin, and configuration and/or "health condition" of key assets	*Predictive(probabilistic) system-wide coordination:* generator coordination (dispatch and control); topology and flow control; demand-side coordination [Manage Risk]

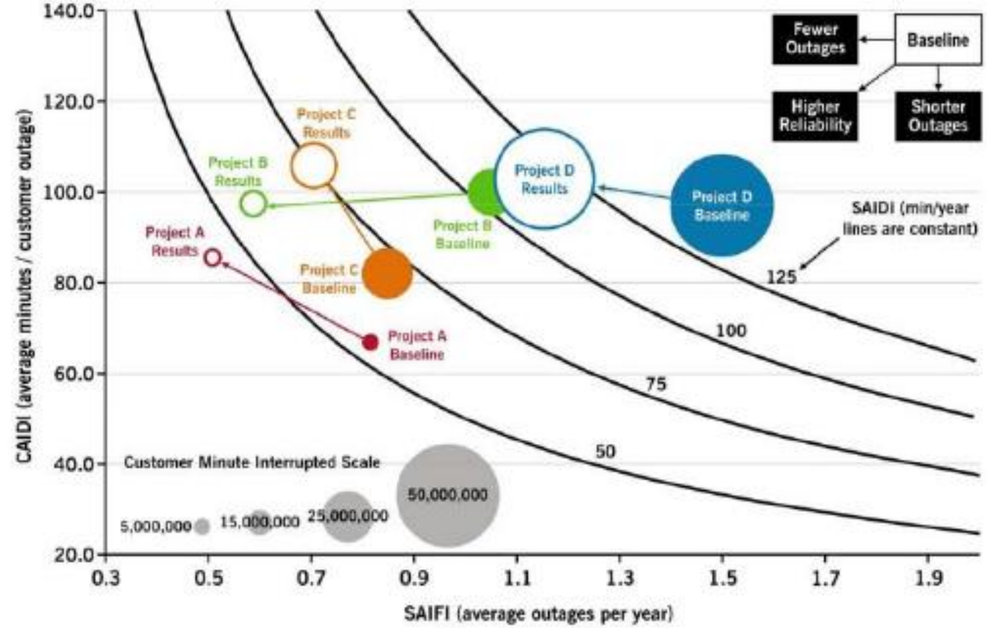
Opportunities:

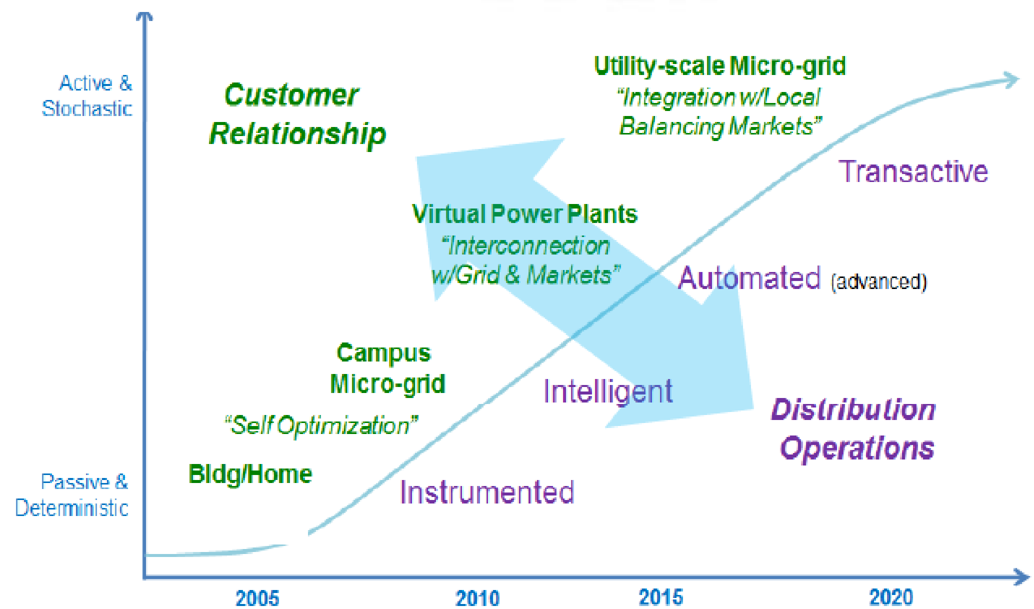
- Dynamic and Global View
- Fast and Predictive Analytics
- System-Wide Coordination



3.2 Control Systems for Electric Distribution

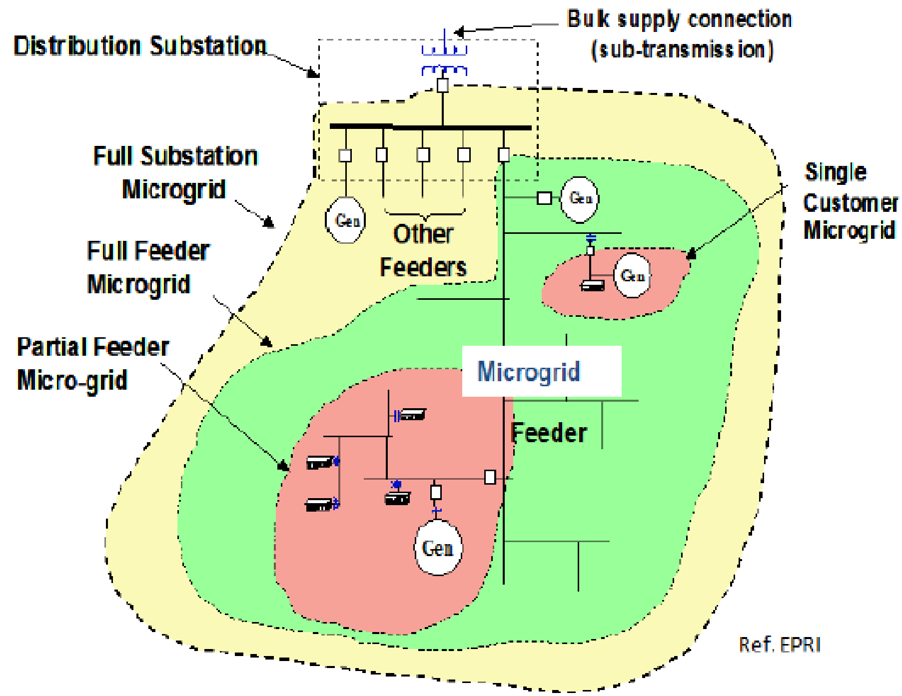
- Distribution systems are "the last" mile and have limited observability and control capabilities.
- Large opportunity to improve reliability and resilience with sensors, distribution automation, and outage management.
- Trends with growing distributed resources and customer participation will require a shift in how to manage and coordinate the explosion in control points (e.g., DERs).





3.3 Distributed Energy Resources

- Distributed generation and customer-sited technologies presents opportunities to support system operations.
- Individual resources (e.g., loads, storage, generation) can be made “smart” with local controls and communication technologies.
- Integrated systems (e.g., smart buildings and microgrids) combine many individual resources and require multi-objective optimization.

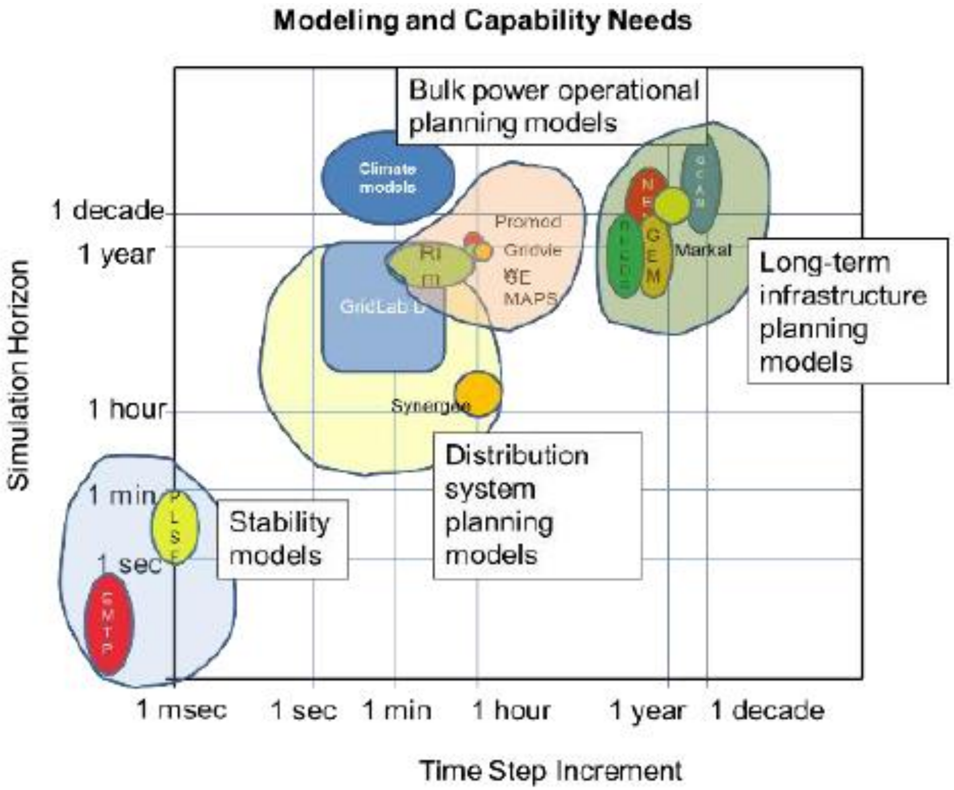


Multiple Objectives/Modes for Microgrids

- **Reliability – serves as a grid resource and can island upon detection of a contingency**
- **Security – ensure critical loads are serve for extended period of times during catastrophes**
- **Economic – responds to real-times changes in prices to minimize total energy costs**
- **Environment – maximize electricity produced from renewable resources to reduce emissions**

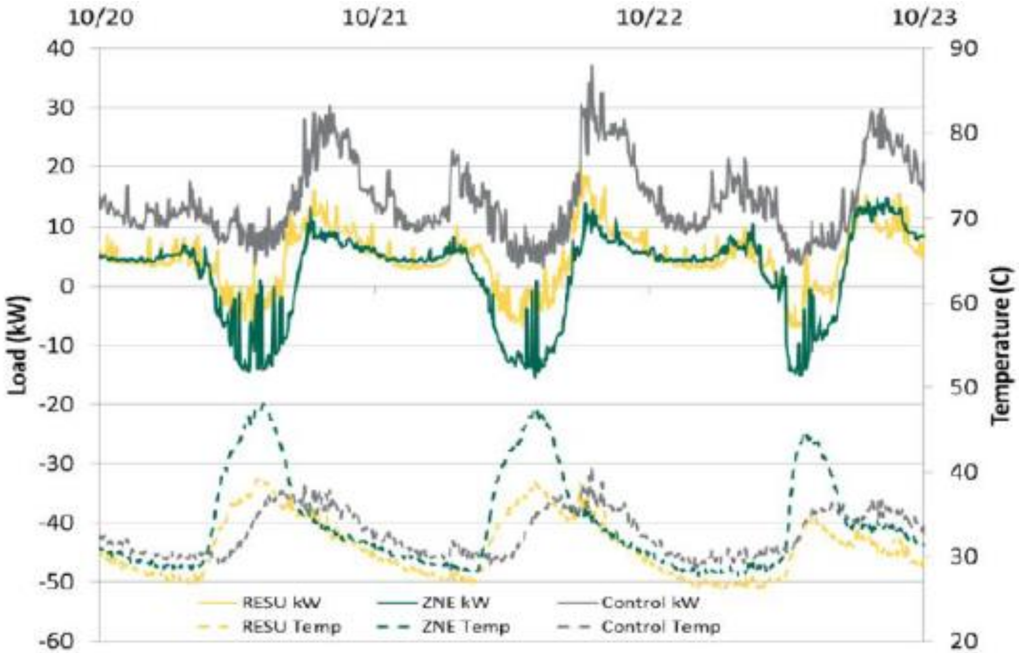
3.4 Planning Tools

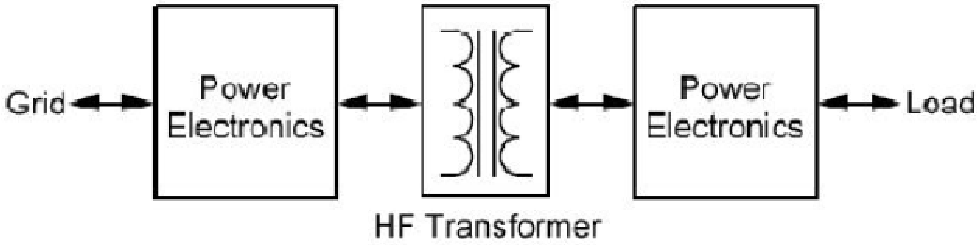
- Planning tools and simulators help answer questions and support decision making for the electric power system.
- Many different tools exist spanning various time horizons and geographic scales.
- Improvements in underlying models, data sets, tool interoperability, and accessibility will support grid modernization.



3.5 T&D Components

- The evolving power system is presenting opportunities and needs to revisit the designs and functionality of grid hardware.
- Innovations such as wide band gap semiconductors, new insulators, and nanotechnology can improve performance.
- Transformers, power flow controllers, protection devices, and cables and conductors can be improved.





3.6 Electrical Energy Storage Systems

- Low-cost energy storage technologies will be a critical tool for providing flexibility.
- Electrical energy storage technologies can store and inject electricity back into the grid.
- There are many storage technologies that can be used for different grid applications.
- Other than cost, there are other performance targets that need to be met.

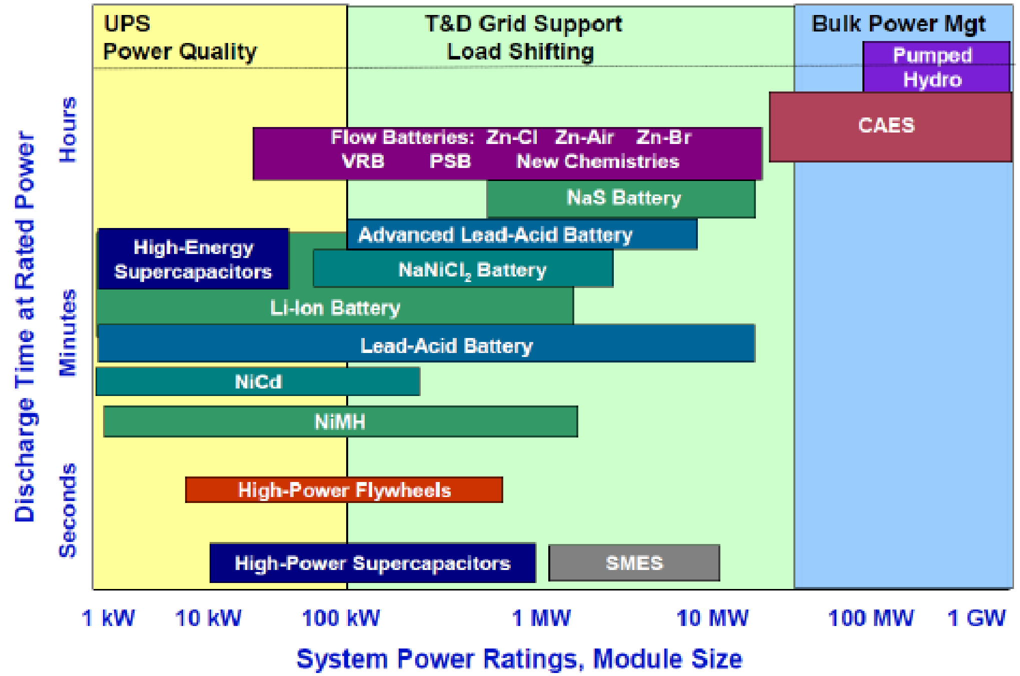
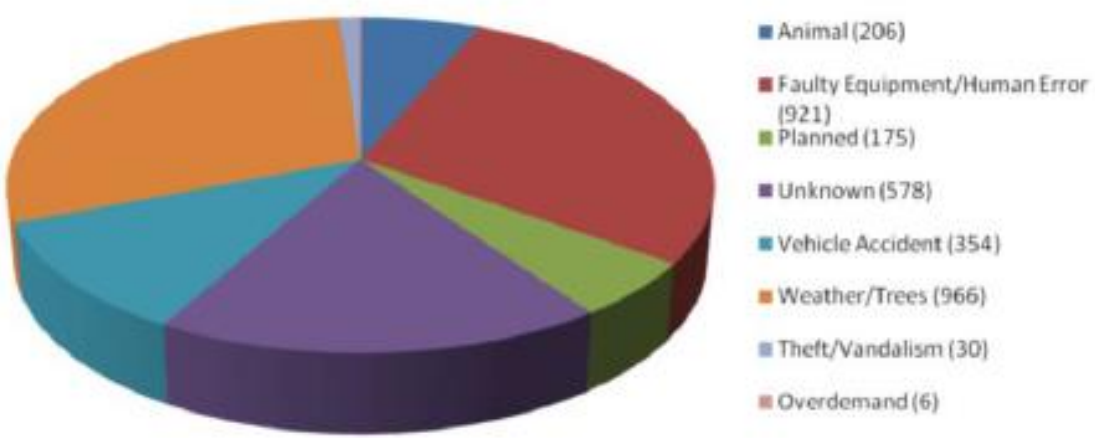


Table 8. Cost and Performance Targets for Electric Energy Storage Technologies	
Range of Baselines	System capital cost by energy: $805-$10,020/KWh Levelized cost: $0.01- $0.64/KWh/cycle System efficiency: 75-92% Cycle life: 5475 -225,000 over life of plant System capital cost by power: $300 -$4,600/kW
Near-term Targets	System capital cost by energy: under $250/kWh Levelized cost: under 20¢/kWh/cycle System efficiency: over 75% Cycle life: more than 4,000 cycles System capital cost by power: under $1,750/kW
Long-term Targets	System capital cost by energy: under $150/kWh Levelized cost: under 10¢/kWh/cycle System efficiency: over 80% Cycle life: more than 5,000 cycles System capital cost by power: under $1,250/kW

3.7 Cyber and Physical Security

- Deployment of advanced information and communication for the grid is occurring in an evolving cyber threat landscape that is getting more sophisticated and effective.
- Increased frequency and intensity of extreme weather events and potential attacks require more consideration into physical security.
- Solutions must consider the risks management strategies of those who will adopt the measures.



Key Findings

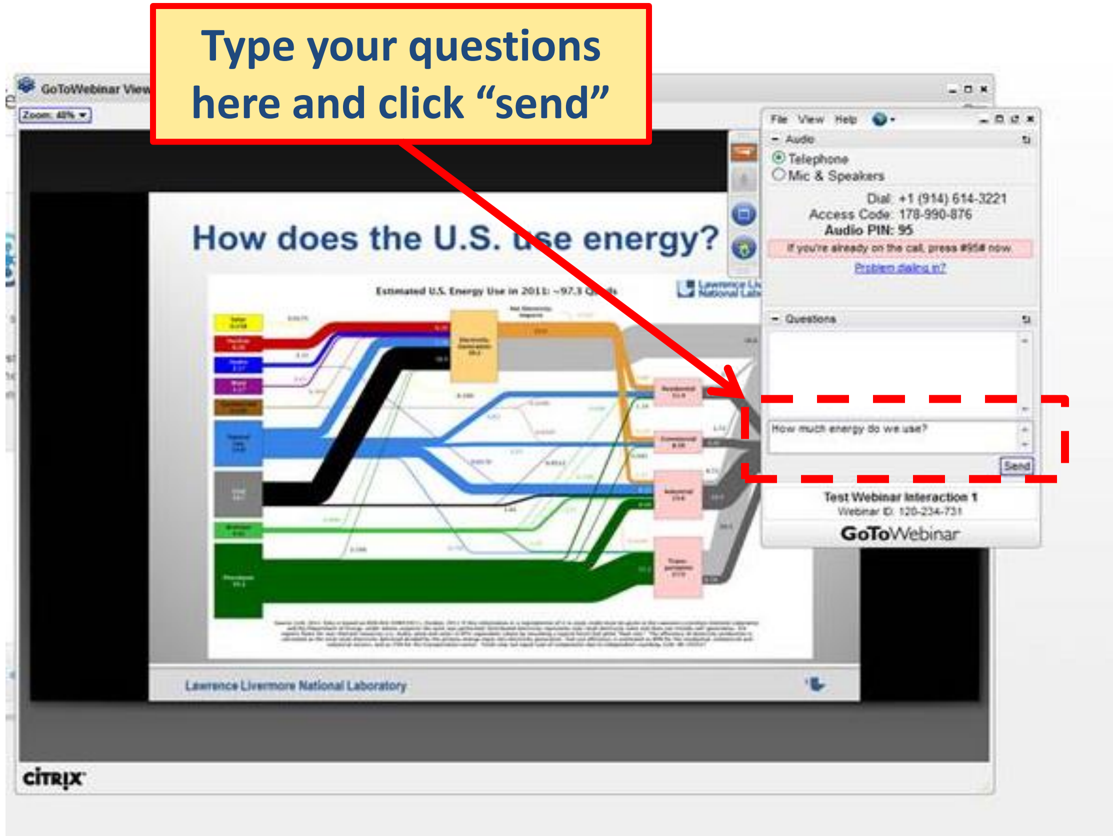
- Controls System - Transmission
  - Dynamic and Global View
  - Fast and Predictive Analytics
  - System-Wide Coordination
- Controls System - Distribution
  - Deep and Comprehensive Visibility
  - Distribution Automation and Outage Management
  - Coordination and Control of Distributed Resources
- Distributed Energy Resources
  - Grid-Enabled Resources
  - Integrated Systems
    - Smart Buildings
    - Microgrids

Key Findings

- Planning Tools
  - Improved Models and Simulators
  - Framework for Tool Interoperability
  - Decision Making Tools
- T&D Components
  - Advanced Transformers
  - Power Flow Controllers
  - Protection Equipment
  - Advanced Cables and Conductors
- Electrical Energy Storage Systems
  - Bulk Energy Technologies
  - Battery Technologies
  - Power Technologies
- Cyber and Physical Security

Public Input

- You are encouraged to submit questions using GoToWebinar's "Questions" functionality. The moderators will respond, via audio broadcast, to as many appropriate questions as time allows.



- If you have questions or comments that cannot be addressed during the webinar, email them to DOE-QTR2015@hq.doe.gov

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