Office of Electricity
Delivery & Energy
Reliability

Welcome and Overview

Kerry Cheung, PhD

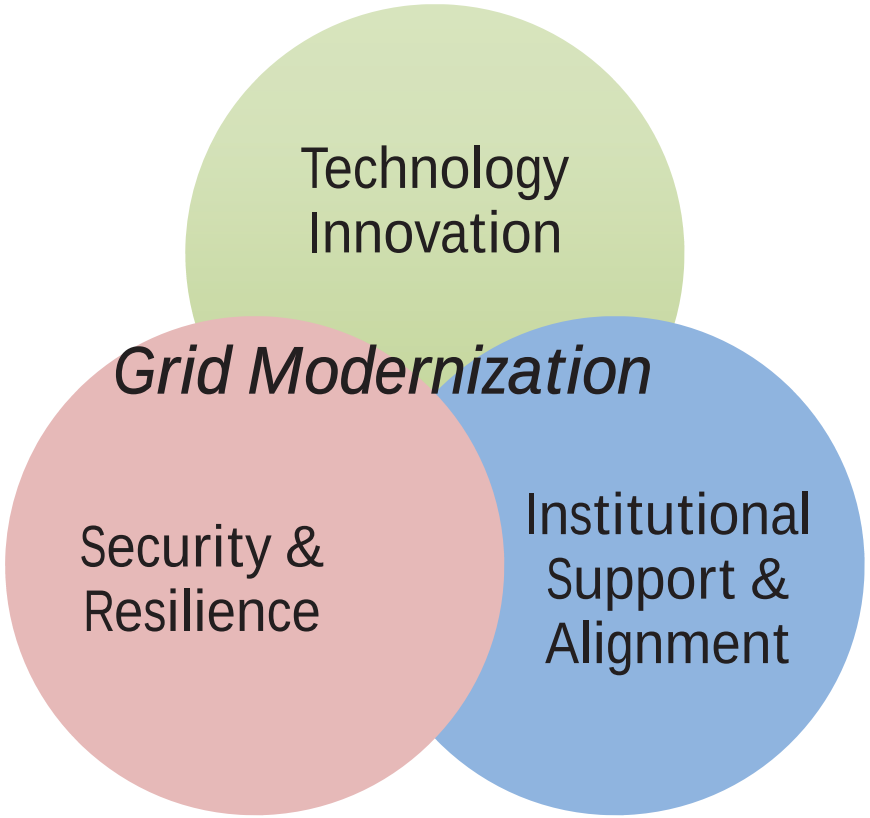
Materials Innovation for Next Generation T&D Grid Components

August 26-27, 2015

OE Mission

The Office of Electricity Delivery and Energy Reliability (OE) drives electric grid modernization and resiliency in the energy infrastructure.

- OE leads the Department of Energy's efforts to ensure a resilient, reliable, and flexible electricity system.
- OE serves as the Energy Sector Specific lead for the Federal emergency response when activated by DHS/FEMA.



Rapidly Evolving Energy Sector

- The last five years have been defined by dramatic changes across the energy sector:
  - Unconventional fossil fuel production
  - Renewables cost reduction and market penetration
  - Nuclear power opportunities
  - Transportation electrification
  - Buildings and industrial efficiency
  - Manufacturing and competitiveness
  - Increasing use of digital technologies in the energy sector: Power, Vehicles, Industry, and Buildings
- The grand challenges, shifting policies, and changes in available technologies require new approaches to better configure our national programs, capabilities, and policies for success.

DOE Quadrennial Reviews

- In November 2010, the President's Council of Advisors on Science and Technology (PCAST) recommended an integrated federal energy policy.

- The Quadrennial Energy Review (QER) was called for by the President on January 9, 2014
  - **Volume 1 released on April 21, 2015**
  - **Focused on energy infrastructure (TS&D)**

- A review of DOE's work on energy technology innovation—the Quadrennial Technology Review (QTR)—is one component.
  - **First QTR published in September 2011**
  - **2015 QTR will be released September 10**

Changing Generation Mix

Figure 31. Electricity generation by fuel in the Reference case, 2000-2040 (trillion kilowatthours)

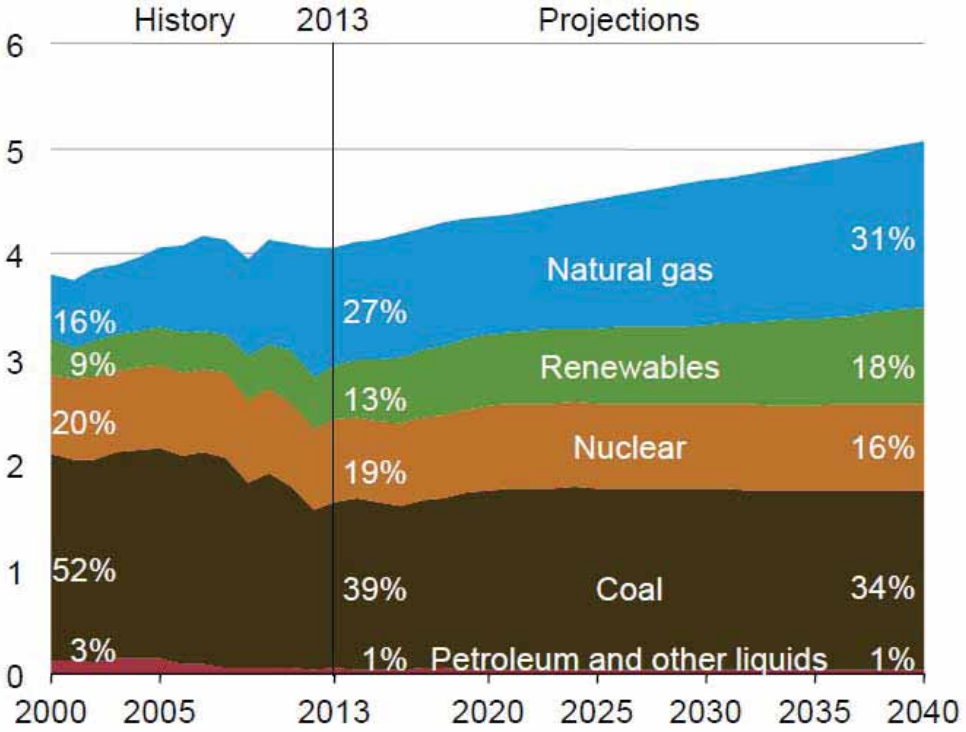
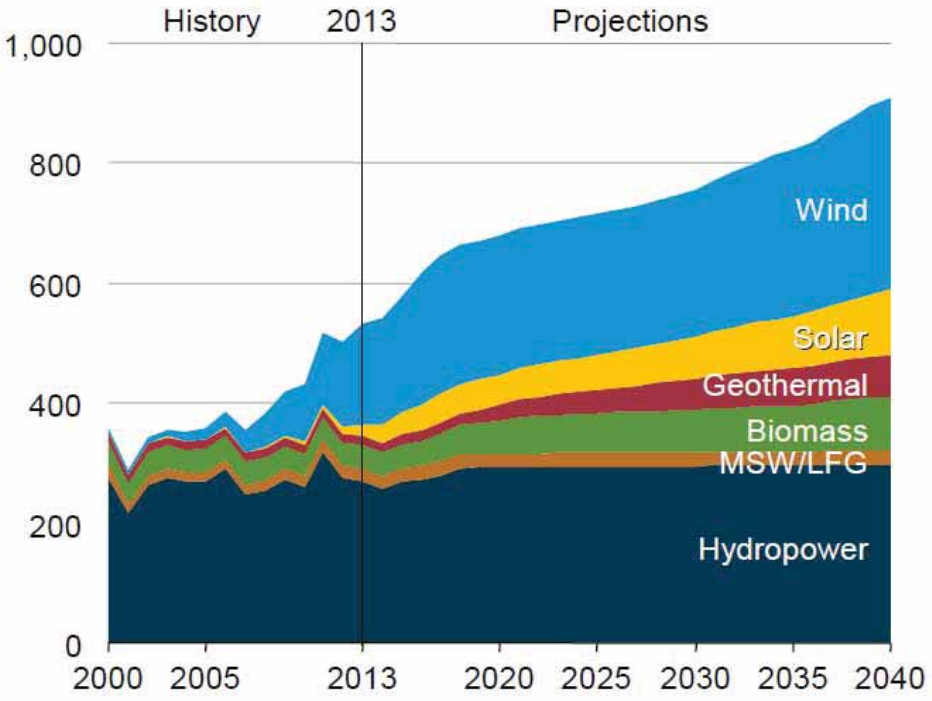
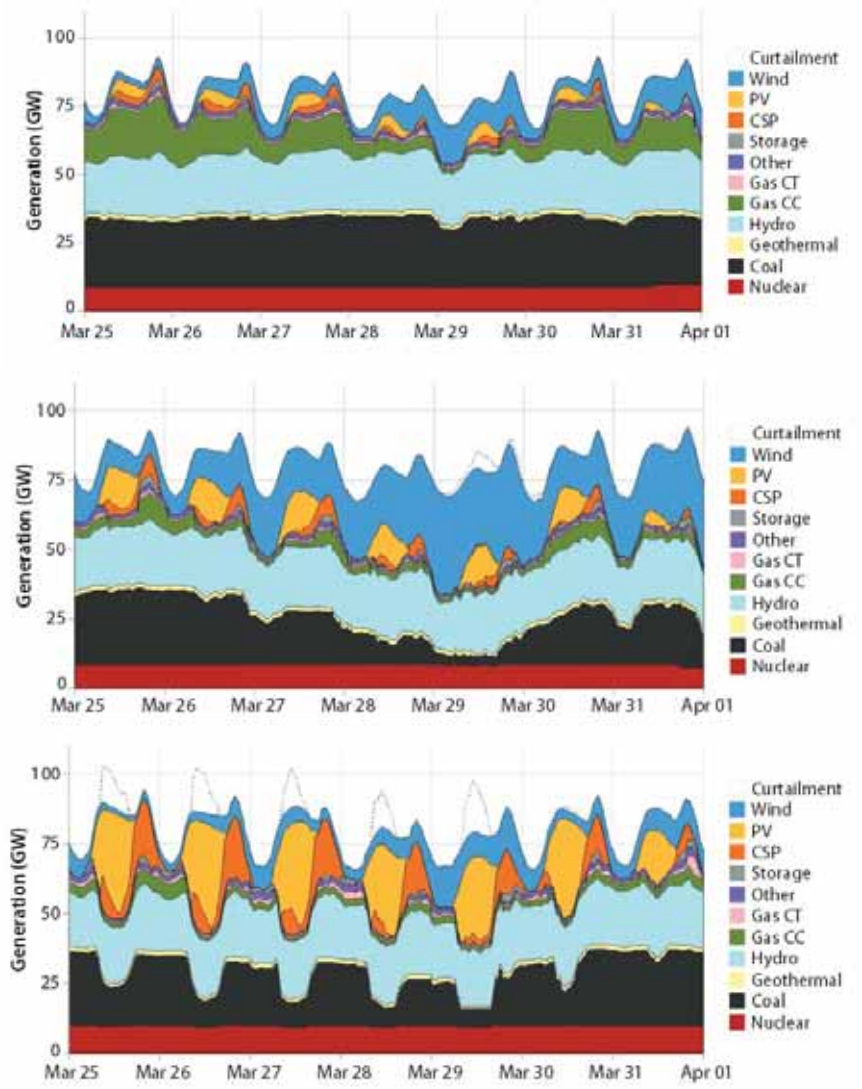


Figure 34. Renewable electricity generation by fuel type in the Reference case, 2000-2040 (billion kilowatthours)

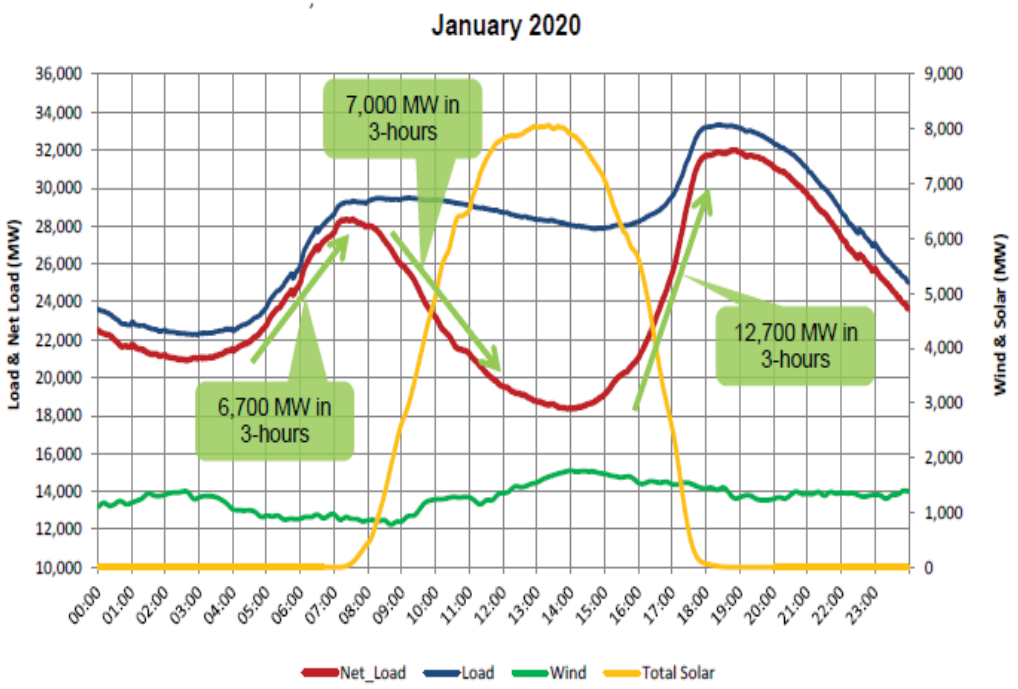


- From 2008 to the end of 2013, electricity generated from wind has more than tripled, and the amount from solar has increased by more than tenfold.
- Cost reductions and supportive policies have resulted in greater deployment of renewable resources and this trend is projected to continue.

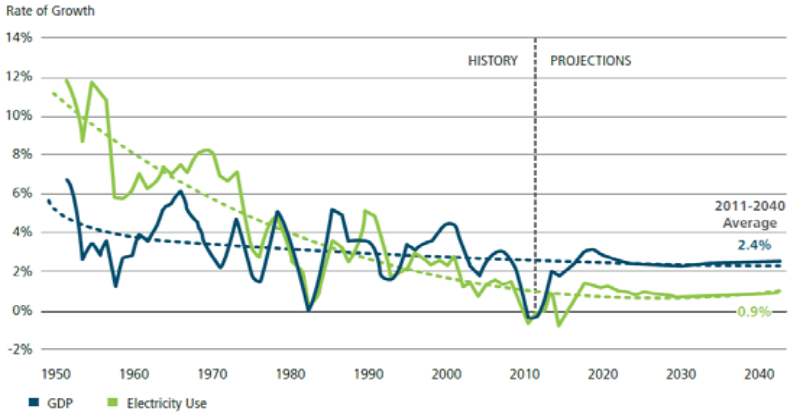
Increased Flexibility Needed



- Increased variability and uncertainty introduced by renewable resources requires greater system flexibility
- There are many options for providing this flexibility

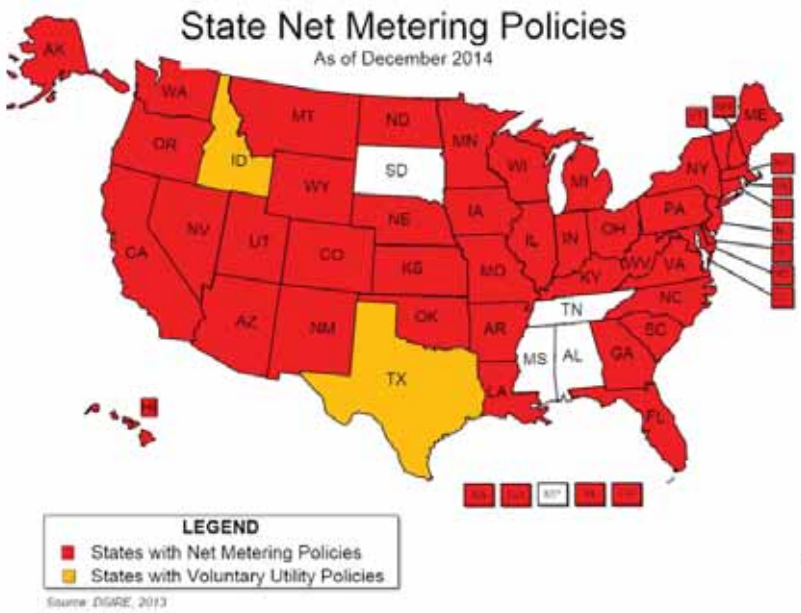


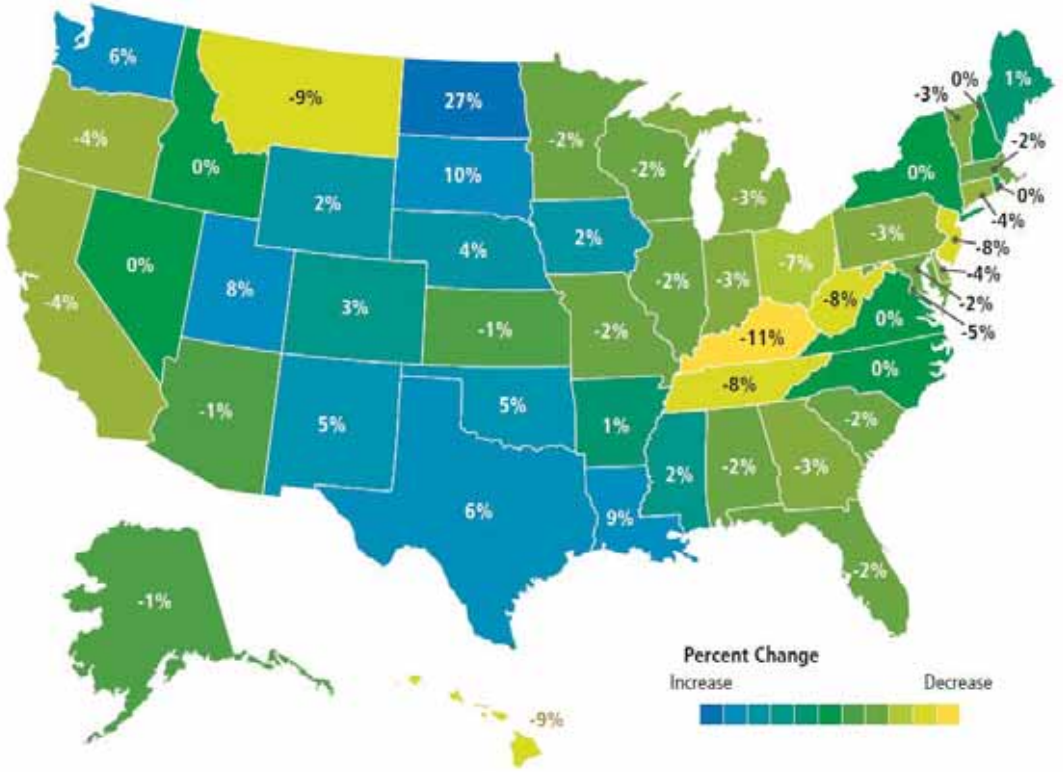
Evolving Customer



The rate of growth in electricity use has declined since 1950, while the rate of growth in gross domestic product has stayed relatively constant. The slower electricity growth rate is a result of several factors, including a decline in energy-intensive industries, increasing energy efficiency, and the slow recovery from the recent recession.

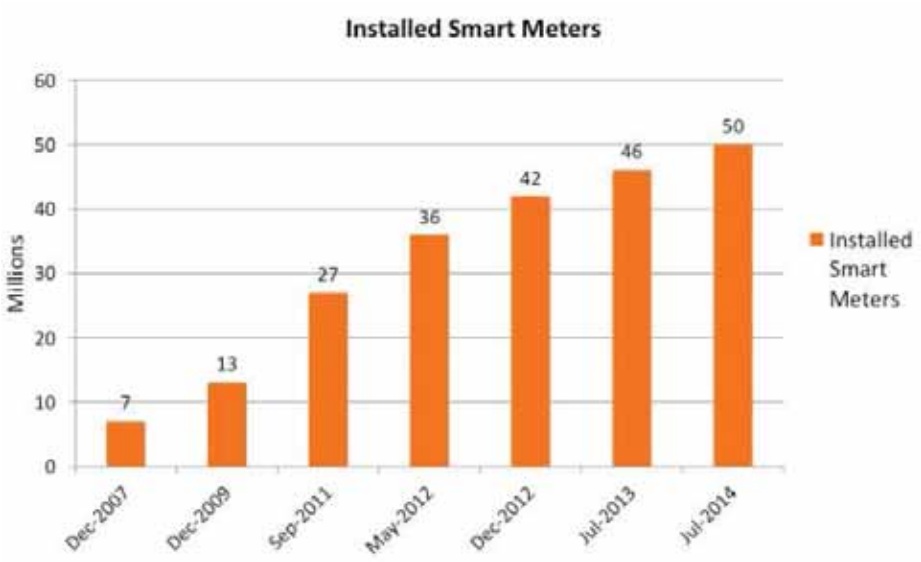
- Electricity more vital to GDP
- Decrease in retail sales varies by state
- Consumer becoming prosumer

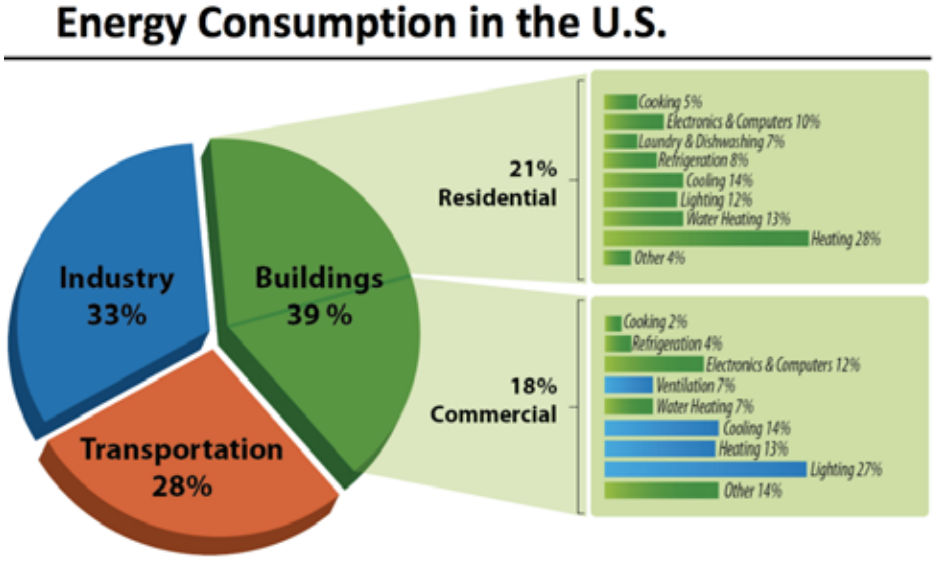


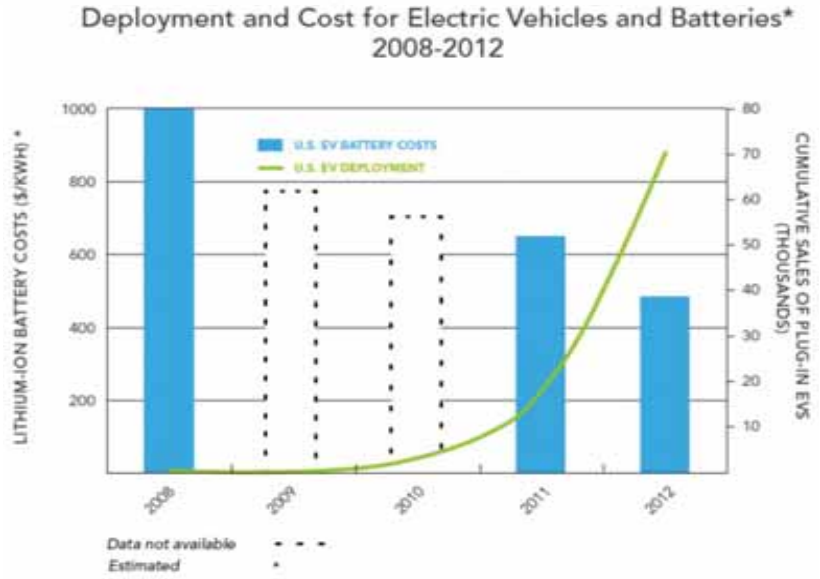


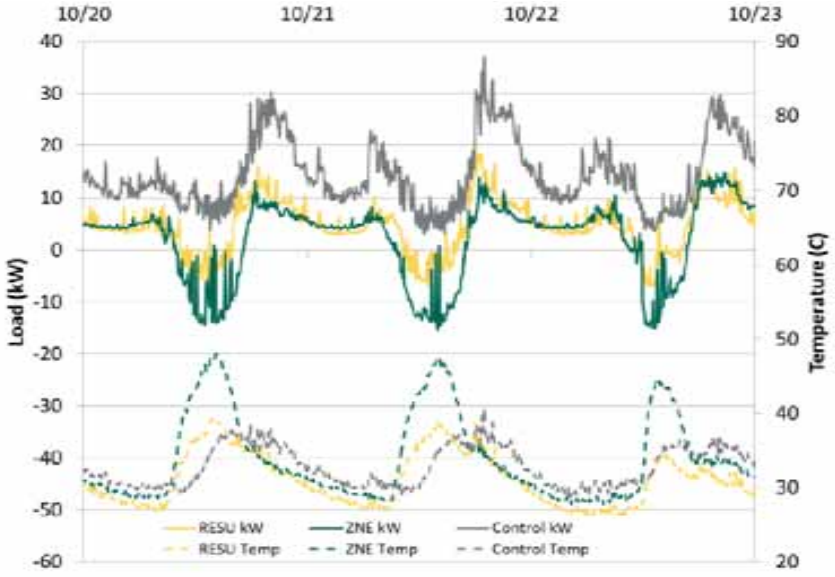
There is a considerable variation in electricity retail sales among states and by region, ranging from an increase of 27 percent in North Dakota to a decrease of 11 percent in Kentucky; these variations are due in part to changes in load growth.

New Customer Technologies

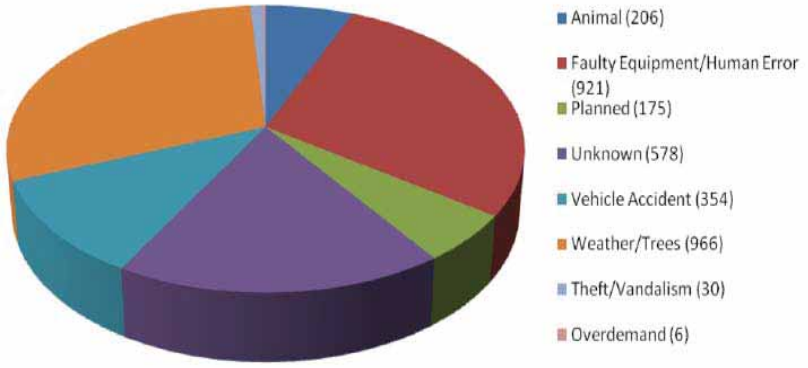




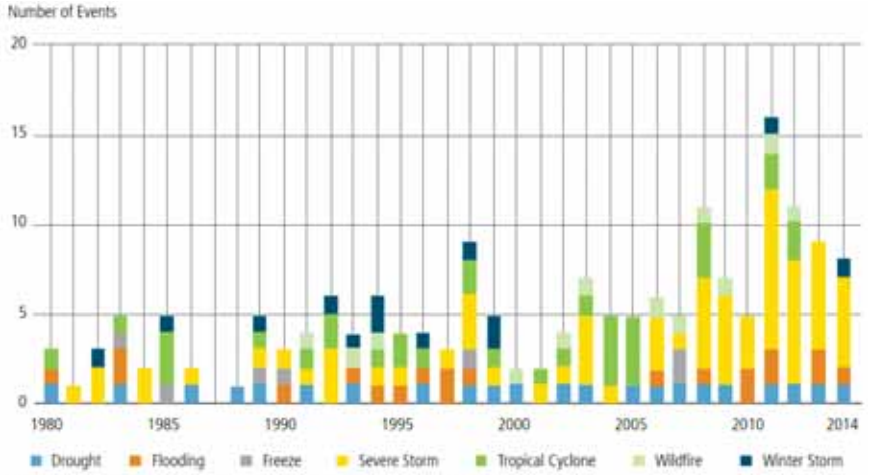


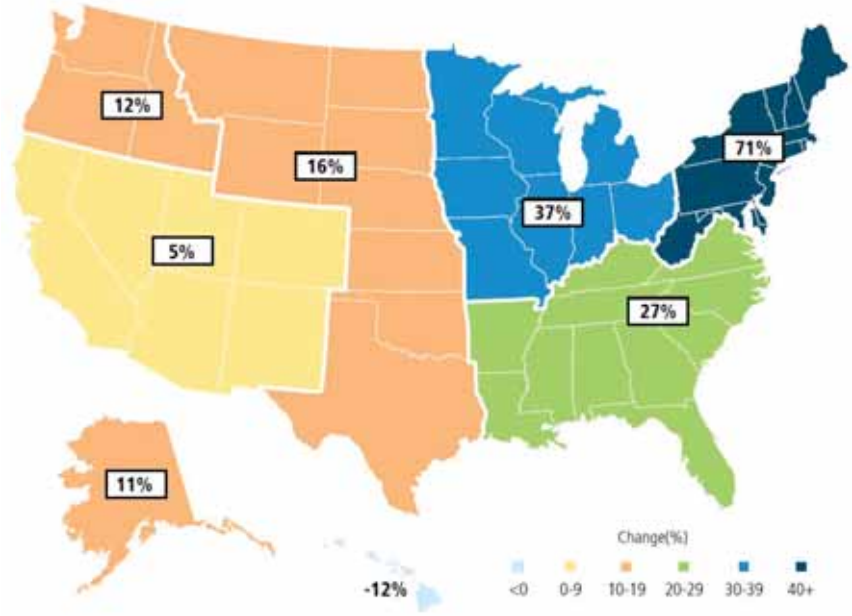


Increasing Risks

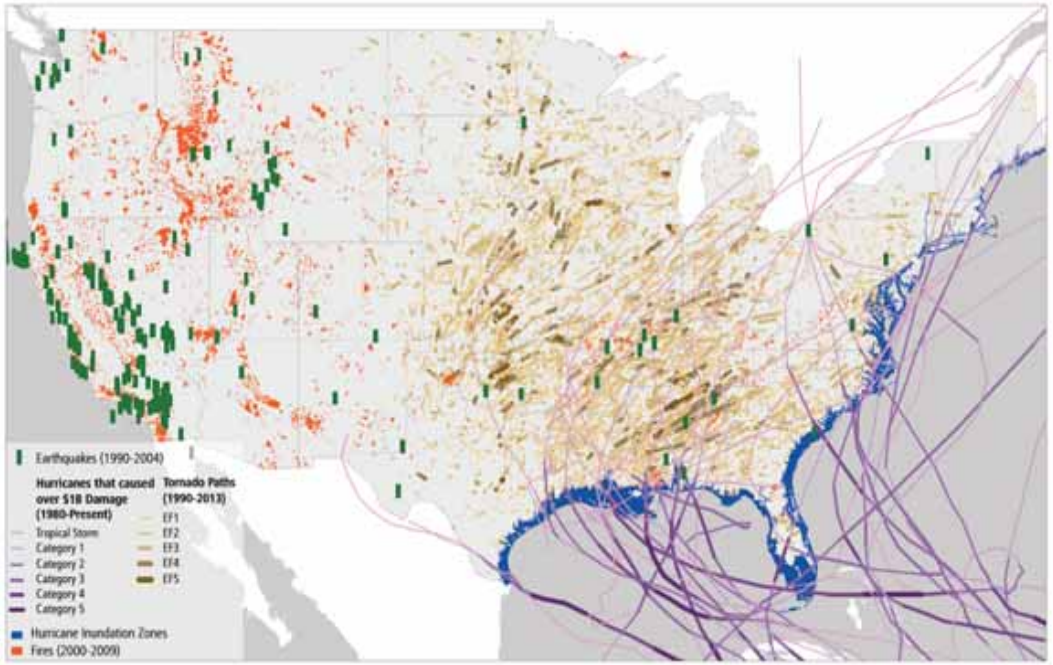


Source: Power Outage Annual Report, Eaton, 2013





Intense precipitation events are becoming more frequent, particularly in the northeastern United States. The map shows percent increases in the amount of precipitation falling in very heavy events (defined as the heaviest 1 percent of all daily events) from 1958 to 2012 for each region of the United States.



Grid Modernization Vision

*The future grid provides a critical platform for U.S. prosperity, competitiveness, and innovation in a global clean energy economy. It must deliver **reliable, affordable,** and **clean electricity** to consumers where they want it, when they want it, how they want it.*

Achieve Public Policy Objectives

- 80% clean electricity by 2035
- State RPS and EEPS mandates
- Access to reliable, affordable electricity
- Climate adaptation and resilience

Sustain Economic Growth and Innovation

- New energy products and services
- Efficient markets
- Reduce barriers for new technologies
- Clean energy jobs

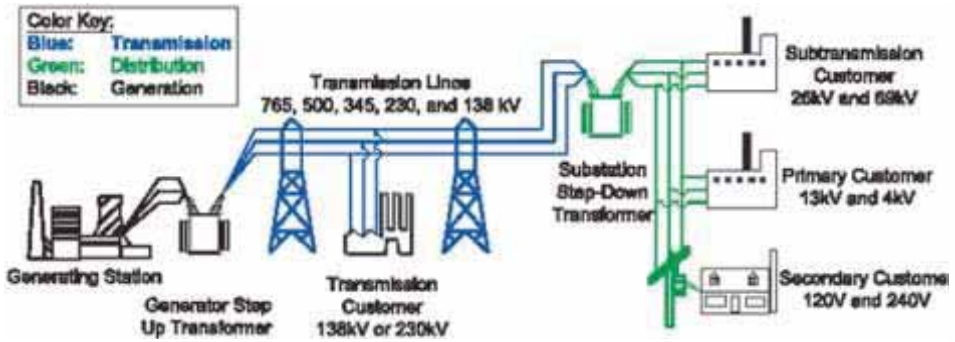
Mitigate Risks and Secure the Nation

- Extreme weather
- Cyber threats
- Physical attacks
- Natural disasters
- Fuel and supply diversity
- Aging infrastructure

Transforming the Grid

Current System

- Monolithic
- Centralized generation
- Decisions driven by cost
- Catastrophic events
- Limited energy choices
- Vulnerable to new threats



Future Paradigm

- Modular and Agile
- Centralized and distributed generation
- Decisions driven by cost and environmental sustainability
- Contained events
- Personalized energy options
- Inherently secure to all threats

American Recovery and Reinvestment Act (ARRA)

In 2009, the Office of Electricity Delivery and Energy Reliability (OE) received $4.5 billion in Recovery Act funds to support grid modernization activities:

- Smart Grid Investment Grants (SGIG) - $3.4 billion
- Smart Grid Demonstration Program (SGDP) - $620 million
- Workforce Training - $100 million
- Interconnection-wide Transmission Planning and Resource Analysis - $80 million
- Interoperability Standards (with NIST) - $12 million
- Technical Assistance to States - $44 million
- Local Energy Assurance Planning - $10 million

SGIG Deployment Status

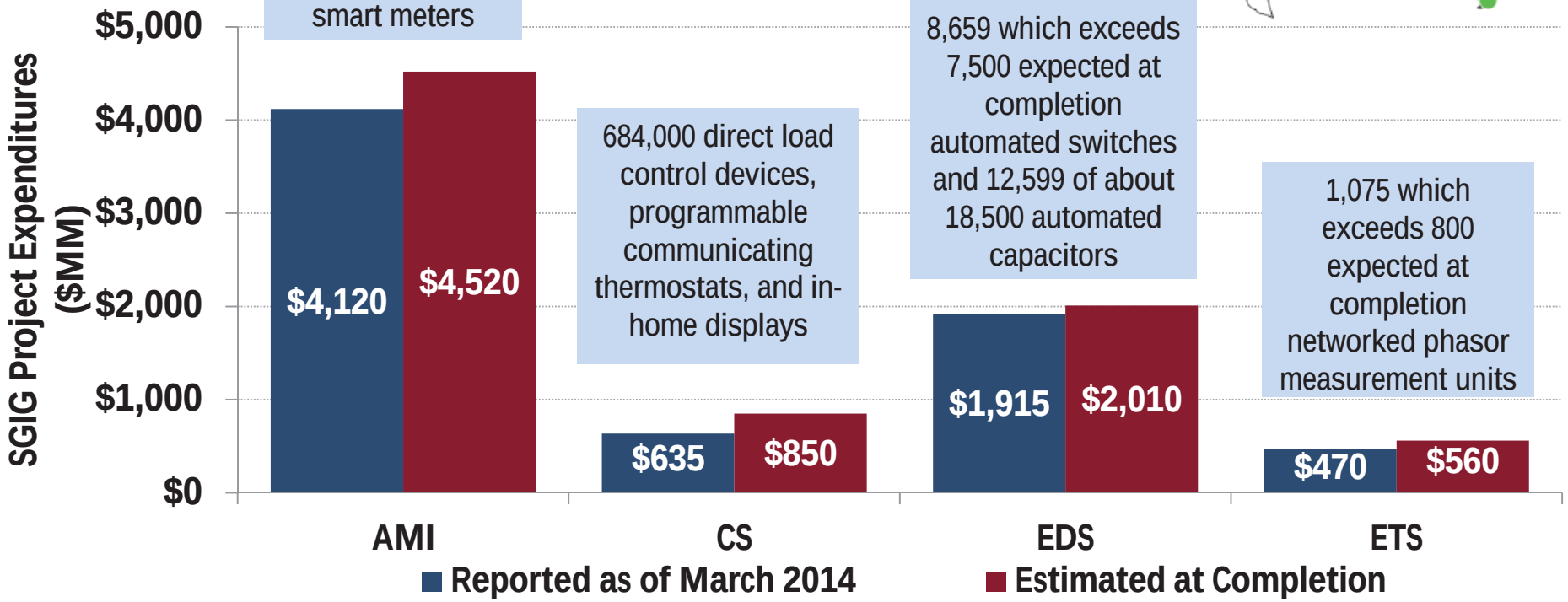
99 Projects with 228 Utilities

15.3 of 15.5 million residential and commercial smart meters

684,000 direct load control devices, programmable communicating thermostats, and in-home displays

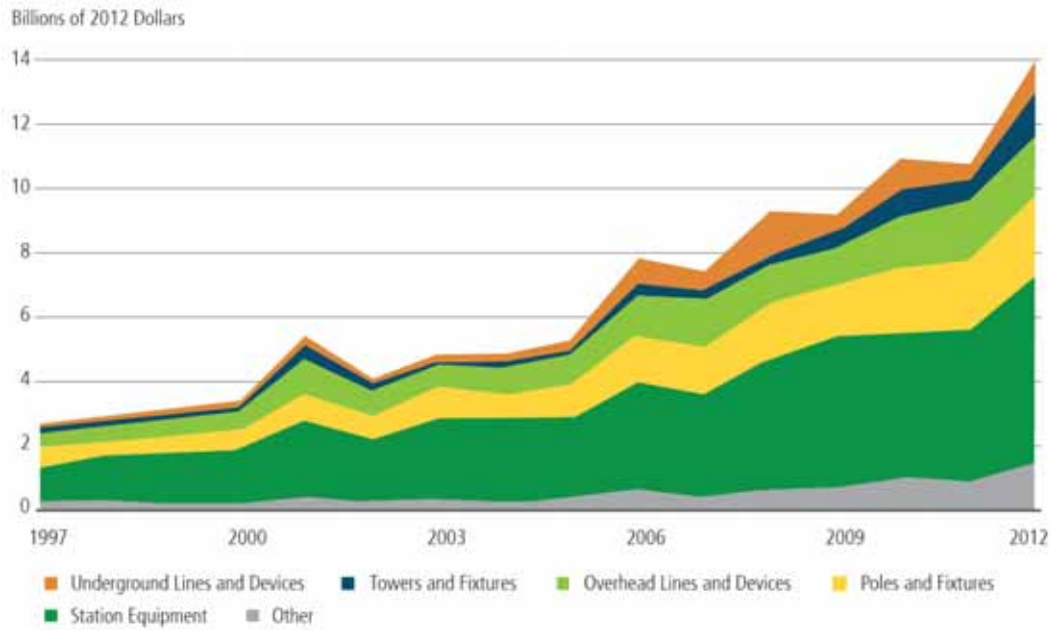
8,659 which exceeds 7,500 expected at completion automated switches and 12,599 of about 18,500 automated capacitors

1,075 which exceeds 800 expected at completion networked phasor measurement units



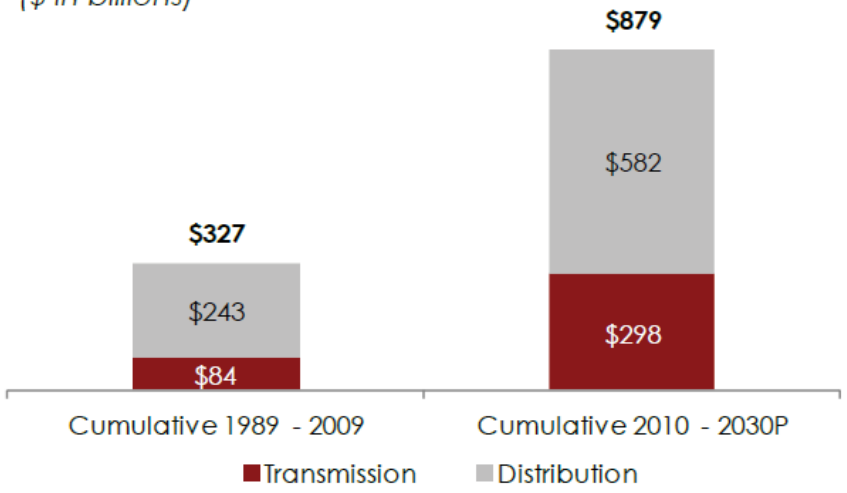
Infrastructure Opportunities

Figure SPM-5. Investment in Transmission Infrastructure by Investor-Owned Utilities, 1997–2012



U.S. T&D Historical and Projected Spending

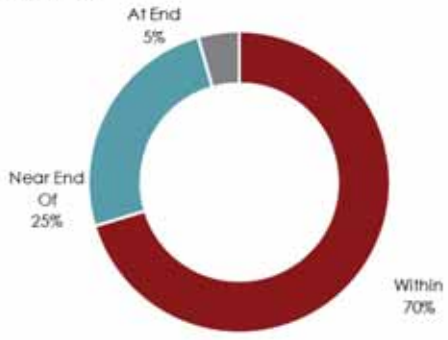
($ in billions)



Current Infrastructure Age Relative to Useful Life

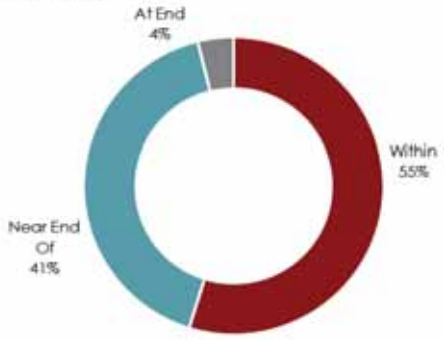
Transmission Infrastructure

(as a % of total)

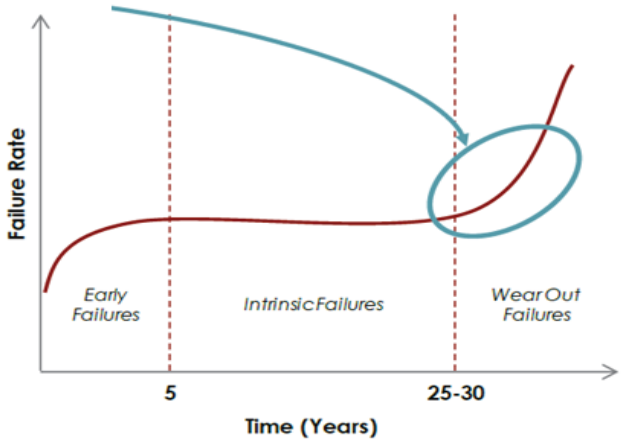


Distribution Infrastructure

(as a % of total)

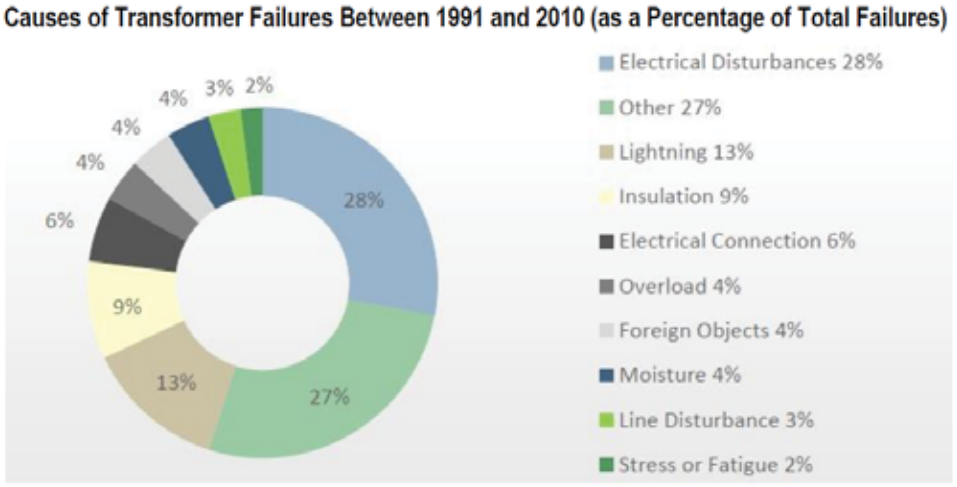


Transformer Failure Rate Curve

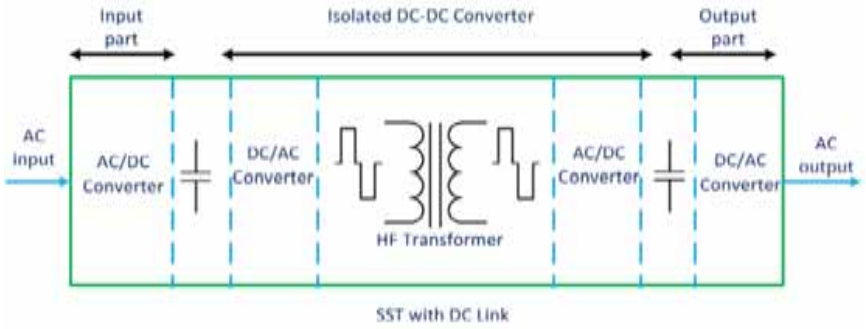


Next Generation Transformers

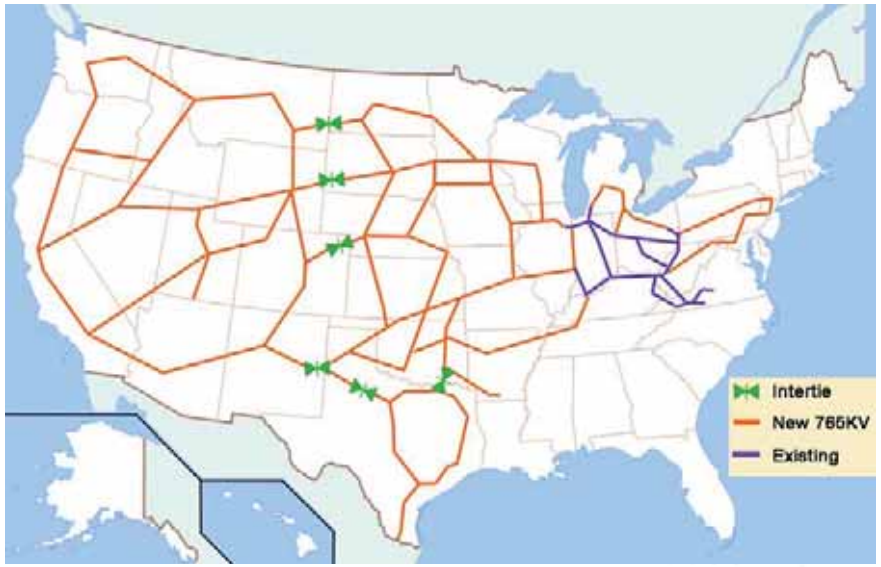
- Almost 50% of LPT failures are associated with the limits of insulation (e.g., lightning, electrical disturbances)
- Manufacturing and delivery of a LPT replacement cant take up to two-years.
- New design concepts for next generation components can address some challenges.



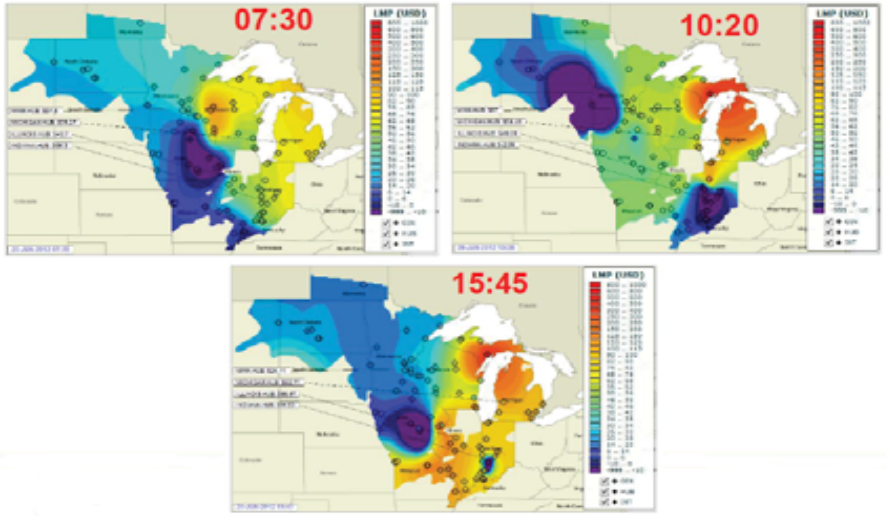
Source: SPX, 2012 Doble Engineering Company—79th Annual International Doble Client Conference; Analysis of Transformer Failures, by William H. Bartley P.E., Hartford Steam Boiler Inspection & Insurance Co.



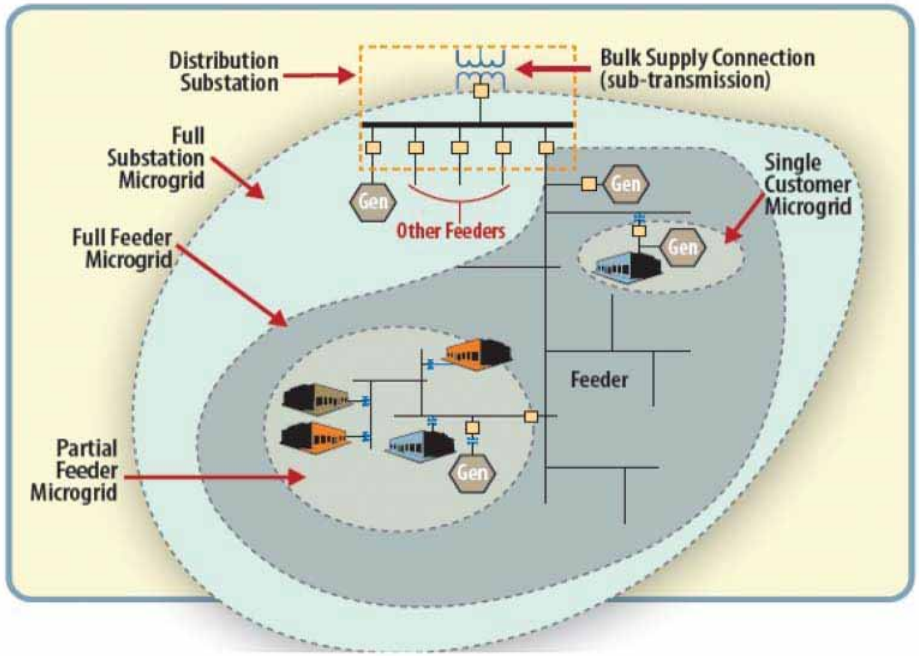
Next Generation Components



Midwest ISO real time LMPs for June 20th, 2012



- **The future grid will have more advanced components and systems across transmission and distribution**
  - HVDC/MVDC Networks
  - Power Flow Controllers
  - Microgrids

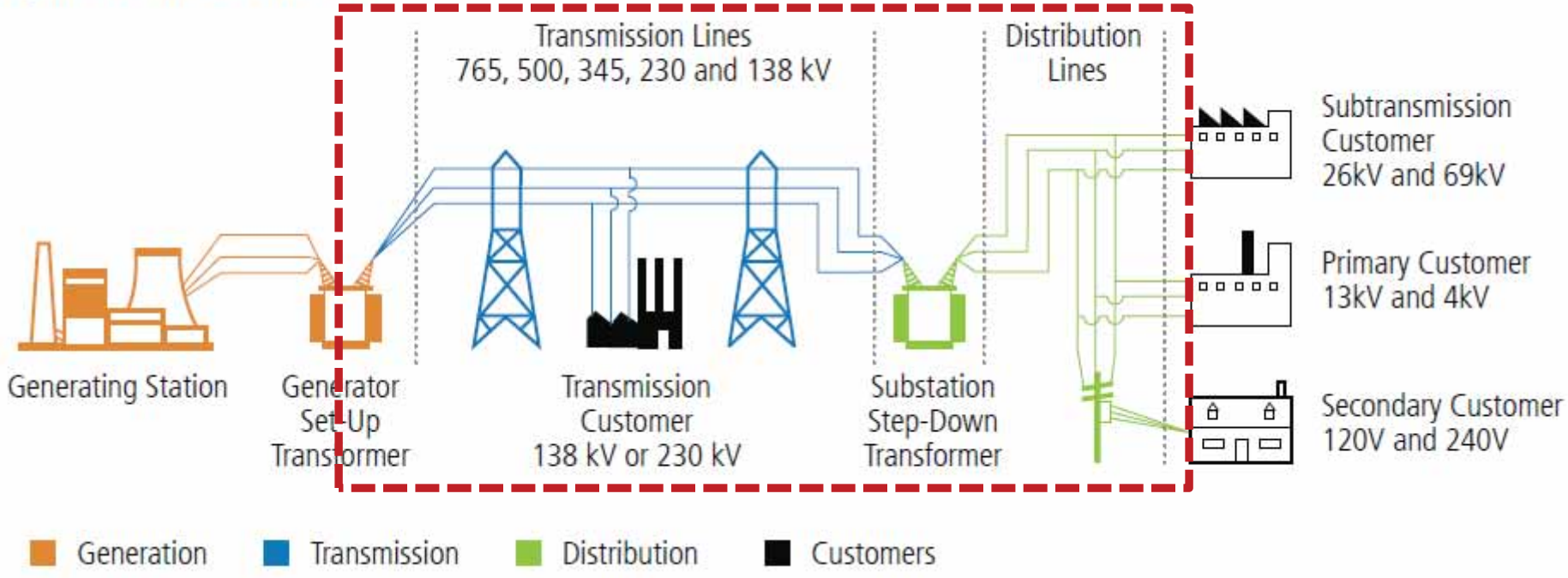


Transformer Resilience and Advanced Components Program

- **Goals**
  - Ensure the resilience of aging assets and identify new requirements for future grid components (**Near-Term Focus**)
  - Accelerate the development, demonstration, and deployment of next-generation components (**Long-Term Focus**)
- **Activities**
  - Component Monitoring, Modeling, and Testing
  - Market and System Impact Analysis
  - **Applied Materials Research and Innovation**
  - Component Design and Development

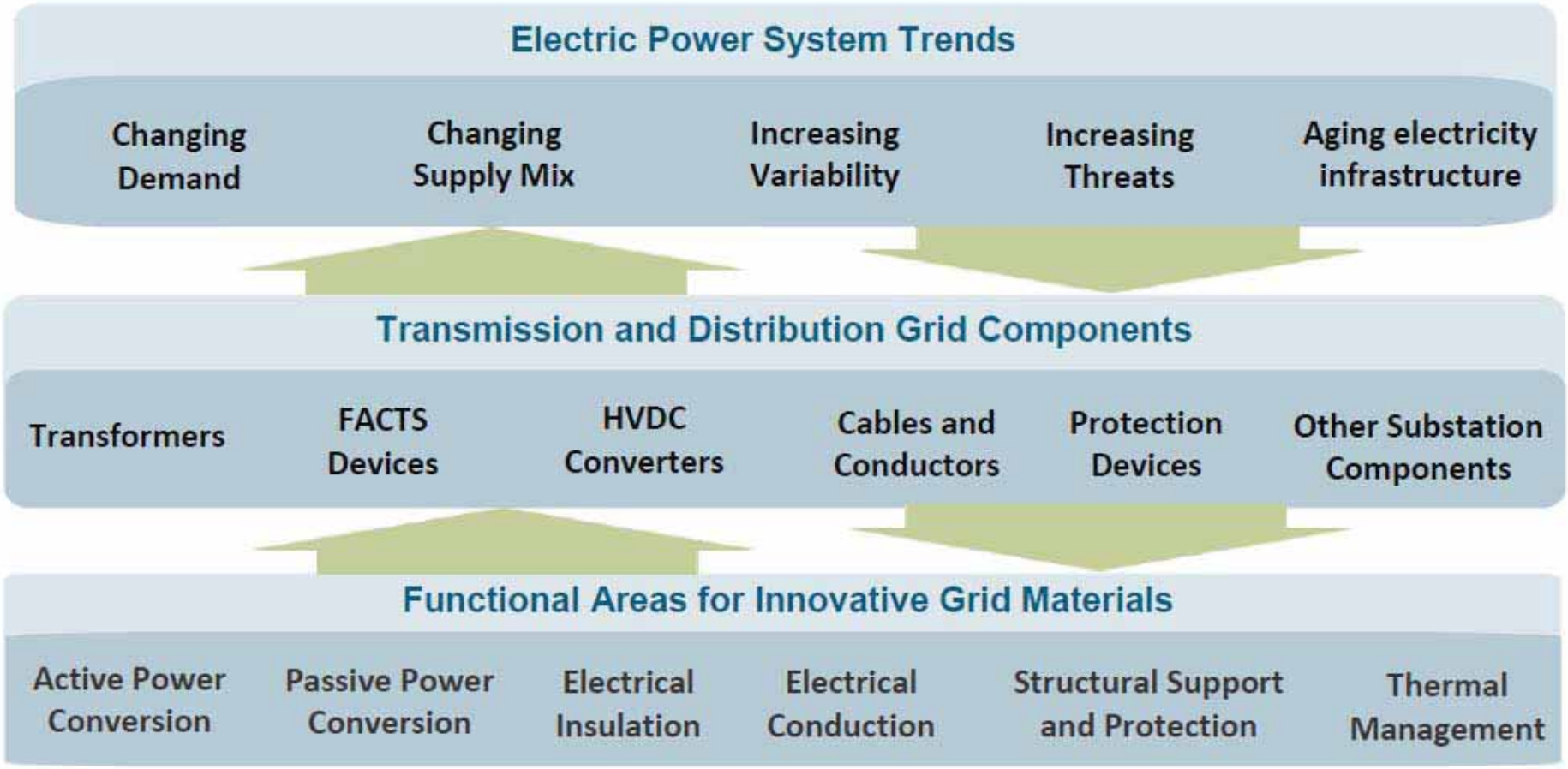
Workshop Scope

Figure 3-1. The Electric Grid[1]



- The electric grid is at the core of the electric power system (dashed box)
- Transmission and distribution components, the hardware responsible for carrying and controlling electric power, are the primary focus.
- **Energy storage, generators (i.e., inverters), and loads are NOT in scope**.

Workshop Purpose



Materials innovation can enhance grid components to address emerging system trends; simultaneously, system trends change grid component requirements that can drive new material innovations.

Speaker Line Up

- **Grid Applications Overview**
  - Joe Schatz (Southern Company)
  - Richard Ord (EPRI)
  - Alex Huang (NCSU/FREEDM Center)
- **Materials Development Overview**
  - Debbie Haught (DOE/OE)
  - Paul Ohodnicki (NETL)
  - Jim Davidson (Vanderbilt University)
- **Manufacturing Innovations**
  - Mark Johnson (DOE/AMO)