Office of Electricity

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Electricity plays a vital role to our economy and national security. Most Americans can not describe what it is or where it comes from.

Yet, we know the impact that reliable electricity plays on nearly all aspects of our lives: health and welfare; communications; finance; transportation; food and water supply; heating, cooling, and lighting; computers and electronics; commercial enterprise; and even entertainment and leisure.

Electric Grid

~ 3000 utilities with diverse business models

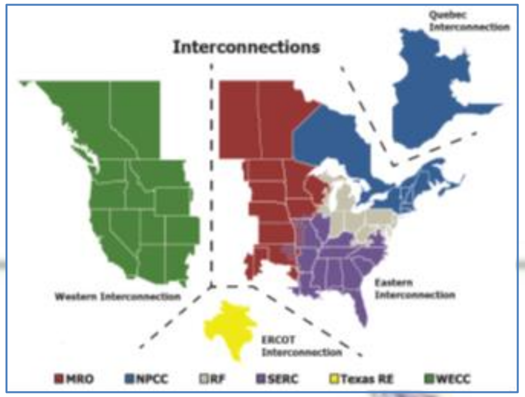
- *Investor-Owned Utilities*
- *Electric Cooperatives*
- *Public Power/ Municipal Utilities*
- *Federal Government*

Diverse markets and regulatory frameworks

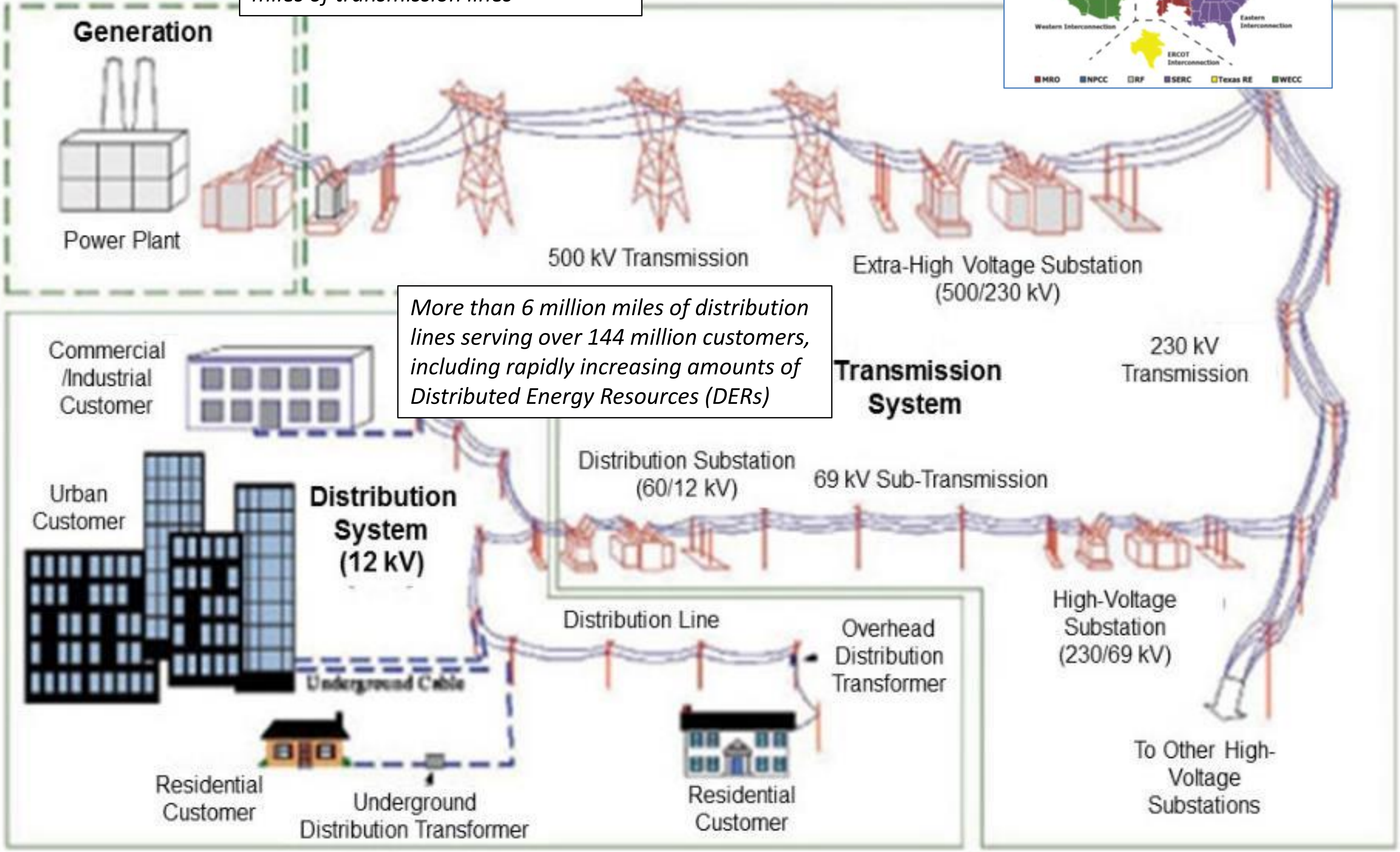
Evolving convergence of utility, 3rd-party, and customer systems and priorities

New, rapidly emerging types of participants offering grid services and technologies which need to coherently integrate with the legacy system

More than 9,200 electric generating units having more than 1 million megawatts of generating capacity connected to more than 470,000 miles of transmission lines



More than 6 million miles of distribution lines serving over 144 million customers, including rapidly increasing amounts of Distributed Energy Resources (DERs)



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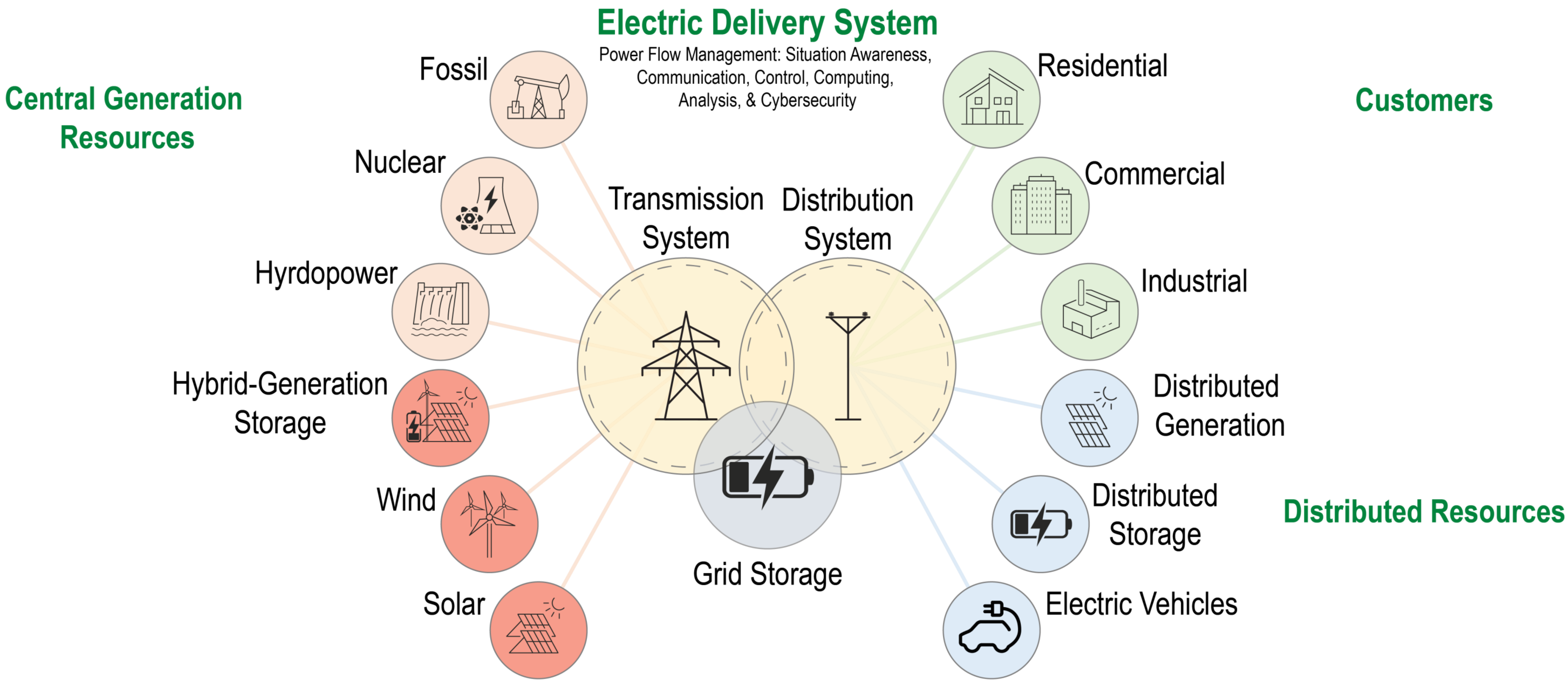
The electricity delivery system is a complex machine that manages the flow of power from diverse resources to where it is needed in real-time under constantly changing conditions



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Unprecedented Evolution in the Power Grid

Growing Asset Stress

- Operating Closer to Edge
- Lower System Inertia
- Aging Infrastructure
- Fewer Power Engineers

Increased Variable Generation

- More Dynamic Behavior
- More Stochastic
- Multi-level Coordination

More Dynamic Markets

- Broader Markets & More Services
- Greater Complexity
- More Frequent Clearing

New Controllable Assets

- Demand Response
- Energy Storage / Electric Vehicles
- Dynamic T&D Assets

Massive Data

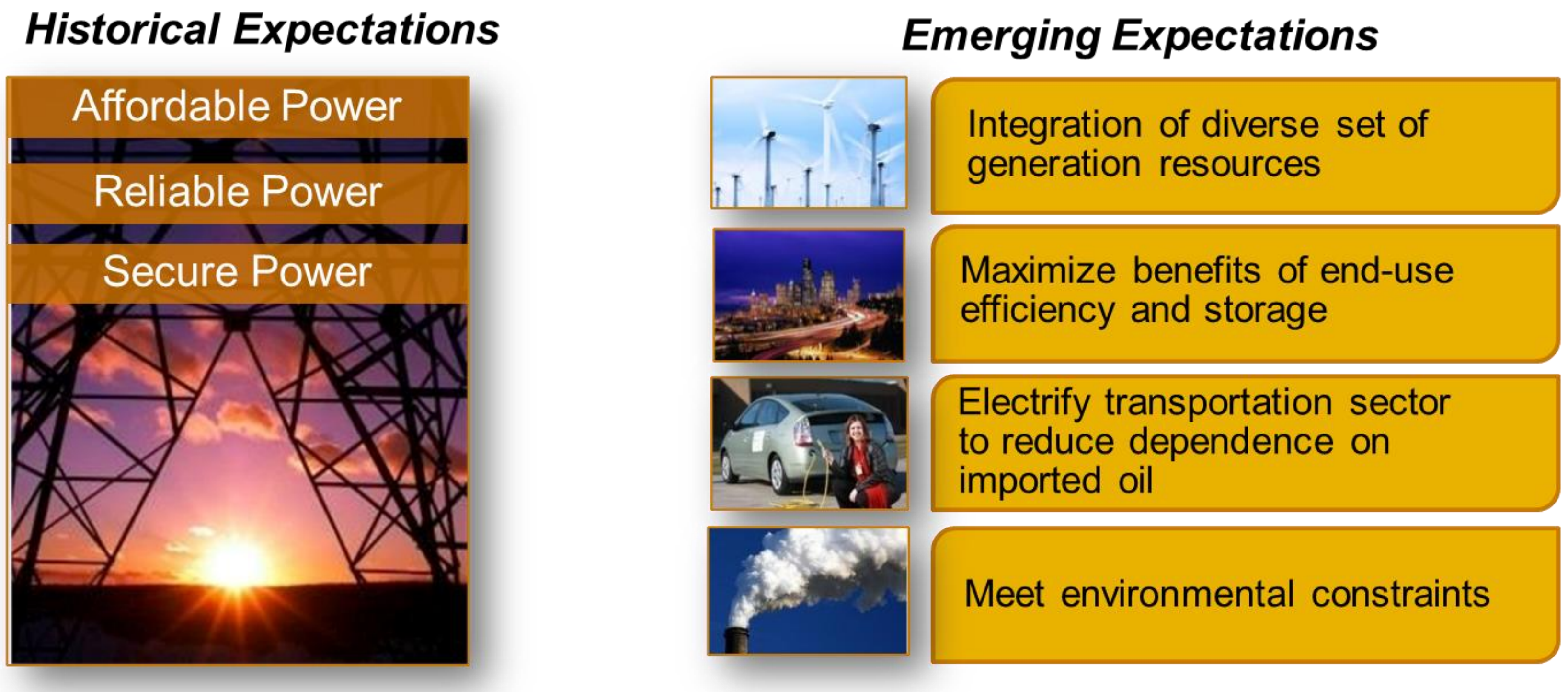
- PMU & Over the Horizon Monitoring
- AI & Machine Learning
- New control paradigms

Computational Advances

- Fast Computation
- Cloud Computing
- Probabilistic Methods
- Pervasive Intelligence

Source: PNNL

Decarbonized Grid is Critical for Energy Transition



The Biden administration has established a national goal of 100% carbon-free electricity by 2035 and reaching net-zero economy-wide greenhouse gas emissions by 2050. Most plausible pathways to net-zero emissions call for the significant expansion of renewables along with electrification of multiple sectors, such as buildings, industry and transportation.

To realize these goals, the United States must not only transition the production of power to cleaner sources of energy, but also make major upgrades to the grid, both structurally and operationally. The transmission and distribution network needs modernization, expansion, and improvements in efficiency as well as stability.

Drivers of Change

- ✓Efforts to decarbonize the grid and the US economy
- ✓Rise of non-dispatchable and invertor-based generation
- ✓Changing grid edge – bi-directional power flow
- ✓Evolving demand for electricity - electrification
- ✓Growing physical and cyber threats
- ✓Efforts to reduce social inequalities
- ✓Impact of energy transition on employment
- ✓Globalization of supply chains

Emerging Conditions Affecting Power System

- **Economics is driving changes in supply and load**
  - *Fuels used to generate electricity*
  - *Locations where electricity is generated*
  - *Means by which electricity generation is managed*
  - *Characteristics of loads served by electricity*
- **Power system characteristics are evolving**
  - *Rotational inertia replaced by reduced stability/faster dynamics*
  - *Transmission and distribution becoming more "adaptive"*
  - *Operator-based grid management and off-line analysis are not sufficient*
- **Operational context is being challenged**
  - *Emerging threats such as frequent and intense weather events, along with potential for cyber and physical attacks*
  - *Consumer expectations for greater reliability and resilience*

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Working closely with *industry and other stakeholders*, the Office leads the Department's efforts to ensure that the Nation's electricity infrastructure is reliable, secure and resilient to disruptions.

These efforts will strengthen, transform, and improve electricity infrastructure so consumers have reliable access to clean sources of energy.

OE's RD&D activities drive grid technology evolution and provide long-term transformational strategies to ensure that electricity delivery systems can *support all evolving generation and new types of loads*, including distributed energy resources, while operating reliably under a variety of conditions.

OE's efforts ensure the grid builds-in security and resilience considerations through grid modernization.

Grid Systems and Components

- Advanced, Modular, Flexible Transformers
- Cables and Conductors
- Solid State Power Substations
- HVDC/MVDC Systems
- Power Floor Controllers (PFC)
- Solid-State Components
- Advanced Materials
- Robotics/Autonomous Vehicles
- Microgrids
- Applied Grid Transformation Solutions

OE RD&D Portfolio

Communications and Controls

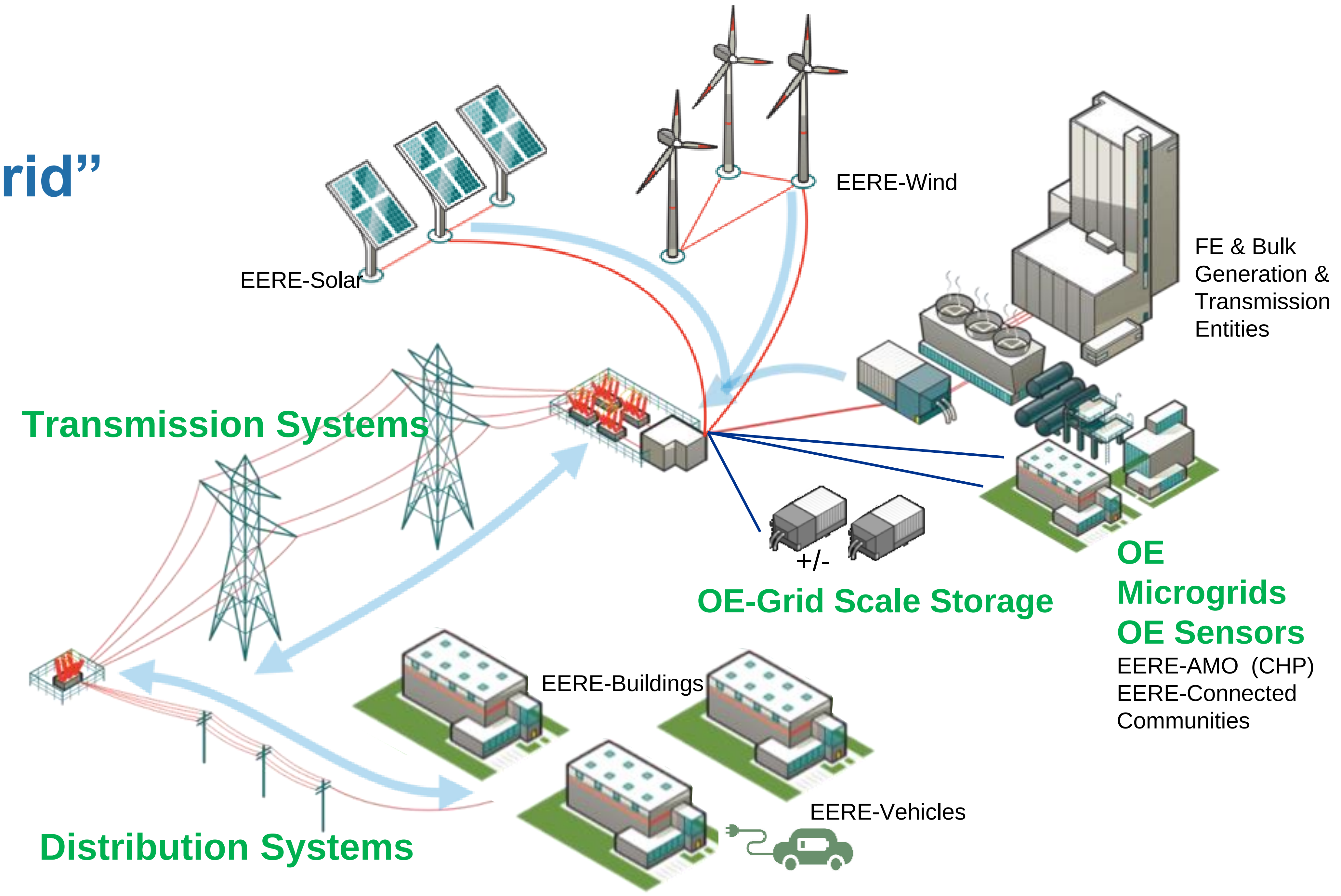
- Advanced Grid Modeling
- Sensors and Data Analytics
- Transmission Reliability – Planning/Operations
- Observability/Controllability
- Advanced Distribution Management Systems
- Transactive Energy
- Buildings/EV- Grid Integration
- T-D integration
- North American Energy Resilience Model
- SecureNet

Energy Storage

- Energy Storage R&D
- Energy Storage Safety and Reliability
- Energy Storage Policy, Valuation,
- Environmental Justice

Office of Electricity
"The Office of the Grid"

- Grid Systems and Components
- Grid Controls and Communications
- Energy Storage



Grid Research, Development and Demonstration

- Leads national efforts to develop next-generation technologies, tools, and techniques for the electricity delivery system, ensuring an efficient, reliable, and resilient electric grid in the U.S. and providing global technology leadership

- Conducts research, development, and demonstrations to improve operations of the electric grid

- Focused on software and hardware technologies including grid scale energy storage, sensors, controls and protection systems, microgrids, power electronics, advanced materials, transformers, and other grid system components; and addresses systems integration, security, policy and other cross-cutting issues

- Modeling efforts focus on building the next generation engineering tools to assess power system performance and reliability/resilience in support of operations and planning

Fundamental Changes

Historical

- Rotational Inertia
- Dispatchable Generation
- Passive / Predictable Loads
- "Static" T&D Infrastructure

- *Operator-Based Grid Management*
- *Centralized Control*
- *SCADA Measurements*
- *Off-Line Analysis / Limit Setting*

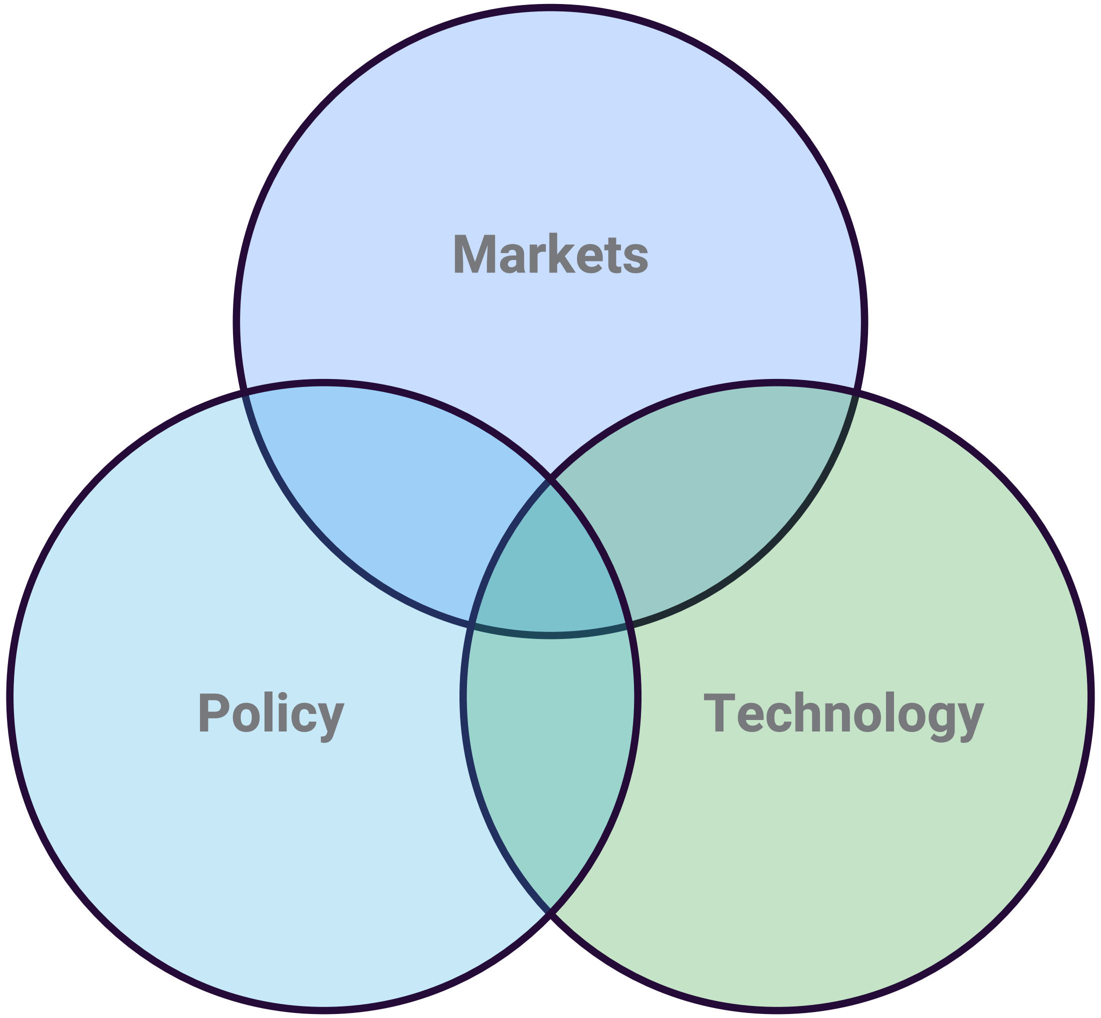
Emerging

- Reduced Stability / Faster Dynamics
- Stochastic Generation
- Engaged Consumers
- "Adaptive" T&D Infrastructure

- *Flexible and Resilient Systems*
- *Multi-Level Coordination / Precise Control*
- *Advanced Sensors and Data Acquisition*
- *Robust and Secure Communications*
- *Faster-than-Real-Time Analysis*

Basic Science Research & Discovery → Application Driven Materials Development → Applied Device and System R&D → Cost & Performance Metrics, Targets → Demonstration and Performance Validation → Systems Analysis and Valuation → Commercialization Strategy

Our ability to transform the electric grid will require a **coordinated strategy**.



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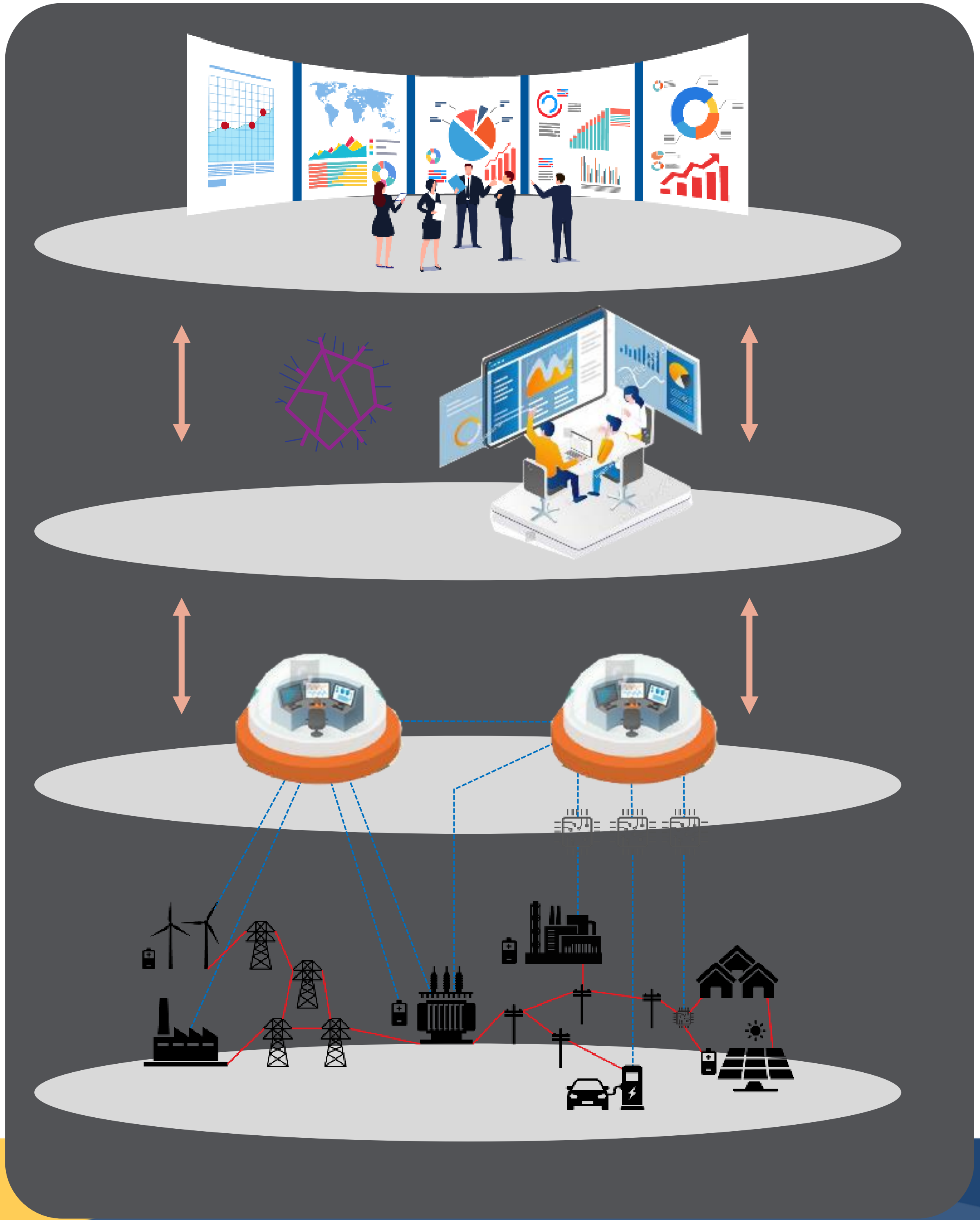
Key Challenges and Needs



Institutional Decision-Making

Institutional processes that align policies, customer expectations, and grid investment strategies AND that bridge the gap between technology development and adoption

Planning and Analysis

Modeling, simulation, and analytical tools to support holistic planning and system design (scenarios, options, architectures)

System Operations

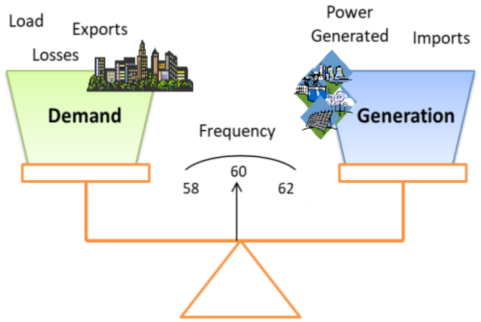
Operations with real-time situational awareness, analytics, control, and coordination under varying system conditions, configurations, and market schemes

Components/Networks

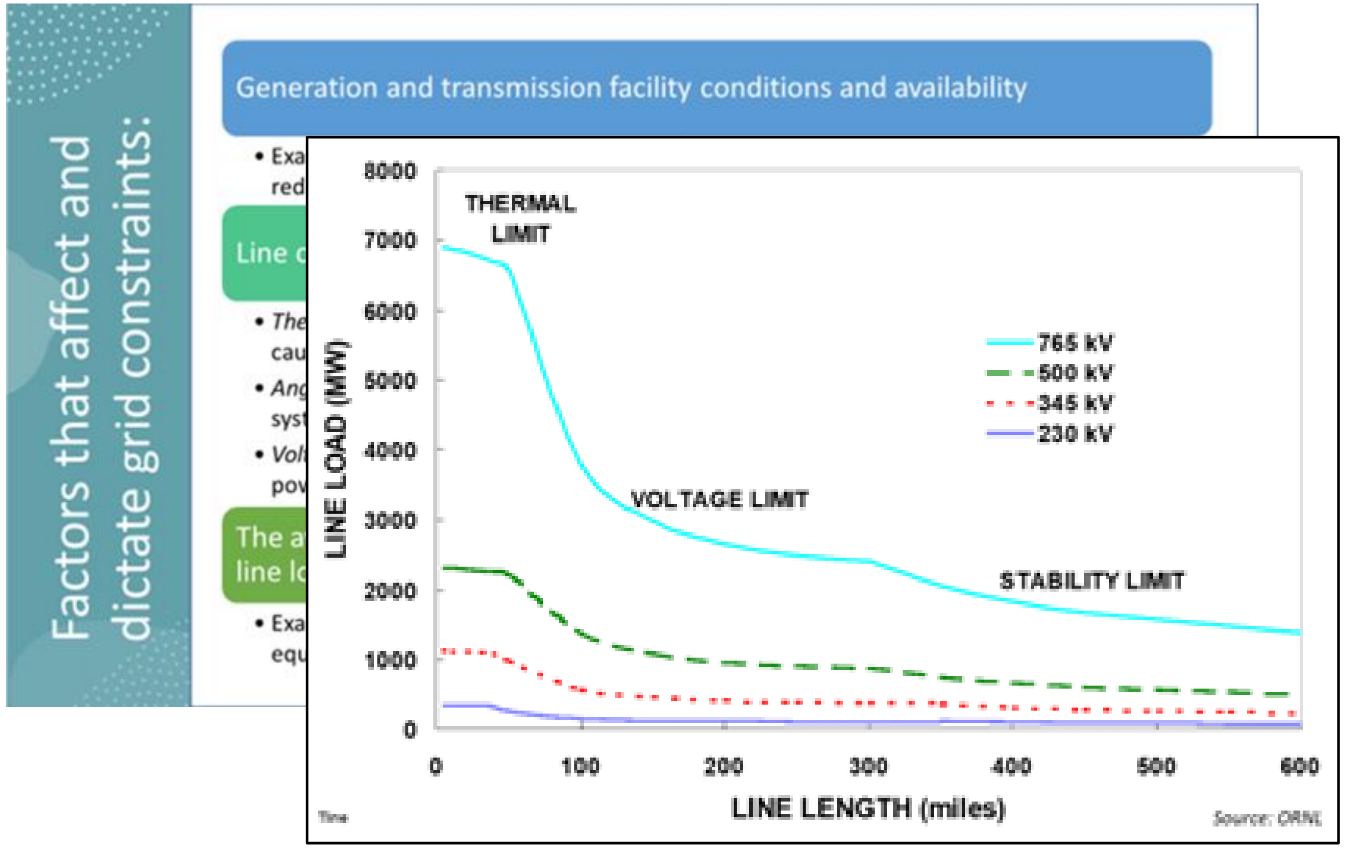
Modular/sustainable systems and components with fast dynamics (power electronics)

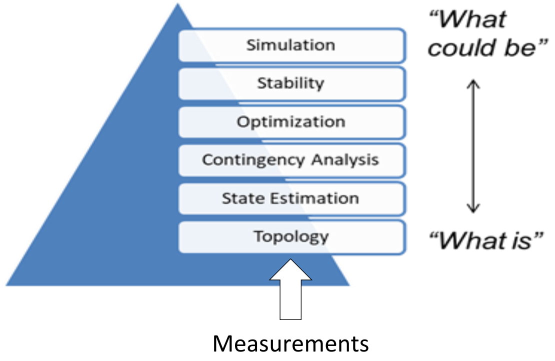
System Operator

- Assuring system reliability per NERC standards at different system levels
  - Local
  - Balancing area
  - Interconnection



- Scheduling, dispatch, and control
- Transmission congestion management
- Measurements to monitor the system
  - Weather, flows on key lines, voltages on key buses, tie flows, line status, generator status and real-power output
  - State estimation
  - Contingency analysis
  - Load and generation forecasting
- Additional responsibilities
  - Ancillary services (and markets)
  - Security coordination
  - Emergency response and coordination





Topology – What does the overall "map" of my system look like?
State Estimation – What does my system look like now?
Contingency Analysis – How responsive is my system to component loss and/or failure?
Optimization – How do I best use operating equipment that I have available to meet my objectives (such as lowest cost)?
Stability – How stable is my system to events?
Simulation – What does the potential future look like?

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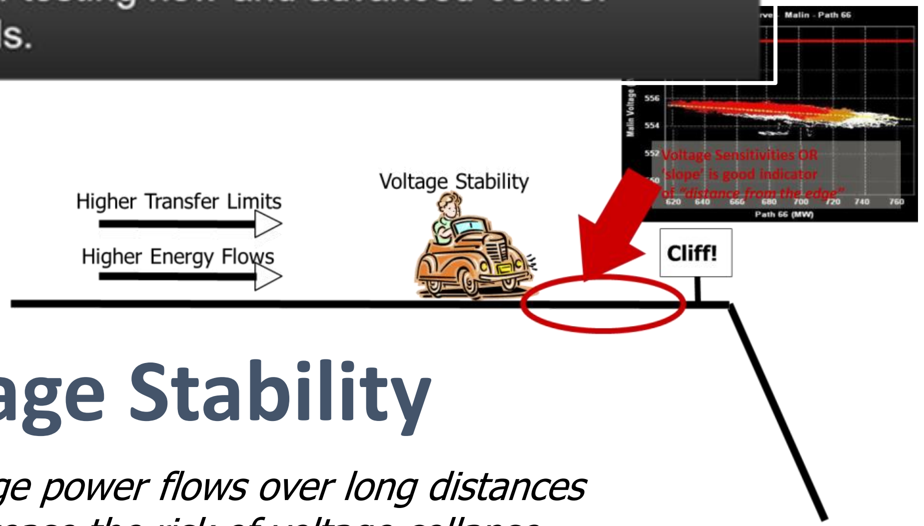
Why Perform Dynamic Modeling Analyses?

- Transient Stability: understand how a system responds to a disturbance
- Small Signal Stability: identify oscillation modes which can harm system stability
- Frequency Regulation: study frequency response, which will change with new types of generation
- Renewable Integration: evaluate impact of generation variability caused by wind & solar
- Control Strategies: serve as a large-scale base case for testing new and advanced control methods.



Voltage Stability

Large power flows over long distances increase the risk of voltage collapse.

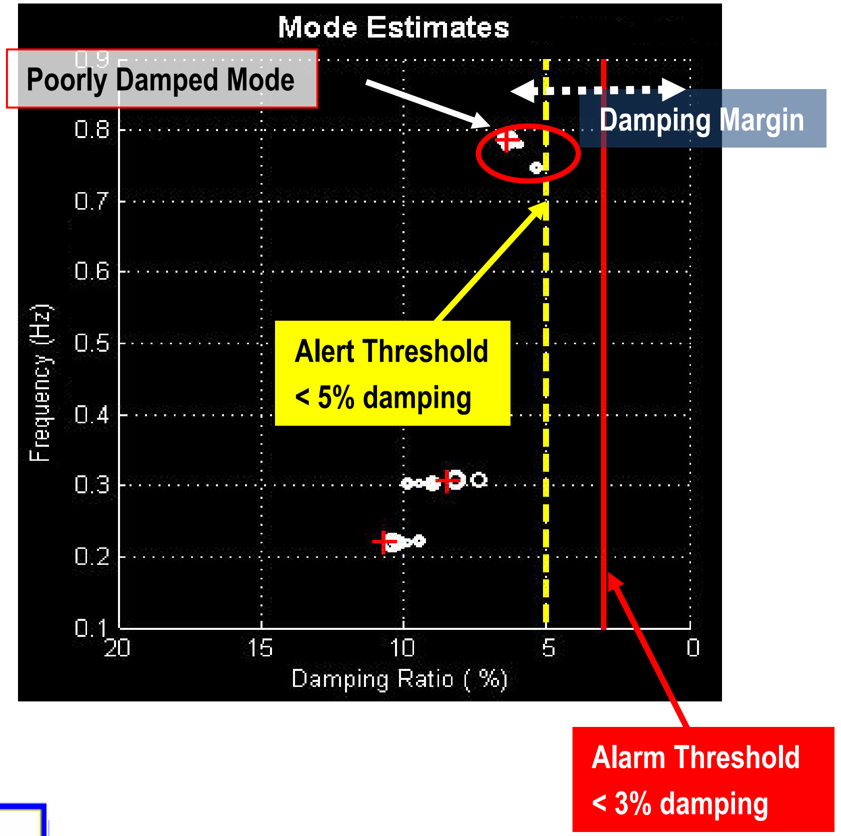
Question: How far are we from the edge?

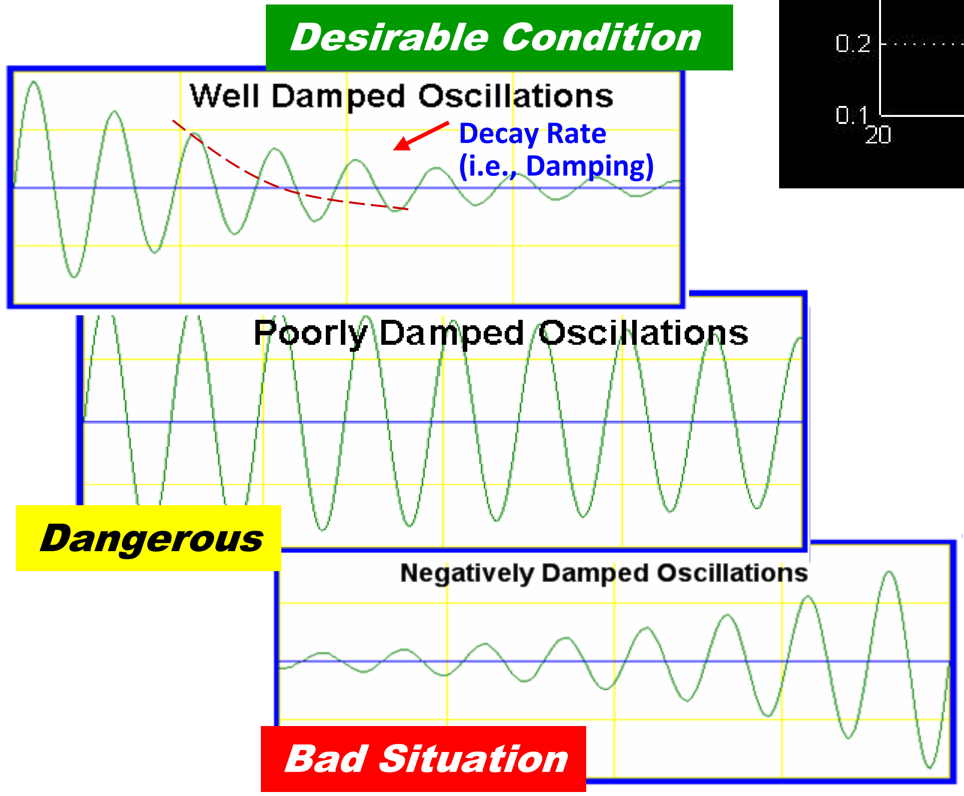
We can directly measure Voltage Sensitivities (kV/100MW) at critical interfaces or load pockets.

Grid Robustness

Question: How well can the system withstand disturbances?

Damping (in %) is a measure of the grid's resilience to system events.





CERTS
Consortium for Electric Reliability Technology Solutions

Government Role to Spur Advanced Grid Modeling

DOE tackles challenges that private industry is either not financially motivated or doesn’t have the expertise to solve to pursue breakthroughs in grid modeling research that will create pathways to the new energy future through:

Convening	**Create new relationships with grid operators, academia, and advanced computing experts to turn complex data analytics into actionable business value**
Catalyzing	**Assess and disseminate successful and innovative modeling solutions throughout the highly fractured electricity industry**
Capacity Building	**Support partnerships with, and between, academic institutions and utilities to create opportunities to build out mathematical capabilities within grid operations**

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Thank you

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ADVANCED GRID MODELING,
NORTH AMERICAN ENERGY RESILIENCE MODEL,
PROTECTIVE RELAYING

U.S. DEPARTMENT OF ENERGY
OFFICE OF ELECTRICITY
DIVISION OF GRID CONTROLS AND COMMUNICATIONS

U.S. DEPARTMENT OF ENERGY

https://www.energy.gov/oe/office-electricity