10TH ANNUAL PITT ELECTRIC POWER INDUSTRY CONFERENCE
Presented by the Swanson School of Engineering & the Center for Energy

Office of Electricity Delivery & Energy Reliability

Grid Modernization Initiatives

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DOE Has Broad Energy R&D Goals

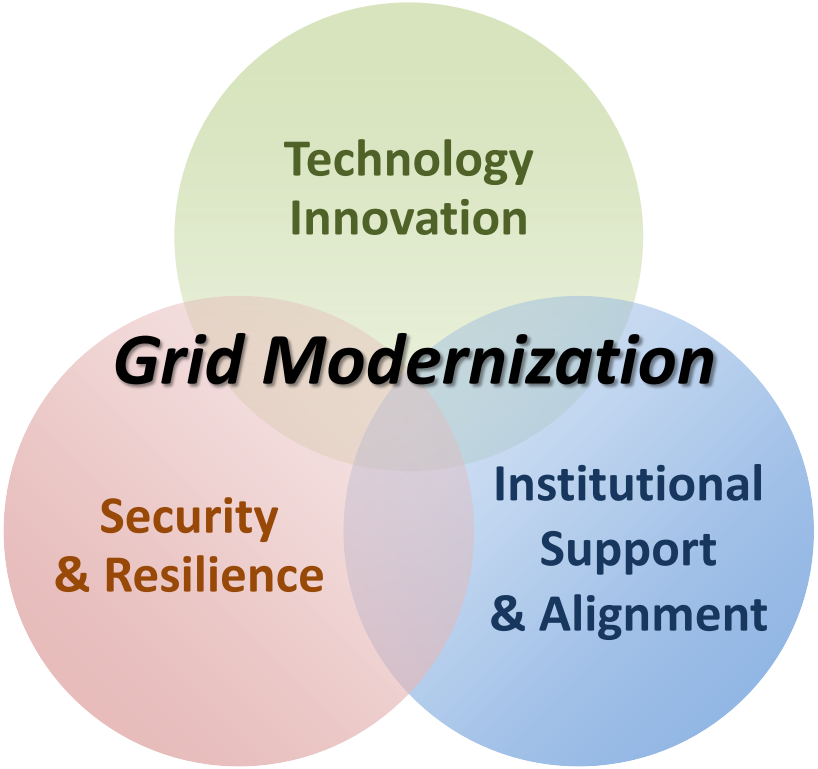
- Advance foundational science, innovate energy technologies, and inform data driven policies that enhance
  - U.S. economic growth and job creation
  - Energy security (including resilience)
  - Environmental quality
- Implement the Climate Action Plan to mitigate the risks of and enhance resilience against climate change*

*From the DOE 2014-2018 Strategic Plan

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.



DOE's Quadrennial Reviews

- Quadrennial Energy Review (QER): Called for by the President to analyze government-wide energy policy, particularly focused on energy infrastructure.
  - QER released in April 2015 analyzed energy transmission, storage and distribution systems
- Quadrennial Technology Review (QTR): Secretary Moniz requested the second volume be published in parallel with the QER to provide analysis of the most promising RDD&D opportunities across energy technologies in working towards a clean energy economy.
  - QTR released in October 2015 informs the national energy enterprise and will guide the Department of Energy's programs and capabilities, budgetary priorities, industry interactions, and National Laboratory activities.

Overarching Themes

Convergence – energy sectors and systems are increasingly interactive, interdependent, and coordinated. Energy sectors couple to water, material flows, wastes, markets, and communications.

Diversification in supply and demand – multiple technologies, fuels, and modes create opportunities for flexibility and challenges for infrastructures and operations

Confluence of enabling science – advances in computing, data management, materials by design, sensors, complex systems analysis and controls create opportunities at many scales

Efficiency throughout – improving efficiency at every step in the energy value chain and system-wide will use resources wisely, contain costs, and reduce climate and other impacts

The Grid Modernization Initiative(GMI)

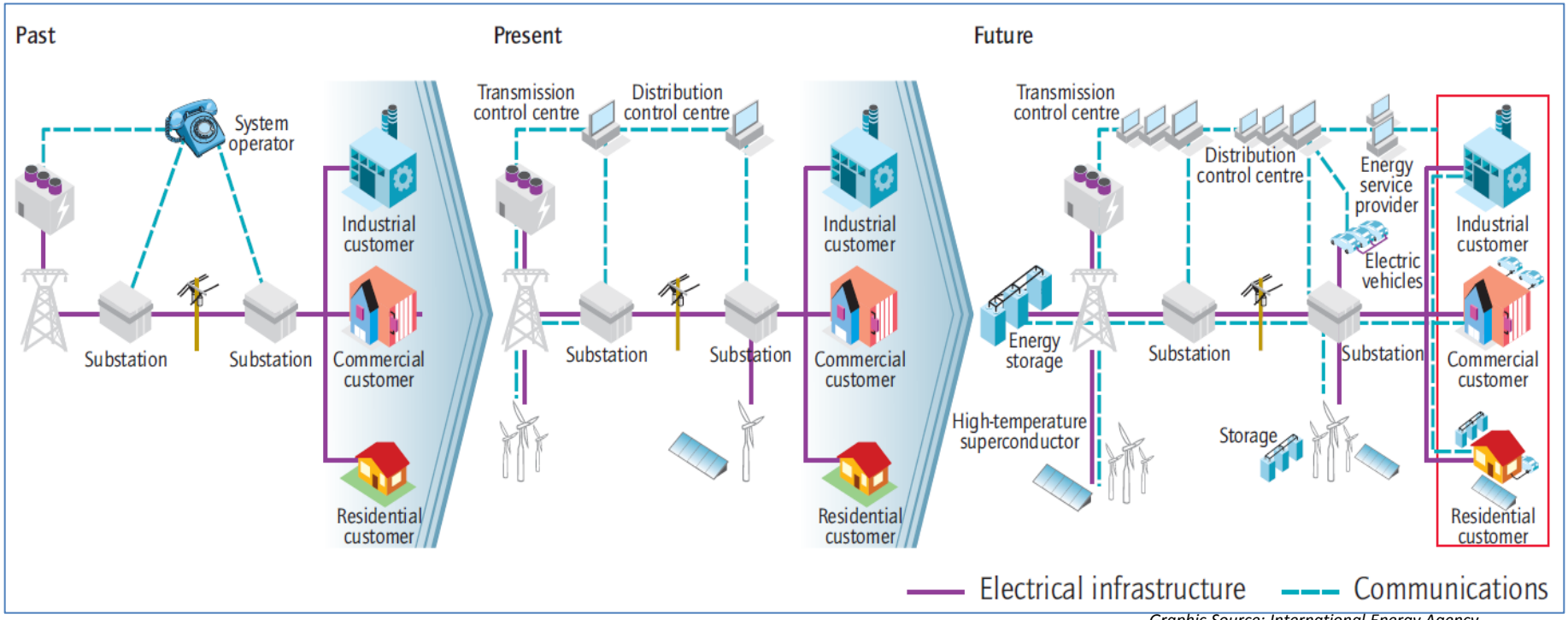
Institutional Support	• **Provide tools and data that enable more informed decisions and reduce risks on key issues that influence the future of the electric grid/power sector**
Technology Innovation: Design and Planning Tools	• **Create grid planning tools that integrate transmission and distribution and system dynamics over a variety of time and spatial scales**
Technology Innovation: System Operations, Power Flow, and Control	• **Design and implement a new grid architecture that coordinates and controls millions of devices and integrates with energy management systems**
Technology Innovation: Sensing and Measurements	• **Advance low-cost sensors, analytics, and visualizations that enable 100% observability**
Technology Innovation: Devices and Integrated System Testing	• **Develop new devices to increase grid services and utilization and validate high levels of variable generation integrated systems at multiple scales**
Technology Innovation: Security and Resilience	• **Develop advanced security (cyber and physical) solutions and real-time incident response capabilities for emerging technologies and systems**

Five Key Trends Are Driving Electricity System Changes

- A changing mix of types and characteristics of electric generation
- Growing demands for a more resilient and reliable grid
- Growing supply- and demand-side opportunities for customers to participate in electricity systems
- The emergence of interconnected electricity information and control systems
- An aging infrastructure

The Future Grid Differs Radically from the Present

Characterized by More Flexibility and Agility



Graphic Source: International Energy Agency

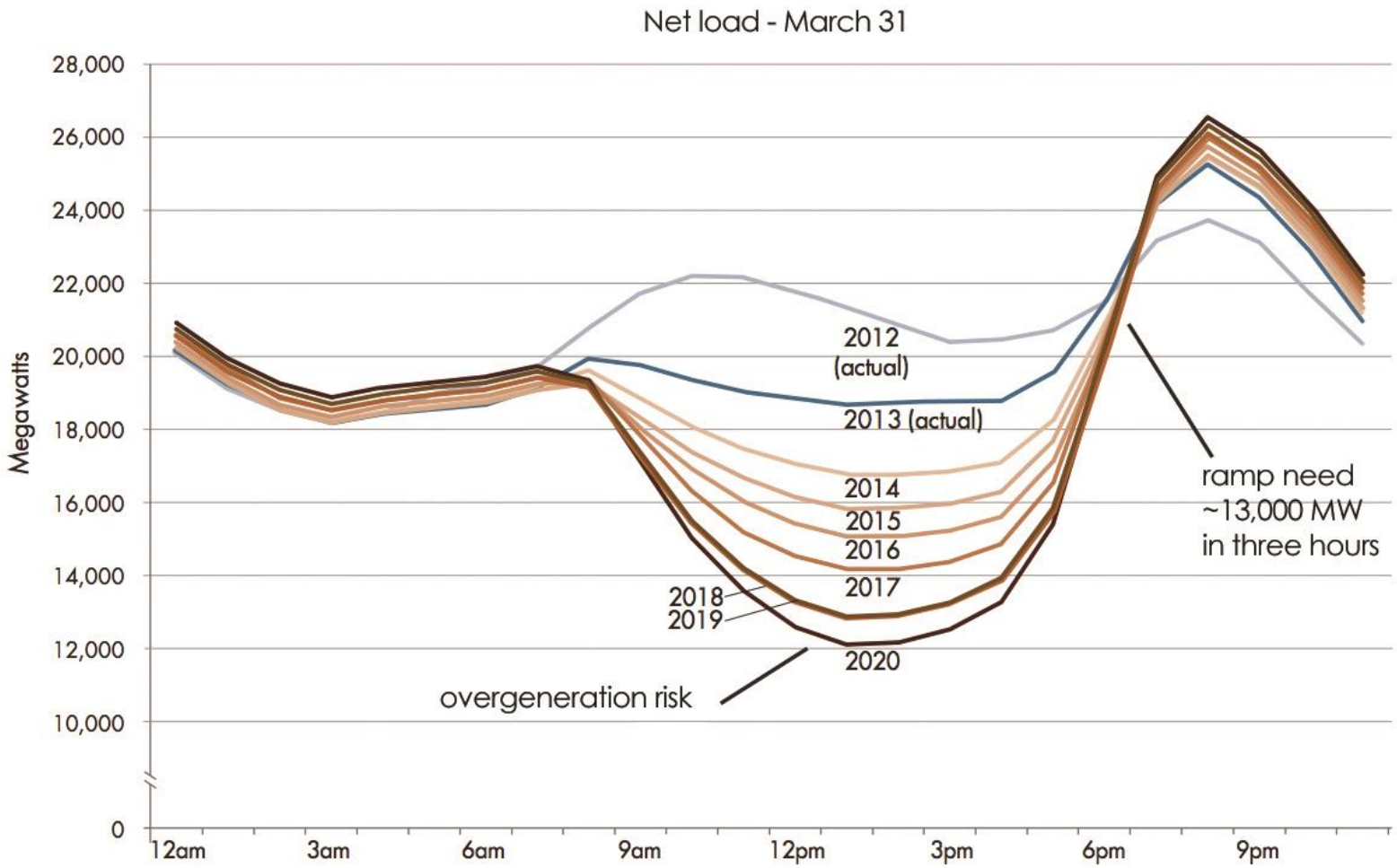
Historical

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

Emerging

- *Flexible and Resilient Systems*
- *Sensors and Data Acquisition*
- *Algorithms and Computer Infrastructure*
- *Multi-Level Coordination / Precise Control*
- *Faster-than-Real-Time Analysis*

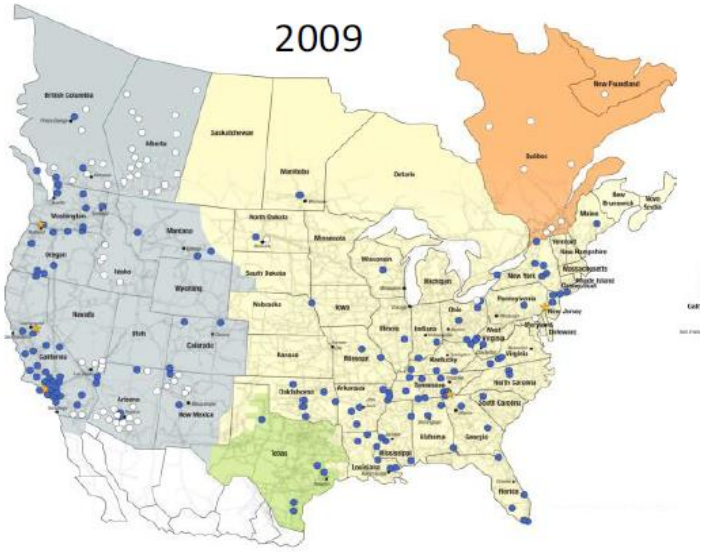
Integration of Intermittent Renewables

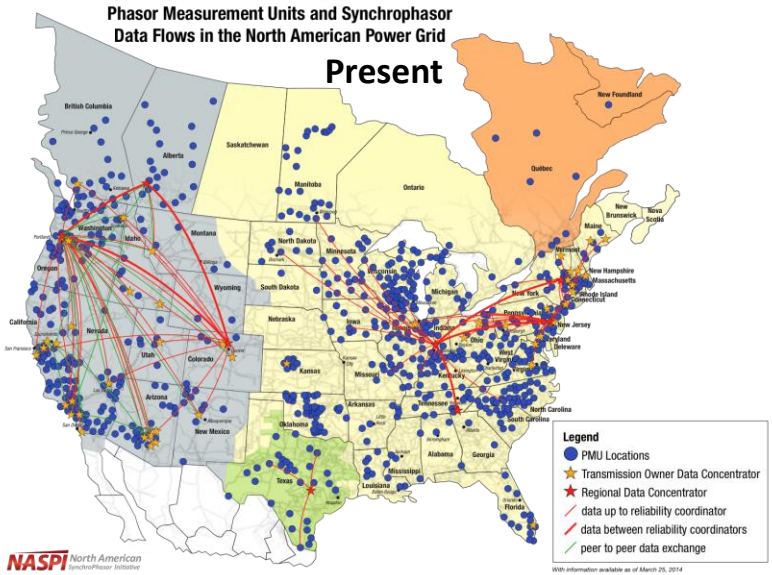


Improved Sensor Deployment

- Phasor measurement units and smart meters deployed with Recovery Act funding

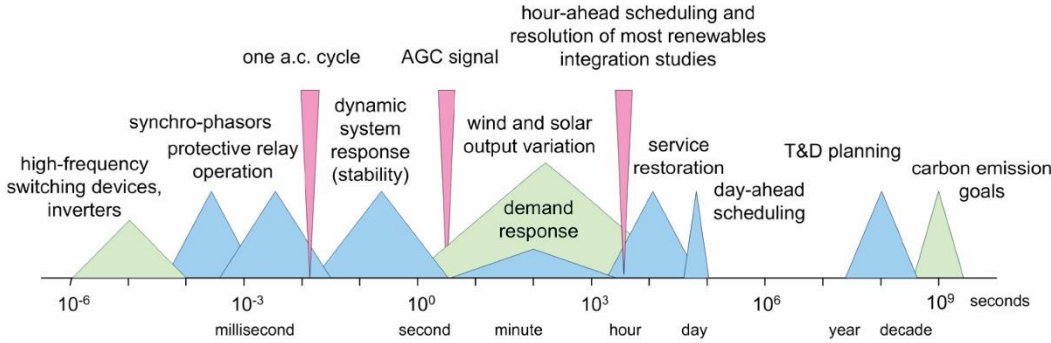
- Much more to do to modernize the transmission and distribution system to improve services, robustness, and resilience.

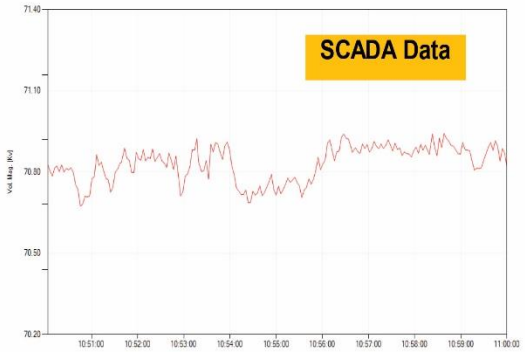


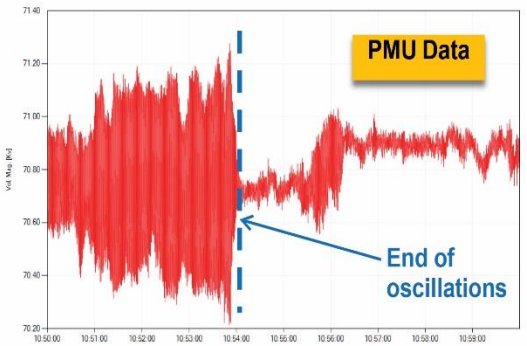


Potential for Much Improved Grid Services

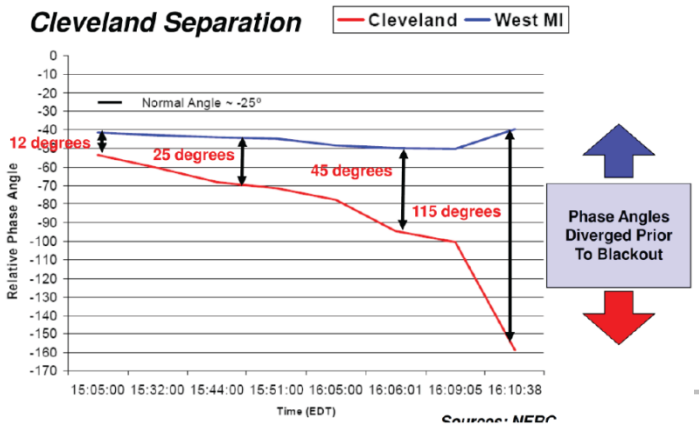
- Many R&D for opportunities for transmission and distribution:
  - ➢ Architecture (microgrids)
  - ➢ New (and cheaper) sensors for
    - ✓ Voltage, freq., phase angle
    - ✓ Current, real, reactive power
  - ➢ Active controls of power flow
  - ➢ Solid state transformers
- Improved communications, data analysis, fast state estimation, automatic controls
- Integration of distributed generation, intermittent renewables
- Cybersecurity





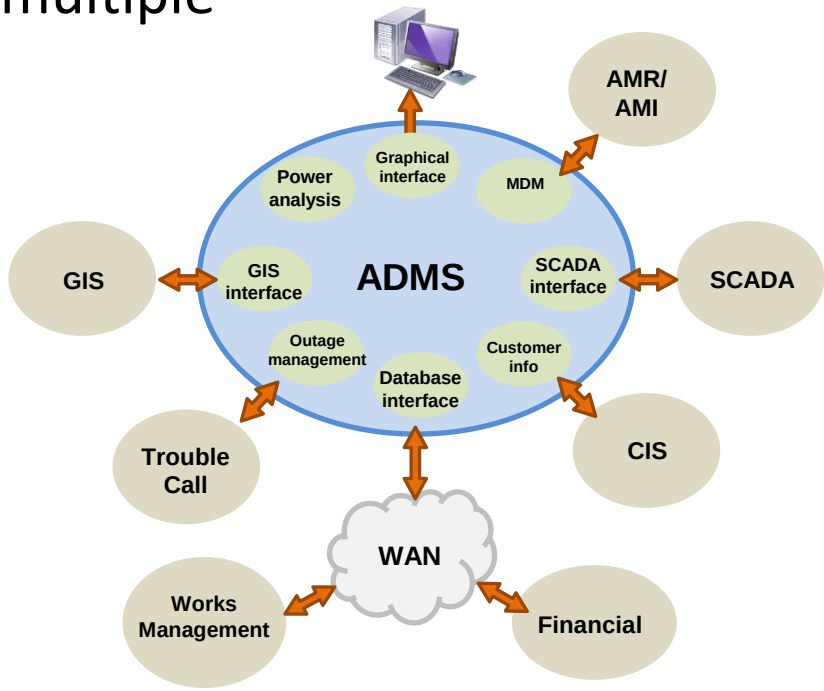


Credit: North American Electric Reliability Corporation



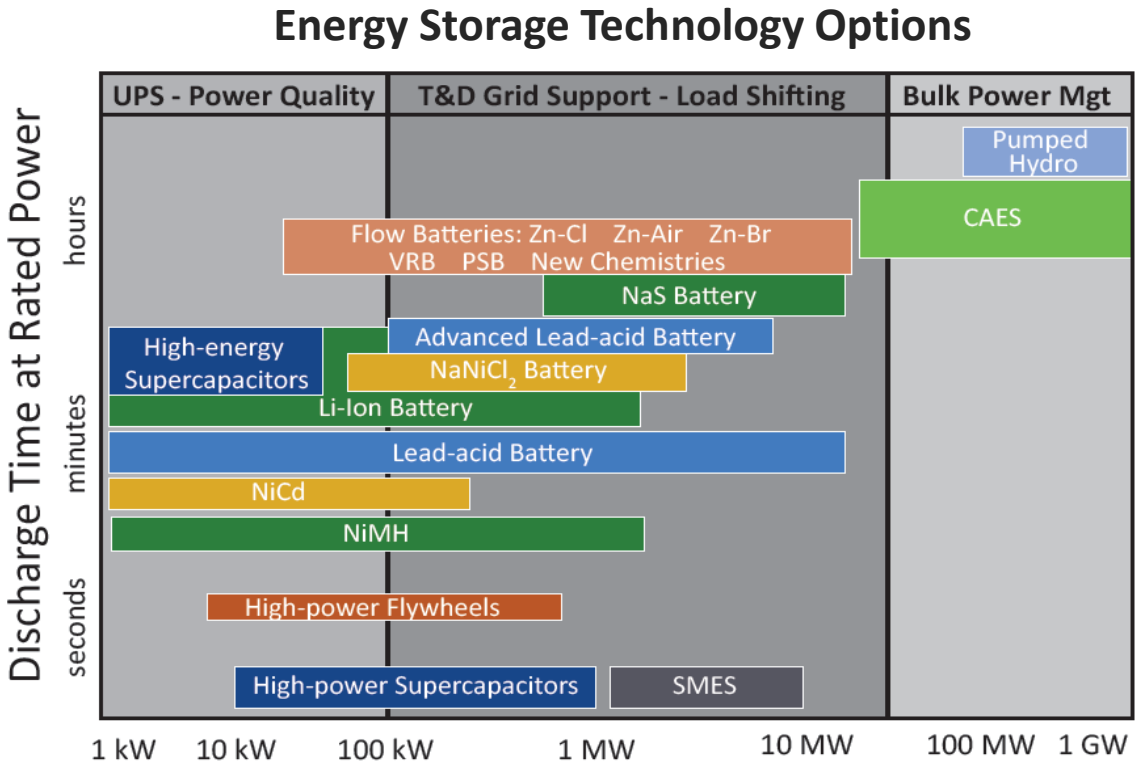
Smart Grid R&D Follows Up from Recovery Act Investments

- R&D on operational optimization for multiple microgrids
- FOA for networked microgrids
- Advanced Distribution Management System R&D
  - Open source
  - Integrate multiple applications
  - Interface with transmission level Energy Management Systems
- R&D in system protection control
  - Address intermittency
  - Manage bidirectional power flows
  - Improve restoration capabilities
  - Accommodate alternative architectures and markets



Energy Storage

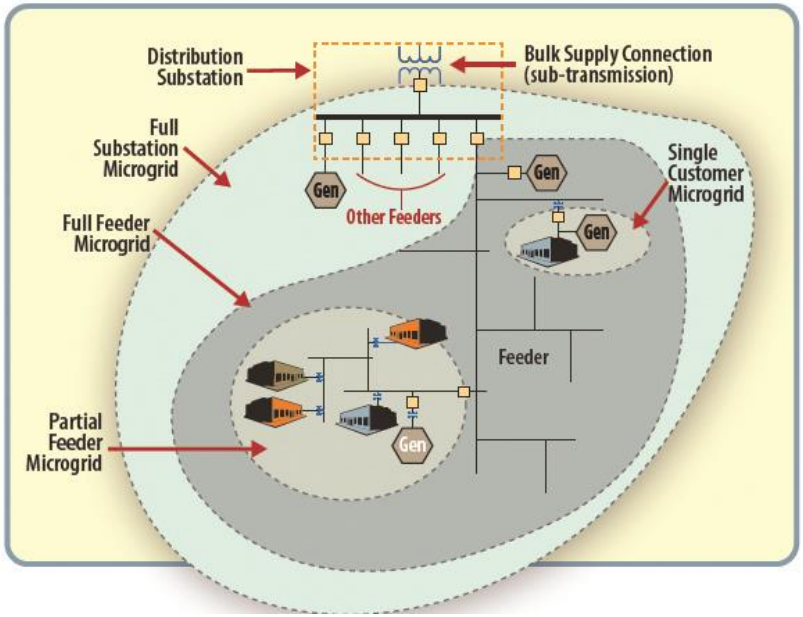
- Role in electric power and transportation
- Options depend on scale of application
- R&D options to reduce costs at all scales
- Integration of storage with infrastructure



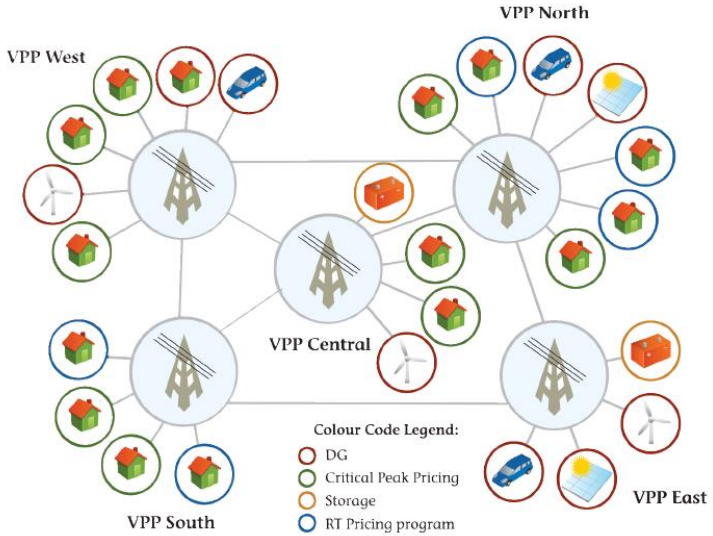
Credit: Sandia Laboratory

Systems of Systems

- Increased interconnection of systems: opportunities for balancing, challenges for communications, fast system models, automatic controls



Credit: Ventyx



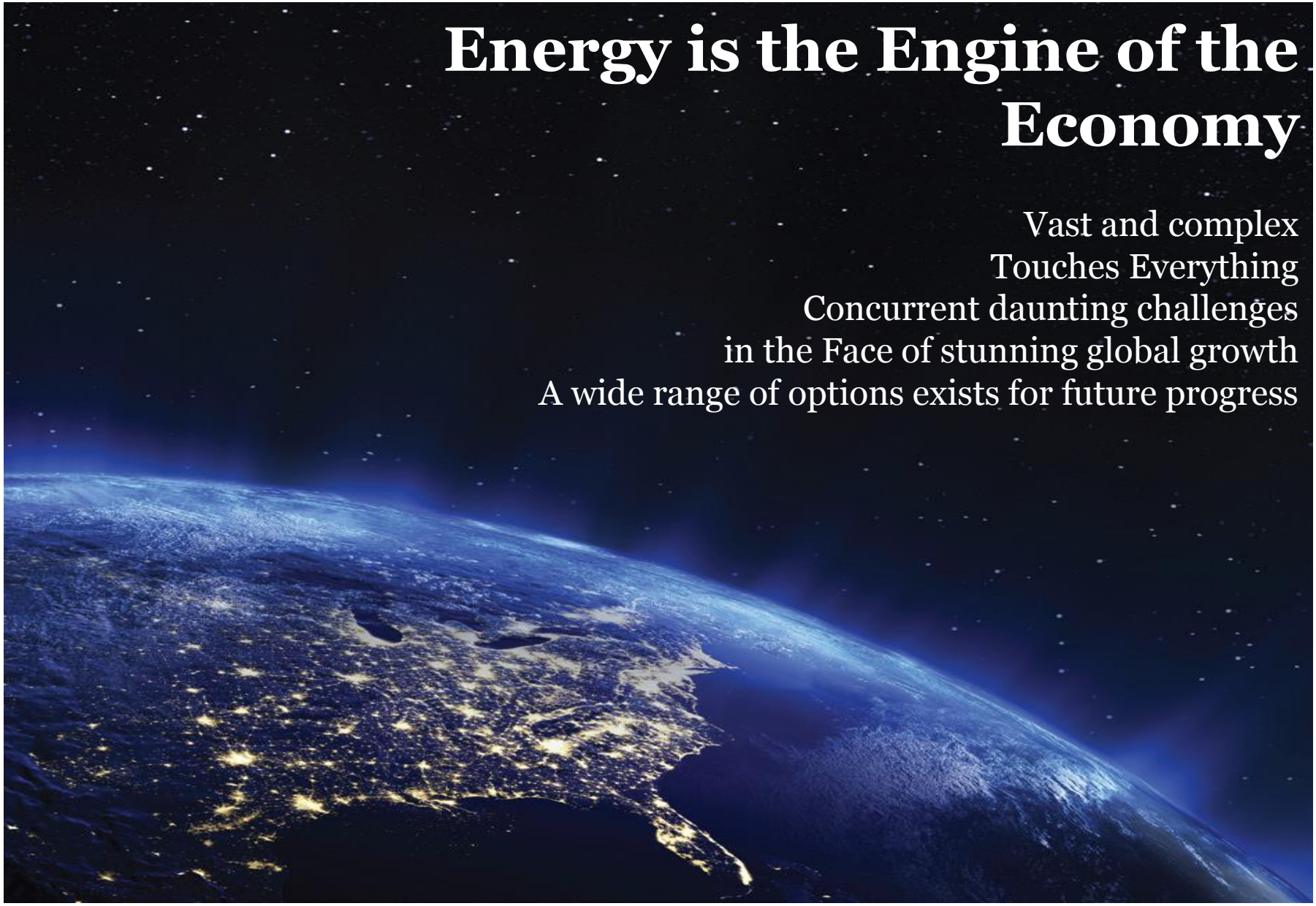
Key: DG = distributed generation; RT = real time

Issues: markets, valuation of services, privacy, security

Conclusions

- ✓ Considerable progress has been made in energy technologies, but much more remains to be done
- ✓ There exists a very wide-ranging opportunity space, for individual technologies and for improved systems
- ✓ A portfolio approach is required: fully stocked across primary energy resources, conversion technologies, systems, and time scales for application, with efficiency everywhere
- ✓ Enabling science and computing are essential to our energy future success

Energy is the Engine of the Economy



Vast and complex
Touches Everything
Concurrent daunting challenges
in the Face of stunning global growth
A wide range of options exists for future progress