AGI ADVANCED GRID INSTITUTE

Energy Systems Innovation Center

U.S. INDIA COLLABORATIVE FOR SMART DISTRIBUTION SYSTEM WITH STORAGE

Evolving future energy distribution grids

www.uiassist.org

The Future of Electric Power in the U.S.

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PNNL/WSU Advanced Grid Institute (AGI) https://natlab.wsu.edu/grid/

- **Our mission**
  Create and implement a national-scale simulation platform and data framework to enable advanced grid controls and operations for complex power systems of the future.
- **Our vision**
  Build the region’s reputation and prominence in power grid science and technology, enhance the workforce pipeline in smart grid innovation, and enable a resilient North American grid.
- **Future AGI/ESIC Webinars – 11 am Pacific**

April 6, 2021 ***Transactive Systems for the Shared Energy Economy***
Thomas McDermott, Distributed Systems Group and the Solar Sub Sector Lead, PNNL
Michael Diedesch, AVISTA Grid Innovation Lab Manager
Anjan Bose, Regents Professor and Distinguished Professor of Power Engineering WSU

April 27, 2021 ***Network Microgrids as Decarbonization And Resiliency Resources***
Kevin Schneider
Chief Engineer and Manager PNNL and Manager of the Distribution and Demand Response Sub-Sector
Gowtham Kandaperumal
Ph.D. Candidate School of Electrical Engineering and Computer Science, Washington State University and WSU-PNNL Distinguished Graduate Research Fellow PNNL

WSU Energy Systems Innovation Center (ESIC) https://esic.wsu.edu/

- **ESIC - An Energy Center Focused On Education, Outreach and Research**
- **Vision**

Leading the transition to affordable, sustainable and resilient electric power systems.

- **Mission**

Collaborative research, education and outreach to solve challenges for modern power systems.

- Weekly Webinars (ESIC, PSERC and AGI/ESIC)
  - https://esic.wsu.edu/seminar-series-spring-2021/

UI-ASSIST: US-INDIA COLLABORATIVE FOR SMART DISTRIBUTION SYSTEM WITH STORAGE

HTTPS://UIASSIST.ORG/

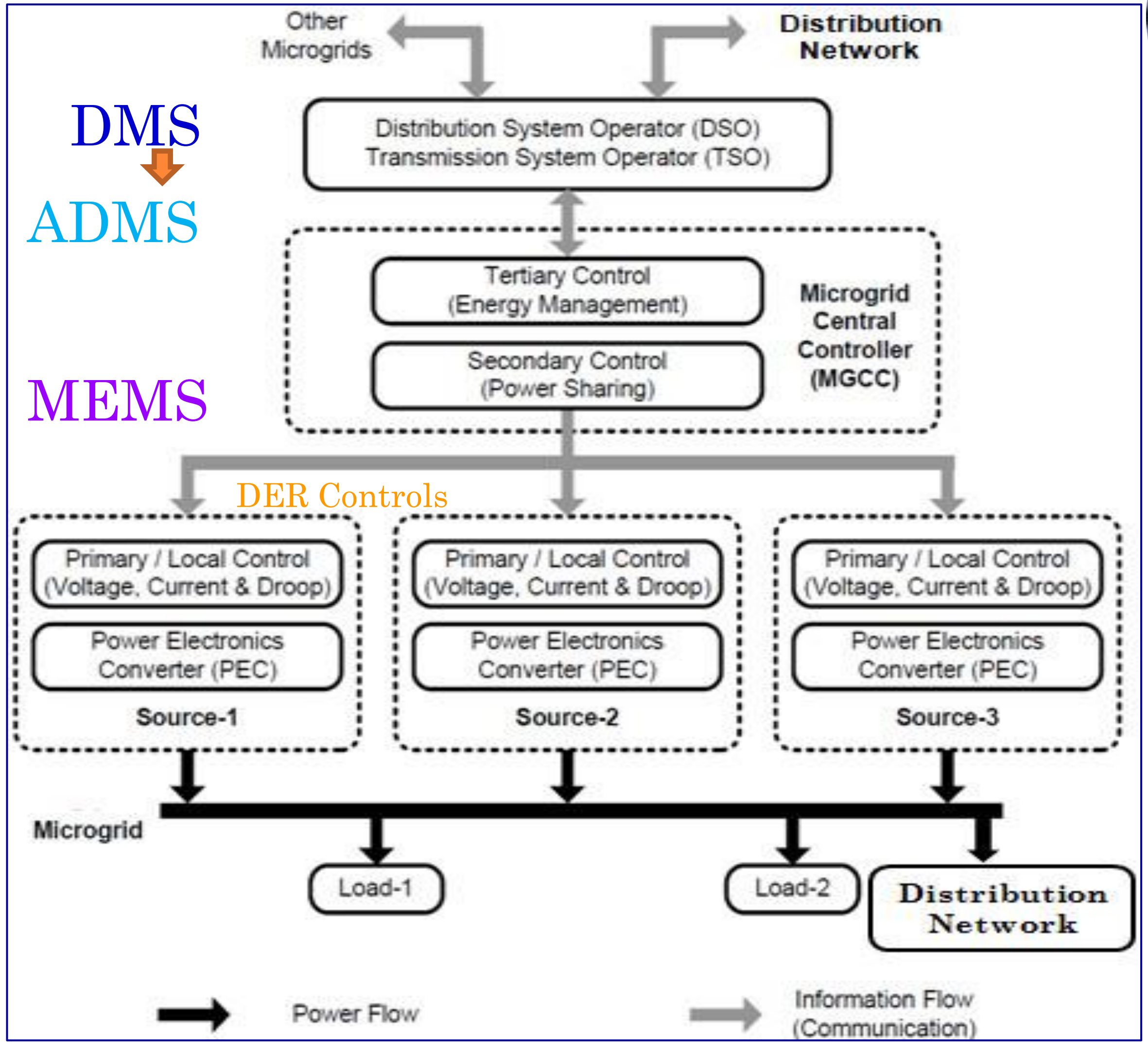
Objectives & Outcomes

To evolve the future distribution grid that will allow the continuing increase of Distributed Energy Resources (DER) penetration towards improving reliability, resiliency, flexibility, and sustainability of electricity delivery

Project work will lead to the fully conceptualized smart distribution grid that optimally utilizes energy storage and distributed generation supported by well-planned workforce development and policy recommendation. Our team will validate developed solutions using ten different unique test beds and deployed in pilot phase at 10 different field demonstrations sites in the US and India.

Technical Scope

To develop and demonstrate the DSO functions for optimal utilization and management of DER by interfacing with DER and microgrid control systems with high penetration of energy storage.



Budget: $30 Million (2017-2023)
$7.5M: USDOE, $7.5M: DST
$7.5M: US Cost Share and
$7.5M: India Cost Share + Additional Cost Share

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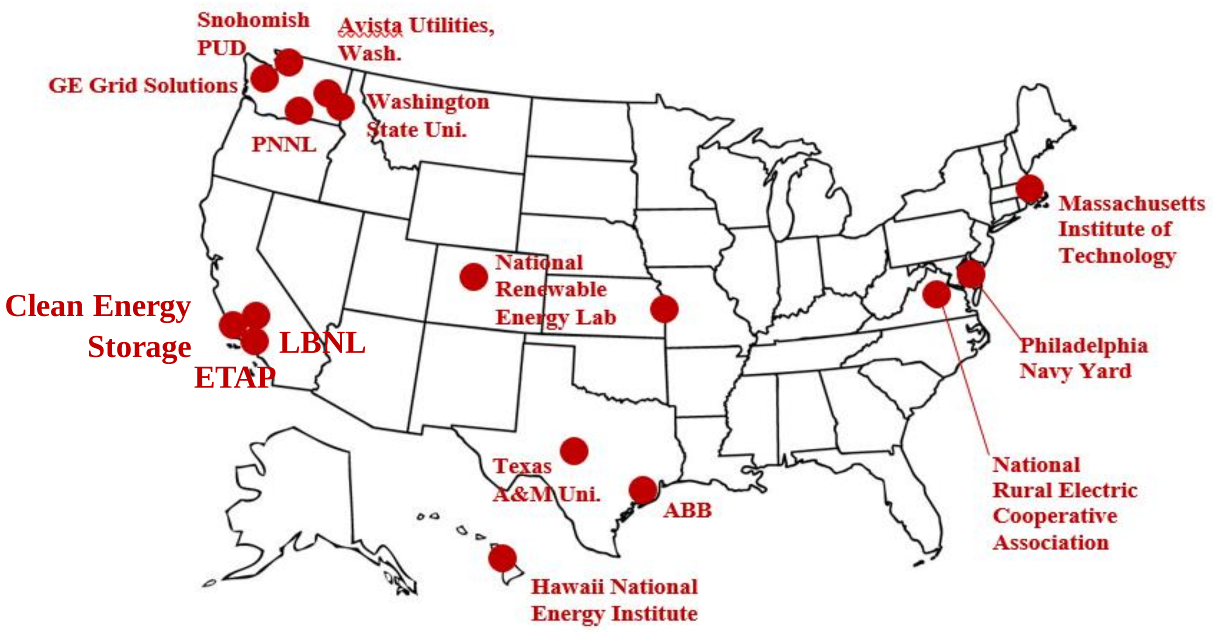
PROJECT TEAM

India Leads
S. C. Srivastava (past-lead)
S. Mishra
A. Sharma

US Leads
N. Schulz
A. Srivastava

ASSIST

Red Indicates Team in USA
Blue Indicates Team in India



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Pacific Northwest NATIONAL LABORATORY
NREL NATIONAL RENEWABLE ENERGY LABORATORY
MIT
AVISTA
THE NAVY YARD PHILADELPHIA
Grid Solutions
A&M
SNOHOMISH COUNTY PUD PUBLIC UTILITY DISTRICT NO. 1
CLEAN ENERGY STORAGE INC.
HNEI Hawai'i Natural Energy Institute
NRECA
etap
BURNS & McDONNELL
VCS

UI-ASSIST: WEBINAR

The Future of Electric Power in the US

Key Findings of the Recent NASEM Report

Speakers: Jeff Dagle (PNNL), Anjan Bose (WSU), Anuradha Annaswamy (MIT)

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Evolving future energy distribution grids

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The Future of Electric Power in the U.S.

March 25, 2021

Download the report at **nap.edu/25968**

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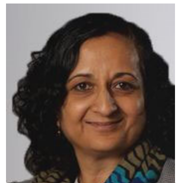
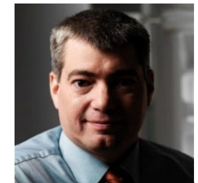
Carnegie Mellon University



Anuradha M. Annaswamy
Massachusetts Institute of Technology

Anjan Bose*, NAE
Washington State University

Terry Boston*, NAE
Terry Boston, LLC



Jeffery Dagle*
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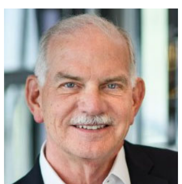
Michael Howard
Electric Power Research Institute

Cynthia Hsu
National Rural Electric Cooperative Association

Reiko A. Kerr
Los Angeles Department of Water and Power

Karen Palmer
Resources for the Future



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William H. Sanders*
Carnegie Mellon University

Susan F. Tierney*
Analysis Group

David G. Victor*
University of California, San Diego

Elizabeth J. Wilson
Dartmouth College

*Committee Member, *Enhancing the Resilience of the Nation's Electricity System* (2017)

The Report

1. Introduction: Framing the Issues
2. Drivers of Change
3. Legal and Regulatory Issues That Shape the Electric System
4. The Persistent Underinvestment in Electric Power Innovation
5. Technologies and Tools to Enable a Range of Future Power Systems
6. Creating a More Secure and Resilient Power System
7. High Level Needs and Specific Recommendations

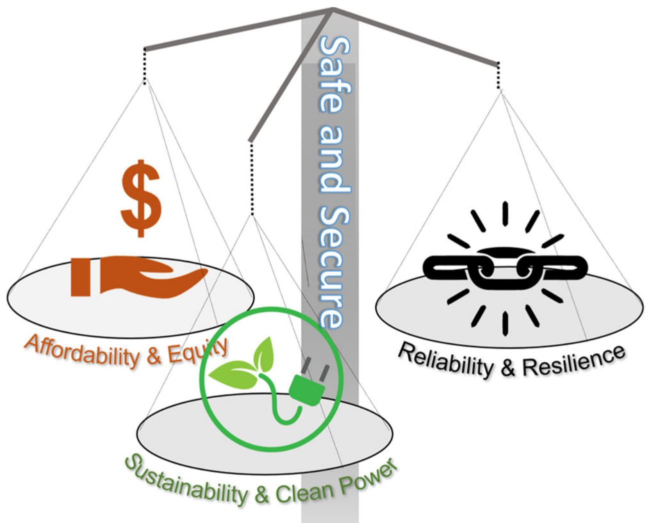
In this report...

We ***do not*** say how the grid ***will*** evolve.

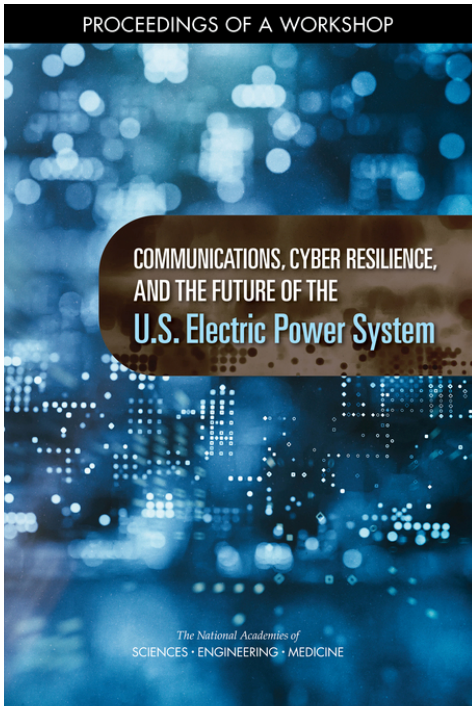
We ***do*** lay out ways in which it ***might*** evolve.

A core value must be *assuring continued safe and secure operations*. Around this central pillar these other attributes should be balanced:

- affordability and equity
- sustainability and clean power
- reliability and resilience



Our work was informed by two workshops and by many briefings and webinars



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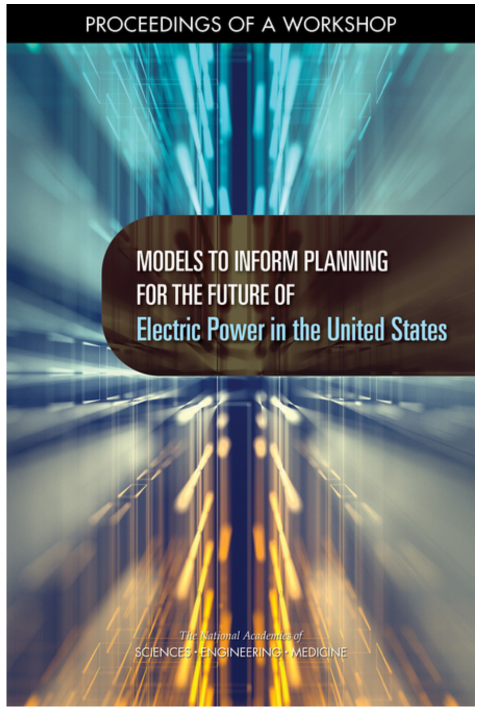


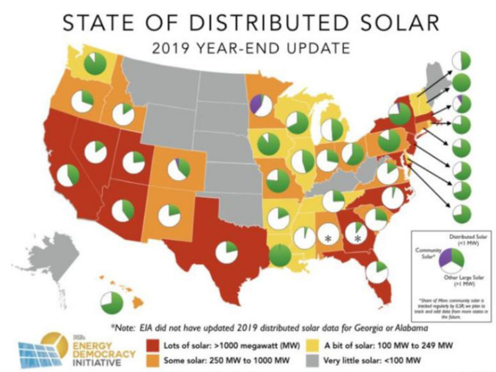
https://www.nap.edu/read/25880

We held workshops on cybersecurity and on modeling.

They have now been downloaded ~1,000 times.

Chapter 2: Drivers of Change

1. Evolving demand for electricity.
2. Efforts to decarbonize the U.S. economy and eliminate conventional pollutants.
3. The changing grid edge.
4. The rise of non-dispatchable wind and solar.
5. A desire to reduce social inequities.
6. Concerns about the impact of the energy transition on employment.
7. The globalization of supply chains.



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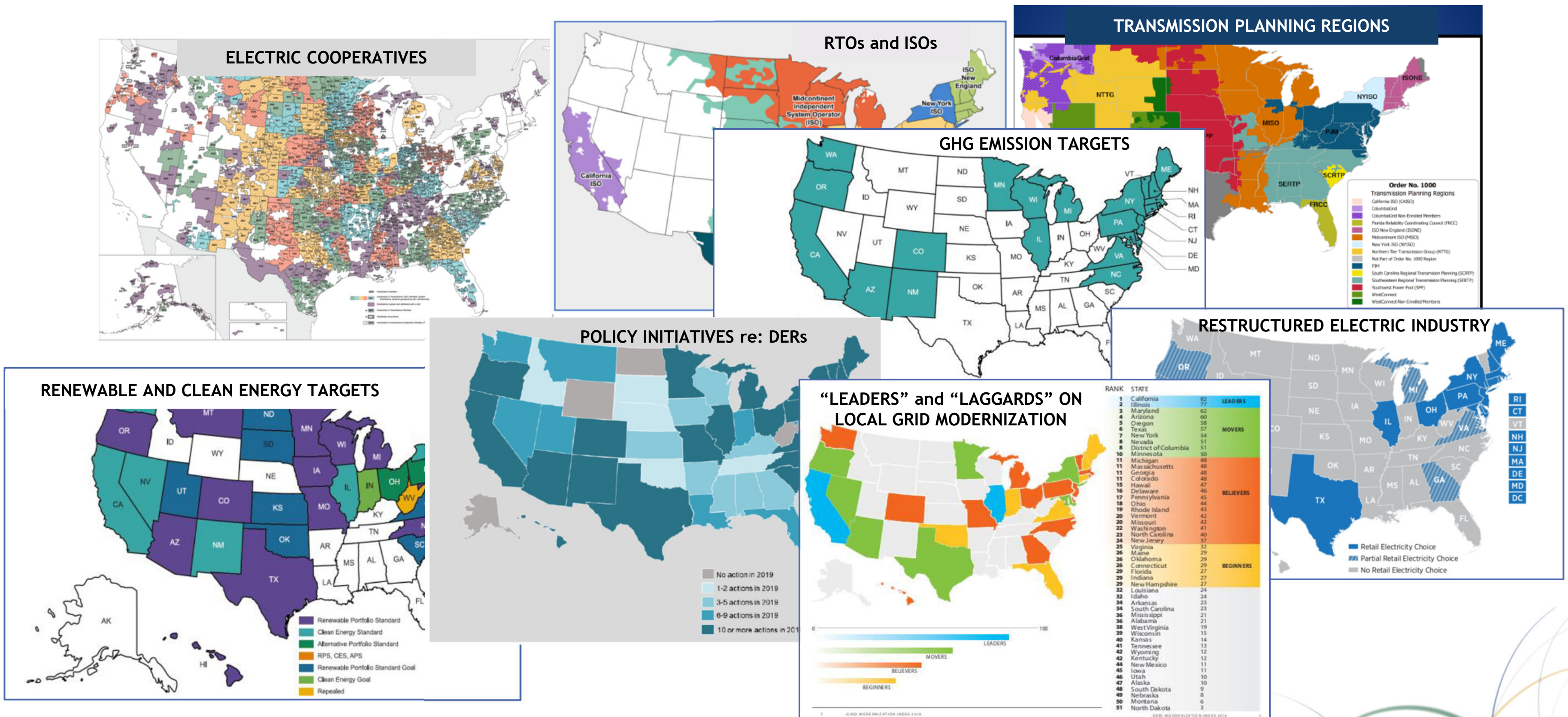
Chapter 3: Legal and Regulatory Issues

- The traditional lines that define jurisdiction of federal versus state regulation in the electric industry have shown signs of increasing tension in recent years, as the industry undergoes significant technological, economic and social change.
- The generation segment is evolving rapidly, and will likely continue to do so.
- Transmission planning and expansion have not kept up with the operational and regional delivery needs anticipated in a low-carbon, resilient electric system.
- Local utility distribution systems are greatly affected by changes at the grid edge, and state regulatory policies and incentives, combined with traditional utility business models, can either enable or frustrate innovation.
- Policy innovation at both the transmission and distribution system levels is critical to enable the vibrant changes needed to assure a low-carbon, reliable, resilient, and accessible power system for the future.

Mapping the Electric System

Myriad policy, legal, institutional, and other influences on system



Regional Transmission Planning

Recommendation 3.3: Congress and the states should support the evolution of planning for and siting of regional transmission facilities in the U.S., with changes in federal law to:

- Establish a National Transmission Policy;
- Direct FERC to expand on the policy bases for regional transmission planning;
- Give FERC the responsibility to designate new National Interest Electric Transmission Corridors and to approve interstate transmission lines in them; and,
- Direct DOE to provide funds to states, communities, tribes to enable meaningful participation in regional transmission planning and siting activities.

Policy Innovation for Local Distribution

Recommendation 3.11: "State regulators… should *accelerate* their investigations into what changes in industry structure, security, rate design and other pricing approaches, and market design are needed to align with significant deployment of DER and to address equity issues in energy access and deployment of clean energy technologies."

Other recommendations relate to sharing of lessons learned and best practices (3.9), and federal funding for policy innovation and research (including social-science and policy research) on these issues.

Standards, Regulations, and Incentives

Recommendation 3.1: Investigation of outages: Creating a federal task force to identify whether any new legislative authority is needed so that the industry and its regulators can understand in a timely manner why a significant physical and/or cyber disruption occurred in the electric power grid.

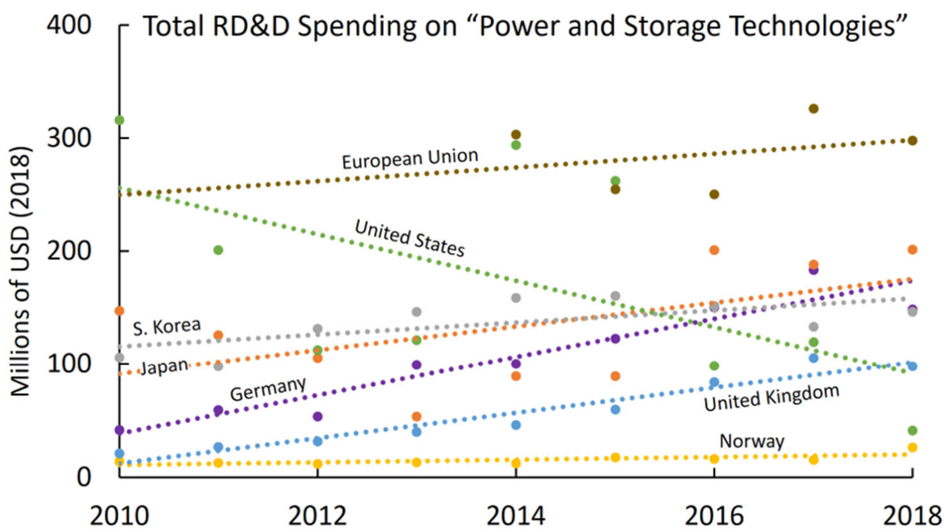
Recommendation 3.2: Gas-system reliability: Authorizing FERC to designate a central entity to establish standards for and otherwise oversee the reliability of the nation's natural gas delivery system.

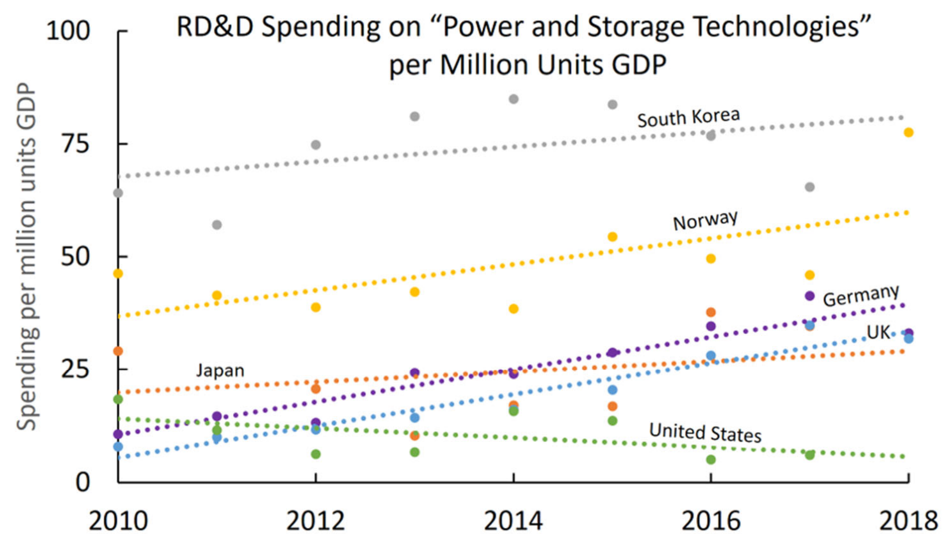
Recommendation 3.10: Grid modernization resources: Providing federal funding (e.g., loans, grants) to encourage publicly owned utilities (e.g., municipal electric utilities, cooperatives, tribal utility authorities) to invest in grid modernization.

Chapter 4: The Persistent Underinvestment in Electric Power Innovation

- Addressing nearly all of the fundamental challenges for the grid of the future—from the integration of renewables to deep decarbonization—requires innovation
- In many parts of the electric power industry the innovation models are shifting toward bigger roles for "outsiders" and disruption
- Meanwhile, because of critical services and national security, a balance must be struck between globalization of supply chains and onshoring and secure supply of critical infrastructure
- The country's investment in innovation is inadequate for the scale of the challenge and what's feasible

The U.S. is lagging behind its peers, and getting worse





Energy RD&D Over Time

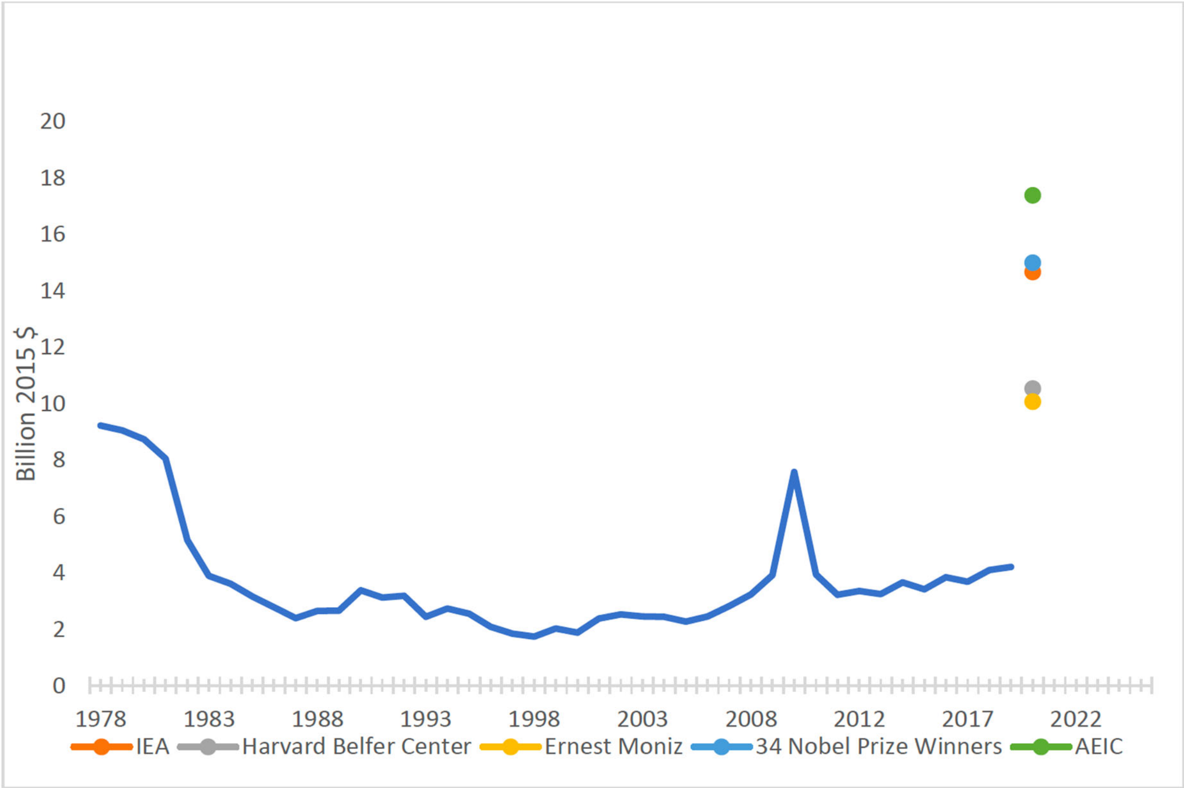


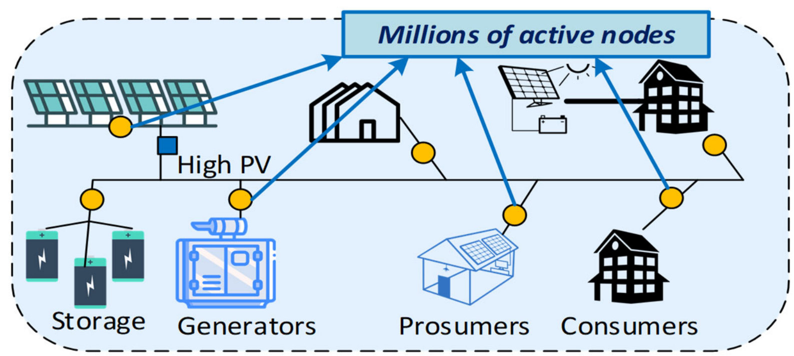
Figure 4-5 Historical US Energy Technology RD&D spending FY 1978-2019, plus multiple studies, most completed a half decade ago, suggesting future spending levels over the decade from 2015 to the middle 2020s. SOURCE: *Adapted from "DOE Budget Authority for Energy Research, Development, and Demonstration Database" by Gallagher and Anadon, 2019; Projections from: IEA, 2015; Belfer Center for Science and Technological Affairs, 2011; Moniz Nomination, 2013; Burton, 2009; and AEIC, 2010.*

Chapter 4: Selected Recommendations

- Improve awareness and "take the pulse" of the innovation system (Recommendation 4.1)
- Manage the tensions between globalized product innovation and national security needs (Recommendations 4.2, 4.3)
- At least double public expenditure on innovation, from states and mainly federal government (Recommendations 4.8, 4.9, and 4.4)
- Put more emphasis on grid modernization technologies and systems (Recommendations 4.5, 4.7)
- Spend these resources wisely, for which there is good experience (Recommendation 4.6)

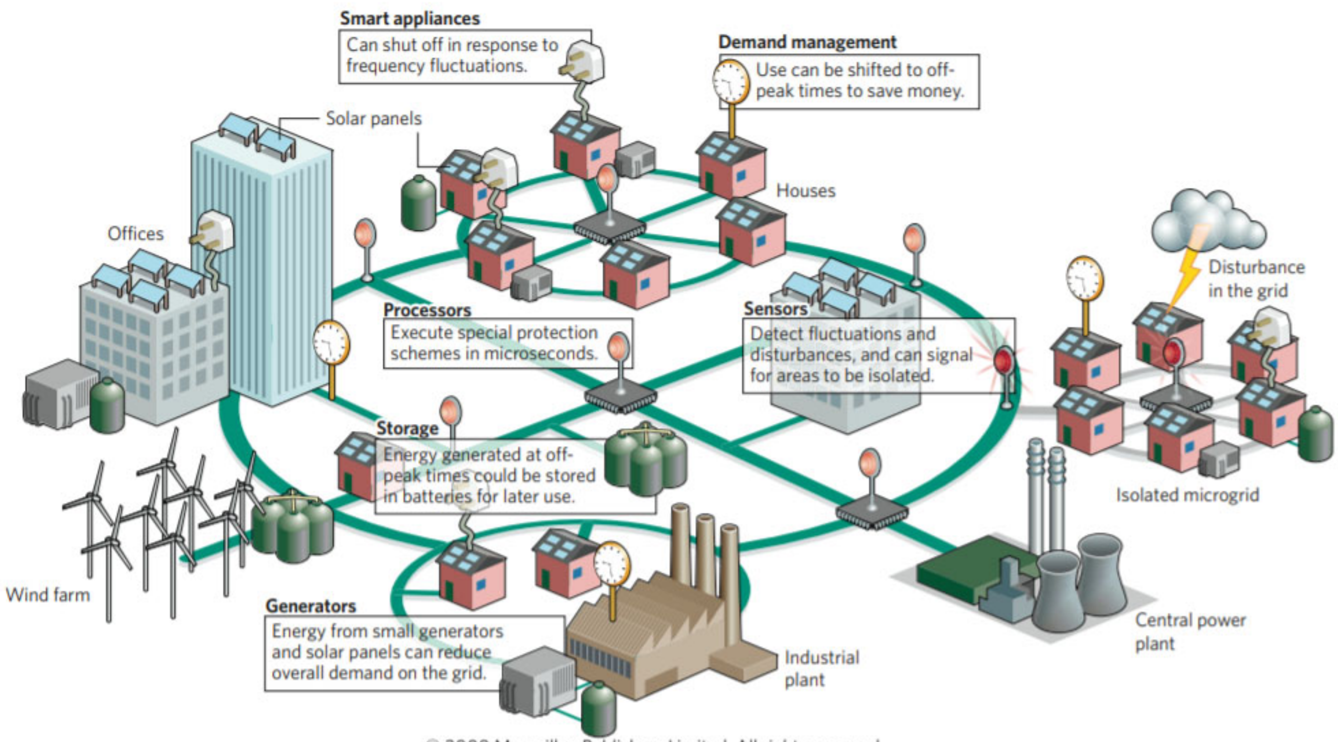
Chapter 5: Pivotal Technologies

- Clean generation
  - Utility-scale Wind&Solar
  - High ramp-rate & dispatchability
- Energy storage
- Power electronics
- Communications
- Advanced grid management systems
  - DERs, microgrids, EVs
  - Sensing & Monitoring
  - Standards and regulation
  - Electricity Markets
- Coordination, Control, and Ultra-automation
- Modeling and Simulation



Grid of the future

Key Takeaways



- Highly distributed and decentralized
- Challenge to model/simulate, plan and operate
- New generation, storage resources, and flexible loads make integrated operation a challenge

Recommendations

Clean Generation and Commercialization (5.1, 5.2)

- Develop generation, storage, and distributed energy technologies with no emissions.
- Government and Industry collaborate to develop, fund and de-risk new and critical technologies essential to the future grid.

Communication, Coordination, and Automation (5.3, 5.4)

- Develop ICT *secure and reliable* technologies to support enhanced participation from grid connected devices to enable a flexible grid.
- Develop technologies to enable a high-level of automation and resilient system.

Develop Workforce of the Future (5.9, 5.10)

- Fund training and retraining of the current and future workforce.

Chapter 6: Creating a More Secure and Resilient Power System

- The power system remains vulnerable to cyber and physical disruptions, and this vulnerability will increase significantly as the grid evolves in the future.
- Cybersecurity and resiliency requires a balanced approach focused on people, processes, and technology.
- The grid of today and the future requires tradeoffs between cybersecurity/resiliency and power system connectivity, automation, and deployment of non-utility-owned devices.
- The cybersecurity posture of other infrastructures and interdependent stakeholders (e.g., supply chain) can have significant effects on power system operations.
- The electric grid's inherent complexity demands a *system-centric* rather than a *component-centric* approach to cybersecurity and cyber resiliency.
- The U.S. workforce faces a critical shortage in cybersecurity skills, particularly in industrial control systems (ICS) cybersecurity professionals.

Cybersecurity Recommendations

Research (6.1, 6.2)

- Fund industry-relevant research driven by an updated DOE R&D roadmap.
- Fund NSF research on the impacts of rapidly evolving computing, communications, and control technologies on grid cybersecurity and cyber resiliency.

Training & Workforce Development (6.3, 6.10)

- Establish cybersecurity training programs for engineers, operators, technicians, and IT and OT positions associated with the real-time operation of electric grid systems.
- Expand and fund interactions with industry through exercises, red and purple teaming, and assessments to enhance the electric power system's security posture.

Information Sharing (6.4, 6.5)

- Create a joint task force identifying new legislative authority to obtain early warnings associated with self-reporting security conditions.
- Create a process to communicate pertinent information about advanced persistent foreign and domestic cybersecurity threats to industry stakeholders in a proactive, timely and effective manner.

Cybersecurity Recommendations (cont.)

Standards and Guidance:

- Establish cybersecurity regulations that specify standards that vendors will implement to develop products with superior cybersecurity attributes across all critical infrastructure sectors for equipment, devices and software used in those sectors. (Recommendation 6.6)
- Develop a joint utility and industry-driven analysis of electric system interdependencies with connected infrastructure (e.g., communications networks, natural gas system) and provide guidelines on how to address the reliability and security vulnerabilities from such interdependencies. (Recommendation 6.7)
- **National Security:** Utilities cannot, on their own, justify covering the cost of implementing protections of the power system against electromagnetic pulse (EMP) or major state-sponsored cyber and other attacks… initiate a process to develop a solution for how to cover the costs of implementing appropriate protections. (Recommendation 6.8)
- Develop guidance for distribution-level resiliency requirements to be implemented at the state and local level. (Recommendation 6.9)

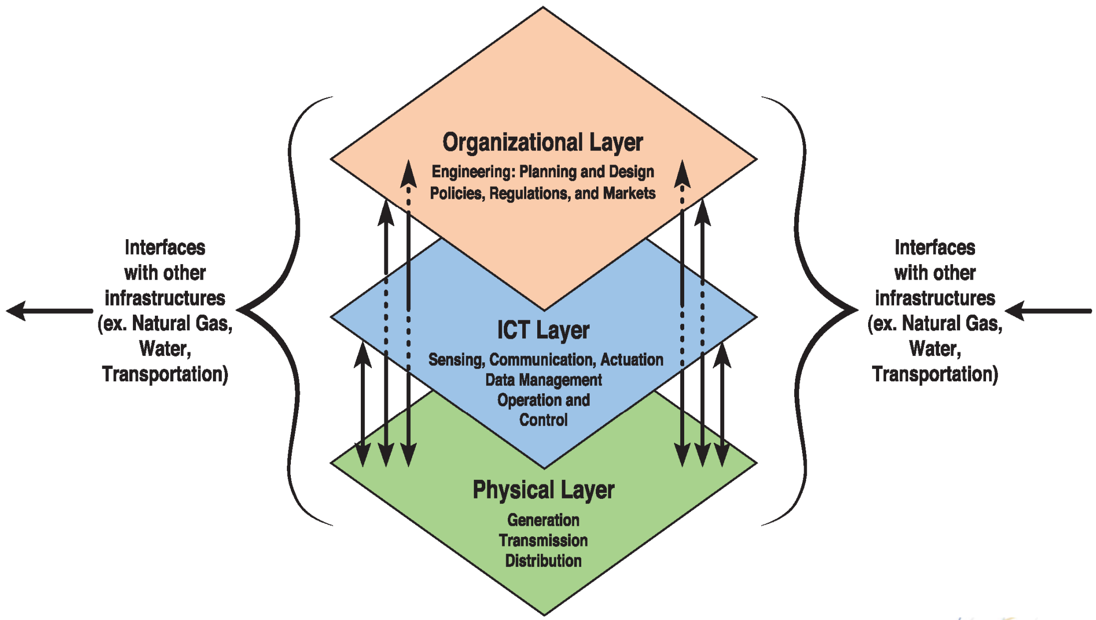
Emerging Architectures

We lay out the key attributes.

We show how poorly past energy forecasts have performed and explain that this is why we don't make predictions.

We summarize how the power system architecture has evolved – noting that it is a mixture of restructured and vertically integrated systems operating under a mix of regulated and competitive market environments across the country.

We wrap up the chapter by introducing and discussing the system's present architecture.



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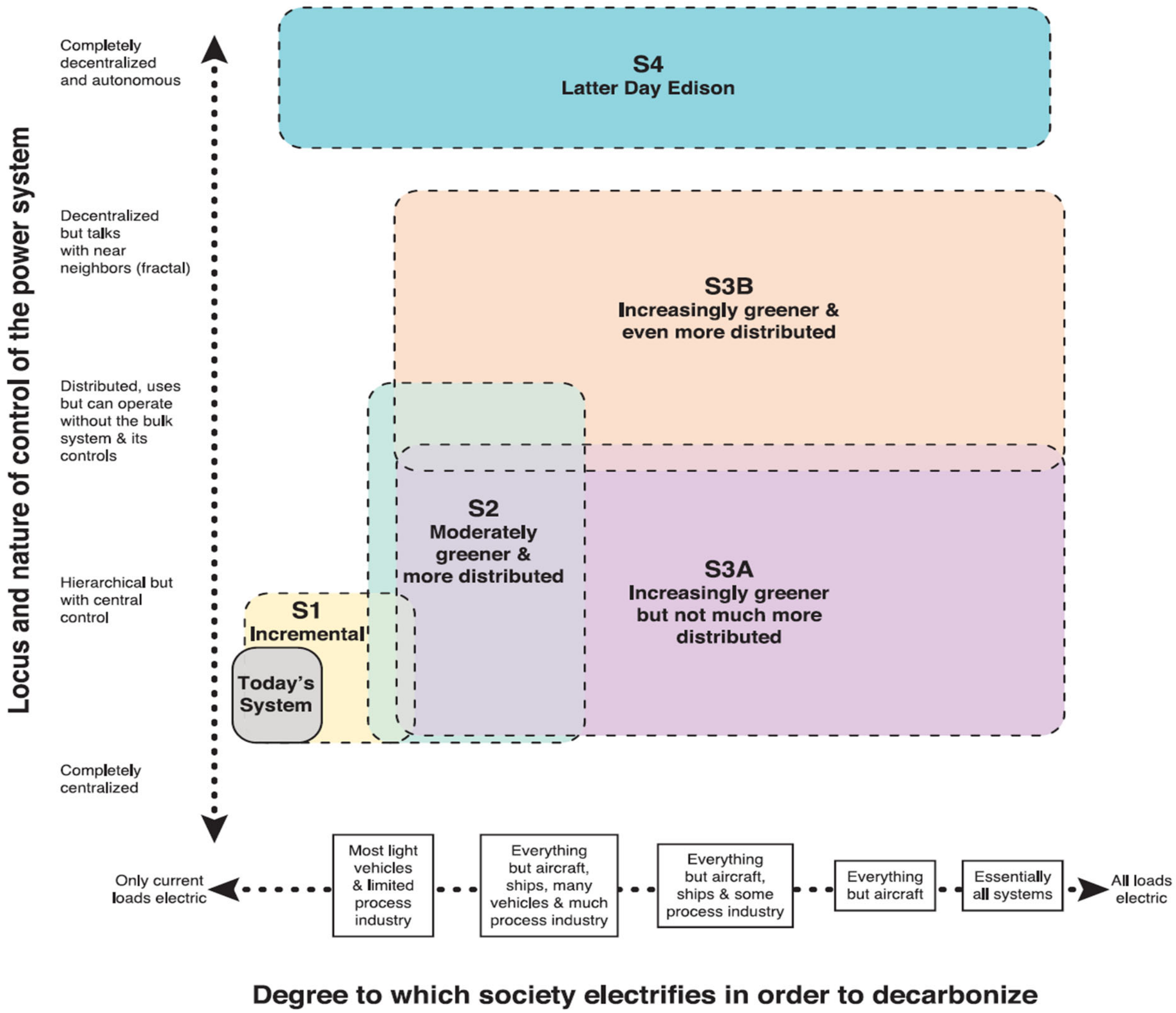
The 7 drivers and possible architectures

...we explore a number of ways in which future generation transmission, distribution and use might evolve.

We conclude by returning to the issue of possible future architectures.



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Architecture Study and Development

- Planning, Operations Planning, Operations, Simulator Training
- The only way to study the performance of the present and evolving grid has been the analytical tools that can model and simulate the grid.
- Because they use different strategies, data, and formats, many of the current generation of models used to assess and plan the power system are incompatible and do not adequately work together. There is a need for standards, frameworks, and platforms such that all new analytical tools are developed to be inter-operable with each other.
- The ability to co-simulate all parts of the grid architecture in a compatible manner is absolutely necessary to study the overall behavior of the end-to-end grid instead of only portions of it.
- FERC/NERC rely on standards to oversee planning of the grid to ensure adequate levels of reliability. They also regulate the reliability and market standards that must be followed. They will need to ensure that the models and analytic tools that are used by planners and operators provide comparable insights about future scenarios of the interconnected grid. Also, the many interconnected power companies in the same grid need to use common processes, like comparable simulation tools, to determine reliability metrics.
- When they can be conducted in a manner that does not create a high risk of service disruption, experimental studies conducted in the operating grid can provide insights that are difficult, and sometimes impossible, to develop solely through the use of simulation.

Architecture Development Tools

Recommendation 5.5: DOE should support a sustained collaboration of national labs, academia, utilities, and vendors to develop a family of intercompatible simulation tools that have common standard interfaces to work together to assess the performance of the present grids and better anticipate the implications of the various ways the grid architectures may evolve in the future. The development and standardization of common interfaces between simulation tools will enable the studies of evolving architectures.

Recommendation 5.6: As new technologies that impact the architecture of the grid are deployed in the grid, FERC/NERC should develop and approve standards that more specifically address new technologies and ensure that information is available to enable the development of improved modeling and simulation tools. They should ensure that the process and parameters for a new technology that affects the grid are made available so that they can be incorporated into the analytical and simulation tools. They should develop new standards or modify old standards to consider and address the impact of all new technologies.

Recommendation 5.7: As more capable and intercompatible simulation tools become available, system planners and operators should use the results and insights that are gained to develop better grid architectures, plans and operational procedures; they should also inform regulators and policy makers, like FERC and NERC, about potential issues and opportunities for improving grid operations and planning, so that this information can be used to update the regulations and standards.

Recommendation 5.8: Because there will always be limits to what can be learned through simulation, DOE should choose the most promising new architectures indicated by large scale simulation studies in order to identify and plan a number of large-scale field experiments that could verify the advantages of such grid architectures under actual operations.

Report Takeaways

Electric power is essential to the welfare of all Americans and is increasingly dependent on other infrastructures.

The system is on the cusp of fundamental transformations many of which are not under industry control.

We can identify drivers of future change but how they will manifest is uncertain – and it will be different in different parts of the country.

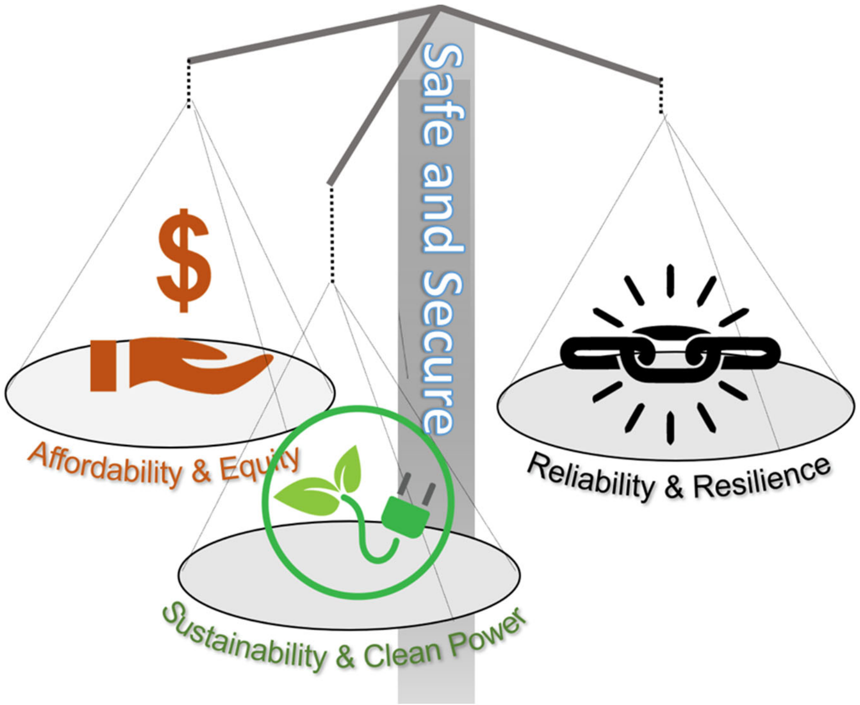
An environment that promotes technical, economic and regulatory innovation is essential to assuring that our future electricity system serves America's needs – and that the U.S. positions itself as an international leader.

This will require R&D and also testing and demonstration of:

- New technologies
- New legal and regulatory frameworks
- Insights from applied social science

No matter how the future unfolds...

...we need to be sure that it remains safe and secure, and balanced in these key attributes:



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