The Future of Electric Power in the U.S.

Congressional Briefing | February 25, 2021

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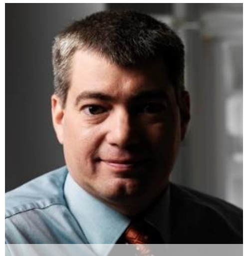

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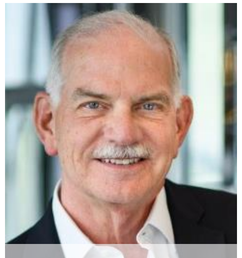

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*Committee Member, *Enhancing the Resilience of the Nation's Electricity System* (2017)

Several were also part of the previous NASEM study on resilience


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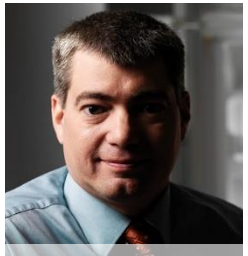
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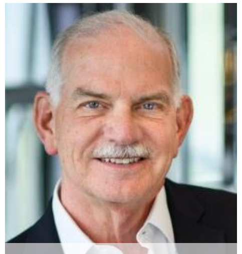
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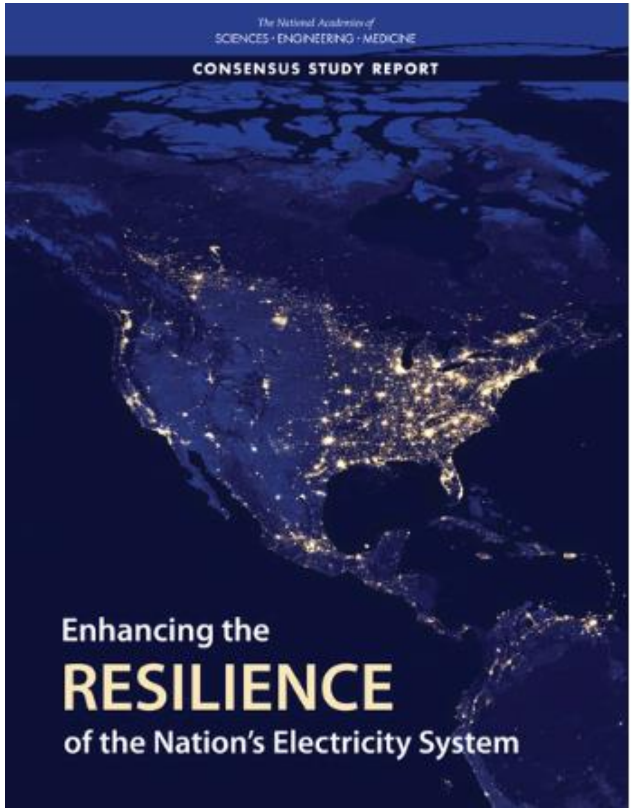
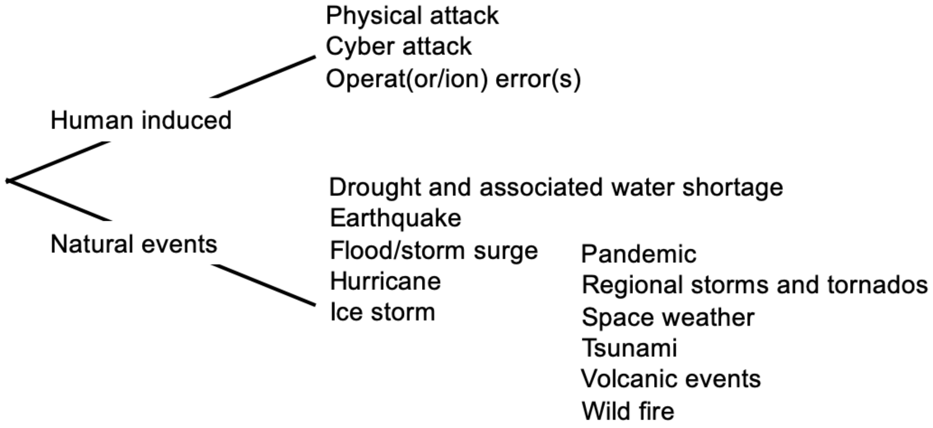
In light of recent events in Texas...

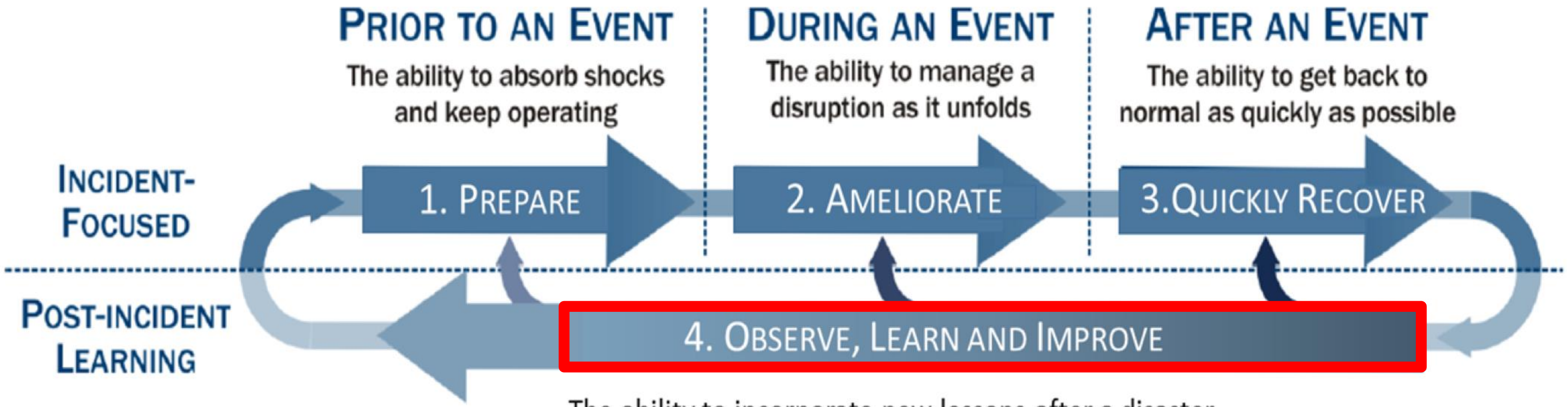
I want to urge you to look again at that study

National Academies, 2017
Download report at **nap.edu**



The report considered a variety of causal events *including extreme weather.*





The ability to incorporate new lessons after a disaster and minimize the risks associated with future events

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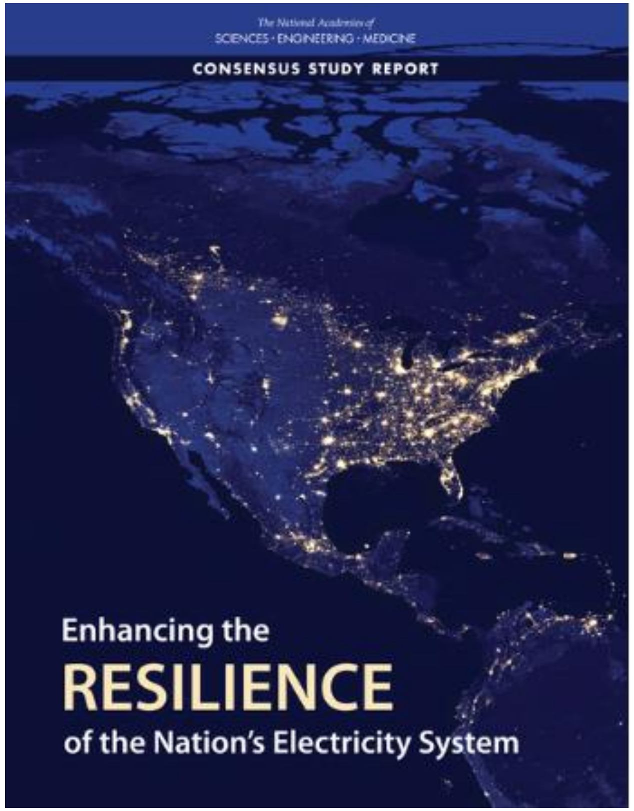
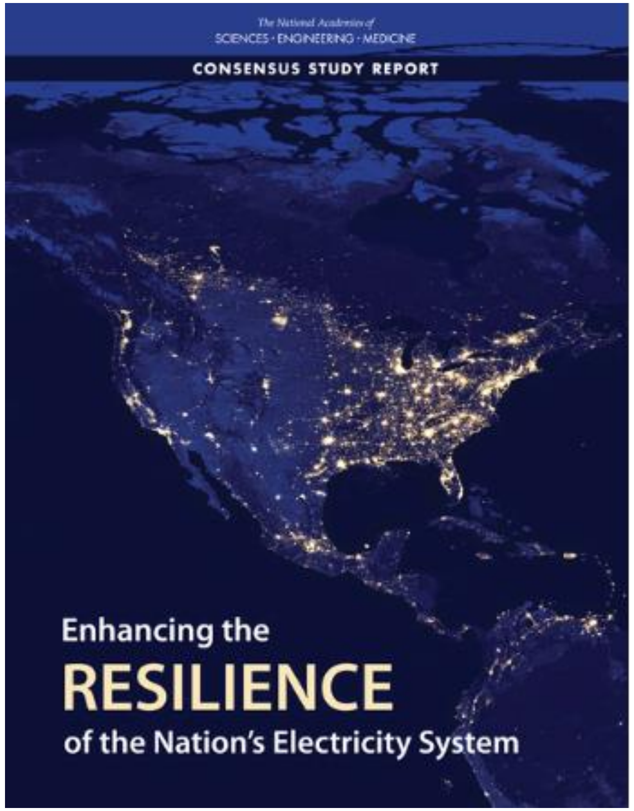
To minimize the chance of large outages:



Overarching Recommendation 6: The Department of Energy and Department of Homeland Security should jointly establish and support a "visioning" process with the objective of systematically imagining and assessing plausible large-area, long-duration grid disruptions that could have major economic, social, and other adverse consequences, focusing on those that could have impacts related to U.S. dependence on vital public infrastructures and services provided by the grid.

Of course in the case of Texas we knew about the vulnerability to cold weather from past events. That leads me to one of our specific recommendations.

And these specific recommendations:



Recommendation 6 to the electric power sector and DOE: The owners and operators of electricity infrastructure should work closely with DOE in **systematically reviewing previous outages** and demonstrating technologies, operational arrangements, and exercises that **increase the resilience of the grid.**

Recommendation 7 to DHS and DOE: Work collaboratively to **improve preparation for, emergency response to, and recovery from large-area, long-duration blackouts**.

Recommendation 9 to state offices and regulators: Work with local utilities and relevant stakeholders to assess readiness of backup power systems and **develop strategies to increase investments in resilience enhancing technologies.**

Turning now to the Present Study

At the request of Congress, the Department of Energy asked the National Academies of Sciences, Engineering, and Medicine to evaluate the medium- to long-term evolution of the electric grid, with particular consideration to:

- *Technologies* – for generation, storage, power electronics, sensing and measuring, controls systems, cyber security, and loads
- *Planning and Operations* – evolution of current practices in response to changing generation, technologies, and end use
- *Business Models* – cost and benefits to modernization; potential changes to oversight and market operations
- *Grid Architectures* – technical and jurisdictional challenges to implementation

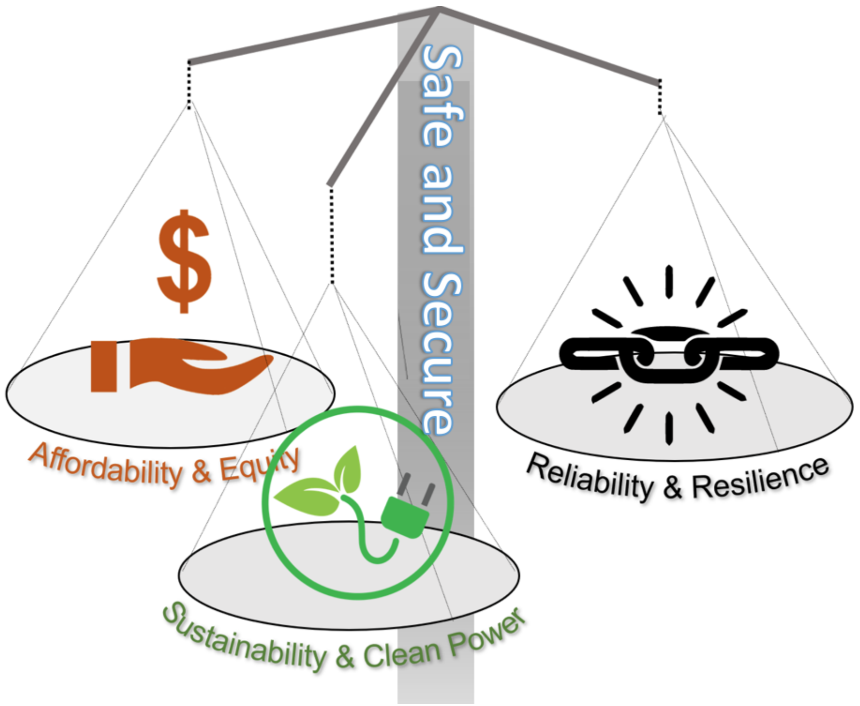
In this report...

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

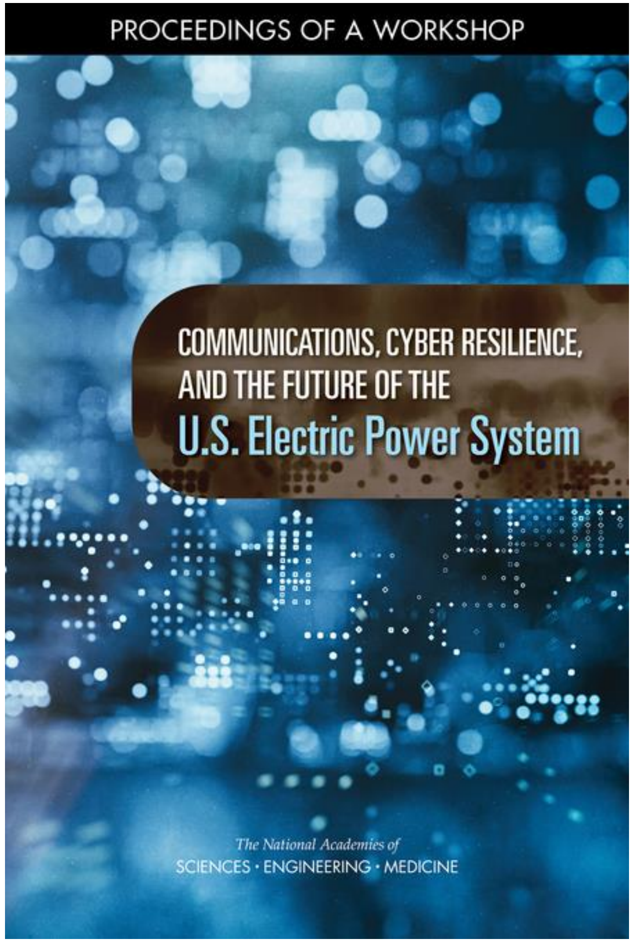
We ***do*** lay out ways in which it ***might*** evolve.

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

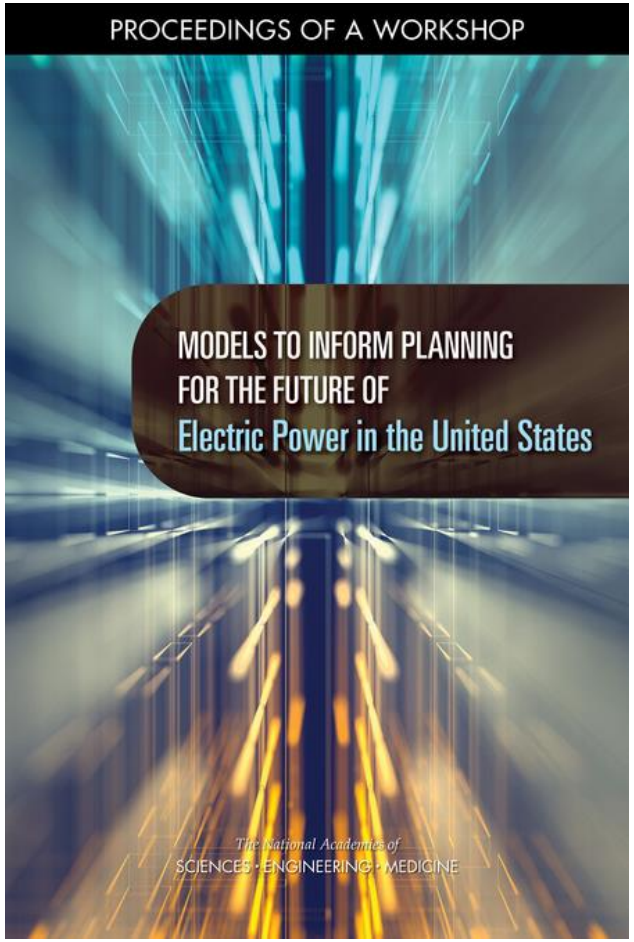
- affordability and equity
- sustainability and clean power
- reliability and resilience



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



https://www.nap.edu/read/25782



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We held workshops on cybersecurity and on modeling.

They have now been downloaded ~1,000 times.

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Structure of 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

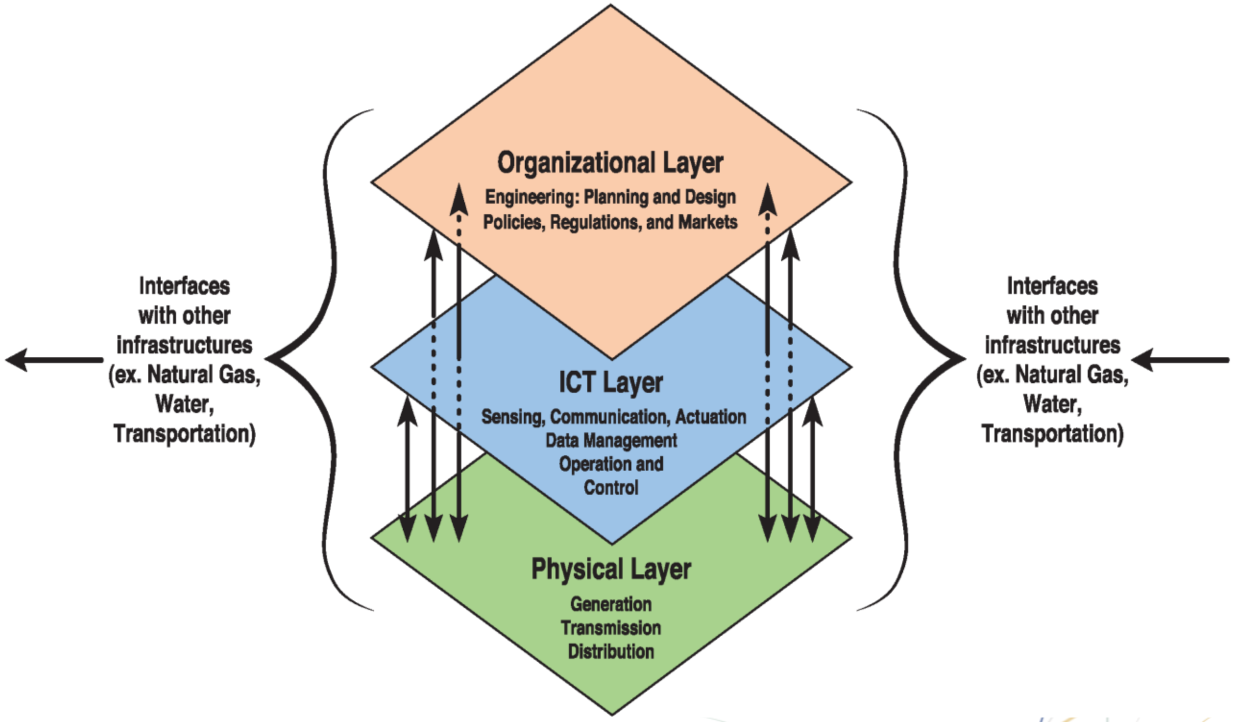
Chapter 1: Framing the Issues

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.



Chapter 1 makes no recommendations

In the five chapters that follow we make 40 recommendations

Stakeholder(s)	# of Recommendations
Department of Energy	30
Congress	16
State Entities	9
Industry	15
Federal Energy Regulatory Commission	6
Departments of Commerce, Defense, Education, Homeland Security, Labor, State	14*
National Labs, National Science Foundation, National Security Council, White House	5*
E-ISAC, EPRI, Foundations, Utility and Electric Power Organizations, NERC, Regulatory Groups, System Planners and Operators, Universities, Vendors	28*

*total number of recommendations pertaining to these stakeholders, not number per organization

This presentation will highlight just a few of these recommendations.

For the full list of recommendations, download the report at ***nap.edu/25968***

We sort the recommendations under 5 basic needs

Who each is directed to

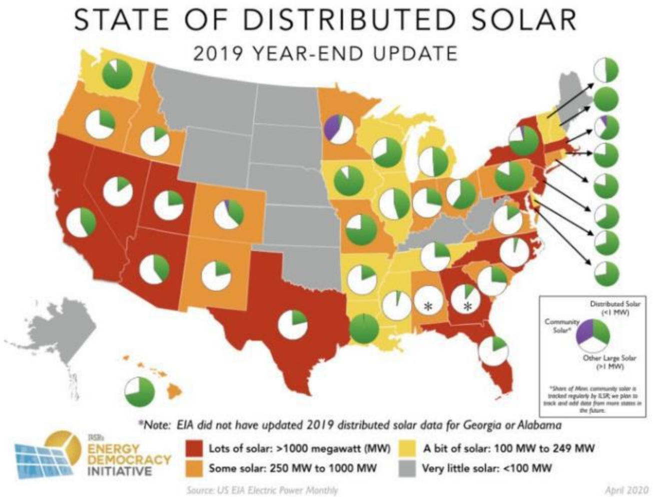
1. Improve our understanding of how the system is evolving
2. Ensure that electricity service remains clean and sustainable, and reliable and resilient
3. Improve understanding of how people use electricity and sustain the “social compact” to keep electricity affordable and equitable in the face of profound technological challenges
4. Facilitate innovations in technology, policy, and business models relevant to the power system
5. Accelerate innovations in technology in the face of shifting global supply chains and the influx of disruptive technologies

4. Facilitate innovations in technology, policy and business mode the power system	
Recommendation 3.6: With support from Congress and state legislatures, DO energy research organizations, and foundations should provide support for social research and regulatory/policy analysis designed to identify and assess alternative mo for regulation, innovation and industry structure in the retail/distribution segment of the electric system. Such research and analysis efforts should also address opportunities and mechanisms to allow for flexible demand and the value of doing so for electric system performance, cost, and emissions. Such research and analysis should also focus on the development and assessment of metrics to measure how infrastructure investment decisions and authorized actions would affect carbon emissions. Such work should involve and be informed by industry, researchers at universities, think tanks and/or the national labs, and/or other institutions with research programs in the following fields (as well as others): energy economics, behavioral economics, public policy analysis, law, finance, and utility regulation.	Directed to: **DOE, State Legislatures, State Energy Research Organizations, and Foundations**
Recommendation 3.7: DOE should expand its program of providing seed grants to support innovative state programs on making business model and/or restructuring reforms in the retail/distribution segment of the electric industry that: (a) allow for and expand opportunities for the safe and secure adoption of innovative technologies, business models, and market designs; and (b) encourage the adoption of best practices.	Directed to: **DOE**
Recommendation 3.8: The states, through the energy and utility regulation committees of their legislatures as well as through their regulatory agencies, should adopt and/or strengthen policies that support the ability of investor-owned utilities and other parties to innovate on business model issues, ratemaking, and rate design. For publicly owned utilities, the national organizations (i.e., NRECA, APPA, LPPA) and DOE should help fund and/or develop innovative ways for these utilities to operate their distribution systems so that these utilities can leverage the benefits and other implications of new rapidly evolving technology.	Directed to: **State Legislatures, National Utility Organizations, and DOE**
Recommendation 3.10: Congress should expand funding for loans, loan guarantees, and grants to provide equivalent opportunities for investment in local utility infrastructure development for publicly owned utilities (e.g., municipal electric utilities, cooperative utilities, tribal utility authorities, and special-purpose utility districts), because they do not have access to incentives provided through tax credits to investor-owned utilities and other developers.	Directed to: **Congress**
Recommendation 3.11: State regulators, in conjunction with local electric-industry market participants and grid operators, 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 clean energy. Because these issues are complicated and need to take into consideration various technical and legal requirements for operating a dynamic system on the local grid, the governing boards of publicly owned utilities and the regulators in states that anticipate significant adoption of DER should place a high priority on exploring and stress-testing emerging approaches and making decisions that will inform market participants about the timing and character of changes in retail industry structure, prices, and market design.	Directed to: **State Regulators and Industry**
Recommendation 4.4: Achieving greater deployment of advanced electrical technologies will require states to implement regulatory reforms that allow utilities to recover the costs of larger R&D budgets alongside other forms of regulatory approval that encourage more adoption of new technologies. In addition, in a few states that provide direct funding for technology demonstration programs, state policy makers should expand those programs and ensure reliable long-term provision of funds. These programs can be models for other state-based innovation funding, especially where they put attention on the need not just for larger spending but also stronger incentives for adoption of new technologies, including those coming from outside the regulated sector.	Directed to: **State Legislatures, Regulatory Groups**
Recommendation 4.6: Greater deployment of advanced electrical technology is essential and will require expanded support for DOE-backed demonstration projects, including through loan programs and support for industrial consortia that deploy critical technologies. Such expanded support should follow best practices in the implementation of technology demonstration and deployment programs. Programs should be designed for rapid learning (and course corrections where needed) and periodic assessment of the overall portfolio for its performance. Proposals for funded projects should include a clear articulation of how a demonstration could be commercialized including a budget for such activities—so that a larger fraction of successful demonstration projects lead to wider deployment.	Directed to: **DOE**
Recommendation 5.3: DOE, EPRI, other domestic and international research organizations, universities, and world-wide industry should develop relevant supporting ICT to permit (a) secure, reliable, private, and fast communication, and (b) security, safety, accuracy, privacy, and speed in computation, so as to incentivize various asset owners to participate in a retail market structure that allows DERs to participate and be compensated for distributed generation, grid support services, and/or flexible load consumption.	Directed to: **DOE, EPRI, other Research Organizations, Universities, and Industry**

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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Energy Poverty and Social Equity

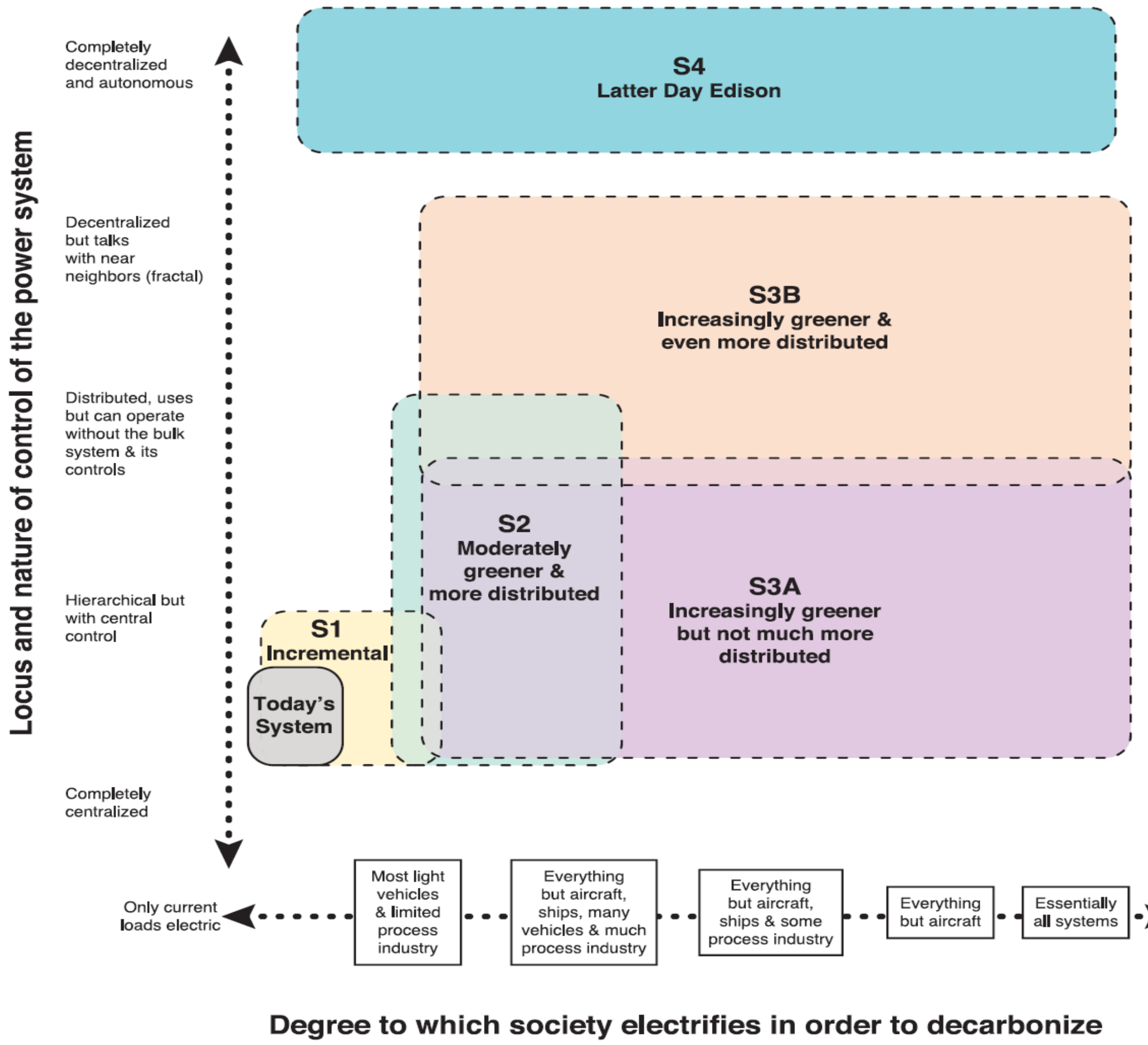
Finding 2.5:

- Paying for adequate energy is a heavy burden on many low-income households, and undermines the goals of affordability and equity.
- Although bill-payment assistance can provide short-term help, investments in energy efficiency...can...provide long-term savings on electricity bills.
- As...new strategies and technologies are adopted by higher income customers, care should be taken to assure that:
  - electricity is an essential service that is universally available and affordable
  - the externalities that arise from its production and use do not disproportionately burden those least able to deal with them.

Then in light of those 7 drivers...

...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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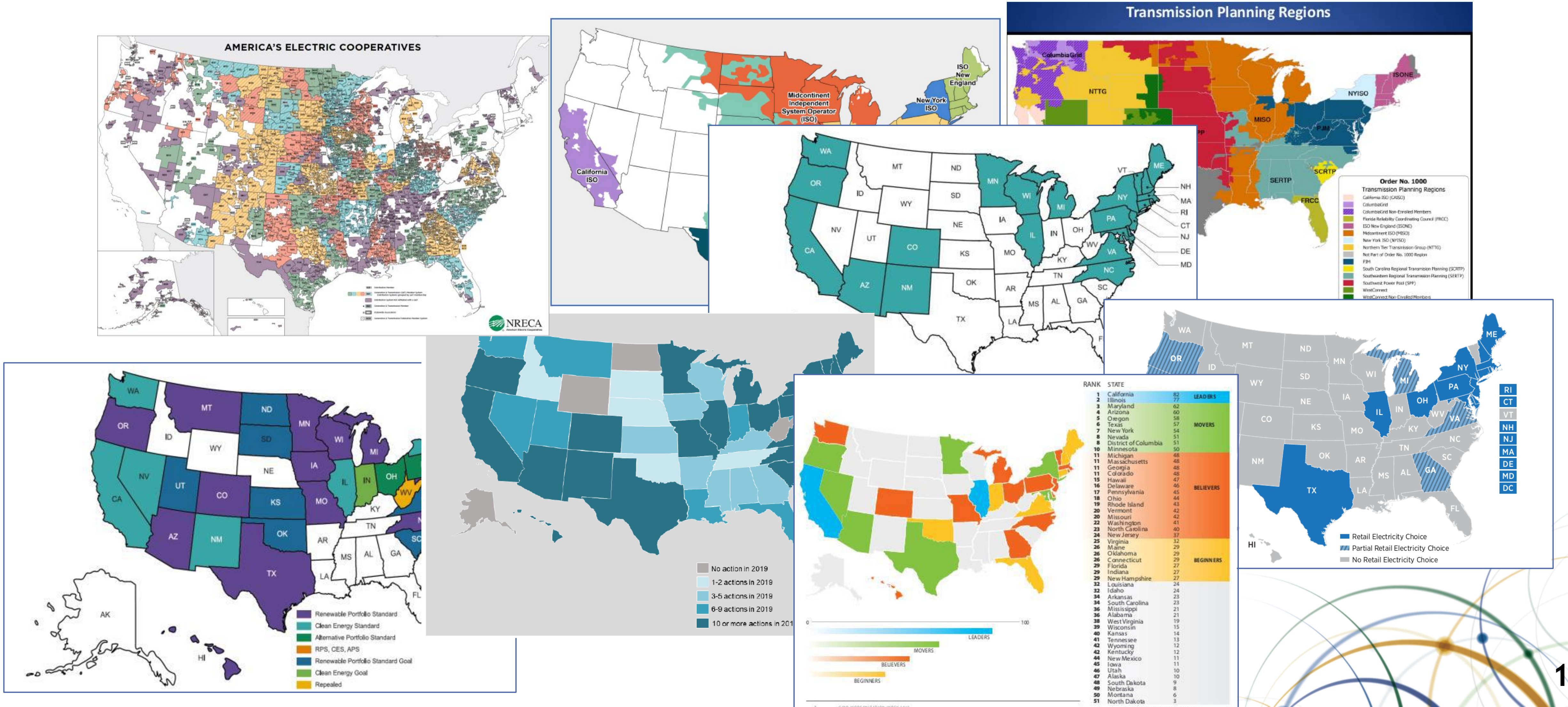
Chapter 3: Legal and Regulatory Issues

Susan F. Tierney
Analysis Group

- 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.

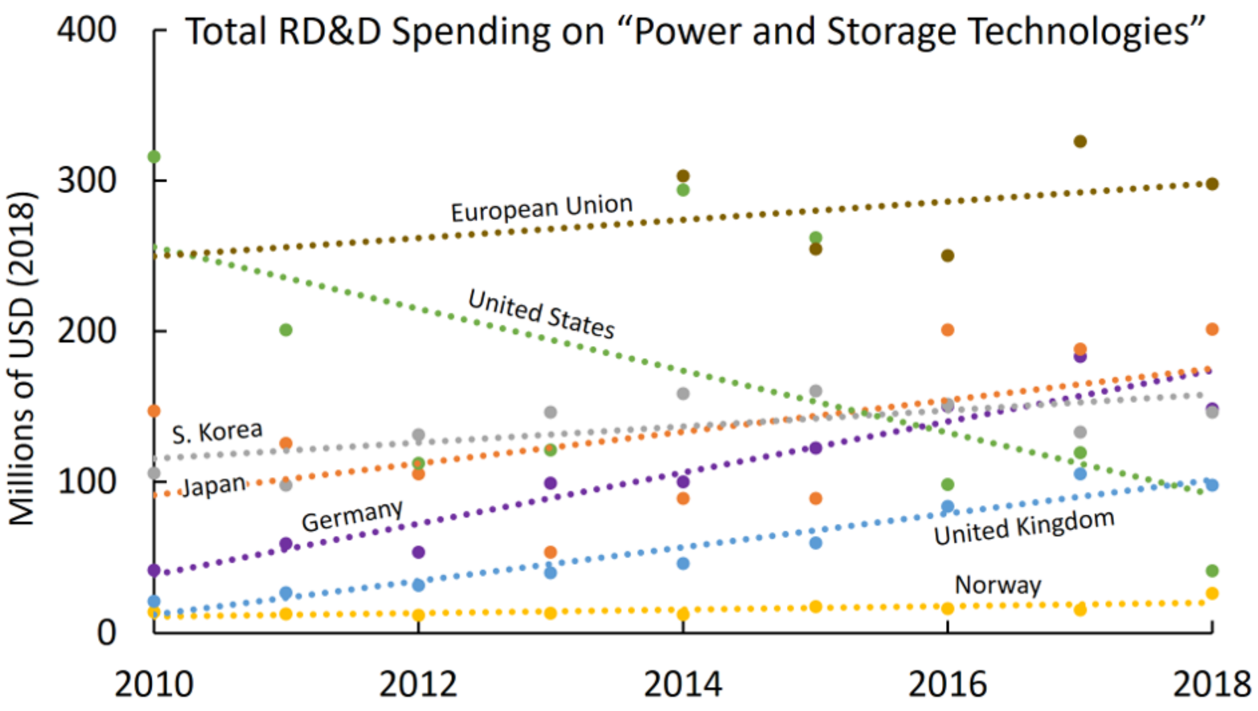
Recommendation 3.10: Grid modernization resources: Providing federal funding (e.g., loans, grants) to encourage publicly owned utilities (e.g., municipal electric utilities, cooperatives, tribal utility authorities) to invest in grid modernization.

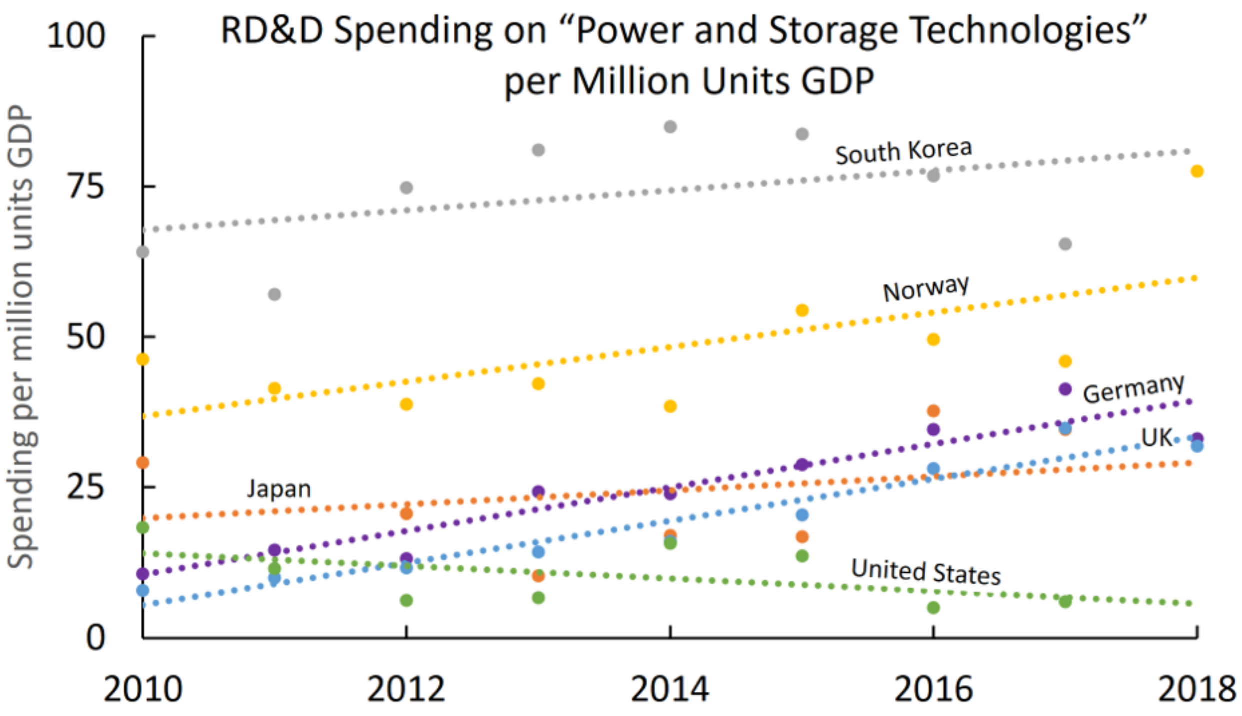
Chapter 4: The Persistent Underinvestment in Electric Power Innovation

David G. Victor
University of California, San Diego

- 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

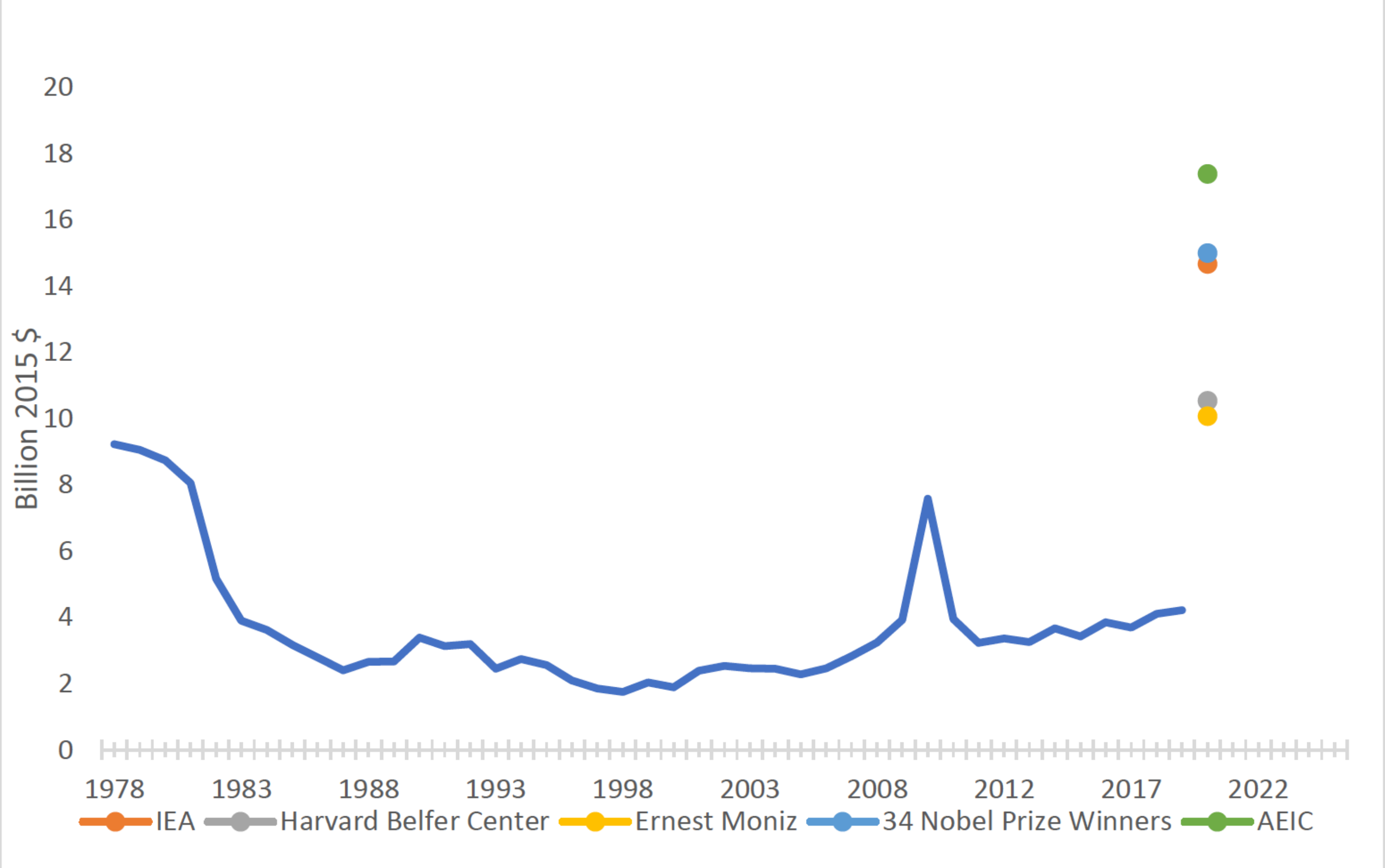


Figure 4-5 Historical US Energy Technology RD&D spending FY 1978-2019, plus multiple studies, most completed a half decade ago, suggesting future spending levels over the decade from 2015 to the middle 2020s. SOURCE: *Adapted from "DOE Budget Authority for Energy Research, Development, and Demonstration 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.*

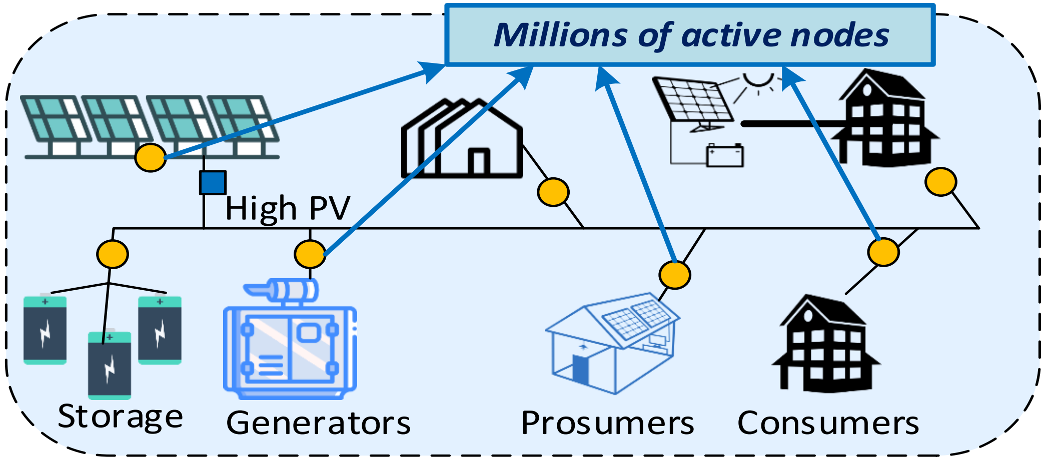
Chapter 4: Selected Recommendations

- 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: Technology and Tools

Michael Howard
Electric Power
Research Institute

- Technology Innovation is the *Foundation* of the Electric Grid
- Key Technologies Include:
  - Clean generation
  - Short and long-term energy storage
  - Power electronics, inverters, DC transmission, EVs, microgrids,
  - Advanced grid protection, control, communications, automation and simulation



Grid of the future

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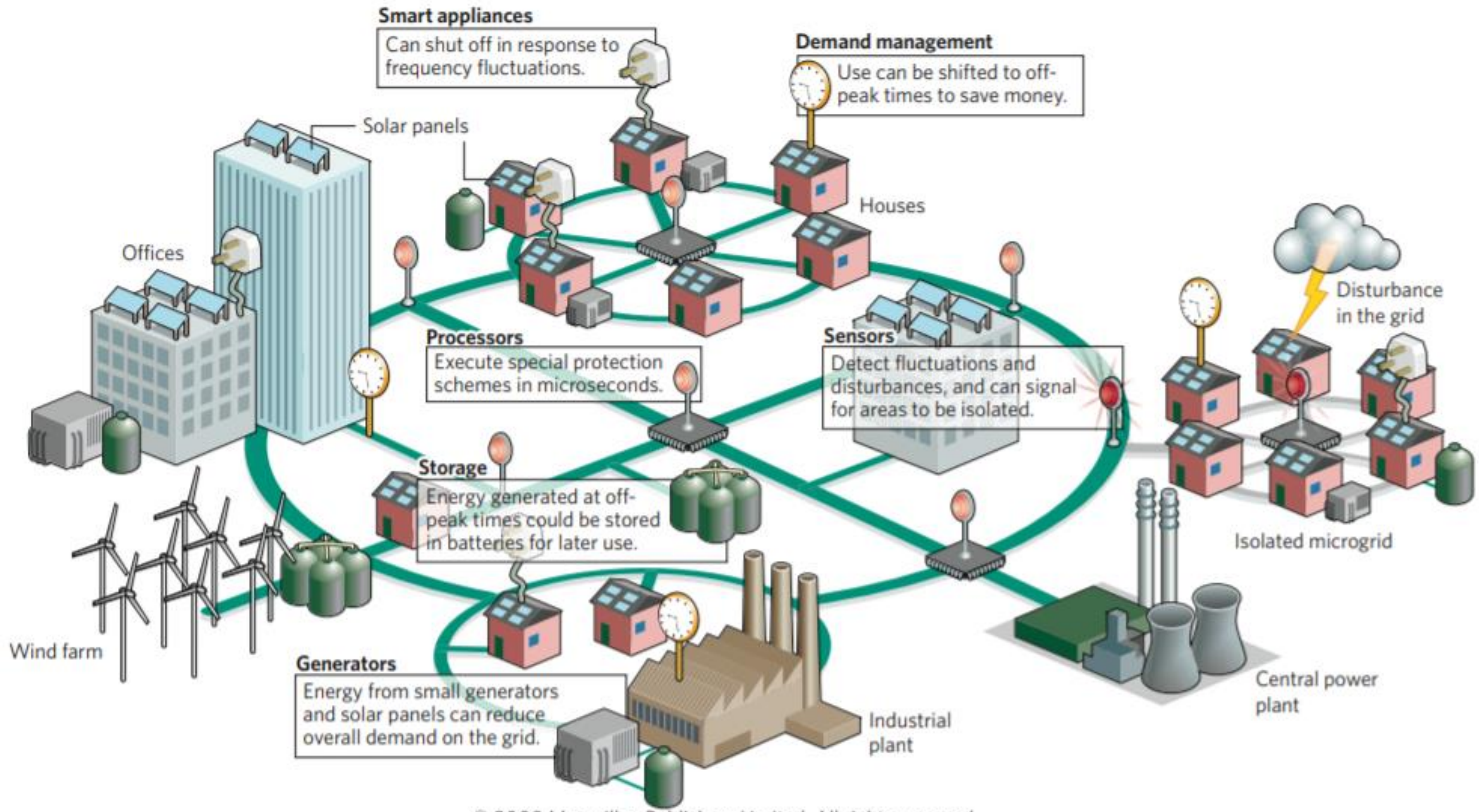
Technologies and Tools to Enable a Range of Future Power Systems



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

Chapter 5: Summarized 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, Automation, and Simulation (5.3-8)

- 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 advanced *inter-compatible* simulation tools that can analyze the evolving grid architectures.
- Explore the use of large field experiments for new grid architectures.

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

Cynthia Hsu
National Rural Electric Cooperative Association

- 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.

Chapter 6: 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.

Chapter 6: 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)
- Develop guidance for distribution-level resiliency requirements to be implemented at the state and local level. (Recommendation 6.9)

Chapter 6: Recommendations (cont.)

Liabilities, roles and responsibilities are not well defined. It is not clear who is responsible for cybersecurity and the associated costs as the grid evolves, especially protecting against nation-state attacks.

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)

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.

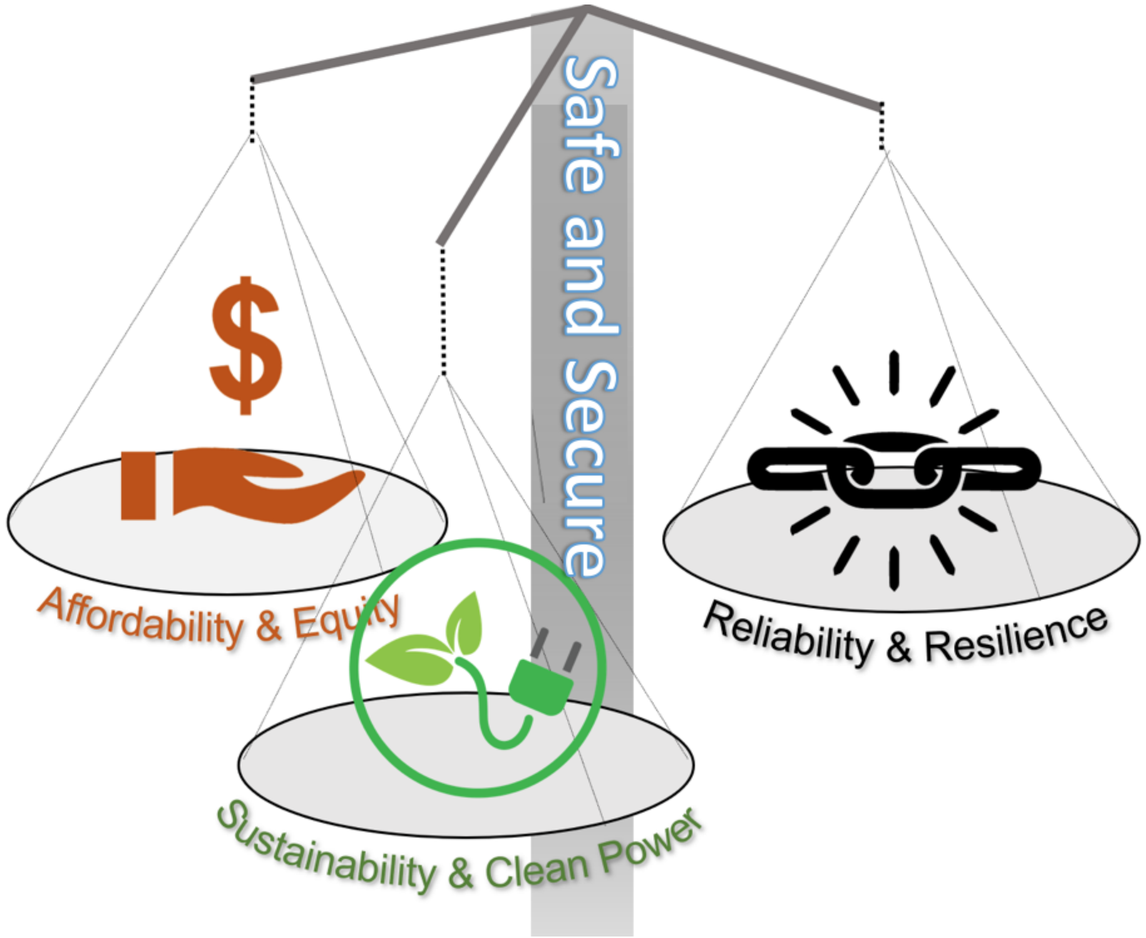
An environment that promotes technical, economic and regulatory innovation is essential to assuring that our future electricity system serves America’s needs – and that the U.S. positions itself as an international leader.

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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We all need to work together if we are going to keep the lights on, and keep America safe, healthy, and productive.

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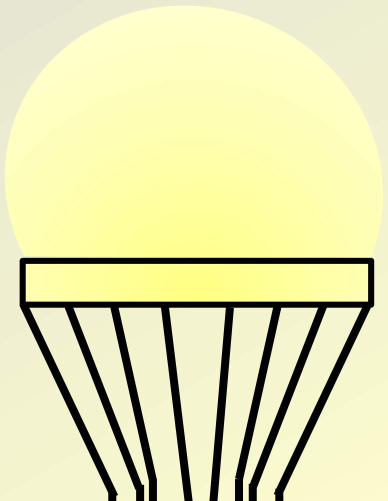

Questions?

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