



# 21<sup>st</sup> Century Power Partnership

An Initiative of the Clean Energy Ministerial

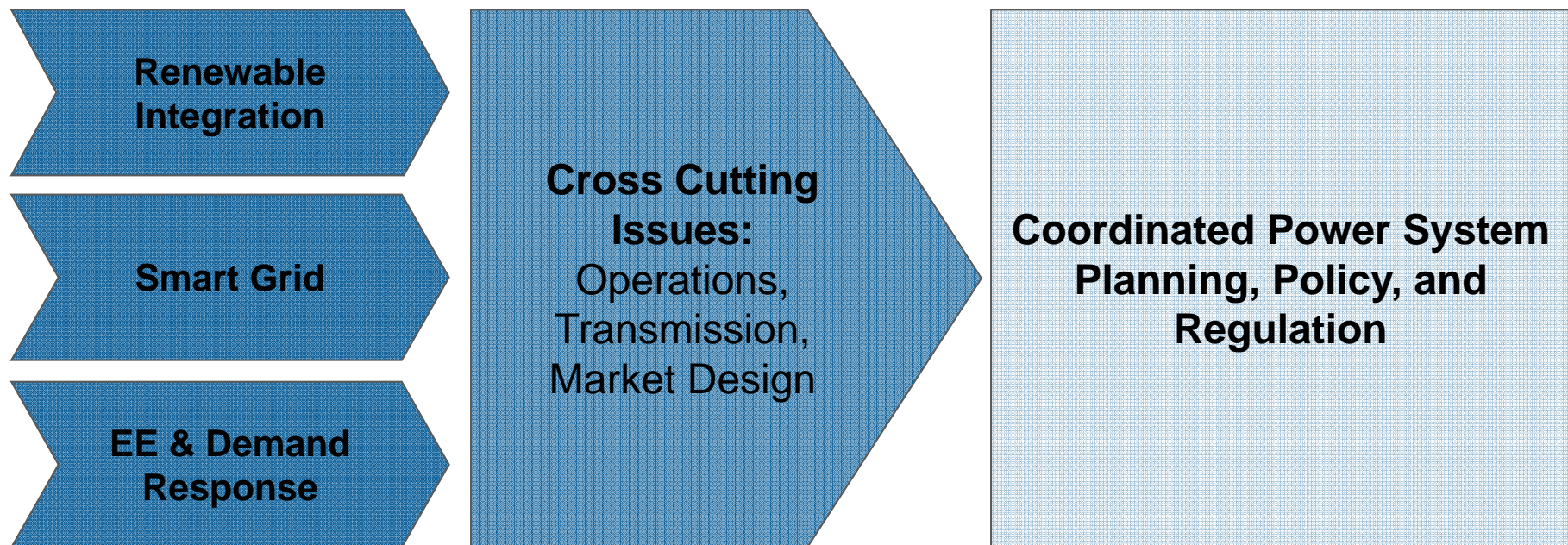
Dr. Douglas Arent

National Renewable Energy Laboratory

Operating Agent for the 21CPP



**Accelerating the transition to clean, efficient, reliable, and cost-effective power systems.**



**Elements of Power System Transformation**

## The Partnership aims to advance integrated policy development through four areas of activity:

### Faster Learning

**Developing and sharing knowledge** on key topics related to power system transformation.

### Better Tools

**Strengthening and disseminating technical tools** to accelerate policy and regulatory analysis.

### Capacity Building

**Bolstering the capacity of experts** to advance the policies, programs, and practices.

### Meaningful Partnerships

**Establishing applied multilateral partnership engagements** to leverage knowledge, tools, and capacity.

## Clean Energy Ministerial

### 21<sup>st</sup> Century Power Partnership Steering Group (PPSG)

Membership open to both CEM- and non-CEM government participation, as well as civic society organizations and private firms. Membership implies in-kind or direct resources to craft and implement annual Program of Work.

### Annual Program of Work

**Operating Agent**  
(NREL/JISEA)

### Public-Private Leadership Forum (PPLF)

Private sector participation to inform and assist in implementing the Annual Program of Work.



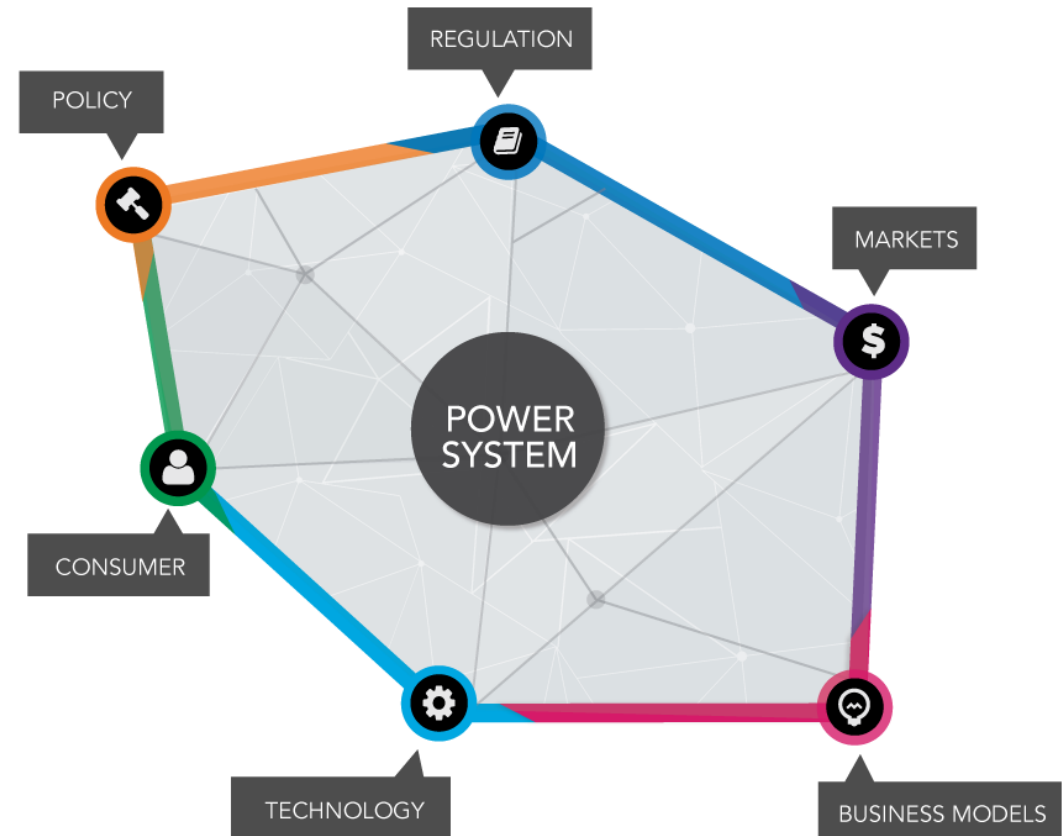
21st Century  
**POWER  
PARTNERSHIP**  
*Accelerating the transformation  
of power systems*

# **POWER SYSTEMS OF THE FUTURE**

## ***A 21ST CENTURY POWER PARTNERSHIP THOUGHT LEADERSHIP REPORT***

# A HOLISTIC APPROACH TO POWER SYSTEMS

- ❖ Power systems as *complex dynamic systems*
- ❖ Power systems are evolving around the world

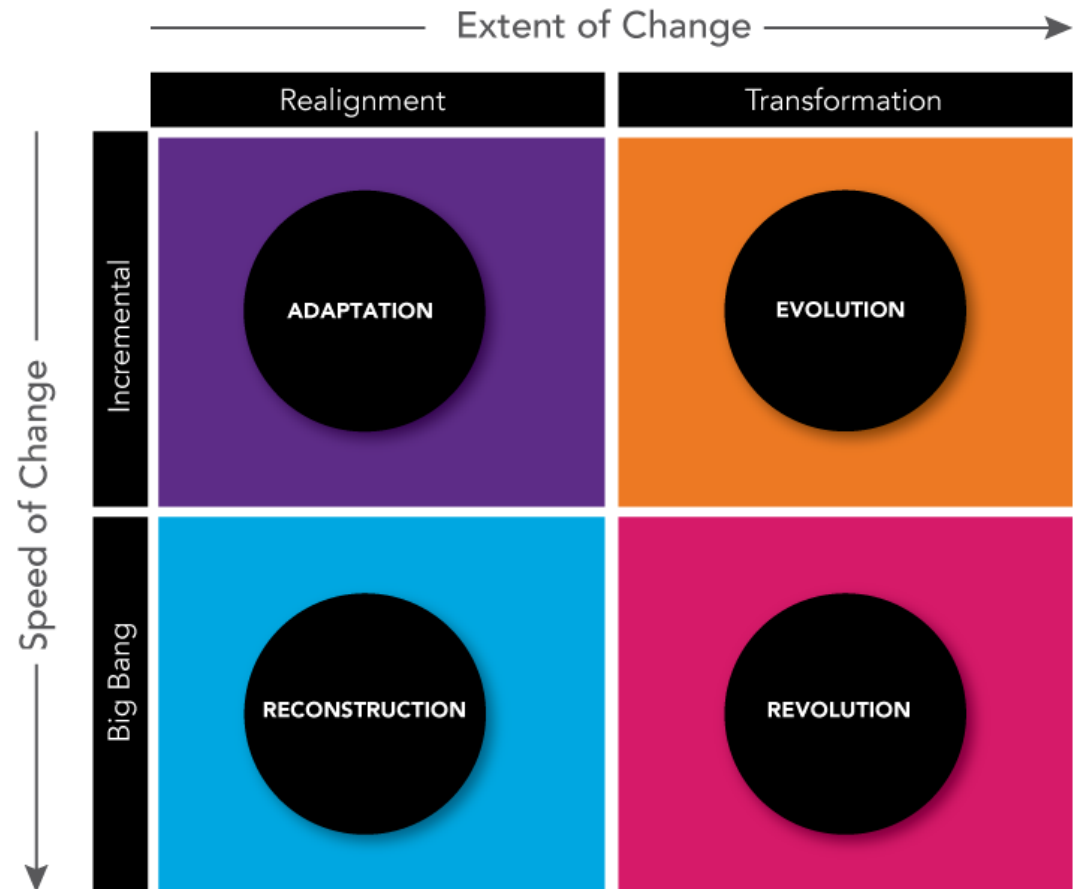


1. Renewable energy cost reductions
2. Data, intelligence, and system optimization innovations
3. Energy security, reliability, and resilience goals
4. Evolving customer engagement
5. A tale of two electricity demand forecasts
6. Increased interactions with other sectors
7. Local and global environmental concerns over air emissions
8. Energy access imperatives
9. Increasingly diverse participation in power markets
10. Revenue and investment challenges.

**Deliberate and proactive collaboration is needed to encourage desired futures.**

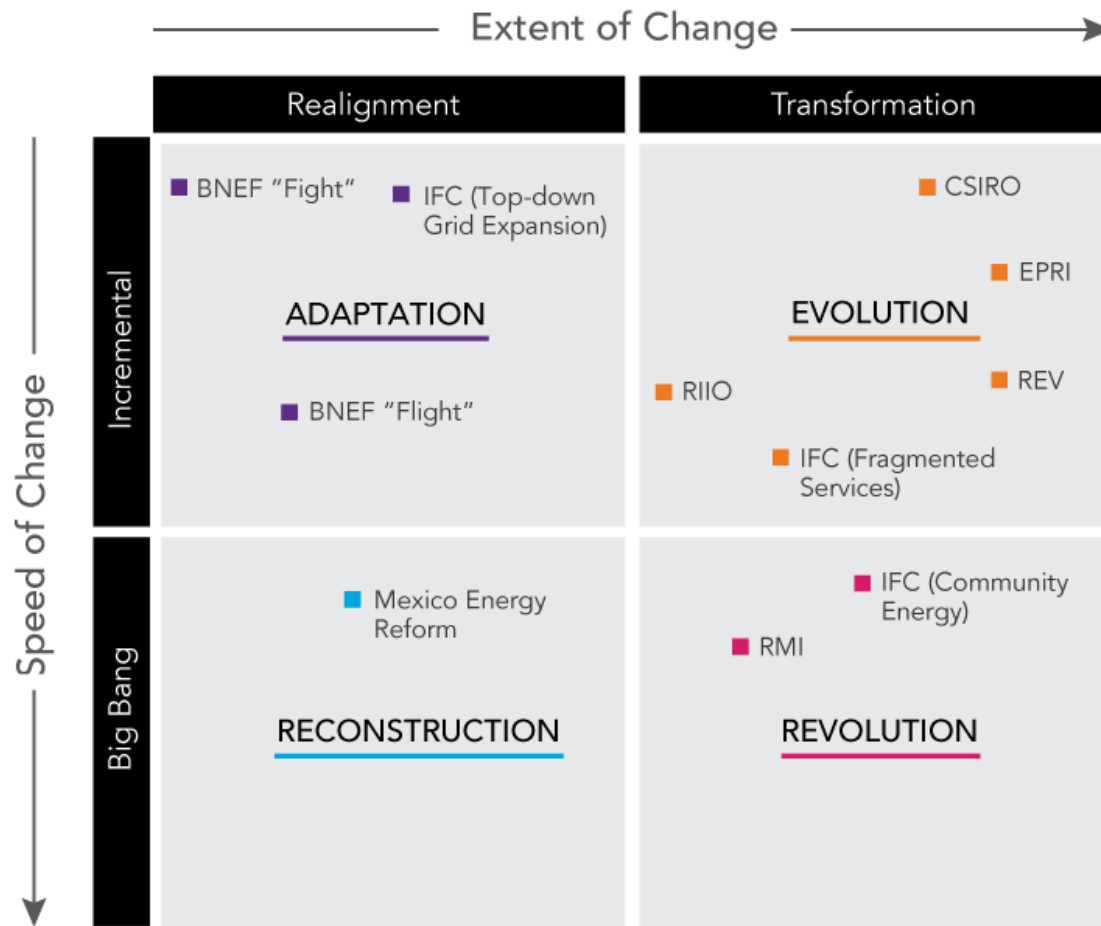
## ❖ Evolution is path-dependent

- ❖ Technological, financial and institutional legacies
- ❖ *Heavier legacies*: cautious incrementalism
- ❖ *Lighter legacies*: more rapid change.



**Types of Strategic Change\***

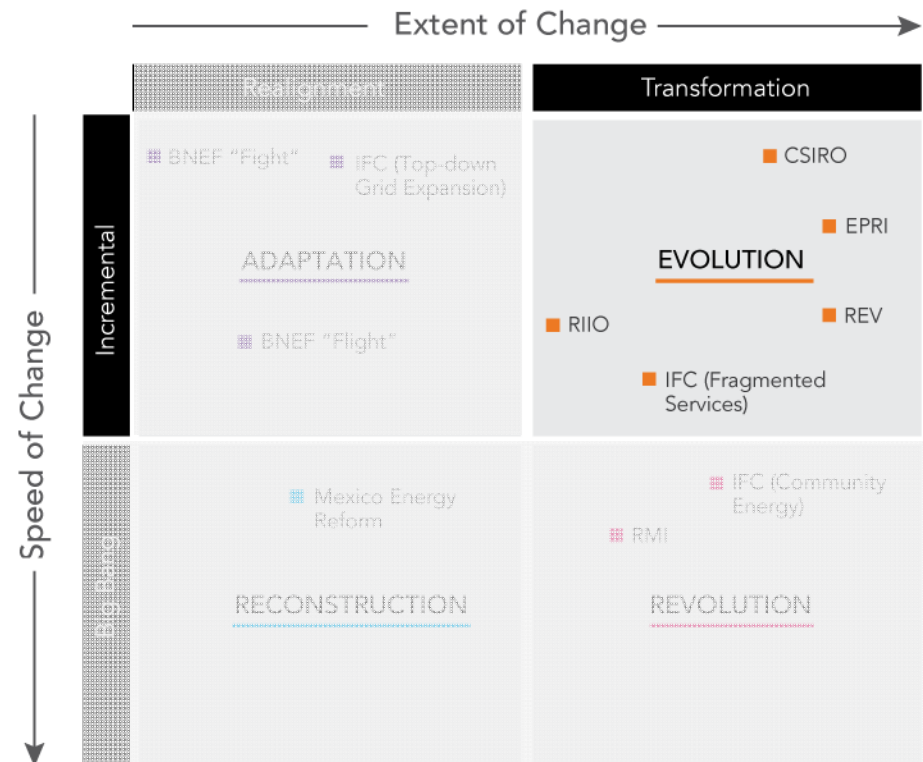




Increasingly heterogeneous landscape with high levels of context-specificity

## Incremental yet dramatic change over 10-20 years

- ❖ *RIIO*<sup>4</sup>
  - ❖ Performance-based incentive and revenue cap regulation
- ❖ *IFC (Fragmented Services)*<sup>2</sup>
  - ❖ Reliance on small-scale energy providers
- ❖ *CSIRO*<sup>5</sup>
  - ❖ Large-scale “prosumer” diffusion
- ❖ *EPRI*<sup>6</sup>
  - ❖ Fundamental changes to the role of the central grid, and associated investment/operational frameworks
- ❖ *REV*<sup>7</sup>
  - ❖ NY state plan to establish retail market and technical/financial integration of DERs



4. Office of Gas and Electricity Markets (OFGEM). (2010). “RIIO –A New Way to Regulate Energy Networks.”

5. Commonwealth Scientific and Industrial Research Organisation (CSIRO). (2013). *Change and Choice: The Future Grid Forum’s analysis of Australia’s Potential Electricity Pathways to 2050*. Clayton South Victoria, Australia: CSIRO.

6. Electric Power Research Institute (EPRI). (2014). *The Integrated Grid: Realizing the Full Value of Central and Distributed Energy Resources*. Palo Alto, CA: EPRI.

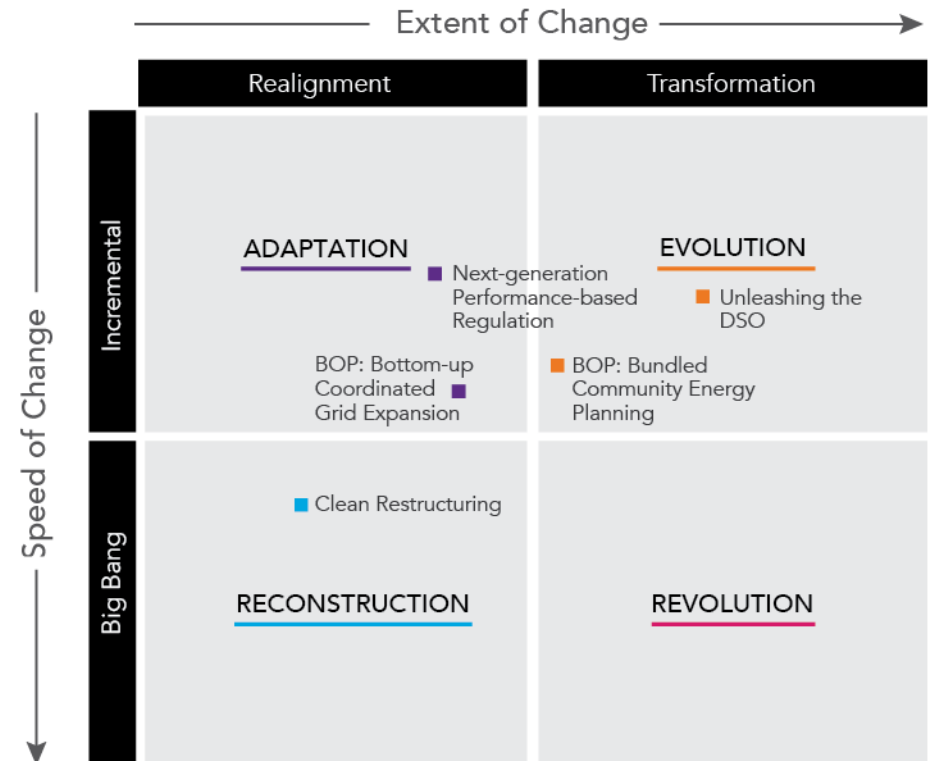
7. New York Department of Public Service (NY-DPS). (2014). *Reforming the Energy Vision: NYS Department of Public Service Staff Report and Proposal*. Case 14-M-0101. Albany, NY: NY-DPS.

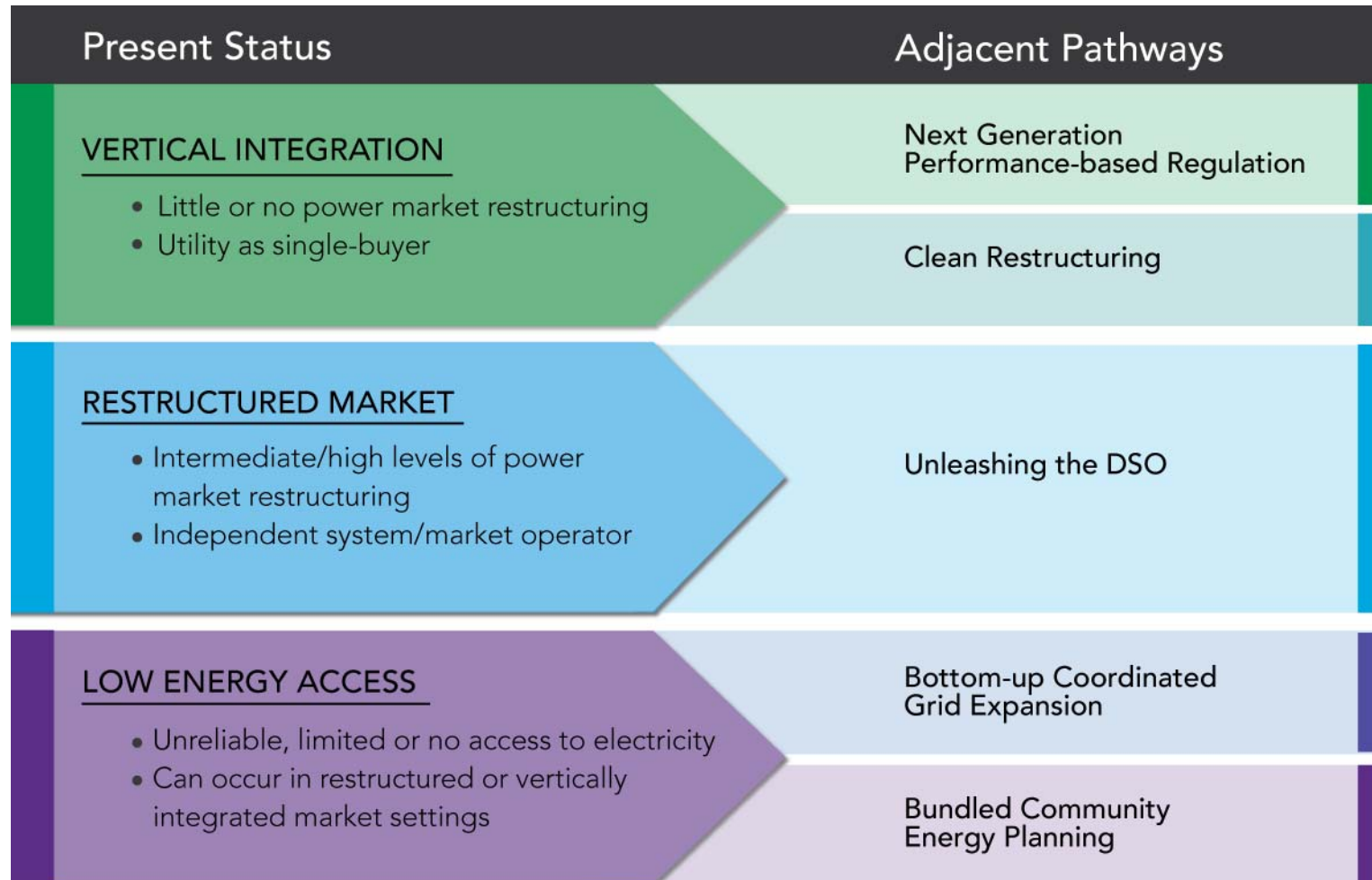
## Nine key variables influencing the evolution of investment trends in the power sector

- ❖ *Regulations on Commercial Banking Risk*
- ❖ *Risk Premium Environments for Investment*
- ❖ *Interest Rates on Government Bonds*
- ❖ *Capital Availability from Development Authorities*
- ❖ *Tax Structures*
- ❖ *Credit Rating of Electric Utilities*
- ❖ *Price and Availability of Inputs*
- ❖ *Market Structure and Valuation Constructs*
- ❖ **Policy and Regulatory Environment.**

## Five archetype pathways toward power system transformation

- ❖ Next-generation Performance-based Regulation
- ❖ Clean Restructuring
- ❖ Unleashing the DSO
- ❖ Bottom-of-the-Pyramid (BOP) Bottom-up Coordinated Grid Expansion
- ❖ BOP Bundled Community Energy Planning





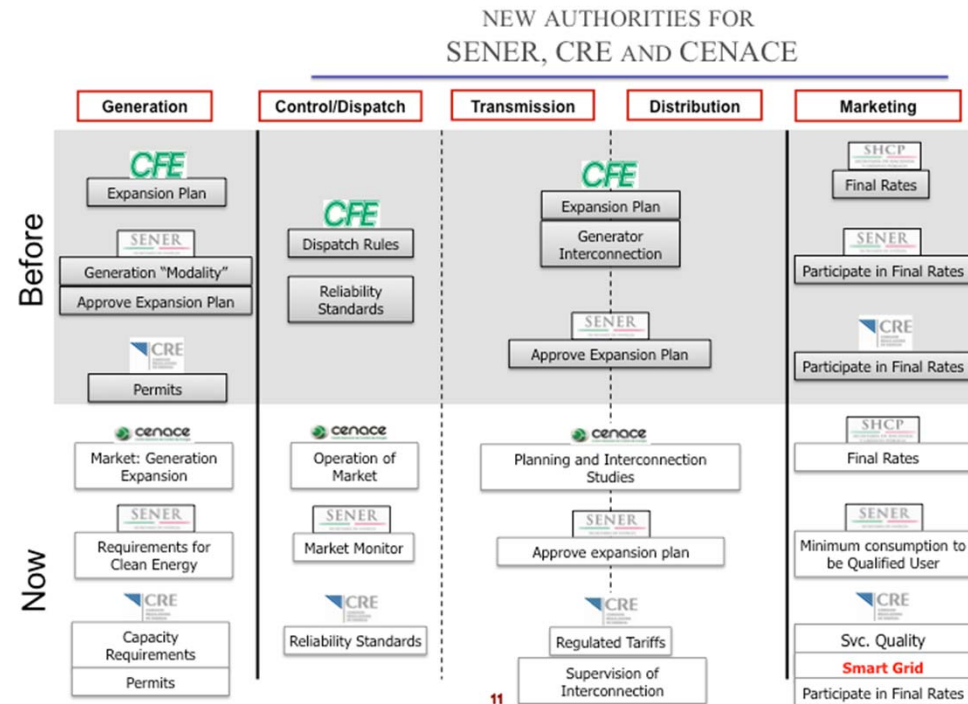


## Next-generation Performance-based Regulation

- ❖ Adaptive change dynamics
- ❖ Vertically integrated utilities remain in recognizable form
- ❖ Regulation evolves to prioritize *delivery of value* rather than prudent compensation for incurred costs
- ❖ As transitions progress, regulation and supporting policy increasingly decouple utility's revenue from costs
- ❖ Earnings increasingly linked to well-defined, quantifiable performance metrics over long performance periods

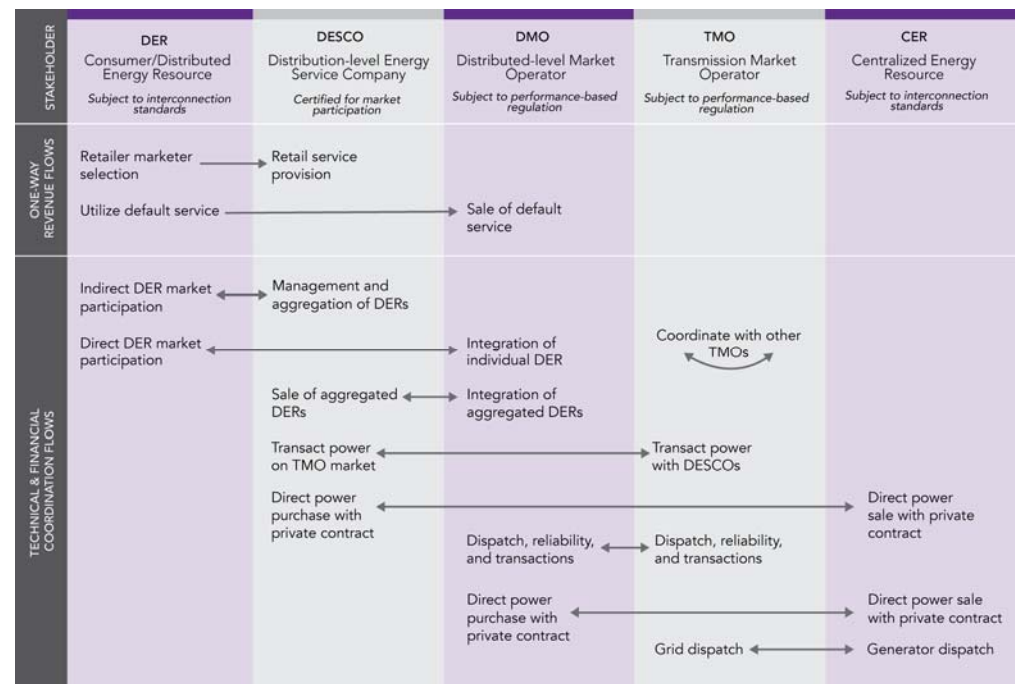
## Clean Restructuring

- ❖ Reconstructive change dynamics
- ❖ Bulk power market restructuring, incorporating lessons learned from the past 20 years
- ❖ Design features to facilitate clean energy integration and system optimization



## Unleashing the DSO

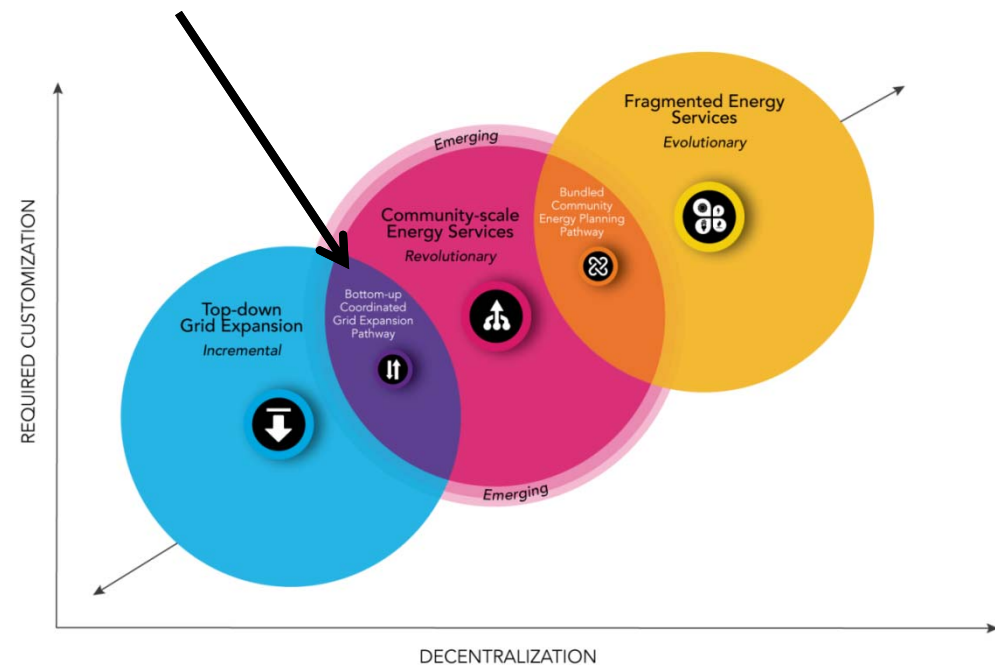
- ❖ Evolutionary change dynamics
- ❖ Distribution system operators (DSOs) facilitate retail power market restructuring
- ❖ Technical and financial integration of distributed energy resources
- ❖ Technology neutrality in policies and standards





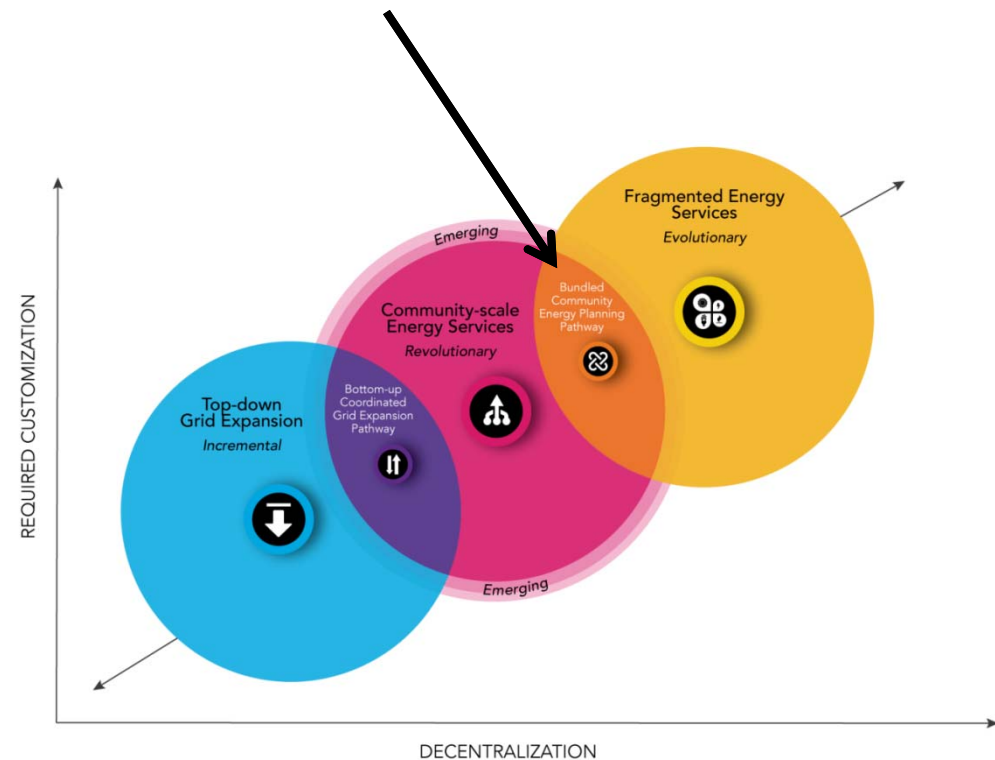
## Bottom-of-the-Pyramid: Bottom-up Coordinated Grid Expansion

- ❖ Adaptive change dynamics
- ❖ Technical and regulatory backwards compatibility of mini-grid solutions
- ❖ Ratepayer or private financing for mini-grid
- ❖ Regulation ensures investors “made whole” upon central grid subsumption

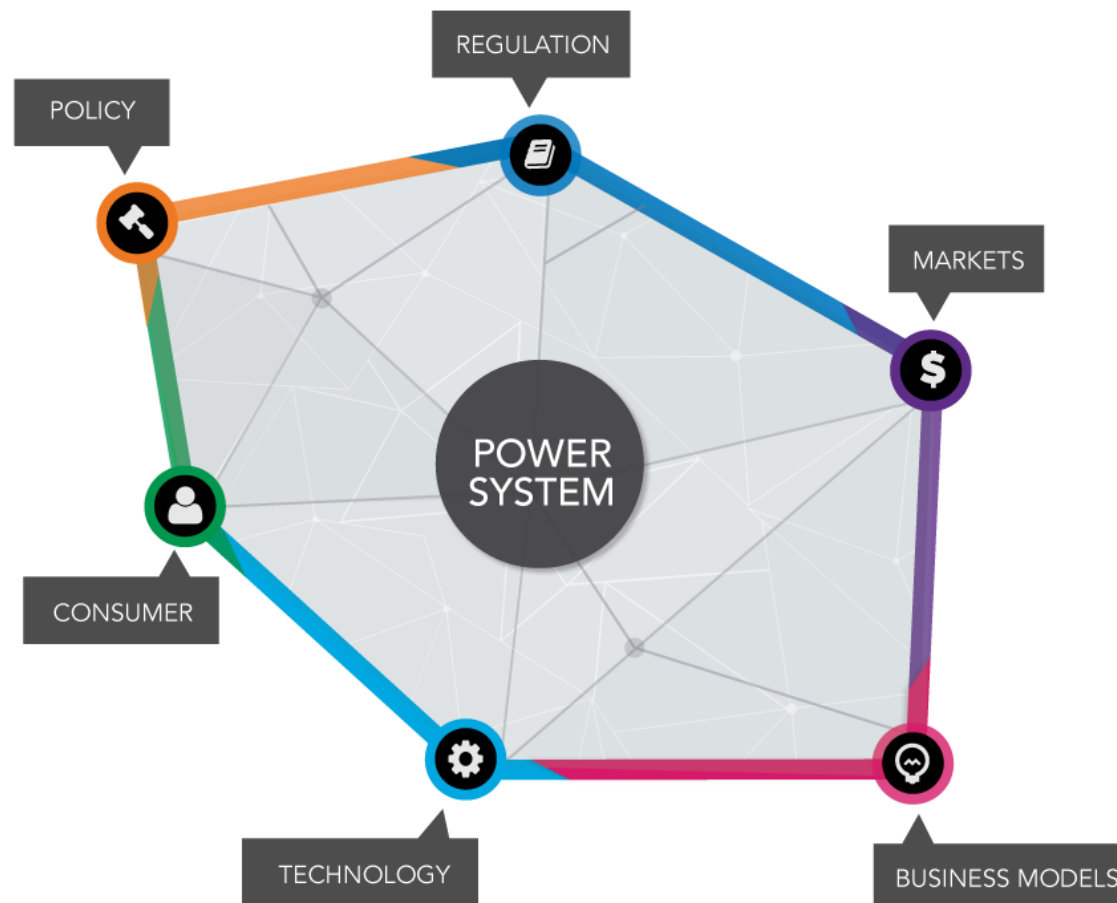


## Bottom-of-the-Pyramid: Bundled Community Energy Planning

- ❖ Evolutionary change dynamics
- ❖ Standardization of technical specifications for energy services across multiple scales
- ❖ Clear regulatory and policy signals help define market needs, unlock gaps in financing and clarify value propositions



The 21<sup>st</sup> Century Power Partnership provides a unique, holistic framework for approaching **power system transformation**.





Visit our website for more information about 21CPP publications, resources, and current activities:

<http://www.21stcenturypower.org/>

For questions about the 21CPP or how you can become involved, contact us at:

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### Flexibility in 21<sup>st</sup> Century Power Systems

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#### Introduction

Flexibility of operation—the ability of a power system to respond to change in demand and supply characteristic of grid-connected variable renewable energy (primarily, wind and solar).

All power systems have some inherent level of flexibility—designed to balance supply and demand at all times. Variability and uncertainty are not new to power systems because loads change over time and in sometimes unpredictable ways, and conventional resources have uncertainty. Variable renewable energy supply, however, can make this balance harder to achieve. Both wind and solar generation output vary significantly over the course of hours to days, sometimes in a predictable fashion, but often imperfectly forecasted.

To illustrate how variable renewable energy can increase the need for flexibility, Figure 1 demonstrates how variable output impacts power system operation. The figure introduces the concept of “net load” which represents the demand that must be supplied by the conventional generation fleet if all the renewable energy is to be utilized. The yellow area in the graph represents demand, and shows the daily variability of demand on an hourly basis for one week. The green shows wind energy and the orange represents the demand-less wind energy that

must be supplied by the remaining generators no curtailing of wind energy. The graph shows output level of the remaining generators must move quickly and be turned to a lower level as energy in the system. Solar energy will cause a similar impact on the power system.

Because it can take several years to design and generators and transmission lines, the planning the first critical activity to ensure that the power the future possesses sufficient flexibility to accommodate the growth of variable renewable generation. A paradigm, this function may resemble a central model in which some combination of industry government jointly assesses potential futures, competitive markets, there must be sufficient signals regarding the potential need for flexibility the absence of either sufficient planning or uncertainty, the resulting power system may not have flexibility to operate efficiently.

**Acknowledgments:** The authors are greatly indebted to the reviewers of this study: Kim Moller-Mikkelsen (Global Green Growth Institute), David H. Wood (U.S. Department of Energy), Government of Denmark, and Jeffrey Cooper (EPRI). For providing access to the authors: Mark Anderson (NREL), Lawrence Jones (EPRI), Scott M. Wood (NREL), and Mark Woodhouse (Department of Energy). The authors are grateful to: Scott Dorman, Andrew Schwenck, and others in the NREL, in office for their production support.

Mark Miller (Reviewed 1/20/14)

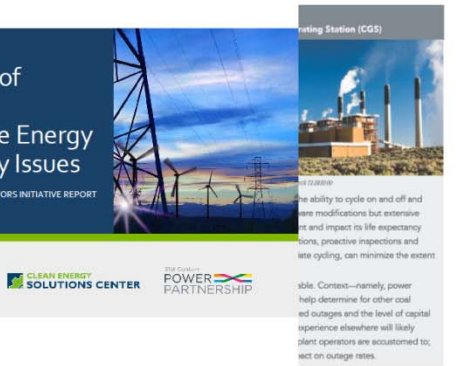


### Flexible Coal Evolution from Baseload to Peaking Plant

The experience cited in this paper is from a generating station with multiple units located in North America referred to as Station X.

### Overview of Variable Renewable Energy Regulatory Issues

A CLEAN ENERGY REGULATORS' INITIATIVE REPORT



### Making Coal Flexible: Getting From Baseload to Peaking Plant

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We have used a case study of this CCS to help power plants intended to run at baseload can evolve to serve other system needs. The CCS case illustrates the types of changes that may occur in global power systems, especially those with legacy plants. CCS experiences challenge conventional wisdom about the limitations of coal-fired power plants and help policymakers better understand how to formulate policy and make investment decisions in the transformation toward power systems in a carbon-constrained world.

“Strategic modifications, proactive inspections and training programs, and various operational changes to accommodate cycling can minimize the extent of damage and minimize cycling-related maintenance costs.”

#### A BRIEF HISTORY OF THE CCS PLANT

When it came online in the 1970s, the CCS plant was intended to run at an 80% annual capacity factor. However, the addition of nuclear power soon thereafter displaced coal as the principal source of baseload generation. Consequently, CCS typically ran at 50% annual capacity factor until the early 2000s. To understand the effects of “two-shift” (i.e., cycling on and off in a day) considerable research was conducted in the 1980s. As a result, plant operations, the steam generator, and supporting equipment were modified.

The competitive market created the incentive for CCS units to continue to operate flexibly—for example, that they be able to



### Variable Renewable Energy: a Regulatory Roadmap

#### Research Highlights

There is not a one-size-fits-all approach to the regulation of variable renewable energy (VRE), but international experience reveals many approaches that are proving successful. Drawing upon research and experiences from various international contexts, the 21st Century Power Partnership in conjunction with the Clean Energy Solutions Center and Clean Energy Regulators Initiative identified key issues and ideas that have emerged as variable deployment has grown.

Many variables shape the issues that arise in a given context, especially power system characteristics, geographic and spatial availability of renewable resources, institutional organization of the power system, public policy goals, and the political economy of power-system issues. Still, common issues arise at each stage of variable renewable energy deployment. The Power Partnership research published in 2014 identified four broad categories of regulatory issues:

- Facilitating New VRE Generation—in accordance with policy mandates, regulators play a role in facilitating new VRE generation through various mechanisms, including setting tariffs, organizing auctions, and influencing grid codes and the interconnection of new VRE generation.
- Ensuring Adequate Grid Infrastructure—Regulators play a role in shaping the grid infrastructure development of a power system, which is a key dimension of VRE deployment and system integration.
- Ensuring Short-term Security of Supply—Flexibility in generation fuels a role in maintaining

These four domains are interrelated, and become more so as VRE deployment levels grow.

#### Case Studies in Integrating Renewables Around the World

The Power Partnership surveyed regulatory experiences around the world in each of these domains, and gathered lessons for meeting the challenges from countries including Austria, Denmark, Germany, Guatemala, India, Mexico, the United Kingdom, and the United States. Unique forces are at play in each regulatory context, but the research provides a framework that highlights the common issues and ideas that emerge across contexts and at each stage of VRE deployment and integration. Some successes:

- Case Study in VRE Generation**  
Denmark sustains high levels of VRE procurement through increased support for resource characterization and project site assessment, and through streamlined, transparent processes. Challenge: To achieve aggressive renewable energy targets, Denmark is looking to obtain more power from offshore wind. The country is trying to cultivate a robust yet cost-efficient offshore wind development industry. Solution: Denmark has refined its approach to offshore wind tenders over the last 10 years (with 16 offshore wind facilities currently operating) and also gained experience from similar approaches in the oil and gas sector. The tender process in Denmark involves the following steps and practices:
  - Site assessment and selection in order to secure risk and cost to investors, Denmark funds site assessment and selection for suitable offshore wind sites.
  - Development of transparent tender processes. Rules

