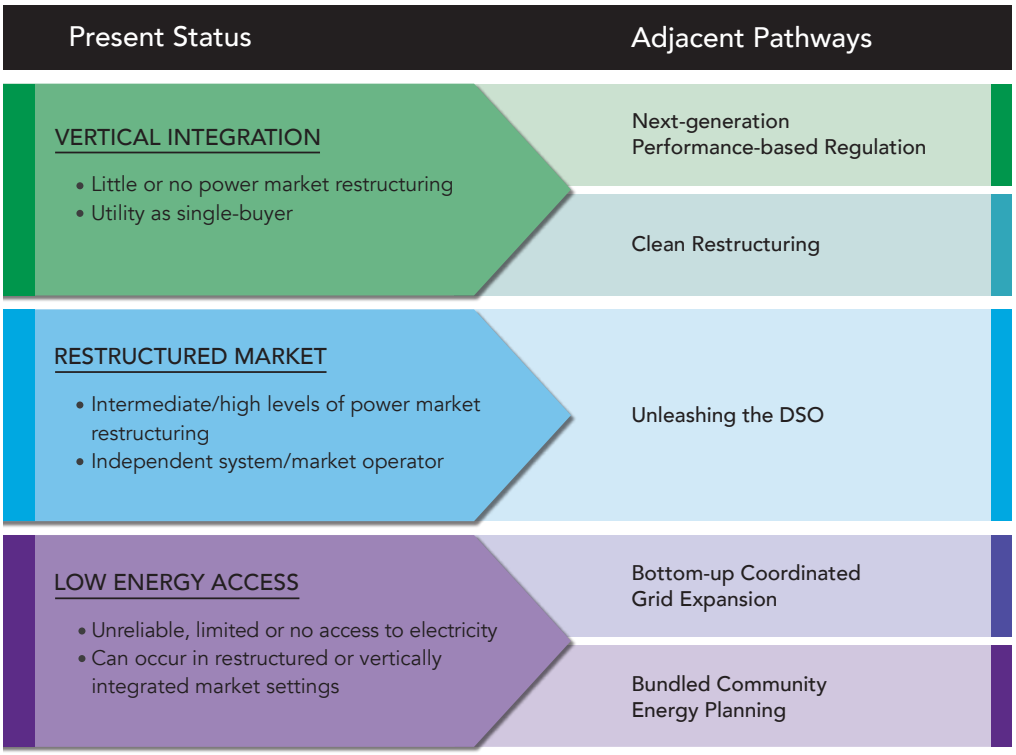
POWER SYSTEMS OF THE FUTURE

A 21st Century Power Partnership Thought Leadership Report

Powerful trends in technology, policy environments, financing, and business models are driving change in power sectors globally. In light of these trends, the question is no longer whether power systems will be transformed, but rather how these transformations will occur.



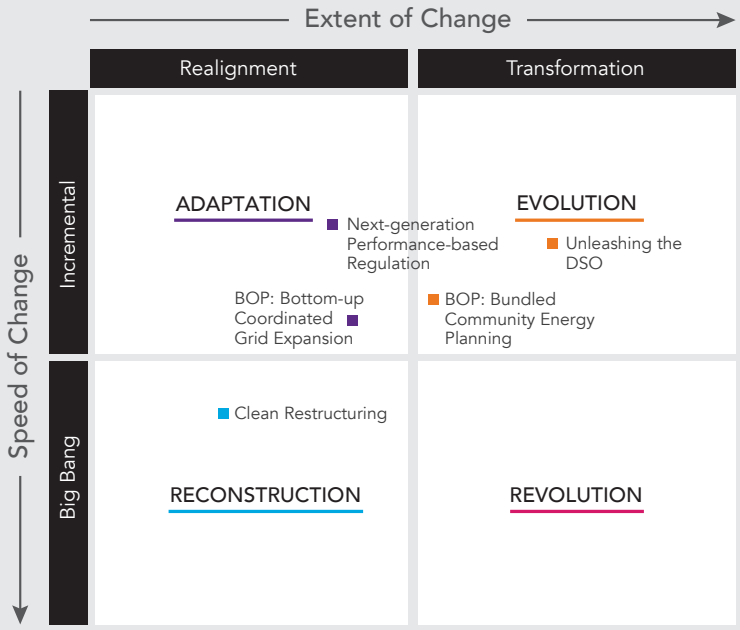
Charting the course for power system change involves complex decision-making across policy goals, technological systems, social contexts, and financial networks. However, it is unlikely that the same transformation will occur everywhere, because in each context the power system of the future emerges from the interacting forces of policy, regulation, global market forces, business model innovation, technological innovation, and consumer behavior.

Given the diversity of starting points, no single model will apply everywhere. Yet there are signs that power systems are converging on five main pathways:

- **Next-generation Performance-based Regulation**
- **Clean Restructuring**
- **Unleashing the DSO**
- **Bottom-of-the-Pyramid Coordination**
  - **Bottom-up Coordinated Grid Expansion**
  - **Bundled Community Energy Planning.**

Power Systems of the Future, a thought leadership report from the 21st Century Power Partnership, explores these pathways and illustrates how they emerge from the big-picture trends driving power system transformation. Each pathway can be understood as either an adaptive, reconstructive, or evolutionary response to the forces of change, varying in depth and speed. The report provides insights into how each pathway holds the promise of dramatically improving the performance of power systems. Finally, the report explores actions that policymakers and regulators can take to encourage desired power system outcomes.

The Pathways



Next-generation Performance-based Regulation
In this ***adaptive*** pathway, vertically-integrated utilities remain in a recognizable form, but evolve to prioritize delivery of value instead of minimizing costs.

Clean Restructuring
In this ***reconstructive*** pathway, new power market restructuring efforts are initiated, incorporating lessons learned from the past 20 years, including design features to facilitate clean energy integration and system optimization. Hindsight is 20/20 – and this reconstructive pathway brings hindsight to bear on restructuring and reform.

Unleashing the DSO
Distribution system operators (DSOs) are poised to innovate in order to drive clean generation deployment and power system flexibility. In this ***evolutionary*** pathway, regulatory and policy frameworks give clear signals to these DSOs, empowering them as the centerpiece for orchestrating distributed energy resources and low-voltage market functioning.

Bottom-of-the-Pyramid Coordination
Accelerating energy access has been a chronic challenge for decades. New technology configurations and business models are opening opportunities for innovative approaches to energy access, especially when linked to broader social development goals. Two pathways support financing mechanisms and technical standardization to achieve customized energy access: *adaptive* **Bottom-up Coordinated Grid Expansion** and *evolutionary* **Bundled Community Energy Planning.**

These pathways, and the organizing framework from which they emerge, can inform sound and proactive choices by decision makers. From technology to tariffs, from business models to investment incentives, decisions can be made to ensure reliable system operation while driving transformation that aligns with policy goals.

Power systems of the future are emerging now.
Power sector decision makers can be better positioned to proactively guide a transition to 21st century power systems. The forces acting on today's systems need not be perceived as headwinds. Reorganizing the policy and regulatory landscape can transform these forces into tailwinds. As the old saying goes, "When you can't change the direction of the wind – adjust your sails."

Zinaman, O.; Miller, M.; Adil, A.; Arent, D.J.; Cochran, J.; Vora, R.; Aggarwal, S.; Bipath, M.; Linvill, C.; David, A.; Kauffman, R.; Futch, M.; Villanueva Arcos, E.; Valenzuela, J.M; Martinot, E.; Bazilian, M.; Pillai, R.K. (2015). *Power Systems of the Future.* NREL/TP-6A20-62611. Golden, CO: 21st Century Power Partnership. www.nrel.gov/docs/fy15osti/62611.pdf

CLEAN ENERGY MINISTERIAL
Accelerating the Transition to Clean Energy Technologies

www.21stCenturyPower.org

The 21st Century Power Partnership is a multilateral effort of the Clean Energy Ministerial and serves as a platform for public-private collaboration to advance integrated policy, regulatory, financial, and technical solutions for the large-scale deployment of renewable e nergy in combination with deep energy efficiency and smart grid solutions.

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