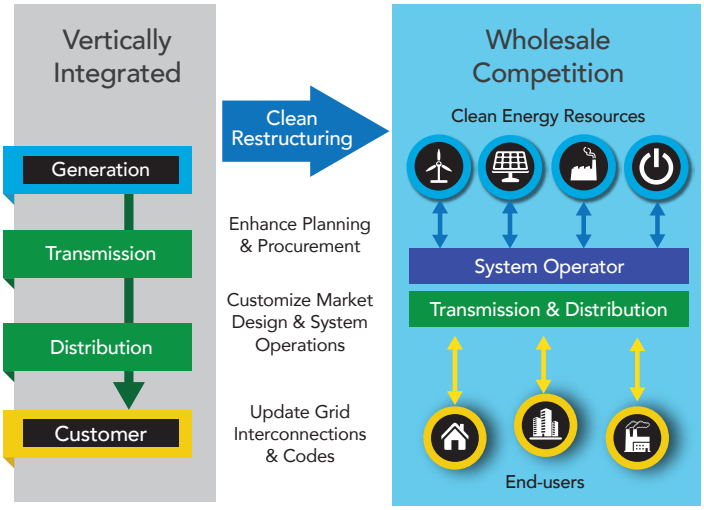
21st Century POWER PARTNERSHIP

Accelerating the transformation of power systems

Clean Restructuring: Design Elements for Low Carbon Wholesale Markets and Beyond

A 21st Century Power Partnership Thought Leadership Report



Power sector structure models on the path to clean restructuring.

Countries around the world are in various stages of power system reform and restructuring to more effectively meet development goals and decarbonization commitments. Changes in social dynamics, technology, business models, and environmental goals are increasing pressure for countries to consider improvements to their power systems.

Previous 21st Century Power Partnership work identified five pathways toward power systems of the future that vary depending on the starting point, and speed and extent of transformation.[1] Clean restructuring, one of these pathways, describes the movement from a vertically integrated power sector toward a more participatory and clean energy-friendly electricity system. *Clean Restructuring: Design Elements for Low Carbon Wholesale Markets and Beyond*, a 21st Century Power Partnership thought leadership report, explores this pathway in depth, envisions an end-state, and articulates three main areas of consideration for decision makers embarking on a clean restructuring process. The report focuses on the design of competitive wholesale markets that rely increasingly on variable renewable electricity sources, demand response, and other flexible, clean energy options. Detailed case studies on Mexico, Denmark, and Germany are provided.

Promote cleaner power systems with next-generation *planning and procurement* practices

Restructuring a vertically integrated sector may result in a more dispersed and diverse set of clean and variable energy resources, changing the nature of traditional planning exercises. Advanced techniques for modeling variable renewable resources and analyzing the flexibility of the power system can help determine

1. Other pathways include Next-generation Performance-based Regulation; Unleashing the Distribution System Operator; Bottom-of-the-Pyramid Bottom-up Coordinated Grid Expansion; and Bottom-of-the-Pyramid Bundled Community Energy Planning. See *Power Systems of the Future*, a 21st Century Power Partnership report, for additional information: http://www.nrel.gov/docs/fy15osti/62611.pdf.

if generation capacity and other resources—such as demand response—can reliably serve demand. Various factors, including higher penetrations of low marginal cost generation, are testing the ability of new and existing generators to recover their costs in clean restructured markets. New planning and procurement processes are available to promote appropriate levels of new capacity deployment, reduce occurrences of over-generation, and strive to maintain the bankability of new infrastructure projects.

Enable flexibility with *market design* and *system operations*

The design of wholesale market rules and system operations has implications for the ability to integrate clean energy. Rules for how generation and other resources are committed and ultimately dispatched can be designed to better absorb and manage variable renewable generation. Integrating variable generation forecasting data into market operations can improve continuous system balancing. Also, ancillary service market rules can be updated to strengthen a system with higher levels of variable resources and enable new, cleaner resources to provide these services. Finally, new market elements, such as ramping products, may be helpful for achieving the additional system flexibility needed to address the uncertainty and variability of renewables. Demand response can also be an important component of cost-effective system flexibility.

Create a level playing field for clean energy with *grid infrastructure, interconnection, and grid codes*

As transmission assets are unbundled from generation, open and transparent processes for network expansion and investment become important in a restructured environment. Streamlining interconnection processes for new resources applying to connect to the network can alleviate barriers to entry, especially in terms of the time and cost of the application process. Grid codes, or rules addressing how generators must connect to the grid, can also be updated to reflect technologies with different operating characteristics and allow all resources to contribute to system reliability. For variable generators, grid code modifications may be needed for some ancillary services.

Early outcomes from recent clean energy certificate auctions in Mexico's restructuring process are promising.

2. *Clean Restructuring: Design Elements for Low-Carbon Wholesale Markets and Beyond is available at* http://www.nrel.gov/docs/fy16osti/66105.pdf. This publication is not intended to encourage or prescribe power market restructuring, nor imply that it may be nationally appropriate in any given setting.

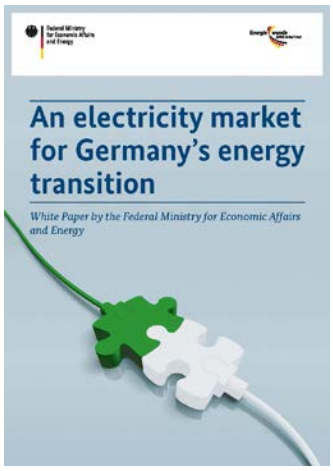
Clean Restructuring in Practice

Case studies for Mexico, Germany, and Denmark feature insights and tactical approaches for clean restructuring efforts.[2]

Mexico

Mexico is in the midst of power sector reforms, where policies and market structures have been designed with an eye toward increasing levels of clean energy in the near future. Sweeping reforms were initiated in December 2013 in the pursuit of a more cost-effective, low-carbon power sector. During the subsequent 18 months, implementation work focused on establishing an operating wholesale electricity market by January 2016 and completing the full transition by 2018. The first phase established the new market structure, an independent system operator (the National Center for Energy Control, or CENACE), the new responsibilities between authorities, and the guidelines for the transition period.

By interlocking clean energy deployment and the new market institutions, Mexico's clean restructuring efforts are designed to achieve both production cost reductions and the expansion of a clean energy portfolio. Clean energy certificate (CEL) mandates and long-term energy auctions were not designed as a by-product or in complement to the reform, but as central elements to it. Subsequently, the grid codes, dispatching rules, and the transmission system planning were designed specifically for the expansion of renewable energy and to serve the ultimate objective of providing less expensive electricity in the Mexican power system. In March 2016, the result of the first long-term energy auction for CELs included the lowest power purchase agreement price for a solar power plant (less than 40 USD per megawatt-hour) and over 300 initial offers. Early outcomes of Mexico's clean restructuring efforts provide an optimistic perspective on the role that clean energy will play in the evolution of the Mexican power market.



Germany continues to experiment with power system transformation.

Germany

Power system restructuring was initiated in Germany in the 1990s, and the liberalization of the market progressed alongside the transition to clean energy, known as *Energiewende*. In recent years, several factors including low marginal prices in the wholesale market and overcapacity of generation were the impetus for public discussions on developing a suitable electricity market design for the future. In particular, discussions addressed how the market and the regulatory framework for the electricity sector should be organized to ensure the energy supply remains reliable, environmentally compatible, and cost-efficient even as the share of electricity from wind and solar energy grows.

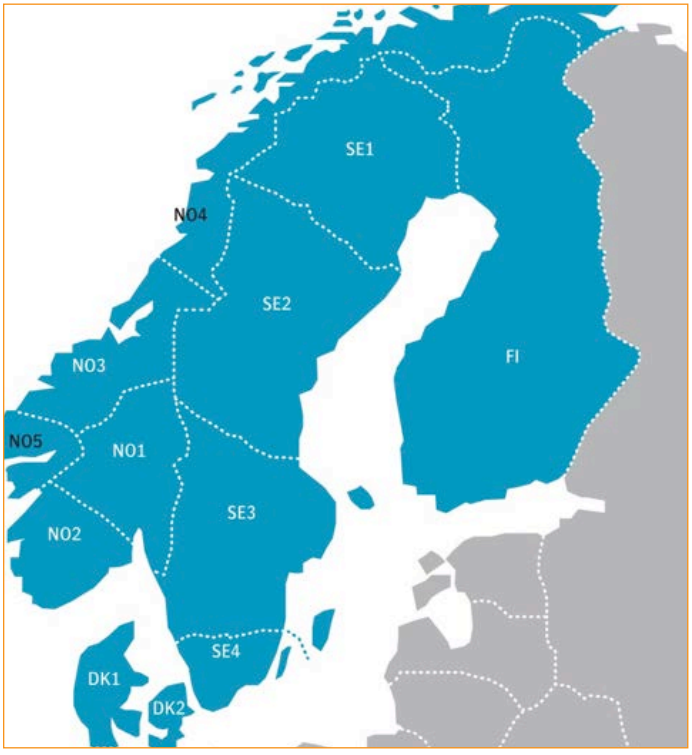
In 2015, the German Federal Ministry for Economic Affairs and Energy (BMWi) conducted a structured process to collect multiple perspectives on methods for addressing these electricity sector challenges. Several phases of public engagement were conducted, including the publication of a "green paper" of initial proposals, public meetings, technical meetings, and comment periods. After much public debate, a white paper was published with the decision to enhance the country's existing energy-only market, *electricity market 2.0*, instead of creating a supplementary forward capacity

3. BMWi. 2015. *An Electricity Market for Germany's Energy Transition. White Paper by the Federal Ministry for Economic Affairs and Energy. Berlin: Federal Ministry of Economic Affairs and Energy.*

market.[3] Finally, legislation will codify the outcomes of this process via the *Electricity Market Act*.
The electricity market 2.0 policy contains 20 primary measures, including guaranteeing free price formation to indicate the scarcity of electricity; monitoring security of supply; introducing a capacity reserve; and developing the balancing capacity markets further. In Germany, a liberalized energy-only market can achieve both a market orientation in the electricity sector and a clean transformation of the energy system.

Denmark

Denmark has a broad-based political vision of an energy system that is fully independent of fossil fuels by 2050. The Danish electricity system plays a key role in achieving this vision. For many years, the system has had a high penetration of renewable generation, and it is well on course to achieve its target of 50% wind power in 2020. It is a political priority for Denmark that renewable energy continues to be integrated into the power system in a cost-efficient manner using market principles. The integration of such high levels of wind power in Denmark has, to a great extent, been possible due to the common Nordic electricity spot market, which is one of the most integrated regional parts of the internal energy market in the European Union. The availability of hydropower from Sweden and Norway has previously contributed to reducing the need for coal-fired power production during peak load times and today, hydropower serves as a means to balance the system as it becomes increasingly reliant on variable wind energy. Meanwhile, Denmark exports large amounts of energy to Sweden and Norway during off-peak hours, allowing them to restrain production of hydropower energy. The daily interplay of wind power generation, hydropower production, and combined heat and power that ensures a reliable and affordable supply of electricity is a result of efficient price signals sent through the highly liquid Nordic day-ahead market.



The Nordic electricity market has enabled the Danish transition to a cleaner power system.

Also, the economic benefits of increased interconnection with neighboring countries are apparent. This has resulted in Denmark becoming an integral part of a regional northern European power system rather than a national energy system. Interconnectors contribute to cost-effective use of generation capacity through the electricity market in Denmark and abroad, reducing the cost of providing a reliable supply of electricity. A unique feature of the Nordic electricity market is the successful cooperation of all the different stakeholders, including producers and retailers, the Nordic transmission system operators, regulators, and political decision makers. The strong political interest, direction, and willingness to compromise on national issues in favor of a Nordic view have been the key to developing and operating an efficient electricity market.

For additional detail, see Shah, Monisha, José María Valenzuela, Héctor Alejandro Beltrán Mora, Kim Møller Porst, Anders Hasselager, Sandra Friis-Jensen, Mette Vingaard, Fabian Wigand, Silvana Tiedemann, Lori Bird, Owen Zinaman, and Jeffrey Logan. 2016. *Clean Restructuring: Design Elements for Low-Carbon Wholesale Markets and Beyond*. TP-6A50-66105. Golden, CO: 21st Century Power Partnership. http://www.nrel.gov/docs/fy16osti/66105.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 largescale deployment of renewable energy in combination with deep energy efficiency and smart grid solutions.

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