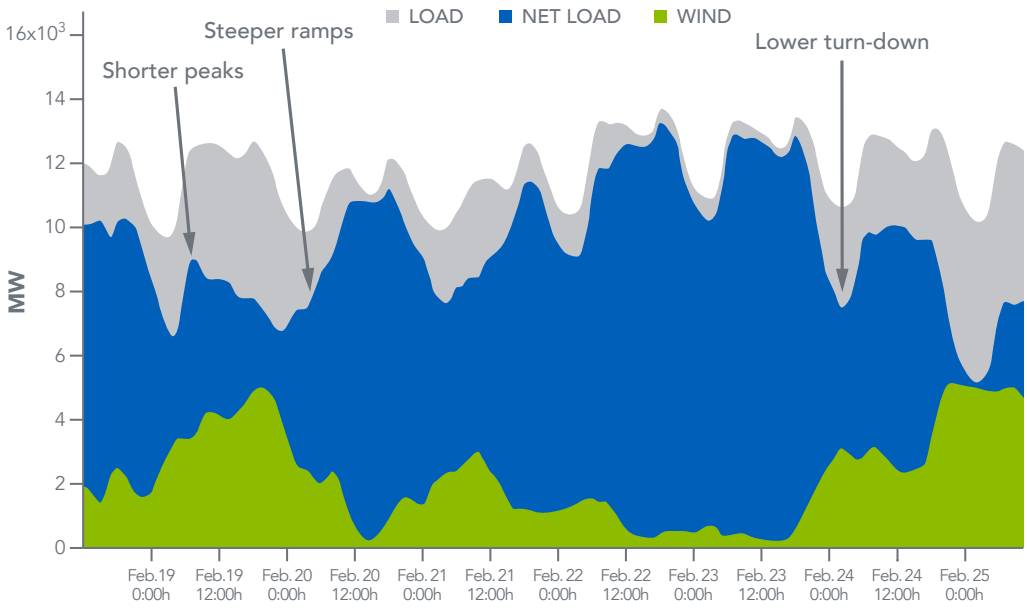
Flexibility in 21st Century Power Systems

Research Highlights

Flexibility of operation—the ability of a power system to respond to change in demand and supply—is a characteristic of all power systems.

Flexibility is especially prized in twenty-first century power systems, with higher levels of grid-connected variable renewable energy (primarily, wind and solar).



High levels of wind and solar generation can increase the need for flexibility in a power system. In this figure, net load (i.e., total load minus wind energy) must be supplied by generation sources other than wind. Flexible generators are able to rapidly increase and decrease output, and operate efficiently at a lower level, in response to variable wind energy generation.

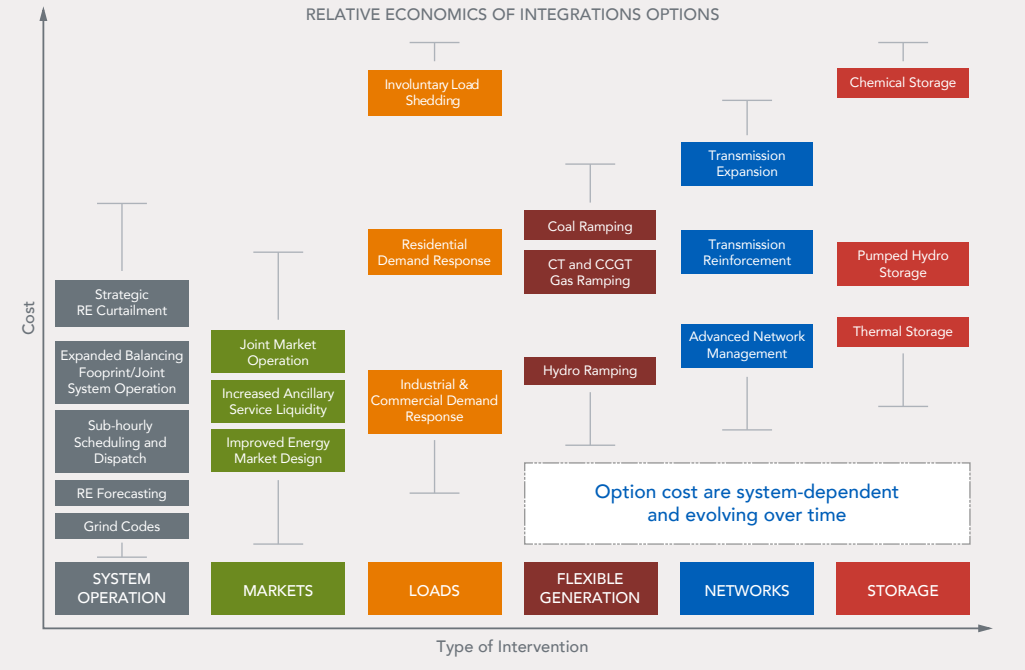
Sources of flexibility

Sources of flexibility exist—and can be enhanced—across all of the physical and institutional elements of the power system, including system operations and markets, demand-side resources and storage; generation; and transmission networks. Accessing flexibility requires significant planning to optimize investments and ensure that both short- and long-time power system requirements are met.

System operations and markets. Changes to system operation practices and markets can unlock significant flexibility, often at lower economic costs than options that require changes to the physical power system. Adjusting day-ahead generation scheduling to allow changes closer to real time allows dispatch decisions to be made based on improved forecasts of both variable renewable energy output and demand. This decreases the need for expensive reserves and allows more accurate and efficient market operation.

Other examples of institutional and operational sources of flexibility include expanding a power system's balancing area to provide access to geographically diverse wind and solar resources; improved wind and solar forecasting; and increased thermal plant cycling.

Flexible demand and storage. Demand-side management and demand response enable consumers to participate in load control based on price signals. Demand response mechanisms include automated load control by the system operator; smart grid and smart metering; real-time pricing; and time-of-use tariffs. Demand response can be relatively inexpensive but



Example options for increasing flexibility in power systems characterized by high levels of variable renewable energy. Relative costs are illustrative, as actual costs are system-dependent.

requires strict regulations related to response time, minimum magnitude, reliability, and verifiability of demand-side resources.

Storage technologies—including pumped hydro and thermal storage and batteries—hold energy produced during periods of excess renewable energy generation and then discharge this energy when it is needed. Relative to demand response and other options for flexibility, storage generally has a higher capital cost.

Flexible generation. Conventional power plants and dispatchable renewable generators such as biomass or geothermal plants provide flexibility if they have the ability to rapidly ramp up and ramp down output to follow net load; quickly shut down and start up; and operate efficiently at a lower minimum level during high renewable energy output periods. New and retrofitted large-scale power plants, as well as smaller-scale distributed generation (e.g., micro combined heat and power units), can supply flexible generation.

Flexible transmission networks. Extending transmission lines and interconnecting with neighboring networks provides the power system greater access to a range of balancing resources. The aggregation of generation assets through interconnection improves flexibility and reduces net variability across the power system. Other sources of flexibility include smart network technologies and advanced network management practices that minimize bottlenecks and optimize transmission usage.

For additional information, see Cochran, J.; Miller, M.; Zinaman, O.; Milligan, M.; Arent, D.; Palmintier, B.; O'Malley, M.; Mueller, S.; Lannoye, E.; Tuohy, A.; Kujala, B.; Sommer, M.; Holttinen, H.; Kiviluoma, J.; Soonee, S.K. (2014). *Flexibility in 21st Century Power Systems.* NREL/TP-6A20-61721. Golden, CO: 21st Century Power Partnership.

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 energy in combination with deep energy efficiency and smart grid solutions.

CLEAN ENERGY MINISTERIAL
Accelerating the Transition to Clean Energy Technologies

15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

Contact Us: 21stCenturyPower@nrel.gov
www.21stCenturyPower.org

NREL/FS-6A20-63021 • October 2014
Photo on front header from iStock, 16542720