U.S. DEPARTMENT OF ENERGY

2013 Economic Dispatch and Technological Change

Report to Congress
March 2014

United States Department of Energy
Washington, DC 20585

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Message from the Assistant Secretary

In this report, the Department of Energy is responding to Sections 1234 and 1832 of the Energy Policy Act of 2005, which directed the Secretary of Energy to conduct an annual study of economic dispatch and potential ways to improve such dispatch to benefit American electricity consumers.

In this 2013 economic dispatch report, the Department examines how technology and policy affect economic dispatch. This report looks at seven current topics that affect economic dispatch. They are: 1) variable generation resources, 2) energy storage, 3) the production tax credit, 4) market structure, 5) environmental regulations, 6) demand response, and 7) market power. The report is not intended to provide an in-depth study of these topics. Rather, the report gives a brief overview of the topics and their implications for economic dispatch, and in some cases suggests future actions that should be considered. Overall, the report stresses the need for grid flexibility – the need for a suite of solutions to address the complexities of economic dispatch as policy and technology enable changes to the grid.

The ability to maximize the dispatch of low cost generation and to fully utilize the large investment already made in the electric system will depend on the flexibility of the system. A flexible system will use price signals, operational procedures, market structures and technology to ensure that the lowest cost resources are dispatched first. Storage, larger balancing areas, and shorter dispatch intervals are just some of the components of the flexible electric system needed to better utilize the investments that we have made in the grid to date.

This report is being provided to the following Members of Congress:

- **The Honorable Joseph Biden**
  President of the Senate

- **The Honorable Mary Landrieu**
  Chairman, Senate Committee on Energy and Natural Resources

- **The Honorable Lisa Murkowski**
  Ranking Member, Senate Committee on Energy and Natural Resources

- **The Honorable John Boehner**
  Speaker of the House of Representatives

- **The Honorable Fred Upton**
  Chairman, House Committee on Energy and Commerce

- **The Honorable Henry Waxman**
  Ranking Member, House Committee on Energy and Commerce

If you have any questions or need additional information, please contact me or Mr. Christopher Davis, Deputy Assistant Secretary, Office of Congressional and Intergovernmental Affairs, at (202) 586-5450.

Sincerely,

Patricia A. Hoffman

Patricia A. Hoffman
Office of Electricity Delivery and Energy Reliability

Executive Summary

Sections 1234 and 1832of the Energy Policy Act of 2005 (EPACT) direct the U.S. Department of Energy (Department) to conduct an annual study of economic dispatch and the potential benefits to American electricity consumers from improving such dispatch to use more non-utility generation. Today, economic dispatch in many parts of the country is being influenced by the increased use of non-traditional forms of utility generation to balance supply and demand.

In this report, the Department looks at how technology and policy affect economic dispatch. This report looks at seven current topics that affect economic dispatch. They are: 1) variable generation resources, 2) energy storage, 3) the production tax credit, 4) market structure, 5) environmental regulations, 6) demand response, and 7) market power. The report is not intended to provide an in-depth study of these subjects. Rather, the report gives a brief overview of the issues and their implications for economic dispatch, and in some cases suggests future actions that should be considered. Overall, the report stresses the need for grid flexibility – the need for a suite of solutions to address the complexities of economic dispatch as policy and technology drive changes to the grid.

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ECONOMIC DISPATCH AND TECHNOLOGICAL CHANGE

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I. Statutory Language

This report responds to statutory language set forth in Sections 1234 and 1832 of the Energy Policy Act of 2005 which requires in *subsection (d)* that

> *… "on a yearly basis…, the Secretary shall submit a report to the Congress and the States on the results of the [economic dispatch] study conducted under subsection (a)..."* This study is described as follows:

(a) Study.--The Secretary, in coordination and consultation with the States, shall conduct a study on--

(1) the procedures currently used by electric utilities to perform economic dispatch;
(2) identifying possible revisions to those procedures to improve the ability of non-utility generation resources to offer their output for sale for the purpose of inclusion in economic dispatch; and
(3) the potential benefits to residential, commercial, and industrial electricity consumers nationally and in each State if economic dispatch procedures were revised to improve the ability of non-utility generation resources to offer their output for inclusion in economic dispatch.

DOE's 2013 Report finds that as it relates to subsection (a)(1), there are no significant changes in utility practices regarding economic dispatch, and therefore this report focuses on subsections (a)(2) and (a)(3).

There are more than 2500[1] non-utility power plants in the United States. Non-utility power plants include Qualifying Facilities established under Public Utility Regulatory Policies Act of 1978. Qualifying Facilities include combined heat and power plants and small power producers. Non-utility power generators also include independent power producers that produce and sell electricity on the wholesale market at market-based rates. Independent power producers generated 1,488,000,000 megawatt hours in 2011 as compared to 2,461,000,000[2] megawatt hours generated by electric utilities.

II. Introduction to Economic Dispatch

The term "economic dispatch" refers to the practice of operating an electric system so that the lowest-cost generators are used first, followed by the more expensive generators. As demand increases, more expensive generators are brought into production, and then ramped down

[1] Energy Information Administration. "Electric Power Annual 2011." Data Table 4.1. http://www.eia.gov/electricity/annual/
[2] Energy Information Administration. "Electric Power Annual 2011" Data Table 1.3. http://www.eia.gov/electricity/annual/

again when loads decrease. However, this theoretically simple economic optimization task is complicated by several factors – the size (in megawatts) of the generation fleet being optimized, the size and configuration of the fleet's geographic footprint, the need to coordinate the differing characteristics and operating costs of different generation technologies and sources, the need to account for significant variations in load over daily and seasonal cycles, and the need to operate the system reliably and within transmission line operating limits.

Security-constrained economic dispatch is the operation of generation facilities producing energy at the lowest cost to reliably serve consumers, recognizing any operational limits of generation and transmission facilities and the possibility of unexpected generator or transmission outages (contingencies). This illustrates a key point – that the practice of economic dispatch is influenced by several factors other than price. This report will use the term economic dispatch, which is inclusive of the term security-constrained economic dispatch.

Economic dispatch must manage generation and demand resources efficiently over time. Electricity demand varies greatly, in daily, weekly and seasonal patterns. Because bulk electricity cannot be stored inexpensively at present, generation must be available to follow changes in load almost instantaneously, and some generation and demand reduction resources must be held in reserve to respond to sudden, unplanned contingencies, such as generator outages, as well as changes in customer demand and variable resource production levels. Different generators have different costs, production capabilities and operating characteristics. A generator's production level at a point in time will be affected by how quickly it can safely move between output levels, whether it is operating in a high- or lower-fuel efficiency zone, fuel availability, and whether there is sufficient transmission capacity available to deliver its output across the grid. Grid operators adjust the output of dispatchable generators – including fossil, nuclear, geothermal and dam-impounded hydro -- frequently (sometimes relying on automatic controls) to reflect changing grid conditions.

The costs associated with ramping large fossil generators up and down can be significant. Increasingly, operators are looking to automatically-dispatched demand-side resources and distributed storage devices, such as batteries and flywheels, to help manage small, short-term fluctuations in variable resource output. Some regions allow for temporarily operating transmission assets above nominal ratings, but still within the limits of reliability rules, to avoid using costly ramping or generator commitments to accommodate short-term conditions. Continued investment and innovation in both equipment and policies is needed to develop a flexible grid that can respond to fluctuations resulting from changes in output from variable resources and demand from consumers while simultaneously avoiding the need to run high-cost ramping resources.

The practice of economic dispatch has become more complex as grid operators seek to incorporate public policy changes, technological innovation and growing amounts of variable generation. To dispatch electricity at the lowest cost possible, grid operators are incorporating a broader set of tools and resources to operate the grid. These tools and resources are components of a flexible electric system.

III. A Flexible Electric System

The underlying theme throughout this report is that the development of a flexible electric system or grid is necessary to ensure that generation resources are dispatched in the most economic manner possible. The International Energy Agency considers a power system to be flexible if it can "within economic boundaries - respond rapidly to large fluctuations in demand and supply, both scheduled and unforeseen variations and events, ramping down production when demand decreases, and upwards when it increases."[3] A flexible system prices the individual services needed to balance the grid on the basis of the value they add to the system. This allows technologies that are cost-effective to meet certain needs, but perhaps not to meet other needs, to compete in the market. This increased competition to provide the various services leads to the lowest cost system and the most efficient use of resources. The body of the paper will discuss some of the specific components of a flexible electric system, both operational and technological.

IV. Variable Generation and Economic Dispatch

Variable generation resources, both utility and non-utility, – primarily wind and solar photovoltaic – have been some of the fastest-growing sources of capacity being added to the grid in the past decade.[4] Twenty-nine states, the District of Columbia and two U.S. territories have enacted renewable portfolio standards, which place binding requirements on electric utilities, generators or consumers for purchasing electricity generated by renewable sources.[5] In addition, eight states and two US territories have legislatively established, non-binding renewable-related goals.[6] These state policies, coupled with the production tax credit, other state programs and market conditions, have catalyzed the development of renewable generation resources.[7] Between 2007 and 2011, installed capacity of wind generators grew from 16,515 MW to 45,676 MW (from 1.7% to 4.3% of total net summer capacity of all fuel sources) and solar thermal and photovoltaic generation grew from 502 to 1,524 MW (<1% of net summer capacity).[8] In 2011, wind generators produced 120 billion kWh of electricity and solar produced 1.8 billion kWh; together these amounted to almost 3% of total U.S. electricity

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[3] International Energy Agency. "Empowering Variable Renewables: Options for Flexible Electricity Systems." 2008.

[4] Energy Information Administration, "Electric Power Annual 2011." Data Table 4.2.A http://www.eia.gov/electricity/annual/

[5] Database of State Incentives for Renewables and Efficiency. "RPS Policies." March 2013. http://www.dsireusa.org/documents/summarymaps/RPS_map.pdf

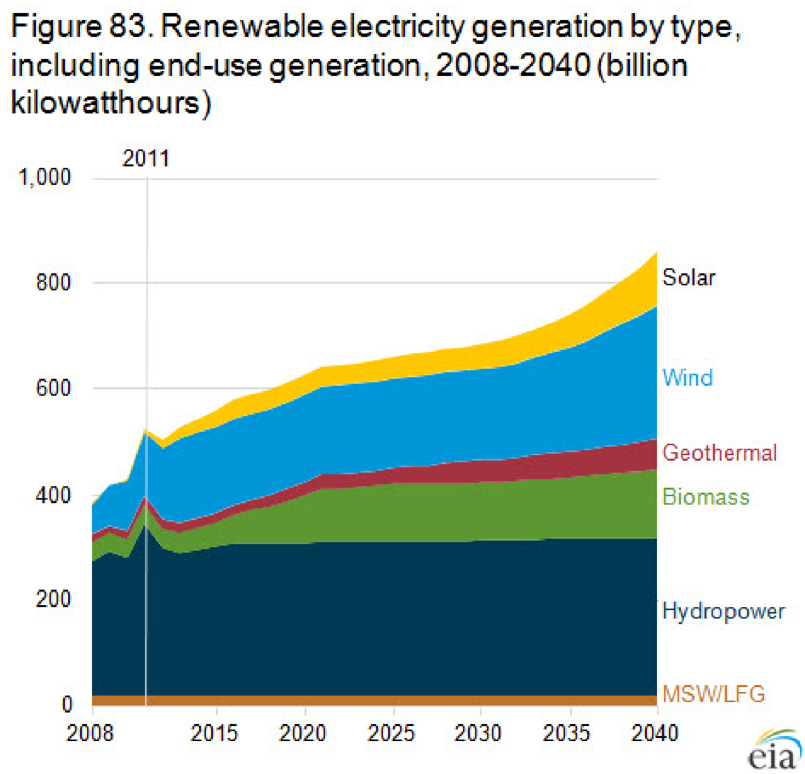
[6] Some of these goals do not exclusively require the use of renewable generation. In particular, West Virginia has a broader "clean energy" goal which can be satisfied with non-renewables (including natural gas).

[7] Energy Information Administration, "Most states have Renewable Portfolio Standards." *Today in Energy*. February 3, 2012. http://www.eia.gov/todayinenergy/detail.cfm?id=4850

[8] Energy Information Administration, "Electric Power Annual 2011." Data Tables 4.2.A and 4.2.B. http://www.eia.gov/electricity/annual/

generation.[9] The U.S. Energy Information Administration projects continued significant growth of wind and solar generation over the coming decades, as shown in Figure 1.

Figure 1 U.S. Renewable electricity generation projections from EIA Annual Energy Outlook base case, 2008-2040 (bn kWh)



Source – Energy Information Administration, "Annual Energy Outlook 2013," April 2013, p. 75.

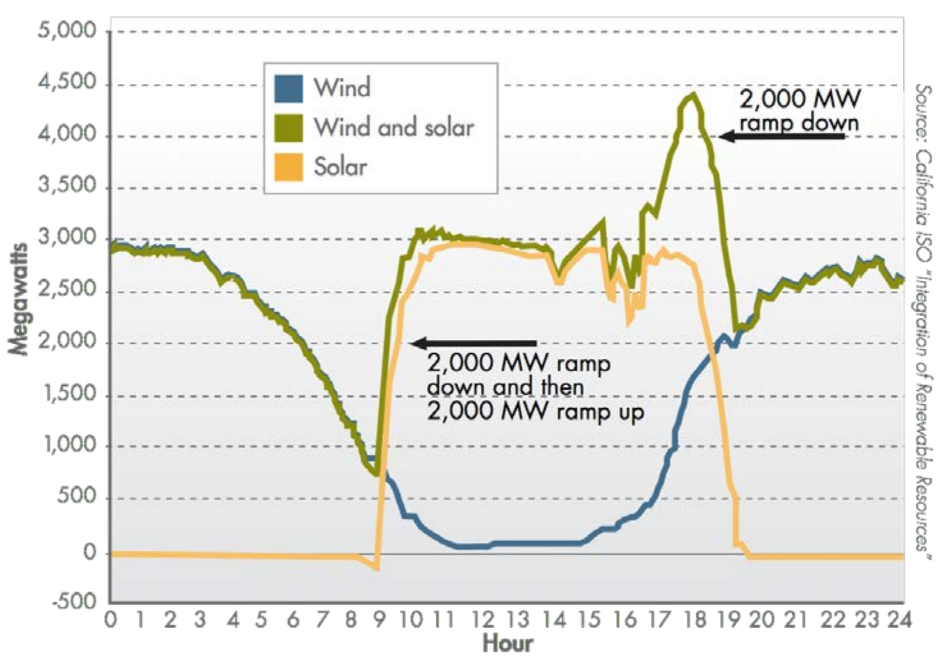
Generally, system operators accept as much electricity as possible from renewable resources, regardless of whether it is utility or non-utility generation, because of its low cost, and only curtail reliance on these sources when forced to by limits on transmission availability or reliability considerations. Most wind and solar generation units are not dispatchable in the traditional sense (i.e., the output cannot be precisely controlled by the grid operator), and their output is often accepted as must-run or must-take production. However, there is a considerable amount of research and development currently underway to develop some level of dispatchability for wind and solar generation technologies. This work is centered on developing capabilities such as frequency response (providing support to system frequency immediately following major disturbances), up-reserves (created by operating in a curtailed mode so production can be increased when required) and ramp control (limiting how quickly

[9] Energy Information Administration, "Electric Power Annual 2011." Data Tables 3.1.A and 3.1.B. http://www.eia.gov/electricity/annual/

production is increased). These are all components of a flexible electric grid. Some of these components have been implemented in the Midcontinent ISO (MISO). MISO introduced a Dispatchable Intermittent Resources product that requires wind to be treated like other generation resources. This will allow wind to participate in the MISO real-time market and help in setting market-clearing prices.

The characteristics of renewable generation differ from that of fossil generation. While renewable generation adds variability and uncertainty to the system because the wind does not always blow and the sun does not always shine (variability), and we cannot perfectly predict when these changes will occur (uncertainty), it is important to note that the grid and its operators have always had to deal with substantial variability and uncertainty due to daily load variation and the unexpected loss of generation or transmission facilities. California ISO (CAISO) observes that "the variability of wind and solar generation somewhat offset each other, but production of both resources can swing dramatically." CAISO projects that within a few years, wind generation serving California could swing by thousands of megawatts within a single hour, as illustrated in Figure 2.[10]

Figure 2 CAISO's ramping extremes under 20% Renewable Portfolio Standard conditions



Source – CAISO, "2011 Annual State of the Grid," August 8, 2011, p. 24.

The California ISO explains that variable renewable resources complicate operation of the traditional fossil fleet, including:

- Increased frequency, speed and magnitude of ramps.

[10] California ISO. "2011 Annual State of the Grid." August 8, 2011.

- Increased procurement of regulation-up and regulation-down energy.
- Increased load-following requirements, leading to the need for additional operating and supplemental reserves.
- Increased stresses on generation fleet from ramping and cycling; and
- Increased frequency and magnitude of over-generation conditions.[11]

To address these issues, greater operational flexibility and improved resource forecasting is needed to integrate higher levels of variable generation resources.

Typically, changes in variable renewable resource output are met by ramping up and down dispatchable generation resources. Gas turbines and hydroelectric units are the most flexible and fastest-responding units in the generation fleet and so they are often used to follow load and provide balancing services.[12] Coal and nuclear units are generally less flexible, but are still able to ramp up and down to some degree to replace intermittent resources and match changes in load.

To ensure that some coal and nuclear generation units will be available for peak hours, grid operators often need to operate them at low output levels during minimum load conditions (e.g., overnight) so that the units will be readily available the next day to meet peak loads and provide ancillary services. Keeping some fossil generation running during the night to ensure next-day operational reliability may at times require operators to “spill” (i.e., curtail) low-cost wind or run-of-river generation in order to keep generation in balance with low off-peak load levels. This practice is referred to as “out-of-merit dispatch.”[13] A flexible electric system will allow operators to address fluctuations in supply and demand through means other than traditional generation and has the potential to reduce the need for out-of-merit dispatch.

V. Energy Storage and Economic Dispatch

Energy storage has the potential to provide significant flexibility to the modern grid. It can provide both energy arbitrage, by absorbing excess power when it is cheap and discharging when it is more valuable, and fast ramping response, to support the system in situations where system conditions change more quickly than can be satisfied by traditional generator ramping.

Several energy storage technologies are applicable in the bulk power context, and they fall into two broad groups. One group stores bulk energy and then transfers it back to the grid over long periods of time (e.g., several hours), such as pumped hydro storage, rechargeable

[11] California ISO, “2011 Annual State of the Grid,” August 8, 2011, p. 21, and Keith E. Casey, CAISO VP – Market and Infrastructure Development, “Renewable Integration – CAISO Perspective,” NARUC Summer Committee Meetings, July 18-21, 2010.
[12] The physical flexibility of hydroelectric units is often constrained by other factors such as environmental concerns or competing uses such as irrigation and flood control.
[13] Also see Section VI of this report for issues related to curtailing renewable resources.

batteries, concentrated solar thermal, ice storage, and compressed air storage. These technologies consume electricity produced in one time period – for instance when it is abundant, cheap, and not needed to meet immediate demand – and feed it back into the grid in a controlled fashion at later periods when electricity is scarce and it is more valuable. These longer-duration storage technologies perform an electricity arbitrage function by buying electricity when it is cheap and releasing it when it is expensive. By doing so, they flatten out variability by increasing demand when electricity is plentiful, and serve as dispatchable resources that can be used to meet on-peak and other grid demands.

One circumstance under which this type of storage could be valuable is when paired with or on the same system as variable renewable sources. Storage could absorb excess electricity produced by non-dispatchable wind or solar when production is high but demand (and prices) are low, and then feed electricity back into the grid when prices are higher.

The second group of energy storage technologies produces and delivers large amounts of electric energy in very short periods of time (seconds or a few minutes). Such devices include high-speed flywheels, certain batteries, and advanced power electronics. They can provide vital fast-response services needed for reliability such as regulation capability and voltage support.

These technologies are promising in the economic and operational value they could bring to the grid. The economic structure for storage operation is to consume power when it is cheap and feed it back into the grid when expensive: this is consistent with the fundamental purpose of economic dispatch. Storage could also give grid operators new tools and capabilities for responding to the operational needs of integrating variable wind and solar resources and a possible reduction in some regions in the amount of dispatchable fossil generation needed. Currently, the main barrier to storage is that the technologies are not economically competitive. However, with continuing investments in research and development for storage technologies, they could become more competitive as components of the future flexible electric system.

VI. Negative Pricing, the Production Tax Credit and Economic Dispatch

In markets, market-clearing prices are set when offers from suppliers are matched with demand. There are a variety of circumstances when offer prices from suppliers can be quite low, zero or even negative: generators with out-of-market agreements to sell their power (power purchase agreements), generators that must run for reliability reasons, mandatory releases from hydro-electric dams, and output from variable renewable resources whose operating costs are very low. In some areas, certain system conditions exist where many low, zero or negative price offers converge with low demand, resulting in low, zero or negative market prices. These situations result from over-abundant low-priced offers and in some cases, transmission constraints or other physical limits preventing the export of power.

Low, zero and negative prices provide an economic signal to reduce generation. However, at times it is in a generation operator's best interest to continue producing electricity even though the market price is much lower than the unit's marginal cost of producing the electricity. This can occur because of physical limitations on the unit such as minimum shut-down times. For example, many coal units and almost all nuclear units have large steam boilers, which are slow to reheat once they have been shut down. As a result, they are typically kept in operation all night at or above their minimum operating level, even if prices are low or negative, so that they will be available the next day when energy prices are more favorable. Prices can frequently be negative for wind during periods where wind production is high but demand is low. During negative pricing periods, wind generators can find it cost effective to continue operation because the negative prices are more than offset by the production tax credit, which is paid based on electricity generated.

Low, zero and negative prices are an artifact of economic dispatch – meeting load with the cheapest power available – and engineering constraints, such as minimum shut-down time or transmission constraints preventing low-cost power from flowing to a wider market. These prices have a major impact on the generators exposed to them, and can require out-of-market payments to resources to ensure they are kept financially whole. For instance, wind generation was curtailed in the Bonneville Power Administration (BPA) system in 2011 because of low demand and a need to maintain minimum hydro releases, according to BPA.[14] In the spring of 2013, BPA proposed a plan for collecting money from transmission customers to compensate wind generators that are curtailed.[15]

In some areas, expansion of the transmission system could allow electricity to be delivered to demand while enabling the lowest cost resources to be fully utilized. Economic and engineering analysis of a particular situation would be needed in order to determine whether an investment in transmission would be a viable or cost effective solution. In some cases transmission capacity is not the bottleneck, but rather other operational issues like availability of reserves are. In other cases, the cost of building transmission may not be outweighed by the benefits of restoring merit order in the economic dispatch.

VII. Market Structure and Economic Dispatch

Market structure and operational procedures can have an effect on economic dispatch. In addition to using generation resources for load following, market design can also be used to address the changes in output from variable generation resources. Larger balancing areas and sub-hourly markets are two of the key ways to address the variable output of renewable generation resources.

[14] Transmission Weekly "FERC orders BPA to revise controversial wind curtailment policy." December 12, 2011.
[15] The Energy Daily, "New BPA curtailment plan trims wind generators' costs," May 1, 2013.

There are several reasons larger balancing areas can have an effect on economic dispatch. In a large balancing area changes in both load and variable resources will generally be non-coincident, meaning that they will generally not experience their peaks or other key operating conditions at the same time. Also, larger balancing areas typically have a larger and more diverse suite of generation units to dispatch, which can help lower the cost to meet load and manage transmission congestion and variability. Sub-hourly markets or shorter market periods can match generator flexibility to real-time conditions more closely than longer market periods. Thus, larger balancing areas and shorter dispatch intervals both give operators more options for meeting real-time system conditions and the opportunity to achieve a more economically-efficient dispatch. Both are components of the new energy imbalance market plan by the California ISO and PacifiCorp, which will dispatch generation across the combined footprint – spanning California and five other western states – every five minutes. Proponents of the new market, planned to begin in October 2013, anticipate improvements in reliability, cost of system dispatch, and integration of variable resources.[16]

Grid operators are also using and considering a number of current and emerging operational procedures and tools to improve economic dispatch and increase system flexibility into grid operations, including:

- Scheduling and dispatching resources to follow net load (customer load minus variable generation), to reduce overall variability and operations costs.
- Improving forecasting of day-ahead, hour-ahead and near-real-time variable resource generation, to reduce the difference between predicted and actual renewable generation and reduce the likelihood of a large mismatch between scheduled supplemental resources and actual generation needs in real time.
- Integrating variable renewable resource forecasting into control centers and decision support tools for grid operations.
- Creating incentives for more flexible, load-following resources available to provide regulation and reserve requirements.
- Increasing the flexibility of dispatchable generation resources such as gas turbines, to have faster starts, faster ramp rates, and efficient fuel use across a wider operational range.
- Using monitoring and communications technologies such as synchrophasors and SCADA[17] to track variable generation and grid conditions and improve the use of available transmission capacity.
- Using redispatch and "conditional firm transmission service"[18] to reduce the impact of transmission constraints on variable generation's access to transmission services.

[16] The Energy Daily, "FERC Oks Calif., PacifiCorp 'energy imbalance' market plan." July 3, 2013.
[17] Supervisory control and data acquisition
[18] Conditional firm transmission service is a way for more generators to use existing transmission lines under long-term contracts. Transmission lines are often "sold out" contractually but have physical capacity available in all but a small percentage of the year. Conditional firm is a service that would make that physical capacity available for

- Using more demand response and interruptible load for load-following and ancillary services, including the aggregation of flexible loads like refrigerated warehouses, agricultural water pumping, and others to meet additional load following needs due to variable resources and intelligent building energy management systems to support on-site photovoltaic resources.
- Backing down (curtailing, also known as “over-generation mitigation”) variable resources when necessary to ensure that needed load-following generators remain on-line during minimum load periods for next-day reliability support.
- Using technologies such as power electronics, dynamic voltage support, and storage to improve the controllability of intermittent generators and their impact on the grid.
- Developing energy storage technologies to serve as buffers and reduce the need for instantaneous balancing of load and generation. Storage technologies that absorb bulk energy can be used to store intermittent generation in one time period and release it into another (e.g., take in on-peak photovoltaic generation and shift it for night-time use, or absorb off-peak wind production for on-peak use), while short-duration storage technologies can be used to mitigate short, fast generation changes.[19]
- Developing and incentivizing new operational capabilities for variable resources such as self-provision of regulation and other active power controls.

VIII. Environmental Regulations and Economic Dispatch

The Environmental Protection Agency (EPA) is in the process of releasing several environmental regulations that will affect the electric utility sector. While some of these rules have already been released, others are still awaiting proposal or finalization. The following table (next page) lists the current major regulations that will affect the electric utility sector and denotes their status and expected compliance dates.

Depending on their configuration, owners of generators that are affected by the rules may need to undertake some degree of operational modifications (e.g., switching fuels to limit emissions) or retrofit with control technologies or purchase allowances (in the case of CSAPR) to meet the new requirements. In some cases, generator owners may choose to retire units instead of investing in such measures. While such retirements, in addition to temporary outages for retrofitting, are unlikely to create wide-spread reliability issues, there is the potential for localized reliability impacts. Timely coordination among stakeholders will be necessary to maintain reliability while implementing these environmental regulations.[20]

use on a long-term basis.
http://www.nationalwind.org/assets/blog/WGA_NWCC_Conditional_Firm_Factsheet.pdf

[19] More detail about energy storage can be found in Section V of this report.

[20] NERC “2012 Long-Term Reliability Assessment.” November 2012. pg 25

Figure 3 TABLE: EPA Electric Utility Sector Environmental Regulations

	Federal Regulation	Impacts	Status
Air	**Cross-State Air Pollution Rule (CSAPR)**	• Establishes pollution caps for SO_2, annual NO_x and seasonal NO_x for 28 states in the eastern half of the U.S. to reduce transported pollution that significantly affects downwind nonattainment and maintenance problems with National Ambient Air Quality Standards (NAAQS).	Rule: finalized 7.6.2011 supplemental rule finalized 12.15.2011; technical revisions finalized 2.7.2012 and 6.5.2012; vacated 8.21.2012 by U.S. Court of Appeals, D.C. Circuit; awaiting review by the Supreme Court[21] Compliance: CAIR currently in affect. Pending decision of the Supreme Court, the status of the rule and its compliance are unknown. If EPA must revise CSAPR, compliance will remain uncertain until replacement rule is finalized.
	Mercury and Air Toxics Standards (MATS) Rule for Electric Generation Units[22]	• Establishes national emission standards for hazardous air pollutants (HAPs), including mercury, heavy metals and acid gases • Will affect existing and new coal- and oil-fired plants	Rule: finalized 2.16.2012; updated standards for new plants finalized 4.24.2013 except for certain startup/ shutdown issues, which were opened for public comment through 8.26.2013 Compliance: sources have until April 2015 to comply;[23] new facilities will need to comply upon construction.
	Greenhouse Gas New Source Performance Standard (NSPS) for Electric Generating Units[24] [25]	• Establishes NSPSs for GHGs that would set national limits on the amount of carbon emissions from new power plants	Rule: new proposal released 9.20.2013 (as Carbon Pollution Standard for New Power Plants)[26] Compliance: compliance timing uncertain until rule is finalized; new facilities built after

[21] In March 2013 the U.S. Solicitor General petitioned the Supreme Court to review the Circuit Court decision vacating the rule, and in June 2013 the petition was granted. By early December 2013, the case will be fully briefed and oral argument is set for December 10, 2013. (http://www.epa.gov/crossstaterule/)
[22] Additional information at: http://www.epa.gov/mats/
[23] The Clean Air Act provides three years for compliance. Additionally, under the Clean Air Act, state permitting authorities can also grant an additional year as needed for technology installation. EPA expects this option to be broadly available. Sources may extend compliance deadline by yet an additional year by seeking an administrative order from EPA.
[24] http://www.epa.gov/carbonpollutionstandard/actions.html
[25] On October 25, 2013, the Supreme Court agreed to hear oral arguments about whether EPA permissibly determined that its regulation of greenhouse gas emissions from mobile sources gases can be extended to regulation of stationary sources; oral argument has been scheduled for February 24, 2014.

			rule is finalized will be expected to comply upon construction
Waste	**Coal Combustion Residuals (CCR) Rule**	• Regulates disposal of coal combustion by-products (fly ash, bottom ash, boiler slag, flue gas desulfurization materials) in landfills as either RCRA Subtitle C "special waste" or Subtitle D "non-hazardous waste" • Addresses risks from leaching of contaminants to groundwater from disposal units and risks from fugitive dust	Rule: comments on proposed 6.21.2010 rule currently under review[27] final rule expected 12.19.2014.[28] Compliance: compliance timing uncertain until rule is finalized
Water	**CWA §316(b) – Cooling Water Intake Structures**	• Establishes national standards for impingement mortality and a process for establishing site-specific entrainment controls • Expected to affect existing and new large fossil and nuclear steam units not already equipped with adequate controls	Rule: rule proposed 4.20.2011; final rule expected 4.17.2014[29] Compliance: compliance required up to 8 years after rule is finalized
	Steam Electric Power Generating Effluent Guidelines	• Strengthens controls on metal and nutrient discharges from certain steam electric power plants[30]	Rule: initiated in 2009; rule proposed 6.7.2013; final rule expected 5.22.2014 (settlement agreement)

As of July 2013, only two of the above tabulated rules have been finalized, the Cross-State Air Pollution Rule (CSAPR) and the Mercury and Air Toxics Standards (MATS). Compliance with

[26] EPA originally released a proposed rule on March 27, 2012 (77 FR 22392). On June 25, 2013, President Obama introduced his Climate Action Plan, which includes reductions in carbon output for new and existing electric power generators, and a Presidential Memorandum (PM) to EPA, which includes direction to achieve this. The PM called for a proposed rule for greenhouse gas regulation of new power plants by September 20, 2013; the PM also addresses exiting power plants, calling for a proposed rule by June 2014 and a final rule by June 2015. EPA released its Greenhouse Gas NSPS for Electric Generating Units proposed rule September 20, 2013, which replaces the March 2012 proposal. See http://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf; http://www.whitehouse.gov/the-press-office/2013/06/25/presidential-memorandum-power-sector-carbon-pollution-standards; http://www2.epa.gov/carbon-pollution-standards.

[27] http://www.epa.gov/epawaste/nonhaz/industrial/special/fossil/ccr-rule/index.htm

[28] Schedule deadline for final rule is a result of a October 29, 2013 court memorandum. Appalachian Voices et al. v. Lisa Jackson, Civil Action No. 12-0523, Consolidated Case Nos. 12-0585, 12-0629 (D.C. Cir. filed Apr. 5, 2012).

[29] http://water.epa.gov/lawsregs/lawsguidance/cwa/316b/index.cfm

[30] http://water.epa.gov/scitech/wastetech/guide/steam-electric/proposed.cfm

MATS is well underway, with some plants retrofitting their pollution control technologies and others retiring.[31] CSAPR is awaiting legal actions; thus even though the rule is final, its impact is still uncertain. The remaining rules are still uncertain with respect to their requirements, implementation and compliance deadlines. Numerous studies were conducted when these rules were first proposed to project the potential impact of the proposed rules upon retirements and electric system reliability.[32]

In part because of these environmental regulations, or anticipation of the pending regulations, operating certain coal plants will be uneconomic and some plants are being retired.[1] Other reasons for these plants becoming uneconomic to operate include the low price of natural gas, slack demand for electricity and the advanced age of the existing coal plants.[33] Between 2013 and 2016, 116 coal-fueled generators, with a combined net summer capacity of over 16 GW, are slated for retirement.[34] These retirements are located in many areas of the U.S., but concentrated in the eastern part of the country.

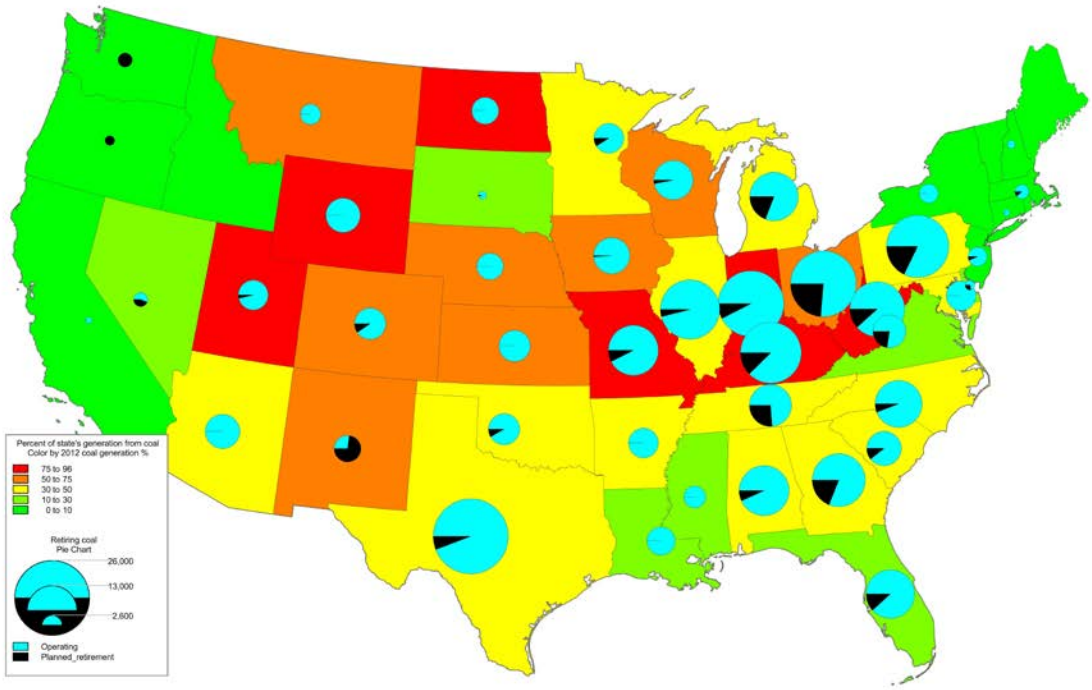
[31] The Energy Daily, "Survey suggests most plants on track with MATS compliance." July 2, 2013. While some coal plants are being closed to avoid the costs of complying with MATS (see The Energy Daily, "Analyst: FirstEnergy move may signal more coal plant closures," July 11 ,2013), others are being retrofitted to burn natural gas (see The Energy Daily "NRG Energy to retool Ohio, Pa. coal plants to run on gas," July 2, 2013). In some cases it is economic to retrofit large coal plants but not small ones. (Smith, "Turning Away from Coal," The Wall Street Journal, September 13, 2010).

[32] References to these studies and summaries of their conclusions can be found in the 2011/2012 Economic Dispatch report to Congress.

For instance, former Exelon Chairman John Rowe said that half of Exelon's expected coal plant retirements are due to the current economics of the plant and relative coal and natural gas prices, independent of the retrofit decision. Rowe said, "cheaper gas, not stricter regulation, is prompting companies to shut older, smaller coal units." (Eileen O'Grady, Reuters, "Cheaper gas forcing coal retirements," June 14, 2011).

[34] During these same years, 146 natural gas plants are planned to be built, for a combined net summer capacity of over 28 GW. Energy Information Administration, "Electric Power Annual," Data Table 4.5. http://www.eia.gov/electricity/annual/

Figure 4 2012 U.S. Coal Generation and Existing and Retiring Coal Capacity



Source: Map produced by NETL using Ventyx's Energy Velocity. Data Sources were Ventyx and EIA's Electric Power Monthly. States are shaded according to the percentage of total 2012 generation output from coal; pie charts indicate the proportion of coal capacity to be retired.

In the short term, these environmental regulations may affect economic dispatch in two ways. First, a combination of plant retirements, temporary outages for retrofits, and the time required for construction of replacement capacity may leave fewer units available to be dispatched at any given point in time. Depending on a number of factors – length and timing of generator outages to retrofit plants, how many additional resources are brought online to replace retiring units – the amount of dispatchable generation available to support renewables integration and grid reliability could be reduced. These retirements could have local consequences for grid reliability that would make economic dispatch more difficult or expensive for affected sub-regions, particularly if those regions are already burdened by transmission congestion or other constraints. As new generation is built, these potential difficulties will be alleviated.

Second, these regulations may change the relative cost of generating electricity by fuel type and that will affect economic dispatch of generators.

IX. The Role of Demand Response in Economic Dispatch

Demand response has the potential to improve economic dispatch by making more resources available to balance supply and demand in the system, potentially reducing costs to consumers. As noted in *Demand Response Compensation in Organized Wholesale Energy Markets*, Order No. 745, 76 FR 16,658 (Mar. 24, 2011), FERC Stats. & Regs. ¶ 31,322 (2011), *order on reh'g and clarification*, Order No. 745-A, 137 FERC ¶ 61,215 (2011), "demand response in organized wholesale energy markets can help improve the functioning and competitiveness of those markets."[35] Demand response provides an additional resource that grid operators can dispatch to reduce rates charged to customers. Simply, when the cost of demand response is lower than the cost of the marginal generation unit, or the next resource that would otherwise be dispatched, net savings accrue to customers (see the Net Benefits Test in FERC Order No. 745 for details).

Demand response also plays another important role as it relates to economic dispatch. Demand response can mitigate generator market power because "the more demand response that sees and responds to higher market prices, the greater the competition, and the more downward pressure it places on generator bidding strategies by increasing the risk to a supplier that it will not be dispatched if it bids a price that is too high." [36]

In addition to wholesale energy markets, demand response resources may participate in ancillary service markets.
FERC Order 719 requires RTOs and ISOs to "accept bids from demand response resources in RTOs' and ISOs' markets for certain ancillary services on a basis comparable to other resources."[37]

FERC Order 755 deals with how those providing frequency response are compensated, and will increase the value of fast-responding demand response resources providing frequency response.[38] These orders could both increase competition in the market to provide ancillary services and appropriately compensate the services demand response can provide. Increased

[35]Federal Energy Regulatory Commission. "Demand Response Compensation in Organized Wholesale Energy Markets." Order No. 745. 2011.
[36] Federal Energy Regulatory Commission. "Demand Response Compensation in Organized Wholesale Energy Markets." Order No. 745. 2011.
[37] *Wholesale Competition in Regions with Organized Electric Markets*, Order No. 719, FERC Stats. & Regs. ¶ 31,281 (2008), *order on reh'g*, Order No. 719-A, FERC Stats. & Regs. ¶ 31,292 (2009), *order on reh'g*, Order No. 719-B, 129 FERC ¶ 61,252 (2009).
[38] *Frequency Regulation Compensation in the Organized Wholesale Power Markets*, Order No. 755, FERC Stats. & Regs. ¶ 31,324 (2011), *order denying reh'g,* Order No. 755-A, 138 FERC ¶ 61,123 (2012). Also see http://www.ferc.gov/whats-new/comm-meet/2011/102011/E-28.pdf

competition should lead to a downward price pressure for ancillary services; appropriate compensation should incentivize more valuable fast-ramping demand response that can be used for maintaining system frequency, in part to facilitate renewable integration.

X. Market Power and Economic Dispatch

As noted in the previous section, the exercise of market power can negatively affect economic dispatch because it can increase the cost of procuring electricity from key sources. The possible increase of market power resulting from mergers continues to be a concern for FERC, state public utility commissions and other stakeholders. As an example, in 2011 Duke Energy and Progress Energy filed a Merger Application with FERC. FERC "conditionally authorized the Proposed Transaction subject to Commission approval of market power mitigation measures" because in the absence of such measures, the merger could have adverse effects on competition in certain areas.[39] In particular, the merger application proposed a virtual divestiture of a certain amount of power from regulated sources, but dispatch of these sources was still under control of the parent company. The Commission commented that "The lack of detail regarding [Duke Energy's] reliability obligations provides [Duke] with too much discretion regarding when delivery [from virtually-divested, low cost sources] may be interrupted."[40]

The merger between Exelon and Constellation in March of 2012 was another example of the potential impact of market power on economic dispatch. A study conducted by the Independent Market Monitor for PJM shows that the merger would raise competitiveness concerns, and that the proposed market mitigation measures could either offset competitiveness issues or "greatly exacerbate the competitive issues."[41] The study examined three scenarios using PJM's own software and input assumptions for the operational characteristics of the facilities comprising the PJM system, and found that post-merger dispatch patterns could vary significantly, depending on the nature of the entity that would acquire certain generation assets proposed for divestiture. Using the so-called "three pivotal supplier test" that "makes explicit and direct use of" incremental dispatch under different merger conditions, the study tested "whether excess supply is adequate to offset other structural features of the market," and found that it was not.[42] Given the structural market issues that may lend themselves to the exercise of market power, ongoing monitoring is prudent to ensure that parties do not exercise market power to increase prices.

[39] *Duke Energy Corp.*, Order Rejecting Compliance Filing, 137 FERC ¶ 61,210, Docket No. EC11-60-001 (December 14, 2011).
[40] *Ibid*., p. 37.
[41] Monitoring Analytics. "Review and Analysis of the Proposed Merger of Exelon and Constellation." September 16, 2011.
[42] *Ibid*,. p. 12, 17, 84.

XI. Conclusion

Increasingly, the electricity industry is being asked to balance the three public policy goals of reliability, cost, and environmental sustainability. Economic dispatch is at the center of how the industry chooses which generators will meet demand and, thus, how the industry performs in terms of these goals. As discussed in this report, economic dispatch is affected by a wide array of factors. While efficient economic dispatch has always been an industry goal, changes in public policy on both the state and national levels promoting growth of variable renewable generation on the grid have forced grid operators to reassess both how they operate the grid and the resources necessary to operate the grid. The ability to maximize the dispatch of low cost generation and to fully utilize existing infrastructure will depend on the flexibility of the physical system, operating procedures and institutional policies. A flexible system will use price signals, operational procedures, market structures and technology to ensure that the lowest cost resources are dispatched first. Storage, larger balancing areas, and shorter dispatch intervals are just some of the components of the flexible electric system that are necessary to better utilize the investments that we have made in the grid to date.