U.S. DEPARTMENT OF ENERGY

2011/2012 Economic Dispatch and Technological Change

Report to Congress
September 2012

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 the benefit to American electricity consumers.

In its 2011/2012 economic dispatch report, the Department examines how technology and policy impacts economic dispatch. This report looks at eight of the current issues that impact 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 on each of these issues, rather the report gives a brief overview of the issues, and their impact on economic dispatch and in some cases suggests future actions that should be taken. Overall, the report points to a need for grid flexibility – the need for there to be 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 be dependent 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 that are necessary to best utilize the investment that we have made in the grid to date.

Pursuant to statutory requirements, this report is being provided to the following Members of Congress:

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

- **The Honorable Jeff Bingaman**
  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. Brad Crowell, Principal 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

Section 1234 (and Section 1832, which is identically worded) of the Energy Policy Act of 2005 (EPACT) directs 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. The Department's previous reports examined economic dispatch and its potential impacts upon consumers, offered recommendations to improve economic dispatch, and concluded that there had been few significant recent changes to how grid operators and utilities conduct economic dispatch.

In this report, the Department looks at how technology and policy impacts economic dispatch. This report looks at eight of the current issues that impact 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 on each of these issues, rather the report gives a brief overview of the issues, and their impact on economic dispatch and in some cases suggests future actions that should be taken. Overall, the report points to a need for grid flexibility – the need for there to be a suite of solutions to address the complexities of economic dispatch as policy and technology drives changes to the grid.

ECONOMIC DISPATCH AND TECHNOLOGICAL CHANGE

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I. Legislative Language

This report responds to legislative language set forth in Sections 1234 and 1832 of the Energy Policy Act of 2005, wherein it is stated:

> *... "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)..."*

(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 nonutility 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 nonutility generation resources to offer their output for inclusion in economic dispatch.

DOE's 2011/2012 Report finds that as it relates to subsection (1), there are no significant changes in utility practices regarding economic dispatch, and therefore this report focuses on subsections (2) and (3) of the Energy Policy Act of 2005.

There are roughly 1738[1] nonutility power generators in the United States. Nonutility power generators include Qualifying Facilities established under Public Utility Regulatory Policies Act of 1978. Qualifying Facilities include combined heat and power plants and small power producers. Nonutility power generators also include independent power producers that produce and sell electricity on the wholesale market at market-based rates. Independent power producers generated 1,341,300,000 megawatt hours in 2010 as compared to 2,471,632,000[2] megawatt hours generated 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 again when loads decrease. However, this theoretically simple economic optimization task is

[1] Energy Information Administration. "Electric Power Industry Overview 2007." http://www.eia.gov/cneaf/electricity/page/prim2/toc2.html
[2] Energy Information Administration. "Electric Power Annual 2010 Data Tables." http://205.254.135.7/electricity/annual/html/table2.1a.cfm

complicated by several factors – the size of the footprint being optimized, 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 generator or transmission outages (contingencies). This illustrates a key point – that the practice of economic dispatch is influenced by numerous factors in addition to 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 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. Continued investment 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 gotten 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 individual services needed to balance the grid based on their value to the system. This allows technologies that are cost-effective to meet a specific need, but perhaps not to meet another, 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 nonutility, – primarily wind and solar photovoltaic – are some of the fastest-growing sources[4] of capacity being added to the grid today. Twenty-nine states, Puerto Rico, and the District of Columbia have either placed a renewable portfolio requirement on their electric utilities or set renewable-related goals, creating long-term demand for renewable generation.[5] These state policies, coupled with the production tax credit, have catalyzed the development of renewable generation resources. Between 2006 and 2010, wind generation grew from 11,329 MW to 37,889 MW (4.2% of summer net nameplate capacity) and solar thermal and photovoltaic generation grew from 411 to 888 MW (<1% of summer net nameplate capacity).[6] In 2010, wind generators produced 95 billion kWh of electricity and solar produced 1.2 billion kWh;[7] together these amounted to over 1 percent of total U.S. electricity consumption.[8] The U.S. Energy Information Administration projects continued significant growth of wind and solar generation over the coming decades, as shown in Figure 1.

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

[4] Energy Information Administration. "Electric Power Annual 2010 Data Tables."
http://205.254.135.7/electricity/annual/html/table1.4.cfm

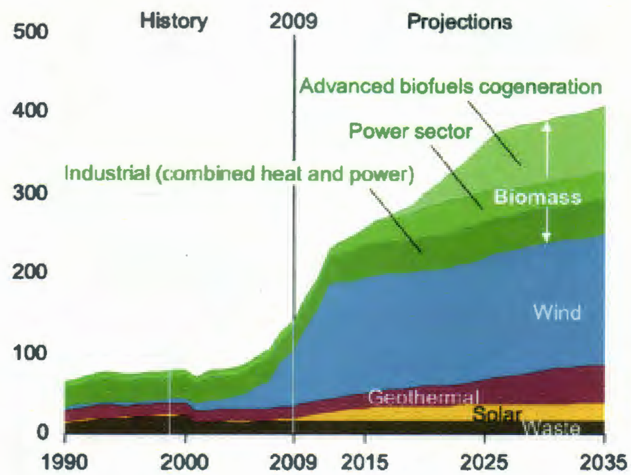
[5] Database of State Incentives for Renewables and Efficiency. "RPS Policies." January 2012.
http://www.dsireusa.org/documents/summarymaps/RPS_map.pptx

[6] U.S. Energy Information Administration, Renewable Energy Consumption and Electricity Preliminary Statistics 2010, Table 4, "U.S. electric net summer capacity, 2006-2010," June 8, 2011.

[7] U.S. Energy Information Administration, Renewable Energy Consumption and Electricity Preliminary Statistics 2010, Table 3, "Electricity net generation from renewable energy by energy use sector and energy source, 2006-2010," June 8, 2011.

[8] The American Wind Energy Association asserts that "wind power provided 2.3% of the U.S. electricity mix" in 2010. (AWEA, "2010 U.S. Wind Industry Market Update," 2011, p. 1).

Figure 1 U.S. Non-hydropower renewable electricity generation, 1990-2035 (bn kWh per yr)

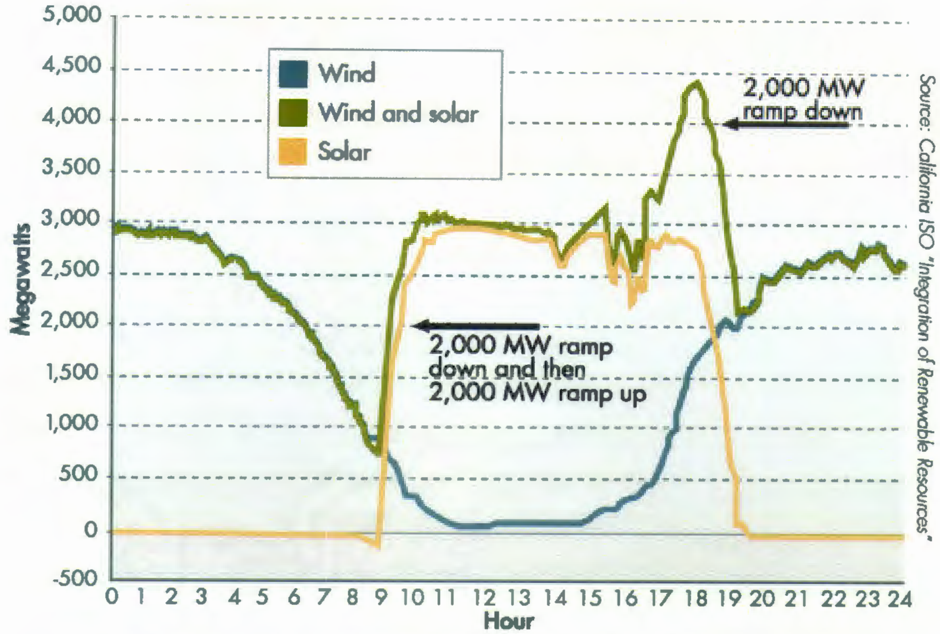


Source – U.S. Energy Information Administration, "Annual Energy Outlook 2011," April 2011, p. 3.

Generally, system operators accept as much electricity as possible from renewable resources, regardless of whether it is utility or nonutility 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., cannot be precisely controlled by the grid operator), but their output is 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 production is increased). These are all components of a flexible electric grid. Some of these components have been implemented in the Midwest ISO (MISO). MISO introduced a Dispatchable Intermittent Resources product that allows wind to be treated like other generation resources. This will allow wind to participate in the MISO real-time market and set market 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, 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"; within a few years, CAISO predicts that wind generation serving California could swing by thousands of megawatts within a single hour, as illustrated in Figure 2.[9]

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
- 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.[10]

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

Historically, changes were met by ramping up and down generation resources. Gas turbines and hydroelectric units are the most flexible and fastest-responding units in the generation

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

[10] 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.

fleet and so they are often used to follow load and provide balancing services.[11] In addition, to some degree, other generation resources like coal and nuclear, ramp up and down to match load.

To ensure that these units will be available for peak hours, grid operators must operate some coal and nuclear generation at low output levels during minimum load conditions (e.g., overnight) so that the units are 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 is referred to as out-of-merit dispatch. 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 a significant portion of the flexibility needed to manage the modern grid. 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 longer periods of time (e.g., several hours), such as pumped hydro storage, rechargeable batteries, concentrated solar thermal, ice storage, and compressed air storage. These technologies can effectively absorb energy produced in one time period – particularly when it is available, cheap, and not needed to meet immediate demand – and feed it back into the grid in a controlled fashion at later periods when it is more valuable (whether in operational or monetary terms). Thus, these technologies can absorb excess energy when wind or solar generation ramps up, and deliver energy back into the system when generation output falls. These longer-duration storage technologies essentially flatten out the effects of variability through use of a synthetic demand that provides another tool for operators to match generation to load, while serving as a dispatchable resource that can be used to meet on-peak and other grid demands.

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 would 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. With investments in the

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[11] While theoretically true, 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.

research and development of storage technologies, they can become an important component of the future flexible electric system.

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

In some areas, there are times when market prices become negative. These situations are an artifact of transmission constraints and provide an economic signal to reduce generation. 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, even if prices are low or negative, so that they will be available the next day when energy prices are more favorable. For wind, during periods where wind production is high but demand is low, prices can regularly be negative. During negative pricing periods, wind generators can find it cost effective to continue operation because the negative prices are offset by the production tax credit which is paid based on electricity generated. Expansion of the transmission system in these geographic areas would allow the electricity to be delivered to demand and the lowest cost resources to be fully dispatched. Economic analysis of a particular situation would be needed in order to determine whether an investment in transmission would be a cost effective solution; in some cases the cost of building transmission would not be outweighed by restoring order in the economic dispatch.

VII. Market Structure and Economic Dispatch

Market structure and operational procedures affect 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. Larger balancing areas can take advantage of the principle of non-coincidence in both load and variable resource production and they typically have a larger or more diverse suite of generation units, which can help in managing variability. Sub-hourly markets or shorter market periods can provide better access to generator flexibility than longer market periods. Sub-hourly dispatch of generation leads to lower overall system operating costs even without solar and wind generation as factors.[12] Larger balancing areas and shorter dispatch intervals can be components of a flexible electric system.

[12] U.S. Department of Energy, Solar Energy Technologies Program. "The Role of Electricity Markets and Market Design in Integrating Solar Generation." DOE/GO-102011-3199. May 2011.

Grid operators are also using and considering a number of current and emerging tools to increase system flexibility and integrate greater amounts of variable resources through economic dispatch into grid operations, including:

- Scheduling and dispatching resources to follow net load (customer load minus variable generation), to reduce overall variability and operations costs.
- Improved forecasting of day-ahead, hour-ahead and near-real time variable resource generation, to reduce the variance 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.
- Scheduling and dispatching resources intra-hour, rather than the more traditional hourly interval.
- 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[13] to track variable generation and grid conditions and improve the use of available transmission capacity.
- Using redispatch and "conditional firm transmission service"[14] to reduce the impact of transmission constraints on variable generation's access to transmission services.
- 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.
- Backing down (curtailing, also known as "over-generation mitigation") variable resources when necessary to assure 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

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[13] Supervisory control and data acquisition

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

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.

- 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 lists the current major regulations that will affect the electric utility sector and denotes their status and expected compliance dates.

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).	finalized 7.6.2011 supplemental rule finalized 12.15.2011; technical revisions finalized 2.7.2012 and 6.5.2012 US DC Circuit Court issued stay order 12.30.2011[15]
	Mercury and Air Toxics Standards (MATS) Rule for Electric Generation Units[16]	• Establishes national emission standards for hazardous air pollutants (HAPs), including mercury, heavy metals and acid gases • Will affect coal and oil-fired plants	finalized 12.16.2011 sources generally will have until April 2016 to comply[17]
	Carbon Pollution Standard for New Power Plants[18]	• Establishes NSPSs for GHGs that would set national limits on the amount of carbon emissions from new and modified power plants	Proposed 3.27.2012 compliance upon finalization of the rule and commencement of operation
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	proposed rule comments currently under review 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	proposed rule comments currently under review final rule expected 6.2013 compliance required up to 8 years after rule is finalized

[15] On December 30, 2011, the United States Court of Appeals for the D.C. Circuit issued its ruling to stay the CSAPR pending judicial review. The court's decision is not a decision on the merits of the rule. EPA is ensuring the transition back to the Clean Air Interstate Rule (CAIR) occurs as seamlessly as possible. Please see http://www.epa.gov/crossstaterule/bulletins.html for updates on CSAPR and the continuing implementation of CAIR.

[16] Additional information at: http//www.epa.gov/mats/

[17] This includes the three years provided to all sources by the Clean Air Act. 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.

[18] Additional information at: http://www.epa.gov/carbonpollutionstandard/actions.html

Depending on their configuration, owners of generators that are affected by the rules will need to undertake some degree of operational modifications (e.g., switching fuels to limit emissions), 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.

As of August 2012, 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); the remaining rules are still uncertain with respect to their requirements, implementation and compliance deadlines. Numerous studies have been conducted[19] to project the potential impact of the proposed rules upon retirements and electric system reliability.[20] While the results of these studies vary widely, they offer some common conclusions:

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[19] Some studies were conducted before final rules were issued. It is important to examine the assumptions about the rules when looking at a report's predicted impacts.

[20] Some studies were conducted before final rules were issued. It is important to examine the assumptions about the rules when looking at a report's predicted impacts. Some examples of electric power impact studies include:

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1. DOE, 12-2011: Department of Energy, "Resource Adequacy Implications of Forthcoming EPA Air Quality Regulations."
2. NERC Study, 11-2011: North American Electric Reliability Corporation, "2011 Long-Term Reliability Assessment."
3. MJBA-AGI Study, 11-2011: MJ Bradley Associates and Analysis Group, "Ensuring a Clean, Modern Electric Generating Fleet while Maintaining Electric System Reliability; Fall 2011 Update."
4. CERES, 11.2011: CERES, "New Jobs-Cleaner Air Part II: An investment in American business and American Jobs."
5. EEI, 1-2011: Edison Electric Institute, "Potential Impacts of Environmental Regulation on the U.S. Generation Fleet.
6. BPC, 6-2011: Bipartisan Policy Center, "Environmental Regulation and Electric System Reliability."
7. Brattle Study, 12-2010: Metin Celebi, Frank Graves, Gunjan Bathla, and Lucas Bressan (Brattle Group), "Potential Coal Plant Retirements Under Emerging Environmental Regulations."
8. Congressional Research Service. "EPA's Utility MACT: Will the Lights Go Out?" January 9, 2012.
9. CRA Study, 12-16-2010: Ira Shavel and Barclay Gibbs (Charles River Associates), 'A Reliability Assessment of EPA's Proposed Transport Rule and Forthcoming Utility MACT."
10. CS Study, 7-2010: Credit Suisse, "A Thought... CATR is First Step in Changing the Coal Fleet."
11. DB Study, 11-2010: Deutsche Bank Group Climate Change Advisors, "Natural Gas and Renewables: A Secure Low Carbon Future Energy Plan for the United States."
12. ICF-EEI Study, 5-2010: ICF, prepared for Edison Electric Institute, "Preliminary Reference Case and Scenario Results."
13. Kaplan-EIA Study, 11-2010: Stan Kaplan, Energy Information Administration, "Potential for Displacing Coal With Generation from Existing Natural Gas Plants," presentation to the National Capitol Area Chapter, U.S. Association for Energy Economics.

- As these regulations go into effect, they will require the owners of many of the affected generators within the U.S. fleet to change their operating practices (in many cases reducing output or switching fuels) and/or apply retrofit control technologies.[21] The owners may also decide that some generators should be retired because the costs of environmental retrofit would make them non-competitive.[22]
- As more dispatchable power plants retire, new replacement capacity will be required. If replacement capacity is not sufficiently deployed there may be less generation on-line in some markets to serve load.[23] Extended outages for plants' undertaking environmental retrofits will also be a factor in determining how much capacity is available to meet load in some markets though it is very unlikely to be a factor during peak demand seasons.[24]
- Some regions have expressed concern that short-term retirements without sufficient replacement capacity could induce reliability problems (e.g., ERCOT[25]); other regions may have enough excess generation and/or few retirements and will satisfy the environmental rules relatively easily. Even if a specific region has sufficient total capacity after any plant retirements and/or retrofits, individual plants may be operationally important for local voltage support, local generation balance or other ancillary services.
- Removing a significant number of plants (even older, inefficient ones) from the supply of generation in a region may lead to an increase in power prices until new generation is added.

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14. MJBA-AGI Study, 8-2010: MJ Bradley et al of MJ Bradley Associates and Susan Tierney and Paul Hibbard of Analysis Group (prepared for the Clean Energy Group), "Ensuring a Clean, Modern Electric Generating Fleet while Maintaining Electric System Reliability."
15. NERC Study, 10-2010: North American Electric Reliability Corporation, "2010 Special Reliability Scenario Assessment: Resource Adequacy Impacts of Potential U.S. Environmental Regulation."

[21] Note, that plants that do retrofit may generate more electrical output given that they will have lower costs for emissions allowances under CSAPR.

[22] Note, however, that many executives and industry observers say that many of these retiring plants are already uneconomic – 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). A recent Congressional Research Service study estimates that a third of all U.S. coal capacity came on-line between 1940 and 1969 and two-thirds of those plants do not have scrubbers, are inefficient generators, and thus are overdue to be replaced regardless of EPA rules. (Daily Mail Reporter, "EPA plans wave of coal plant shutdowns lawmakers say will send energy costs soaring," August 21, 2011).

[23] The EIA's Electric Power Annual 2010 reported that over 52 GW of new capacity is planned to come online between 2012 and 2015, the initial year for MATS compliance. The vast majority of this capacity is natural gas fired. U.S. Energy Information Administration, Electric Power Annual 2010, Table 1.4, "Planned Generating Capacity Additions from New Generators, by Energy Source, 2011-2015" November, 2011.

[24] Note, however, that retrofit outages are almost never scheduled during peak demand periods and are typically undertaken in the fall and spring when peak demand is lowest.

[25] Electric Reliability Council of Texas. "Impacts of the Cross-State Air Pollution Rule on the ERCOT System." September 1, 2011.[26]Federal Energy Regulatory Commission. "Demand Response Compensation in Organized Wholesale Energy Markets." Order No. 745. 2011.

In the short term, these environmental regulations may affect economic dispatch in two ways. First, as noted, a combination of plant retirements, temporary retrofit outages and the construction of replacement capacity may leave fewer units available to be dispatched at any given point in time. Depending on how many additional resources are brought online, this could reduce the amount of dispatchable generation available to support renewables integration and grid reliability. Second, these retirements could have local consequences for grid reliability that make security-constrained 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. In the long term, the price on pollutants under CSAPR and any additional variable costs related to compliance with all EPA rules will continue to affect economic dispatch of generators. The future flexible system may be less dependent on large central generating stations to provide energy, capacity and ancillary services. In this scenario, the reliability of the system will be less dependent on a single facility and will be able to easily adapt to both retirements and unplanned outages.

X. The Role of Demand Response in Economic Dispatch

Demand response has the potential to improve economic dispatch by lowering costs to consumers. As noted in FERC Order No. 745, "demand response in organized wholesale energy markets can help improve the functioning and competitiveness of those markets."[26] 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. "This is 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." [27]
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." This increases the competition in the market to provide

[26]Federal Energy Regulatory Commission. "Demand Response Compensation in Organized Wholesale Energy Markets." Order No. 745. 2011.
[27] Federal Energy Regulatory Commission. "Demand Response Compensation in Organized Wholesale Energy Markets." Order No. 745. 2011.

ancillary services. This competition should lead to a downward price pressure for ancillary services.

XI. Market Power and Economic Dispatch

As noted in the previous paragraph, the exercise of market power can negatively impact economic dispatch. The 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 its absence, the merger could be expected to have adverse effects on competition in certain areas.[28]

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 offset competitiveness issues (in some cases, however unlikely) or "greatly exacerbate the competitive issues."[29] Given the structural market issues that may lend themselves to the exercise of market power, ongoing monitoring is prudent to ensure that parties are not exercising their market power to increase prices.

XII. Conclusion

Increasingly, the practice of economic dispatch will be called on to balance the three public policy goals of reliability, cost, and environmental sustainability. As discussed in this report, economic dispatch is affected by a wide array of factors. Changes in public policy on both the state and national levels have led to the growth of variable renewable generation on the grid which has 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 the large investment already made in the electric system will be dependent 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 that are necessary to best utilize the investment that we have made in the grid to date.

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[28] Federal Energy Regulatory Commission. "Order Rejecting Compliance Filing." Docket No. EC11-60-001. December 14, 2011.

[29] Monitoring Analytics. "Review and Analysis of the Proposed Merger of Exelon and Constellation." September 16, 2011.