NERC

NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Reliability Impacts of Climate Change Initiatives:

Technology Assessment and Scenario Development

to ensure the reliability of the bulk power system

July 2010

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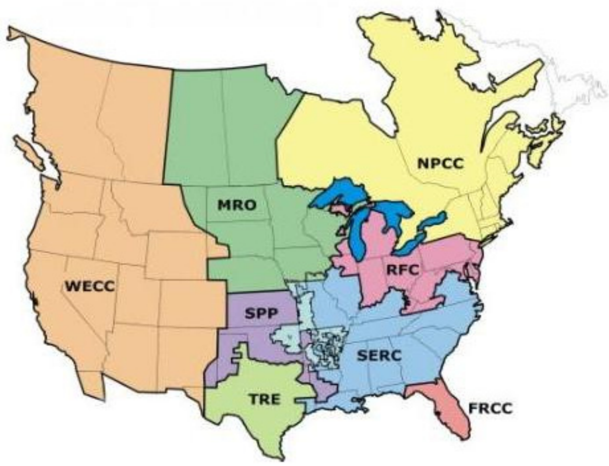
NERC's Mission

The North American Electric Reliability Corporation (NERC) is an international regulatory authority to evaluate reliability of the bulk power system in North America. NERC develops and enforces Reliability Standards; assesses adequacy annually via a 10-year forecast and winter and summer forecasts; monitors the bulk power system; and educates, trains, and certifies industry personnel. NERC is the electric reliability organization in North America, subject to oversight by the U.S. Federal Energy Regulatory Commission (FERC) and governmental authorities in Canada.[1]

NERC assesses and reports on the reliability and adequacy of the North American bulk power system divided into the eight Regional Areas as shown on the map below (see Table A). The users, owners, and operators of the bulk power system within these areas account for virtually all the electricity supplied in the U.S., Canada, and a portion of Baja California Norte, México.



Note: *The highlighted area between SPP and SERC denotes overlapping regional area boundaries: For example, some load serving entities participate in one region and their associated transmission owner/operators in another.*

Table A: NERC Regional Entities

FRCC Florida Reliability Coordinating Council	**SERC** SERC Reliability Corporation
MRO Midwest Reliability Organization	**SPP** Southwest Power Pool, Incorporated
NPCC Northeast Power Coordinating Council	**TRE** Texas Reliability Entity
RFC Reliability*First* Corporation	**WECC** Western Electricity Coordinating Council

[1] As of June 18, 2007, the U.S. Federal Energy Regulatory Commission (FERC) granted NERC the legal authority to enforce Reliability Standards with all U.S. users, owners, and operators of the BPS, and made compliance with those standards mandatory and enforceable. In Canada, NERC presently has memorandums of understanding in place with provincial authorities in Ontario, New Brunswick, Nova Scotia, Québec, and Saskatchewan, and with the Canadian National Energy Board. NERC standards are mandatory and enforceable in Ontario and New Brunswick as a matter of provincial law. NERC has an agreement with Manitoba Hydro, making reliability standards mandatory for that entity, and Manitoba has recently adopted legislation setting out a framework for standards to become mandatory for users, owners, and operators in the province. In addition, NERC has been designated as the "electric reliability organization" under Alberta's Transportation Regulation, and certain reliability standards have been approved in that jurisdiction; others are pending. NERC and NPCC have been recognized as standards setting bodies by the *Régie de l'énergie* of Québec, and Québec has the framework in place for reliability standards to become mandatory. Nova Scotia and British Columbia also have a framework in place for reliability standards to become mandatory and enforceable. NERC is working with the other governmental authorities in Canada to achieve equivalent recognition.

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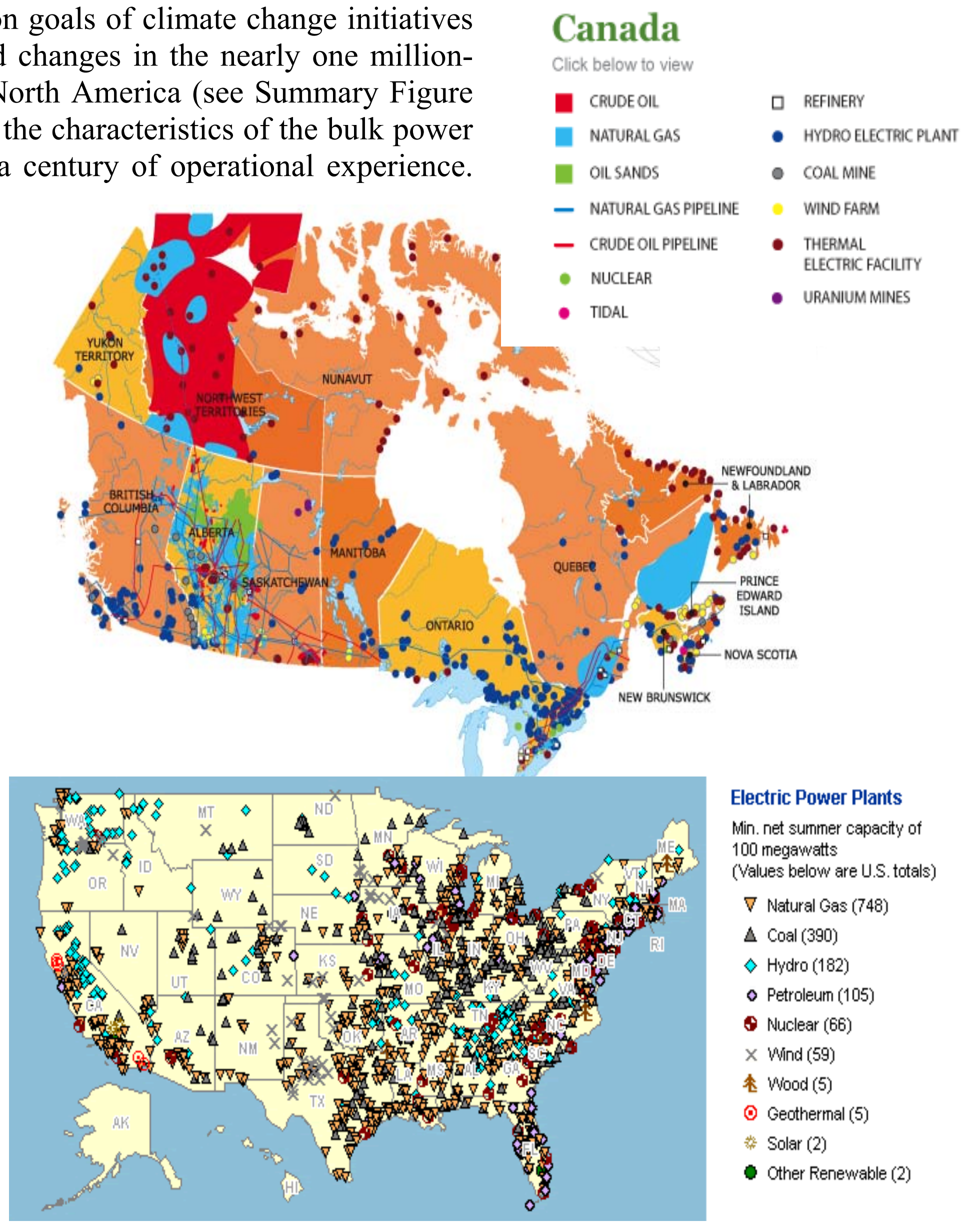
Executive Summary

Climate change initiatives proposed by governments and industry organizations will affect the way energy is used in North America. The aggressiveness or pace of mandates/targets affects near-term and long-term outcomes and the rate of new technology deployments. This report assesses the status and reliability effects from integrating new technologies promulgated by climate change initiatives as well as develops a framework for scenario assessment.

Meeting the carbon reduction goals of climate change initiatives could lead to unprecedented changes in the nearly one million-megawatt resource mix in North America (see Summary Figure 1). Industry's knowledge of the characteristics of the bulk power system comes from nearly a century of operational experience. Throughout North America, climate change initiatives, aimed at reducing carbon dioxide (CO_2) and other greenhouse gas emissions of electric power plants, are either in place (e.g., renewable portfolio standards) or under consideration. In its November 2008 report, NERC sought stakeholder advice on reliability considerations of climate change initiatives on the bulk power system.[2]

NERC's Planning and Operating Committees recognized the need to inform industry, the public, and policymakers on the reliability considerations resulting from integrating technologies required to meet the emission goals of climate change initiatives. Therefore, the Reliability



Summary Figure 1: Current Energy Mix in North America[3]

[2] NERC Special Report "*Electric Industry Concerns on the Reliability Impacts of Climate Change Initiatives,*" http://www.nerc.com/files/2008-Climate-Initiatives-Report.pdf, November 2008

[3] http://www.centreflow.ca/2009/07/03/canadas-energy-map/ and http://tonto.eia.doe.gov/state/

Impacts of Climate Change Initiatives Task Force (RICCITF) was created and charged with assessing the reliability considerations of climate change initiatives, supply resource responses, fuel mix changes and associated technologies deployed, ranging from large-scale integration of smart grids, integration of renewable, nuclear, and energy storage resources.

To form a basis for the emission reduction timeframes and goals, the task force investigated current and ongoing climate change initiatives. For example, in 2009 the U.S. House of Representatives passed the Waxman-Markey initiative proposing emission reductions below the 2005 base-year by three percent by 2012, 17 percent by 2020, 42 percent by 2030, and 83 percent by 2050.[3] In addition, Canada and the U.S. agreed to meet 17 percent reductions below the 2005 base-year by 2020 as part of their participation in the Copenhagen Accords.[4] These non-binding commitments and mechanisms formed the basis for this report's assessment.[5]

Policymakers and regulators need to consider the impacts on bulk power system reliability as part of their development of legislation and regulation processes as such analyses are generally not considered by climate scientists or policymakers. As binding emission targets and mechanisms for carbon are not known at this time, no attempt was made to complete detailed simulations addressing the magnitude of resource change and technology deployment. Until these obligations are better understood, it is difficult to identify and address all the potential effects on the reliability of the bulk power system from the resulting unprecedented shift in resources and system characteristics. However, once decided, NERC should develop a detailed assessment of the affects of mandated emission targets and mechanisms on reliability. Further detailed technical analysis will be required during the system's evolution as technologies mature, their characteristics are better understood, and sufficient operational experience is gained to provide input into NERC's Standards process.

This report reviews ongoing climate change initiatives in North America, discusses some of the reliability considerations of the resources and technologies anticipated in three time horizons between the years 2010 through 2050 (Horizon I: 1–10 years, Horizon II: 10–20 years, and Horizon III: 20-plus years), and outlines a systematic way of evaluating future pathways/scenarios. While this assessment previews potential reliability affects from integrating a variety of technologies, not all reliability impacts are known, given the current state of development. Each of the three Horizons will present unique challenges to the reliability of the bulk power system and will likely be addressed by a combination of different technologies accommodating the unique attributes of various regions in North America. For example, in Horizon II (2020–2030), a large number of coal unit retirements are projected, challenging reliability, especially in the Midwest, unless the retired capacity is offset with low-carbon emitting generation and/or sufficient quantities of demand-side management.

As Horizon III (2030–2050) approaches, continued change in the North American fuel mix could require substantial quantities of new low-carbon resources to replace additional retirements of fossil-fired units not fitted with carbon capture and sequestration (CCS). Further, in order to meet

[3] American Clean Energy and Security Bill of 2009

[4] http://www.ec.gc.ca/default.asp?lang=En&n=714D9AAE-1&news=EAF552A3-D287-4AC0-ACB8-A6FEA697ACD6

[5] The emission targets derived from the Waxman-Markey Bill and Copenhagen Accords are not representative of all aspects of these initiatives, or all mechanisms they provide. Further, only technological solutions were considered to address the full amount of the reductions.

carbon reduction targets, natural gas units without CCS may no longer be viable, increasing the need for non-emitting resources. In both Horizons II and III, the introduction of an array of existing and new technologies (e.g., coal/natural gas plants with CCS, large energy storage units, large-scale integration of Demand Response, power electronics, variable renewable generation, and electric vehicles) is possible. However, their actual implementation is dependent on substantial technological development and their effects on the reliability of the bulk power system.

The following are the key observations on reliability considerations identified in this report:

The timing of carbon reduction targets will require an unprecedented shift in North America's resource mix.

The capacity of the current resource mix is close to one million-megawatts (MW). Meeting carbon dioxide (CO_2) and other greenhouse gas emissions reduction targets will require a significant change in this resource mix, as industry reduces the use of fossil fuels. Importantly, the pace and aggressiveness of these emission targets will affect the options available for this evolution. Climate change initiatives must consider timing of emission targets and the required time for this unprecedented resource mix evolution, so industry can gain experience with new technology behavior and provide input into NERC's Reliability Standards process. Reliability considerations associated with substantial retirements of fossil fuel generation are dependent on the construction of new, low-carbon generation; new or upgraded transmission; penetration of demand-side management; integration of variable resources; deployment of carbon capture and sequestration (CCS); cyber implications of smart grids; and the construction of a large number of nuclear plants.

Regional solutions are needed to respond to climate change initiatives, driven by unique system characteristics and existing infrastructure.

While the carbon emission targets may be common to all jurisdictions, the impacts will be regional.[6] There are significant differences in generation, transmission, and distribution infrastructure characteristics across North America, so some regions presently emit proportionately greater greenhouse gases than others. Thus, meeting carbon emission targets will have significant and varying regional impacts. In some cases, resource portfolios would be dramatically changed due to different energy supply characteristics, and regional resource availability and agreements, along with other aspects that are not under federal jurisdiction. In addition, state/provincial goals/targets further drive regional aspects. Therefore, a concerted, North American-wide cooperative effort will be required to meet the goals of climate change initiatives while maintaining regional reliability of the bulk power system.

[6] This is not mean to be indicative of "NERC Region," but rather of geographical regions.

The addition of new resources increases the need for transmission and energy storage/balancing resources.

In response to climate change initiatives and resource mix mandates, location-constrained large-scale solar, wind and, in the future, increased geothermal, nuclear, and coal units fitted with CCS resources are projected. For successful integration of these resources, large quantities of new or upgraded transmission will be required to support their integration into the bulk power system. System planners will need to change their approaches to ensure that operational flexibility is available to integrate variable plants, along with other location-constrained resources. Beyond integrating transmission, additional system operational flexibility may be needed requiring deployment of a wide array of operational strategies, including access to ancillary services through balancing area agreements, shorter dispatch intervals, transmission additions, and fuel mix augmentation. Operational flexibility can be further enhanced by deploying technologies such as energy storage, Demand Response, power electronics, and variable plant diversity/resource capacity.

Carbon reduction from increasing demand-side management must be balanced against potential reliability impacts.

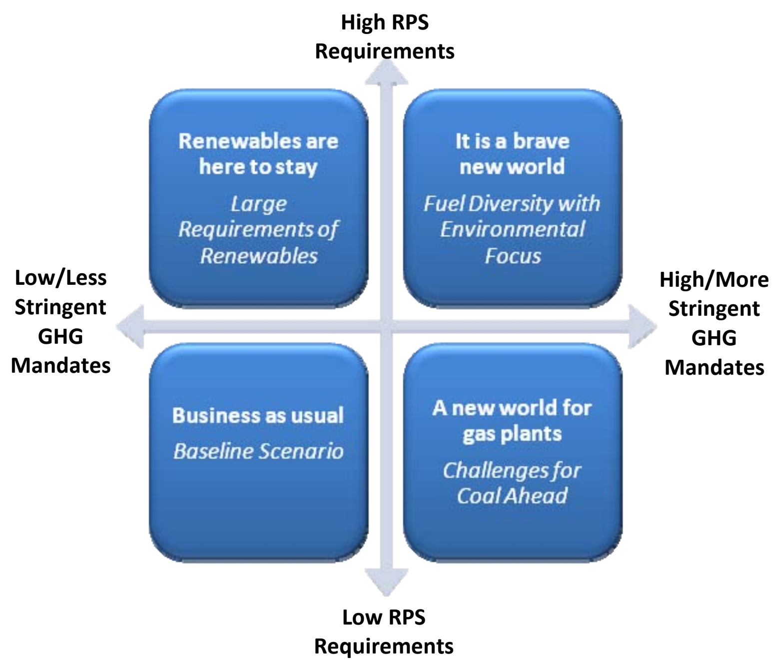
Climate change initiatives at the state/provincial level along with consumer-led efforts to reduce energy consumption will broaden the size and scope of DSM programs. Both Energy Efficiency and Demand Response can make significant contributions to the reduction in greenhouse gases. Much of the investment in Demand Response is being made at the residential level, though large end-users can provide large contributions. As demand-side management (DSM) is deployed, its certainty, locality, and characteristics must be considered to ensure reliability. Depending on DSM for long-term capacity, energy reductions, and ancillary services will require operating experience, providing more certainty of DSM's role in maintaining reliability of the bulk power system.

Climate change efforts that increasingly depend on distribution system options and applications can, in aggregate, impact bulk power system reliability.

As the amount and type of generation, or generation-like resources (e.g., plug-in electric vehicles) on the distribution system increases, it functions in a similar manner as bulk transmission, as power can flow into the distribution system, and outward onto the bulk power system. While the options and scope of the changes is not yet defined, they could include bidirectional power flow, increased use of distributed variable generation resources, and the implementation of more advanced switching and information technologies. Further, smart grid deployments on the distribution system must be completed in a secure fashion with defined preventative actions, ensuring reliability of the bulk power system.

In addition, as part of this assessment, a framework was developed to structure future reliability assessment by reviewing existing scenarios and models developed by governmental and industry organizations. This body of work involved a wide array of variables and potential outcomes, such as a large deployment of renewable resources and different cap and trade regimes. A high-level structure providing a relative comparison of renewable portfolio standards (RPS) requirements and Green House Gas (GHG) mandates is presented in Summary Figure 2.

Summary Figure 2: Proposed Scenario Matrix



Recommendations

This report concludes that various climate change initiatives will require substantial changes to the bulk power system, including the addition of new or upgraded low-carbon generation and transmission, expanded demand resources, and changes to the processes and approaches used in system planning and operations. In the future, a variety of demands on existing infrastructure will be made to support the transition from the bulk power system's current state, to one that meets carbon emission reductions. If the necessary resources are not operational in a timely manner, experience with the new resource mix may be insufficient potentially affecting reliability or require moderation of aggressive climate change goals (e.g., 80-percent reduction in carbon emissions by 2050) may be unattainable. To maintain reliability of the bulk power system, NERC should:

ASSESS

- *Assess the implications of climate change initiatives through pertinent NERC/regional scenarios as further certainty emerges around industry obligations, timelines, and targets.*

MONITOR

- *Monitor relevant studies (continent-wide, national, and regional) performed by industry groups and government agencies to provide reliability insights.*

SUPPORT

- *Support the development of tools, technology, and skill sets.*

ENHANCE

- *Continuously enhance existing and develop new Standards.*

1.0 Introduction

The electric sector is the largest source of man-made (anthropogenic) carbon dioxide (CO_2) in the United States, emitting 38 percent of the CO_2 released, while Canada's electric sector is responsible for 17 percent of their CO_2 emissions.[7] This report reviews ongoing climate change initiatives in North America, assesses the reliability considerations on the bulk power system of integrating a variety of solutions in three time horizons between the years 2010 through 2050, and outlines a systematic way of evaluating future pathways/scenarios.

In its November 2008 report, NERC sought stakeholder advice on reliability considerations of climate change initiatives on the bulk power system.[8] Recognizing the potential bulk power system reliability implications of climate change initiatives, NERC's Planning and Operating Committees formed the Reliability Impacts of Climate Change Initiatives Task Force to assess the potential reliability affects of integrating new technologies and the subsequent long-term (20 years and beyond) evolution of the grid to meet the carbon emission goals of climate change initiatives. Reliability assessment of the Climate Change initiative requires a multi-decadal outlook, a timeframe that extends well beyond the typical horizon for power system analysis and reliability assessment performed by NERC and its stakeholders. However, any assessment of the reliability of the bulk power system requires analysis of system characteristics over a variety of time scales. Such analyses are generally not considered by climate scientists or policy makers. Assessment of the reliability effects from technology integration, which are still undergoing development, is considered in the context that their design, in many cases, is not final. Design characteristics, once better understood, are important reliability considerations, vital to successful integration.

This report investigates the effects of the integration of technology on reliability targeting timeframes of 1–10 years, 10–20 years, and 20-plus years, concentrating on a variety of new generation, demand, transmission, and distribution equipment.[9] The actual technology deployments will vary throughout North America, to take advantage of regional availability of renewable fuels. In addition to the variation of natural resources, system characteristics and the topology of existing infrastructure also varies significantly across the regions. These immutable differences will drive the implementation of new technologies at a regional level, resulting in varying resource mixes and reliability considerations in each region. Therefore, these differences must be taken into account as strategies to reduce carbon emissions are evaluated and deployed across North America. For example, Figures 1-1 through 1-7[10] shows how the availability and viability of renewable fuels vary significantly across the United States.[11]

Regional solutions are needed to respond to climate change initiatives, driven by unique system characteristics and existing infrastructure

[7] Canada National GHG inventory 2008

[8] NERC Special Report "*Electric Industry Concerns on the Reliability Impacts of Climate Change Initiatives,*" http://www.nerc.com/files/2008-Climate-Initiatives-Report.pdf, November 2008

[9] See NERC's 2009 *Long Term Reliability Assessment* at http://www.nerc.com/files/2009_LTRA.pdf

[10] National Renewable Energy Laboratory, "Renewable Energy Technology Resource Maps for the United States, Updated May 2009"

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Figure 1-1: U.S. Photovoltaic Solar Resources, May 2009

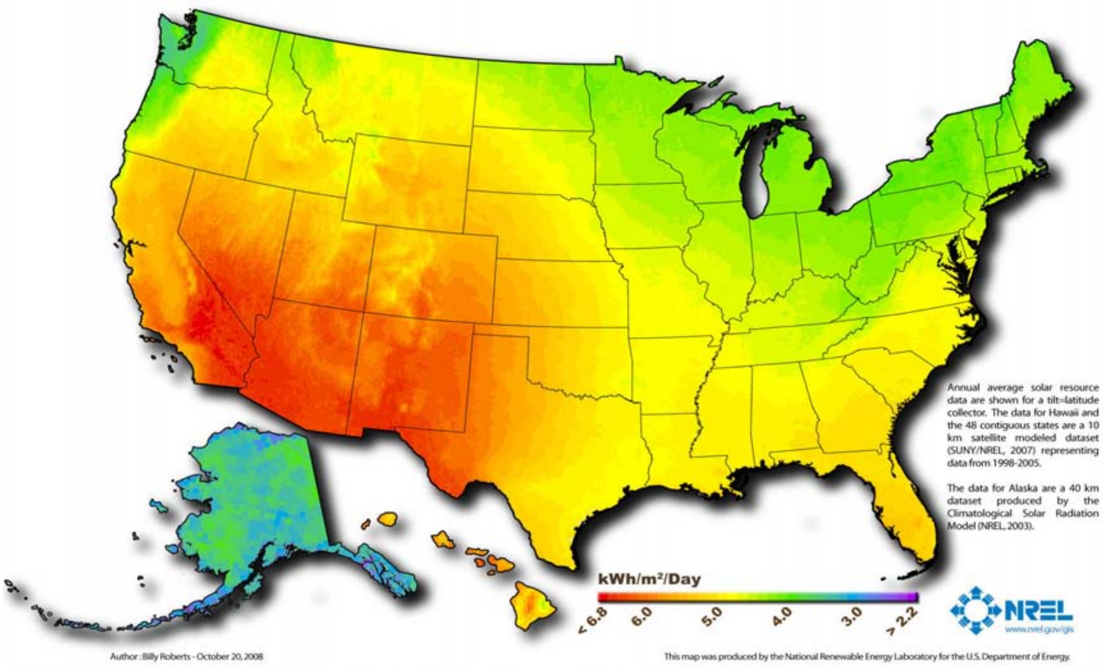

Figure 1-2: U.S. Concentrating Solar Resources, May 2009

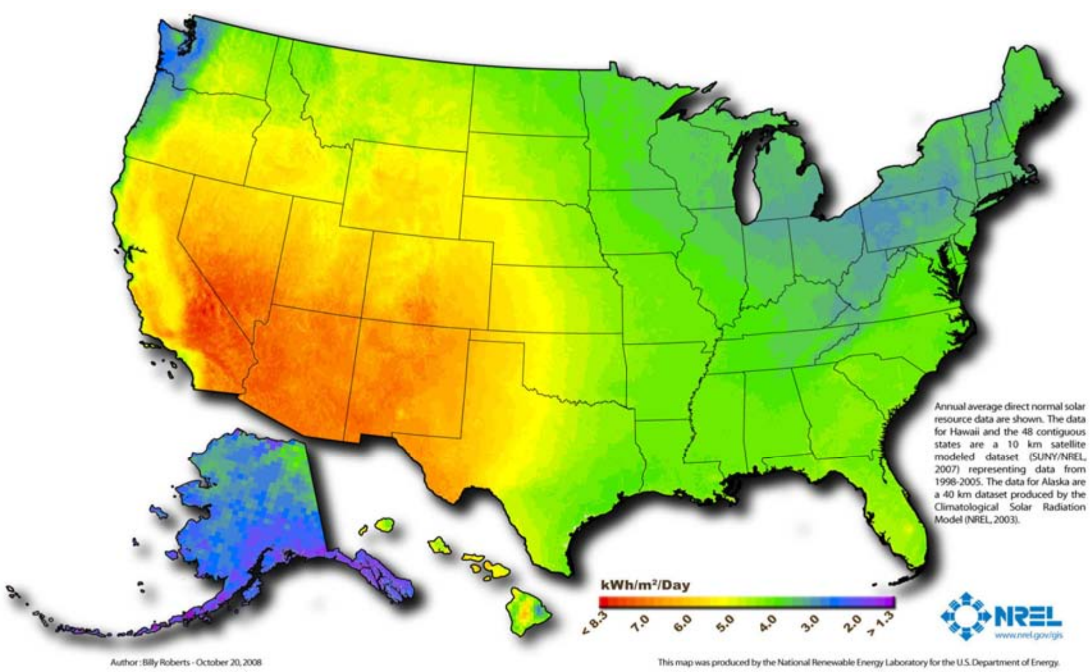

Figure 1-3: U.S. Wind Resources (50m), May 2009

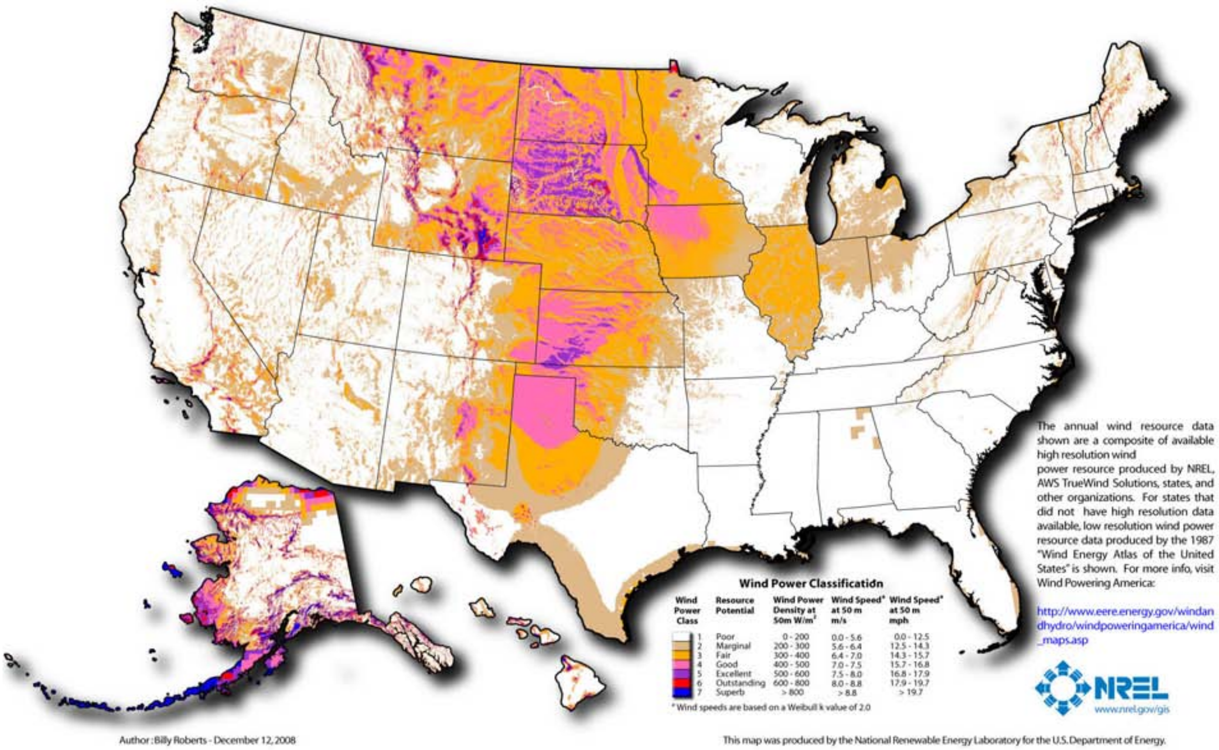

Figure 1-4: U.S. Geothermal Resources Map

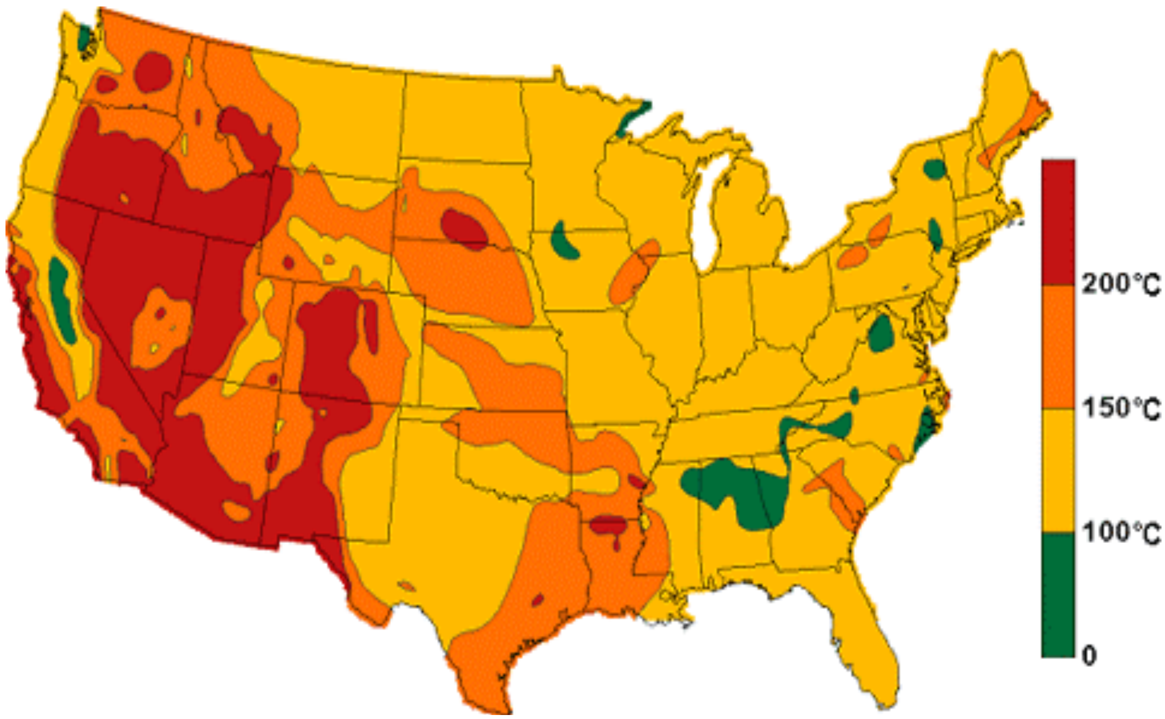

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Figure 1-5: U.S. Biomass Resources, May 2009

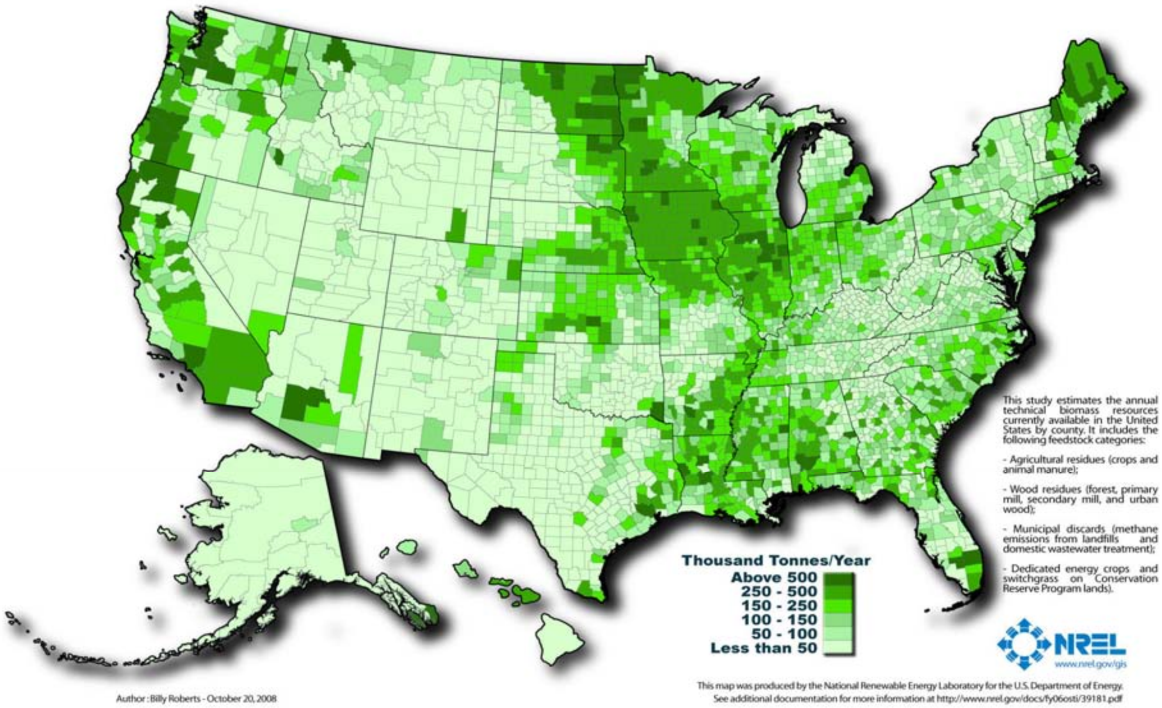
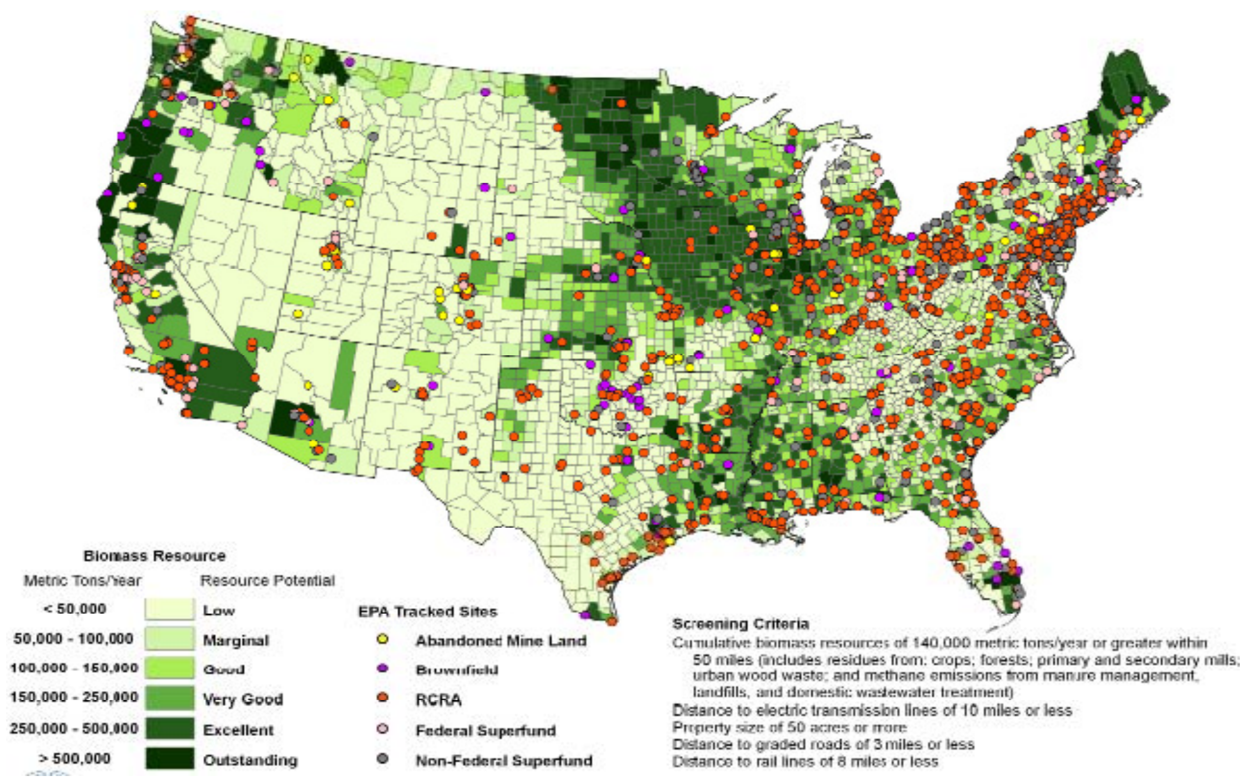
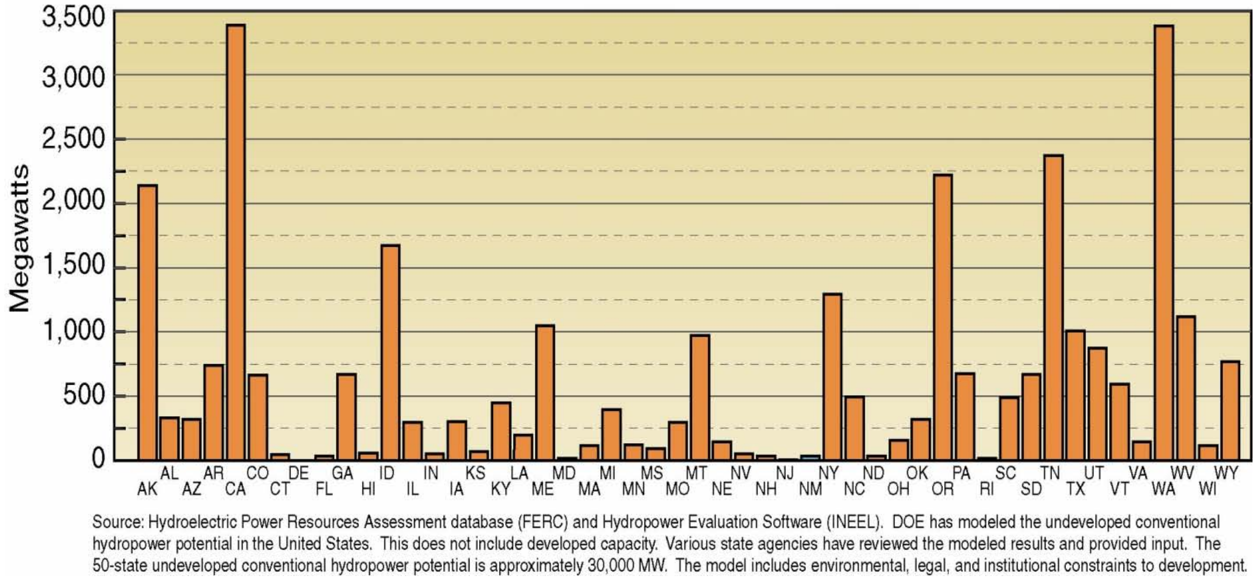


Figure 1-6: EPA Tracked Sites with Biomass Siting Potential[12]



12 EPA, March 2009

Figure 1-7: Undeveloped hydropower potential for the 50 states[13]



The bulk electric power industry is already responding to the challenges of federal, state/provincial, and regional climate change initiatives and regulations. Regulatory environments (e.g., transmission siting, permitting, cost allocation, carbon regulation, etc.) have led to uncertainty and potential reliability considerations. These considerations are not addressed in this report, though they do play a role in the industry's ability to meet carbon emission targets, now and into the future.

Report Organization

Chapter 2 provides an overview of climate change initiatives in North America; Chapter 3, a review of published scenarios and models; Chapter 4, a framework for scenario development and classification; Chapter 5, a reliability assessment of technologies for the studied time horizons; and Chapter 6, conclusions and recommendations.

[13] Idaho National Engineering and Environmental Laboratory, *U.S. Hydropower Resource Assessment Final Report*, December 1998, http://hydropower.inel.gov/resourceassessment/pdfs/doeid-10430.pdf. Also, for this graph at http://hydropower.inel.gov/hydrofacts/undeveloped_potential.shtml

2.0 Climate Change Initiatives in North America

Today's climate change initiative regulatory landscape is a patchwork of measures, using a combination of mandates to deploy renewable resources and demand-side management efforts, to reduce CO_2 and other greenhouse gas emissions. Some of these laws and regulations have been enacted at the federal, regional, state/province, or local level.

Recently, a number of proposals have been made, especially at the federal level in the U.S. Some of these climate change initiatives have received substantial support, though their proposed obligations are not finalized. This chapter provides a high-level overview of existing climate change regulation and legislation, portions of which may ultimately make up the timeframe and mechanisms for carbon emission reductions. However, it is not clear what the final obligations, if any, will be until legislation or regulation has been finalized. These proposals are provided here as context to the current legislative and regulatory environment, driving industry's resource considerations and potential effects on the reliability of the bulk power system.

2.1 United States

2.1.1 Regulation

Clean Air Act *(Existing)*
In 2007, the U.S. Supreme Court ruling in Massachusetts versus Environmental Protection Agency (EPA)[14] allowed the agency to use the Clean Air Act to regulate CO_2 emissions if they were deemed a danger to public health. In early April, 2009, the EPA declared CO_2 emissions a danger to public health. By doing so, the agency set the stage to propose new rules and to regulate emissions of the greenhouse gas from a range of industries (e.g., coal-fired power plants, refineries, chemical plants, cement firms, vehicles, and other emitting sectors).

To date, no regulation limiting these emissions has been set. However, the EPA issued an Advanced Notice of Proposed Rulemaking[15] to require reporting of greenhouse gas emissions from all sectors of the economy. The rule applies to fossil fuel suppliers and industrial gas suppliers, as well as direct greenhouse gas emitters. The proposed rule does not require control of greenhouse gases, and only those sources above certain threshold levels are required to monitor and report emissions. Recently, the EPA announced a proposal that is focused on large facilities emitting over 25,000 tons of greenhouse gases a year. These facilities would be required to obtain permits that would demonstrate they are using the best practices and technologies to minimize greenhouse gas (GHG) emissions.[16]

[14] http://www.supremecourtus.gov/opinions/06pdf/05-1120.pdf
[15] http://www.epa.gov/climatechange/emissions/downloads/ANPRPreamble.pdf
[16] http://www.epa.gov/NSR/fs20090930action.html

2.1.2 Legislation

Energy Independence and Security Act (EISA) of 2007 *(Existing)*

This Act addresses climate-related initiatives by providing:

- R&D funding for renewables and carbon capture and sequestration (CCS);
- Energy Efficiency measures and objectives for federal institutions;
- appliance standards;
- plug-in hybrid electric vehicle (PHEV) and electric vehicle (PEV) incentives; and
- definitions for "smart grid" functions, tasking the National Institute of Standards and Technology (NIST) to develop voluntary interoperable standards and a foundation for future grant programs and government funding.

The Act establishes a Renewable Fuels Standard that increases the use of these fuels from nine billion to 36 billion gallons starting in 2008 and ending in 2022. Vehicle incentives include the Corporate Average Fuel Economy (CAFE), which sets a target of 35 miles per gallon (mpg) for all light vehicles by 2020, opening the way for a higher penetration of PHEVs and PEVs over the next decade, and which could result in the need for additional resources for charging, along with demand-side management capability to promote charging during daily off-peak periods. Furthermore, EISA continues to fund research and development (R&D) for carbon capture and sequestration (CCS). To meet carbon reduction targets without CCS, industry would likely retire existing coal-fired generation and would not construct new coal-fired plants over the next 30 years. According to the Congressional Research Service, two measures—the renewable energy portfolio (RPS) and tax provisions that included oil and gas tax subsidies—were deleted from the final bill.[17] This legislation also requires the U.S. Federal Energy Regulatory Commission (FERC) to adopt voluntary smart grid interoperability standards.

American Recovery and Reinvestment Act of 2009[18] *(Existing)*

This Act includes provisions for significant investments in energy and climate related initiatives. Areas of focus include, but are not limited to, the following:

- Smart grid
- Energy efficiency
- Loan guarantees for renewables and transmission
- Interconnection-wide transmission planning
- Weatherization credits
- Geothermal and CCS research
- Electric vehicles
- PHEV support: includes $2 billion for the Advanced Battery Loan Guarantee and Grants Program potentially going toward PHEV batteries
- Energy Storage

[17] Congressional Research Service, "Energy Independence and Security Act of 2007: A Summary of Major Provisions," CRS Report for Congress, December 21, 2007, http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=110_cong_bills&docid=f:h6enr.txt.pdf

[18] http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=111_cong_bills&docid=f:h1enr.txt.pdf

The U.S. Department of Energy (DOE) has been tasked to provide guidelines for how these funds or grants will be awarded. Specifically, there are two funding opportunity announcements: the *Smart Grid Investment Grant Program* and *Smart Grid Demonstrations*. The first announcement focuses on enabling "measurable improvements that can result from accelerated achievement of a modernized electric transmission and distribution system."[19] The U.S. Department of Energy has already awarded the funds and grants for this first announcement.[20] The second is more focused on proof-of-concept exercises with specific emphasis on smart grid, synchrophasors, and energy storage, supporting demonstration projects across the transmission and distribution landscape.

American Clean Energy and Security Bill of 2009 *(Proposed)*

Informally known as the Waxman-Markey initiative, the bill was passed by the U.S. House of Representatives on June 26, 2009. The bill includes the creation of a cap-and-trade system with distinct provisions for integrating newly created emissions credit markets with international markets and specific emissions credit allocation schemes. Additionally, the bill sets forth new Combined Efficiency and Renewable Energy Standards (CERES) of 20 percent by 2020 for retail electricity suppliers, and an enhanced Renewable Energy Credit (REC) framework.[21] The legislation is currently under deliberation by the U.S. Senate.

One of the most critical points of the bill is the creation of targets and timetables for the reduction of CO_2 and other greenhouse gases. According to the bill, these emissions would be reduced below the 2005 base-year by three percent by 2012, 17 percent by 2020, 42 percent by 2030, and 83 percent by 2050. The bill also sets forth an allowance distribution program under the cap-and-trade system to achieve these goals. Under the Waxman-Markey bill, the EPA is required to establish a "federal greenhouse gas registry" for covered entities and vehicle fleets emitting more than 25,000 tons of CO_2-equivalent annually. Furthermore, the EPA is directed to finalize regulations for geologic CCS storage and propose new regulations under the Clean Air Act as well as New Source Review rules. The projected allowance distributions[22] for 2016 and 2030 are shown in Figures 2-1 and 2-2, respectively.

Another critical element of this bill is the creation of carbon offsets as the main cost-containment mechanism, allowing the use of up to two billion tons annually of an offset—up to one billion tons from domestic sources and, with a waiver, up to 1.5 billion tons from international sources. The domestic offsets are mainly from agricultural and forestry projects, while the international offset are divided into three basic categories: (1) credits from developing countries under a sector-based program, (2) credits issued by an international body (e.g., Clean Development Mechanism or CDM), and (3) credits from reduced deforestation. Nevertheless, there are restrictions on the use of the offsets for compliance as restrictions arise over time. These carbon offsets, if the bill is unchanged and approved by the U.S. Senate, will have a direct impact on the current generation fleet.

[19] Pg. 2, Funding Opportunity Announcement for the Smart Grid Investment Grant Program, DE-FOA-0000058
[20] http://www.energy.gov/recovery/smartgrid_maps/SGIGSelections_Category.pdf
[21] American Clean Energy and Security Bill of 2009
[22] Congressional Research Service, "*Climate Change Cost and Benefits of the Cap-and-Trade Provisions of H.R. 2454,*" http://energy.senate.gov/public/_files/R40809.pdf

Figure 2-1: Simplified Emission Allowance Distribution under Waxman-Markey 2016

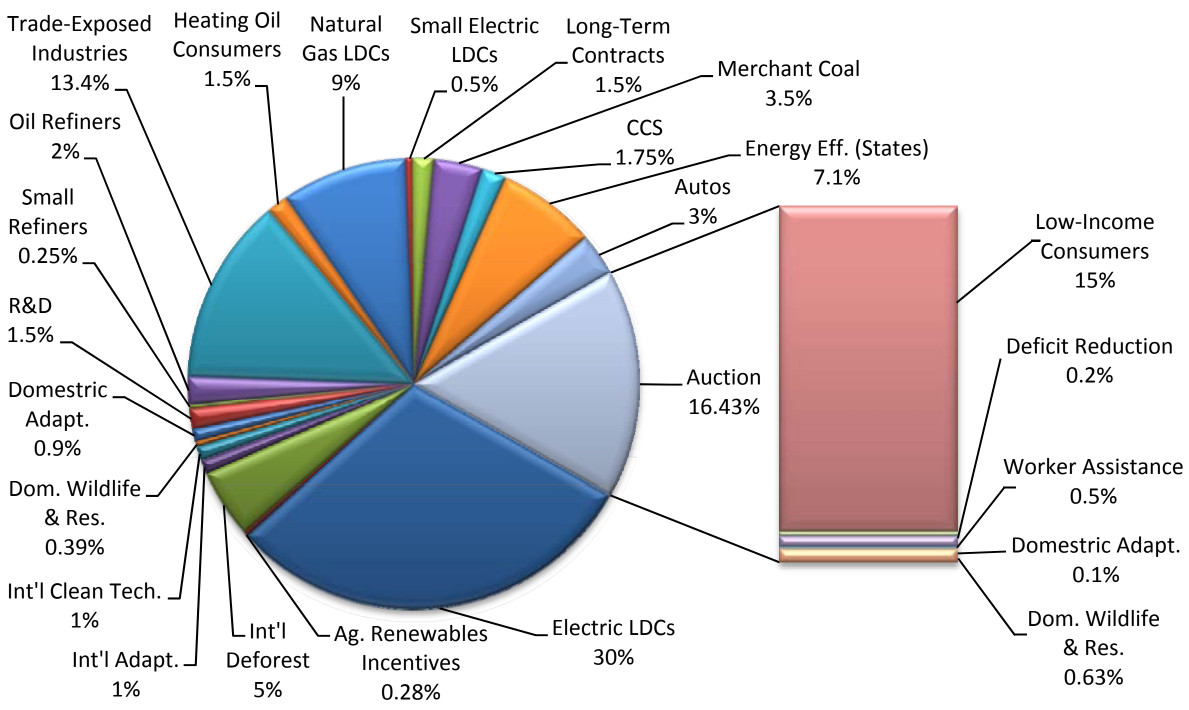
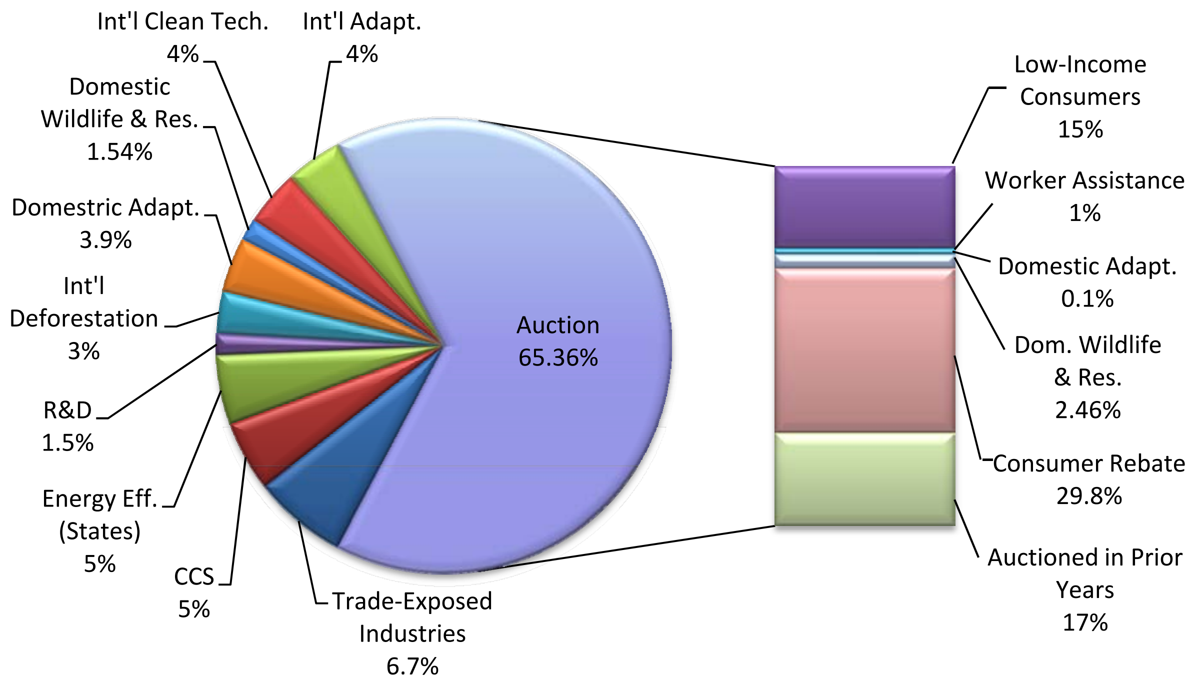


Figure 2-2: Simplified Emission Allowances Distribution under Waxman-Markey 2030



Climate Change Initiatives in North America

The bill also sets smart grid and peak-demand reduction goals to be established no later than one year after the enactment of the bill. It applies to any load-serving entity (LSE) with demand larger than 250 MW. FERC will be responsible for developing a method for adjustments to the applicable baseline, while DOE—in consultation with FERC, EPA and NERC—will develop a system and rules for measurement and verification of demand reductions. LSEs must specify reduction and mitigation by a minimum percentage from the applicable baseline to a lower peak demand during 2012, with greater reductions required in 2015.[23]

The bill calls for the submission of a detailed plan to address legal and regulatory barriers to the commercial availability of carbon capture and sequestration (CCS) technologies. The technology is projected to be commercially available by 2020 and must come on-line by 2025 to be viable. Overall, an initial EPA analysis of the initiative's Discussion Draft reveals that the Energy Efficiency and subsequent reduced energy demand would delay energy consumption levels previously forecast for 2015 until around the middle of the century. However, there are wide-ranging estimates of the annual economic impact of this legislation.

Federal Renewable Portfolio Standards *(Proposed)*

In addition to the Waxman-Markey bill, other legislative initiatives include renewable energy portfolio standards. Specifically, potential legislation S. 1462, called the "American Clean Energy Leadership Act," was drafted in response to the President's call for a federal renewable portfolio standard (RPS) of 25 percent by 2025. Another piece of legislation that would have a direct impact on the enablement of RPS is legislation S. 539, called the "Clean Renewable Energy and Economic Development Act." The legislation provides, among other things, a framework and process for the government to designate geographies that will become "National Renewable Energy Zones." Furthermore, the draft legislation also provides specific provisions for transmission to ensure "interconnection-wide coordination of planning to integrate renewable energy resources from renewable energy zones into the interstate electric transmission grid and make the renewable energy resources fully deliverable to electricity consuming areas."[24]

Additional Federal Emission Trading Programs *(Existing)*

The United States has put into effect other emissions trading programs since the 1970s, including EPA's Clean Air Markets Program, consisting of various market-based programs aimed at reducing concentrations of sulfur dioxide, nitrogen oxides, and mercury. These pollutants and corresponding mitigation technologies would also play a role in evaluating fossil generation going forward, especially if regulations are changed and become more stringent.[25]

[23] Based on EEI Global Climate Change Subcommittee Meeting, June 22, 2009
[24] Pg.17, proposed Clean Renewable Energy and Economic Development Act
[25] EPA Clean Air Markets website; http://www.epa.gov/airmarkt/

2.2 Canada

In December 2002, Canada ratified the Kyoto Protocol,[26] committing to reduce greenhouse gas emissions to six percent below the country's 1990 levels between 2008 and 2012. To meet these objectives, a "Climate Change Plan for Canada"[27] was developed to bridge the 240 million-ton (MT) gap between the business-as-usual scenario and Kyoto Protocol objectives. The plan was structured around five main instruments:

- emission reductions targets for large industrial emitters, including power generators;
- creating a partnership fund that will share the costs of emissions reductions;
- investing in strategic infrastructure and innovative climate change proposals;
- defining an innovation strategy supporting commercial benefits to Canadian industries; and
- implementing targeted measures to achieve climate change objectives in specific areas (e.g., incentives, regulations, and tax measures).

In further developments since 2002, Canada has committed to reducing its greenhouse gases by 17% below the 2005 level by 2020. This target is aligned with the US commitment under the Accord.

Pursuant to this commitment, the Government of Canada is taking action to reduce greenhouse gas emissions in the electricity sector by moving forward with regulations on coal-fired electricity generation. The proposed regulations will apply a stringent performance standard to new coal-fired electricity generation units and coal-fired units that have reached the end of their economic life. The standard will be based on parity with the emissions performance of high-efficiency natural gas generation. The standard will promote the replacement of coal-fired units that are reaching the end of their economic life. Additionally, it will encourage investment in cleaner generation technologies, such as high efficiency natural gas generation and renewable energy, as well as the use of carbon capture and storage. The regulation will be very clear—when each coal burning unit reaches the end of its economic life, it will be required meet the standard or close down. Offsets, credits, and trading will not be permitted. In order to allow for adequate replacement generation to be brought on-line, this proposed standard will take effect five years from the announcement made on June 23rd, 2010.[28]

2.3 Regional (State or Provincial) Legislation

2.3.1 United States

States have also begun enacting climate change related initiatives, often targeting different areas: greenhouse gas emissions targets, carbon-cap or offset requirements for power plants, public benefit funds (renewables and Energy Efficiency), renewable portfolio standards, net metering, green pricing, Energy Efficiency resource standards, and building and appliance standards.

[26] Under the Kyoto Protocol, the European Union put into effect a cap-and-trade program consisting of an initial learning phase through 2005 and a subsequent trading period in 2008, which controlled CO_2 emissions from certain sectors.

[27] http://dsp-psd.pwgsc.gc.ca/Collection/En56-183-2002E.pdf

[28] http://www.ec.gc.ca/Publications/default.asp?lang=En&xml=AD9054AB-6F3E-4A78-9557-E4010A980D92

According to the Pew *Climate Change 101* report,[29] state initiatives include:

- 28 states with developed climate action plans;
- 12 states with GHG emissions targets;
- 30 states with RPS;
- 41 states with net metering; and
- 36 states with green energy pricing programs.

Regional Greenhouse Gas Initiatives

- **Northeast Regional Greenhouse Gas Initiative (RGGI)**: RGGI is "the first-in-the-nation mandatory, market-based effort in the United States to reduce greenhouse gas emissions,"[30] a cap-and-trade system aimed at reducing CO_2 emissions from power plants. RGGI went into effect on January 1, 2009, for ten Northeastern and Mid-Atlantic States: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. Most allowances are auctioned rather than distributed. RGGI's first carbon auction occurred on September 25, 2008. Auction revenues are directed towards investment in Energy Efficiency and renewable energy. The system is regulated primarily at the state level according to a template called the Model Rule.[31] According to RGGI, fossil fuel power plants of at least two megawatts (MW) should keep current CO_2 emissions at a stable level until 2014, when the cap will decline by 2.5 percent annually until 2018, after which, they are targeted to be 10 percent lower than 2009 levels.
- **Northeast regional NO_x Budget Trading Program**: EPA set up a regional cap-and-trade program to reduce NO_x emissions in 2003.[32]
- **Western Governors' Association (WGA)**: Strategies focused on increasing Energy Efficiency while expanding the use of renewable energy sources in the region and encouraging carbon capture and sequestration (CCS). Recently, the WGA released a roadmap outlining the need for transmission to support integration of renewable resources.[33]
- **Southwest Climate Change Initiative**: Signed by the governors of Arizona and New Mexico in February 2006. Under the agreement, the two states will collaborate to reduce greenhouse gas emissions and address the impacts of climate change in the Southwest.
- **West Coast Governors' Global Warming Initiative**: The West Coast states—Washington, Oregon and California—are cooperating to reduce emissions. Among the governors' plans: adopting comprehensive state and regional goals for reducing emissions, expanding markets for renewable energy, Energy Efficiency, and alternative fuels.
- **New England Governors and Eastern Canadian Premiers**: In 2001, six New England states agreed to the New England Governors and five Eastern Canadian Premiers (NEG-ECP) climate action plan including short- and long-term goals for greenhouse gas emissions.

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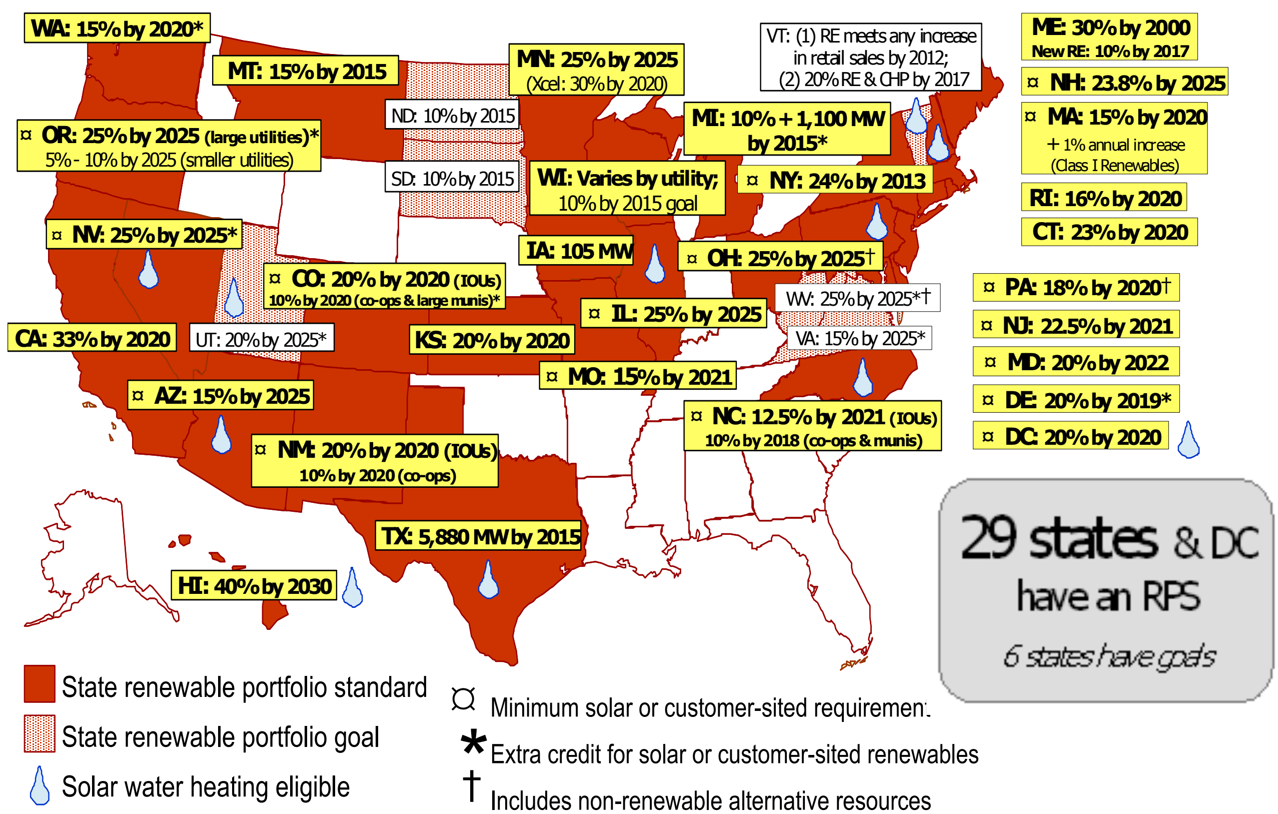
[29] http://www.pewclimate.org/global-warming-basics/climate_change_101
[30] Regional Greenhouse Gas Initiative, "About RGGI," RGGI website: http://www.rggi.org/home
[31] McMillan, "The Regional Greenhouse Gas Initiative: First Auction to Occur September 25, 2008," *Emissions Trading and Climate Change Bulletin* (September 2008), http://www.mcmillan.ca/Upload/Publication/RegionalGreenhouse_0908.pdf
[32] Ibid - http://www.epa.gov/airmarkt/progress/docs/2006-NBP-Report.pdf
[33] Western Governors' Association, *Renewable Energy Transmission Roadmap,* June 2010, http://www.westgov.org/index.php?option=com_joomdoc&task=doc_download&gid=1282

- **Powering the Plains:** In 2002, participants from five Midwestern states—North and South Dakota, Minnesota, Iowa, and Wisconsin—and the Canadian province of Manitoba agreed to develop strategies and policies. The goal is to support alternative energy demonstrations for coal gasification, hydrogen, and biomass.

State Renewable Portfolio Standards

Nearly 30 states have adopted RPS specifying a percentage of the electricity energy supply to be generated from renewable energy sources. The specific percentage objective, the target achievement year, the nature of eligible renewable activity, voluntary versus mandatory, new build versus legacy, and the nature of the objectives are some of the parameters that vary from state to state. Generally, the RPS targets would require phasing in 15–25 percent of energy from renewable generation by 2020 to 2025 (see in Figure 2-3).

Figure 2-3: RPS details by U.S. State[34] (November 2009)



2.3.2 Canada

Most individual provinces have set objectives to reduce GHG emissions taking complementary measures to promote renewable energy development and Energy Efficiency (see Table 2.1).

[34] From http://www.dsireusa.org/summarymaps/index.cfm?ee=1&RE=1

Climate Change Initiatives in North America

Table 2.1: Reliability portfolio standard details by Canadian Province[35]

Province	Year	Target[36] (relative to 1990 emissions)	Other Electrical Sector Specific
Alberta	2020 2050	+20% to 35% +18%	• RPS Generate 12.5% of electricity from renewables by 2008 • RPS 20% renewables by 2020
British Columbia	2020 2050	-10% -73%	• Carbon Capture and storage required for all coal-fired electricity generation facilities • 90% of electricity must come from clean or renewable energy (no target date) • By 2016, electricity generation facilities must be carbon neutral
Manitoba	2010 2012	+12% -6%	• New transmission line (East-West) to improve distribution of renewable energy
New Brunswick	2012 2020	No Change -10%	• RPS 10% renewables in generation mix by 2016 • Energy Efficiency measures that aim to reduce GHG emissions by 2.2 megatons by 2012
Newfoundland	*None*	*None*	
Nova Scotia	2020	-10%	• RPS 18.5% renewables in generation mix by 2013
Ontario	2014 2020 2050	-6% -15% -80%	• All coal-powered plants phased out by 2014 • Baseline and credit system • Double hydro, wind and solar capacity 2025
Quebec	2012 2020	-6% -20%	• Possible joint cap-and-trade with Ontario • Carbon tax on fuels
Saskatchewan	2020	-30%	• Generation - Since 2007 new plants must be carbon neutral or offset by credit purchases • DSM - 300 MW saved by 2017

2.4 Joint Canadian – U.S. Initiatives

Western Climate Initiative

The Western Climate Initiative (WCI) is signed by seven U.S. states and four Canadian provinces. It includes a regional cap-and-trade program that adopts the WCI regional goal of reducing greenhouse gas emissions by 15 percent from 2005 to 2020, regulating six of the most common greenhouse gases. The initial regional emissions cap applies to sources that emit 25,000 metric tons or more of carbon dioxide per year and may be revised.[37] Phase I of the initiative is set to begin in 2012.

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[35] Accenture Analysis. Data: Peterson Institute for International Economics, report entitled *"North America Climate Change Action by State and Province,"* at http://www.piie.com/publications/papers/fickling0811.pdf

[36] "

[37] Western Climate Initiative, "Design Recommendations for the WCI Regional Cap-and-Trade Program," September 23, 2008, http://www.westernclimateinitiative.org/

Clean Energy Dialog

The federal governments of both Canada and the U.S. have discussed cooperative and collaborative efforts aimed at clean energy development.[38] The goals of this dialog are to:

- expand clean energy research and development;
- develop and deploy clean energy technology; and
- build a more efficient electricity grid based on clean and renewable generation.

2.5 Copenhagen Accords

The 2009 United Nations (UN) Climate Change Conference, commonly known as the Copenhagen Summit, was held in Copenhagen, Denmark, from December 7–18, 2009. The conference included the 15th Conference of the Parties (COP 15) to the United Nations Framework Convention on Climate Change and the 5th Meeting of the Parties (COP/MOP 5) to the Kyoto Protocol. The Copenhagen Accord[39] was drafted by the U.S., China, India, Brazil, and South Africa on December 18, 2009. The document suggested that actions should be taken to keep any temperature increases to below 2°C. The document is not legally binding, nor does it contain legally binding commitments for reducing CO_2 and other greenhouse gas emissions. It was recognized by the participants, but not passed. The Copenhagen Accord asked countries to submit emissions targets by the end of January 2010, and paved the way for further discussions to occur at the 2010 UN climate change conference in México and the mid-year session in Bonn, Germany. Recently, Canada and the U.S. made a non-legally binding commitment to meet 17 percent reductions in carbon emissions by 2020 below the 2005 base-year.

2.6 Carbon Reduction Assumptions in this Report

As mentioned above, the U.S. House of Representatives passed the Waxman-Markey Bill in 2009, proposing emission reductions below the 2005 base-year by three percent by 2012, 17 percent by 2020, 42 percent by 2030, and 83 percent by 2050.[40] As part of their response to the Copenhagen Accords, Canada and the U.S. made a non-legally binding commitment to meet 17 percent reductions below the base-year of 2005 by 2020.[41] These emission reduction targets form the basis for the conclusions of this reliability assessment.[42]

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[38] http://www3.thestar.com/static/PDF/090219Annex_US-Canada_CleanEnergyDialogue.pdf
[39] http://unfccc.int/resource/docs/2009/cop15/eng/l07.pdf
[40] American Clean Energy and Security Bill of 2009
[41] http://www.ec.gc.ca/default.asp?lang=En&n=714D9AAE-1&news=EAF552A3-D287-4AC0-ACB8-A6FEA697ACD6
[42] The emission targets derived from the Waxman-Markey Bill and Copenhagen Accords are not representative of all aspects of these initiatives, or all mechanisms they provide. Further, only technological solutions were considered to address the full amount of the reductions.

3.0 Overview of Published Scenarios and Models

Scenarios have been developed and published by government and industry organizations to model the impact of new technologies as well as various potential legislative and regulatory activities. A variety of models and scenarios from past and current work were reviewed as part of the development of this report and the results of this assessment appear below.

➢ **NERC: *2009 Scenario Reliability Assessment*** [43]

Two scenarios representing a ten-year horizon were studied and documented by the North American Electric Reliability Corporation (NERC) and its stakeholders. Each was based on a 50/50 summer/winter peak demand forecast, and projected changes in the project resource mix for one of the following scenarios:

- **Scenario 1: North American-wide Renewable Portfolio Standard**—A target of 15 percent of all energy must be met with new renewable resources. Thirty-three percent of this target may be met by Energy Efficiency and Demand Response. Seven of the eight NERC Regions chose this option.
- **Scenario 2: Another Similar Scenario of the Region's choosing**—SERC chose this option, studying the integration of high-levels of new nuclear capacity.

The highlights of NERC's *2009 Scenario Reliability Assessment* were as follows:

- Wind power formed the basis of the projected renewable expansion
- Transmission is critical to meeting targets, as over 40,000 miles were projected
- Energy Efficiency increases were projected
- Increased penetration of variable generation may require higher operating and planning reserve margins

➢ **Charles River Associates International: The Impact of the Climate Provision in the Obama Administration's FY2010 Budget Proposal**[44]

This effort uses the Multi-Sector, Multi-Region Trade (MS-MRT) model, the Multi-Region National (MRN) model, and the North American Electricity and Environment Model (NEEM). The CRA models used in this analysis simulate the operations of major features of the U.S. economy and its energy system, so that it is possible to trace the many pathways through which legislation can affect various economic sectors and activities. The study examines the climate provisions of the Obama administration's FY 2010 budget proposal as it relates to the energy sector. The base case is constructed to conform to the projections of the 2009 Annual Energy Outlook (AEO) produced by the Energy Information Administration (EIA) of the U.S. Department of Energy. The dataset included the following sectors:

[43] http://www.nerc.com/files/2009_Scenario_Assessment.pdf
[44] http://library.uschamber.com/sites/default/files/reports/0904climateprovision.pdf

Overview of Published Scenarios and Models

- Coal
- Crude oil
- Electricity
- Natural gas
- Refined petroleum products
- Agriculture
- Energy-intensive sectors
- Manufacturing
- Services
- Commercial transportation

The FY 2010 budget proposal provided baseline growth rate, energy consumption, energy production, and energy prices to which the model is benchmarked. The model is benchmarked to assume baseline rates of economic growth based on official government statistics and a common rate of return on capital in all countries. Key variables include:

- Effect on international price
- Investment
- Industry output
- Changes in household welfare
- Gross domestic product
- Terms of trade
- Wage impacts
- Commodity price changes

- **U.S. Department of Energy: 20 Percent Wind Energy by 2030**

The DOE examined the generation capacity required for wind to comprise 20 percent of U.S. electricity by the year 2030.[45] Two main issues examined were transmission and variability using the WinDS model, a national electric capacity expansion model developed by the National Renewable Energy Laboratory. The scenario does not consider the variable nature of wind generation to be a hindrance in achieving 20 percent wind, stating the costs of integration "amounted to about 10 percent or less of the wholesale value of the wind energy."[46] It does, however, recognize its contribution in each scenario and in the system's operating cost. "The impact of wind's variability depends on the nature of the dispatchable generation sources, their fuel cost, the market and regulatory environment, and the characteristics of the wind generation resources."[47]

- **U.S. Energy Information Administration: Annual Energy Outlook 2008[48]**

The EIA used its National Energy Modeling System (NEMS) to evaluate numerous modules by sector. It examined four types of scenarios: a baseline projection, alternative world oil prices, proposed energy fees or emissions permits, and proposed changes in Corporate Average Fuel Efficiency (CAFE) standards. It evaluated these scenarios based on energy supply and demand, delivered prices of energy to consumers, examined quantities consumed, and other characteristics specific to each sector. Model outputs showed the impacts of alternative energy policies—specifically production, imports, conversion, consumption, and prices of energy—and of different assumptions about energy markets.

[45] DOE, "20% Wind Energy by 2030," July 2008, http://www1.eere.energy.gov/windandhydro/pdfs/41869.pdf
[46] DOE, "20% Wind Energy by 2030," July 2008, http://www1.eere.energy.gov/windandhydro/pdfs/41869.pdf
[47] Ibid., Pg. 82
[48] http://www.eia.doe.gov/oiaf/aeo/pdf/0383(2008).pdf

- **U.S. Energy Information Administration: Impacts of a 25 Percent Renewable Electricity Standard (RES) as Proposed in the American Clean Energy Security Act (ACESA)[49]**

  An analysis of the RES provisions in the ACESA draft on a stand-alone basis shows resultant renewable generation levels as follows:

  - Reference case from AEO 2008 (updated)
  - RES with its Full Efficiency Credits case assumes the maximum level of efficiency credits, up to one-fifth of the credits in the target for any given year, are claimed. This is reflected as a 20-percent reduction in the effective target for eligible renewable generation.
  - RES with its No Efficiency Credits case assumes that states cannot qualify for, or elect not to use, efficiency credits.

  Variables included the amount of renewable generation increases in biomass, wind, solar, etc., the value of the RES credits and the renewable credit prices, and electricity prices (increase, decrease). Constraints used involved wind and solar power development. Also acknowledged was the variable nature of the wind and solar resources, which may lead to the need for additional capacity to ensure that consumers' need for electricity can be met at all times. Outputs addressed the level of renewables required to comply with the RES, growth in renewable generation, natural gas, and price changes. Regional results were determined, such as compliance and the number of credits imported or exported.

- **Electric Reliability Council of Texas (ERCOT): Effects of Proposed Climate Change Legislation on Electricity Prices in the ERCOT Market[50]**

  A study was completed in Texas to assess the effects of proposed climate change legislation on electricity market prices. The scenarios were intended to illustrate the impacts due to several discrete levels of carbon emissions costs, natural gas prices, and reductions in consumer electrical demand due to higher electric prices. Additionally, the intent was to illustrate the impact of increased penetration of wind generation in combination with some of these other variables. The effort simulated the cost-based, hourly dispatch of all existing and committed generation in the ERCOT region to serve the electric load for the year 2013. Inputs included several scenarios defined by:

  - the level of natural gas prices ($7 and $10 per MM British thermal unit or BTU);
  - the size of potential reduction in energy use as compared to the forecast load for 2013 (zero percent, two percent, five percent, and ten percent reductions); and,
  - The amount of installed wind generation (the approximately 9,400 MW of existing and committed wind generation installed capacity and the 18,456 MW of total wind generation installed capacity for which the PUCT has ordered a transmission plan to be constructed in the Competitive Renewable Energy Zones or CREZ Docket 33672).

[49] http://www.eia.doe.gov/oiaf/servicerpt/acesa/pdf/sroiaf(2009)04.pdf
[50] http://www.ercot.com/content/news/presentations/2009/Carbon_Study_Report.pdf

For each scenario, the study performed simulations at increasing carbon allowance costs of \$0, \$10, \$25, \$40, \$60, and \$100 per ton of CO_2 (in U.S. dollars). Variables costs, including carbon emissions allowance costs, were considered.

Because the economic dispatch used in the simulations performed for the study are cost-based, they do not include any market-driven bidding behavior or scarcity pricing. The wholesale prices and wholesale market costs reported from the simulations are cost-based as a result.[51] Outputs included the change in total annual wholesale power costs (the costs paid by consumers) and wholesale prices (expressed as load-weighted average locational marginal prices or LMPs), production costs, and total CO_2 emissions. Similar output variables were noted for each scenario, such as emissions, wholesale prices, and the cost of producing electricity on an annual basis.

➢ **Intergovernmental Panel on Climate Change (IPCC) Emissions Scenarios**

As background, the IPCC first developed long-term emissions scenarios in 1990. Since that date, they have gone through extensive revisions. The most recent effort by the IPCC to refresh and redesign these scenarios began in 1996 and was finalized and reported on in 2000.[52]

The goal of this IPCC effort was to develop a set of scenarios that demonstrate how driving forces, such as demographic development and socio-economic development, will affect future levels of emissions. Modeling emissions of future greenhouse gas is a complex task and, therefore, the IPCC refrained from interpreting the results to support potential policy decisions. In other words, they did not create scenarios that explicitly assume implementation of the United Nations Framework Convention, Climate Change (UNFCCC) or the emissions targets of the Kyoto Protocol. Instead, they constructed four storylines "to describe consistently the relationships between emission driving forces and their evolution and add context for the scenario quantification." Moreover, "each storyline represents different demographic, social, economic, technological, and environmental developments, which may be viewed positively by some people and negatively by others" (Source: Pg. 3, IPCC Special Report: Emissions Scenarios, IPCC, 2000).

Scenario descriptions comprised four storylines, labeled A1, A2, B1, and B2. They are described by the IPCC (Source: Pg. 4–5, IPCC Special Report: Emissions Scenarios, IPCC, 2000) as follows:

- The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes include convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income.

51 http://www.ercot.com/content/news/presentations/2009/Carbon_Study_Report.pdf
52 *IPCC Special Report: Emissions Scenarios,* IPCC, 2000, http://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf

- The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological changes are more fragmented and slower than in other storylines.
- The B1 storyline and scenario family describes a convergent world with the same global population that peaks in mid-century and declines thereafter as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.
- The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with continuously increasing global population at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

In summary, the climate modeling done by the IPCC is dependent on a base of inputs and assumptions that underlie key social, economic, institutional, and technological factors. Some primary inputs include regional per capita incomes, world gross domestic product (GDP), and world population forecasts. Others include global and regional energy intensities, primary energy consumption and the share produced by coal, and the share of primary energy consumption produced by zero-carbon resources. In addition, the key to this modeling exercise was to establish important variables including demographic shifts as well as future fossil fuel consumption patterns that would drive the variation in reported results. These results included forecast world populations, future levels of economic activity, potential fuel mixes for energy generation, and estimated greenhouse gas emissions.

Overall, while this analysis produced estimates for these results for all storylines and scenarios, the focus was to establish a program for "on-going evaluations and comparisons of long-term emissions scenarios, including a regularly updated scenario database."

➢ **Midwest-ISO: Midwest Transmission Expansion Plan (MTEP)**[53]

Potential Midwest ISO transmission expansion scenarios were developed. Methods involved production cost simulation that projected location-specific prices that would occur in a bid-based energy market. Four generating scenarios, as listed below, were evaluated against 11 transmission scenarios:

[53] http://www.midwestmarket.org/publish/Folder/193f68_1118e81057f_-7f900a48324a

- Baseline
- Higher natural gas
- Higher coal
- High wind

For the wind scenario, Midwest ISO used the Midwest Wind Development by the American Wind Energy Associations (AWEA) and Wind on the Wires, a stakeholder group aimed at developing new transmission for wind projects in the Midwest. The plan called for 10,000 MW of wind at various points in the Midwest to serve metropolitan areas. The effort identified projects required to maintain reliability for a 10-year period. The study used an average natural gas price of $3.50 per MMBTU and a "high" natural gas price scenario of $5 per MMBTU (which was considered high at the time but is currently about the national average for natural gas prices). The key variable used was cost. Midwest ISO determined that under the high wind scenario, lower marginal costs of wholesale energy might be realized as long as there is additional transmission investment.

➢ **Massachusetts Institute of Technology (MIT): Assessment of U.S. Cap and Trade Proposals**[54]

Three core cases were evaluated using the MIT Emissions Prediction and Policy Analysis model (EPPA). The assessment conducted a multi-region, multi-sector, recursive-dynamic representation of the global economy looking at six sectors and addressed energy, unconventional gas, etc., in developed and developing countries/regions.

Inputs to the assessment included proposed mitigation measures—actions directed at CO_2—and targeted control measures and reductions in the emissions of:

- CO_2 from the combustion of fossil fuels;
- industrial gases that replace CFCs controlled by the Montreal Protocol and produced at aluminum smelters;
- CH_4 from a number of sources; and
- N_2O from chemical production and improved management of inorganic fertilizer applications.

For the core cases, three allowance paths were specified that start in 2012 by returning to 2008 levels, extrapolating 2008 emissions from the 2005 inventory by assuming growth at the recent historical rate of one percent per year as documented in U.S. EPA. The assumptions included decisions made based on current period prices. Variables included representation of abatement of non-CO_2 greenhouse gas emissions (CH_4, N_2O, HFCs, PFCs, and SF_6). Calculations considered both the emissions mitigation that occurs as a byproduct of actions directed at CO_2 and reductions resulting from gas-specific control measures, including the following:

[54] http://web.mit.edu/globalchange/www/MITJPSPGC_Rpt146.pdf

- Capital
- Labor
- Crude Oil Resources
- Shale Oil Resources
- Coal Resources
- Natural Gas Resources
- Nuclear Resources
- Hydro Resources
- Wind/Solar Resources
- Land

The model seeks out least-cost reductions regardless of sector of origination or area of control to apply the same marginal emissions penalty across all controlled sources, leading to least-cost abatement. It draws heavily on neoclassical economic theory. However, the model fails to capture much of the economic rigidity that could lead to unemployment or misallocation of resources. Nor does it capture regulatory and policy details that are particularly important in the utility sector.

Outputs include costs, energy system implications, emissions prices, welfare costs, and results that illustrate measures of cost and effects on energy and agricultural markets.

- **McKinsey: "Reducing U.S. GHG Emissions: At What Cost?"[55]**

Three possible outcomes rather than "scenarios" are described. They are low-range, mid-range, and high-range reference case forecasts for U.S. emissions between 2005 and 2030. The low-range addresses incremental efforts to capture a portion of Energy Efficiency potential, including the following:

- Residential/commercial lighting improvements
- Combined heat and power (CHP) applications
- Increased penetration of wind at the most attractive sites
- Integration of land-use practices into carbon policy
- Early piloting of CCS

Mid-range outcomes demand a concerted national effort to capture full Energy Efficiency potentials and support the development and deployment of low-carbon technologies. Abatement efforts involve all sectors and geographies. They include:

- improving building efficiencies;
- enhancing fuel economy in light-duty vehicles;
- developing low-carbon energy supplies (solar photovoltaic, biofuel, nuclear, CCS); and
- pursuing early retirement of inefficient power generation facilities.

High-range outcomes reflect aggressiveness across all sectors and geographies as follows:

- High urgency assumes significant streamlining of nuclear power permitting and the construction process
- Aggressive renewables development (especially solar)
- Biofuels and other potential alternatives

[55] http://www.mckinsey.com/clientservice/sustainability/pdf/Greenhouse_Gas_Emissions_Executive_Summary.pdf

- Additional improvement of fuel economies within vehicle fleets
- Expanded CCS new-builds and retrofits for existing coal-fired plants

Inputs include 250 abatement options and the following five clusters:

1) Improving Energy Efficiency (EE) of buildings and appliances
2) Encouraging higher EE in vehicles while reducing carbon intensity of transportation fuels
3) Range of targeted measures across energy-intensive portions of the industrial sector
4) Expanding and enhancing carbon sinks
5) Reducing carbon intensity of electric power production

The reference case includes emissions of six GHGs: CO_2, methane, nitrous oxide, sulfur hexafluoride, hydrofluorocarbons, and perfluorocarbons. Further, the case addresses initial investment and ongoing net operating costs over the opportunity's lifetime (equaling the abatement cost).

Assumptions were as follows:

- Price of imported low-sulfur crude oil varies between $50 and $69 per barrel from 2005– 2030, $59 in 2030; natural gas: $5.46–$8.60 per MMBTU, $6.52 in 2030; economy growth of 2.9 percent
- No major breakthroughs; relies on evolution of existing technologies
- Emission baseline created using the macroeconomic general equilibrium model, not taking into account non-economic factors (e.g., public opposition)
- No changes in legislative policy from those largely in place in 2005
- Emissions and sinks generated within U.S. borders
- Considers GHG emissions on annual basis, not build-up in atmosphere over time

Variable costs included the following:

- Abatement cost (initial investment, ongoing net operating costs over lifetime)
- Technical feasibility
- Potential for cost reduction and technology improvement
- Current penetration, underlying cost drivers, GHG emissions, and absorptions across seven sectors (power generation, buildings, industry, transportation, forestry, agriculture, and waste)
- Emissions of six greenhouse gases (CO_2, methane, nitrous oxide, sulfur hexafluoride, hydro-fluorocarbons, and perfluorocarbons)

The study calculated the value of specific opportunities and did not evaluate "imported" carbon generated outside the U.S. The study assumed no material changes in consumer utility or lifestyle preferences, although it did not estimate dynamic implications of price signals (elasticity of energy demand) from carbon caps or taxes. It used technologies with predictable cost and development paths, proven at commercial scale. Output included abatement supply curves, amounts, potentials, and resource costs for more than 250 options to reduce/prevent GHG.

4.0 Scenario Framework and Classification

The goals of this section are to:

- present a framework for reliability assessment, and
- use the framework to classify each scenario found during the research efforts.

A framework was developed to structure future reliability assessment by reviewing existing scenarios and models developed by governmental and industry organizations. This body of work involved a wide array of variables and potential outcomes, such as a large deployment of renewable resources and different cap and trade regimes. A high-level structure for these scenarios providing a relative comparison of renewable portfolio standards (RPS) requirements and Green House Gas (GHG) mandates can serve as a guide for scenario development and assessment that NERC might consider in the future.

After this review, the first observation is that there are two prevalent legislative themes: Green House Gas (GHG) reduction mandates, including Energy Efficiency and Demand Response; and RPS requirements. The second observation is that there are three market dimensions: supply and demand of commodities (e.g., coal, natural gas, oil); technology introduction (e.g., incremental vs. disruptive); and capital costs (e.g., inflation vs. deflation).

Each of the themes and dimensions will affect both short and long-term reliability and will allow us to define the scenarios and respective sub-scenarios for analysis and review.

Legislative Themes:

- **GHG Reduction Mandates** (including Energy Efficiency and Demand Response) — The first legislative theme will define and reshape the classic supply-focused generation portfolio to include demand side resources such as capacity associated with Energy Efficiency and Demand Response programs. In the short-term, it will drive modest adoption of Demand Response and Energy Efficiency programs. For integrated utilities, these projections would be reflected in utility integrated resource plans (IRP) that would be available for transmission planners. For organized markets, current rules allowing these demand resources to be bid into energy and capacity markets will increase their visibility and will demonstrate their dependability as dispatchable resources. Additionally, in the short-term, the new GHG reduction mandates will shift IRPs away from traditional coal generation to natural gas. In the long-term, if large-scale penetrations of demand-side management programs prove to be viable along with the shift from coal to natural gas, it will reshape the energy supply in North America.

- **Renewable Portfolio Standards (RPS) Requirements**—The second legislative theme will be to define the amount of renewable resources that will be brought to the market in the short- and long-term. Moreover, it will define the types of technology to be considered and the unique reliability challenges associated with connecting and dispatching these resources via the transmission grid.

Market Dimensions:

- **Supply and Demand of Commodities** (e.g., coal, natural gas, oil)—The first market dimension measures the relationship between the supply and demand of commodities and the different generation technologies. Moreover, it would study how these changes in supply or demand will affect the adoption of new generation technologies and how this will affect the reliability of the system in the short- and long-term. More specifically, understanding and modeling the relationship between the supply and demand of energy commodities would identify the choices and trade-offs between the different types of generation as they apply to each of the four scenarios that will be defined below.

- **Technology Introduction** (e.g., incremental, disruptive)—The second market dimension would measure the magnitude of change that will be driven by the deployment of new technologies. By assessing the reliability impacts of each technology, those that are incremental (e.g., smart grid, nuclear power) would be differentiated from those that have the potential to be disruptive [e.g., plug-in hybrid electric vehicles (PHEVs), electric storage]. Incremental technologies would affect short-term reliability and include "smart" technologies that provide better control of the transmission and distribution system, reducing system losses and optimizing power flow. These incremental technologies will also increase the system planning and operating reserve margins as well as alleviate chronically congested bulk power systems. The introduction of disruptive technologies would alter the load shape, thereby stressing the transmission system and its reliability. Overall, the introduction of these technologies in the short- and long-term will introduce reliability challenges and opportunities.

- **Capital Costs** (e.g., inflation, deflation)—The last market dimension would measure the impact of increasing or decreasing capital costs for the implementation of new generation, environmental mitigation (e.g., CCS), and transmission as well as distribution technologies. The maturity and implementation of these technologies in the short- or long-term will affect reliability in different ways, requiring more or less investment and infrastructure depending on economic conditions.

With these themes, four distinct scenarios were identified based on previous scenario analyses performed by government agencies. Though there is overlap in terms of key variables and outcomes, the structure of scenario analysis provides insights. Identifying a limited set of key drivers can guide the future vision and assessment of potential bulk power system reliability outcomes.

Business as usual—The first scenario is entitled "*Business as usual*" because there are only very small incremental changes from the status quo. Under this scenario, less stringent GHG mandates are enacted where there is either an abundance of carbon credits under a cap and trade regime or a small carbon tax. The mandates for greenhouse gas (GHG) reductions are long-term because most of the stringent goals are set long into the future—at 2030 and beyond. In addition to the weak GHG mandates, RPS requirements are low, 15 percent or less, and are mostly dictated regionally. Moreover, the rules about the generation of renewable energy credits (REC) are very broad and RECs can be easily generated and can be used to achieve the mandated goals. This scenario represents the continuation of the historical industry trends, and the issues with reliability of the bulk power system includes replacement of aging infrastructure and old equipment with new "smart" technology. Operational reliability considerations include short-term integration issues with existing and new renewable resources along with the desired control of their dispatch.

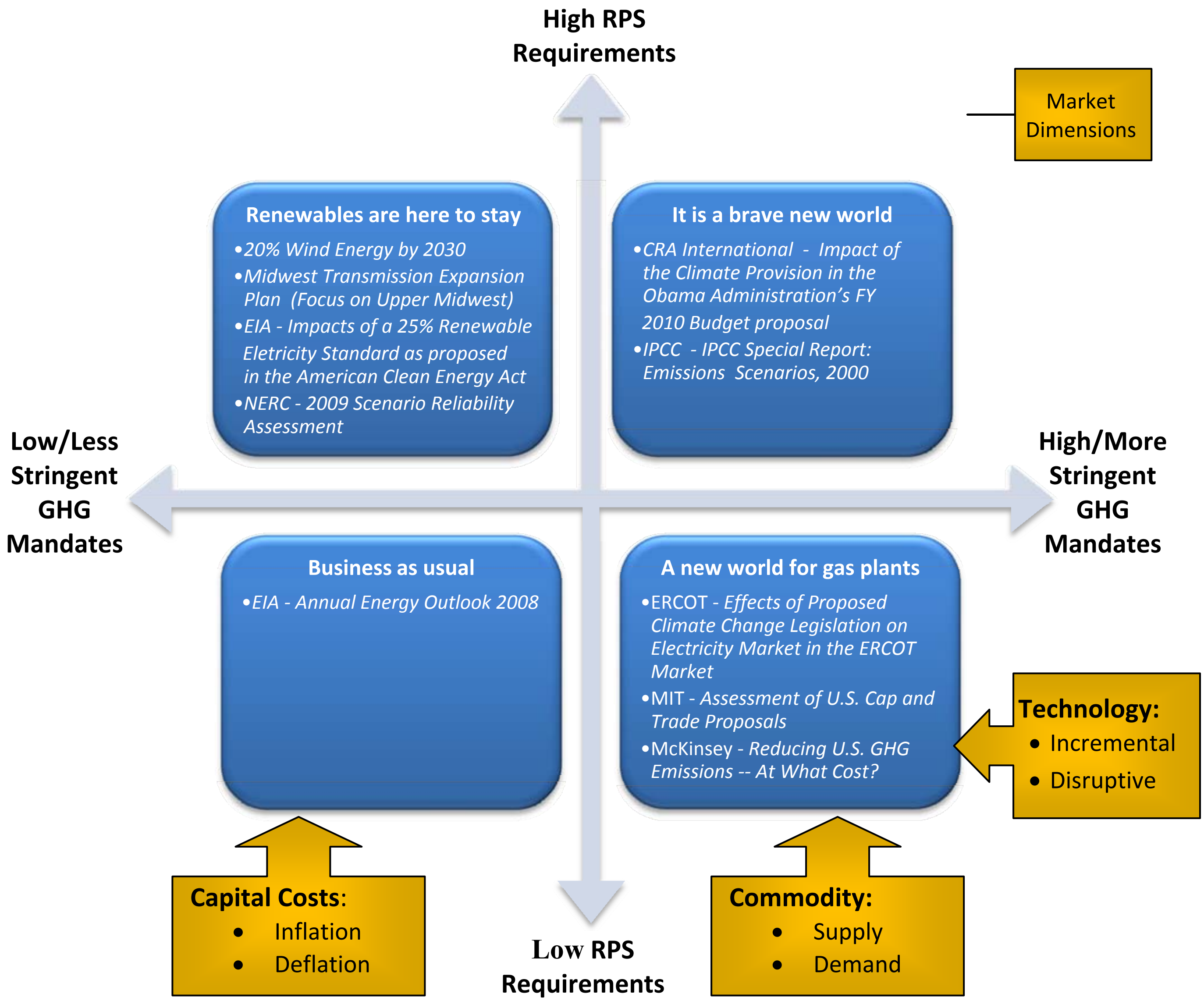
A new world for gas plants—The second scenario is entitled "*A new world for gas plants*" because of the shift in generation from coal to natural gas. Under this scenario, strong legislation is enacted with very aggressive GHG mandates. There are very limited amounts of carbon credits or a significant carbon tax. The mandated targets for GHG reduction are strong in the short- and long-term and could be federally mandated. The carbon credits or taxes are allocated or charged to stationary carbon sources. In this scenario, the RPS requirements are also low, as described in the first scenario. The requirements are 15 percent or less, RECs are easily generated, and mandates are easily achieved. This scenario represents a shift from the industry's history, when most of the power generated was coal-based. Nuclear and natural gas slowly gain a more relevant role in base load in the short term and dominate the base load generation in the long term. Reliability issues under this scenario are centered on the ability of the system to transition from coal to natural gas. Additionally, there is also the issue of integration of renewable resources into the transmission grid and the control of their dispatch.

Renewables are here to stay—The third scenario is entitled "*Renewables are here to stay*" because large-scale penetration of renewable generation is modeled in this scenario. Like the first scenario, less stringent legislation is enacted with low GHG mandates and either an abundance of carbon credits under a cap-and-trade regime or a lower carbon tax. The mandates for GHG reduction are long-term because most of the stringent goals are set into the distant future at 2030 and beyond. Instead of aggressive carbon pricing, the enacted legislation would achieve emissions reductions through aggressive RPS requirements with renewable generation targets of more than 20 percent. Additionally, the rules for generating RECs are very stringent and targets have to be met mostly by construction of new renewable generation facilities. Moreover, under this scenario, Energy Efficiency (EE) and Demand Response (DR) programs are widespread and load growth is flat in the short-term and declining in the long-term. Reliability issues under this scenario include integration of large amounts of interruptible and dispatchable generation and supply assets into the bulk power system and its impact on other generation assets—mostly generating assets that are not designed to cycle.

It is a brave new world—The fourth and last scenario is entitled "*It is a brave new world*" because of the significant amount of changes relative to the current industry resource mix. Much like the "*A new world for gas plants*" scenario, it is characterized by approved legislation that contains strong GHG reduction mandates in the short- and long-term. Additionally, just as in the "*Renewables are here to stay*" scenario, there are also strong RPS-mandated renewable generation targets that exceed 20 percent. There is also a strong penetration of EE and DR programs, resulting in a flattening of the load growth in the short-term and a slowing or decline of load growth over the long-term. Reliability issues under this scenario include all elements of the three previous scenarios, presenting the greatest challenges to maintaining reliability of the bulk power system.

Together, these themes and dimensions form a comprehensive framework for creating scenarios and structuring further analysis and review. Finally, each of the scenarios and models discussed in Section 3.0 were positioned into the appropriate quadrant of the resulting scenario matrix (Figure 4-1).

Figure 4-1: Scenario Matrix—Scenarios and Models Fit in the Matrix



5.0 Reliability Assessment of Technologies

As deadlines for various climate-related initiatives at the state and regional levels approach, the electric industry is actively engaged in integrating new technologies to support the transition to a fuel mix that results in lower overall CO_2 emissions. In the future, further work will be needed to integrate a host of new generation, demand, transmission, and distribution technologies—from large-scale wind plants to smart meters. Reliability impacts associated with integration of new resources and technologies are dependent on three variables: 1) when the technologies are introduced, 2) when they gain significant scale, and 3) relative impacts on the reliability of the bulk power system resulting from their integration. As these technologies are integrated at scale, significant modifications to the way industry plans, designs, and operates the bulk power system will be needed to maintain reliability, including new tools, technologies, and skills.

Though not all effects on reliability are known, this chapter provides an assessment and preview of potential effects on reliability resulting from changes to, and integration of, generation and demand-side management (DSM),[56] transmission, and distribution technologies in three cumulative time horizons: 1–10 years, 10–20 years, and more than 20 years. The timing of integration is based on meeting CO_2 and other greenhouse gas reduction targets identified in Section 2.6.[57] Further, it was assumed that the reductions were solely obtained through the electric power industry, and that only technological solutions would be used.

This chapter does not assess the reliability impacts of policy or regulatory actions, such as those affecting transmission siting or cost allocation, though they will affect successful integration. Rather, an overview of each technology and associated reliability effects, including a brief discussion of their status, is included. In addition, drawn from industry experts and literature, the potential reliability issues, present assumptions, and additional mitigating measures are described in tabular format.

[56] Generation and DSM technologies are coupled in this report as Demand Response and Energy Efficiency are increasingly being used as a resource providing capacity, energy, and ancillary services on similar basis as generating resources.

[57] The emission targets derived from the Waxman-Markey Bill and Copenhagen Accords are not representative of all aspects of these initiatives, or all mechanisms they provide. Further, only technological solutions were considered to address the full amount of the reductions.

5.1 Generation and DSM Technology Reliability Assessment

Climate change initiatives will affect the peak load along with energy consumption, patterns of energy use, and, therefore, the load duration curve. A number of prominent and new supply and demand-side management (DSM) technologies are on the horizon. This section provides a brief description of the technologies and concepts that underlie climate change initiatives. Key bulk power system reliability considerations for each time horizon (e.g., Horizon I: 1–10 years, Horizon II: 10–20 years, and Horizon III: 20-plus years) are identified and discussed in Tables 5-1 through 5-3. Details are subsequently provided about the status of each technology.

5.1.1 Horizon I: 1–10 years Generation and DSM Technology Reliability Assessment

The Horizon assessments are cumulative, and, therefore, reliability considerations will not be repeated after each time horizon unless reliability considerations change.

Table 5-1: Generation and DSM Technology Issue Matrix—Horizon I (1–10 years)

Technology	Potential Reliability Issue	Present Assumption	Additional Mitigating Measures
Biomass	• Insufficient fuel • Greenhouse gas emissions lead to early shutdown	• Sufficient waste is available to support the growth in biomass • Federal policies, tax incentives, RPS, etc. will support continued growth.	• Scrubbing and sequestration technologies can be used in the future • Other non-carbon emitting resources
Wind and Solar Generation	• Development of wind and solar power technologies ends • Integration causes significant secondary operation impact • Not enough transmission is built to bring resources to market and support integration	• Wind and solar generation will grow with federal policies, tax incentives, RPS, etc. • There are a significant number of new technologies being developed that can support wind and solar power technology improvements • Resources can be successfully integrated into the system using conventional fossil technology, energy storage (such as pumped hydro), Demand Response, and variable plant diversity • Sufficient transmission will be sited and built	• Increased system flexibility and access to ancillary services • Upgrade existing transmission and use of advanced transmission technologies (e.g., dynamic thermal circuit rating, phasor measurement unit, etc.) • Conventional plants • Demand side management • Biomass

Table 5-1: Generation and DSM Technology Issue Matrix—Horizon I (1–10 years)

Technology	Potential Reliability Issue	Present Assumption	Additional Mitigating Measures
Nuclear Generation	• Public does not support the construction of plants at existing nuclear sites • Public does not support construction at new sites • Siting difficulties and lack of investment results in insufficient transmission to bring resources to market and support integration	• Renewed interest in new nuclear generation is under-way, but public is still wary • Sufficient transmission will be sited and built	• Conventional plants • Demand side management • Biomass • Variable resources such as wind and solar • Upgrade existing transmission and use advanced technologies. • Accelerate Storage technology deployment
Natural Gas Generation	• Current combined cycle plants cannot be run continuously • Current infrastructure cannot support increase in natural gas volumes and pipeline expansion. New storage delayed • Insufficient North American natural gas supplies	• Combined cycle plants will be able to operate continuously and deal with natural gas quality issues • Sufficient affordable North American gas available due to unconventional gas supplies • Low capacity factor gas turbine plants may be required to manage system variability.	• Conventional coal-fired and variable plants will keep running until new natural gas plants come on line • Demand side management • Liquefied natural gas
Hydroelectric Generation	• New hydro are not able to replace fossil-fired units	• Much hydro is location-constrained, will take long transmission and lead-times for construction	• Increase number of nuclear units • Lift emission restrictions of fossil-fired generation
Demand-side Management (Demand Response and Energy Efficiency)	• DSM does not achieve penetration higher than current, due to industry structures or end-user resistance	• DSM will be supported by state programs • Despite huge financial potential, Energy Efficiency (EE) is still voluntary	• Build new peaking generation • Make Energy Efficiency improvements part of new building codes

Reliability Impacts—Biomass Generation

The biggest challenges for biomass generation are the small size of the facilities and emissions vary significantly depending on fuel type. In some cases, though biomass uses renewable fuels, their greenhouse gas emissions can be worse than from conventional coal plants. A recently released U.S. Environmental Protection Agency ruling regarding the Boiler Maximum Achievable Control Technology (MACT) covers existing and new biomass-fired boilers and would require facility enhancements. Under the proposed standards issued for a 45-day comment period on June 7, 2010, biomass boiler units conventionally considered multi-fuel boilers would instead be classified as incinerators and potentially subject to new emission limits.[58] Based on the proposal, it is unclear if biomass-fired boiler conversions can technologically and economically meet the stringent emissions limits proposed in the industrial boiler MACT. Only

[58] http://www.biomassmagazine.com/article.jsp?article_id=3813

after detailed emissions modeling is completed and the emissions limits are finalized in the final rule (expected late 2010), can industries determine if particular biomass conversions are viable.

Nevertheless, for some regions, biomass could be a viable alternative to achieve renewable portfolio standard targets.

Technology Status: Biomass

Biomass is a renewable energy source from materials derived from living, or recently living (not ancient), organisms. It includes wood, waste, and alcohol fuels. Biomass is commonly plant matter grown to generate electricity or produce heat. For example, forest residues (such as dead trees, branches, and tree stumps), yard clippings, and wood chips may be used as biomass. However, biomass also includes plant or animal matter used for production of fibers or chemicals. Biomass may also include biodegradable wastes that can be burnt as fuel. It excludes organic material such as fossil fuel that has been transformed by geological processes into substances such as coal or petroleum.

Today, most of the biomass generation is originated in landfills or in industrial installations. It has a current capacity of about 1,700 MW. The U.S. Energy Information Administration (EIA) has estimated that the U.S. has annual biomass resources of 590 million wet tons (approximately 413 million dry tons). Since 20 million wet tons equals about 3GW of capacity, this translates into 88.5 GW of electrical capacity.[59]

Most current biomass conversion is for heat and power generation and is based on direct combustion in small, biomass-only plants with relatively low electric efficiency of about 20%. Technology exists so that total-system efficiencies can approach 90% if combined heat and power system are applied.[60] There are also a number of technological options available to generate power from biomass. The most common is thermal conversion, where heat is the dominant mechanism to convert the biomass into another chemical form. The basic alternatives are separated principally by the extent to which the chemical reactions involved are allowed to proceed: combustion, torrefaction, pyrolysis, or gasification. There are also a number of more experimental or proprietary thermal processes such as hydrothermal upgrading (HTU) and hydro-processing. Some processes have been developed for use on high moisture content biomass, including aqueous slurries, converting them into forms that are more convenient. These applications of thermal conversion are being used in Combined Heat Power (CHP) and co-firing.

Reliability Impacts—Variable Generation (Wind and Solar)

Wind and solar generation are two of the most prevalent new alternatives to fossil-fired generation and have experienced significant growth over the past several years. A recent NERC report projected over 200 GW of proposed and conceptual wind and solar plants over the coming ten years. Though much of this may not be ultimately built, the figures are indicative of a substantial change in new resource development in the coming decade.[61]

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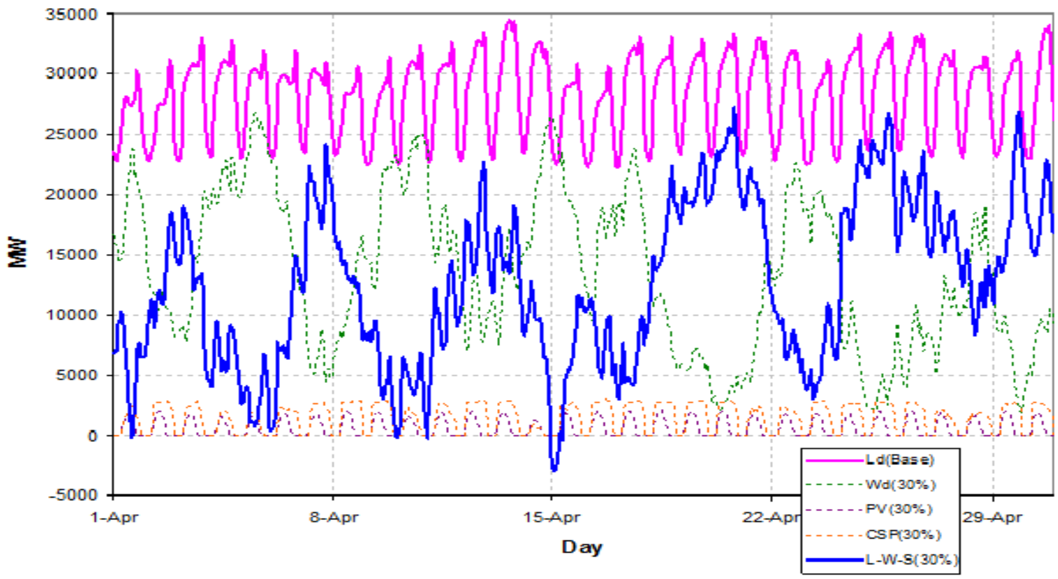
[59] http://www.ecoleaf.com/green_energy/biomasspower.html
[60] http://www.climatetechnology.gov/library/2005/tech-options/tor2005-236.pdf
[61] http://www.nerc.com/files/2009_LTRA.pdf

Resources such as wind and solar are designated as "variable" due to the changing availability of their primary fuel source. While solar power correlates more closely to load patterns, wind power can often reach its peak output during times of relatively low demand for electricity. As neither resource can be sufficiently stored at a large scale at this time, this creates significant challenges for grid operators as they seek to keep the system in balance (see Figures 5-1 and 5-2).

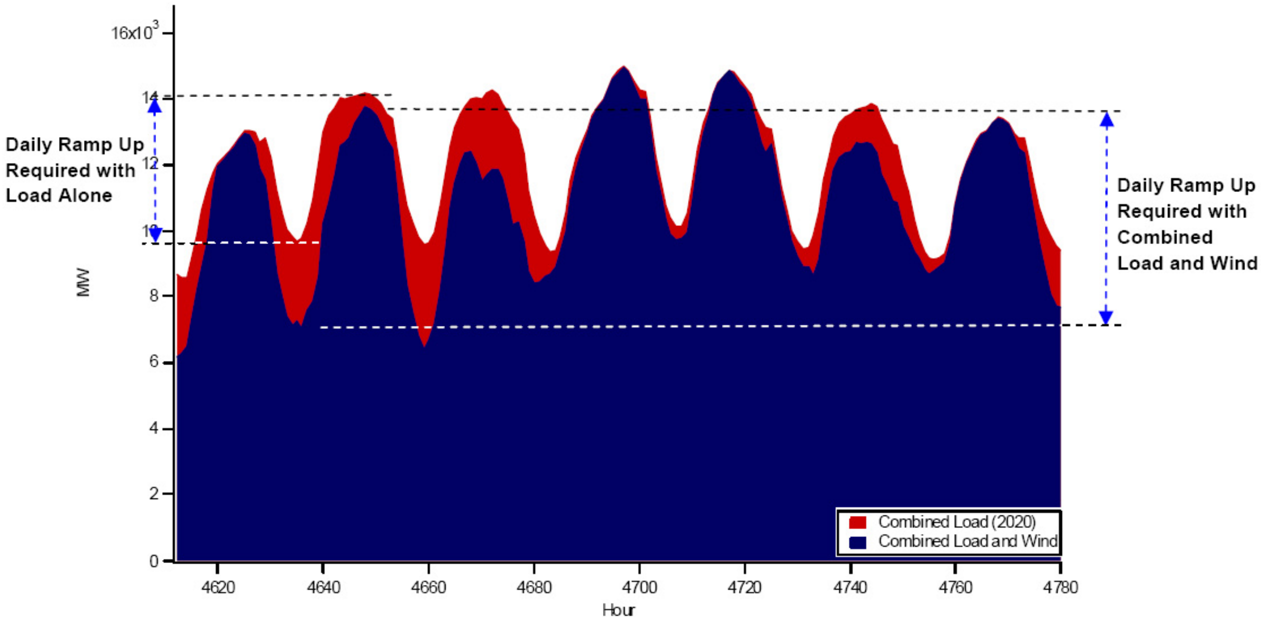
Figure 5-1: Total Load, Wind and Solar Variation for April (30% in Area Scenario)[62]



According to NERC's 2009 Special Reliability Assessment,[63] there are two major attributes of variable generation that affect bulk power system planning and operations. The first is variability of plant output, as the primary fuel is not delivered in the same consistent fashion as coal, gas, or uranium. Rather, the output of variable generation changes according to the availability of the fuel, whether it is wind, sunlight, or moving water. The second is uncertainty in forecasting the timing of plant output. Together, these attributes demonstrate potential challenges to integrating variable resources at scale. Due to its limited availability during times of peak demand, wind power provides limited capacity and high volumes of "energy-dominant" resources (or those resources predominately available during off-peak hours). Further, integration of storage facilities, such as pumped hydro, can support conversion of this energy into capacity, as stored energy from variable resources can be dispatched at time of daily, weekly, or monthly peaks. Integrating large amounts of these resources, therefore, will require significant changes to traditional planning and operating techniques.

[62] Western Wind and Solar Integration Study DOE/GE Energy Study Impacts
[63] NERC Special Reliability Assessment, "*Accommodating High Levels of Variable Generation*," April 2009, http://www.nerc.com/files/IVGTF_Report_041609.pdf

Figure 5-2: Increased dispatchable ramping capability required with wind generation[64]



An additional challenge often associated with large-scale wind- and solar developments is that the best sites are located in remote areas, without sufficient supporting infrastructure.[65] Bulk power system planners must ensure there are sufficient transmission, distribution, and flexible resources available to unlock the energy resources and manage variability. This could be accomplished in the near term with Demand Response; larger, virtual/actual balancing areas; sufficient transmission; improved forecasting and scheduling tools; coordination with new or existing pumped storage hydropower; and diversity of plant locations designed to provide access to ancillary services. Sufficient transmission and/or energy storage capacity will be required to support variable generation integration. If transmission capacity or grid-scale storage is not available for transactions, variable resources may be curtailed after conventional resources are reduced to their minimum outputs. Curtailment of steam units would cause operational reliability concerns over the short term, as they would not be able to be returned to service when wind becomes unavailable. Furthermore, repeated cycling of steam units can cause reliability problems over the long term as the thermal stresses due to cycling will increase their

[64] If conventional generation resources are assumed to provide all the ramping capability for the system, the figure shows that, in the absence of wind generation, these conventional resources must be able to ramp from 9,600 MW to 14,100 MW (4,500 MW of ramping capability) to meet the variation in demand during the day, as shown in the figure by the red curve. With the additional wind generation, the variation in net demand, defined as the load minus wind generation, must be met using the ramping capability from the same conventional generators on the system. As shown in the Figure, wind generation is significantly higher during the off-peak load period than during the peak load period. Hence, the net demand during the day, shown in blue, varies from 7,000 MW to 13,600 MW, requiring the conventional generators to ramp from 7,000 MW to 13,600 MW (6,600 MW of ramping), which is approximately 45 percent greater than the ramping capability needed without wind generation. See *Accommodating High Levels of Variable Generation,* NERC Special Report, April 2009, at http://www.nerc.com/files/IVGTF_Report_041609.pdf

[65] Western Governors' Association, *Renewable Energy Transmission Roadmap,* June 2010, http://www.westgov.org/index.php?option=com_joomdoc&task=doc_download&gid=1282

maintenance requirements and potentially increase their forced outage rates, lowering the reliability of the system overall. Interconnection requirements for variable generation plants should support reliability of the bulk power system by providing sufficient voltage ride-through, frequency response, inertial response, and reactive support.

Large-scale deployment of photovoltaic (PV) technologies on customer rooftops could represent a significant change in the way that distribution system operates, which can affect the reliability of the bulk power system. Central grid-connected PV installations could have profound consequences given the frequent and severe ramping of output from PV that will require system operators and planners to allow for sufficient resources for system balancing and regulation (on a second-to-second and minute-to-minute time basis) to maintain system reliability.

In addition, large conventional plants have historically been operated at close to peak output continuously, while other generating plants could be cycled over the course of a day to meet varying demand. When variable generation sites are diversified or have capacity from persistent fuel sources, a portion of its installed capacity exhibits similar characteristics and capabilities as traditional generation. That said, variable generation integration is projected to require more operational flexibility. The future fleet of lower or non-carbon emitting resources must be designed to provide this capability. The following sections will provide more detail about the status of wind- and solar power.

Technology Status: Wind Generation

Wind power has experienced the fastest growth rate of all energy sources in North America, with capacity growing 30 percent per year over the last five years.[66] Wind resources now constitute almost half of new construction of generating capacity in the United States. By the end of 2008, the wind industry had installed almost 29,000 MW of capacity (see Figures 5-3 and 5-4). Furthermore, some organizations have estimated there are an additional 300 GW available and only awaiting adequate transmission for grid connection.[67]

The aggregate energy output from wind plants spread over a reasonably large area tends to remain relatively constant on a minute-to-minute timeframe, with changes in output tending to occur gradually over an hour or more. Wind plants currently are not operated as dispatchable resources, although they could be operated in this manner in the future.[68] Additional operational flexibility will be required to accommodate the variability of such resources. This will likely necessitate consideration and deployment of a wide array of operational strategies such as gaining access to ancillary services through balancing area agreements, shorter dispatch intervals, transmission additions, and fuel mix augmentation. Operational flexibility can be further enhanced by deploying technologies such as Demand Response, bulk transmission, power electronics, and variable plant diversity/resource capacity.

[66] NERC Special Report, "*Accommodating High Levels of Variable Generation*," April 2009 at http://www.nerc.com/files/IVGTF_Report_041609.pdf
[67] 2009 estimate by American Wind Energy Associations (AWEA)
[68] Western Business Roundtable, "WCI and Grid Reliability," 2009

Figure 5-3: Installed wind capacity by state, 2008 (MW)

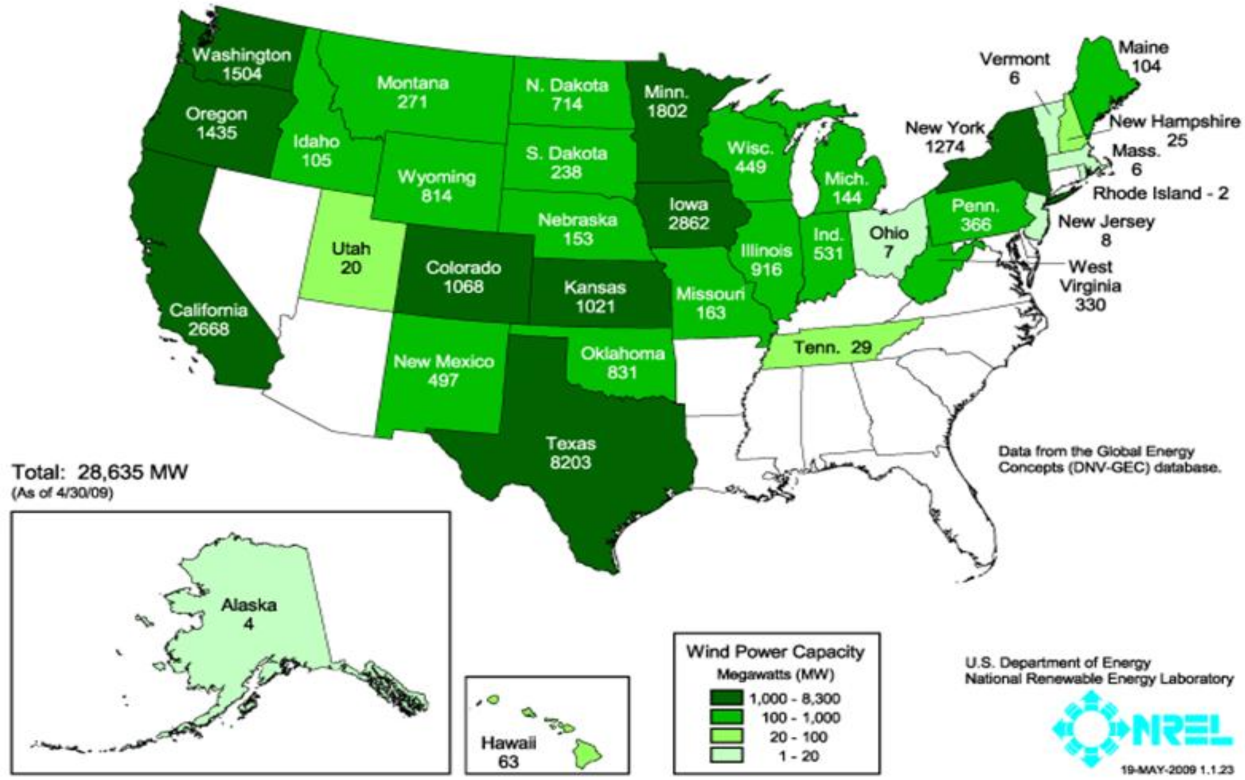
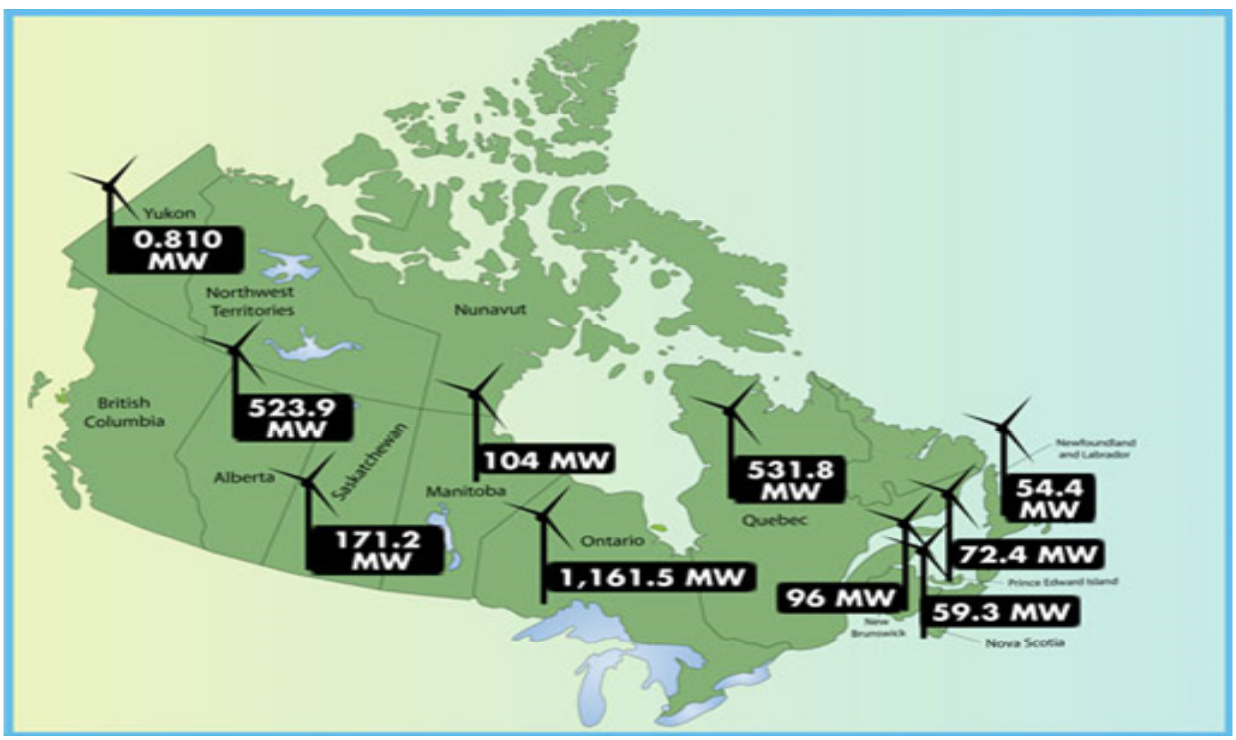


Figure 5-4: Installed wind capacity by province, 2009 (MW)[69]



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[69] Canadian Wind Energy Association, http://www.canwea.ca/farms/index_e.php

Reliability Assessment of Technologies

Wind plant installations can be onshore or offshore, and range from simple wind turbines that vary up to 5 MW in size to wind plants that can provide up to several thousand megawatts of capacity. In the U.S. today, most wind installations are large scale. However, there is mid-term potential for distributed wind resources that are connected to the distribution network closer to load centers. Finally, in terms of the actual turbine technologies, there are differing levels and applications of control technologies, which can include frequency response,[70] voltage control, inertial response,[71] and power management.

Technology Status: Solar Generation

As with wind power, the variable nature of the fuel source makes solar technology alone unsuitable for the dependable and dispatchable supply of capacity to meet variable demand. Typically, peak solar output occurs during the mid-day and in the summer, which does not necessarily coincide with peak demand.

Today, most research into solar technologies focuses on photovoltaic or concentrating solar power technologies. The R&D is focused on reducing capital costs and creating systems that directly address the dispatching challenge outlined previously.

Solar photovoltaic generation converts sunlight directly into electricity. Installations of these generation technologies include small consumer installations, larger commercial solar electric systems, and a few grid-connected installations ranging from one to 25 MW. The reliability implications for large-scale deployment of PV depend on the nature of the future installations. For example, if there is significant penetration on the distribution level, ramp rates created by cloud cover will require management and controls to minimize impacts on the bulk power system.

Concentrating solar power (CSP) first converts sunlight into heat (via a collector system) and subsequently into electricity (via a power block).[72] These systems have the potential to offer utility-scale dispatchable renewable power. Utility-scale systems, or solar plants, have the potential to provide hundreds of megawatts of electricity for the power grid from remotely located central generation plants. In either case, any solar power must be integrated with other technologies to improve reliability due to the variable nature of the fuel source. When deployed with thermal energy storage (i.e. steam accumulator, molten salt, graphite, phase-change materials, etc.), CSP facilities are able to generate electricity even during cloudy periods or at night. If combined with fossil-fired power plants, the resulting hybrid power plants can function like traditional resources to provide dependable power that can be dispatched throughout the day.

DOE has identified the following as key market barriers to adoption of solar technologies and is working through its Solar Energy Technologies Program (SETP or the Solar Program) to address them:[73]

[70] http://www.uwig.org/ISONEFinal16Nov09Interconnectionreqnewis_report.pdf
[71] http://www.gepower.com/businesses/ge_wind_energy/en/downloads/GEA17210.pdf
[72] NERC Special Report, "*Accommodating High Levels of Variable Generation,*" April 2009 at http://www.nerc.com/files/IVGTF_Report_041609.pdf
[73] http://www1.eere.energy.gov/solar/market_transformation_program.html

- insufficient product standards;
- inconsistent interconnection, net metering, and utility rate structures and practices for solar systems;
- inadequate codes, and complex and expensive permitting procedures;
- inconsistent and insufficient state and local financial incentives and other market drivers;
- a lack of flexible, sophisticated, and proven financing mechanisms; and
- limited education for and insufficient numbers of trained and experienced personnel and services.

Overall, the stated goals of current DOE research and development efforts include:

- Grid parity for PV technologies by 2015 to facilitate the rapid and significant growth of solar penetration in the United States;
- CSP technology competitive in the intermediate power market by 2015 and in capacity power markets by 2020 through the development and integration of advanced technologies to reduce overall cost.

Reliability Impacts—Nuclear Generation

Nuclear plants produce almost no greenhouse gases—only 17 tons per GWh in total lifecycle emissions. Today, nuclear power represents 70 percent of carbon-free electricity produced in the U.S. and is the dominant source for clean energy.

The current North American nuclear generation fleet is designed to provide continuous energy and capacity and little load following (regulating, ramping, cycling, starting/stopping, etc.), which is provided by smaller fossil-fired plants. Consequently, nuclear plants are generally run at close to peak output continuously, while fossil-fired plants may be cycled over the course of a day to meet demand. As variable generation integration will require more operational flexibility, the future fleet of plants should be designed to ensure overall flexibility of the power system. Though this flexibility may be increasing somewhat with advanced designs, nuclear plants are generally not suited for cycling, and their high capital cost provides incentives for them to operate at the highest capacity factor possible.

Requiring nuclear units to provide ancillary services can make refueling periods less certain. The predictability of refueling schedules can be forecast within hours. However, if ancillary services are provided, the complexity of scheduling refueling will increase.

Technology Status: Nuclear Generation

Currently, there are 104 commercial nuclear generating units in the U.S.; 31 states have at least one operating reactor. Total nuclear generation capacity is approximately 100 GW, of which two-thirds are Pressurized Water Reactors (PWRs) and one-third Boiling Water Reactors

(BWR). In Canada, there are 18 CANDU (CANada Deuterium Uranium)[74] commercial nuclear reactors with nearly 13 GW of installed capacity representing 6% of generated energy in 2006, making Canada the seventh largest nuclear producer in the world. The majority of these plants are located in Ontario (See Figure 5-5).

The North American nuclear fleet could be at risk in the medium term as nearly all of the units were built in the 1960s and 1970s, and most plants are nearing the end of their lifespan. No new nuclear power plants have been commissioned in Canada since 1992 (Darlington Nuclear Station, Ontario) and since 1996 in the U.S. (TVA, Watts Bar Nuclear Station, Tennessee).

While minimal new construction has occurred, consolidation of nuclear plant ownership over the past decades has resulted in economies of scale and consolidated new operational expertise. Further, nuclear safety has improved while operational and maintenance costs have decreased. For example, over the past few years, nuclear reactors in the U.S. have operated at an average of 90 percent capacity. In addition, a “nuclear expansion” has occurred in the United States and Canada driven by upgrading and rebuilding existing nuclear plants. The result has been an increase in capacity by around 5,400 MW since 1977, the equivalent of five to six new nuclear units. Finally, the projected lives of the existing plants have been increased through refurbishment and addition of advanced applications.

Figure 5-5: Location of CANDU Nuclear Plant in Canada

[74] CANDU is a light water reactor with pressurized water contained within multiple smaller vessels instead of a single larger pressure vessel. The reactor uses natural uranium instead of enriched uranium. Fuel bundles can be replaced individually leading to a better duty cycle (PWRs and BWRs have to be shut down for refueling).

With increased emphasis on reducing carbon emissions, 23 applications were submitted to the U.S. Nuclear Regulatory Commission (NRC) from 2007 to 2009.[75] Furthermore, NRC has simplified the procedures required to obtain a nuclear construction and operation license. In the past, the NRC required developers to obtain two different licenses: one to build a nuclear plant and a second to operate the plant. NRC now has combined the two licenses, allowing developers to apply for a single combined construction and operating license. NRC also vets vendor designs in advance. Therefore, when a developer applies to build an approved reactor design, the NRC will only review the design changes that are unique to the site.

New nuclear unit designs have significantly increased capacity (up to 1,600 MW versus 600–1,000 MW). Historically, operators within a balancing area dispatch "spinning reserves," thereby enabling the bulk power system to withstand the loss of the largest unit on their system. With increased unit capacity, both planning and operational reserves may need to be increased to support bulk power system reliability. For the operations, increased fast-start, energy storage, and spinning reserve resources (supply- or demand-side) might be required to support the reliability requirements of the bulk power system. Furthermore, significant bulk transmission system reinforcements would also be required to ensure reliable integration.

Handling and storing spent fuel and its disposal has been an important challenge to developers. After three years of use, the fuel is depleted of most fissile uranium. What is left is a very long-lived nuclear material that cannot be used in conventional reactors. Currently, most spent fuel is stored near the plants until it can be moved to a permanent facility.

One option available to deal with spent fuel is reprocessing, which is a procedure in which plutonium is separated from the rest of the spent fuel and can then be turned into new fuel. However, because of nuclear proliferation concerns, the U.S. halted civilian reprocessing in 1977. Another option being explored through a multi-national program called "Advanced Fuel Cycle Initiative" focused on deploying spent fuels for "fast" nuclear reactors. In contrast to today's "thermal" reactors, fast reactors do not employ moderators and use much faster neutrons to produce a stable nuclear chain reaction. Thus, these "fast reactors" are able to consume many of the long-lived materials that thermal reactors cannot. This approach would reduce the life of nuclear waste from hundreds of thousands of years to a few centuries, and increase fuel efficiency while reducing waste volumes. However, there are only a few of these reactors worldwide and the technology has not reached commercial scale.

Construction and deployment of new nuclear reactors will depend on many factors, including successful spent fuel and proliferation management, financing availability, and public acceptance.

[75] Note: a number of 2009 and 2010 applications are estimates. Source: U.S. Nuclear Regulatory Commission. "Expected New Nuclear Power Plant Applications," August 18, 2009, http://www.nrc.gov/reactors/new-licensing/new-licensing-files/expected-new-rx-applications.pdf

Reliability Impacts—Natural Gas Generation

Natural gas-fired on-peak capacity is projected to exceed coal-fired on-peak capacity by 2011. Among the primary drivers are that natural gas generation plants are generally easier and faster to site, and have lower capital costs than other alternatives. If some form of carbon tax or cap-and-trade is implemented, natural gas will become a more desirable fossil-fuel because its combustion results in almost 50 percent less carbon dioxide than coal per MW generated. Coupled with higher availability of unconventional natural gas supplies (e.g., gas in shale formations, which represent up to two-thirds of North America's technically recoverable gas reserves[76]), developers could substantially increase gas-fired plant additions, changing the North American fuel mix while increasing the dependency on a single fuel type.

With the addition of large amounts of variable generation (e.g., wind and solar) low capacity-factor gas turbine plants may be required to manage increased system variability to meet reliability requirements. In addition, because some combustion turbines will be required to operate at low ambient temperatures, they will require retrofitting with cold weather packages and technologies to ensure their availability during extremely cold temperatures.

Access to new conventional and unconventional natural gas supplies in North America, coupled with the need to meet the goals of climate change initiatives, is projected to drive the transition from coal to gas plants beginning in the 1–10 year Horizon. As the bulk power system has been developed to support the delivery of energy from the existing generating fleet, sufficient time will be required to both site new gas-fired generation and reinforce the bulk power system.

Technology Status: Natural Gas Generation

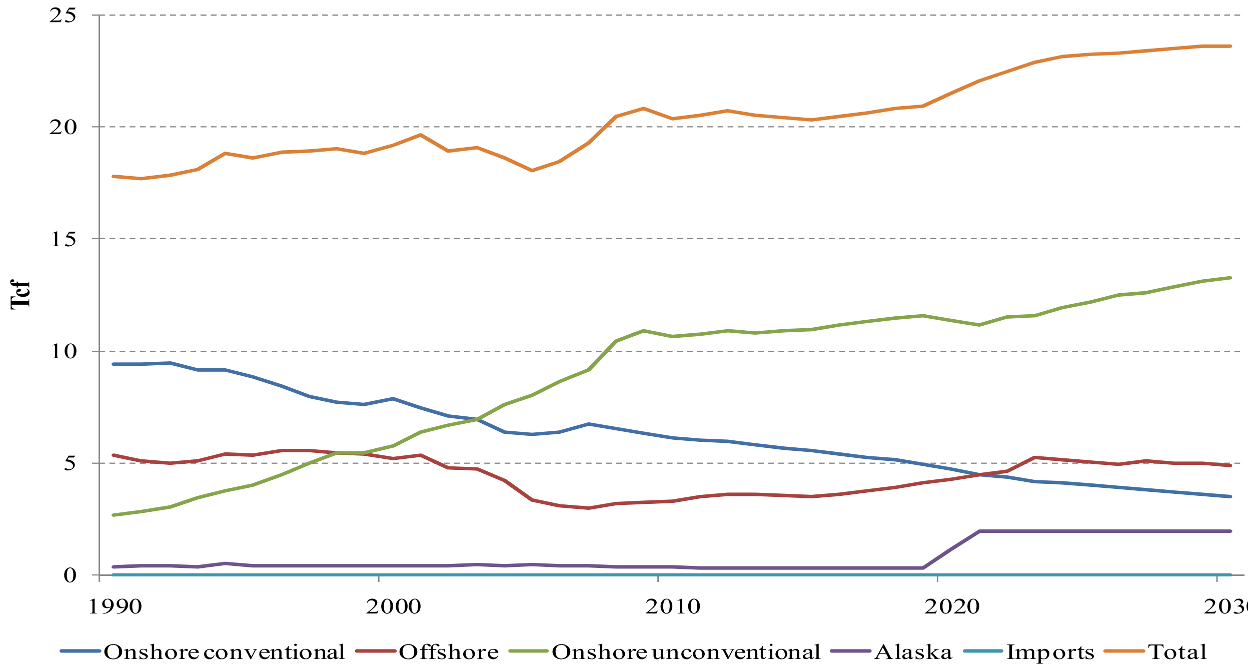
Natural gas generation plants have low fixed costs and can support energy needs in a variety of ways, either through continuous energy/capacity or peak-power requirements. Refinements in natural gas-fired generation have continued to focus on fuel-modulation, continuous operation applications, increased efficiencies, and environmental controls.

Natural gas production and imports in the United States from 1990 to 2030—both historical and forecast—are shown in Figure 5-6. Higher estimates of available North American natural gas come from access to unconventional sources[77] such as shale formations. These sources were formerly difficult and expensive to reach. Advances in horizontal drilling and the hydraulic fracturing of rock have made it possible to get previously inaccessible gas out.

[76] *The Economist*, August 15–21, 2009, Pg. 24, *"The Economics of natural gas: Drowning in it"*

[77] Unconventional Gas refers to gas not found in conventional types of formations. Tremendous advances in drilling techniques use multiple fractures in a single horizontal well bore with real-time micro-seismic technology to monitor fractures. This approach can unlock gas from tight sands, coal-bed methane, and shale.

Figure 5-6: Natural gas production by source and net imports, 1990–2030 (Tcf)



Reliability Impacts - Hydroelectric Power Generation

Since hydroelectric dams do not burn fossil fuels, they do not directly produce carbon dioxide.[78] While some carbon dioxide is produced during manufacture/ construction of the project, and decaying trees and other organic matter submerged under water during the creation of reservoirs, this is a tiny fraction of the operating emissions of equivalent fossil-fuel electricity generation.

Hydroelectric generation depends on rainfall or snowmelt in the watershed, and may be significantly reduced in years when precipitation is low. Further, Large hydro systems require significant leads times due to permitting, licensing and construction. Unlike fossil-fuelled combustion turbines, construction of a hydroelectric plant requires a long lead-time for site studies, hydrological studies, environmental impact assessment and construction.

Technology Status: Hydroelectric Power Generation

In Canada, the hydroelectric system is immense. For example, existing systems include 5,000 MW at Upper Churchill, 5,000 MW at LaGrande and 4,000 MW Mica/Revelstok where BC Hydro is adding 2,000 MW for peaking purposes. A dam is under construction at Lower Churchill will increase Canadian hydropower by over 2,800 MW. Each year, nearly two-thirds of power generated in Canada is from hydroelectric generation. Figure 5-7[79] provides an atlas of hydroelectric resources in Canada.

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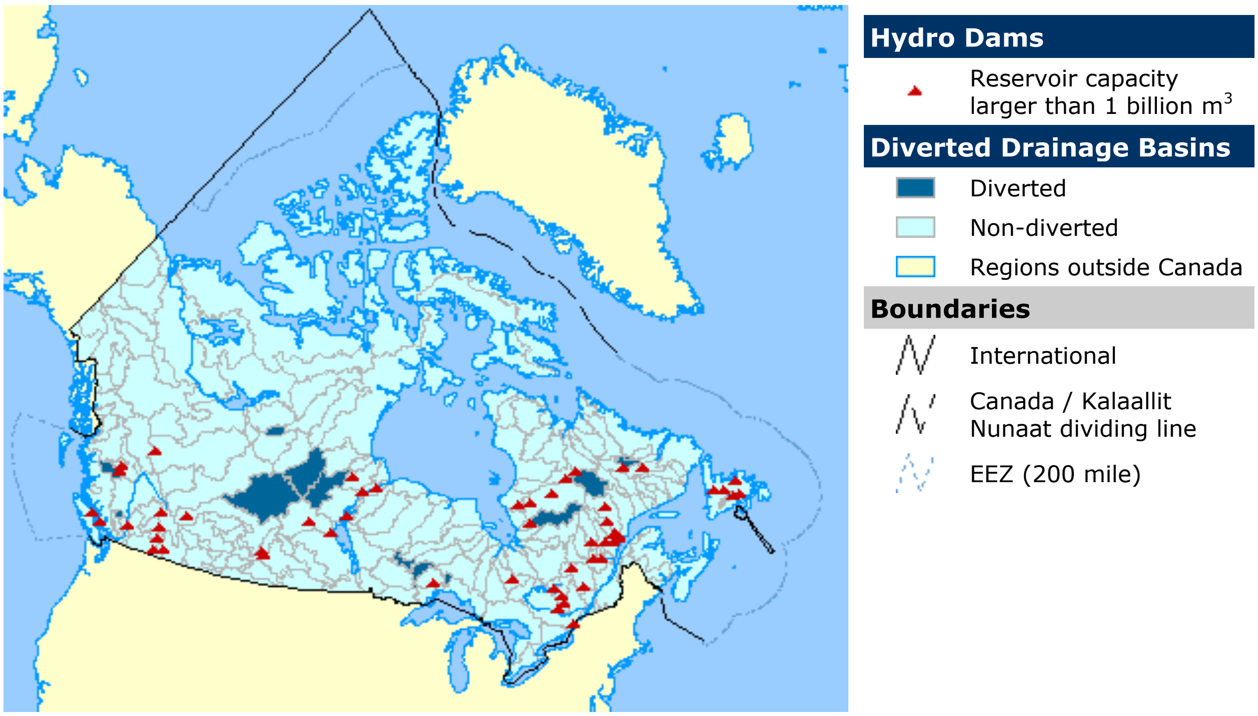
[78] According to a forthcoming National Academy study that will detail life-cycle greenhouse emissions from electricity generation technologies

[79] http://atlas.nrcan.gc.ca/auth/english/maps/freshwater/consumption/hydroelectric/1

Figure 5-7: Existing Canadian Resources in 2009



Large hydro capacity, with heights from between 10 meters to 150 meters, is expected to increase by 20% by 2025.[80] This increased generation will come primarily from British Columbia, Manitoba, Québec, Newfoundland and Labrador.[81]

Hydroelectric facilities in the United States can annually generate as much electricity as nearly 500 million barrels of oil— enough electricity to supply 28 million households. Today, the total U.S. and Canadian developed hydropower capacity—excluding pumped storage facilities—is about 79,500 MW and 89,000 MW respectively. Developed pumped storage hydro capacity in the U.S. increases this figure by 22,000 MW and there is significant potential for adding new pumped storage hydro capacity throughout North America.

Studies have shown that incremental capacity in the U.S. can be obtained from existing river impounds by adding a powerhouse to dams where none exists, or adding more capacity to existing powerhouses resulting in an additional 2,900 MW. The U.S. has approximately 30,000 MW undeveloped sites for hydroelectric power generation (See Figure 1-7).[82]

The U.S. DOE has reestablished R&D efforts for both conventional hydropower technologies and advanced waterpower technologies.[83] In April 2010 the Secretary of Interior, Secretary of Energy, and Assistant Secretary of the Army signed an interagency memorandum of understanding (MOU) to help facilitate additional hydropower development at U.S. federal

[80] http://www.neb.gc.ca/clf-nsi/rnrgynfmtn/nrgyrprt/spplydmnd/spplynddmndt20252003/spplydmnd2003-eng.pdf
[81] http://canmetenergy-canmetenergie.nrcan-rncan.gc.ca/fichier/78697/cctrm_e_(lowres).pdf
[82] http://hydropower.inel.gov/resourceassessment/
[83] http://www1.eere.energy.gov/windandhydro/hydro_about.html

facilities. It includes an assessment of growth opportunities on the federal system with a commitment to upgrade federal facilities, and demonstration of new technologies at existing locations; coordination of research and development on advanced technologies; and increasing generation through low-impact and sustainable development.[84] For example, a closed loop pumped storage hydropower system contains an upper and lower reservoir, not in direct contact with a river or stream. In addition, there is no fishery or aquatic environmental impacts caused by damming rivers to construct one of these project reservoirs, however there may be land use conflicts or terrestrial specie impacts.

Reliability Impacts—Demand-Side Management (DSM)

DSM has led to reductions in supply-side and transmission requirements and supplements long-term planning reserves along with supporting operational reliability through the provision of ancillary services and overall system flexibility. It has also been used to manage the risk associated with construction and operations of traditional supply-side resources as well as a variety of new operating characteristics associated with variable renewable resources. For example, Energy Efficiency provides permanent change to electricity use through replacement with more efficient end-use devices or more effective operation of existing devices. In many areas in North America, Demand Response, the other component of DSM, is also being used to support capacity requirements, energy requirements, and ancillary services.

Carbon reduction from increasing demand-side management must be balanced against potential reliability impacts

Demand-Side Management (DSM) has been used for decades and has led to reductions in supply-side, transmission, and distribution requirements. DSM is an important part of the overall portfolio required to meet the electricity demand in North America and has two basic components: 1) Energy Efficiency (EE), and 2) Demand Response (DR). EE concentrates on end-use energy solutions and targets permanent reduction of electricity consumption, attempting to reduce the demand for power. Demand Response works to change the timing of energy use from peak to off-peak periods by transmitting changes in prices, load control signals, or other incentives to end-users to reflect existing production and delivery costs. Currently, DR penetration averages approximately six percent across all reliability regions in the U.S.[85]

As demand-side management (DSM) is increasingly deployed in response to climate change initiatives or mandates, it will become a larger portion of the overall resource portfolio. Climate change initiatives at the state/provincial level, along with consumer-led efforts to reduce energy consumption, will broaden the size and scope of DSM programs. Both Energy Efficiency and Demand Response can make significant contributions to the reduction in greenhouse gases, with Energy Efficiency providing ongoing benefits and Demand Response driving energy use to time

[84] Advances include application of adjustable speed machines, for example: 1) "Technical Analysis of Pump Storage and Integration with Wind Power in the Pacific Northwest," prepared for the U. S. Army Corps of Engineers-Northwest Division Hydroelectric Design Center, dated August 14, 2009 and 2) "Application of Adjustable Speed Machines in Conventional and Pumped Storage Hydro Projects," EPRI report TR-105542; published by Electric Power Research Institute, Palo Alto, Calif., November 1995

[85] http://www.nerc.com/files/2009_LTRA.pdf

periods when lower or non-carbon emitting resources are available. Demand Response can also enable the integration of renewable resources by supporting a variety of new operating characteristics associated with variable resources. Therefore, broader industry experience is needed, as the certainty, locality, and characteristics of DSM become increasingly important to reliability of the bulk power system

Energy Efficiency

The benefits and characteristics of Energy Efficiency have been well studied and documented.[86] In addition to energy savings, Energy Efficiency may reduce peak demand and defer the need for new investments.

There is a variety of ways for Energy Efficiency to be measured. The most straightforward method is to use the projected, or average, impact. In some cases, a more conservative measure may be used, de-rating Energy Efficiency impacts for uncertainty in load reduction (the "dependable" reductions). Successful integration of Energy Efficiency into resource planning requires close coordination between those responsible for Energy Efficiency and those in bulk system planning to ensure appropriate capacity values are estimated while meeting reliability objectives.

The type of Energy Efficiency programs (industrial, commercial, and residential) influence total capacity (MW) reduction depending on the time of day reduction is desired. Load forecasting is a critical component to understand the overall peak reduction observed or projected. Tracking and validating Energy Efficiency programs is vital to increase the accuracy of forecasts.

The largest demand reduction from an Energy Efficiency measure may not occur during peak demand. The coincident peak reduction is generally lower than the non-coincident peak reduction:

1. The timing of the largest reduction does not match the timing of the utility peak
2. Not all measures will be operating at the time of the peak (e.g., people are not home)
3. Equipment may not be installed or maintained properly

In addition, there are synergistic effects that can increase or decrease the reductions depending upon other Energy Efficiency measures.

Demand Response

Demand Response programs have been in use for many years, providing more direct control to system operators. In addition, high performance factors are emerging from Demand Response providers not using direct control methods. The influence of Demand Response on reliability concentrates on peak demand reduction, periods of high wholesale prices, or low-reserve conditions rather than on reductions in overall energy consumption. Long-term reliability benefits include reduced supply-side and transmission requirements at time of peak or other

[86] "National Action Plan for Energy Efficiency," at http://www.ferc.gov/industries/electric/indus-act/demand-response.asp and http://www.epa.gov/cleanenergy/pdf/napee/napee_report.pdf

times when resource availability is reduced. Additionally, Demand Response supports the management of operational reserves/flexibility as well as long-term planning reserves.

All Demand Response resources may benefit overall system reliability, though some Demand Response options benefit system reliability more than others do. The most dependable Demand Response can be dispatched by grid operators under contractual obligation to perform, and required to meet measurement and verification standards consistent with their importance to grid reliability. Some Demand Response options can have more reliability benefits than conventional supply-side peaking resources such as combustion turbine generators. The reliability benefits of Demand Response are a function of, among other things, any limits on annual interruptions, the frequency of interruptions, the duration of interruptions, the ramp-up time to reduce load, and penalties or sanctions for non-performance.

There currently is a significant existing potential for Demand Response[87] opportunities from large commercials and industrials. Many large end-users have the necessary metering and telemetry equipment capable of providing Demand Response for many years. The cost of advanced metering and telemetry does not appear to be a significant barrier to increasing their participation; rather, Demand Response program design is an extremely important consideration when decisions for investments are made. Expanding Demand Response to smaller customers requires significant investment in technologies to assure adequate measurement and verification of the load response, including advanced metering, load curtailment technologies, and two-way customer communications. Such investments must be recognized alongside other investments as part of overall bulk power system rejuvenation. It is not clear if smaller customers will resist mandatory real-time pricing and other incentives to change their energy use.

Like all significant resources, large-scale integration of Demand Response must be visible and capable for dispatch by system operators[88,89] to ensure reliability of the bulk power system. Therefore, much like the criticality of measuring the reliability of generating units, data on the performance of Demand Response must be collected and measured to provide a decision-making foundation in bulk power system operations and resource forecasting. Finally, increased penetration of Demand Response programs will result in a flatter load curve. While the shape of the load curve has an influence on the mix of resources, the replacement of proven generation technologies with emerging technologies, unproven at scale, introduces additional reliability uncertainty until more industry experience is gained.

Technology Status: Demand-Side Management

NERC has developed a categorization scheme and is developing a data collection mechanism to measure the reliability performance of Demand Response (see Figure 5-8).[90]
Carbon reductions from DSM can occur in two ways:

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[87] http://www.ferc.gov/legal/staff-reports/06-09-demand-response.pdf
[88] NERC Special Report, *"Data Collection for Demand-Side Management for Quantifying its Influence on Reliability,"* December 2007, http://www.nerc.com/docs/pc/drdtf/NERC_DSMTF_Report_040308.pdf
[89] NERC Special Report, *"Demand Response Availability Data System: Phase I & II,"* found at http://www.nerc.com/docs/pc/drdtf/DADS_Phase_I&II_Final_050510.pdf
[90] Ibid.

1. Energy Efficiency reduces overall demand, thereby reducing the need for carbon-emitting resources; and/or
2. Demand Response can shift energy use into periods when low or non-emitting resources are available, thereby reducing carbon emissions. This assumes that the energy is not served through local, carbon-emitting distributed resources.

In Canada, Ontario has made a substantial commitment to demand-side management[91] with the f province's long-term target of 6,300 MW of peak-demand reduction by the end of 2025. In June 2008, the OPA reported that Ontario had met its interim target of 1,350 megawatts (MW) of peak-demand reduction by the end of 2007.[92]

In the U.S., there are currently seventeen states with performance incentives for Energy Efficiency (Figure 5-9). Some states, like Pennsylvania and Maryland, have imposed strict mandates for Demand Response and Energy Efficiency.[93] These initiatives are targeting the reduction or elimination of load growth, along with providing industry and end-users with more resources and choices in their use of energy, respectively.

The deployment of smart meters in North America used for Demand Response and Energy Efficiency is projected to grow in the future. For example Figure 5-9 provides the performance incentives for Energy Efficiency in the United States as of June 2009.

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[91] Ontario Power Authority, *"Ontario's Integrated Power System Plan: The Road Map for Ontario's Electricity Future,"* http://www.ontla.on.ca/library/repository/mon/16000/271290.pdf

[92] Ontario Power Authority, " *2008 Final Conservation Results, January 2010*," http://www.powerauthority.on.ca/Storage/113/16044_2008_Final_Conservation_Results_report_20100125_final.pdf

[93] Demand Response comes in the form of either peak shaving or load shifting, depending on the type of load being shifted from on-peak to off-peak time; Energy Efficiency typically comes in the form of higher efficiency appliances; and conservation is voluntary and driven by changes in customer energy consumption levels and patterns.

Figure 5-8: NERC Demand-Side Management (DSM) Definitions

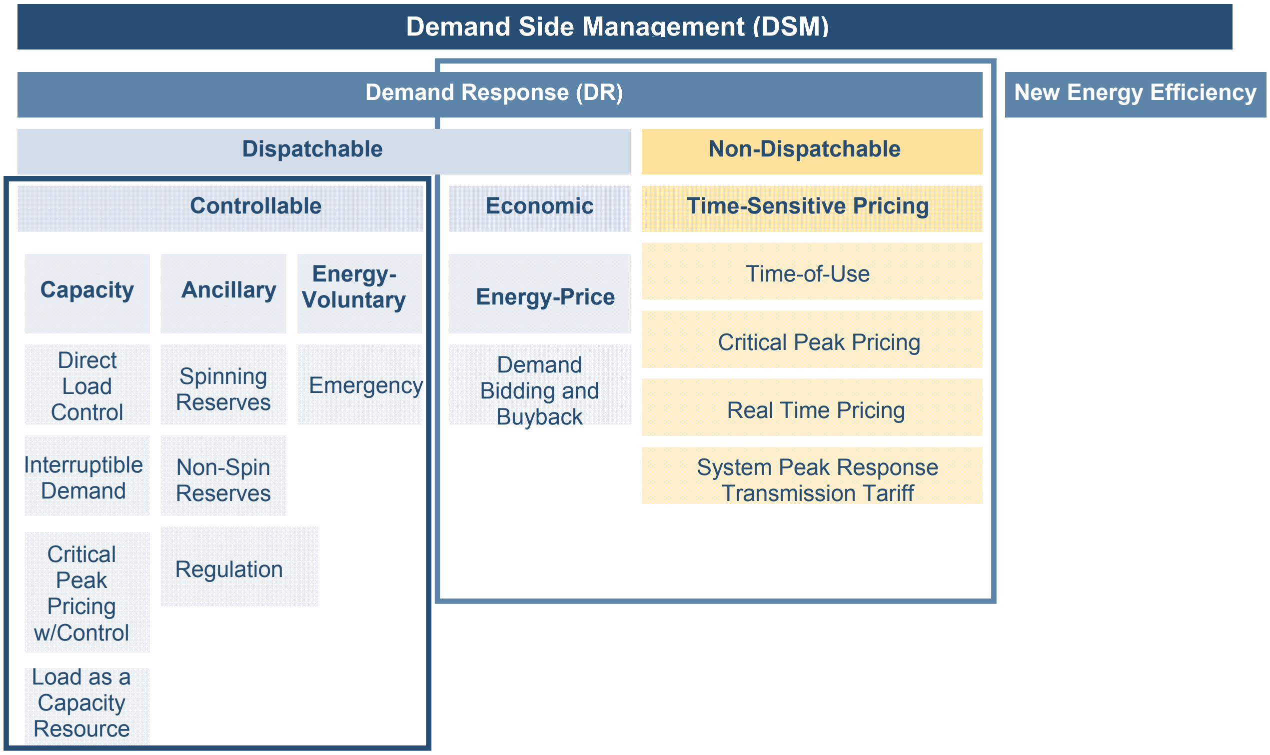
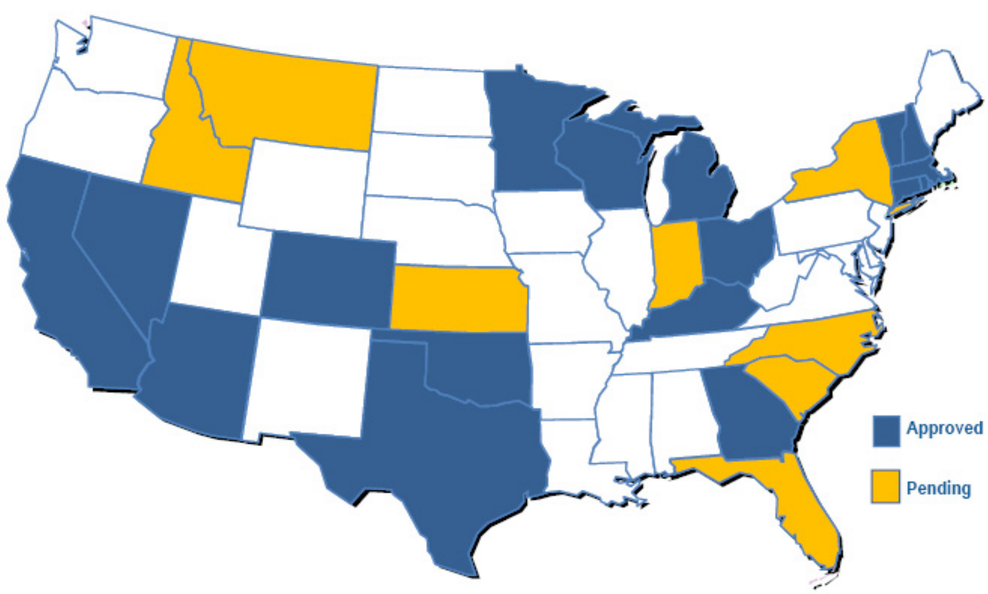


Figure 5-9: Performance Incentives for Energy Efficiency by State June 2009[94]



[94] Pg. 5 "EEI State Energy Efficiency Regulatory Frameworks," The Edison Foundation's Institute for Energy Efficiency

Reliability Assessment of Technologies

5.1.2 Horizon II: 10–20 years Generation and Demand Technology Reliability Assessment

The Horizon assessments are cumulative, and, therefore, previous reliability considerations will not be repeated after each time horizon unless reliability considerations change.

Table 5-2: Generation and DSM Technology Risk Matrix—Horizon II (10–20 years)

Technology	Potential Reliability Issue	Present Assumption	Additional Mitigating Measures
Clean Coal Technology and Carbon Capture and Sequestration (CCS)	• Public safety and security risk (e.g., plume and water quality) • CCS will not be commercially available until it is too late • No non-electric infrastructure is deployed to support CCS (coal gasification, storage, etc.) • Coal retrofits are not economic • Operational flexibility of the unit is significantly reduced	• May be commercially available during the 2020-2025 timeframe • High cost and complexity • Higher station loads • Retrofits will not be viable for all unit sizes • Operational flexibility of the unit will be significantly reduced	• American Clean Energy and Security Bill of 2009 calls for detailed plan to address legal/regulatory risks • Currently no U.S. CO_2 storage regulation • Ultra Super-Critical technology may be alternative if commercially available
Natural Gas Generation	• Transition from coal to gas quicker than projected, supporting infrastructure must be upgraded	• Potential outcome if aggressive CO_2 initiatives are implemented • Current infrastructure will be upgraded • Low-capacity-factor gas turbine plant may be required to manage increased system variability to meet reliability requirements	• Extend life of coal assets or eliminate emission caps • Add system flexibility through other options, such as DSM, advanced technologies
Wind and Solar Generation	• Large amounts of variable generation are integrated into the bulk power system	• Large scale variable generation can be integrated reliably if appropriate steps are taken • Increasing amounts of variable generation will be integrated by 2020 to meet RPS targets, providing additional operational experience needed for integration at scale	• Substantial system flexibility will be needed, requiring operational changes • Transmission could provide access to resources providing flexibility • Demand Response could help match demand to plant output • Variable generation curtailment • Energy storage could support flexibility requirements

Table 5-2: Generation and DSM Technology Risk Matrix—Horizon II (10–20 years)

Technology	Potential Reliability Issue	Present Assumption	Additional Mitigating Measures
Distributed Generation	• Distributed generation will not be commercially available and deployed in large scale	• Viable technologies will emerge as a result of currently high R&D spending in this area • System operators will need visibility of these resources to ensure ability to dispatch and reliability. • Substantial R&D investments focused on new distributed resources will increase adoption	• Large central plants will still be the predominant configuration for power generation • American Clean Energy and Security Bill of 2009 gives preferential treatment to distributed renewable resources with respect to the allocation of renewable energy credits
Energy Storage	• Deployment of large amounts of energy storage is not cost effective	• Large energy storage units are likely to be commercially available and cost effective • New pumped hydro and compressed air energy storage	• More Conventional generation • Variable generation curtailment • Advanced pricing and Demand Response

Reliability Impacts—Clean Coal Technology, and Carbon Capture and Sequestration

Climate change initiatives could accelerate the retirement of many fossil plants beyond current projections, especially smaller, older, and less efficient coal plants, which are responsible for much of the load-following, voltage support, and other ancillary services in parts of North America. The impact of retirement of these older and smaller coal units will differ across North America. The pace and aggressiveness of emission targets will affect the options available for resource transition. Depending on the magnitude of retirements, in aggregate this could present regional or North American-wide reliability challenges depending on the timing and type of replacement capacity. Further, the reliability of the bulk power system could be impacted if the penetration of non-fossil generation and demand resources lags current forecasts. Recent forecasts conclude that increasingly renewable generation, gas-fired generation, nuclear generation, and demand side management will represent a larger proportion of the supply resource mix.[95] This evolution will require sufficient time and operating experience to ensure reliability of the bulk power system throughout the transition.

The timing of carbon reduction targets will require an unprecedented shift in North America's resource mix

As CO_2 reduction requirements become more stringent later in Horizon II, retirement of larger coal units, on which it would be uneconomical or impractical to install CCS, could take place.

95 NERC *2009 Long-Term Reliability Assessment*, http://www.nerc.com/file/2009_LTRA.pdf

The loss of capacity, regulating ability, and voltage support from the retirement of coal units could have reliability impacts, which will require attention.

As carbon capture and sequestration (CCS) technologies mature over the next 10 to 20 years, there could be notable reliability considerations associated with implementing this technology as industry operational experience will be limited:

- First, to support quick commercialization, there will be some full-scale CCS demonstrations, therefore introducing reliability risks associated with implementing equipment with minimal testing and few proven deployments.
- Second, the reliability impacts of supporting additional equipment that is increasingly complex are also unknown and therefore present a risk. For example, plants that use pre-combustion carbon separation techniques require chemical supply pipelines to fuel the separation process.

Sequestration, regardless of storage options, will also require the construction of significant infrastructure to move captured CO_2 from the coal/natural gas facility to its final destination. Generally envisioned as a pipeline network, this infrastructure will require the development of what will essentially become an entirely new industry. Separation of CO_2 pipelines would be needed to support the potential transport of carbon to storage facilities. Any interruption in these transport lines could affect overall plant reliability, increasing the risk of forced outages.[96] In addition, operational flexibility in coal assets is reduced and new flexibility will need to be introduced into the system for ancillary service, such as voltage regulation and load following.

Finally, de-ratings of coal units due to the high parasitic power requirements of CCS operations could be significant, depending on their operational specifications and associated carbon regulation. However, if required, the carbon sequestration could be quickly terminated, returning a portion of the lost energy for use as spinning reserves. Furthermore, CCS technology demands the use of more water for cooling, which might be a consideration to site these plants in the future.[97]

Technology Status: Clean Coal Technology, and Carbon Capture and Sequestration

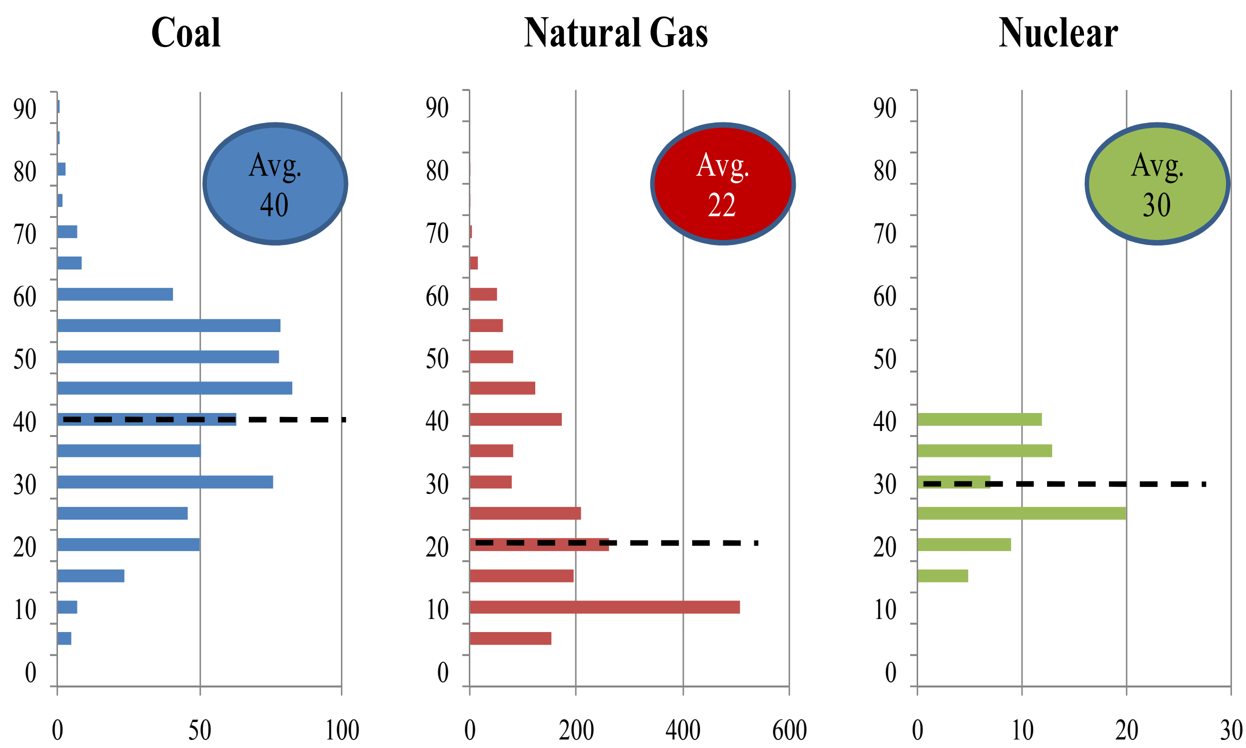
To the extent that fossil plants, which were able to follow load, are replaced and variable output renewable generation is integrated, additional operational flexibility must be made available to maintain system reliability. Though variable generation can provide energy/capacity requirements, additional ancillary services are required to support integration of high levels of variable generation. This additional system flexibility is likely to be met by a wide array of technologies from such sources as energy storage, Demand Response, transmission, bulk transmission power electronics, variable plant diversity, and resource capacity.

By 2025, most of the super-critical coal-fired generation plants will reach an age where they will need to be rebuilt or retired (see Figure 5-10). By 2030, the majority of nuclear plants, which have already had their operating licenses extended from 40 to 60 years, will have to be retired

[96] "*APPA Comments to NERC on Reliability Impacts of Climate Change Initiatives,*" July 16, 2008
[97] IEEE Spectrum, "The Carbon Capture Conundrum," pp. 38-39, July 2010.

because their cores will have reached the end of their useful lives. Thus, between 2025 and 2030, North America will need new generation plants for sufficient resources to be available to balance demand and supply. Depending on the environmental regime and the greenhouse gas emissions reduction targets, replacement options for these resources may be limited. Only a portion of the currently available technologies—like nuclear power, natural gas-fired power, wind power, concentrated solar power, Energy Efficiency, and, potentially, geothermal—provide available alternatives for resources in the long-term.

Figure 5-10: Age profile for U.S. fossil and nuclear Generation Fleet[98]



It is vital that climate change initiatives consider the impact on unit retirements, including their contributions to capacity and operational flexibility, to ensure reliability of the bulk power system. Even if the projected resources develop fully, the timing of accelerated retirements might affect reliability of the bulk power system, reducing margins and challenging system operations.

Therefore, there is significant interest in "Clean Coal Technology."[99] One such potential technology, demonstrated in several plants around the world, is the Ultra Super Critical (USC) power cycle. The USC cycle includes increased boiler temperatures and pressures, with steam properties of 600°C and 305 bar[100] pressure. These higher temperatures and pressures result in

[98] Accenture Analysis of EIA data for 2008, http://www.eia.doe.gov/cneaf/electricity/page/capacity/capacity.html
[99] The term "clean coal" is defined here to describe technologies and industry practices that are doing one of the following: increases generation efficiency of coal plants (this includes coal gasification or ultra-super critical units); or significantly reduces coal plant emissions (e.g., reducing CO_2 through carbon capture and sequestration)
[100] A bar is a unit of pressure equal to 100 kilopascals, and roughly equal to the atmospheric pressure on Earth at sea level. An atmosphere is defined to be 1.01325 bars exactly.

higher plant efficiencies—above 45 percent—requiring less coal per megawatt-hour, leading to lower emissions (including carbon dioxide), higher efficiency, and lower fuel costs per megawatt. Another example is Integrated Gasification Combined Cycle (IGCC),[101] a technology that turns coal into synthetic gas. Impurities are then removed before it is combusted. This results in lower emissions of sulfur dioxide, particulates, and mercury. IGCC is considered by some as being "*capture ready*," for carbon capture and sequestration (CCS).

USC plants have been built and operating commercially around the world.[102] There are challenges, however, to large scale deployment of USC technology:

- Uneconomic option compared to alternative technologies such as subcritical coal-fired power plants and natural gas-fired Combine-Cycle Gas Turbine (CCGT) power plants
- Requisite steels require approval for their use in plants by equipment standards organizations
- Better understanding of maintenance needs of the USC boiler and steam turbine along with related auxiliary systems is essential for long-term, reliable operation

IGCC plants have also garnered interest. For example, in the 1970s the Great Plains Coal Gasification Plant in Beulah, North Dakota was built to use coal gasification to produce methane, the chief constituent of natural gas. However, when price controls on natural gas were lifted in the U.S., large quantities of natural gas became available for electric generation, and no other coal-to-methane gasification plants have been built in the United States. Interest in coal gasification was revitalized in the 1990s, driven primarily by environmental concerns over burning coal. By turning coal into a combustible gas that could be cleansed of virtually all of its pollutant-forming impurities and burned in a gas turbine, the environmental performance of coal would be at the same level or better than natural gas plants. Subsequently, two IGCC plants have been built in the United States: Wabash River Generating Station in Indiana, and Polk Power Station in Florida. Research and development is ongoing to improve designs and reduce the current high capital costs.

At present, CCS has been in use to enhance oil recovery for decades. The technology must be further developed before its adoption as a plant that can provide cost-effective greenhouse gas abatement. The U.S. DOE, through its Carbon Sequestration Program, has been performing research and development over the past decade aimed at reducing the high capital costs of CCS equipment. The goal is by 2020 to have a commercial, cost-effective and operational CCS facility.[103] Another aim of the U.S. DOE's R&D efforts has been to reduce the "energy penalty" associated with operating carbon capture equipment at the coal-fired power plant. For example, the amount of energy needed to support CCS equipment is significant. For amine scrubbing, the net power plant output is reduced by approximately 20–30 percent of total generation, though the theoretical minimum is about 12 percent.[104] However, depending on the coal/natural gas plant specification and regulations, a portion of the reduced plant output may be available for spinning reserves if the equipment can be disconnected quickly in response to system disturbances.

[101] http://www.netl.doe.gov/energy-analyses/pubs/deskreference/B_IG_051507.pdf
[102] http://www.imteag.com/2-PGA-2004.pdf
[103] "Clean Coal Technology Roadmap," NETL. June 2004
[104] http://www.cctft.org/Docs/Amine%20Scrubbing%20for%20CO2%20Capture%20-%20Science.pdf

There are essentially three options for the sequestration of carbon once it is captured: geologic, terrestrial, and ocean. There are long-term risks associated with geologic and terrestrial sequestration that include leakage. In response to this, the EPA is currently developing CO_2 injection regulations for sequestration that are planned for release by 2011.[105] Ocean sequestration includes using carbon to fertilize biological systems or injecting carbon into the deep ocean. Both techniques are controversial and are not supported by current R&D efforts due to the high level of uncertainty and general lack of understanding of the side effects of adding excess carbon to ocean ecosystems.

CCS technology has been the subject of significant research and development during the last decade. CCS collects CO_2 and stores it long-term in secure reservoirs, or enhances natural carbon sinks via sequestration in soils, vegetation, or the ocean. According to the National Energy Technology Laboratory (NETL), the total U.S. storage potential for captured CO_2 is between 2.3 and 8.1 billion metric tons.[106]

Reliability Impacts—Natural Gas Generation

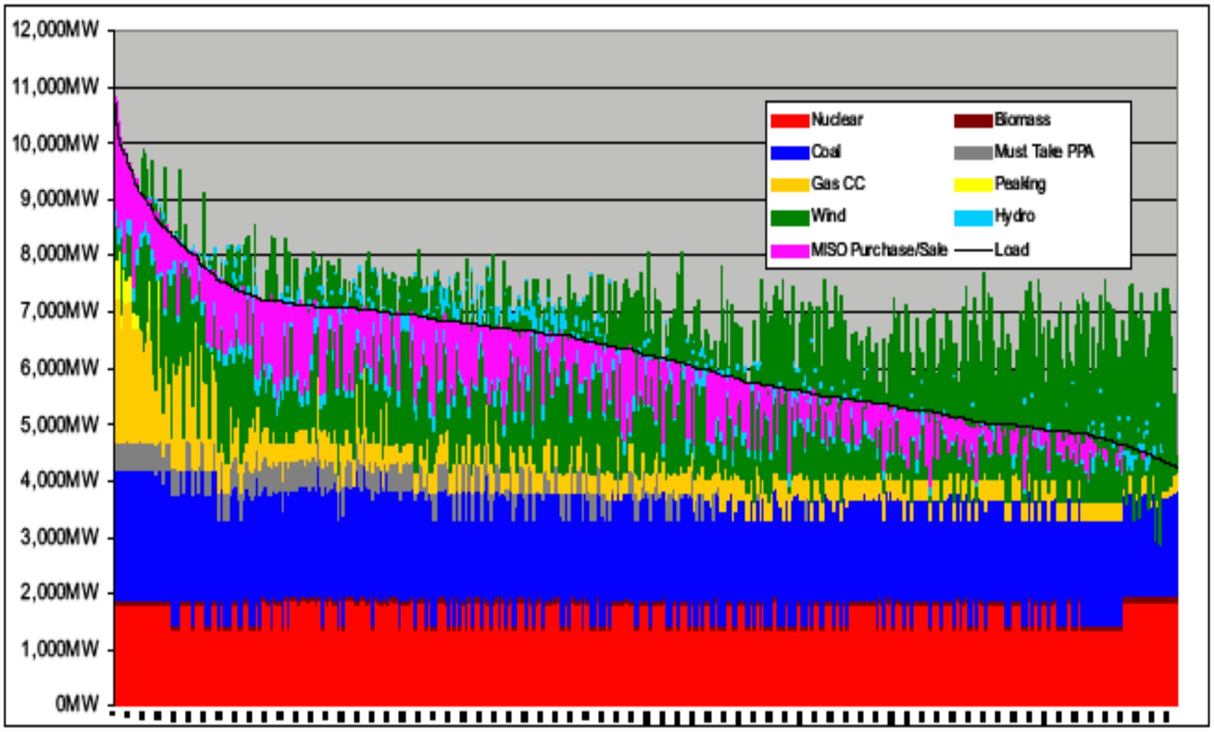
As more gas-fired turbines are built and coal units are retired or mothballed (or become uneconomical to run due to carbon taxes or cap-and-trade), the transition to gas as the fuel of choice is likely to peak during Horizon II. If natural gas plants replace coal-fired plants, significant bulk power system and gas infrastructure investments may be needed so the requisite volume of natural gas can reach them.

Reliability Impacts—Variable Generation (Wind and Solar)

Large-scale deployment of variable generation will require increased system flexibility to counter its uncertainty and variability. Some potential resources include transmission to support transactions, energy sources from other locations, and technologies that can provide additional system flexibility such as Demand Response, simple-cycle gas turbines, energy storage, transmission, etc.(Figure 5-11).

[105] "Storage of Captured Carbon Dioxide Beneath Federal Lands," NETL, May 8, 2009, Pg. 41
[106] "Carbon Sequestration R&D Overview," National Energy Technology Lab (NETL), October 2007

Figure 5-11: 2020 Load Duration Curve with Projected Thermal Dispatch with Net Imports/Exports to MISO Day-Ahead/Real-Time Markets (Northern States Power)[107]



Reliability Impacts—Distributed Generation

Distributed generation (also called on-site generation, dispersed generation, embedded generation, decentralized generation, decentralized energy, or distributed energy) generates electricity from many small energy sources. Today, distributed generation in North America is principally in the form of backup generation and is defined as generation units up to 500 kW. Examples of distributed generation technologies include engines, small turbines, fuel cells, photovoltaic systems, distributed wind systems, and combined heat and power ("CHP" or "cogeneration") systems.

The potential reliability impacts resulting from integrating large amounts of distributed energy resources must be evaluated, as it is likely that reliability concerns will arise when the

[107] This figure depicts where wind generation resources **may need to be curtailed** for much of the year (green color) when supply exceeds demand (black line) and insufficient transmission capacity is available to support transactions (purple). To better manage variable resources and avoid resource curtailments, large-scale implementations of proven centralized bulk power energy storage, including pumped hydro and compressed air energy storage (CAES), can convert this energy into dispatch-capable capacity. Even with large amounts of storage, it is likely that significant amounts of wind energy may need to be curtailed during off-peak periods, making full use of this renewable resource up to its full natural energy potential difficult to achieve. For more information: Steve Wishart, Xcel Energy*, Resource Planning Perspective on Wind Integration*, a presentation for the Midwest ISO Stakeholders' Meeting, April 16, 2008, *audio file is available at*: http://www.midwestiso.org/publish/Document/77a68f_119522dab5e_-7b250a48324a?rev=1

penetration of these resources reaches critical mass. NERC's *2008 Long Term Reliability Assessment* highlights some of these threats to system reliability at scale.[108] For example, the collective loss of many distributed generators could have a significant and unpredictable impact on the operations of the bulk power system. In addition, DG must be visible to system operators to allow for real time decision-making. While generation connected to the distribution system is not covered by NERC's authority as the Electric Reliability Organization (ERO), technical specifications for large-scale interconnection must support requirements for reliability of the bulk power system. Evolving to a system more heavily reliant on distributed resources to serve demand will require significant changes to the way the system is planned, designed, and operated.

Distributed generation can improve reliability by:

- relieving transmission and distribution system conditions,
- reducing energy losses, and
- mitigating some system events.[109]

Technology Status: Distributed Generation

Distributed generation's main advantage is that it reduces the amount of energy lost in transmitting electricity because the electricity is generated very near where it is used; perhaps even in the same building. This also reduces the size and number of power lines that must be constructed.

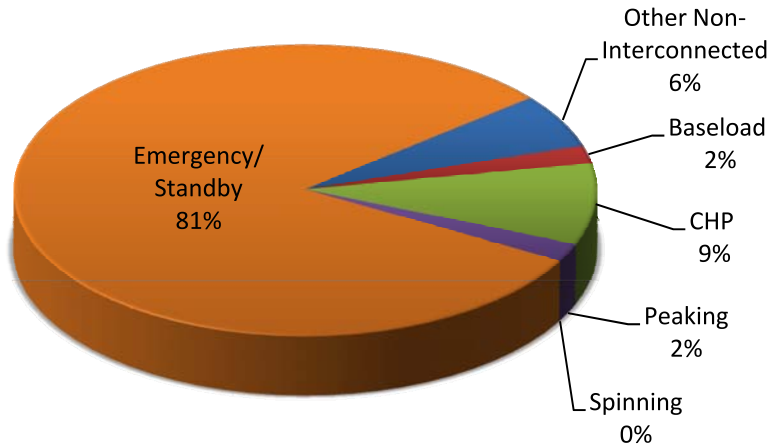
According to the Energy Information Association (EIA) as reported in 2000, there was 27,000 MW of co-generation capacity and 40,000 MW of backup generation capacity reported in the U.S. commercial and industrial sectors. Furthermore, EIA projects 49.5 GW of additional capacity by 2025 will be in the form of distributed generation (DG).[110] Today, most distributed generation is stand-by and backup power (see Figure 5-12).

However, these applications could change in the near future. Investment in research and development can lead to increased adoption of distributed resources. For example, in the U.S., the Combined Heat & Power Advancement Act of 2001 required the interconnection of co-generation with transmission and distribution grids, provision of backup power without price discrimination, and a 10-percent tax credit to organizations that added cogeneration capacity between June 30, 2001, and June 30, 2005.[111] More recently, the American Clean Energy and Security Bill of 2009 provided some preferential treatment for distributed energy resources with respect to the allocation of renewable energy credits (RECs). By allocating three RECs for every megawatt-hour produced using renewable distributed generation, the legislation expresses the intent to *"make distributed renewable generation facilities…cost competitive with other sources*

[108] Page 41, 2008 Long-Term Reliability Assessment, "Increased Adoption of Distributed Generation and Demand-Side Resources," at http://www.nerc.com/files/LTRA2008v1_2.pdf
[109] Physical Review, "Structural Vulnerability of the North American Electric Grid," 2004
[110] Congressional Budget Office, "The Current Status of and Prospects for Distributed Generation," Chapter 2, September 2003
[111] U.S. House of Representatives, H.R. 1945, "Combined Heat & Power Advancement Act of 2001"

of renewable electricity generation."[112] State-level renewable portfolio standards also define the type of renewable technologies that are included. Despite their low emissions, fuel cells and micro-turbines are not included in most states' RPS definitions. This change in application and the broader application of variable generation, fuel cells, and energy storage will be driven by not only climate change initiative-driven support, but also by technological advances in their suitability for new applications.

Figure 5-12: Distributed Generation Capacity by Application Percentage in 2003[113]

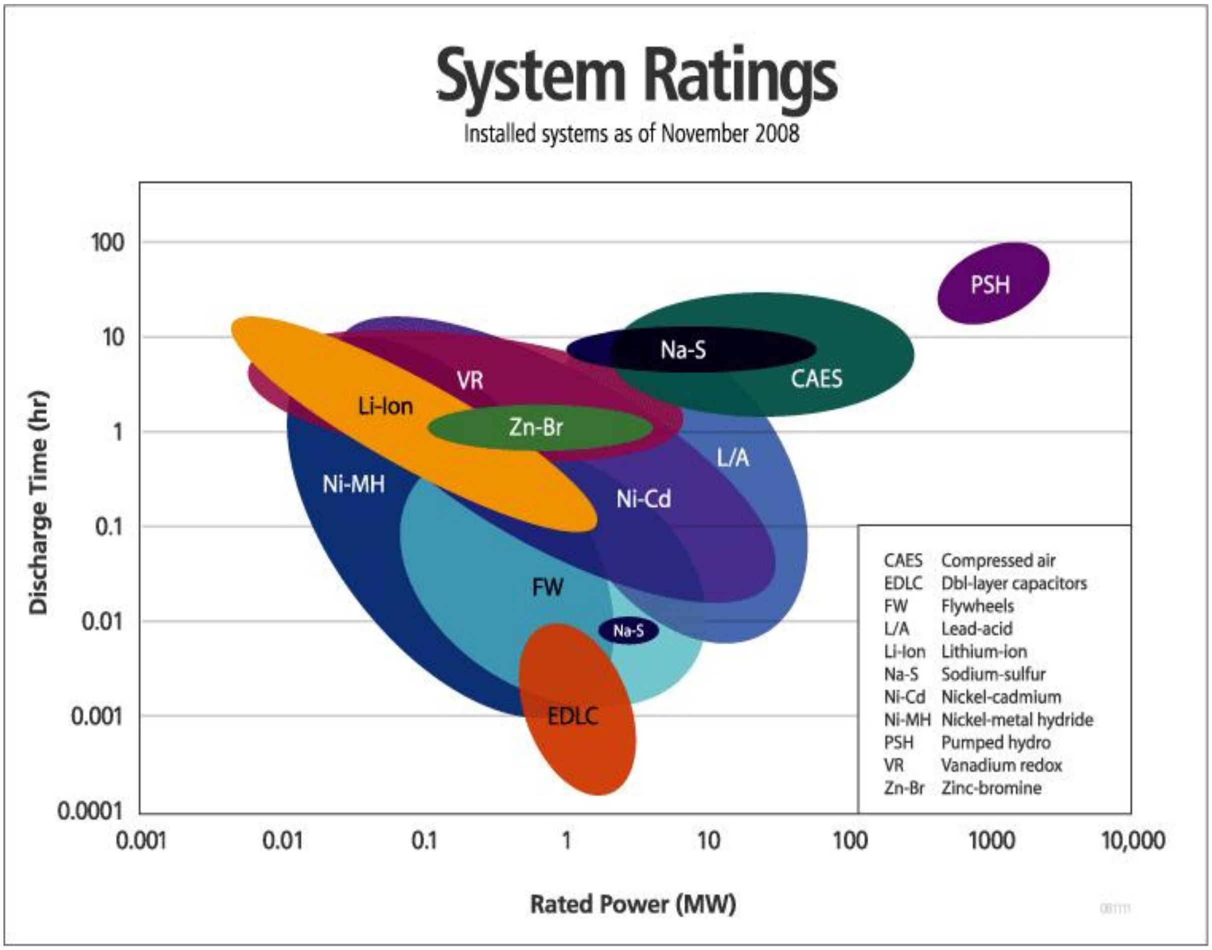


Reliability Impacts—Energy Storage

Energy storage technologies enable the decoupling of the instantaneous supply of energy from the variable nature of demand (Figure 5-13). This characteristic would enhance the integration of variable renewable resources into the grid and the provision of ancillary services. Other than water stored in existing hydroelectric systems, pumped storage hydropower is the most widespread energy storage system in use on power networks worldwide. Today, over 40 pumped storage projects operating in the United States and one in Canada, whose main applications are for energy management, frequency control, and provision of reserve, primarily spinning reserve, due to large turn-down ratios. Pumped hydro is available at almost any scale, with the largest operating plant capacity of just under 3,000 MW and with storage times ranging from several hours to a few days. Response time from speed no load to full power can be less than five seconds. Pumped storage plants are characterized by low operating costs and a 50- to 100-year life, but also long construction times and high capital expenditure.[114]

[112] Page 33, American Clean Energy and Security Bill of 2009
[113] EPRI, "Distributed Energy Resources: Current Landscape and Road Map for the Future," report number 1008415, www.epri.com, November 2004
[114] http://www.electricitystorage.org/ESA/technologies/pumped_hydro/

Figure 5-13: Comparison of Energy Storage Technology Characteristics[115]



Storing energy during conditions when it is available, such as low-load periods, could provide additional resources for capacity, energy, or ancillary services. For example, energy storage resources could be used to serve peak loads as a dispatch-capable resource, making energy storage a viable way to manage generation minimums and provide additional capacity.

Depending on the energy storage device, it could maintain voltage and frequency as backup generation comes on-line, or provide sustained capacity when wind becomes unavailable. Second, energy storage can be used to provide ancillary services such as spinning reserves and frequency regulation. For example, when an energy storage device is used as a spinning reserve, the overall efficiency of the power system is increased. Third, storage can transform energy into capacity by storing available energy when demand is low and making it available when demand increases. This is especially helpful for variable generators that are available to counter daily peaks, such as wind generation. Parenthetically, pumped hydro has been used extensively to support nuclear plant installations, and provides grid-scale storage around the world.

[115] Energy Storage Association, http://www.electricitystorage.org/ESA/technologies/technology_comparisons/

Cost-effective energy storage would improve overall system reliability because stored energy can replace or augment generation capacity at times of high demand. Thus, electricity providers could manage variable renewable resources needed to meet RPS requirements or nuclear plants with deployments of energy storage. Additionally, energy storage would improve frequency regulation and local capacity reliability, and enable injection of power into the system when the electric grid experiences system disturbances or is facing stability issues.[116]

Accordingly, the electric industry is interested in the progression of energy storage technologies as a way to convert energy into capacity and as a way to provide ancillary services.

Technology Status: Energy Storage

Energy storage technologies are generally used to meet one of three categories. The first is providing continuity of service as generation is being switched from one source to another. In this application, the time period ranges from seconds to minutes. The second application is energy management. In this setting, storage devices are charged when energy demand is low, and discharged when demand is high. By providing capacity the storage unit can act as a load leveling device, increasing system efficiency. The third application is for ancillary services.

Pumped storage hydroelectric projects have been providing valuable storage capacity, transmission grid ancillary benefits, and renewable energy in the United States since the 1930s. Only one large scale plant has been started since the 1980s, the Rocky Mountain Pump Storage project in Georgia, with a 40 MW plant currently under construction in California. However, since the 1990s, a number of existing pumped storage hydropower plants have been repowered and upgraded with plant capacity increases between 10 to 20 percent, growing to over 22,000 MW. In response to the growing applications for storage, and the potential synergy between pumped storage and variable renewable energy sources such as wind and solar, more than double the pumped storage capacity has been proposed. The U.S. Federal Energy Regulatory Commission (FERC) has recently issued 32 preliminary permits for new pumped storage hydro projects, representing nearly 26,000 MW of storage capacity. Another four applications for preliminary permits pending before FERC could provide an additional 3,000 MW of capacity.[117]

Canada is the largest producer of hydroelectricity in the world, generating over 60% of its electricity using hydroelectric dams, which inherently have stored energy from water in the associated reservoir, resulting in little need for pumped hydro storage facilities. There is one pumped hydro plant built in 1957 at Niagara Falls, which can delivery up to 174 MW (Sir Adam Beck Hydroelectric Power Stations).

Other than pumped hydro storage, to date widespread use of energy storage technologies on the bulk power system has been cost-prohibitive and therefore had minimal penetration. However, storage has been used in commercial and industrial facilities, especially to serve critical loads such as server plants and data centers. A number of prototype storage technologies are being tested throughout North America. For example, sodium-sulfur (NaS) batteries appear to be both

[116] "Energy Storage for Wind Integration, a Conceptual Roadmap for California," Carnegie Mellon Conference on the Electric Industry, March 10, 2008, Slide 5

[117] http://www.ferc.gov/industries/hydropower.asp

compact and long lasting. For example, American Electric Power is testing a prototype battery with a capacity of 1.2 MW, with another being considered at double that size. Pacific Gas & Electric is reviewing the potential for a 5 MW version. Additional prototypes are being tested within the Midwest ISO (7 MW) and PJM Interconnection (5 MW).

Compressed air energy storage (CAES), first tested at Alabama Electric Cooperative (PowerSouth Cooperative), is being considered by the Iowa Stored Energy Park[118] as a way to collect wind energy by storing compressed air in caverns below ground. The plant uses off-peak electricity to pump air into the cavern. When the compressed air is needed for generation, it is mixed with natural gas and used in a conventional gas turbine during peak periods.

Another way to store energy is to refine fuel from excess energy. For example, wind to hydrogen production and storage is currently being demonstrated at the National Wind Technology Center in Golden, Colorado.[119] The project is the result of a partnership between The United States' Department of Energy's National Renewable Energy Laboratory (NREL) and Xcel Energy. The goal of the wind-to-hydrogen (Wind2H2) project is to improve the efficiency of producing hydrogen from renewable resources so as to make it competitive with traditional energy sources. As part of this project, hydrogen produced from wind is stored and used to fuel a generator when wind speeds drop.

A similar project in Prince Edward Island is being promoted by the PEI Energy Corporation. PEI Energy Corporation began tendering in the fall of 2006 for equipment for the Prince Edward Island Wind-Hydrogen Village. This project will demonstrate how wind energy and hydrogen technologies can work together to offer clean energy solutions for small and remote communities. The first phase of the Prince Edward Island Wind-Hydrogen Village Project includes the installation of a hydrogen production station, a hydrogen storage depot, a hydrogen fuelled generator, and a wind-hydrogen integrated control system. Wind energy from the turbines at the Wind Energy Institute of Canada will be used to meet ongoing electricity needs and to provide power to electrolysis equipment. The hydrogen will then be used in a hydrogen fuelled engine to provide backup electricity.

Finally, flywheel technologies are being deployed to supply electricity for brief periods—from a few seconds to a few minutes—to help support ride-through for sensitive loads.[120]

[118] http://www.isepa.com/

[119] http://www.ic.gc.ca/eic/site/wei-iee.nsf/eng/00177.html

[120] The CIGRE (*Conseil International des Grands Réseaux Électriques* or International Council on Large Electric Systems) Study Committee C6, "Distribution Systems and Dispersed Generation" has recently initiated Working Group C6.15, entitled "Electric Energy Storage Systems," to evaluate different storage technologies and support their integration in power systems with high penetration of dispersed generation and renewable based generation.

5.1.3 Horizon III: 20-plus years Generation and DSM Technology Reliability Assessment

The Horizon assessments are cumulative, and, therefore, previous reliability considerations will not be repeated after each time horizon unless reliability considerations change.

Table 5-3: Generation and DSM Technology Risk Matrix—Horizon III (20-plus years)

Technology	Potential Reliability Issue	Present Assumption	Additional Mitigating Measures
Nuclear Generation	• Provides carbon-free generation, but public not completely comfortable with the technology • Increased flexibility is not developed for new designs • More operational reserve may be required	• New nuclear plants may or may not be constructed • More than 300 new units at existing and new sites with a capacity of 1,000MW will be required to replace coal fleet • More cycling capability required of nuclear plants to provide operational flexibility	• Lift emission restrictions of gas-fired generation • Increased variable renewable generation • Demand-side management • Conventional generation • Build more transmission
Geothermal	• Geothermal plants not able to supplement nuclear or replace natural gas units	• May offer small scale relief for nuclear unless technology advances significantly	• Increase number of nuclear units • Emission restrictions of gas-fired generation lifted
Natural Gas Generation	• More stringent CO_2 regulations have made gas units less economical	• New build will be replaced with geothermal, hydro, or nuclear units	• Lift emission restrictions of gas-fired generation
Energy Storage	• Deployment of large amounts of energy storage is not cost effective	• Larger energy storage is likely to be commercially available & cost effective • New pumped storage	• Conventional generation • Curtail variable generation

Reliability Impacts—Nuclear Generation

According to the DOE's Energy Information Agency (EIA), nuclear energy is projected to play a predominant role as CO_2 emissions are further reduced in this Horizon. In terms of reliability, the bulk power system will be dependent on energy storage for regulation and balancing unless advanced nuclear plant designs can support these services. Moreover, the addition of new nuclear units must be adequate to make up for the retirements of the 60-year-old first-generation fleet of nuclear units after 2030. Once existing nuclear sites are fully used, it is likely that abandoned and new nuclear generation sites will be developed, increasing the nuclear portion of the overall resource mix.

Further, as new nuclear sites are developed that have generally larger capacity then the current fleet, additional bulk transmission system may be required along with supporting operational reserves, used to offset the unexpected loss of an individual plant's capacity. To accommodate any significant increases in nuclear output, either nuclear fuel reprocessing or a permanent solution to spent nuclear fuel storage will be required.

Reliability Impacts—Geothermal Generation

The addition of geothermal units can support achieving emission reduction goals. However, the deployment of these units will be largely dependent on achieving relative commercial viability.

Geothermal Generation

Geothermal generation can easily be integrated into the bulk power market in its current format and structure as its maximum capacity is nearer to its installed amount. About 10 GW of geothermal electric capacity had been installed around the world as of 2007, generating 0.3 percent of global electricity demand. The U.S. is the world leader with approximately 30 percent of the total worldwide on-line capacity. An additional 28 GW of direct geothermal heating capacity is installed for district heating, space heating, spas, industrial processes, desalination, and agricultural applications.

Geothermal power is reliable and can support emissions goals, but, like other resources, large-scale application availability of this resource is highly concentrated in only a few states, mostly in the western United States. To date, the U.S. Geological Survey (USGS) has focused its assessments of geothermal power potential on the following states: Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

According to the latest estimates from the USGS, the potential for geothermal production is:

- over 9,000 MW from domestic, conventional, identified geothermal systems,
- over 30,000 MW from conventional, undiscovered geothermal resources, and
- almost 520,000 MW from unconventional (high temperature, low permeability) Enhanced Geothermal Systems (EGS) resources.[121]

Technology Status: Geothermal Generation

For the 20 years following the boom of geothermal construction in the 1970s and 1980s, few geothermal plants were constructed in the U.S. Then, the Energy Power Act of 2005 spurred activity in the geothermal industry because it made new geothermal plants eligible for full federal production tax credits and increased funding for DOE research, and established a competitive leasing process while simplifying the procedure for assessing royalties.

These changes, along with the Geothermal Steam Act Amendment of 2005, gave authority to the U.S. Bureau of Land Management (BLM) for the exploration, development, and use of geothermal resources on all public lands.[122] Since then, the BLM has been able to address its backlog of geothermal leases and permits. As of August 2008, 103 new projects were underway in 13 U.S. states, with a total potential capacity of almost 4,000 MW.

[121] "Substantial Power Generation from Domestic Geothermal Resources," U.S. Geological Survey, September 29, 2008, http://www.usgs.gov/newsroom/article.asp?ID=2027

[122] "Geothermal Resource Leasing and Geothermal Resources Unit Agreements" EPA, May 2, 2007, http://www.epa.gov/EPA-IMPACT/2007/May/Day-02/i7991.htm

Additionally, with the increase in research funding, DOE was able to establish the Geothermal Technologies Program (GTP) with the goal of developing innovative geothermal energy technologies to find, access, and use its geothermal resources.[123] If these goals are met, the DOE estimates that approximately 15,000 MW of new capacity could come on line over the next decade.[124]

Reliability Impacts—Decline of Natural Gas-Fired Plants

After 2030, the use of natural gas may begin its decline as more stringent CO_2 regulations phase-in. However, there is interest in expanding the use of CCS technology for natural gas plants. Research and development on this technology could result in a larger role for natural gas-fired plants in the future, if retrofitted and new plants contribute less CO_2 then conventional plants.

The system will be dominated largely by less flexible nuclear, coal/natural gas with CCS, and renewable units, with a few gas units to cover the diurnal and seasonal load changes. System flexibility could be enhanced through the addition of Demand Response, transmission, energy storage, etc.

This bulk power system could be challenging to operate, requiring additional procedures to support the continuous balancing of demand and supply. Even if the construction and operation of natural gas-fired power plants are curtailed, it is likely that a significant amount of low capacity-factor gas turbine power plants would still be required to manage the increased net system variability resulting from high wind/solar penetration, to meet reliability requirements.

Reliability Impacts—Energy Storage

After 2030, with other fossil-fueled options less attractive, significant penetration of variable generation will require a sufficient amount of additional system flexibility, including energy storage and demand shaping. By 2030, storage technology must be advanced enough to deploy devices able to convert off-peak energy into on-peak capacity and supply regulation, frequency response, and balancing. Large amounts of energy storage, both at the supply level and the distribution level, will be needed to cover the ramping and regulation requirements of the system. DSM resources will help, but with fewer coal and gas units with load following characteristics, it will be difficult to manage all load fluctuations with DSM on the system. Control of thousands of gigawatt-hours of energy by operators of storage resources will be challenging.

[123] http://www1.eere.energy.gov/geothermal/about.html
[124] http://www1.eere.energy.gov/geothermal/powerplants.html

5.2 Bulk Transmission Technology Reliability Assessment

The current configuration of the bulk transmission system developed around the location and distribution of both generation resources and demand centers. The impact of climate change initiatives on the transmission grid will vary significantly from region to region, influenced by the natural resources available and the current infrastructure. Nevertheless, there are common trends in all regions, the most significant being the difficulty to site new transmission corridors.

The integration of the new generation technologies on the bulk power system and the ability to move power long distances will be crucial for the maximization of variable resources over the coming 30 years. Bulk transmission will be a key resource to taking advantage of non-coincidental generation patterns throughout the regions. Siting and cost-allocation for these crucial resources remain barriers to their construction. In a recent report, NERC cited the need for entities to more than double the average number of transmission-miles constructed over any five-year period since 1990 to meet planned levels of development over the coming ten years.[125]

The addition of new resources increases the need for transmission and energy storage/balancing resources

Beyond the simple expansion and strengthening of the transmission system, a number of technologies, with varying reliability considerations, are under consideration to improve flexibility, capacity, and operation. "Smart" transmission technologies and strategically placed energy storage will be used to make more efficient and reliable use of the system.[126]

Horizon assessment for bulk transmission technologies is shown in Tables 3-4 through 3-6; therefore, reliability considerations will not be repeated after each time horizon unless reliability considerations change.

[125] http://www.nerc.com/files/2009_LTRA.pdf

[126] There have been strides worldwide on increasing the voltage (both alternating and direct current) of the bulk power system (i.e., 1000 kV) and development of superconducting facilities. These technologies will have specialized applications to support long-distance transmission and increase the efficiency of resource delivery.

5.2.1 Horizon I: 1–10 years Transmission Technology Reliability Assessment

The Horizon assessments are cumulative, and, therefore, previous reliability considerations will not be repeated after each time horizon unless reliability considerations change.

Table 5-4: Transmission Reliability Impact—Horizon I (1–10 years)

Technology	Potential Reliability Issue	Present Assumption	Additional Mitigating Measures
"Smart" Transmission Technologies	• PMU, DTCR, and FACTS[127] will not deliver all promised benefits and will not sufficiently help manage and relieve transmission congestion • Cyber security concerns	• PMU, DTCR, and FACTS have already proven valuable for transmission management • Devices will be installed at large substations and variable generation/ energy storage sites • Protection schemes will be developed to appropriately address cyber security concerns	• Construction of new and/or upgrades of existing transmission lines are options to relieve congestion • Develop new tools and techniques to support planning, design, and operations • Ensure that cyber- and physical security are part of the planning, design, and operations of the bulk power system
Energy Storage	• Deployment of large amounts of energy storage is not cost effective; energy storage is not deployed and does not mitigate transmission constraints	• Larger energy storage is likely to be commercially available and cost effective • New pumped storage	• Curtail variable generation or use other technologies such as Demand Response to manage variability

Reliability Impacts—"Smart" Transmission Technologies

The deployment of automation, or "smart," technologies, on the bulk power system has continued to grow and evolve. The goal for these deployments has been to better match energy supply with demand. "Smart" technologies have been implemented at the substation (in the form of SCADA, or supervisory control and data acquisition) and more recently, in smaller numbers, directly on transmission circuits. Some examples of this include automated reconfiguration capabilities, Dynamic Thermal Circuit Rating (DTCR), phasor measurement units (PMUs), and Flexible AC Transmission Systems (FACTS).

Today, the transmission grid has a high level of observability and some basic remote control. The basic transmission parameters—voltage, frequency and current—are well monitored and understood. One potential benefit to be gained from the deployment of "smart" transmission technology is a better understanding of the real-time operation parameters (e.g., the relative angle of the voltage) of the grid, allowing for the subsequent improvement to the precision of control, response, and view of the transmission system. The increased visibility into the system will allow

[127] Phasor Measurement Unit (PMU), Dynamic Thermal Circuit Rating (DTCR), and Flexible AC Transmission System (FACTS)

operators to more effectively manage the bulk power system, especially during off-peak periods—an ability that will be critical to the reliable integration of variable renewable resources such as wind and solar.

Two significant reliability considerations must be addressed with the implementation of new "smart" transmission technologies. Unless carefully planned and operated, new communications channels can provide a vehicle for cyber attack on the bulk power system through a variety of entrance and exit points. Further, the physical assets that support Smart Grids will require protection as dependence grows on their functionality.

Second, new tools and analysis techniques will be required to design and manage the deployment of broad-scale smart control systems across the bulk power system. As it is a large system with non-linear characteristics, the ramifications and design of Smart Grid controls must be modeled, simulated, and designed to ensure that the projected performance improvements will be realized without any unintended consequences.

Technology Status: "Smart" Transmission Technologies

Today, the transfer capability can be increased by the addition of equipment, by raising the operating voltage, and by reconfiguring conductors into a more compact arrangement. More advanced technologies, such as DTCR, PMUs, and FACTS, will contribute to the industry's ability to make effective use of existing assets. These technologies enable the operator to gain intelligence of the status of the transmission grid on a real-time basis, and to make better use of existing transmission capacity and energy carrying capability.

Phasor measurement units (PMU) produce data useful to improve planning and operations for the purpose of disturbance monitoring, stability model validation, data retention, and disturbance analysis. This will enable more efficient transmission system use through the employing of dynamic ratings and the advent of new special protection systems, thus significantly improving operating reliability.[128] The implementation of PMUs throughout systems in North America has been gradual due to a number of factors:

- reliability benefits of PMUs for planning and operations require industry awareness,
- physical and cyber security considerations must be addressed prior to deployment,
- regulatory uncertainty with respect to cost recovery and data access, and
- development of tools required to use the information both for operations and planning.

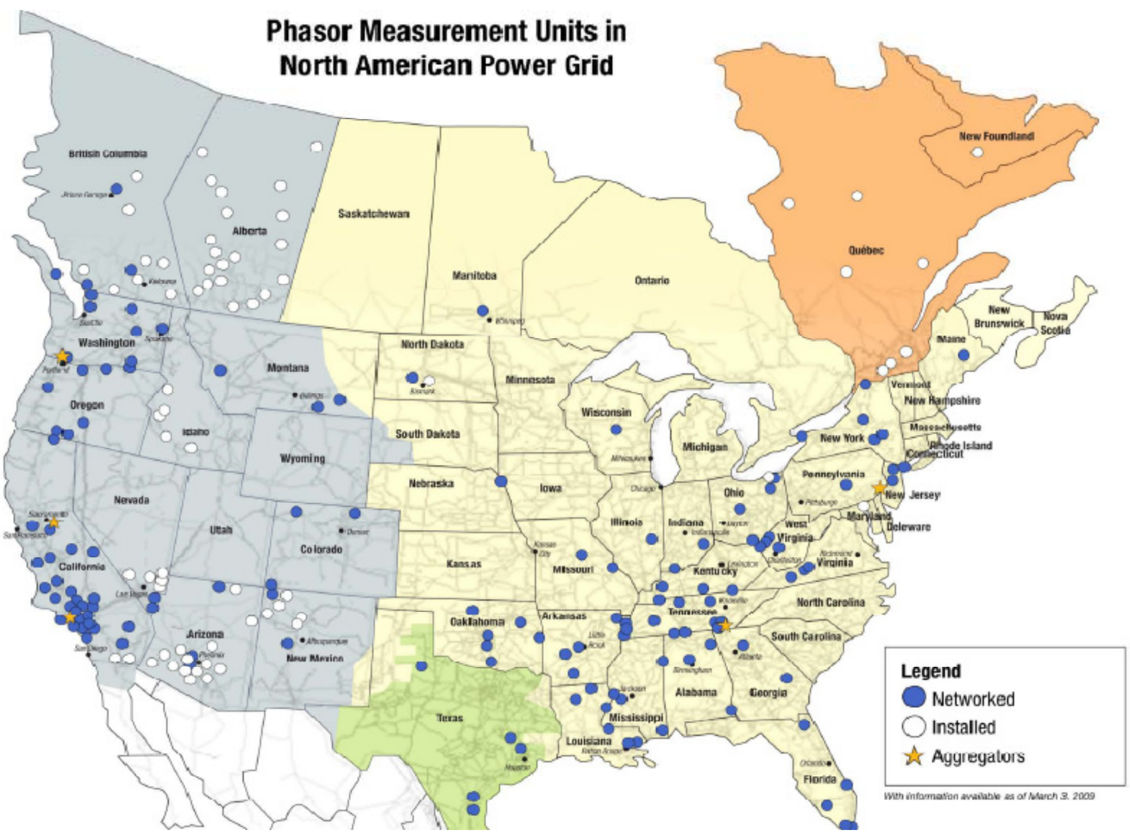
As of early 2009, there were nearly 150 PMUs (see Figure 5-14) connected to and supplying data-to-data concentrators at TVA or CAISO. An additional 100 operational PMUs are in the field collecting data but are not networked to the data concentration sites. In addition, there are hundreds of digital relays that can perform PMU-like functions if activated. The North American SynchroPhasor Initiative (NASPI) estimates that 1,200 PMUs are required to provide the needed level of wide area visibility of the four interconnections in North America. Current NASPI plans

[128] SynchroPhasor Technology Roadmap. North American SynchroPhasor Initiative (NASPI), March 13, 2009, http://www.naspi.org/resources/2009_march/phasortechnologyroadmap.pdf

call for PMU deployments by 2014 at major transmission interconnections, 500 kV and above substations, near major load centers, and at large wind, solar, or storage facilities.[129]

Additionally, the deployment of Dynamic Thermal Circuit Ratings (DTCR) will be used to increase the thermal loading capacity of individual transmission lines and substation equipment. Present limits are static and often conservative, based on worst-case weather conditions. DTCR uses real-time information about weather, load, temperature, line tension, and/or line sag to estimate actual thermal limits, thus allowing higher thermal capacity of transmission lines and substation equipment. DTCR is being demonstrated on a number of transmission systems and, in some cases, deferred planned line upgrades.

Figure 5-14: Phasor Measurement Units in the North American Power Grid[130]



Flexible Alternating Current Transmission Systems (FACTS), coupled with storage devices, will increase the power transfer capability of individual transmission lines or a transmission corridor, and improve overall system reliability by reacting almost instantaneously to disturbances, allowing lines to be loaded closer to their inherent thermal limits. Specifically, the deployment of Unified Power Flow Controller (UPFC) and the Convertible Static Compensator (CSC) will increase the ability to control both real and reactive power flows among transmission corridors and maintain the stability of transmission voltage. FACTS technologies are a commercial technology that has seen a slow implementation due to its relative cost compared to alternatives.

[129] SynchroPhasor Technology Roadmap, North American SynchroPhasor Initiative (NASPI), March 13, 2009
[130] North American SynchroPhasor Initiative Phasor Applications Update, NERC OC Briefing, March 17, 2009

Reliability Impacts—Energy Storage

The multifaceted character of energy storage enables it to be classified across the spectrum of facilities (e.g., supply, transmission facilities, distribution facilities, and demand). The introduction of reliable and cost-effective energy storage technologies would provide the following benefits:

- **More resources to manage effective transmission use**—The proper placement of storage devices can be leveraged to alleviate bulk power system transmission reliability constraints by minimizing instances where power flow nears the capacity of a transmission line.
- **Reduced transmission losses**—According to published research, almost 2.8 percent of line losses occur in the bulk power system. These line losses are higher when line loadings are larger. In other words, the percentage of lost power is larger during on-peak periods than it is during off-peak periods. By placing storage devices closer to load centers, high peak periods and losses can be minimized. Lower losses unlock resources otherwise unavailable to support reliability.
- **Transmission asset life extension**—By using storage at substations or on transmission lines, equipment overload conditions, which can reduce asset life, can be reduced.

For example, pump storage hydropower has historically been categorized as a generation asset in the North American power system. With the invention of new adjustable speed technology for pump storage hydro in Japan in the 1990s, it is possible to improve the energy exchange between the rotating mass of the machine and the transmission system with response times improved to milliseconds, making it possible for a pump storage machine to provide system damping during transient disturbances in both pump and generation mode. Adjustable speed technology also allows for power regulation in pump mode that is not possible with older synchronous motor-generators.[131] Experience with Dinorwig in the United Kingdom and Vianden in Luxembourg are two examples of how pumped storage plants can be used to provide system-wide transmission services.

Technology Status: Energy Storage

Currently, the bulk power system application of energy storage technologies can be categorized into one of two categories: The first is grid stability, where stored energy is needed for seconds or less to assure continuity of service. The second is the positioning of devices to manage flows on transmission. These devices are charged during off-peak times and discharged to serve loads that are downstream from congested transmission facilities.

[131] "Application of Adjustable-Speed Machines in Conventional and Pumped-Storage Hydro Projects," Final Report EPRI TR-105542, Palo Alto, Calif., 94304; November 1995, Weis H, and Krecke M.;
"The Vianden Pumped Storage Power Plant," presented at the IEEE-PES 1994 Winter Power Meeting, New York, N.Y., February 2, 1994, and Scott J.; and
"Using Pumped Storage as a System Management Tool," Panel Session on Advanced Pump Storage Technology and Operation; presented at the IEEE 1994 Winter Power Meeting, New York, N.Y., Feb. 2, 1994

Another possible application for energy storage technology is deploying ultra-capacitors for grid stability. Currently, ultra-capacitor technologies have lower energy storage per unit volume than typical battery technologies. However, ultra-capacitors function well in a wide range of temperature and humidity environments, are characterized by lifetimes that are in the range of millions of charge and discharge cycles, and require minimal maintenance. Overall, however, application of ultra-capacitors on a scale appropriate for integration into the bulk power system is untested due to their relative cost compared to alternative solutions.

5.2.2 Horizon II: 10–20 years Transmission Technology Reliability Assessment

The Horizon assessments are cumulative, and, therefore, previous reliability considerations will not be repeated after each time horizon unless reliability considerations change.

Table 5-5: Transmission Reliability Impact—Horizon II (10–20 years)

Technology	Potential Reliability Issue	Present Assumption	Additional Mitigating Measures
"Smart" Transmission Technologies	• PMU, DTCR, and FACTS will not deliver all promised benefits and will not sufficiently help manage and relieve transmission congestion • Cyber security	• PMU, DTCR, and FACTS have already proven valuable for transmission management • PMUs, FACTS, and DTCR are deployed throughout the 115 kV and above transmission system • Protection schemes will be developed to appropriately address cyber security concerns	• Construction of new and/or upgrades of existing transmission lines are options to relieve congestion • Ensure that cyber- and physical security consideration are part of the planning, design, and operations of the bulk power system
Energy Storage	• Deployment of large amounts of energy storage is challenging due to project costs and uncertain revenues; energy storage is not deployed and does not mitigate transmission constraints	• Larger and more powerful energy storage devices will be available	• Curtail variable generation or use other technologies such as Demand Response to manage variability • Increased transmission can support needed transactions.

Reliability Impacts—"Smart" Transmission Technologies

Phasor data and functionality can support primary voltage control, wide-area monitoring, and situational awareness and model benchmarking.[132] Furthermore, the next generation of FACTS controllers will increase the use of phasor deployments, which can improve reliability and coordinate the operation of multiple FACTS controllers in a transmission grid. Their controls must also be coordinated so they do not interfere with other controllers to optimize power flow and reduce instabilities on a regional basis. The fourth generation of FACTS controllers will use

[132] SynchroPhasor Technology Roadmap, North American SynchroPhasor Initiative (NASPI), March 13, 2009

new power semiconductor switches (e.g., Emitter Turn-Off or ETO) that have the potential of significantly reducing the cost and improving reliability and functionality of FACTS controllers. Their deployment will provide an enhanced sense of transmission system “state” and could have operational reliability benefits.

In addition to the previously mentioned cyber- and physical security along with design considerations, operation and maintenance considerations of new equipment must be understood as part of the design and operation of the bulk power system.

Reliability Impacts—Energy Storage

Providing sufficient large-scale storage, augmented by distributed storage associated with plug-in electric vehicles (PEVs), stationary storage, etc. could support both adequacy and operating reliability. Furthermore, the design process and market rules driving the development of the bulk power system would change.

5.2.3 Horizon III: 20-plus years Transmission Technology Reliability Assessment

The Horizon assessments are cumulative, and, therefore, previous reliability considerations will not be repeated after each time horizon unless reliability considerations change.

Figure Table 5-6: Transmission Reliability Impact—Horizon III (20-plus years)

Technology	Potential Reliability Issue	Present Assumption	Additional Mitigating Measures
“Smart” Transmission Technologies	• PMU, DTCR, and FACTS will not deliver all promised benefits and will not sufficiently help manage and relieve transmission congestion • Cyber security	• PMU, DTCR, and FACTS have already proven valuable for transmission management • PMUs, FACTS, and DTCR will be deployed on the 69 kV and above transmission system • Advanced protection schemes will be developed to appropriately address next-generation cyber security concerns	• Construction of new and/or upgrades of existing transmission lines are options to relieve congestion • Ensure that cyber- and physical security consideration are part of the planning, design, and operations of the bulk power system
Energy Storage	• Deployment of large amounts of energy storage is not cost effective; energy storage is not deployed and does not mitigate transmission constraints	• Larger and more powerful energy storage devices will be available	• Curtail variable generation or use other technologies such as Demand Response to manage variability • Increased transmission can support needed transactions.

Reliability Impacts—“Smart” Transmission Technologies

PMUs, FACTS, and DTCR will have been effectively integrated throughout the transmission system as part of intelligent electronic devices on the transmission system. No new impacts are anticipated after the next 20 years.

Reliability Impacts—Energy Storage

Providing energy storage can meet its cost and efficiency objectives, it will become an integral and established component of the transmission system, significantly affecting and improving bulk power system reliability. A large amount of storage on the electric system will help withstand sudden disturbances such as electric short circuits or the unanticipated loss of system components.

5.3 Distribution Technology Reliability Assessment

A number of prominent technologies will be integrated into the distribution system in the coming years. Changing the distribution system characteristics can affect the reliability of the bulk power system.

This section identifies and discusses key reliability considerations related to the cumulative time horizons of 1–10 years, 10–20 years, and 20-plus years presented in Tables 3-7 through 3-9, and, therefore, reliability considerations will not be repeated after each time Horizon reliability considerations change.

5.3.1 Horizon I: 1–10 years Distribution Technology Reliability Assessment

The Horizon assessments are cumulative, and, therefore, previous reliability considerations will not be repeated after each time horizon unless reliability considerations change.

Table 3-7: Distribution Technology Reliability Impact—Horizon I (1–10 years)

Technology	Potential Reliability Issue	Present Assumption	Additional Mitigating Measures
Smart Meters	• Limited consumer interest in smart meter applications, and projected reductions in energy are not realized • Growing resistance to mandatory dynamic pricing by residential end-users • Cyber security	• Smart meters will be largely deployed across North America over the next 10 years, enabling substantial reduction in energy use • Dynamic pricing will be extensively piloted and deployed in many areas • Smart meters can provide attackers entry to information and communication systems enabling the exploitation of bulk power system vulnerabilities	• Without substantial uptake in smart meter applications, additional resources will be required to serve demand • The design and deployment of smart meters must ensure that they cannot be used as attack vectors compromising bulk power system reliability
"Smart" Distribution Technologies	• The technology will not become commercially viable and gain enough scale to have an impact • Cyber security • Dynamic stability considerations	• High cost and complexity • Involves the collection and analysis of large amounts of data • Network is still vulnerable to cyber attacks and compliance is complex • More visibility and controllability needed to ensure reliability	• The American Clean Energy and Security Bill of 2009 calls for detailed plans to deploy distribution automation across the system, emphasizing reduction of line losses and improved system reliability • Build private networks that are not interoperable for network control • Develop advanced planning and operating tools

Reliability Impacts—Smart Meter

The deployment of advanced metering infrastructure (AMI) and smart grids could potentially support reliability of the bulk power system at the distribution level, as owners consider options for portfolios of Demand Response and Energy Efficiency programs. In addition, AMI provides the data and the visibility needed to enhance DSM applications. Further, smart meters support two-way flows of energy and communications, enabling consumers to manage their energy use.

However, this increased communications capability can also amplify the number of points for potential cyber attacks. Trusted components and communications associated with AMI deployment and overall infrastructure must be designed to maintain cyber security, and protect against potential cyber threats against reliability of the bulk power system.

Therefore, planners must design the bulk power system to ensure it will have the resources/technologies needed to respond to cyber attacks and remain reliable, including from threats that may originate from the distribution system. Operators will require tools that identify cyber attack vectors and provide guidance on mitigation actions ensuring that the bulk power system will remain reliable, while enabling operators to counter cyber attacks.

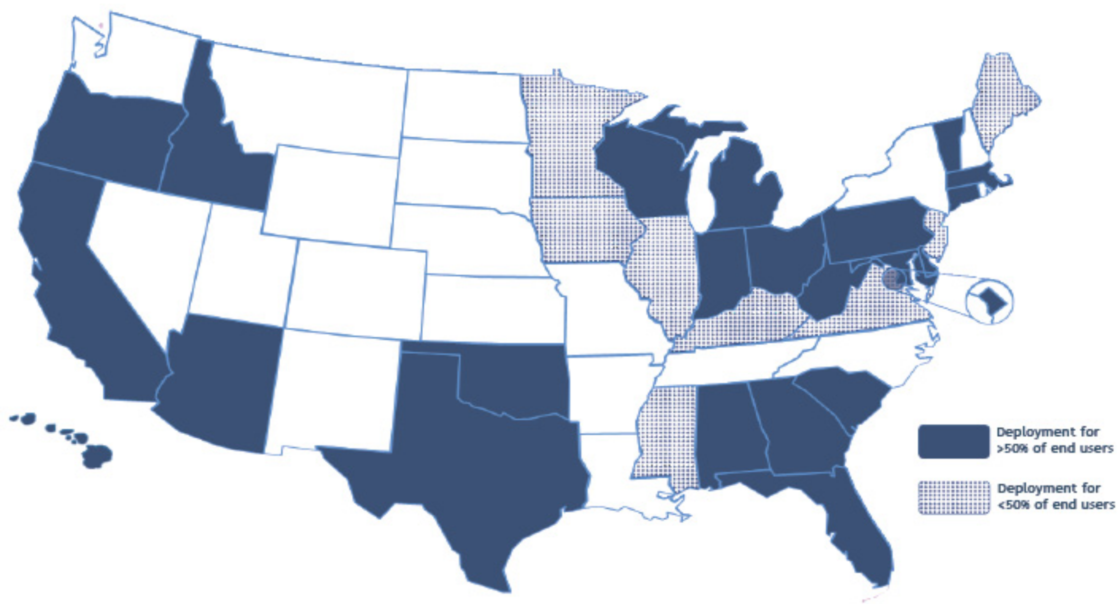
Technology Status: Smart Meter

Today, most electric meters are electromechanical or solid-state. Electric meters are either predominately read manually or by drive-by. Typically, meter readings are completed on a monthly basis, though due to weather or access restrictions, estimation techniques based on historic consumption levels are often used. Most often, such estimation leads to inexact electric billings. Additionally, the increase in capital costs highlights the need for industry to further automate operations and improve operational efficiency of distribution systems. Specifically, smart meters enable customers to have almost real-time measuring capability. Based on federal support, many state/provincial regulators have included measures that led to the installation of smart meters. As of May 2009, about 30 states and two Canadian provinces had pending advanced metering infrastructure (AMI) plans or proposals (Figure 5-15).[133]

Most of these proposals specify a full deployment to be completed over the next five years. The costs of an AMI program are typically not justified by their operational benefits, as proposals tend to include expanded demand-side management programs. Advanced meters with two-way communications broaden the capabilities available and greatly improve an organization's ability to manage these programs. Accordingly, forecast peak load reductions associated with Demand Response and Energy Efficiency has increased.

[133] "Utility-Scale Smart Meter Deployments, Plans & Proposals," The Edison Foundation's Institute for Energy Efficiency

Figure 5-15: U.S. Smart Meter Deployments, Plans and Proposals (IOUs), May 2009[134]



In Ontario, *the Energy Conservation Responsibility Act, 2006*, supports the deployment of smart meters to consumers. By 2011, most consumers in Ontario will have made the switch to Time-of-Use rates, where the price of electricity depends on when it is used. The Independent Electricity System Operator (IESO) is responsible for the management of the province-wide data repository that collects and manages smart meter consumption data used to create Time-of-Use bills.[135]

Reliability Impacts—"Smart" Distribution Technologies

Climate change efforts that increasingly depend on distribution system options and applications can, in aggregate, impact bulk power system reliability

The increase in the amount and type of generation, or generation-like resources (e.g., plug-in electric vehicles), drives the function and characteristics of the distribution system to be similar to the transmission system, as both generation and demand are connected and power can flow onto both the distribution system and the bulk power system. The range of impacts on the bulk power system from the deployment of "smart" distribution system options represents fundamental changes in the supply/demand and control processes needed to maintain the bulk power system reliably.

The options and scope of the changes that might be deployed within the distribution system to respond to climate change initiatives is not yet defined, and the potential impacts on reliability of the bulk power system are not fully known. Some of the options discussed include bidirectional

[134] This map represents smart meter deployments, planned deployments, and proposals by investor-owned utilities and some public power utilities, http://www.edisonfoundation.net/IEE

[135] http://www.ieso.ca/imoweb/siteShared/smart_meters.asp?sid=ic

power flow, the increased use of distributed variable generation resources, and the implementation of more advanced switching and information technologies. Increased dependence on distributed generation, Demand Response, and distribution system applications increases the potential exposure to cyber vulnerability. All of these changes in aggregate, as well as their potential impacts, must be carefully considered to effectively plan, design, and operate the bulk power system reliably. Many smart grid devices will operate on assets not traditionally considered part of the bulk power system. However, these assets may require cyber protection to mitigate vulnerability of the bulk power system.

A cyber-secure and reliable grid will ensure smart grid technologies operate effectively and leverage their full potential. With the deployment of demonstrations and the overarching characteristic of inter-operability, industry experts have recognized the need for deeper and broader cyber-security to manage reliable deployment of the next generation of smart-grid technologies. NERC's Critical Infrastructure Protection (CIP) Standards continue to be modified and improved to manage cyber vulnerability.[136]

"Smart" technologies on the distribution network can improve reliability of the bulk power system. For example, by reducing line losses, system peak loads can be reduced, thereby reducing strain on the bulk power system. In addition, by reducing the frequency and duration of facility and customer outages, the impact of these disturbances on the bulk power system is also reduced.

Not all of the impacts on reliability of the bulk power system are known. Fundamental changes in distribution system operations, such as two-way flow of energy, can, in aggregate, affect reliability. While a smarter grid can improve reliability, new models and tools will be required to develop reliable designs. For example, the effect of changing the dynamic characteristics of demand and distribution systems must be well understood. Though not insurmountable, these challenges must be studied and technologies developed to ensure that the resulting system achieves greater levels of security and remains reliable. Therefore, system planners, designers and operators will need to change their approach and processes to integrate large amounts of smart distribution technologies.

Technology Status: "Smart" Distribution Technologies

"Smart" distribution technologies have advanced and become more cost-effective during the last decade. A Smart Grid, in this context, is considered as distribution automation technologies that include remote monitoring and control devices; fault detection, isolation, and restoration capabilities; and load and phase measurement and balancing devices (e.g., synchrophasors).

Smart Grid demonstrations on the distribution system are increasing in number throughout North America. For the most part, they seek to demonstrate key "smart" capabilities on a small scale (usually a medium-sized city). These demonstrations are also normally part of a broader initiative that could include advanced meters, home area networks, distributed renewable generation installations, and testing for plug-in hybrid electric vehicles.

[136] http://www.nerc.com/files/Reliability_Standards_Complete_Set_2010Jan25.pdf

For example, Xcel Energy is heading one of the most advanced Smart Grid pilot projects, investing about $100 million to build a *Smart Grid City* in Boulder, Colorado. Other pending or announced projects include a *Smart Grid Corridor* project proposed by Dayton Power & Light in Ohio and a Smart Grid pilot by National Grid (approximately 15,000 customers) in Worchester, Massachusetts. Finally, the Ontario Energy Board in Ontario, Canada, has worked to define smart grid technology and develop the regulatory framework for its implementation. The government of Ontario set a target of deploying smart meters to 800,000 homes and small businesses (i.e., small "general service" customers under 50 kW demand) by the end of 2007 and throughout the province by the end of 2010. The Independent Electricity Service Operator of Ontario (IESO) released a report outlining their view of future opportunities in smart grid applications.[137]

5.3.2 Horizon II: 10–20 years Distribution Technology Reliability Assessment

The Horizon assessments are cumulative, and, therefore, previous reliability considerations will not be repeated after each time horizon unless reliability considerations change.

Table 5-8: Distribution Reliability Impact—Horizon II (10–20 years)

Technology	Potential Reliability Issue	Present Assumption	Additional Mitigating Measures
Energy Storage	• Technology does not mature and is not commercially viable	• Energy storage is likely to mature in this timeframe	• Increase conventional generation • Make greater use of DSM
Plug-in Electric Vehicle (PEV)	• Electric vehicles will represent a significant part of the load • Pricing signals do not adequately subsidize consumers to charge the vehicles during off-peak hours	• Due to federal, state, and provincial support, the number of PEVs will grow. • Dynamic pricing will be in place to support appropriate charging patterns	• If effectively integrated, little new generation will be required. • If not effectively integrated, more generation may be required

Reliability Impacts—Energy Storage

Cost-effective energy storage deployed on the distribution system may improve overall system reliability by relieving system conditions, ancillary services, and wear and tear on distribution equipment. Additionally, with energy storage to charge during off-peak hours, off-peak energy is converted to meet on-peak capacity requirements. That said, managing and controlling thousands of gigawatts of energy from storage devices will require bulk power system operator visibility to ensure the system remains reliable.

Energy storage in the distribution system has multiple applications ranging from improving power quality to extending the life of distribution equipment. For example, upgrades of

[137] http://www.ieso.ca/imoweb/pubs/smart_grid/Smart_Grid_Forum-Report.pdf

substation components or perhaps even an entire substation can be deferred by deploying energy storage system at the proper location. A storage facility within the substation enables stored electricity to be distributed at specific times when the power limits of one or more transformers or circuit breakers would be exceeded.

Technology Status: Energy Storage

Currently, the most common energy storage devices in the distribution system are lead-acid batteries, the oldest and most developed battery technology.[138] For example, lead-acid batteries are a low cost and popular storage choice for power quality, uninterruptible power supplies (UPS), and some spinning reserve applications. Their application for energy management, however, has been limited due to a battery's short life cycle. The amount of energy (kWh) a lead-acid battery can deliver is not fixed and depends on the rate of discharge. Nevertheless, energy storage has been used in a few commercial and large-scale energy management applications. The largest one is a 40 MWh system in Chino, California, built in 1988.

Another technology used in distribution systems is vanadium redox batteries (VRB), which store energy by employing vanadium redox couples (V2+/V3+ in the negative and V4+/V5+ in the positive half-cells). VRB was pioneered in the Australian University of New South Wales (UNSW) in the early 1980s. The Australian Pinnacle VRB bought the basic patents in 1998 and licensed them to Sumitomo Electric Industries (SEI) and VRB Power Systems. VRB stores up to 500kW; 10 hrs (5 MWh) have been installed in Japan by SEI. VRBs have also been applied for power quality applications (3 MWh, 1.5 second, SEI)

Finally, the Zinc Bromide (ZnBr) battery, developed by Exxon in the early 1970s, deploys two different electrolytes flowing past carbon-plastic composite electrodes in two compartments separated by a microporous polyolefin membrane. Integrated ZnBr energy storage systems are now available on transportable trailers (storage systems including power electronics) with unit capacities of from 1 MWh to 3 MWh for utility-scale applications. As a building block, these units can be paralleled and expanded for much larger applications.

Reliability Impacts—Plug-in Electric Vehicles

According to the Brookings Institution,[139] plug-in electric vehicle (PEV) introduction may take one of two scenarios:

1) best-case scenario: smart grids ensure PEVs are powered by renewables that are generated during off-peak hours, or
2) worst-case scenario: electricity providers and the government are not well equipped to deal with the rapid innovation and technology necessary for PEVs.

In the best-case scenario, no additional power plants would be needed and electric rates may increase by only one to two percent. Almost 73 percent of the existing U.S. vehicle fleet may be supported in this fashion, thus decreasing demand for oil in the U.S. by 50 percent and

[138] Information based on the Electricity Storage Association, http://www.electricitystorage.org/site/applications/
[139] The Brookings Institution, "Plug-in Electric Vehicles 2008: What Role for Washington," June 2008, Pg. 39

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subsequently reducing greenhouse gas emissions. In the worst-case scenario where PEVs are charging on-peak and vehicle-to-grid (V2G) systems are not properly functional, Load Serving Entities (LSE) will not be well prepared for high PEV penetrations. As a result, additional capacity may be required to support charging.

Technology Status: Plug-in Electric vehicles

As a part of its energy efficient federal vehicle fleet procurement, the American Recovery and Reinvestment Act of 2009 sets aside $300 million and tax credits for capital and necessary expenditures associated with PEV purchases. Furthermore, the American Clean Energy and Security Act requires each organization to develop a plan "to support the use of plug-in electric drive vehicles." The Act further requires the Secretary of Energy to create a program that includes financial assistance for the integration of PEVs in multiple regions.[140] A number of production PEV automobiles were introduced in North America in 2009 and more are projected to be introduced in 2010. A recently release report suggests that PEVs will predominately grow in the coastal (West Coast and Northeast) regions and large urban areas in North America, and total almost one million vehicles in ten years.[141]

Advanced metering solutions, when implemented at scale, would enable electric-powered vehicles with batteries that may be recharged with an electric power source. Among many factors slowing PEV penetration are:

- distribution system infrastructure requirements;
- long cycle for the renewal of the automotive fleet—17 years;
- high cost of PEVs when compared with standard internal combustion cars;
- requires large deployment of AMI to control charging times;
- significant cost and innovation requirements to improve electric batteries; and
- uncertainty in preferred battery technology (e.g., lithium-ion versus nickel-metal hydride).

The Canadian government and companies have supported the introduction of Plug-in EVs for decades.[142]

[140] American Clean Energy and Security Act of 2009, Pg. 99
[141] http://www.isorto.org/atf/cf/%7B5B4E85C6-7EAC-40A0-8DC3-003829518EBD%7D/IRC_Report_Assessment_of_Plug-in_Electric_Vehicle_Integration_with_ISO-RTO_Systems_03232010.pdf
[142] Nigel Fitzpatrick,, *Canadian Sponsored Plug-in Hybrids and Their Impact*, http://www.electricgvan.com/Documentation/PluginHwy_PHEV2007_PaperReviewed_Fitzpatrick.pdf

5.3.3 Horizon III: 20-plus years Distribution Technology Reliability Assessment

The Horizon assessments are cumulative, and, therefore, previous reliability considerations will not be repeated after each time horizon unless reliability considerations change.

Table 5-9: Distribution Reliability Impact—Horizon III (20-plus years)

Technology	Potential Issue	Present Assumption	Additional Mitigating Measures
Electric Vehicles and PEVs	• System operators will not be able to use Plug-in Electric Vehicles as storage devices	• System operators will have the ability to use PEV as storage	• Development and implementation of other energy storage technologies will provide operational experience that can be applied to large-scale deployment of PEVs. • Additional demand and carbon emission-free resources would be required.

Reliability Impacts—Plug-in Electric Vehicles

Some of the challenges to the reliability of the bulk power system from large-scale deployments of PEVs include significant changes to distribution system architectures to support two-way flows of energy (e.g., communications, protection systems, etc.). In aggregate, multiple injections from energy sources onto the bulk power system must be visible and dispatchable by the system operator to ensure reliability.

That said, PEVs could result in efficient use of generation capacity due to the vehicle-to-grid (V2G) system, as studied in detail by the Pacific Northwest National Laboratory (PNNL). In this system, PEVs act as energy storage in regions where renewable resources are available during off-peak hours. Electricity flows to the grid at peak use time and the flow reverses back to the PEV at nighttime, when more wind-generated energy is typically available. PNNL estimates this off-peak capacity could power more than 70 percent of the overall light-duty vehicle fleet in the U.S.[143] The total effect on reliability will be to stabilize power quality and the grid overall by balancing the voltage in the grid. However, V2G technology will not be commercially available to enable full integration into the grid for another ten to 20 years.[144]

Vehicle-to-grid electrical storage can provide multiple benefits, namely, capacity, dynamic, and strategic benefits. The capacity benefit results from the ability to delay or circumvent supplementary central peaking capacity, transmission, or distribution. Operational reliability benefits could be realized by improving load following and spinning reserve, and regulating

[143] Pacific Northwest National Laboratory, "*Potential Impacts of High Penetration of Plug-in Hybrid Vehicles on the U.S. Power Grid,*" June 2007

[144] Ibid., Pg. 42

frequency, voltage, and power factor. These characteristics can also support the system operator's ability to stabilize the variability of wind generation, increasing the dispatchability of wind generation.

5.4 Summary

Today, the bulk power system is designed to meet customer demand in real time—meaning supply and demand must be constantly and precisely balanced. As electricity cannot be presently stored on a large scale, changes in customer demand throughout the day and over the seasons are met by controlling conventional generation, using stored fuels to generate electricity when needed. Even with climate change initiatives and the potential for changes in fuel mix and technologies, this continuous balancing of resources and demand will be required to maintain reliability of the bulk power system.

Each studied Horizon, between 2010 and 2050, presents distinct challenges to reliability of the bulk power system. As new technologies are integrated, sufficient operational experience will be needed to ensure reliability and provide input into NERC's Reliability Standards.

6.0 Conclusion and Recommendations

Meeting the carbon reduction goals of climate change initiatives will lead to unprecedented changes in North America's nearly one million-megawatt resource mix. Industry's knowledge of the characteristics of the bulk power system has been acquired from nearly a century of operational experience, which has formed the basis for reliable performance. In the future, a variety of demands on existing infrastructure will be made to support the evolution from the current fuel mix, to one that meets targeted carbon reductions.

A host of existing and less developed technologies has been suggested to support this fuel mix transition, and the status and capabilities of these technologies vary from existing to conceptual. The system's evolution will include integrating these technologies, many of which may use the bulk power system in ways for which it was not originally designed. Not all the potential effects on the reliability of the bulk power system are known and, therefore, sufficient time will be needed to meet carbon emission targets, gain experience with the unprecedented change in resource mix, and provide input into NERC's Standards process. Further, bulk power system planning and operations approaches, processes, and tools will require sufficient time for the fuel mix evolution, otherwise either reliability will suffer or aggressive climate change goals may not be attainable.

Each of the three studied Horizons (1–10 years, 10–20 years and beyond 20 years) would present unique challenges that are likely to be addressed by a combination of different technologies supporting the unique attributes of various regions in North America.

Key observations from this assessment are as follows:

- *The timing of carbon reduction targets will require an unprecedented shift in North America's resource mix.*
- *Regional solutions are needed to respond to climate change initiatives, driven by unique system characteristics and existing infrastructure.*
- *The addition of new resources increases the need for transmission and energy storage and balancing resources.*
- *Carbon reduction from increasing demand-side management must be balanced against potential reliability impacts.*
- *Climate change efforts that increasingly depend on distribution system options and applications can, in aggregate, impact bulk power system reliability.*

Recommendations:

To maintain reliability of the bulk power system as new technologies are integrated into the bulk power system to address climate change CO_2 and other greenhouse gas emissions, NERC should:

ASSESS	• *Assess the implications of climate change initiatives through pertinent NERC/regional scenarios as further certainty emerges around industry obligations, timelines, and targets.*
MONITOR	• *Monitor relevant studies (continent-wide, national, and regional) performed by industry groups and government agencies to provide reliability insights.*
SUPPORT	• *Support the development of tools, technology, and skill sets.*
ENHANCE	• *Continuously enhance existing and develop new Standards.*

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